California Environmental Protection Agency

Air Resources Board

LOCATION:
Air Resources Board
Byron Sher Auditorium, Second Floor
1001 I Street
Sacramento, California 95814

Public Meeting Agenda

This facility is accessible by public transit. For transit information, call (916) 321-BUSS, website: http://www.sacrt.com
(This facility is accessible to persons with disabilities.)

TO SUBMIT WRITTEN COMMENTS ON AN AGENDA ITEM IN ADVANCE OF THE MEETING GO TO:
http://www.arb.ca.gov/lispub/comm/bclist.php

July 24, 2008
9:00 a.m.

Item #

08-7-1: Health Update: Short-Term Health Effects Associated With Exposure to Air Pollution During Exercise

Health impacts from pollution are a concern to the public; however, specific populations may have an even greater risk from air pollution. One group at risk, that is often overlooked, is comprised of people who exercise outdoors. At this Health Update, ARB staff will present findings from studies which investigate the effects of exposure during exercise and examine the associations between traffic-related air pollution and health outcomes, including airway inflammation and decreases in lung function. Part of this presentation will include ways for those exercising outdoors to reduce their exposure to potentially harmful air pollutants.

08-7-3: Public Meeting to Consider the Fiscal Year 2008-2009 Research Plan

Staff will present the Fiscal Year 2008-2009 Annual Research Plan.

08-7-4: Public Hearing to Consider Proposed Regulation for Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels Within California Waters and 24 Nautical Miles of the California Baseline

The Air Resources Board staff is proposing a regulation for the Board's consideration that would reduce emissions of particulate matter, oxides of nitrogen, and sulfur oxides from auxiliary and main diesel engines and auxiliary boilers on ocean-going vessels operating within 24 nautical miles of the California coastline. Vessel operators would be required to use cleaner marine distillate fuels to reduce emissions and the proposed regulation would apply to both the United States-flagged vessels and foreign-flagged vessels.

08-7-5: Public Hearing to Consider Proposed Amendments to the Current Spark-Ignition Marine Engine and Boat Regulations

The Air Resources Board staff is proposing amendments to the current spark-ignition marine engine and boat regulations that would provide optional relief to the manufacturers of high-performance (greater than 500 horsepower) sterndrive/inboard engines. The proposal also includes carbon monoxide and not-to-exceed limits for all categories of spark-ignition marine engines, as well as more general relief provisions and other modifications.

Item #

08-7-8: Report to the Board on the International Carbon Action Partnership

The Air Resources Board staff will present an overview and update of the International Carbon Action Partnership, including the European Union emissions trading system and carbon offsets.

08-7-9: Report to the Board on Assembly Bill 32 Implementation: Western Climate Initiative

The Air Resources Board staff will update the Board on the status and activities of the Western Climate Initiative as they relate to Assembly Bill 32 implementation.

08-7-10: Green Chemistry Initiative Overview Report to the Board

The Department of Toxic Substances Control's Director will update the Board.

CLOSED SESSION – LITIGATION

The Board will hold a closed session, as authorized by Government Code section 11126(e), to confer with, and receive advice from, its legal counsel regarding the following pending litigation:

Central Valley Chrysler-Jeep, Inc. et al. v. Goldstene, U.S. District Court (E.D. Cal. - Fresno), No. 1:04-CV-06663-AWI-GWA.

Fresno Dodge, Inc. et al. v. California Air Resources Board and Witherspoon, Superior Court of California (Fresno County), Case No. 04CE CG03498.

General Motors Corp. et al. v. California Air Resources Board and Witherspoon, Superior Court of California (Fresno County), Case No. 05CE CG02787.

State of California by and through Arnold Schwarzenegger, Governor, and the California Air Resources Board v. U.S. Environmental Protection Agency, and Stephen L. Johnson, Administrator, U.S. Court of Appeals (Ninth Circuit) Case No. 08-70011, filed January 2, 2008.

Green Mountain Chrysler-Plymouth-Dodge-Jeep, et al. v. Crombie, 508 F.Supp.2d 295, U.S. District Court Vermont (2007), appeal to Second Circuit Court of Appeals pending, Docket Nos. 07-4342-cv(L) and 07-4360-cv(CON).

OPPORTUNITY FOR MEMBERS OF THE BOARD TO COMMENT ON MATTERS OF INTEREST

Board members may identify matters they would like to have noticed for consideration at future meetings and comment on topics of interest; no formal action on these topics will be taken without further notice.

OPEN SESSION TO PROVIDE AN OPPORTUNITY FOR MEMBERS OF THE PUBLIC TO ADDRESS THE BOARD ON SUBJECT MATTERS WITHIN THE JURISDICTION OF THE BOARD

Although no formal Board action may be taken, the Board is allowing an opportunity to interested members of the public to address the Board on items of interest that are within the Board's jurisdiction, but that do not specifically appear on the agenda. Each person will be allowed a maximum of three minutes to ensure that everyone has a chance to speak.

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http://www.arb.ca.gov/lispub/comm/bclist.php

IF YOU HAVE ANY QUESTIONS,
PLEASE CONTACT THE CLERK OF THE BOARD
1001 I Street, 23rd Floor, Sacramento, California 95814

(916) 322-5594
FAX: (916) 322-3928
ARB Homepage: www.arb.ca.gov

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- **If you are a person with limited English, and would like to request interpreter services to be available at the Board meeting, please contact ARB's Bilingual Manager at (916) 323-7053.**

THE AGENDA ITEMS LISTED ABOVE MAY BE CONSIDERED IN A DIFFERENT ORDER AT THE BOARD MEETING.

SMOKING IS NOT PERMITTED AT MEETINGS OF THE CALIFORNIA AIR RESOURCES BOARD

California Environmental Protection Agency

Air Resources Board

PUBLIC MEETING AGENDA

LOCATION:
Air Resources Board
Byron Sher Auditorium, Second Floor
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Sacramento, California 95814

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July 24, 2008
9:00 a.m.

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CALIFORNIA AIR RESOURCES BOARD

NOTICE OF PUBLIC MEETING TO CONSIDER THE APPROVAL OF A DRAFT REPORT: *PLANNED AIR POLLUTION RESEARCH, FISCAL YEAR 2008-2009*

The Air Resources Board (ARB or the Board) will conduct a public meeting at the time and place noted below to consider a draft report, titled *"Planned Air Pollution Research, Fiscal Year 2008-2009."*

DATE: July 24, 2008

TIME: 9:00 a.m.

PLACE: California Environmental Protection Agency
Air Resources Board
Byron Sher Auditorium, Second Floor
1001 I Street
Sacramento, California 95814

This item will be considered at a one-day meeting of the Board, which will commence at 9:00 a.m., Thursday, July 24, 2008. Please consult the agenda for the meeting, which will be available at least 10 days before July 24, 2008, to determine the order in which the items will be considered.

For individuals with sensory disabilities, this document is available in Braille, large print, audiocassette, or computer disk. Please contact ARB's Disability Coordinator at (916) 323-4916, by voice, or through the California Relay Services at 711, to place your request for disability services. If you are a person with limited English, and would like to request interpreter services, please contact ARB's Bilingual Manager at (916) 323-7053.

California Health and Safety Code sections 39700-39705 establish ARB's research program. These sections direct the Board to coordinate and administer all air pollution research that is funded with State funds. To facilitate this process, Health and Safety Code section 39705 directs the Board to appoint a Research Screening Committee (RSC) to give advice and recommendations on all air pollution research projects proposed for funding.

The draft report is comprised of research ideas for the current fiscal year. The general public, business and academic communities, and ARB staff submitted the ideas. More than 230 research ideas were submitted and provided to RSC for review and comment. RSC met on May 22, 2008, to review and approve the final list of projects.

At the July 24, 2008, meeting, ARB staff will present their draft report, *Planned Air Pollution Research, Fiscal Year 2007-2008,* to the Board for approval. The report describes projected funding allocations and proposed research projects, some recommended for funding and others recommended if funding becomes available.

Copies of the report may be obtained from the Board's Public Information Office, Environmental Services Center, 1001 "I" Street, First Floor, Sacramento, California 95814, (916) 322-2990. The report may also be obtained from ARB's website at http://www.arb.ca.gov/research/apr/apr.htm.

Interested members of the public may also present comments orally or in writing at the meeting, and in writing or by e-mail before the meeting. To be considered by the Board, written comments not physically submitted at the meeting must be received **no later than 12:00 noon, July 23, 2008,** and addressed to the following:

Postal mail submittal:	Clerk of the Board, Air Resources Board 1001 I Street, Sacramento, California 95814
Electronic submittal:	http://www.arb.ca.gov/lispub/comm/bclist.php
Facsimile submittal:	(916) 322-3928

Please note that under the California Public Records Act (Government Code section 6250 et seq.), your written and oral comments, attachments, and associated contact information (e.g., your address, phone, email, etc.) become part of the public record and can be released to the public upon request. Additionally, this information may become available via Google, Yahoo, and any other search engines.

The Board requests, but does not require, 30 copies of any written submission. Also, ARB requests that written and e-mail statements be filed at least ten days prior to the meeting so that ARB staff and Board members have time to fully consider each comment. Further inquiries regarding this matter should be directed by mail to Dr. Susan Fischer, Air Resources Engineer, Air Resources Board, 1001 I Street, Sacramento, California, 95814, or by phone at (916) 324-0627

CALIFORNIA AIR RESOURCES BOARD

Michael N. Schulte

for James N. Goldstene
Executive Officer

Date: July 9, 2008

California Environmental Protection Agency

Air Resources Board

PLANNED AIR POLLUTION RESEARCH

Fiscal Year 2008-2009

July 2008

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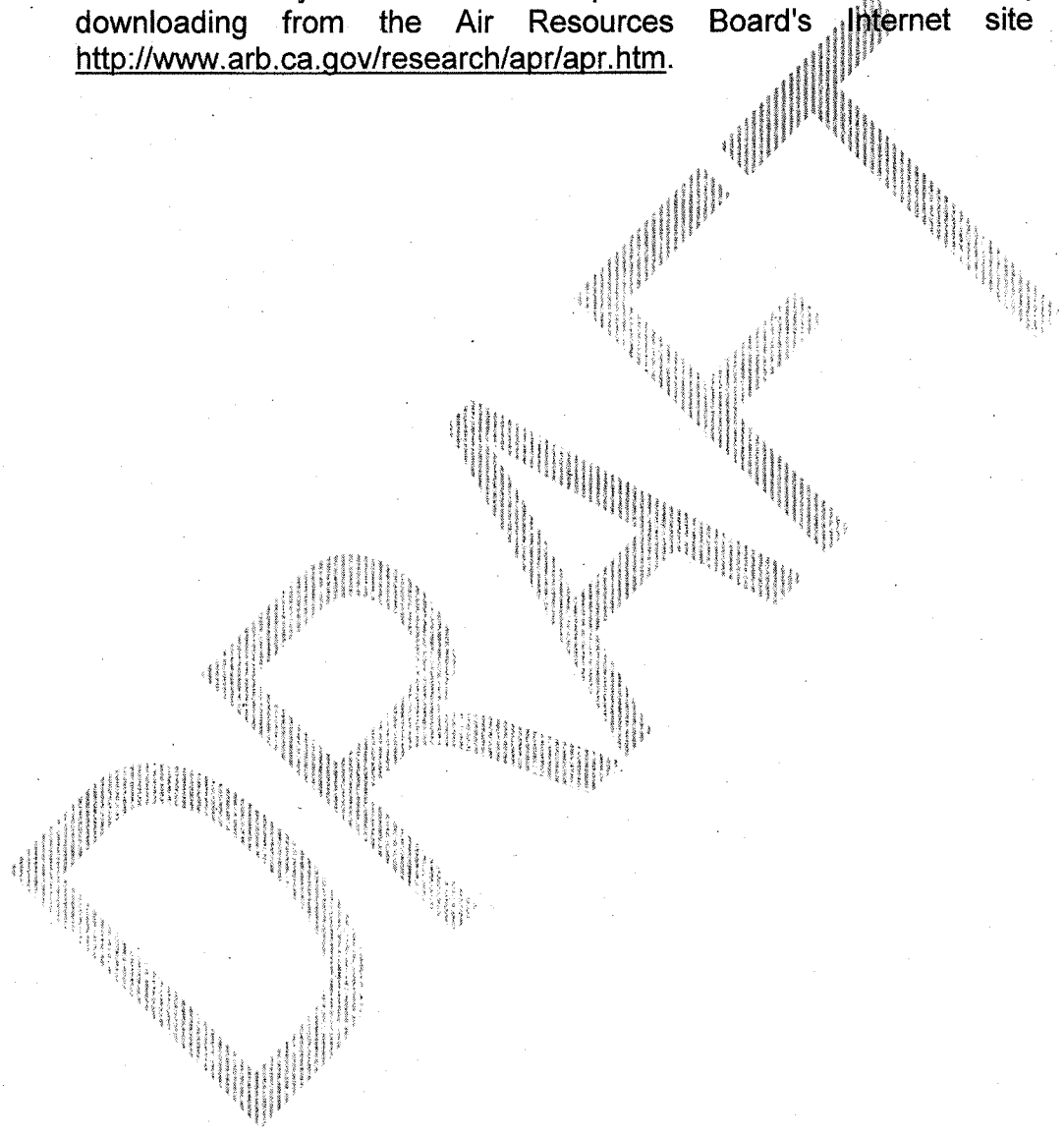

Acknowledgments

This report was prepared with the assistance and support of managers and staff from the Research Division, Mobile Source Control Division, Monitoring and Laboratory Division, Planning and Technical Support Division, Office of Climate Change, and Stationary Source Division of the Air Resources Board. We would also like to acknowledge the members of the academic community, government agencies, private businesses, and the public who submitted research ideas.

Prepared by:

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California Department of Transportation
California Energy Commission
California Integrated Waste Management Board
California Public Utilities Commission
Coordinating Research Council
Health Effects Institute
New York State Energy Research and Development Authority
Office of Environmental Health Hazard Assessment
South Coast Air Quality Management District
United States Environmental Protection Agency

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SUMMARY

This report presents the Air Resources Board's planned air pollution research for the fiscal year 2008-2009. Nineteen projects that support the ARB's programs are recommended for funding. An additional eleven projects are offered for consideration, should resources become available. This research portfolio is organized by key policy and regulatory drivers that it supports: Health Effects and Air Quality Standards, Climate Change, Diesel and Goods Movement, Atmospheric Science, State Implementation Plan (SIP) Support, and Toxic Air Contaminants. Issues related to agriculture and environmental justice are integrated into several of these primary categories. From these key policy and regulatory drivers, the following sub-categories are presented with research concepts recommended for funding or for consideration, should resources become available:

- Health Effects and Air Quality Standards
  - Health and Environmental Justice
- Climate Change
  - Mitigation and Science
  - Behavioral Change
  - Emissions
  - Water
- Diesel and Goods Movement
  - Diesel Emissions
  - Goods Movement
- Atmospheric Science
  - CalNEX 2010
- State Implementation Plan (SIP) Support
  - Monitoring
  - Ozone
  - Particulate Matter
- Toxic Air Contaminants
  - Toxic Air Contaminants
  - Ultrafine PM

This annual plan proposes research in the areas listed above, with a significant effort to clarify heath impacts of air pollution, develop technologies and behavioral change strategies to reduce emissions of greenhouse gases, improve emission inventory efforts, characterize and assess the behavior of pollutants in the atmosphere, and reduce emissions of conventional air pollutants and their precursors. The total budget for projects recommended for funding is approximately $6,600,000.

INTRODUCTION

The Air Resources Board (ARB) sponsors a comprehensive program of research addressing the causes, effects, and possible solutions to air pollution problems in California. This research program also provides support for establishing ambient air quality standards. The Board's research program was established by the Legislature in 1971 (Health and Safety Code Sections 39700 et seq.) to develop a better understanding of air pollution in California, including air pollution's effects on health and the environment, atmospheric chemistry and transport of pollutants, and inventory and control of emissions. Several legislative mandates have expanded and further defined the scope of the program in recent years.

The ARB's mission to protect California's public health, welfare, and ecological resources is supported by a Strategic Plan for Research covering the years 2001-2010. Based on regulatory priorities for the next several years, the Strategic Plan provides direction for the ARB's research program. The Plan can be downloaded from: http://www.arb.ca.gov/research/apr/apr.htm.

This research plan is organized according to key policy and regulatory drivers that it supports: Health Effects and Air Quality Standards, Climate Change, Diesel and Goods Movement, Atmospheric Science, State Implementation Plan (SIP) Support, and Toxic Air Contaminants, with issues related to agriculture and environmental justice integrated into several of these primary categories. Brief overviews of specific research areas to be funded (or considered if additional funds become available) under each key policy driver are provided (as listed on p. iv). These topical overviews indicate the link(s) between the research area and ARB's mission, ongoing research efforts in the area, research and knowledge gaps that need to be addressed, and recommended research concepts. Topical overviews are followed by the nineteen projects recommended for funding (p. 20) and the eleven projects recommended if additional funds become available (p. 56).

The proposed research projects are not intended to be exhaustive or exclusive. Unanticipated opportunities, unique or innovative study approaches, or urgency may lead to consideration of other projects.

Objective of the Research Program. The goal of the research program is to provide timely scientific and technical information that will allow the Board and local districts to make sound policy decisions and effectively implement air pollution control programs in California. Specifically, this plan supports ARB's missions to protect public health through health-based air quality standards; develop and implement strategies to reduce greenhouse gas emissions in accord with the near-term (2020) goals of the California Global Warming Solutions Act (AB 32) as well as longer-term (2050) goals; protect Californians from toxic effects of diesel emissions; devise goods movement strategies that are protective of community health; and identify and regulate toxic air contaminants.

Process for Developing this Research Plan. The Board sends out a public solicitation inviting and encouraging the public to contribute ideas for project consideration.

Members of the public, the academic community, and ARB staff submit research ideas. To aid in the evaluation, the Board's Executive Officer established interagency committees, led by ARB staff, to review research ideas. These interagency review teams comprised, in addition to ARB staff, experts from state agencies with resonant research priorities and responsibilities as well as experts from other state, district, federal, and non-profit institutions with scientific research or regulatory authority in areas of policy relevance to ARB. In response to this year's solicitation, approximately 250 research ideas were submitted. Proposed projects were examined for relevance to regulatory questions facing the Board, scientific and technical merit, and opportunities to leverage State resources through co-funding. Proposals were modified as necessary. Reviewers then prioritized candidate projects in order of urgency and importance. The Board's scientific external review committee, the Research Screening Committee (RSC), which was established by Health and Safety Code Section 39705, reviewed these candidate projects. A list of projects recommended for funding, as well as projects to consider pending availability of resources, was compiled based on discussions between interagency review committees, feedback from ARB's divisions, and comments from the RSC as well as an agricultural stakeholder outreach working group. This list of recommended projects was forwarded to the Executive Research Review Committee, whose members are the Executive Officer, his three deputies, and the Chief of the Research Division. The Executive Research Review Committee reviewed all of the proposed projects and modified the draft list of projects recommended for funding based on ARB's most pressing policy and regulatory needs. The RSC reviewed the selected projects and recommended the Plan to the Board.

Implementation of the Plan. The next step for projects approved in the plan will be their development into full research projects. The submission and selection of an idea does not guarantee a resulting contract for the submitter. Rather, the ARB is required to consider public California universities for expertise to execute these projects. If the universities do not possess the expertise, then a public solicitation is issued or a sole source contract is awarded. A list serve distributes updates on research activities. To subscribe to the list serve, visit http://www.arb.ca.gov/listserv/research.htm.

Research Budget. The nineteen recommended projects total approximately $6.6 million. An additional eleven projects totaling $4.1 million are recommended if resources become available. Allocations for the nineteen projects recommended for funding are organized according to key policy or regulatory drivers as follows:

RESEARCH CATEGORY	BUDGET
Health Effects and Air Quality Standards	$ 825,000
Climate Change	$1,650,000
Diesel and Goods Movement	$ 300,000
Atmospheric Science	$2,000,000
State Implementation Plan (SIP) Support	$1,635,000
Toxic Air Contaminants	$ 170,000
TOTAL	**$6,580,000**

Project Co-sponsorships. The Research Division is continually looking for co-funding opportunities and other ways to leverage the State's research dollars. This effort allows the ARB to be part of projects and studies that may otherwise lie beyond the state's fiscal reach. ARB has successfully worked with other research organizations and has participated in multimillion-dollar collaborations.

Summaries of Past Research. Projects completed since the beginning of 1989 are summarized in the Research Division's publication, Air Pollution Research, at www.arb.ca.gov/research/apr/past/past.htm. Research Division's final reports are available at the same web site.

OVERVIEWS OF RESEARCH AREAS

Health Effects and Air Quality Standards

Health and Environmental Justice

Policy Drivers: The majority of health and environmental justice research addresses needs for ambient air quality standards. The relevant legislation driving this area of research includes the Children's Environmental Health Protection Act (SB 25), as well as provisions of Title 17 and the Health and Safety Code that define ambient air quality standards and require regular reviews of the adequacy of the standards. Specifically, projects in the health and environmental justice area focus on (1) the effects of air pollution on individuals, (2) the effects of air pollution on populations, (3) identification of sub-populations that may be more susceptible to adverse effects of air pollution, including infants and children, (4) population groups that are highly exposed due to work or lifestyle factors, (5) biological mechanisms that could explain or support epidemiologic associations between air pollution exposure and adverse health effects.

Ongoing Efforts: The U.S. Environmental Protection Agency, as well as the National Institutes of Health (NIH) and the Health Effects Institute (HEI) are responsible for ongoing extensive research efforts that inform health effects and air quality standards.

Research/Knowledge Gaps: To support its mission to protect public health, the ARB must illuminate knowledge gaps regarding neurotoxicity of PM, biological mechanisms for PM-related health effects, variability of sensitivity to air pollution, responses of children and infants to air pollution exposure, health effects in highly exposed populations, and differential toxicity of PM originating from different sources.

Research on PM has focused primarily on lung-related endpoints, although recent efforts have begun to focus on endpoints related to the heart. Preliminary data suggest that PM may also have adverse effects on some portions of the nervous system, but little is known about the potential of ambient PM to have neurotoxic effects.

While many epidemiologic studies report statistical associations between PM exposure and a range of adverse health effects, research to date has not fully described biological mechanisms that could explain these associations.

To support its responsibility for setting ambient air quality standards, ARB must clarify the basis for the high variability of sensitivity to air pollution within California's population, in particular the susceptibility of children and infants to air pollution exposures.

Little information is available on the effects of PM exposure in sub-populations that are highly exposed, for example, outdoor workers and people who are frequently active outdoors. These groups have considerably higher exposure than populations at risk of death or hospitalization who have chronic diseases, which have been the focus of most PM-related research.

ARB must also resolve the differential toxicity of PM from various sources to support cost-effective emissions control regulations.

Recommended for Funding

Environmental Exposures in Early Childhood Education Environments

This study addresses requirements of SB 25 regarding exposure of infants and children to air pollutants. It will provide an assessment of exposure to toxic air contaminants, volatile and semi-volatile chemicals, pesticides, and allergens in child care facilities. There is little information on these exposures or on this population and the resulting data will directly inform ARB's efforts on indoor air quality in educational institutions. *Proposed funding level: $300,000*

Neurotoxic Effects of Ambient Particulate Matter: The Role of Oxidative Stress

The results of this study will contribute to ensuring that ambient air quality standards are adequately protective of public health. This study addresses a new area of research: effects of air pollution on the neurological system. There little information on air pollution effects on organ systems other than the heart and lungs, and preliminary data suggest that the potential for PM to induce neurotoxicity should be investigated. *Proposed funding level: $300,000*

Personal, Indoor and Outdoor Particulate Air Pollution and Heart Rate Variability in Elderly Subjects with Coronary Artery Disease

Study results will provide support for ambient air quality standards. The study will investigate risk of cardiovascular events in patients who already have cardiovascular disease. This population has already been identified as at elevated risk of adverse effects with PM exposure, and the study will help to clarify the degree to which PM elevates cardiovascular risk. *Proposed funding level: $150,000*

Recommended if Funding Available

Vulnerable Populations Among People Who Exercise or Work Outdoors: Acute Health Effects of Traffic-Related Air Pollution During Outdoor Exercise

This project supports review of ambient air quality standards for PM. The standards are required to protect all groups of people, but there are no epidemiologic studies of the effects of PM exposure on outdoor workers, and only a few small panel studies on people exercising outdoors. While outdoor workers and people exercising outdoors are the most highly exposed to PM by virtue of their time-activity patterns, little is known about the acute effects of PM exposure in these groups. *Proposed funding level: $490,000*

Climate Change

Mitigation and Science

Policy Drivers: Funding recommendations to address AB 32 Mitigation and Science were guided by the needs for technical data to enable development of AB 32 early action measures and for regional resolution of global warming in California. In the area of AB 32 Mitigation, recommendations for funding support early action programmatic needs for collaborative research on N_2O emissions from nitrogen land application and technical assistance to a voluntary "cool communities" program for promoting near-term reduction of GHGs. In the area of AB 32 Science, the recommended project initiates research to resolve source apportionment of particles' climate forcing in California, with an emphasis on vehicular sources and biomass combustion. It is also anticipated that as the Scoping Plan is developed over the next several months, additional research needs and methodological refinements will be identified. For example, the economic analysis currently being applied to support the Scoping Plan will benefit from input received as part of the public process, which is likely to reveal additional opportunities for further economic studies to support implementation of the Plan. To the extent that they support near-term needs, we will bring additional research proposals to the Board prior to completing next year's research plan.

Ongoing Efforts: In the area of nitrogen land application, the California Department of Food and Agriculture (CDFA) is currently sponsoring several research projects in the area of nitrogen fertilizer management. Although these projects will not collect field data on N_2O emissions, they are directly relevant to the related goals of AB 32 early actions and will provide critical information required for developing best management practices for N_2O reductions from agricultural soils. For more than two decades, the Heat Island Group (HIG) at Lawrence Berkeley National Laboratory (LBNL) has quantified the abilities of urban vegetation and solar-reflective surfaces to reduce the need for cooling energy, lower the outdoor air temperature, and improve air quality. In the area of source apportionment of aerosols' climate change impacts, there are pioneering academic efforts in California on detailed emission measurements and source-oriented air quality modeling of aerosols to clarify climate forcing.

Research/Knowledge Gaps: Technical and scientific support for AB 32 early actions is a critical and immediate need for ARB, particularly in the areas of mitigation of non-CO_2 greenhouse gases such as N_2O and support of voluntary actions such as the cool communities program and behavioral change campaigns. Scientific research is also needed to delineate the climate-forcing properties of combustion-derived aerosol and to clarify the health and climate implications of emissions controls. Two areas of potential research interest to the Board that did not result in any two-page submittals in the current ARB public solicitation are vulnerability assessment and adaptation to climate change at the California scale. The California Energy Commission's (CEC's) first overview of "Scenarios of Climate Change in California" included limited work in vulnerability assessment and adaptation. The CEC's current solicitation seeks research on local to regional scale adaption. Mitigation has long been in the center stage of the

climate debate, but increasingly important areas of research include understanding susceptibility to adverse effects of climate change and adjusting to impacts.

Recommended for Funding

Assistance to Develop a Cool Community Program in Support of AB32

ARB has specified a voluntary "cool communities" program as an early action program (TIER 1) in support of AB 32. The recommended project will provide technical assistance to promote energy savings, GHG emissions reductions, and improvements to the urban environment. *Proposed funding level: $350,000*

Radiative Forcing and Source Apportionment of Combustion-Derived Particles in California

Scientific research to support AB 32 will clarify the atmospheric evolution of optical properties of combustion-derived aerosols so that their radiative forcing can be better represented in climate models. This work will also include regional modeling to illuminate source contributions to radiative forcing in California. *Proposed funding level: $750,000*

Collaborative Research to Understand How to Reduce N_2O Emissions from Nitrogen Land Application

Developing strategies to mitigate N_2O emissions requires establishing baseline emissions and measurement protocols to reduce substantial uncertainties in the existing emission inventories, especially for agricultural soil management. This research is expected to characterize the relationship between nitrogen land application and N_2O emissions from agriculture, landscaping, and other uses and the identification of emission reduction opportunities. The Agricultural stakeholder community is supportive of the proposed research-oriented approach included in ARB's AB 32 Early Action Plan and CDFA has expressed strong interest in co-funding some agricultural research. *Proposed funding level: $300,000*

Behavioral Change

Policy Drivers: Meeting near-term (AB 32) and long-term (2050) climate goals will require extensive behavioral changes in home energy and water use, business operations, and transportation patterns. Regarding residential energy consumption, studies indicate that behavioral and demographic factors typically account for as much variability as size, construction features, and efficiency of major home appliances. Nevertheless, behavioral change campaigns and exploitation of demographic determinants to streamline public outreach have been deficient, despite the success of many well-designed and adequately funded initiatives to change behavior in sizeable portions of target populations when behaviors have tangible benefits (including peer approval). While social science research delineating behavioral and demographic determinants of greenhouse gas emissions has historically been neglected, interest is rapidly growing as government agencies recognize the necessity and potentially high returns of this knowledge. Effective policies and social marketing to reduce greenhouse gas emissions must internalize a clear understanding of how behavioral and demographic factors affect individual choices regarding residential consumption, transportation, and business operations that affect carbon footprints.

Ongoing Efforts: Most of the required social science research has not been initiated, but there are a number of projects that should be watched and could complement initiatives that the Air Resources Board may develop. In California, for example, the Public Utilities Commission (PUC), working through the California Institute for Energy and Environment of the University of California, has commissioned a series of white papers on Consumer Behavior and Energy Consumption. They will address energy efficiency potential, measurement, and program evaluation, among other issues. Agencies in other states (e.g., the New York State Energy Research and Development Agency) are starting similar initiatives, and discussions regarding behavioral research are beginning in the U.S. Department of Energy.

Research/Knowledge Gaps: Several questions need to be clarified in the California context to support effective climate mitigation strategies, including:

- *What determines household consumption of energy, water, natural gas, and transportation resources*? Comparable households—with apparently similar perceptions and experiences regarding quality of life—in California can vary by an order of magnitude or more in consumption of these resources. Moreover, pilot research in California suggests that behavioral and demographic factors determine at least half of the variability in consumption patterns. Understanding these social factors will be critical in replicating low- or no-cost household behavioral changes and crafting effective social marketing campaigns.
- *How do choices upstream of households affect home energy efficiency?* Research is needed to clarify how home energy efficiency is shaped by decision makers such as home builders, home equipment manufacturers, mortgage lenders, rental housing owners and managers, heating and cooling system contractors, and appliance retailers and repair personnel.
- *What determines household choices among available homes and equipment?* Little research has been done to clarify an important but little understood trend driving

home energy use, the trend of housing units to grow in size and to contain more and larger energy-using appliances, even while the number of people per household decreases. In particular, research is needed to clarify the role that climate change, energy use, and energy cost considerations might play in the choices underlying these trends.

- *How can better systems be designed to inform consumers about their best options for improving home energy efficiency and reducing their carbon footprints?* Effective outreach requires identifying mistaken beliefs about behaviors with significant mitigation potential, developing and testing ways to correct them, and crafting systems for delivering trustworthy, clear information to consumers at the time of choice.
- *What can be done to decouple energy consumption from perceptions (and misperceptions) of well-being?* This important fundamental research question is of long-term relevance in California with regard to home energy use as well as transportation. Subjective well-being is linked much more closely to meeting needs than to energy consumption, and it is imperative to decouple the two.
- *How can improved government links to energy users promote policy goals?* The most effective outreach is a two-way street: not only does it deliver information to users, but it serves as a source of insight into what information would be useful. For example, research into consumer behaviors during the 2001 electricity deregulation crisis showed that behavioral change was instrumental in curtailing black-outs, but that the critical behavior (turning off A/C) was not the behavior (slightly raising the thermostat) prescribed by outreach campaigns. Knowing what behaviors are actually practiced by citizens would facilitate more effective outreach campaigns.

Recommended for Funding

Behavioral and Demographic Determinants of Low Residential Consumption Patterns Observed in California Households

This project addresses knowledge gaps that are crucial supports to crafting effective behavioral change campaigns. First, it will delineate the demographic and behavioral determinants of household consumption of energy, water, natural gas, and transportation resources. Secondly, it will help forge effective social marketing as well as two-way exchange between government and energy users. Research results will help ARB devise effective outreach strategies and design sound social marketing programs. *Proposed funding level: $250,000*

Emissions

Policy Drivers: The passage of Assembly Bill 32 (AB 32) mandates not only specific targets for the state's aggregate greenhouse gas (GHG) emissions, but also the need to monitor GHG concentrations within California and to verify GHG emission source strengths. Achieving the emissions reductions specified in AB 32 requires a verified emission inventory of GHGs. Given uncertainties in the current emissions inventory, it is possible that sources may be missing or some source strengths inaccurately accounted. Comprehensive measurements of GHG emissions within California are needed to substantiate and constrain the state's emissions inventory.

Ongoing Efforts: There are few GHG measurement efforts within California focusing on identification and quantification of emission sources or inventory verification. Despite ongoing collaboration among extant projects, their combined efforts are inadequate to provide the level of resolution and accuracy needed to verify the greenhouse gas inventory for California and to monitor emissions reductions as mitigation strategies are put in place.

Research/Knowledge Gaps: Methane (CH_4) and nitrous oxide (N_2O) are listed as high research priorities by the California Energy Commission due to the possibility of large uncertainties in the emission inventory for certain source categories.

Recommended for Funding
None

Recommended if Funding Available
Improving Methods for Assessment of California Greenhouse Gas Emissions
The project to be considered for funding directly relates to emissions of methane (CH_4) and nitrous oxide (N_2O), which are significant uncertainties in the current emissions inventory. Results would enhance the understanding of possible errors associated with simulated meteorology when combined with inversion modeling to assess regional emission sources measured at tower monitoring sites. *Proposed funding level: $270,000*

Water

Policy Drivers: Water resource planning in the state is critical to meeting AB 32 goals and adapting to climate change. Concerns regarding climate change and its potential effect on water resources include a projected dramatic decrease in the Sierra Nevada snowpack, challenges in securing adequate water supplies, potential reduction of hydropower, and loss of winter recreation. Given the amount of energy used in transporting and heating water in the state, reductions in water usage offer means to mitigate greenhouse gas emissions through reduced water-related energy consumption. In the AB 32 Early Action Plan by the Climate Action Team, the Department of Water Resources (DWR) identified three discrete early actions dealing with water use efficiency, the State Water Project, and cleaner energy for water supply.

Ongoing Efforts: The Department of Water Resources, which is a member of the Climate Action Team, and the U.S. Bureau of Reclamation have joint forces to manage the complex aspects of water supply, flood management, environmental protection, and recreation of the two massive state projects: the State Water Project and the federal Central Valley Project. DWR conducts climate change studies using global climate models and downscaled data to assess regional impacts on water resources. In addition, CEC's PIER program has funded studies on the potential impact of climate change on water flows in rivers in the state. Presently, PIER and the U.S. Geological Survey have commissioned a roadmap study on snow conditions and water recharge. In concert with this roadmap, CEC's current PIER research solicitation is seeking research on the contribution of snowmelt to underground water recharge.

Research/Knowledge Gaps: Research needs at the water-climate change interface in California include adaptation to shifting hydrological cycles and mitigation to reduce emissions from treatment, distribution, and use of water in California. Research on climate change and water is of interest to the water boards, DWR and SWRCB, and should be coordinated accordingly.

Recommended for Funding

None

Recommended if Funding Available

Assessing the Energy Savings and Greenhouse Reduction Potential of Water Efficiency Improvements in the California Industrial Sector

While a substantial body of information exists on industrial water efficient technologies and practices, no study has assessed the water, energy, and GHG emissions savings potential, life-cycle costs, and sub-sector level applicability of water efficiency measures across California industry. This work will support improved industrial water efficiency to help California meet energy efficiency and GHG emission reduction targets as well as facilitate availability of scarce water resources, reduce peak electrical demand, and reduce air pollution. *Proposed funding level: $300,000*

Diesel and Goods Movement

Diesel Emissions

Policy Drivers: Ten years since the identification of diesel PM as a Toxic Air Contaminant (TAC) and eight years into the Board-adopted Diesel Exhaust Exposure Risk Reduction Management Plan, diesel emissions research continues to play a critical role for supporting and informing inventory and regulation development. With increasingly stringent emission standards for new on- and off-road diesel engines, statewide ultralow sulfur diesel fuel, a world-leading diesel retrofit program, and successful implementation of many regulations, ARB is positioned to continue reducing diesel emissions from all major sources in the state. New research supports clarification of health impacts of exposure to diesel emissions and identification of additional emissions reduction opportunities.

Ongoing Efforts: Research, development, and demonstration of diesel controls are evidenced by the increasingly successful gatherings of the Coordinating Research Council's On-Road Vehicle Emissions Workshop and the U.S. Department of Energy's (DOE's) Diesel Engine Efficiency and Emission Reduction Conference. In addition, the multimillion, multiyear Advanced Collaborative Emissions Study and other efforts in Europe and Japan indicate that diesel emissions research is a high priority for the environmental community at large.

Research/Knowledge Gaps: On-road diesel engines are now 90+% cleaner in terms of PM emission than they were just a year ago and similar reductions in NO_X emissions are expected in two years. Remaining frontiers in diesel emission control are sources such as off-road vehicles and engines, ships, and locomotives as well as characterization of equipment deterioration and retrofit performance. In related research (see Toxic Air Contaminants), measurement of climate and health impacts of diesel emissions under changing controls is a priority.

Recommended for Funding

Measurement of Off-Road Diesel Engine Deterioration

Off-road diesel emissions now account for a significant fraction of all PM emissions from the diesel sector. Just as new off-road engine emissions standards have historically lagged behind standards for new on-road engines, the development and improvement of the inventory model OFFROAD has lagged behind the EMFAC model. This project would improve the OFFROAD model's estimates of deterioration rates. *Proposed funding level: $300,000*

Recommended if Funding Available

On-Road Heavy Duty Vehicle Emissions Measurements Including Ammonia, Sulfur Dioxide, and Nitrogen Dioxide

The concept describes an effort to collect a large set of emissions, including direct emissions of NO_X and PM as well as PM precursors, using remote sensing. The project leverages ARB's funding with co-funding from the SCAQMD and NREL. *Proposed funding level: $100,000*

Goods Movement

Policy Drivers: Activities related to goods movement are a major source of emissions and contribute substantially to health risks in the state. Emissions from this category have SIP implications, and risk assessments for the ports and rail yards indicate an immediate need to clean up emissions associated with goods movement to reduce significant health risks.

Ongoing Efforts: ARB is heavily invested with implementing goods movement regulations, and is working on regulations such as the private truck fleet and main engine ship rules. The agency is also heavily involved in developing emission inventories for goods movement categories, and evaluating the health risks at ports and at rail yards. There are also regional efforts (primarily at the ports) to reduce localized risk.

Research/Knowledge Gaps: A critical need remains for improved emission activity data, especially for trucks. Characterizing truck types and activity at ports is needed to support mitigation of air quality impacts of goods movement. Additionally, exposures of port workers to air pollutants remain uncertain due to their exposure on- and off-site; the project recommended if additional funding becomes available would illuminate port workers' total exposure.

Recommended if Funding Available

Port Workers' Exposure to Air Pollution

The Ports of Los Angeles and Long Beach and their terminal operators provide employment to thousands of workers in on-dock and transportation jobs. Characterizing their potentially elevated exposure to air pollutants will provide important health information to decision makers. The recommended study would utilize a combination of personal monitoring and area sampling to characterize the exposure of port workers. *Proposed funding level: $300,000*

Atmospheric Science

CalNEX 2010

Policy Drivers: This is a unique opportunity to have the National Oceanic and Atmospheric Administration (NOAA) conduct a major field study in California that would improve our understanding of climate change, air quality and their coupling. The air quality and meteorological data collected would improve ARB's air quality models used in SIP development, our understanding of atmospheric formation of ozone and PM and the emission inventories of GHGs and traditional air pollutants and precursors.

Ongoing Efforts: NOAA has extensive experience in field studies (e.g. Central California Ozone Study (CCOS), New England Air Quality Study, Texas Air Quality Study, East Tennessee Ozone Study and Bay Region Atmospheric Chemistry Experiment). California has conducted major air quality field studies in the past (CCOS, California Regional Particulate Air Quality Study (CRPAQS), the 1997 Southern California Ozone Study - North American Research Strategy for Tropospheric Ozone (SCOS97 – NARSTO)) but has not undertaken a major field study focusing on climate and the atmosphere. As part of CalNEX 2010, NOAA would deploy research platforms (e.g., planes and a research vessel) to collect data that is otherwise unavailable. The range of the NOAA planes and vessel allow this study to address a larger spatial extent (the Southern California Air Basin (SoCAB), the San Joaquin Valley, and the San Francisco Bay Area) than previous field studies. NOAA's costs are estimated at $12.7 million over four years, so a $2 million contribution from ARB will leverage State funds by more than six to one.

Research/Knowledge Gaps: The CalNEX study will improve the emissions inventory for GHGs and precursors of ozone and PM. ARB's air quality modeling will also benefit from improved understanding of chemical processes, transport and meteorology in multiple areas of the state.

Recommended for Funding

All of the recommended projects address issues with policy relevance to ARB and would be of value as independent studies. Their benefits will be magnified by the synergism of multiple, simultaneous data collection efforts. As planning proceeds and contributions to CalNEX from other sources become clear, areas that would benefit from additional funding may be revealed. The studies below total approximately $1.4 million, and the balance of $2 million committed to CalNEX collaboration will be devoted to developing additional projects that leverage otherwise unavailable resources.

Nocturnal Chemistry in the Urban Boundary Layer of Los Angeles

This work will address the fact that many air quality models perform poorly at night and have not been validated for nocturnal conditions, introducing considerable uncertainties in our ability to model urban air quality. *Proposed funding level: $200,000*

Chemical Signature Differences between the South Coast & the San Joaquin Air Basins

The purpose of this study is to improve our understanding of differences in the atmosphere in the SoCAB and SJV which can impact response to control measures. *Proposed funding level: $550,000*

Mass Spectral Characterization of Organic Particulate Matter (PM) Sources and Processes Using Novel Instrumentation and Advanced Data Processing Methods
The unique data generated by this investigation will furnish critically needed information on organic aerosols (especially SOA) and their sources and evolution, which will improve air quality modeling of PM formation and source apportionment of OC. *Proposed funding level: $282,000*

Sulfur Study in Bight of Southern California
This work will collect information about the relative contributions of oceanic sources of sulfur, SO_x emissions from maritime shipping activities, and SO_x emissions sources in Mexico. Identification of sources of excess PM sulfate in Southern California is necessary to reduce PM sulfate and the health effect associated with it. *Proposed funding level: $350,000*

Recommended if Funding Available

Optical Remote Sensing from Mt. Wilson: A New Approach to Study Sources of Pollutants and Greenhouse Gases in the South Coast Air Basin
This project will provide observations of greenhouse gases (CO_2, CO, CH_4, N_2O) and NO_2, HCHO with a vertical resolution of 0.2 to 1 km, a horizontal resolution of at least one kilometer, and a temporal resolution of 0.5 - 1 hour. Data of such temporal and spatial resolution will be very valuable in validating the GHG inventory and air quality models. *Proposed funding level: $285,000*

Global Chemical/Aerosol Data Assimilation Experiments in support of the proposed 2010 California Air Quality and Climate Study
The integration of satellite observations and global models in this study will benefit ARB's SIP modeling through improved characterization of the temporal, spatial distributions oceanic boundary conditions and from quantification of the contribution of background ozone and PM to California's air quality. *Proposed funding level: $480,000*

Measurement of Ozone Aloft for the 2010 Air Quality and Climate Field Study in California
This work will provide vertical ozone measurements to fill in concentration fields based on surface and aircraft measurements collected during CalNEX and would help answer questions about the magnitude and extent of ozone reservoirs aloft. *Proposed funding level: $600,000*

State Implementation Plan (SIP) Support

Monitoring

Policy Drivers: One of ARB's goals is to provide accurate, relevant, and timely measurements of air pollutants and their precursors in California. ARB's air quality monitoring program collects accurate real-time measurements of ambient level pollutants at over 40 sites located throughout the state. The monitoring program also collects emissions data from cars, trucks, industrial processes, and other sources. The data generated are used to define the nature and severity of pollution in California; determine which areas of California are in attainment or non-attainment; identify pollution trends in the state; develop air quality models and emission inventories, and support regulatory development.

Ongoing Efforts: Recent efforts to improve air quality have increasingly focused on measuring and reducing particulate matter (PM) and ozone formation precursors (e.g., VOCs and NO_X). ARB and outside researchers have led the way in evaluating and deploying both standard methods and new technology for determining the amount of PM and ozone precursors in the air.

Research/Knowledge Gaps: Air quality measurements at ambient monitoring stations routinely show consistent effects for important health endpoints. However, there is also recognition that actual human exposure sometimes differ substantially in temporal and spatial distribution from what these monitoring stations measure. To better understand the relationship of particle exposures and ill-health and to better target control measures to address exposure, there is a need for technologies to monitor particle levels in a wide range of locations, preferably with high temporal resolution.

Recommended for Funding

Inexpensive NO/NO_2/NO_X/PANs Analyzers for Ambient Monitoring

This research will support development of lower-cost, more accurate NO_2 analyzers that are capable of simultaneous measurement of NO and key chemicals involved with ozone formation. *Proposed funding level: $100,000*

Low-Cost Environmental Sensors for Use in Air Quality Enforcement and Compliance, Surveillance, Exposure and Research Studies

Community groups are interested in particle monitors that can be used to determine spatial and temporal resolution easily to characterize the impact of local pollution sources. This research addresses the need of both technical and community groups for reliable, quiet, portable, long-lasting, easy-to-deploy, quick reading, high temporal resolution, and inexpensive devices for monitoring air quality. *Proposed funding level: $350,000*

Ozone

Policy Drivers: Many areas of the state are non-attainment of the current 8-hour ozone standard, and U.S. EPA has proposed a new, lower standard. Recent SIPs demonstrated the difficulties in achieving the necessary emission reductions to achieve the current standard, and the new standard will require new and innovative control strategies. Some areas of the state, in particular the San Joaquin Valley, have seen little progress recently in ozone design values. The South Coast has seen remarkable progress in their design values over the past two decades, yet recently their progress has leveled off. Until the standards are achieved, much of the state's population will remain exposed to unhealthy levels of ozone.

Ongoing Efforts: Many areas of the country recently prepared, or are in the process of preparing, 8-hour ozone SIPs. ARB and U.S. EPA have ongoing research programs that include projects related to inventory development and science improvements. The Central California Ozone Study has funded several research projects related to ozone, and will be near completion after the final increment of funding is contracted. The SCAQMD funds some ozone work, primarily for SIP support. NOAA's planned 2010 field study would provide data to further our understanding of basic atmospheric chemistry and dynamics relevant to the state's ozone problem.

Research/Knowledge Gaps: Regulatory efforts that rely on reactivity scales (MIRs) are limited by a dearth of data and understanding reflecting the current mixture and behavior of VOCs in California's air districts. Use of low-VOC stain-blocking primers, which could accrue substantial emissions reductions, is thwarted by inadequate performance of available products. There also remains much work to be done to support future ozone SIPs. These include efforts to improve anthropogenic and natural emissions inventories (especially for agriculture, mobile sources, and biogenics), improve our fundamental understanding of atmospheric chemistry, refine precursor relationships in the major non-attainment areas of the state, support optimized monitoring networks, and address the new ozone standard.

Recommended for Funding

Development of an Updated Base Case Ambient VOC Mixture

Many reactivity-based regulations rely on reactivity scales (such as MIRs) to promote or regulate VOC-containing compounds and fuels to be less reactive. However, current reactivity scales were derived in the late 1980s using ambient VOC mixtures that are now approximately 20 years old. The first recommended study would update the mixtures to reflect current conditions, and lead to improved reactivity scales and more effective regulations. *Proposed funding level: $40,000*

Near-Zero VOC Stain Blocking Primer Formulations

New near-zero (emissions substantially less than 100g/L) VOC technology will allow for the maximum reduction in emissions (>2.63 tons/day) while providing performance properties equal to the 350 g/L alkyd based technology that currently dominates California's marketplace. *Proposed funding level: $400,000*

Recommended if Funding Available

Cluster Analysis of Air Quality and Meteorology Data for 1996-2008

This study would explore meteorological influences on ozone and PM air quality at inter-basin and intra-basin scales, using cluster analysis for seven major air basins in the state (San Joaquin Valley, South Coast, Sacramento, San Diego, North and South Central Coast, and Mojave Desert). The results would be useful for assessing how atmospheric processes contribute to ozone and PM exposures over a wide range of actual conditions; this approach complements episodic air quality modeling and provides a conceptual framework for evaluating seasonal and annual air quality modeling. *Proposed funding level: $250,000*

Particulate Matter

Policy Drivers: The South Coast Air Basin and San Joaquin Valley are both non-attainment for PM2.5. The recent SIP for the South Coast demonstrated the uncertainties associated with PM2.5 spatial patterns, speciation, and control. PM levels in the two non-attainment areas are such that a large portion of the state's population is subject to unhealthy levels of PM which have been linked to compromised health.

Ongoing Efforts: Work is ongoing to develop improved monitoring capabilities for organic aerosols, as well as to separate out individual species using ATOFMS (Aerosol Time-Of-Flight Mass Spectrometer) samplers. Work is ongoing to improve PM and precursor inventories at ARB, the SCAQMD, the SJVAPCD, and at universities. The California Regional PM10/2.5 Air Quality Study (CRPAQS) funded several PM-related projects, and although some of these projects are still underway that effort is winding down.

Research/Knowledge Gaps: The recommended projects would improve our fundamental understanding of secondary organic aerosol (SOA) formation, and elucidate the optical properties of fine particulate emissions with diesel particulate filters (DPFs). SOA is an important component of PM that affects visibility, climate, and health. The optical properties of particulate emissions are expected to change with DPFs, and this could have climate implications.

Additionally, uncertainty remains in organic speciation and characterization that facilitate identifying source contributions to the organic carbon portion of PM. Specifically, ARB needs to be able to distinguish the individual contributions of combustion sources (cooking, biomass, etc.) for modern carbon. Since nitrates are a significant portion of the PM loading in the South Coast and San Joaquin Valley, any efforts to improve the NO_X inventory will improve PM SIPs. Also, the climate forcing of particulates remain an area with some uncertainty, especially with the introduction of new control technologies.

Recommended for Funding

Formation of Secondary Organic Aerosols: Chamber Study and Modeling

Secondary organic aerosol (SOA) constitutes an important component of fine particulate matter (PM) that impacts visibility, climate, and health. The chemical and physical processes involved in SOA formation are poorly understood, and the semi-empirical models used to predict SOA involve many highly uncertain assumptions. Previous models have under-predicted ambient SOA formation by as much as an order of magnitude. The recommended project would provide a new model that accurately tracks SOA formation. Also, increasingly stringent controls on NO_X emissions for both on-road and off-road sources will lead to changes in the VOC/NO_X ratios within the atmosphere. Such changes in atmospheric reactivity directly impact the extent of gas-to-particle conversion of VOCs. This project would provide the information needed to study SOA formation across a range of VOC/ NO_X ratios. *Proposed funding level: $475,000*

Bridging On-Road and Laboratory Emission Measurements: An Integrated Approach

Particulate emissions measured in the laboratory are not directly comparable with on-road measurements. Discrepancies are particularly pronounced for ultrafine particles. Further, the introduction of diesel particulate filters (DPFs) as a retrofit technology will complicate the formation of ultrafine particles since DPFs removes nearly all solid soot particles in the accumulation mode (0.3 to 1 μm, diameter). Most of these solid soot particles are made of black carbon, a strong light-absorbing compound. Therefore, the optical properties and climatic impact of diesel exhaust are likely to change significantly. This project would evaluate the effects of DPFs on the optical properties of vehicle emissions. *Proposed funding level: $420,000*

DRAFT

Toxic Air Contaminants

Toxic Air Contaminants

Policy Drivers: The Board identifies and regulates toxic air contaminants (TACs) based primarily on their toxicities and the extent of the population's exposures to them, plus other factors such as feasibility of emission reduction and available technologies. Diesel exhaust has remained a high priority since its identification 10 years ago. In past years, metals such as lead, arsenic, and chromium VI, and combustion emissions such as PAHs have also been identified as TACs. In 2007, the Board identified environmental tobacco smoke (ETS) as a TAC and approved an ATCM to limit formaldehyde emissions from composite wood products. A list of compounds for prioritization is currently being assembled and will soon be submitted to the Scientific Review Panel for their review and comment. Crystalline silica has not yet been identified as a TAC, but is currently in the second tier group of compounds on the draft prioritization list.

Ongoing Efforts: The priorities of the TAC program and fuels program include diesel exhaust and projects focused on greenhouse gas reduction, goods movement, and the like. For ETS, staff are currently assessing the further regulations, voluntary measures, and outreach efforts that may be appropriate to address ETS exposures beyond the statewide ban of smoking inside buildings and in vehicles when children are present. Toxic metals are controlled through a variety of regulations, primarily for stationary sources but also for some fuels. Crystalline silica is undergoing study by industry, and CAPCOA is also reviewing information.

Research/Knowledge Gaps: There are substances that may pose public health risks on which ARB still lacks sufficient data. For example, monitoring data suggests that acrylonitrile and acrolein may pose health risks at ambient levels, but we do not have good source information. Conversely, there are other substances that we may not currently monitor that may pose risks of which we are simply unaware. The project that is recommended if funding becomes available would potentially confirm the accuracy and usefulness of a passive monitor for measuring environmental tobacco smoke (ETS) exposure in different parts of a multifamily dwelling, which would help facilitate actions by landlords and local governments to prevent such exposures.

Recommended for Funding

None

Recommended if Funding Available

Guidelines and Sampling Protocols for Measuring ETS in Multifamily Dwellings

ARB identified ETS as a TAC in 2006. Exposures in multifamily dwellings, where households may not be able to control residential ETS exposures, can be quite elevated. *Proposed funding level: $425,000*

Ultrafine PM

Policy Drivers: The ARB may at some time in the future consider a particle number ambient air quality standard. Before enacting a particle number standard, however, ARB will need a measurement protocol and convincing health data to justify the level of the standard. In addition, new limits on and controls for motor vehicle sources may be needed.

Ongoing Efforts: The ARB has on-going research efforts to evaluate the proposed new European methodology for determining particle number emissions and its potential in California for in-use screening. The ARB is also participating in the European Particle Measurement Programme (PMP) program as an unofficial member and has recently reported on the application of the PMP measurement protocol for heavy-duty diesel engine emissions. Also, a number of animal and human studies funded by the ARB are focused on the health effects of ultrafine exposure.

Research/Knowledge Gaps: Research is needed to understand and predict the particle formation potential of an exhaust system for such a standard. Particle number production depends on many factors. They include driving cycle, dilution, temperature, humidity, and particle precursors like semi-volatile organics and sulfates. Also, the toxicity of ultrafine particles relative to fine and coarse particles needs to be determined.

Recommended for Funding

Measurement of Diesel Solid Nanoparticle Emissions Using a Catalytic Stripper for Comparison to Europe's PMP Protocol

This project will help inform ARB, should it consider a number standard for PM in the future. It would also critically evaluate the European PMP protocol and characterize the composition of ultrafine particles. *Proposed funding level: $170,000*

Recommended if Funding Available

Sources, Composition, Variability and Toxicological Characteristics of Ultrafine Particles in Southern California

This project could add evidence for consideration of UFP particle number standard. The research team is experienced in particle measurement, but lacks toxicological expertise. *Proposed funding level: $650,000*

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Health Effects and Air Quality Standards

TITLE: Environmental Exposures in Early Childhood Education Environments

PROBLEM: Approximately 900,000 California children ages 0-5 and 146,000 staff spend up to 40 or more hours per week in child care centers or preschools. Although school environments are known to contribute significantly to older children's exposures to a number of pollutants, including volatile organic compounds (VOCs), there is virtually no information available on environmental exposures to these or semi-volatile organic compounds (SVOCs) such as brominated flame retardants, phthalates, or perfluorinated compounds in California childcare environments. These exposures can cause or exacerbate asthma and other respiratory illnesses or impair neurocognitive functioning in children. Many of these chemicals are serious reproductive toxicants and may be harmful to the developing child; some of these chemicals (e.g. aldehydes) are also carcinogenic. Collectively, Early Childhood Education (ECE) facilities are varied and include home-based providers, centers operated like private schools, or programs run by government agencies (e.g. pre-school in school districts or Head Start) or religious institutions. These facilities are located in different building types, including homes, schools, private commercial buildings, and portable classrooms. Data on exposures in these environments are critical to assess the potential health risks and, if warranted, to devise and implement policies to mitigate these exposures.

PREVIOUS WORK: The First National Environmental Health Survey of Child Care Centers, conducted by the U.S. EPA and Dept. of Housing and Urban Development (HUD), was a probability-based study that tested 168 childcare centers for allergens, pesticides, and lead (1). These compounds were commonly detected; however, few sites were tested in the western U.S., and this study did not test for other pollutants, including VOCs or SVOCs. To date, there are no data available to assess child and staff exposures to these compounds in ECE environments. Sources of exposure include indoor sources such as sanitizers required by licensing regulations and VOCs from building materials, and outdoor activities (e.g., industrial and vehicle emissions). Several studies have also shown that poor housing quality, poor air quality, and other pollutant exposures of children are highest in low-income communities; thus, levels of unhealthy environmental exposures may be higher in facilities located in low-income communities.

OBJECTIVE: To determine levels of Toxic Air Contaminants (TACs) and other chemicals and particulates that may require future regulation in a sample of ECE facilities located in California's urban and agricultural communities.

DESCRIPTION: We will measure air pollutants in 40 ECE facilities including selected VOC and SVOC TACs, some Proposition 65 substances that may warrant consideration for regulation as TACs, and a criteria pollutant (fine and ultrafine particles). We will also conduct detailed facility inspections. To select participants, we will identify all licensed ECE facilities in one urban (Alameda) and one rural (Monterey) county. We will group all licensed facilities (627 in Monterey, 2,522 in Alameda) into home- or center-based facilities, and further subdivide center-based facilities into private for-profit,

governmental, or non-profit categories. Address information will be used to map the facilities by census tract. We will then randomly select 100 facilities, ensuring general representation based on socioeconomic characteristics and urban/rural classification. Facility directors will be asked to participate in a phone questionnaire to collect data.

We will select a subset of 40 facilities (20 in Alameda County and 20 in Monterey County) with a range of conditions and building types, for detailed environmental health inspections and extensive environmental sampling. We will measure VOCs (EPA Method TO-15), aldehydes (formaldehyde, acetaldehyde, etc. by DNPH), phthalates, brominated flame retardants, perfluorinated compounds, and fine and ultrafine particles in air samples. For a subset of 20 facilities, we will also measure brominated flame retardants, phthalates, and perfluorinated compounds in floor/carpet dust. Limited outdoor measurements will be obtained as well. The inspection protocols will follow procedures developed by our research group (2,3), HUD, and school districts, adapted for use in ECE environments.

The environmental measurement data will be used to characterize contaminant levels in ECE environments and estimate potential health risks associated with specific exposures. Where appropriate, concentrations will be compared to chronic or acute reference exposure levels (RELs) or exposure-dose estimates will be calculated and compared to other health-based benchmarks. We will also identify factors associated with the presence of these substances, such as building materials and local land use such as industrial facilities and traffic density.

BENEFITS: Direct benefits to ARB include development of new concentration and exposure data for young children for several volatile and semi-volatile TACs and other chemicals for which there are virtually no data in California. These data may provide useful information for further regulation of TACs and future revisions of the PM2.5 AAQS. Results may also identify new chemicals that should be considered for regulations as TACs, because many of the target chemicals are known or potential reproductive, developmental, or respiratory toxicants. We will also work with our community partners to highlight findings from the study and to build knowledge and support efforts to improve environmental and public health for California's children.

COST: $375,000

REFERENCES:

(1) Westat Inc. (2003). First National Env. Health Survey of Child Care Centers.
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TITLE: Neurotoxic Effects of Ambient Particulate Matter: The Role of Oxidative Stress

PROBLEM: The brain is a potential target for adverse effects after inhalation exposure to particulate matter. Kreyling and others demonstrated that inhaled, nanosize particles quickly left the lungs and were deposited in extra-pulmonary tissues. We and others have shown that the activities of signaling pathways that mediate inflammatory responses are up-regulated in the brains of mice exposed to concentrated ambient particles in areas near primary emission sources. In addition, biomarkers of oxidative stress and tissue injury are observed at higher concentrations in mice after exposure to concentrated ambient particles for as long as 2-weeks post-exposure. It is essential to determine the degree to which neurotoxicity in the central nervous system (CNS) is dependent on particle dose and particle composition as well as how long oxidative stress and injury persist after exposure ceases.

PREVIOUS WORK: Studies of mice exposed to fine and ultrafine PM in southern CA cities showed that these exposures were associated with significant biological activity resulting in increased rates of formation of atherosclerotic-like plaques and changes in cardiac function. In vivo inhalation studies of airway allergies near freeways suggested that the greatest biological activity was associated with the fraction of PM that contained the greatest amounts of elemental carbon and organic carbon compounds (Kleinman et al., 2006). The genetically modified mice (ApoE -/-) used for our cardiovascular disease studies are also a well recognized model for CNS neurotoxicity These mice exhibit heightened levels of oxidative stress and errors in modulating oxidative stress in the brain. Previous work has demonstrated significant upregulation of the immune-related transcription factors NF-kB and AP-1, as well as the principal proinflammatory cytokines IL-1a and TNF-a in the brain after exposure to concentrated ambient particulate matter present in air pollution (Campbell *et al.*, 2005). NF-kB promotes the expression of genes involved in inflammation, such as proinflammatory cytokines and inducible nitric oxide synthase (iNOS). In mice that were similarly exposed to northeast regional (New York) particles, glial fibrillary acidic protein (GFAP) staining, which is highly expressed in the macrophage-like astroglial cells of the brain, was increased significantly and there was evidence of degeneration of dopaminergic neurons (Peters *et al.*, 2006). Loss of dopaminergic neurons is a hallmark of neurodegenerative diseases such as Parkinson's. Thus PM exposure, in addition to contributing to cardiopulmonary disease may also be linked to neurodegenerative diseases.

OBJECTIVE: To examine the neurotoxicity, mechanism of action, persistence of oxidative stress and inflammatory responses, and the role of PM composition on effects in the CNS of mice exposed to concentrated ambient particles. This will be a multicity study that will take advantage of an ongoing program sponsored by the Health Effects Institute at New York University. Exposures will be conducted in New York City, Ann Arbor, MI, Seattle, WA and in Los Angeles, CA as part of an investigation of the role of PM composition and concentration on development and exacerbation of cardiovascular disease. This study will extend the investigation to the examination of neurotoxic outcomes in mice exposed in all four locations.

DESCRIPTION: Brains from mice exposed to CAPs for 6 month durations in 4 U.S. cities will be examined using biochemical, immunohistochemical and molecular biological methods. At each site mice will be exposed to concentrated PM using a preagreed protocol and identical exposure systems. Samples will be collected at each site and analyzed for organic and inorganic constituents. Samples of brains from animals exposed at each location will be prepared and evaluated at UCI as part of this proposed study. The time course of CNS injury and persistence of injury will be determined in mice exposed in LA for acute, subchronic and chronic durations. Neurotoxic outcomes will be examined immediately and 2 weeks post-exposure. To accomplish this, additional mice will be exposed along with the mice exposed for the cardiovascular study. Samples of brains of CAPs and air exposed ApoE-/- mice (6–9/treatment) will be embedded and serially sectioned in the coronal plane. Slides will be immunohistologically stained for markers of oxidative stress (iNOS, heme oxygenase-1) and markers of neurotoxicity (tyrosine hydroxylase (TH), a marker for dopamine containing neurons and glial fibrillary acidic protein (GFAP), a marker of astrocytic proliferation). Frozen tissue processed and Westerns will be run and analyzed for the transcription factors NfkB and AP-1. Extracted tissue will be analyzed for inflammatory cytokines (IL-1, TNFα) and for a marker of lipid peroxidation, malonaldehyde.

BENEFITS: This project may improve understanding of the mechanism of neurotoxic action of urban aerosols and identify specific components of the aerosol causally related to health effects. Dose-response and persistence data from the study will aid regulators and planners in developing air quality regulations and land use guidance to better protect the health of California residents.

COST: $300,000.

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Peters, A., Veronesi, B., Calderon-Garciduenas, L., Gehr, P., Chen, L. C., Geiser, M., Reed, W., Rothen-Rutishauser, B., Schurch, S., and Schulz, H. (2006).

TITLE: Personal, Indoor and Outdoor Particulate Air Pollution and Heart Rate Variability in Elderly Subjects with Coronary Artery Disease

PROBLEM: Findings in cohort and time series studies suggest that environmental exposure to particulate matter (PM) air pollution is associated with increases in cardiovascular hospitalization and mortality. Individuals at greatest risk include elderly individuals with preexisting cardiovascular or other diseases that place them at high risk for myocardial infarction or stroke (Pope and Dockery 2006). Pathophysiological mechanisms underlying the epidemiologic studies are beginning to emerge. There is a growing body of recent evidence that proinflammatory characteristics of PM may produce deleterious autonomic effects on cardiac function and vascular tone, which increase the risk of more adverse cardiovascular events. However, air pollutant sources and their causal components responsible for autonomic effects remain to be identified. We hypothesize that traffic-related sources are important.

PREVIOUS WORK: Ultrafine particles (UFP) appear capable of inducing the greatest amount of oxidative stress and inflammation per unit of PM mass (Delfino et al. 2005; 2007). Accurate exposure assessment methods are critical to assess the magnitude of human health effects from UFP (Sioutas et al. 2005). Ambient particulate air pollution has been associated with decreased heart rate variability (HRV) in humans, but there is little data on impacts from personal air pollutant exposures, and few studies have used repeated daily ambulatory ECG, opting instead to record short ECG strips at in-clinic visits (Delfino et al. 2005; Pope and Dockery 2006). We recently reported on results using data from the first of two years of data in the proposed study (Delfino et al. 2007). We showed that elemental carbon and estimated primary organic carbon, as well quasi-ultrafine particles < 0.25 μm in diameter ($PM_{0.25}$) were associated with sustained increases in biomarkers of systemic inflammation and platelet activation, and decreases in antioxidant enzyme activity in elderly people with CAD. Associations were stronger for indoor PM of outdoor origin than uncharacterized indoor PM. Results suggest that products of fossil fuel combustion primarily from traffic are behind associations.

OBJECTIVE: The study will examine relationships between cardiovascular autonomic function and exposures to personal, indoor and outdoor home air pollutants. We hypothesize that $PM_{0.25}$ will be inversely associated with HRV, which will support the view that UFP leads to disturbances of cardiovascular autonomic function. We will evaluate effect modification of associations by genotypes involved in oxidative stress. We will also conduct sensitivity analyses using source tracers, including tracers for vehicular emissions and secondary photochemical processes.

DESCRIPTION:

Population and Design: This proposal will produce new HRV data merged with available intensive exposure and health outcome assessments currently in progress for an NIH, NIEHS-funded panel study. The parent study scope of work included an analysis of ST segment changes and arrhythmias from ambulatory ECGs, but not HRV. Briefly, we are conducting a panel study with repeated measures to evaluate acute cardiovascular health effects of exposure to PM, with a focus on ultrafine particles.

Exposure Assessment: During every person-day of ambulatory ECG monitoring, we collected personal 24-hr quasi-ultrafine ($PM_{0.25}$), accumulation ($PM_{0.25-2.5}$) and coarse

mode ($PM_{2.5-10}$) mass on Sioutas impactors. Extensive exposure data was collected under current funding at both indoor and outdoor home sites.

Analysis: We will conduct multiple regression analyses of HRV using the general linear mixed model that estimates both fixed and random effects. In addition to examining the relationship of HRV to same day and exposures lagged several days, we will conduct hourly analyses to determine whether there are different pollutant effects for various averaging times of hourly air pollutants (cumulative hourly averages and 1, 4 or 8 hour peaks) and for differing proximities to the outcome using polynomial distributed lag models. We will also assess subject susceptibility to decreased HRV with increasing air pollutant exposures, including medication use (e.g., beta-blockers), psychological stress (from hourly PDA diaries), and polymorphisms for genes likely involved in driving oxidative stress or antioxidant responses to air pollutant exposures.

BENEFITS: This project will contribute substantial new data to improve understanding of the air pollutant characteristics and sources that affect cardiac autonomic vulnerability among elderly Californians at greatest risk of cardiovascular morbidity and mortality.

COST: $150,000

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Climate Change

TITLE: Assistance to Develop a Cool Community Program in Support of AB32

PROBLEM: The Global Warming Solutions Act of 2006 (AB 32) sets up an enforceable program to cap greenhouse gas emissions in California. AB 32 requires that the state's greenhouse gas emissions be reduced to 1990 levels by 2020. ARB has specified a voluntary "Cool Communities" program as an early action measure for promoting reductions of greenhouse gases that can begin to occur in the near-term. Cool Community technologies, such as reflective roofs, shade trees, and cool pavements, are available and ready for deployment. A mechanism for dissemination of technical information to stakeholders is needed to ensure effective use of Cool Community tools.

PREVIOUS WORK: For more than two decades, the Heat Island Group (HIG) at Lawrence Berkeley National Laboratory (LBNL) has quantified the abilities of urban vegetation and solar-reflective surfaces to reduce the need for cooling energy, lower the outdoor air temperature, and improve air quality. These studies have demonstrated building cooling-energy savings in excess of 20% upon increasing roof solar reflectance from an existing 0.1 – 0.2 to about 0.6. LBNL has also demonstrated that installing shade trees next to a house can reduce its net annual energy consumption by about 10%, with the added benefit of sequestering atmospheric carbon. Increasing the solar reflectance of a city and planting vegetation can also lower the outdoor air temperature and slow the temperature-dependent formation of smog.

OBJECTIVE: The objective of this project is to provide technical assistance for ARB's development of a "cool community" program to save energy and reduce emissions of greenhouse gases.

DESCRIPTION: Developing effective cool community programs requires comprehensive outreach that promotes complete understanding of the technologies and involvement of stakeholders who can potentially benefit from and contribute to such programs. Cool community measures include cool roofs (in some cases also cool walls), cool pavements, and shade trees.

The ultimate goal of this project is to help ARB develop effective implementation programs for cool communities. Such programs need to inform developers, builders, building code authorities, and municipal operations (schools, libraries, and parks) about examples of cool roofs in their climate zone, costs, aesthetic and building material options, and data on energy savings. Deliverables for this project could include web based databases that provide full documentation including images on specific examples of cool roofs and cool pavements, and provide access to regional shade tree collections. Deliverables could also include developing training programs and standards for different parts of the building industry and presentation materials, including case studies, for developers, home owners, commercial building owners, and retail establishments, as well as for cities and counties. The documentation that is developed is expected to include costs, payback periods, lifecycle emission reductions, potential environmental/performance issues, as well as supplemental resources. An online tool

that allows individuals to receive customized guidance will also be explored. Developing scenarios for cool roof market penetration and assistance with toolkits and guidelines for cool communities would also be useful.

Programs need input from all stakeholders and should be customized for each locality. There are many components of a cool community program, including guidelines for public programs (shade trees, cool roofs, cool pavements); local ordinance, codes and standards (model ordinance for new developments, air quality standards); and funding and regulatory options.

BENEFITS: This program supports ARB's "cool communities" early action measure, which will reduce GHG emissions through reduced energy consumption and improve the livability of the urban environment.

COST: $350,000

TITLE: Radiative Forcing and Source Apportionment of Combustion-Derived Particles in California

PROBLEM: Atmospheric aerosols play an important role in the global climate system through modifications of the global radiation budget: directly, by scattering and absorption of radiation; indirectly, by the modification of cloud properties. The effects of aerosols on regional and global climate are extremely complex. A number of factors complicate the understanding of aerosol absorption, even at the local scale. The radiative properties of an individual particle are determined by composition, refractive indices, size, and shape. There are considerable regional differences and uncertainties in the relationship between emissions and radiative forcing.

Understanding the role of aerosols, including black carbon (BC) particles, in climate change requires inclusion of realistic representations of aerosols and their radiative forcings in climate models. Little is currently known about the climate impact of aerosols originally released from different combustion sources in California. Measurements indicate that particles emitted from combustion sources strongly absorb light. However, there are scant measurements of how the optical properties and hygroscopicity of combustion-generated aerosols evolve due to atmospheric aging either by oxidation or condensation of secondary particulate matter (PM).

PREVIOUS WORK: Rosenfeld and co-workers (Lynn et al., *J. Geophys. Res.*, 2007) have shown that orographic precipitation in California is strongly influenced by particles that are likely emitted from local sources. This influence has been associated with increased particle number concentration. Rosenfeld et al. speculated that radiative heating due to absorbing soot particles may also play an important role in precipitation suppression. Rigorous model calculations for radiative effects will require information about the atmospheric evolution of particle optical properties that are currently not available.

Jacobson (*Nature*, 2001) indicated that the mixing state of absorbing aerosol (mainly BC) plays a key role in determining the radiative forcing by aerosols. Kirchsteller et al., (2007a) estimated BC concentrations and diesel vehicle emission factors based on coefficient of haze measurements in the San Francisco Bay Area from 1967-2003. Cappa has shown that measurements of light absorption by aerosols using traditional techniques are often biased significantly high, dependent upon the abundance of non-absorbing organic aerosol. Kleeman and his team *(Robert et al., JAWMA, 2007, and Ying and Kleeman, Atm. Env., 2006*) have measured the size-resolved composition of particle emissions from numerous combustion sources. Recently Kleeman (*Howard et al., Atm. Env., 2007)* has developed a transportable reaction chamber to directly study the aging of source-oriented emissions.

OBJECTIVE: This research project will be conducted in two phases. Phase I will: (a) determine past and future trends in BC concentrations by analyzing archived data in California; and (b) include laboratory investigations of the time evolution of combustion aerosol optical properties (in particular, BC particles) and hygroscopicity. This work will facilitate better understanding of how climate-relevant properties evolve after emission to the atmosphere. In Phase II, regional modeling studies will be performed to calculate source contributions to radiative forcing in California.

DESCRIPTION: This research will illuminate past and future trends in BC concentrations throughout California. This task can be performed by deriving statewide temporally (weekly, seasonal, and long term) and spatially resolved BC concentrations, wherein ambient BC concentrations and estimated combustion emission factors can be analyzed by using archived data. Laboratory experiments will be performed to investigate the changes in aerosol mass absorption efficiency and single scattering albedo as particles age. A carbon source characterization laboratory can be performed by using a diffusion flame of methane and air in an inverted flow reactor to generate BC aerosols. A list of additional combustion sources to be investigated will be developed in consultation with ARB staff and is expected to include biomass combustion, diesel engines, gasoline engines.

"Aging" in the lab will mimic atmospheric transformations, such as surface oxidation (changing the surface from hydrophobic to hydrophilic), morphology changes due to the collapse of the BC aggregates by action of the surface tension of water coating, and coating with non-absorbing aerosol species, including salts, organics and sulfates. Advanced techniques such as cavity ring down aerosol absorption spectroscopy (CRD-AES, used to measure total light extinction) and photoacoustic spectroscopy (PAS, used to measure light absorption) will be used to monitor how the optical properties of various combustion aerosols evolve upon aging in a reaction chamber. Additionally, the absorption measurements by the PAS will be compared to absorption measured using filter-based methods, which are traditionally used in ambient monitoring of aerosol absorption, to characterize the biases that likely occur in the filter-based measurements due to the presence of the oxidized semi-volatile material. In Phase II, regional modeling studies will be conducted to calculate source contributions to radiative forcing in California.

BENEFITS: Improved understanding of source contributions to climate forcing originating in California will facilitate reductions to the state's climate "footprint" and demonstrate leadership for the rest of the world to follow. This work will also provide data to substantiate more realistic representation of BC in climate models, which will clarify the impacts of BC emissions.

COST: $750,000

TITLE: Collaborative Research to Understand How to Reduce N_2O Emissions from Nitrogen Land Application

PROBLEM: Nitrous oxide, or N_2O, is a greenhouse gas (GHG) with a Global Warming Potential (GWP) 298 times higher than CO_2. Annual emissions of N_2O are roughly 15 $MMTCO_{2E}$, or 3% of the total GHG emission inventory for California in 2004. Agricultural soil is considered the largest source of N_2O emissions in California, contributing an estimated 8.1 $MMTCO_{2E}$ or more than 50% of total N_2O. Application of synthetic and organic fertilizers account for 5 $MMTCO_{2E}$. Because N_2O is generated through microbiological processes of nitrification and denitrification in soil as part of the natural nitrogen cycling, emissions are influenced by the amount of nitrogen compounds in the soil. There remains considerable uncertainty on how much N_2O is emitted under California conditions for the wide range of commodities and farming practices in the state.

PREVIOUS WORK: Application of nitrogen fertilizers is an prominent feature of modern agriculture. California is the top agricultural producer in the nation and a major revenue generator in the state, providing 31.4 billion dollars in farm receipts in 2006. The California Department of Food and Agriculture is currently sponsoring several research projects in the area of nitrogen fertilizer management. Although these projects will not collect field data on N_2O emissions, they will provide critical information required for assessing N_2O reductions from agricultural soils (1-3).

OBJECTIVE: This collaborative research with stakeholders will assess and validate baseline N_2O emission estimates for agricultural ecosystems under California-specific conditions and identify practices that could reduce N_2O emissions by increasing nitrogen application efficiency. Limiting input of nitrogen sources into agricultural soils by improving nitrogen application efficiency or plant uptake offers a strategy for mitigating N_2O emissions. Alternative practices that influence soil microbial activities through modifications to physical, chemical, or biological properties of the soil environment could also offer opportunities to reduce N_2O emissions.

DESCRIPTION: The IPCC estimates that, on average, roughly 50% of nitrogen fertilizer applied in the field is lost to the transport pathways of volatilization, leaching, and runoff. Maintaining industrial agricultural productivity while minimizing nitrogen inputs requires improving nitrogen application efficiency. Determining current baseline emissions under a range of California-relevant conditions will aid identification and implementation of methods for reducing emissions through enhanced application efficiency. Because California agriculture is highly variable with respect to crop, soil, and climatic conditions, staff will consult with State experts and other stakeholders to identify preliminary data gaps and research areas in nitrogen management, and will coordinate with stakeholders to prioritize our research activities. The establishment and validation of baseline emission estimates will help refine the greenhouse gas emissions inventory and will inform work that will lead to specific N_2O emission reduction strategies.

BENEFITS: The California Global Warming Solutions Act of 2006 (AB 32) mandates that the State reduce greenhouse gas (GHG) emissions to 1990 levels by 2020, and Executive Order S-3-05 of 2005 establishes a goal of 80 percent below 1990 levels by

2050. Under the statutory authority of AB 32, the California Air Resources Control Board (CARB) has identified collaborative research on nitrogen land application an early action measure for the reduction of greenhouse gas emissions. This measure targets reducing N_2O emissions from agricultural soil management through improved nitrogen application efficiency. It is the only measure under CARB's consideration that addresses N_2O emissions. This research effort is expected to improve the existing N_2O inventory and inform work that will lead to development of specific emission reduction strategies.

COST: $300,000

REFERENCES:

(1) Site Specific Fertilizer Application in Orchards, Nurseries, and Landscapes (2007-2009). Principal Investigator: Michael Delwiche, et al., Dept. of Biological & Agricultural Engineering, University of California, Davis, CA 95616.

(2) Fertility Management in Rice (2006-2008). Principal Investigator: Chris van Kessel and Bruce Linquist, Department of Agronomy and Range Science, University of California, Davis, CA.

(3) Development of practical fertility monitoring tools for drip-irrigated vegetable production (2007-2009). Principal Investigator: Tim Hartz, Department of Vegetable Crops, University of California, Davis, CA 95616; and Michelle LeStrange, Tulare County Farm Advisor, University of California Cooperative Extension

TITLE: Behavioral and Demographic Determinants of Low Residential Consumption Patterns Observed in California Households

PROBLEM: The role of individuals' behaviors is often acknowledged to be a primary determinant of residential energy and water consumption and often accounts for greater variability in consumption patterns than does efficiency of household appliances or household size. However, the roles played by behavioral factors such as habits, attitudes, and knowledge of energy matters, as well as demographic factors such as age, race, and social class are not well understood. Resolving the behavioral and demographic dimensions of orders-of-magnitude variability in consumption patterns between otherwise similar households is crucial to crafting effective policy efforts to encourage home energy savings. This research will probe a sample of California residences to delineate what factors, decisions, and behaviors differentiate very low-consumption households from their higher-consumption counterparts. Results will indicate what strategies are already working for low-consumption households, facilitate replication of these strategies through public outreach, and support effective social marketing to target groups. This knowledge of behavioral determinants of low residential energy and water consumption is critical to supporting near-term (AB 32) and long-term (2050) climate goals in California.

PREVIOUS WORK: According to data supplied by Pacific Gas & Electric (PG&E), inter-household variation in monthly electricity and gas consumption by residents of the City of Berkeley varies by a factor of one hundred. Similar data from East Bay Municipal Utility District suggest large disparities in residential water consumption. A Berkeley Energy Commissioner initiated and coordinated a series of local contests designed to confirm the existence of extreme low usage, quantify low consumption, and reveal the patterns underlying it. Subsequent research using consumption data acquired through these contests revealed a very low correlation between the energy efficiency of end use technologies and electricity consumption. Rather, behavioral and demographic factors were the primary determinants of low consumption households. Moreover, residents' knowledge of their own consumption patterns was revealed to be deficient. Although levels of energy consumption vary significantly among households, consumption is frequently assumed by the consumer to be average, even when it may diverge from the mean by as much as a factor of ten. Robust social marketing results indicate the importance of visibility of models that are very low-consumption, so it is critical to quantify the level of consumption of these households and characterize the behavioral and social factors that differentiate them from higher consumption residences.

OBJECTIVE: This research aims to identify what factors are responsible for the substantial variation within current energy and water use in the California residential sector, and establish a framework within which to assess the contributions of different social, cultural, and behavioral factors toward such disparate consumption levels. The research will characterize a set of household profiles corresponding to different combinations of behavioral, physical, and demographic factors that yield low residential consumption. These profiles will be used to support outreach campaigns by indicating how messages should be focused for different residential groups, portraying a variety of low-consumption model households, and delineating low- or no-cost behavioral strategies that are effective in reducing household water and energy consumption.

DESCRIPTION: Through in-home interviews and a survey, this research will explore both the factors contributing to low energy and water use as well as attitudes among low use customers about their use of energy.

Data Acquisition: Acquire a dataset from PG&E consisting of usage histories of approximately 4,000 residential accounts at the bottom end of the usage spectrum for both gas and electricity. This number encompasses all residential accounts up to the 5th percentile usage level. These accounts would include 12 consecutive months of electricity and natural gas consumption and either the account number or a code allowing subsequent matching to the account number. The approximate monthly billing cutoff levels for such data extraction are 30 kWh and 5 therms. A similar approach will be engaged with East Bay Municipal Utility District as a source for data regarding water usage.

Screening: Screen the data set to remove apparently unoccupied residences as well as customers whose bills reflect fuel substitution, e.g., low gas users with above-average electric consumption.

Consent Form: Design a study participation consent form. Personal information in the data set would be redacted so that research staff would have no ability to access personal information or contact customers unless and until customers have consented.

Sampling & Interviews: Develop sampling criteria for identifying a subset of participating households to be interviewed in their homes. Conduct and transcribe interviews with low-use households. Interviews are designed to establish a working understanding of the circumstances and parameters corresponding to exceptional use patterns and to facilitate development of appropriate survey questions.

Survey: Draft, pretest, and mail a detailed survey to all household participants.

Analysis: Perform quantitative and qualitative analysis on findings from interviews and household surveys. Identify household profiles using physical, social-demographic, and attitudinal categories developed through analyzing the responses.

Applications: Derive applications, focusing on the potential for significant energy savings through transferable strategies. In particular, design social marketing strategies by delineation of effective segmentation of residential groups, identification of appropriate models of low consumption for various groups, and identification of resonant language and conceptual framing for the different groups. As funds allow, social marketing strategies could be tested in focus groups.

BENEFITS: Reaching both near- and long-term climate goals will require extensive, voluntary behavior change. This research will identify what behaviors are already working in low-consumption households and enable social marketing campaigns based on understanding the behavioral and demographic factors that underlie variability between household consumption patterns. Social scientists have demonstrated the limited efficacy of prescribing standard bundles of technical solutions to everyone. This research will enable effective social marketing based on real-world combinations of technologies, habits, and building characteristics that correspond to low energy consumption patterns commensurate with the mandates of California's Global Warming Solutions Act (AB 32) and Executive Order S-3-05, which established near- and long-term (2050) GHG emission reduction targets.

COST: $250,000

Diesel and Goods Movement

TITLE: Measurement of Off-Road Diesel Engine Deterioration

PROBLEM: Emissions generated by internal combustion engines tend to increase over time. This phenomenon, called deterioration, has a significant impact on emissions inventory estimates and the estimated benefits of emissions controls and regulatory strategies. In diesel engines, deterioration is currently assumed to occur due to tampering, mal-maintenance, and/or malfunction of engine components. Deterioration rates in diesel engines have been developed in OFFROAD 2007 (ARB's emissions inventory model for off-road equipment) based upon limited data representing similar on-road diesel engines. The OFFROAD model represents deterioration in diesel engines 25 HP or higher as the percent increase in emissions per useful life consumed. Depending on the pollutant and type of equipment, emission rates in OFFROAD can increase by 10% to 70% above emission rates for new engines.

Because most off-road engines typically operate under highly variable load and adverse operating conditions, the use of on-road engine deterioration assumptions may not be appropriate. Further, the integration of new control technologies such as diesel particulate filters will have a major impact on deterioration in newer, well controlled engines. Additional studies are required to more fully understand deterioration of off-road diesel engines, and how that deterioration affects emissions estimates and projected regulatory effectiveness.

PREVIOUS WORK: In 1988, Radian Corporation developed 23 specific categories of tampering and component malfunction in on-road heavy duty trucks (Weaver and Klausmeier, 1988). Subsequent review by other contractors revised the Radian estimates for the U.S. Environmental Protection Agency (Weaver et al., 1998). The Radian model has been updated periodically by ARB staff as the model forms the basis for heavy duty diesel truck deterioration estimates in ARB's EMFAC model. Using the results of surveys and discussions with industry, staff have made estimates of tampering, mal-maintenance, and malfunction frequencies and associated emissions impacts in future model year trucks equipped with PM and NO_X controls.

No comprehensive studies have been conducted regarding the deterioration rate for off-road equipment therefore deterioration in OFFROAD2007 is based on assumptions for comparable on-road diesel engines from previous versions of ARB's EMFAC model.

OBJECTIVE: The proposed study will qualitatively and quantitatively assess deterioration in off-road diesel engines for key criteria pollutants including but not limited to NO_X and PM. Key objectives are to: (1) evaluate the impact of engine deterioration on emissions; (2) demonstrate methodologies for better quantification of engine deterioration; and (3) quantify the deterioration rates with regard to emissions.

DESCRIPTION: This study should focus on deterioration in diesel off-road engines caused by tampering, mal-maintenance, malfunction, normal wear caused by accumulative engine use, and any other factors. Elements of the study may include literature review, consultation with engine manufacturers, surveys, engine bench

emissions testing, in-use emissions testing, modeling of engine operations, or any other feasible approach. ARB is looking for bidders to provide a scope of work which they feel can most efficiently accomplish the required goals given the available budget.

BENEFITS: The research will provide critical information to support the incorporation of updated diesel engine deterioration rates into OFFROAD. These new deterioration rates will affect assessments of air quality planning and regulatory effectiveness, and potentially help identify new regulatory strategies.

COST: $300,000

Atmospheric Science

TITLE: Nocturnal Chemistry in the Urban Boundary Layer of Los Angeles

PROBLEM: Nocturnal chemistry in urban areas can considerably influence the composition of the boundary layer by removing ozone, NO_X, and hydrocarbons as well as by changing the size and composition of aerosol particles. Studying the mechanisms determining the chemical composition of the nocturnal boundary layer is difficult because of the interplay of homogeneous and heterogeneous chemical processes and weak turbulent mixing. This interaction, coupled with direct emissions of NO and hydrocarbons at the ground, leads to strong vertical variations of trace gas concentrations, rendering the chemistry in the nocturnal boundary layer very altitude-dependent. Many air quality models perform poorly at night and have not been validated for nocturnal conditions, introducing considerable uncertainties in our ability to model urban air quality. Accordingly, nocturnal chemistry has been identified by NOAA and the ARB as one of the most pressing research needs for the proposed 2010 California Air Quality and Climate Study.

PREVIOUS WORK: The researchers have many years of experience in performing field experiments of nocturnal urban boundary layer chemistry, including participation in Mexico City's MIRAGE research in 2006 and Houston's TEXAQS II in 2006. We have recently also lead an ARB-funded field effort in Malibu, CA, to study the potential presence and impact of coastal halogen chemistry on the air quality in the South Coast air basin. Our experimental approach to study nocturnal chemistry is based on the measurement of vertical profiles of the most important nocturnal species, i.e., O_3, NO_2, HONO, NO_3. The observations are interpreted with a one-dimensional chemical transport model that allows us to simulate the field observations of vertical trace gas profiles. Because this model, which was developed specifically for this purpose, is relatively simple and fast, it allows us to study individual chemical processes at night and to elucidate the role of vertical mixing. The results of our previous efforts have been published in a number of papers in the Journal of Geophysical Research and Atmospheric Chemistry and Physics.

OBJECTIVE: We propose to set up an urban field site in the Los Angeles Basin during the proposed 2010 California Air Quality and Climate Study. Our long-path DOAS instrument will be set up to provide continuous measurements of the vertical distribution of O_3, NO_2, NO_3, HONO, HCHO, and SO_2. O_3 and meteorological in-situ sensors will be placed at different altitudes to supplement the DOAS measurements. Our 1D chemical transport model will be used to give insight into various aspects of the chemistry and meteorology that occurs in the South Coast air basin at night. In particular, we are interested in the nocturnal ozone and NO_X budgets, the role of NO_3 / N_2O_5 and HONO chemistry, the impact of vertical mixing, and the influence of these nocturnal processes on daytime ozone and particles.

DESCRIPTION: Studying nocturnal chemistry in urban areas is challenging due to the very strong vertical variation in the atmospheric composition (O_3, NO, NO_2, HONO, and NO_3) in the lowest 200 m in the atmosphere. For example ozone and NO_2 gradients of

20 – 50 ppb over the lowest 100 m are not uncommon. It is therefore crucial to consider not only trace gas concentrations at the ground, where most air monitoring stations are, but the entire lower 200 m of the nocturnal atmosphere. The proposed measurements are based on a long-path Differential Optical Absorption Spectrometer (LP-DOAS), which measures the open air absorptions of various trace gases along an extended path between the main telescope and a reflector array, which is typically placed 2 – 5km away. This absolute (no instrument calibration needed) method is not very sensitive to local emissions and derived path-averaged concentrations often compare better to the grid-cell averaged results of urban air-shed models than in-situ measurements. To measure vertical trace gas profiles 3 – 5 reflectors are mounted at different altitudes on buildings in an urban area. The instrument then aims at these reflectors, thus probing different altitude intervals. Similar measurements were performed in Houston in 2006, at a height interval of 20 – 300 m altitude. We anticipate a similar vertical coverage for Los Angeles. Meteorological sensors will be deployed to measure temperature, RH, and wind speed and direction at the location of the retro-reflectors. In addition, we will seek collaboration with colleagues to increase the number of chemical and meteorological parameters measured at the field site. Interpretation of nocturnal vertical concentration profiles is often quite challenging, requiring the consideration of both chemistry and micrometeorology. We found that 1D chemical transport models, such as the one we are using in our group, provide an ideal tool to interpret the measurements with respect to the combined chemical and mixing processes occurring at night. Through possible collaboration with researchers from the ARB and other universities, we will also compare our observations with the output of 3D urban airshed models, with the goal of improving the description of nocturnal processes.

BENEFITS: The State of California is currently pursuing an ambitious plan to improve its air quality over the next decade. The proposed measurements will provide a unique data set to improve our understanding of the chemical and meteorological mechanisms used in urban airshed models at night. In addition, the data will allow the validation of nocturnal emission inventories for NO_x, SO_2 and HCHO.

COST: $200,000

TITLE: Chemical Signature Differences between the South Coast & the San Joaquin Air Basins

PROBLEM: Responding to control measures that ARB has adopted over the years, the South Coast Air Basin (SoCAB) has experienced some reductions in exposures to ozone and PM2.5. In particular, nitrogen species concentrations have to some extent responded to control measures. The San Joaquin Valley Air Basin (SJVAB) has not responded as well to control measures in terms of ozone, PM2.5 and nitrogen species reductions. Research is needed to clarify whether differential response to the same regulatory control is due to different chemical signatures for the two basins.

PREVIOUS WORK: During the 1993 Los Angeles Free Radical Study, a team from Portland State University used fluorescence assay with gas expansion (FAGE) technique to measure OH and O_2H. These measurements were supported with Unisearch Associates Tunable Diode Laser (TDLAS) and Differential Optical Absorption (DOAS) measurements of HCHO, HONO, H_2O_2, NO_3-, nitric acid, and NO_2. A Pennsylvania State University Team has used laser induced fluorescence to measure OH and O_2H recently in the ambient air and at environmental chambers at University of California Riverside. Professor Sanford Sillman has successfully demonstrated the use of O_3/NO_Y and H_2O_2/HNO_3 as more accurate in describing free radical/ozone/fine particulate chemistry than the standard VOC/NO_X ratios.

OBJECTIVE: To describe differences in ozone/PM2.5 chemistry of SoCAB and SJVAB through measurements of free radicals and trace parent species at one representative site per basin and development of new ratios from these measurements that describe such chemistry more accurately.

DESCRIPTION: The ARB and the National Oceanic and Atmospheric Administration (NOAA) will conduct an intensive field study in California in 2010 (2010 CalNEX). During this study an instrumented airplane capable of similar trace level measurements will be deployed by NOAA. This instrumented airplane would fly over both SoCAB and SJVAB, along transacts to connect the atmospheric chemistry of each site to the general photochemical dynamics that govern the air basins.

As a part of 2010 CalNEX this project will collect data to support an observations-based method (e.g. the Sillman indicator species ratio method) to describe summertime atmospheric chemistry in the SJVAB and SoCAB. Photochemical ratios or signals derived from these trace level measurements (airplane and ground level) will be used to delineate differences between SoCAB and SJVAB photochemical regimes.

BENEFITS: This research will demonstrate any differences between ozone and PM2.5 photochemical regimes of SoCAB and SJVAB. Such differences can guide us to perhaps design SJVAB specific control measures. Such measures that would cost effectively move the basin towards compliance with state and federal ambient air quality standards, including the new stringent 8-hour standards, are of significant value to the San Joaquin Unified Air Pollution Control District and to the ARB.

COST: $550,000

TITLE: Mass Spectral Characterization of Organic Particulate Matter (PM) Sources and Processes Using Novel Instrumentation and Advanced Data Processing Methods

PROBLEM: Aerosols have important effects on human health, visibility, and climate. Mitigation of adverse impacts requires a fundamental understanding of aerosol processes, chemistry, and microphysics. Organic aerosols (OA) constitute a large fraction of the aerosol mass and may be responsible for significant health effects, but their complexity makes quantification of their properties and effects, as well as prediction of effects, difficult. Furthermore, aerosols are deemed the most uncertain component in the radiative forcing of climate [IPCC 2007 Report].

PREVIOUS WORK: The high-resolution time-of-flight aerosol mass spectrometer (HR-ToF-AMS), co-developed and demonstrated with Aerodyne [DeCarlo et al., *Anal. Chem.*, 2006], is offers rapid determination of size and chemical composition of submicron aerosols. It has emerged as a powerful tool for the characterization of OA and led to a number of advances in the field. Factor analysis of AMS data by our group has pointed out the dominance of secondary organic aerosols (SOA) in the polluted regions of the Northern Hemisphere [Zhang et al., *ACP* 2005 & *GRL* 2007]. Recent work using Positive Matrix Factorization (PMF) has allowed us to quantify the contributions of various primary sources, such as biomass burning aerosols (BBOA) [Ulbrich et al., *Fall AGU Mtg.* 2006], and is leading to promising advances in the study of SOA formation and aging. Simultaneously, the high mass resolving power of the HR-ToF-AMS has enabled increased source specificity in PMF, as well as fast determination of oxygen-to-carbon ratio (O/C) and nitrogen-to-carbon ratio (N/C) of organic aerosol [Aiken et al., *Anal. Chem.*, 2007].

OBJECTIVE: The proposed work will deploy novel aerosol mass spectrometric instrumentation to a ground-based Supersite as part of the 2010 field campaign in California, for measurement of organic and inorganic aerosol composition and time trends. Field data will be analyzed using PMF and O/C and N/C algorithms. Results will address uncertainties in SOA formation and aging and CCN closure.

DESCRIPTION: All Aerodyne AMSs are capable of quantifying both organic and common nonrefractory inorganic fractions of ambient atmospheric particulate matter in PM1, as well as providing information on several classes of OA. The HR-ToF-AMS provides a mass resolving power (m/Δm) of up to 5000, allowing for the separation of ions of the same nominal mass that have different elemental composition. Such resolution enables the direct separation of inorganic aerosol components, and organic ions can be classified into groups based on the subset of elements they contain (CxHy, CxHyOz, etc.). This allows the measurement of the elemental composition of the aerosol (particulate C, O, N, etc.) with a new method developed by the Jimenez Group [Aiken et al., *Anal. Chem.*, 2007].

A particularly powerful technique in analyzing AMS data and classifying organic aerosol involves Positive Matrix Factorization (PMF), in which the time-dependent mass spectra are deconvolved into their major components. Application of PMF to AMS data has confirmed the identification of several subclasses of organic aerosol, such as OOA with

different levels of oxidation, and POA from sources such as motor vehicles and biomass burning [Lanz et al., *ACP*, 2007]. These algorithms will be applied to the California data in order to characterize aerosol sources and processing.

While the AMS represents a great advance for the characterization of organic aerosols, certain types of analysis are hampered by the extensive molecular fragmentation caused by electron impact (EI) ionization, which is the standard ionization method in all AMSs. It is widely surmised that organic aerosols contain hundreds to thousands of organic compounds in many chemical classes [Hamilton et al., *ACP*, 2004], but EI-generated aerosol mass spectra are dominated by peaks corresponding to ubiquitous fragment ions, and molecular identification is generally unattainable. Instead, detected ions are sorted into broad chemical classes, such as hydrocarbon-like OA (HOA), BBOA, oxygenated OA (OOA), etc., and analysis focuses on determining total mass contributions, time trends, and O/C for these various classes. Our group has recently demonstrated a novel metastable atom bombardment (MAB) ionization source with the AMS that yields mass spectra with significantly reduced fragmentation and high sensitivity (~1/10 of EI) that is sufficient for field analysis [Kimmel et al., *FACSS Mtg.,* 2007]. By limiting molecular fragmentation, this source reduces redundancies in the mass spectra of organic aerosols and enables the determination of molecular composition. The source design allows alternating operation between EI and MAB ionization sources in the same instrument on a timescale of minutes. Combination of the quantitative data retrieved from EI mass spectra with the enriched chemical information obtained by MAB ionization will yield more detailed characterization of SOA formation and aging. Likewise, the increased specificity in aerosol mass spectra will greatly expand the power of PMF to isolate OA sources.

The most uncertain effect of aerosols is the indirect effect on cloud properties and precipitation. Clouds are formed when water condenses on a subset of particles (the Cloud Condensation Nuclei or CCN) as the air rises in a cloud. Prediction of which particles will activate to CCN remains a significant challenge, with widely varying degrees of success especially under high organic concentrations [Stroud et al., *J. Atmos. Sci.,* 2007; Ervens et al., *JGR*, 2007]. The techniques developed and applied in this project will result in a more precise and nuanced characterization of the properties and evolution of OA and SOA in the atmosphere. We expect to deploy our instrumentation to a major Supersite where a DMT CCN counter would also be deployed by another group. We will then carry a CCN closure study in which the hygroscopic properties of each type of OA are constrained based on the observed hygroscopicity / CCN activity during periods of strong influence of each component, and/or optimized based on the properties observed in lab studies (e.g. fresh SOA in chambers is relatively hydrophobic, while it becomes more hygroscopic as it ages). This would allow the extension of our results on OA sources and processing to another important climate-relevant property.

BENEFITS. The unique data generated by these techniques will furnish critically needed information on organic aerosols (especially SOA) and their sources and evolution.

COST: $282,000

TITLE: Sulfur Study in Bight of Southern California

PROBLEM: Sulfate concentrations in coastal Southern California are frequently elevated above levels that are consistent with emission estimates. Sulfates are a component of particulate matter, which remains the largest air quality health risk for Californians. The contributions of various sulfur sources resulting in these sulfate concentrations is not well-characterized. Origins of this sulfur could be natural (dimethyl sulfide or DMS) from oceanic metabolism, uncontrolled SO_x emissions from naval warships, SO_x emissions from maritime shipping activities, SO_x emissions sources in Mexico (e.g., Rosarito Beach power plant, maquiladoras), or trans-Pacific transport of SO_x emissions and reaction products. Maritime and Asiatic emissions will undoubtedly increase in the future without additional restrictions on emissions.

PREVIOUS WORK: NOAA has made DMS and other aerosol measurements from ships (Atmospheric Chemistry Program in the Pacific Marine Environmental Laboratory). Scripps Marine Institute has attempted to use isotopic information to characterize ship impacts.

OBJECTIVE: To better characterize and quantify the contribution of various emission sources of sulfur impacting Southern California.

DESCRIPTION: Sulfur emissions, whether as SO_x, DMS, or H_2S, are precursors to sulfate particles, which contribute to the aerosol burden. Sulfur emissions have a complex fate and can substantially influence the cloud albedo and climate. If the sulfur source is anthropogenic in nature, co-emitted pollutants such as CO, NO_X, and VOCs become important in their own right because atmospheric photochemistry, transport, and deposition will influence the ambient concentrations. When these concentrations are measured offshore, aloft, or distant from a central study area, they help create the boundary and initial conditions of air quality model applications, which are extremely important to the accuracy of the modeling results. In order to accurately predict air quality throughout southern California and efficiently regulate pollution sources, it is necessary to better understand the nature and magnitude of emissions of these compounds off the coast of California, in Mexico or at the US-Mexico border, and aloft.

This research effort should be planned to overlap with the CalNEX 2010 study to support and enhance both measurement programs. The effort would entail collocated field measurements of sulfuric compounds and combustion products such as CO and NO_X to improve the estimates of sulfur emissions and to better characterize the sources (natural versus multiple potential anthropogenic). Pollutant ratios and potentially isotopic analysis would be used to indicate the relative contribution of different source types. Supporting measurements collected by NOAA's aircraft could also help to differentiate the sources and help characterize the spatial extent of the impacts.

This project's tasks may include: purchase high-sensitivity sulfur dioxide and carbon monoxide analyzers; arrange for collection and analysis (size and chemistry) of aerosols; make the air quality and meteorological measurements on islands/ships, at the shoreline, inland, and, in possible, aloft (e.g., aircraft, remote sensing, balloons) to quantify the pollutants; analyze the data to characterize the chemical and atmospheric

processes. QA/QC protocols and analysis of the measurements would be conducted to characterize the contributions of the various sources of sulfur and combustion-related pollutants. The coordination of this project with the CalNEX study would enable analysis of additional chemical species and so would provide insights into the atmospheric chemistry and processes involved in oxidation of sulfur compounds.

BENEFITS: This project will help guide the decisions of State and local regulators as they address the sulfate air quality problem in Southern California. Depending on the results, other regions of California could also benefit from what is learned and also develop effective sulfur reduction strategies as needed. The sulfur results would also benefit the climate change research program as it would help characterize the relative contribution of natural and anthropogenic sources of sulfur, which contributes to sulfate particles, which act as cloud condensation nuclei, which affect the weather and climate. The measurements of aerosols, CO, CH_4, NO_X, and VOCs would benefit photochemical modeling efforts for support of the State Implementation Plan (for ozone and PM2.5) as they would better characterize initial and boundary conditions (to which modeling efforts are sensitive).

COST: $350,000

State Implementation Plan (SIP) Support

TITLE: Inexpensive $NO/NO_2/NO_X$/PANs analyzers for Ambient Monitoring

PROBLEM: Chemiluminescence NO analyzers are used statewide to determine NO and NO_2 levels by conversion of NO_2 to NO and detection of NO chemiluminescence. However, chemiluminescence suffers from errors due to water quenching in any environment of non-negligible humidity as well as the generation of species besides NO_2 that can produce false signals. These factors can result in significantly reduced NO and NO_2 readings (Hargrove, Wang et al. 2006).

PREVIOUS WORK: The technology for measuring NO_2 by cavity-attenuated phase shift detection (CAPS) is well-established and not patented (Kebabian, Herndon et al. 2005).

OBJECTIVE: To develop and begin production of cavity-attenuated phase shift (CAPS)-based NO_2 analyzers and implement converters that will permit the simultaneous measurement of NO and PANs.

DESCRIPTION: To successfully replace chemiluminescence detection methods, CAPS-based systems must be able to measure NO in addition to NO_2. A proprietary technique has been developed that will accommodate this extension. The cost per analyzer will be less than those for chemiluminescence analyzers with similar detection sensitivities. The analyzer that is under development will also be useful for stack measurements and medical applications, where higher concentrations of NO_X will allow for dilution of samples.

BENEFITS: The successful development and marketing of a CAPS-based NO/NO_2 analyzer will allow for more accurate NO and NO_2 measurements regardless of the humidity. Because CAPS-based analyzers measure a fundamental property of NO_2 using time-based measurements, there will be no need for gas calibration and instruments will require only occasional zeroing to attain accurate results.

COST: $100,000

REFERENCES:

Hargrove, J., L. Wang, et al. (2006). "Cavity Ring-Down Spectroscopy of Ambient NO_2 with Quantification and Elimination of Interferences." *Environ. Sci. Technol.* **40**(24): 7868- 7873.

Kebabian, P. L., S. C. Herndon, et al. (2005). "Detection of nitrogen dioxide by cavity attenuated phase shift spectroscopy." *Analytical Chemistry* **77**(2): 724-728.

TITLE: Use of Low-Cost Environmental Sensors for Use in Air Quality Enforcement and Compliance, Surveillance, Exposure and Research Studies

PROBLEM: Air pollution surveillance is limited in part by the cost of instrumentation. A typical instrument to collect high-quality air pollution data for comparison with U.S. EPA standards costs on the order of tens of thousands of dollars and usually requires a highly trained person for operations and maintenance. This relatively high cost puts monitoring out of reach of many small businesses and community groups who would use such instrumentation were it affordable. In many cases, a screening instrument is would suffice to meet the needs of small businesses and community groups. Screening instruments can be cheaper because they do not require low detection limits and comparability to EPA federal reference methods.

PREVIOUS WORK: In recent years, there has been a proliferation of low-cost electronics, data logger and miniature sampling instrumentation in the market. For example, there are numerous commercial temperature, humidity, data logger combination devices on the market for less than $200. Furthermore, costs for light emitting diodes, semiconductor lasers and associated electronics have seen drastic falls recently, making optical-based measurements relatively inexpensive.

OBJECTIVE: To build, test and assess several low-cost air pollution sensor designs for use in air pollution surveillance, exposure and fence-line monitoring.

DESCRIPTION: Research will evaluate existing low-cost sensors and data logger packages and assess their suitability for use in surveillance and in exposure assessment. Improvements on extant designs will be proposed and incorporated into development of new sensors packages for sensing ambient aerosols and gas phase pollutants using novel optical and chemical methods. The instrument package will be battery powered, simple to operate, and capable of signaling an alert upon sensing concentrations above a pre-set threshold. The instrument will include a data logger to store data averaged over short (e.g., hourly) time intervals over a period of several weeks. Data will be directly downloadable to personal computer. This convenient instrument package, at a cost on the order of $200, will be an attractive and useful tool for communities.

BENEFITS: Providing low-cost alternatives to expensive instruments for ambient air monitoring will allow community groups to perform independent surveillance. For the general public, this would benefit work on environmental justice projects. Additionally, persons who are particularly sensitive to air pollution might use such instrumentation. Widespread use of such instrumentation in homes, business, and public places could help fine-tune exposure models and illuminate how community scale monitors relate to actual distributions of individual exposure.

COST: $350,000

TITLE: Development of an Updated Base Case Ambient VOC Mixture

PROBLEM: Various types of atmospheric model analysis or model development work of regulatory or research interest requires use of "base reactive organic gas (base ROG)" mixture that appropriately represents mixtures of reactive VOCs emitted into urban atmospheres. These include, but are not limited to: (1) developing condensed mechanisms for airshed models from chemically detailed mechanisms that appropriately incorporate the chemical detail in models; (2) calculation of the MIR and other VOC reactivity scales using models that appropriately represent the chemical composition in the atmosphere; (3) deriving an appropriate base case mixture for use in environmental chamber studies of VOC impacts under chemically realistic conditions; (4) serving as a standard against which to define relative reactivities; and (4) calculating the indirect effects of emissions on secondary pollutants from other VOCs present. The base ROG mixture used to develop condensed versions of the SAPRC99 and SAPRC07 mechanisms, used to derive the most recent MIR and other reactivity scales, and used in most recent chamber experiments for mechanism evaluation, is out of date and needs to be updated.

PREVIOUS WORK: The current base ROG used in the applications discussed above was based primarily on an analysis by Jeffries et al. (1989) of air quality data from 1986, with oxygenated species added based on an analysis by the CARB staff in 1991 of data from the SCAQS database. Since that time, emissions compositions have changed due to ongoing control strategies and other developments, and analytical methods have improved. However, this analysis of base ROG has not been revised.

DESCRIPTION: Available speciated VOC measurements made in various urban areas will be compiled and analyzed. Measurements taken during the morning or during periods of low photochemical reactivity will be utilized to derive an estimated composition of VOCs as emitted. Analytical limitations will be taken into account, and measurements using methods suitable for difficult-to-analyze VOCs will be employed to estimate their levels. Available emissions data will be used to inform the analysis. Recommendations will be made as to a representative mixture for use in various applications such as discussed above.

BENEFITS: Condensed chemical mechanisms developed from detailed mechanisms are more representative of ambient conditions and potentially more accurate. Scenarios used in reactivity scales will better represent ambient conditions.

COST: $40,000

TITLE: Near-Zero VOC Stain Blocking Primer Formulations

PROBLEM: Development of near-zero VOC primers with stain-blocking performance that rivals higher VOC alkyd technology does has proved quite difficult to date. Although water-based primers have been developed and are commercially available, these products typically require application of two coats and suffer marginal results in blocking water soluble stains and tannins. A variety of water-based products have been developed and specified, often in multicoat applications, to do the job that a conventional solvent-based primer often accomplishes with one coat application. There remains a need for a near-zero VOC primer technology that performs similarly to conventional solvent-based primer technology.

PREVIOUS WORK: Resin manufacturers and coating manufacturers alike have been and are actively engaged in the development of technology that will successfully replace alkyd resin technology for specialty applications. Most of this technology is based on aqueous emulsion technology. To date however, this technology is lacking in critical application and performance properties for stain blocking primer applications. Recent work in our laboratories has identified a potential technology that shows promise as a base technology for the development of near-zero VOC (substantially less than 100g/L) stain blocking primers with potential improved properties compared to commercial water-based primers in the market place.

OBJECTIVE: The objective of this research is the development of near-zero VOC stain blocking primers that perform as well as current state of the art solvent-based alkyd primers.

DESCRIPTION: This project goal is development of near-zero VOC stain blocking primer technology. The research involves the development of emulsion technology combined with formulation methodologies and protocols that will result in primer formulations that apply and perform similarly to solvent-based alkyd primers. The research involves identification and/or synthesis and/or validation of emulsion technologies with the base properties required to successfully block a variety of stains, including water-soluble stains and tannins. Novel formulation methodologies and protocols will be applied to the identified emulsions in the development of stain-blocking primer formulations. Specific technical goals for developing optimized near-zero VOC stain-blocking primers include:

a. Identification, synthesis, and validation of emulsion technology;
b. Optimization of pigmentation: concentration and types for flat gloss (<10 gloss at 85 angle) and for sanding;
c. Optimization of adhesion over waxy stains and old painted surfaces;
d. Optimization of cure through:
   - Sanding: preferably within 1 hr, maximum time 4 hours;
   - Recoat (with latex and oil based topcoat): preferably within 1 hour, maximum time 4 hours;
e. Optimization of product stability:
   - Viscosity;
   - Performance;
   - Consistency;

f. Manufacturability.

In addition to laboratory evaluations of product performance, accelerated exposure studies and field studies of the technology will be performed.

BENEFITS: The successful development of this technology would allow Californians and California businesses to utilize environmentally compliant near-zero VOC coating technology. Current solvent-based stain blocking primer technology has a VOC content of approximately 350 g/L. Specialty primers of this VOC range are no longer acceptable according to proposed ARB regulations. Current water-based stain blocking primers do not perform as well, as even stated on their label. New near-zero VOC technology will allow for the maximum reduction in emissions (>2.63 tons/day) while providing performance properties equal to 350 g/L alkyd based technology.

COST: $400,000

TITLE: Formation of Secondary Organic Aerosols: Chamber Study and Modeling

PROBLEM: Secondary organic aerosol (SOA) formed from atmospheric reactions of volatile organic compounds (VOCs) in the presence of NO_X constitutes an important component of suspended fine atmospheric particulate matter (PM) that impacts visibility, climate, and health. Due to limited knowledge of chemical and physical processes involved in SOA formation, SOA modeling is afflicted by large uncertainties (Volkamer et al, 2006; Galbally and Goldstein, 2007; Q. Zhang et al., 2007). Increasingly stringent controls on NO_X emissions for both on-road and non-road sources will lead to changes in the VOC/ NO_X ratios within the atmosphere. Such changes in atmospheric reactivity directly impact the extent of gas-to-particle conversion of VOCs. Development of reliable and effective SOA control strategies depends on model predictions that require nuanced understanding of SOA formation processes.

PREVIOUS WORK: Johnson et al. (2005), Song et al. (2005), and Ng et al. (2007) performed initial characterizations of the role of VOC/NO_X on predicted aerosol formation. These studies indicate that earlier work performed in chambers at high NO_X concentrations may have grossly underestimated the extent of gas-particle partitioning for several aromatic species. Significant changes in aerosol formation potential with changes in atmospheric reactivity must be accounted for in predictive models used to assess fine particle formation in the atmosphere. A model has been developed that tracks the gas phase precursors and applies a semi-empirically determined gas/particle partitioning coefficient to single precursors (Warren et al., 2007). This model shows promise for tracking the influence of NO_X on SOA formation.

OBJECTIVE: Perform controlled environmental chamber studies to facilitate improvement of SAPRC-07 to estimate secondary organic aerosol formation from select VOCs.

DESCRIPTION: Experiments will be carried out in an atmospheric chamber to measure SOA formation from selected aromatic compounds under a range of ambient concentrations and conditions. Parameters varied will include VOC and NO_X concentrations, the presence of other reactive VOCs, temperature and relative humidity. These experiments will provide a basis for evaluating the changing aerosol formation potentials of precursor VOCs through current and future atmospheric reactivities. These data will be used to improve SAPRC-07 to simulate SOA formation using a modeling platform currently used by Air Resources Board. The results will be analyzed with respect to both theoretical predictions of SOA formation and model simulations of gas-phase processes.

BENEFITS: Data on SOA formation in well-characterized experiments representing a range of atmospheric conditions are essential to test and improve our theories and models for predicting SOA in the atmosphere. Since SOA can exceed 70% of the fine particulate burden on highly impacted days, accurately predicting its formation is essential to developing cost-effective control strategies for find PM, and assessing how proposed ozone control strategies may also impact PM. The model will provide critical information to identify regulations to reduce SOA contributions to fine particulate matter.

COST: $475,000

TITLE: Bridging On-Road and Laboratory Emission Measurements: An Integrated Approach

PROBLEM: Understanding the health and climatic impacts of mobile source emissions and developing appropriate control technologies requires laboratory measurements of vehicle emissions that represent in-use conditions. However, there is disparity between particulate emissions measured on road and in the laboratory. This discrepancy is particularly pronounced for ultrafine particles (<100 nm), which are not only directly emitted as a result of incomplete combustion, but also formed in the exhaust dilution process. The possible introduction of a Diesel Particulate Filter (DPF) as a retrofit technology in the state of California would further complicate the formation of ultrafine particles since it removes nearly all solid soot particles in the accumulation mode (0.3 to 1 μm diameter). Most of these solid soot particles are made of black carbon, which is a strong light absorbing compound. Therefore, the optical properties, and thus the climate impact, of diesel exhaust is likely to change significantly if DPFs are widely deployed. It is critical to understand how on-road and laboratory measurements relate and to evaluate the effects of DPFs on optical properties of vehicle emissions.

PREVIOUS WORK: The rapid cooling of hot exhaust by entrainment of ambient air triggers sulfuric-water homogeneous nucleation, generating nuclei around 1 nm. These nuclei grow into detectable, larger sizes via augmentation with sulfate and/or organic materials. Extensive measurements have revealed the highly non-linear nature of ultrafine particle formation and growth processes. There are three major types of sampling methods: laboratory dilution tunnel, on road chasing, and wind tunnel. In the wind tunnel sampling, emissions are characterized by running the test vehicle on a chassis dynamometer located in a wind tunnel. A full scale wind tunnel is able to mimic atmospheric dilution, thus eliminating the sampling artifacts associated with laboratory dilution tunnel measurements. Because the dynamometer is located in the indoor environment, the driving cycles and sampling conditions are well controlled and generally repeatable. Repeatability is essential for particle quantification, and often challenges on-road chasing measurements due to variable atmospheric conditions. Two wind tunnel measurements were carried out recently. The first test was conducted by Ford researchers at the Ford Research Lab, where a garage-like wind tunnel was used. The second test was conducted by researchers from West Virginia University (WVU), who measured emissions from a Class-8 heavy-duty diesel truck in the Langley wind tunnel. The WVU study has demonstrated the feasibility of emissions characterization in a full scale wind tunnel. However, there were several limitations in their study, some of which will be discussed in the Description section. It is worth noting that only unloaded conditions were tested in the WVU study. A literature review did not reveal any optical properties measurements for diesel emissions installed with a DPF.

OBJECTIVES: The objectives are to quantify (1) ultrafine particle formation/growth potentials; and (2) optical properties (scattering, absorption, extinction coefficients) of exhaust particles for representative diesel vehicles with and without a DPF.

DESCRIPTION: Measurements associated with ARB's ongoing laboratory and on-road (using a mobile platform) research, will be complemented by data collection and modeling of vehicle emissions in a full scale wind tunnel at NASA Ames Research

Center in Moffett Field, California. The same diesel vehicles used in the laboratory and on-road studies, selected to represent the current California fleet, will be tested in the Ames wind tunnel. With a test section of 80 by 120 foot (the largest in the world), this wind tunnel is capable of providing a wide range of dilution rates. The flow is non-recirculating so vehicle emissions will not build up over time. (The Langley wind tunnel in WVU's study is a recirculating one). There is 180 ft downwind distance to measure the plume evolution, compared to less than 50 foot in the previously-described WVU study. NASA's wind tunnel is well-suited for investigation of the plume aging process.

Plume dilution rates, determined by using CO_2 or CO as an inert tracer, will be adjusted to match those measured by the mobile platform. The measurements of CO_2 (or CO) at various positions also allow a mapping of the plume trajectories aided by flow visualization. The physical and chemical characteristics of plumes will be measured at 8 downwind distances, under different dilution ratios, temperature and relative humidity. All the instruments will be housed in a gantry-mounted platform, which move along the plume center lines remotely controlled by the staff. The proposed study is unique in that it incorporates: 1) Intensive hydrocarbon measurements. In spite of their important roles in growing nucleation mode particles, hydrocarbons measurements were mostly ignored in previous studies; 2) Evaluation of the contribution of photochemical reactions to ultrafine particle formation/growth by turning on/off UV lights in the wind tunnel; 3) Optical properties measurements of exhaust plumes at several downwind distances (corresponding to different aging stages). The main instrument to be employed is a compact optical properties analyzer using cavity ring-down technology developed by NASA. It has the capacity to conduct in-situ measurement of aerosol extinction and scattering coefficients with a time resolution around 1 second. An additional photoacoustic instrument will also be employed to measure absorption coefficient; 4) Comparison of the results from three sampling methods under similar conditions, i.e., same vehicles, dilution ratios, temperature and relative humidity. The intercomparisons will generate a reference guide on how to improve laboratory sampling systems to represent real-world conditions; 5) Development of a mechanistic, predictive model to quantify the formation and growth potential of ultrafine particles. In addition, we will visualize the quantification in forms of isopleths for each type of vehicles. Furthermore, we will classify each vehicle (with different types of fuels) into sulfur-limited and HC-limited categories, providing a first-order reference for developing control technologies.

BENEFITS: Resolving and reducing the health effects and climatic impacts of diesel particulates are among ARB's main challenges. For the first time, investigators will be able to quantify both the ultrafine particles formation/growth potentials and the optical properties for diesel exhausts. This full-scale wind tunnel study also provides a platform for evaluation of real-time PM measurement instruments. The optical property measurements will provide a critical link between air pollution emitted by diesel trucks and their effects on climate. The effects of DPFs on diesel emissions will be elucidated, providing policy makers with a scientific basis for developing air quality and climate regulations.

COST: $420,000

Toxic Air Contaminants

TITLE: Measurement of Diesel Solid Nanoparticle Emissions Using a Catalytic Stripper for Comparison to Europe's PMP Protocol

PROBLEM: Gravimetric methods currently used for the legal determination of emissions will be challenged to quantify PM mass emissions as regulations continue to get more stringent. The European PMP protocol, developed to measure solid particle number emissions, holds promise to complement regulatory mass measurements. While the method was developed to regulate light duty diesel PM primarily in Europe, CARB has conducted projects to evaluate this method for heavy-duty diesel PM in the last few years. The protocol ignores nucleation-mode particle from diesel exhaust and measures only solid particles in an effort to enhance repeatability and accuracy of the measurement.

Recent experiments conducted using CE-CERT Mobile Emissions Laboratory (MEL) revealed unexpectedly high concentration of particles under the PMP protocol during some conditions on our on-road testing for the CARB European PMP program. These high particle concentrations occur when exhaust temperature downstream of a DPF is higher than a threshold temperature of approximate 350°C. This raises a potential contradiction with the European PMP since it indicates that nucleation can occur under PMP protocol. It is also possible that high particle concentrations reflect penetration of solid partially burned soot or ash particles during regeneration process of DPF or that the particles are composed of low volatile organic compounds that do not evaporate in the evaporation (Sakurai et al. 2003). The possibility of charring of organic particles was excluded in Sakurai et al.'s work but might warrant re-investigation with addition of control technology and PMP system, which can alter emission profiles and charring conditions.

It is necessary to understand the relationship of high particle concetrations under certain conditions to the PMP protocol and to understand what types of particles are either penetrating or forming. The PMP system is designed to ignore semivolatile nucleation mode particles by assuming that semivolatile particles do not survive under PMP protocol or that CPC with a high cutoff diameter (23nm) cannot detect them. However, ARB's recent laboratory work performed using a chassis dynamometer (Herner et al. 2007), revealed solid sub-20nm particles that can make it past the PMP volatile particle remover (a.k.a. evaporation tube). In addition, CECERT found solid particle penetration through the PMP system in our recent on-road work. It is critical to discover whether these presumably solid particles are artifacts or not. If they are not artifacts, then they should be counted in the PMP protocol, which could require a change in the PMP CPC cutoff diameter.

PREVIOUS WORK: CE-CERT performed on-road testing for the CARB European PMP project in June 2007. The objective of that project was to evaluate the proposed PMP method for determining particle emissions from heavy-duty diesels and its potential in California for PM emission measurement and in-use screening. We observed the above mentioned solid particle penetration repeatedly for some operating conditions.

Interestingly, we observed a greater extent of penetration of solid particles past PMP system when we drove our MEL on road without following any specific cycle. We tried increasing the PMP dilution ratio and increasing the temperature of the evaporation tube but we could not remove penetration of particles through PMP. This suggested that the penetrating matter is either solid particles or particles formed in the PMP system. This important finding has been addressed in the literature.

OBJECTIVE: Investigation of particle penetration/formation under PMP protocol to assess its impact on the PMP measurement protocol.

DESCRIPTION: The catalytic stripper (Kittelson et al., 2005) is a small catalytic converter that is maintained at constant temperature to enhance both the evaporation and the oxidation of volatile organics. Volatile organics diffuse to and oxidize on the catalyst-coated wall of the stripper. While the evaporation tube under PMP protocol maintains high temperature to suppress possible nucleation of semivolatiles by lowering the supersaturation ratio, the catalytic stripper makes nucleation of diesel exhaust completely impossible by oxidizing particle precursors. In terms of advantages, the evaporation tube is a simpler, lower cost system, whereas catalytic stripper is more complete in eliminating the possibility of any nucleation. We propose to compare particle number emissions before and after replacing the evaporation tube with the catalytic stripper. This will show whether the high concentration particles we observed in our on-road testing for the CARB European PMP project were solid particles or particles formed by other mechanisms, as discussed in the PROBLEM section herein. We also propose to use the TEM technique to determine the morphology of particles under PMP protocol. A thermophoretic sampler and a low-pressure impactor will be used to collect particles of 2-50nm and above 50nm respectively. TEM technique is going to be used as a complementary or exploratory means since chemical analysis using EDS is going to be challenging for small particles under 10 nm due to weak scattering. We propose to use CE-CERT Mobile Emissions Lab (MEL) as a platform to test the PMP protocol as it was used with our previous project. We propose to run MEL on the road with a repeatable route with and without a catalytic stripper to compare with PMP method. We plan to rent one PMP system from Matter Engineering and we will replace an evaporation tube with a catalytic stripper. We plan to procure another PMP system from ARB to run experiments with two PMP systems in parallel.

BENEFITS: CARB has had a leadership role in improving air quality in California for public health. This project will help CARB scientists critically evaluate PMP protocol, which could be complementary or replace the current regulatory mass measurement as particle emissions standards get more stringent.

COST: $170,000

REFERENCES:

Herner et al., 2007 *SAE Tech Paper* 2007-11-1114
Kittelson et al. 2005 *Journal of Aerosol Science* 36, 1089-1107
Sakurai et al. 2003 *Atmospheric Environment* 37, 1199–121

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Health Effects and Air Quality Standards

TITLE: Vulnerable Populations Among People Who Exercise or Work Outdoors: Acute Health Effects of Traffic-Related Air Pollution During Outdoor Exercise

PROBLEM: Little is known regarding the acute health effects of ultrafine particles and air pollutant mixtures like traffic emissions on otherwise healthy individuals during outdoor exercise. Children, the elderly, and persons with lung disease such as asthma, constitute vulnerable populations particularly sensitive to air pollution. Vulnerability can also be a function of a person's activity level in certain microenvironments. Healthy people can become vulnerable to air pollution at relatively low concentrations during exercise due to their higher ventilation rates (Grievnink et al., 1998; Mautz et al., 1988). Chamber studies have been performed to characterize this effect, but chamber studies are limited by their high expense and necessarily small subject numbers. Furthermore, it is difficult to simulate real-world pollution mixtures in chambers. The extent of exercise-induced vulnerability to air pollution, particularly traffic-related air pollution, is not well-characterized. Potentially large numbers of otherwise healthy persons may be experience enhanced vulnerability during high air pollution episodes or at locations of frequent high concentrations, such as athletic fields located close to busy roadways.

PREVIOUS WORK: There were two recent attempts to study the health effects of exposure to real-world traffic pollutant mixtures on adults, but neither sought to address the problem in this study. The North Carolina Trooper Study (Reidiker et al, 2004) tested Troopers working at night under conditions of relatively light traffic. A study funded by ARB, "Cardiovascular Health Effects of Fine and Ultrafine Particles during Freeway Travel," examined cardiovascular effects of freeway PM on elderly subjects (Hinds et al.). Both studies used vehicles as a type of exposure chamber. However, the Trooper study did not measure ultrafine particles. The Hinds study suffered from the difficulty in producing full high versus low exposure contrast, as gaseous pollutants were high in all scenarios. In addition, both studies had relatively low numbers of subjects, nine and 16, respectively, and neither examined the higher ventilation rates that occur during exercise. The few studies that have examined pollutant exposures during intense exercise have been chamber studies with small subject numbers using single pollutants (Grievnink et al.,1998).

OBJECTIVE: The two-fold objective of this work is: to advance knowledge of the effect of exposure to real-world pollutant mixtures, including traffic emissions, on otherwise healthy individuals during periods of sustained high respiration while exercising; and to overcome the limitations of related studies using small numbers of subjects and artificial pollutant mixtures.

DESCRIPTION: We propose to study two, relatively large groups of cyclists (e.g., groups of 12 to 20 per exposure period) undergoing simultaneous exposures while cycling predetermined routes in the L.A. air basin and possibly in Fresno. The study will take advantage of the heightened exposures caused by increased ventilation during exercise.

Investigators will chose routes to maximize exposure differences and to vary specific pollutant concentrations. Routes being considered include an on-road route with high ultrafine particles, high NO_X, and low ozone; two low concentration routes on bike trails where traffic emissions are low, one with higher ozone on a route located inland and ridden by cyclists during the summer months, a route in the Palm Springs area with low traffic emissions but high coarse PM; and a Fresno route with high PM2.5. A suite of lung function tests, blood and respired air markers of inflammation, and urinary biomarkers, will allow comparing relatively large numbers of highly exposed persons to health endpoint measures of lung function, lung inflammation, and blood coagulation. Two large groups of cyclists will be recruited to undergo pre- and post-exercise lung function tests (FEV1, FVC, peak flow), exhaled NO, and to provide pre- and post-exercise blood (e.g., C-reactive protein, IL-6, IL-8, TNF-alpha, fibrinogen) and urine samples for markers of inflammation or oxidative stress (e.g., clara cell proteins, F2-isoprostanes). Buccal (mouth) cells will also be collected and archived for possible later genetic analysis of known genetic vulnerability for lung anti-oxidant protective responses such as the GSTM1 genes. These will be analyzed if acute responses indicate significant divergence in individual acute responses. Heart rate will be monitored to ensure equal exertion and breathing rate during exposures. Pollutants will be continuously monitored (including particle number and mass, ozone, and NO_X) during the ride by either the use of the ARB Mobile Monitoring Platform (MMP), an instrumented electric bicycle, or both. One study PI is already familiar with the MMP and in the analyses of the real-time data it produces. Furthermore, other study PIs have successful experience in subject recruitment, lung function testing including exhaled NO, and in testing biomarkers in blood and urine.

BENEFITS: This study will provide policy makers, epidemiologists, and others with significant new information on the adverse health effects of high activity in traffic-impacted locations on otherwise healthy individuals. It will also add knowledge about the health effects of ultrafine particles. As short-term air quality standards are frequently driven by the effects seen in vulnerable populations, the results of this study may play a helpful role in the evaluation of the adequacy of current air quality standards in protecting the health of the outdoor-exercising portion of the population.

COST: $490,000

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Grievnink, L., Jansen, S., van't Veer, P., Brunekreef, B. (1997) Acute effects of ozone on pulmonary function of cyclists receiving antioxidant supplements. *Occup Environ Med* 55:13-17.

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Reidiker, M., Cascio, W.E., Griggs, T.R., Herbst, M.C., Bromberg, P.A., Neas, L., Williams, R.W., Devlin, R.B. (2004) Particulate matter exposures in cars is associated with cardiovascular effects in healthy young men. *Am J Respir Crit Care Med* 169:934-940.

Climate Change

TITLE: Improving Methods for Assessment of California Greenhouse Gas Emissions

PROBLEM: Significant uncertainty afflicts current emission inventories of greenhouse gases (GHGs), particularly for non-CO_2 gases. These uncertainties must be reduced to accurately quantify current inventories and verify future emission reductions required by AB32. Inverse modeling is a powerful technique for estimating greenhouse gas emissions by comparing measured and predicted atmospheric GHG concentrations to back-calculate the most probable emissions estimates and their uncertainties. Inverse modeling is requires accurate representation of atmospheric transport and mixing. Current mesoscale meteorological models, necessary for inverse modeling of air basins, do not to provide sufficiently accurate and high resolution representations of atmospheric transport to substantially improve many emission inventories. The lack of highly resolved representations of atmospheric transport in non-uniform terrain of coastal California is particularly noteworthy.

PREVIOUS WORK: Efforts to reproduce trace-gas distributions in California have shown that transport model errors limit the accuracy of air quality models and emissions estimates (Wheeler et al., 2006). Recent work also has shown that the performance of transport models can be greatly improved by incorporating high resolution, three-dimensional meteorological data (MacDonald et al., 2000; MacDonald et al., 2006).

Work has shown that CO_2 fluxes caused by California's fossil fuel combustion and net terrestrial ecosystem carbon exchange generate variations in the atmospheric CO2 mixing ratio that are should be readily measurable (Fischer et al., 2004; Riley et al., 2007). One successful approach to estimating continental scales net CO_2 exchange has used CO_2 measurements from aircraft and tower platforms in an inverse model approach (Lin et al., 2003, 2004; Gerbig et al., 2003a,b). Directly relevant to this proposal, the uncertainty in estimated surface emissions due to transport model errors were formally quantified (Lin and Gerbig, 2005). To minimize errors introduced by transport models at regional scales, recent work has focused on development of a specialized version of the NOAA Weather Forecast Research (WRF) model that provides output optimized for use with the stochastic time inverted particle Lagrangian transport model (STILT) and enables assimilation of three-dimensional meteorological data (Nehrkorn et al., in preparation; Eluszkiewicz et al., in preparation).

Until recently, few sites in California exist with the required capabilities to measure multiple GHGs (Li et al., 2005). In 2007, two new projects were initiated. First, the California Air Resources Board (ARB) conducted a series of 10-day measurement campaigns at Mt. Wilson Observatory, overlooking greater Los Angeles. Canister sampling and later analysis revealed strong correlations between different GHGs and carbon monoxide (CO). Under the assumption that GHG:CO concentration ratios reflect the ratio of GHG:CO emissions (e.g., that the emissions are either well-correlated or well-mixed in the LA Basin before reaching Mt Wilson), existing inventories of CO emissions can be used to estimate GHG emissions. Accurate, highresolution meteorology will be an essential tool in testing the validity of the assumption that

emissions are well-mixed, providing a means to identify which subregions of the LA Basin (e.g., port shipping) are responsible for most emissions. Second, in a California Enery Commission Study, measurements of multiple GHGs have begun at a site near Sacramento (Walnut Grove) and in the Bay Area (Sutro Tower). By combining analysis of these (and possibly other) sites, the stage is set to begin assessing emissions of several GHGs that are poorly understood at present (Farrell, 2005). Progress in this area is important in setting the stage for a California Climate and Air Quality (CCAQ) field study being planned by ARB, CEC, and NOAA for 2010.

OBJECTIVE: The objective of this project is to evaluate and enhance a state-of-the-science mesoscale transport model for inverse model studies of GHG and air pollutant emissions.

DESCRIPTION: First, we will assemble month-long meteorological data sets that capture interseasonal and inter-annual (e.g., average, El Niño, La Niña) variations. The data sets will include standard meteorological data collected at surface sites and by radiosondes and enhanced data, including hourly mixing heights, vertical profiles of winds, and virtual temperature measured by radar wind profilers, Radio Acoustic Sounding Systems, and sodars. Second, we will perform WRF simulations for each month of measured meteorology for a set of three or four sites identified in cooperation with ARB (e.g., Mt. Wilson, Walnut Grove, Sutro Tower). For each site, simulations will include a set of nested grids from approximately 10 km (covering all of California) down to as small as 1 km (covering perhaps 30 km) for sites in complex terrain. Third, the WRF simulations will then be evaluated by comparing predicted variables (e.g., mean wind velocities, boundary layer depth, turbulent kinetic energy, convective potential energy, etc.) with those obtained from the measured meteorology. Both mean bias and root mean square error will be computed. Fourth, source-receptor influence functions will be calculated for the selected observation sites using ensemble STILT runs driven by the WRF meteorology. The ensembles will include the random components of WRF errors determined above. Best estimates of GHG emissions and their uncertainties due to transport model errors will be quantified. Finally, we will determine the necessary resources to perform similar meteorological data assimilation and additional emissions modeling to support the planning of the 2010 CCAQ field study.

BENEFITS: This project will provide California with the high-resolution meteorology necessary to accurately estimate GHG emissions from previous GHG measurement intensives, allowing a crucial and independent test of (currently uncertain) non-CO2 GHG emission inventories, and identifying the observations and modeling needed to verify future emissions reductions in response to AB-32.

COST: $270,000

TITLE: Assessing the Energy Savings and Greenhouse Reduction Potential of Water Efficiency Improvements in the California Industrial Sector

PROBLEM: Recent estimates by the California Energy Commission (CEC) suggest that roughly 3% of California's annual electricity use and 14% of its annual non-power plant natural gas use can be attributed to the treatment, distribution, and use (e.g., heating, pressurizing, and cooling) of water by the California industrial sector (1). Based on California's latest greenhouse gas (GHG) emissions inventory, this energy use generates around 10% of California's annual non-transportation related GHG emissions arising from fossil fuel combustion (2). Industrial water efficiency improvements can therefore play a significant role in reducing California's energy demand and GHG emissions. While a substantial body of information exists on industrial water efficient technologies and practices, to date no study has assessed the water, energy, and GHG emissions savings potential, life-cycle costs, and sub-sector level applicability of water efficiency measures across California industry. Thus, accurate estimates of the potential statewide benefits and costs of industrial water efficiency improvements are lacking, which constitutes a critical information barrier to policy efforts to reduce the energy use and GHG emissions of California industry.

PREVIOUS WORK: Many "bottom up" resources exist globally on water efficient technologies and practices for individual industrial sub-sectors, some of which are directly applicable to California industry. For example, LBNL developed a water and energy benchmarking tool for California's wine industry, which characterizes the water savings and costs of specific water efficiency measures (3). LBNL also compiles water efficiency data for various industries in support of the U.S. EPA's ENERGY STAR for Industry Program (most recently for the food processing, pulp and paper, and chemical industries (4). Several "top down" studies of statewide water use and efficiency opportunities have been published (5,6), but these studies lack key details on applicable technologies, savings potentials, and implementation costs within industrial sub-sectors. Moreover, available studies applicable to California don't appear to quantify the energy use and GHG emissions savings associated with industrial water efficiency measures.

OBJECTIVE: To perform an assessment of the water use, energy use, and GHG emissions reductions achievable through water efficiency improvements in California's industrial sector. This assessment will be based on detailed study of applicable technologies and strategies within key California industrial sub-sectors, and will include water and energy savings potentials and life-cycle costs associated with each measure.

DESCRIPTION: LBNL has performed detailed energy efficiency potentials studies for a variety of industrial sub-sectors, and is currently leading a statewide industrial energy efficiency potential study for the CEC. The approach employed in these studies for the environmental and economic assessment of energy efficiency opportunities will be applied to water efficiency assessment as follows. First, water use estimates for California industrial sub-sectors will be developed based on state-level water balances, water intensity data for typical sub-sector processes, available case study data, and engineering estimates (e.g., boiler fuel may serve as a proxy for steam system water use). The goal will be to develop reasonable estimates of water use by application (e.g., steam, process cooling, and washing) for major water consuming California subsectors

(e.g., food processing and semiconductors). Second, estimates of the energy and GHG savings achievable per liter of water use avoided will be derived for each subsector. Estimates of indirect energy and GHG savings (i.e., due to avoided water purchases and discharges) will be derived based on water system analyses by LBNL's Water Energy Technology Team (WETT). Estimates of direct energy and GHG savings (e.g., due to decreased demand for water heating, pressurization, and cooling) will be based on LBNL's industrial sub-sector energy use studies. Third, data on available water efficient technologies and practices applicable to each sub-sector will be compiled to characterize the potential water savings and life-cycle costs associated with each measure. Finally, a model will be developed to estimate the potential water, energy, and GHG savings associated with the deployment of identified water efficiency measures across California industry. The model will also generate water efficiency supply curves for integrated environmental and economic analysis. A final report will summarize methods, results, and recommendations for water efficiency improvements.

BENEFITS: This work will fill a critical gap in knowledge regarding the energy savings and GHG emissions reduction potentials and costs of specific water efficient technologies and strategies in California's industrial sector, and will therefore provide the detailed information necessary for developing informed action plans and incentives for improving industrial water efficiency. Improved industrial water efficiency can help California meet its energy efficiency and GHG emission reduction targets, and will also lead to greater availability of scarce water resources, reductions in peak electrical demand, and reductions in air pollution in the state.

COST: $300,000

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(1) California Energy Commission (2005). Integrated Energy Policy Report: Chapter Eight: Integrating Water and Energy Strategies. Sacramento, California. CEC-100-2005-007CMF. November.

(2) California Energy Commission (2006). Inventory of California Greenhouse Gas Emissions and Sinks: 1990 to 2004. Sacramento, California. CEC-600-2006-013-SF. December; and California Energy Commission (2007). Revisions to the 1990 to 2004 Greenhouse Gas Emissions Inventory Report. Sacramento, California.

(3) Benchmarking and Energy Saving Tool (BEST) for the Wine Industry: http://water-energy.lbl.gov/node/19

(4) See for example: Masanet, Worrell, Graus, and Galitsky (2007). Energy Efficiency Improvement and Cost Saving Opportunities for the Fruit and Vegetable Processing Industry – An ENERGY STAR Guide for Plant and Energy Managers. Lawrence Berkeley National Laboratory. Berkeley, California. LBNL-59289.

(5) Gleick, Cooley, and Groves (2005). California Water 2030: An Efficient Future. Pacific Institute. Oakland, California. September.

(6) House, L.W. (2006). Water Supply Related Electricity Demand in California. Prepared for the California Energy Commission by the Demand Response Research Center, Lawrence Berkeley National Laboratory. Berkeley, California. LBNL-62041.

Diesel and Goods Movement

TITLE: On-Road Heavy Duty Vehicle Emissions Measurements Including Ammonia, Sulfur Dioxide, and Nitrogen Dioxide

PROBLEM: Starting in 2007, most manufacturers chose to meet increasingly stringent PM emissions standards for on-road, new engine HDDVs using Diesel Particulate Filters (DPFs). To regenerate these filters, intentional NO/NO_2 conversion catalysts are employed. On-road measurements made with a chase vehicle have found that the NO_2/NO_X ratio from DPF-equipped transit buses was 33% whereas non-DPF equipped buses emitted less than 10% of the NO_X as NO_2 (Shorter et al 2005). The ability to measure and monitor on-road NO_2 release from DPF equipped vehicles will be important in evaluating this technology's overall success. There is a CARB standard for the emissions of nitrogen dioxide from future HDDV which can now be verified by on-road techniques. Current HDDV emit no ammonia, but to the extent that future NO_X controls include urea injection, ammonia emissions might well increase from HDDV. Ammonia is a major component of airborne PM2.5 and there are few ammonia sources in the LA basin other than motor vehicles. Sulfur dioxide emissions, especially from diesel vehicles, are a potential indicator of misfueling. This is an illegal activity and the fines are high but the incentives are significant.

PREVIOUS WORK: There has been one previous on-road RSD study of HDDV emissions of NO, CO and HC in the LA basin (Bishop et al 2001). We have now developed a UV based on-road remote emissions sensor which reliably gives not only CO, HC, CO_2 and NO fuel-based mass emissions readings from passing heavy duty vehicles but also provides the same quality of data for ammonia, nitrogen dioxide and sulfur dioxide. The results of a single on-road HDDV study will be published soon in Environ. Sci. Tech. A second HDDV study in Japan has been carried out with this unique instrument because in Japan they have found with their many DPF equipped vehicles that while NO_X has gone down both NO_2 and ozone have increased. Several typical HDDV were observed with 50/50 NO/NO_2 emissions on a molar basis. Regarding misfueling, the 2005 study in Colorado showed perhaps as many as 27 vehicles out of 1409 to be using illegal high sulfur fuel. If future HDDV are significant ammonia emitters, this could have an important impact on PM2.5.

OBJECTIVE: To monitor the above pollutants from approximately 3000 heavy duty vehicles under load as they exit the same weigh and check station in Riverside CA. The results, when combined with fuel sales data, will provide a fuel-based emission inventory and will investigate potential misfueling. The results will also determine the extent to which the new model HDDV meet the new CARB NO_2 emissions standard and perhaps slip excess ammonia from urea decomposition.

DESCRIPTION: The FEAT 3000 is the University of Denver's routine on-road emissions monitor. It has been used in California for the CARB and IMRC at several sites, and for the CRC every two years at a single site, the intersection of LaBrea Blvd. and I-10 in Los Angeles. The instrumentation is fully described in CRC E-23 reports available on the web at www.feat.biochem.du.edu. and in a recent Rev. Sci. Instrum. paper also

available from the web site. The new features which have been added include new optics and a wider UV detector array which allow NO_2, SO_2 and NH_3 to be monitored simultaneously with the routine pollutants. This development was described by Burgard et al at the April 2006 CRC Meeting in San Diego. Colorado and Tulsa HDDV and LDDV results with the new capability will shortly be published in Environmental Science and Technology. In operation, a mobile van sits at the roadside during daylight hours for one week at the measurement location and the sensors are placed on a rented scaffold. We suggest a return to the Riverside site close to the LA basin in part to compare the data with data taken earlier at the same site by the same instrument before the modifications. The techniques or research methods to be employed are identical to those used in two recent studies in the Denver area and in Tulsa OK which were reported at CRC 2006 in San Diego by Burgard et al. Other than the addition of the three new pollutant channels they are identical to those used in the CRC E-23 studies. Tasks to be achieved include apply to CALTRANS for permits for the site, ensure that all calibration gases are available and certified by appropriate authorities, carry out the studies, read partial vehicle ID numbers, match partial vehicle ID numbers with complete VINs (as done in Colorado) for make and model year with California DMV and report the findings.

BENEFITS: New knowledge of the current HDDV ammonia, nitrogen dioxide and sulfur dioxide emissions inventory. An indication as to whether these emissions when measured on-road are within the guidelines set by the new CARB emission standards.

COST: $100,000

TITLE: Port Workers' Exposure to Air Pollution

PROBLEM: The Ports of Los Angeles and Long Beach (Ports) and their terminal operators provide employment to thousands of workers in on-dock and transportation jobs. Current ARB and SCAQMD efforts to characterize air pollution levels in the surrounding communities do not address on-job air pollution exposure. As many of the workers live in the surrounding communities, assessing overall pollutant exposure of this sub-population requires knowledge of occupational exposure as well.

PREVIOUS WORK: A previous study funded by NIOSH and conducted by Cal-EPA measured the on-job pollution exposures of several occupation classes at the Ports. The study did not address many pollutants of concern such as diesel particulate matter. Other studies have assessed diesel exposure in other occupational settings.

OBJECTIVE: To characterize the exposure of Port terminal and transportation workers to air pollutants.

DESCRIPTION: To characterize exposure of Port workers, a combination of personal monitoring and area sampling will be conducted. A set of occupation types and settings will be selected after an initial scoping task to determine jobs and areas with potential for high exposures. This will be accomplished via site visits and include input from occupational hygienists, the Ports, terminal operators, and the local dock workers union (ILWU #13). The exact number of samples, subjects, areas, and sampling durations will be determined based on the scoping exercise and available resources. Once the jobs and areas for sampling are identified, volunteers for personal monitoring and appropriate IRB approval will be sought.

Area sampling will include established methods for air monitoring of selected pollutants and air toxics. PM2.5 and PM10 filter samples will be collected and analyzed for mass, air toxic species, and elemental carbon as an indicator of diesel exhaust. Methods for measuring continuous PM mass will also be considered as resources allow. Ultrafine particle counters will also be considered. Eight-hour duration silanated canisters will collect organic gas air toxics for subsequent analysis.

Personal sampling may include some more recently developed active and passive methods. Many traditional occupational exposure monitors do not have the sensitivity to measure pollutants at ambient levels. Since the objective of the personal monitoring is to measure exposures that may be well below established occupational limits or guidelines and provide comparisons to fixed site monitors, the methods deployed for epidemiological exposure assessment are more appropriate. Methods that will be considered include personal, active PM samplers or impactors, passive and active gas samplers, and particle counters for ultrafine particles. Sampling analysis techniques will be as similar as possible to those used for the area sampling and the other ongoing monitoring studies in the surrounding areas.

Data analysis will include direct comparisons between on-job exposures, area concentrations, and community concentrations as measured by ongoing SCAQMD and

ARB monitoring studies. The specific source of the exposures will be assessed based on the chemical analysis of PM filters, gases, and estimated source profiles.

BENEFITS: Assessing the impact of goods movement includes the health effects costs associated with exposure to air pollution from goods movement activities. Given the large number of jobs associated with Port activities, and the proximity of these jobs to pollution sources, an impact assessment should include the potentially elevated exposures of this sub-population of residents. This study will help to identify these exposures and impacts and provide important information for decision-makers regarding Port operations and pollution mitigation measures.

COST: $300,000

DRAFT

Atmospheric Science

TITLE: Global Chemical/Aerosol Data Assimilation Experiments in support of the proposed 2010 California Air Quality and Climate Study

PROBLEM: The California Air Resources Board (CARB), in partnership with the California Energy Commission and the National Ocean and Atmospheric Administration (NOAA), has begun preliminary planning for a proposed 2010 Air Quality and Climate field study. The 2010 field study will collect data to address key science questions regarding; interactions between air quality and climate change, influences of long-range transport, and characterization of ozone and aerosol precursors and greenhouse gas emissions. These data sets will be used to assess the fidelity of air quality modeling in support of California State Implementation Planning (SIP) activities. Characterization of temporal, spatial distribution of inflow oceanic boundary conditions has been identified as critical due to the influence of long-range transport of ozone, aerosols, and their precursors into California. Quantification of the role of background ozone and aerosol formation on California air quality requires a nested global to regional to local scale modeling approach. Global chemical and aerosol analyses, constrained with satellite trace gas and aerosol observations, can be used to provide the global component of this nested modeling system.

PREVIOUS WORK: The NASA Applied Sciences Program, in partnership with the U.S. EPA, conducted a benchmark study to determine whether lateral boundary conditions based on assimilation of satellite ozone measurements improve air quality prediction within the U.S. EPA CMAQ model [http://aiwg.gsfc.nasa.gov/esappdocs/benchmarks/AirQuality_CMAQ_Benchmark_Final.pdf]. Results indicated that using boundary conditions generated from the Real-time Air Quality Modeling System (RAQMS) [Pierce et al., 2003, 2007] improved the performance of CMAQ in the middle troposphere. Impacts on surface ozone were largest over the coastal and mountain regions of the western U.S. where high biases were increased slightly (2 ppbv) and diurnal variations were improved by ~10%. Subsequent studies using RAQMS assimilated boundary conditions [Tang et al., 2007, Song et al., 2007] also show that boundary conditions from global chemical analyses improve regional model predictions. RAQMS chemical analyses (constrained with NASA Aura OMI and TES measurements), in conjunction with Lagrangian chemical back-trajectory analysis, where used to quantify the role of background ozone production on local air quality in the Houston and Dallas metropolitan areas during the 2006 NOAA TEXAQS II field study [http://www.tceq.state.tx.us/assets/public/implementation/ air/am/workshop/20061012-13/RSST_Preliminary_Findings_Report_20061031.pdf] The RAQMS TEXAQS II study demonstrated the benefit of synthesizing satellite, aircraft, and surface measurements of aerosol and trace gases in conjunction with advanced modeling techniques for characterizing the impact of emissions from remote sources on local air quality.

OBJECTIVE: Conduct global chemical data assimilation experiments utilizing satellite based trace gas and aerosol measurements to provide observationally constrained lateral boundary conditions for regional air quality modeling in support of the California SIP activities.

DESCRIPTION: Assimilation of cloud cleared OMI total column ozone and TES global survey O_3 and CO profile retrievals from the NASA Aura satellite and MODIS aerosol optical depth and wildfire detections from the NASA Terra satellite will be conducted within RAQMS using uni-variate Optimal Interpolation (OI) analyses techniques. RAQMS is a unified (stratosphere/troposphere), multi-scale (global to regional) online (meteorological, chemical, and aerosol) modeling system which has been developed for assimilating satellite based observations of atmospheric chemical composition and providing real-time predictions of trace gas and aerosol distributions [Pierce et al., 2003, 2007; Kittaka et al., 2004]. For an up-to-date description of the RAQMS chemical mechanism see Pierce et al. [2007]. The RAQMS aerosol modules [Chin et al. 2003] and MODIS AOD assimilation has been tested in the regional component of RAQMS. Implementation of aerosols into the global model is currently underway.

Tasks:

1. Retrospective OMI+TES+MODIS chemical and aerosol assimilation experiments will be conducted during Spring and Summer 2008 to provide CARB regional air quality modelers with RAQMS chemical analysis for developing interfaces and evaluating impacts on California air quality assessment modeling.
2. Real-time OMI+MODIS assimilation/forecasting will be conducted during 2010 to provide support for field study activities.
3. Retrospective OMI+TES+MODIS assimilation experiments will be conducted during 2010 to provide CARB regional modelers with lateral boundary conditions for SIP modeling activities.

BENEFITS: Global chemical and aerosol analyses produced under this research activity would be beneficial to the California regulatory planning and technical community at the district, state, and federal levels because they will provide improved constraints on background ozone and aerosol distributions for state implementation plan (SIP) modeling efforts. This work will build capacity for air quality forecasting and assessment through the use of satellite observations.

COST: $480,000

References:

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TITLE: Measurement of Ozone Aloft for the 2010 Air Quality and Climate Field Study in California

PROBLEM: Both ozone and secondary particulate matter are formed in complex photochemical reactions of air pollutants emitted from a wide variety of sources. Despite many years of reducing precursor emissions, many areas in California are classified by the U.S. Environmental Protection Agency as in non-attainment for ozone and particulate matter (PM). In addition both ozone and PM interact with sunlight, affecting the energy input to the atmosphere and earth's surface, thus having potential for contributing to global climate changes. To formulate additional cost-effective emission control strategies, a better understanding of the meteorological and chemical processes contributing to high ozone concentrations is needed. In order to fully understand formation processes it is necessary to have as much concentration as possible in an air shed in order to develop and validate air quality simulation models. While ozone, PM and some precursor concentrations are measured routinely at ground level, there is little current concentration data of the vertical distribution. The draft list of scientific questions proposed for the 2010 Air Quality and Climate Field Study in California (2010 Study) included "What are the important transport corridors for key chemical species" and "What are the sources and physical mechanisms that contribute to high ozone concentrations aloft". In order to address these questions both meteorological and pollutant concentration data are needed as a function of altitude. The following will focus on obtaining ozone data aloft, although meteorological data will also be obtained concurrently.

PREVIOUS WORK: The 1997 Southern California Ozone Study (SCOS97-NARSTO) provided an expanded understanding of the distribution of ozone in Southern California and the mechanism of formation. This study emphasized the collection of data on the vertical distribution of ozone and meteorological parameters. During intensive operating periods or IOPs, ozone concentrations were measured aloft using a number of techniques.

Ozone can be measured aloft by a number of techniques. Instrumented aircraft are commonly used, but they have many limitations. Cost has been a major limitation, especially for sporadic forcasted use, since the crew and aircraft must be maintained while waiting for acceptable study days. In addition to cost, there are several other limitations. To obtain a vertical ozone gradient, the aircraft must perform spirals over one location. It is often difficult to obtain permission to do this in urban areas because of the large amount of air traffic. Except when taking off or landing, aircraft are limited to flying at least 1,000 feet above ground level (AGL) in populated area and 500 feet AGL in unpopulated areas. This would be a significant limitation since during the highest ozone days most of the ozone is within the first 1,000 feet AGL. Ozone vertical distributions also can be measured using tethered balloons. While these balloons can be easily varied in height and do not move spatially, it is difficult to obtain permission from the Federal Aviation Administration to fly them above 200 feet, especially in urban areas or at night, due to potential interference with aircraft. Vertical ozone measurements can also be made remotely by using LIDAR instruments. These are research instruments that are expensive and labor-intensive. Correction factors are often necessary, and the quality of the data is difficult to quantify. Comparison with data

obtained by other methods has shown significant variability. Ozonesondes have advantages to the above-mentioned techniques and were used extensively during the SCOS97-NARSTO study. On a per-measurement basis, their cost is generally less than that of a research aircraft. There are no major limitations as to where they can be flown. The instruments are simple, inexpensive direct measures of ozone that are easily calibrated.

OBJECTIVE: The objective of this research is to determine ozone concentrations and meteorological data as a function of altitude for the critical geographic areas in support of the 2010 Study.

DESCRIPTION: Our approach is to use En-Sci model 2Z ECC ozonesondes flown on helium-filled balloons to make vertical sounding of ozone. Ozone data from the sonde, in addition to air pressure, temperature and humidity, are transmitted to a ground station. From the receiver, the data are sent to a personal computer. The En-Sci model 2Z ECC ozonesonde uses the principle of ozone reacting at constant stoichiometry with a solution of potassium iodide (KI) in a buffered solution of an electrochemical cell. The performance of all ozonesondes will be verified at a central facility prior to deployment in the field. The location and frequency of launches will be finalized during future 2010 Study planning sessions. It is anticipated that launch sites should be located in all of California's major urban air basins and at significant mountain passes that lead from one air basin to another. Thus the San Diego County, South Coast, San Joaquin Valley, Sacramento Valley, and San Francisco Bay Area air basins should be included. Mountain passes between these air basins would include Altamont, Pacheco, Tejon, Cajon, and Tehachapi passes. A total of ten launch sites are therefore likely. In order to follow the transport and transformation processes launches should be made at least four times a day for at least two contiguous days. This is the protocol that was used during SCOS97-NARSTO. The balloons will be filled with helium to produce a free lift of 350 grams. This provides an ascent rate of approximately 1.5 m/s, which will give the maximum vertical resolution while providing a lift rate sufficient for a successful launch.

Site operators (two per site) will be recruited from areas near launch sites. They will be trained to launch the sondes as a group at a central facility. Training launches will be conducted using a tethered sonde. Site operators will be on-call for the entire 2010 Study measurement period. After launching, the data will be monitored on a computer screen until the sonde reached a pressure of 500mb or less. Data will then be immediately sent to a central facility for processing, storage, and validation.

BENEFITS: This project will provide much needed vertical ozone concentration data to answer the scientific questions raised by the 2010 Study.

COST: $600,000

State Implementation Plan Support

TITLE: Cluster Analysis of Air Quality and Meteorology Data for 1996-2008

PROBLEM: This study will assess exposures to fine particulate matter (PM) and ozone throughout California over an extended study period. Certain regions of the state have reduced ambient pollutant levels through emissions reductions (e.g. SoCal), whereas others have not (e.g. SJV). The relationship between pollutant concentrations and emissions reductions is profoundly impacts of atmospheric processes on ambient air quality. Relationships between meteorology and air quality can be elucidated by statistical analysis, providing a complement to detailed episodic analyses of relatively brief air pollution events. Extended records of routine measurements can be used to characterize the full range of meteorological scenarios that are likely to both occur and to have elevated air pollution potentials. This study is the first to perform systematic cluster analysis to explore meteorological influences on air quality at both the intra-basin and inter-basin scales. Results will aid air quality planning by identifying the full range of scenarios across which the benefits of emissions reductions can be evaluated to determine cost effective control strategies.

PREVIOUS WORK: Two related studies are being performed under CCOS and BAAQMD contracts: a 1996-2004 ozone study for Central California and a 1999-2007 PM study for the Bay Area. Both the Bay Area and SJV Districts found research results useful in their planning efforts.

OBJECTIVE: To use advanced statistical modeling to determine the effects of atmospheric processes on ambient pollutant levels to aid in exposure assessment. The study will consider both PM and ozone pollution during the period 1996-2008.

DESCRIPTION: This project is envisioned as a 3-year study, implemented in 3 tasks. Task #1 considers intra-basin effects of meteorology on air quality for 7 air basins defined by District boundaries. Task #2, an inter-basin analysis, explores overall trends in state-wide air quality in response to evolving meteorological conditions. Task #3 performs exploratory receptor modeling for PM source apportionment.

Task #1 performs intra-basin cluster analyses of routine, hourly surface wind measurements to identify meteorological patterns affecting 7 California air basins: Central Coast (North and South), Mojave Desert, Sacramento Valley, San Diego County, San Francisco Bay Area, San Joaquin Valley, and South Coast. For each basin, a separate clustering will be performed for the ozone (1 May through 15 October) and PM (1 October through 28 February) seasons. Through cluster analysis, we will identify key meteorological processes affecting air quality at both the mesoscale and synoptic scales. Emphasis will be placed on mesoscale circulations allowing for the formation of localized ozone or PM "hot spots." For each basin, the air pollution potentials (considering weekday/weekend effects) for both PM and ozone will be assessed under the entire range of atmospheric conditions occurring during the 13-year study period. Results will indicate subtle differences in meteorology that trigger exceedances for a given level of emissions. Vertical (ozone sonde) measurements will

be incorporated in the analyses to assess the potential of ozone layers aloft affecting surface ozone levels. Quality assurance will be performed for the data. This characterization of 1996-2008 meteorology may aid in future climate change research.

Task #2 considers meteorological effects on inter-basin air quality, focusing on temporal coherence between meteorology and air quality in distant regions of California. Meteorologically coupled basins will be identified, with attention to determining scenarios for large-scale flow patterns that could establish source-receptor relationships between adjacent air basins. Meteorological dynamics will be characterized for the flow splitting between the Bay Area, SJV, and Sacramento Valley; variations in oceanic boundary conditions along the Central Coast; potential marine flows from the Central Coast into SJV; scenarios in which the South Central Coast (Ventura County) is upwind of SoCab; and the connectivity between SJV, Mojave Desert, and SoCab. For basins experiencing coupled meteorology, the timing at which evolving meteorological systems (e.g. marine intrusion, migrating anticyclones, or storm activity) influence distant locations will be explored. The evolution of the inter-basin spatial distribution of pollutants will be characterized in response to the meteorological dynamics. This study serves as a basis for an inter-basin transport study by identifying a number of recurring scenarios under which long-range transport mechanisms could occur.

Task #3 is an exploratory use of statistical receptor models for PM source apportionment. A novel approach will be taken to perform the receptor modeling in a "meteorologically disaggregated" framework. For a given basin, receptor modeling will be applied independently to data pooled according to the meteorological patterns identified in task #1. Pooling data by meteorological classes will prevent the receptor model from capturing conflicting trends on days exhibiting vastly different source-receptor relationships and/or degree of airmass photochemical aging. Meteorological disaggregation will enable identification of different sources or source strengths affecting receptor locations under different meteorological conditions. Incorporation of the meteorological patterns identified in task #1 allows for increased insight when interpreting the speciated PM measurements that are not sampled every day.

BENEFITS: This project will leverage enormous datasets on surface meteorology and air quality to enable more accurate assessments of how atmospheric processes contribute to ozone and PM exposures over a range of scenarios. This approach complements episodic air quality modeling, which explores only a limited range of scenarios. This study will provide technical guidance to planners and regulatory agencies to improve public health by providing cleaner air throughout California.

COST: $250,000

REFERENCES:

Beaver S and Palazoglu A, 2006. A cluster aggregation scheme for ozone episode selection in the San Francisco, CA Bay Area. *Atmos. Environ.*, **40**, 713-25.

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Beaver S, Palazoglu A, and Tanrikulu S, 2007. Cluster sequencing to analyze synoptic transitions affecting regional ozone. *J. Appl. Meteor. Climatol.*, in press.

TITLE: Optical Remote Sensing from Mt. Wilson: A New Approach to Study Sources of Pollutants and Greenhouse Gases in the South Coast Air Basin

PROBLEM: Observation of pollutants and greenhouse gases and their spatial and temporal distributions is a crucial aspect of monitoring air quality as well as the current efforts, mandated by AB32, to curb greenhouse gas emissions in California. To date the strategy to monitor atmospheric trace gases on a regional scale has relied upon networks of in-situ ground observations. The limited number of ground sites in these networks often poses challenges due to possible influence of local emissions and large spatial gaps between the stations. Without complementary data from aircraft, balloons, satellites or other exotic platforms, the ground-based network is inadequate to characterize the emissions of pollutants and greenhouse gases, and to monitor their vertical and horizontal distributions. Novel, more readily deployable experimental methods are therefore needed to augment the capabilities of the existing monitoring network.

PREVIOUS WORK: A pilot study using multi-axis Differential Optical Absorption Spectroscopy (MAX-DOAS) to measure NO_2, HCHO, and aerosol extinction from the new NASA-JPL "California Laboratory for Atmospheric Remote Sensing" (CLARS) has been performed in April 2007 at Mt. Wilson. The results of this experiment clearly show that enough information can be derived to retrieve spatial concentration fields of these compounds in the South Coast air basin. These measurements will be continued in Fall 2007.

Through a NASA-sponsored project we have shown the feasibility of near-IR measurements and are currently building a dedicated near-IR FTIR to measure the spatial distribution of various greenhouse gases. The instrument is based on a long heritage of Fourier transform spectrometers developed at JPL for ground-based, aircraft, balloon and spaceflight applications. We anticipate that the near-IR capability will be fully operational by Summer, 2008.

OBJECTIVE: We propose to use optical remote sensing techniques in the UV/Vis and near IR wavelength regions from CLARS to measure the spatial and temporal distributions of various pollutants (NO_2, HCHO, aerosol extinction) and greenhouse gases (CO_2, CO, CH_4, N_2O). We will also explore measurements of the average concentrations of other greenhouse gases (CFC's, HCFC's, etc.) in the South Coast air basin during sunset. The observations can be used to validate and improve current emission inventories and urban airshed models.

DESCRIPTION: JPL's "California Laboratory for Atmospheric Remote Sensing" (CLARS) is located on a mountain ridge at Mt. Wilson with a near full view of the South Coast air basin. We propose to perform four month-long field experiment during different seasons in the years 2009 and 2010, measuring the spatial and temporal distribution of various pollutants (NO_2, HCHO, aerosol extinction via O_4) and greenhouse gases (CO_2, CO, CH_4, N_2O) using a UV-vis MAX-DOAS and a near-IR FTIR spectrometer. Both instruments will use scanning systems to measure the absorptions of these trace gases in different viewing directions. Concentration fields of

these compounds with a vertical resolution of 0.2 to 1km, a horizontal resolution of at least one kilometer, and a temporal resolution of 0.5 - 1 hour, will be retrieved using radiative transfer calculations. Operational software to allow the fast and accurate retrieval of these concentration fields will be developed. We will also perform solar occultation measurements during sunset to explore measurements of the average concentrations of less abundant greenhouse gases, such as CFC's and HCFC's, in the basin. A validation strategy will be developed and applied to ensure the quality of our data. The precise scanning geometry of our measurements can be chosen such that a good overlap with urban airshed models and ground measurements is achieved. Our observations will provide a novel and unique dataset of concentration fields of pollutants and greenhouse gases. The vertical concentration profiles within the boundary layer i.e. surface – 1000m altitude can be used to study the average fluxes of the various trace gases from the surface. By comparing our observations with the output of urban airshed models, emission inventories can be validated. We will seek collaboration with teams specializing in modeling the South Coast air basin to fully exploit our observations.

BENEFITS: The State of California is currently pursuing an ambitious plan to reduce its greenhouse gas emissions and to improve its air quality over the next decade. The proposed measurements will provide a unique data set to support these activities, by allowing the validation of emission inventories and urban airshed models. While we are currently proposing a campaign style observational strategy, the methods that we will employ could also be developed into a year-round observational system to monitor future changes in trace gas concentrations and emissions in the South Coast air basin and other urban areas in California.

COST: $285,000

Toxic Air Contaminants

TITLE: Guidelines and Sampling Protocols for Measuring ETS in Multifamily Dwellings

PROBLEM: The California Air Resources Board (ARB) identified Environmental Tobacco Smoke (ETS) as a Toxic Air Contaminant (TAC) on January 26, 2006. ETS has been associated with many adverse health effects including: Sudden Infant Death Syndrome, lung cancer, heart disease deaths, and acute and chronic respiratory illnesses, including asthma. In multi-family housing, residents may not be able to control their exposure to ETS if a resident in a neighboring unit smokes. Local public health officials report receiving a high number of complaints about secondhand smoke from apartment residents, and in the past two years several California cities have passed local ordinances to restrict smoking in multi-family dwellings. Multi-family dwellings make up nearly 40 percent of California's housing stock and two-thirds of the population in the Los Angeles area lives in multi-family buildings. There are no statewide laws to prevent involuntary exposure to ETS in multifamily housing. Additionally, there are no guidelines or protocols to assist the public or industrial hygienists in the measurement of ETS in multifamily housing. Measurement of ETS in units that may only share heating, ventilation, or plumbing conduits is complicated by the need to determine the nature and extent of the transfer between units. This degree of transfer is complicated by the age of the housing, the degree of ventilation, and the type of heating and air conditioning in the building. Measuring ETS is also complicated by the fact that the substance is a mixture of several thousand pollutants, many of which are also the result of other indoor contaminants. While nicotine is typically used to demonstrate exposure to ETS, the rate of transfer of nicotine from one unit to the next is complicated by the absorption properties of nicotine and particle filtering. Tracer gas studies have demonstrated a high potential transfer rate for the volatile components of ETS, which are also some of the most deleterious; these include 1, 3-butadiene, benzene, formaldehyde and acrolein.

PREVIOUS WORK: The most extensive research on ETS transfer in multifamily dwellings was performed in Minnesota by the Center for Energy and Environment (CEE). Multiple fan pressurization tests and passive tracer gas methods were used to characterize the transfer of ETS between apartment units. These measurements were supplemented by measurements of nicotine and fine particulate mass. Tests were conducted on six multifamily buildings representative of the type most common in Minnesota. Tracer gas studies confirmed that air flow between units could be a significant concern. At least one unit in each of the buildings contained 10 percent of the air from a different unit. Units on higher floors had a greater fraction of air from other units. The average fraction of inter-unit air flow ranged from 2 percent for a new four-story condominium to 35 percent for a 1930-era up/down duplex. The median value for all units was 5 percent. A previous study found 13 to 25 percent transfer in the Pacific Northwest. While there appeared to be a tendency for greater inter-unit air flow in older buildings, one three-story apartment building built after 1999 had unit air flows greater than 20 percent. The Minnesota study concluded that passive monitoring for nicotine was not an effective measure of the transfer between units. This was assumed to be due to the result of nicotine absorption and particulate filtering. The tracer gas transfer

rate ranged from 2 percent to 10 percent higher than the nicotine transfer rate. Measurements of fine particulate matter in this study were hindered by high and variable levels of background PM2.5.

OBJECTIVE: The primary purpose of this research is to document the potential for ETS transfer between units in multifamily housing. The authors will provide a direct measurement sampling protocol for each of a variety of multifamily housing stocks based on investigation of transfer rates as well as report on the results of sampling for nicotine and particulate matter in a variety of exposure settings in multifamily housing.

DESCRIPTION: The investigators will use Census information and information from the State's Department of Housing and Community Development to develop an estimate of the types and ages of multifamily dwellings in California. Using State building code information, the investigators will discuss the types of insulation, ventilation, heating and cooling that can be encountered in these various dwellings. A sampling protocol will be set up to measure ETS in a sample of units that are representative of California's multifamily housing stock. Investigators will then measure tracer gas concentrations, nicotine, and fine particulates (PM2.5, PM1.0) in a variety of dwellings and document the characteristics of each dwelling that could potentially affect the results in similar housing. Specifically, the investigator will answer the questions concerning: 1) Typical contaminant dispersion and airflow rates between apartment units in multifamily dwellings in California; 2) How the transfer of nicotine and fine particulates compare to the transfer of tracer gases; and 3) How air flow and contaminant transfer between units differ by building type. Approximately 8-10 buildings would be investigated, with at least 4-6 units in each building examined under a variety of climatic conditions. The investigator will then write a final report and establish a website for disseminating the information. Ongoing support of the website will be accomplished through collaboration with the Department of Health Services, the investigators, and ARB.

BENEFITS: This information will provide a basis for the development of smoke-free policies in apartment buildings, and will provide residents of multifamily housing, public health authorities, landlords, and property owners needed reliable scientific and technical information on how to demonstrate ETS exposure in multifamily housing. This information will also provide a basis for determining how transfer of ETS can be reduced through better design or ventilation.

COST: $425,000

TITLE: Sources, Composition, Variability and Toxicological Characteristics of Ultrafine Particles in Southern California

PROBLEM: Current regulatory efforts are focused on reduction of ambient levels of particulate mass for PM10 and PM2.5, but recent studies have demonstrated that ultrafine (UF) particles (less than ~100 microns in diameter) are more toxic. Studies that show individual particles penetrating cellular membranes and causing cell damage, suggest that particle number rather than particle mass may be a more health relevant metric of ambient particles. The majority of ambient particle numbers are UF particles, but, due to their small size, only a small fraction of ambient PM mass is UF. Since there is generally low correlation between ambient particle numbers and mass, ambient particle number measurements are becoming more important. Unlike PM2.5, for which there is an abundance of continuous and time-integrated mass (and in several areas chemical speciation) data generated by local and state agencies, a nationwide network of UF monitors is not currently in place, and may or may not become available in the near future. As a result, significantly less is known about the diurnal, spatial and seasonal characteristics of UF particles as well as chemical composition in urban and rural areas of the US. Since these PM characteristics may be important in evaluating the health effects of UFP relative to coarse PM or PM2.5, it is desirable to have intensive UFP measurements that will provide insights into the source, composition and health effects of these particles.

PREVIOUS WORK: UFP measurements in the proximity of freeways have been one of the focal points of the research undertaken by the Southern California Particle Center and Supersite. Results from these studies have been extensively cited in the scientific literature and used in legislation at the state and federal level. More recently, a CARB project granted to our group at USC focuses on the assessment of the spatial variability of ambient particle number concentrations within two impacted communities (source and receptor areas of Long Beach and Riverside, respectively). None of these studies , however, provides information on the larger scale distribution and characteristics of UFP in the Los Angeles Basin, which is the focus of the proposed project.

OBJECTIVE: The objective of this proposal is to provide the much needed and currently unavailable or very limited information on the relationships between UFP sources, spatial and seasonal characteristics, and toxicity in Southern California. Towards this goal, a highly multi-disciplinary research team will investigate the following research questions: a. What are the spatial, daily and seasonal differences in UFP number, mass and chemical composition found in rural and in urban areas of the Los Angeles Basin? b. What is the fraction of chemically speciated UFP that penetrates indoors and how does indoor and outdoor UFP differ toxicologically? c. How do the chemical characteristics of UFP collected in each of the above environments and over different seasons determine their toxicity? d. How does UFP PM toxicity differ from that of fine and coarse PM, measured in studies undertaken by the PIs, and sponsored separately by the recently renewed SCPC? e. How do the physical, chemical and toxicological characteristics of UFP in the urban and rural sites of this study compare to those near light- and heavy-duty freeways, airports and seaports?

DESCRIPTION: The proposed project spans an approximate 30-month cycle of measurements (24 months plus 2 intensive winter summer campaigns of 3 months each) at 10 locations impacted by different PM sources and representing distinctly different areas (urban, rural- receptor and desert) of the Los Angeles Basin (LAB). Seven of these locations are also sampling sites of the MESA (Multi-Ethnic Study of Atherosclerosis) Air Pollution Study ("MESA Air"). Two of them are high schools in urban Los Angeles with a high Hispanic student population. Of the 10 sites, the "*near freeway*" sites will selected to be as proximally close to the neighborhood freeway as possible (typically within a road2 width or so), and the *community sites* are in the generalized recruitment areas for some of the MESA subjects, away from the freeway. The general classification of these sites is as follows 1) the West LA area, from the I-405 Freeway to the coast (listed in the table as "*coastal*"); 2) the metropolitan/greater LA area, across the city and valleys, on either side of the 10 Freeway (listed as "*central*"); 3) the mostly rural-agricultural "*receptor areas*" of Mira Loma /Rubidoux/Riverside portion of Riverside County, situated about 80-90 km downwind of downtown Los Angeles. All of the sites have 115VAC power, are elevated (typically on the roof of a one-story building), and have protected access. In each of our fixed sites, measurements of UF number, mass, inorganic ions (sulfate and nitrate), elemental and organic carbon (EC-OC), speciated organic tracers, trace elements and metals as well as concurrent in vitro measurements of their redox activity and oxidative potential will be conducted on continuous and time-integrated bases. In addition to the UFP measurements listed above, the hourly concentrations of gaseous co pollutants (CO, NO_X, O_3) as well as meteorological parameters (RH, temperature, wind speed and direction) are also available in each site. We will also conduct winter and summer intensive campaigns in these areas. The 24 hr averaged sampling campaigns are designed to give us an estimate of the spatial variability of UF PM metrics in a large metropolitan areas such as the LA Basin, and how they affect the observed particle toxicity, whereas the purpose of the intensive campaigns will be to determine the diurnal variability in chemical composition of these particles. Indoor-outdoor ratios for UF PM mass and each species will be determined for selected sites. UF PM source apportionment and linkages of sources to toxicological outcomes will be a major focus of analysis.

BENEFITS: Our research will help federal and state regulatory agencies understand the linkage between sources, composition and the toxicity of UFP, which provides a strong scientific basis to develop cost-effective strategies to protect the public from the toxic sources of UF particulate matter. The current data will help determine if there is a scientific foundation for controlling UF particulate matter from only a subset of UF particulate sources. Moreover, data on UF PM characteristics will become an invaluable resource to the ongoing and planned PM exposure and health studies in the Los Angeles Basin, including major research programs, such as the Southern California PM Center (SCPC) and MESA Air investigations.

COST: $650,000

TITLES 13 AND 17. CALIFORNIA AIR RESOURCES BOARD

NOTICE OF PUBLIC HEARING TO CONSIDER THE ADOPTION OF A PROPOSED REGULATION FOR FUEL SULFUR AND OTHER OPERATIONAL REQUIREMENTS FOR OCEAN-GOING VESSELS WITHIN CALIFORNIA WATERS AND 24 NAUTICAL MILES OF THE CALIFORNIA BASELINE

The Air Resources Board (ARB or Board) will conduct a public hearing at the time and place noted below to consider adoption of a regulation to reduce diesel particulate matter (diesel PM), particulate matter (PM), nitrogen oxides (NOx), and sulfur oxides (SOx) by requiring the use of low sulfur marine distillate fuels in auxiliary diesel and diesel-electric engines, main propulsion diesel engines, and auxiliary boilers in ocean-going vessels operating within Regulated California Waters.

DATE: July 24, 2008

TIME: 9:00 a.m.

PLACE: California Environmental Protection Agency
Air Resources Board
Byron Sher Auditorium, Second Floor
1001 I Street
Sacramento, California 95814

This item will be considered at a two-day meeting of the ARB, which will commence at 9:00 a.m., July 24, 2008, and may continue at 8:30 a.m., July 25, 2008. This item may not be considered until Friday, July 25, 2008. Please consult the agenda for the meeting, which will be available at least 10 days before July 24, 2008, to determine the day on which this item will be considered.

For individuals with sensory disabilities, this document is available in Braille, large print, audiocassette or computer disk. Please contact ARB's Disability Coordinator at (916) 323-4916 by voice or through the California Relay Services at 711, to place your request for disability services. If you are a person with limited English and would like to request interpreter services, please contact ARB's Bilingual Manager at (916) 323-7053.

INFORMATIVE DIGEST OF PROPOSED ACTION AND POLICY STATEMENT OVERVIEW

Sections Affected: Proposed adoption of new section 2299.2, title 13, California Code of Regulations (CCR) and new section 93118.2, title 17, CCR. The following documents would be incorporated in the regulations by reference: (1) International Standard ISO 8217, "Specifications of Marine Fuels Requirements for Marine Residual Fuels," (as revised in 2005); (2) International Standard ISO 8754, "Determination of

Sulfur Content -- Energy-dispersive X-ray Fluorescence Method," (as adopted in 2003); (3) ASTM Designation E 29-93a, "Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications" (published May 1993); and (4) the following National Oceanic and Atmospheric Administration (NOAA) Nautical Charts, as authored by the NOAA Office of Coast Survey: (A) Chart 18600, Trinidad Head to Cape Blanco (January 2002), (B) Chart 18620, Point Arena to Trinidad Head (June 2002), (C) Chart 18640, San Francisco to Point Arena (August 2005), (D) Chart 18680, Point Sur to San Francisco (June 2005), (E) Chart 18700, Point Conception to Point Sur (July 2003), (F) Chart 18720, Point Dume to Purisima Point (January 2005), and (G) Chart 18740, San Diego to Santa Rosa Island (April 2005).

Background:

Emissions from ocean-going vessels are significant sources of air pollution and have an adverse impact on public health and air quality. Ocean-going vessels are responsible for approximately 20 percent of the statewide goods-movement related diesel PM emissions and about 12 percent of the statewide NOx emissions.[1] Ocean-going vessels also contribute significantly to community health risks. Recent ARB studies at the Ports of Los Angeles and Long Beach and in the West Oakland community found that of the port-related emissions, ships are responsible for over half of the increased population-weighted cancer risks in nearby communities. Since 2004, the ARB has adopted several regulations to address emissions from marine vessels, which include cleaner fuels and emission standards for commercial harbor craft, lower-sulfur fuels in ocean-going ship auxiliary diesel engines, and further restrictions for using auxiliary diesel engines on commercial vessels while docked at a California port.[2] However, significant opportunities exist to further reduce emissions from ocean-going vessels.

Control of Criteria Air Pollutants

Health and Safety Code (H&S) sections 43013 and 43018 direct ARB to adopt standards and regulations that the Board has found to be necessary, cost-effective, and technologically feasible for various mobile source categories, including off-road diesel engines and equipment such as marine vessels, through the setting of emission control requirements. Specifically, H&S section 43013(b) directs ARB to adopt such standards and regulations for marine vessels to the extent permitted by federal law.

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[1] 2005 ARB Goods Movement Emissions Inventory

[2] ARB's fuel standards for harbor craft are codified at title 13, CCR, section 2299. ARB's operational requirements for ships berthed at dock were approved for adoption by the Board at its December 2007 hearing (proposed title 13, CCR, section 2299.3 and title 17, CCR, section 93118.3). ARB's fuel standards and other requirements for diesel auxiliary and diesel-electric engines on ocean-going vessels are codified at title 13, CCR, section 2299.1 and title 17, CCR, section 93118, which were later declared to be emission standards, as drafted, and preempted without federal authorization under Clean Air Act section 209(e). *Pacific Merchant Shipping Ass'n v. James Goldstene,* No. 07-16695 (9th Cir. Feb. 27, 2008). The proposed regulatory action is intended to apply non-preempted operational fuel requirements to these auxiliary and diesel-electric engines.

Control of Toxic Air Contaminants

The California Toxic Air Contaminant Identification and Control Program (Air Toxics Program), established under California law by Assembly Bill 1807 (Stats. 1983, ch. 1047) and set forth in H&S sections 39650 through 39675, requires ARB to identify and control air toxics in California. The identification phase of the Air Toxics Program requires ARB, with participation of other state agencies such as the Office of Environmental Health Hazard Assessment, to evaluate the health impacts of, and exposure to substances, and to identify those substances that pose the greatest health threat as toxic air contaminants (TACs). ARB's evaluation is made available to the public and is formally reviewed by the Scientific Review Panel (SRP) established under H&S section 39670. Following ARB's evaluation and the SRP's review, the Board may formally identify a TAC at a public hearing. Following identification, H&S sections 39658, 39665, and 39666 require ARB, with participation of the air pollution control and air quality management districts (districts), and in consultation with affected sources and interested parties, to prepare a report on the need and appropriate degree of regulation for that substance (a "needs assessment") and to adopt airborne toxic control measures (ATCMs).

In 1998, the Board identified diesel PM as a TAC with no Board-specified threshold exposure level. A needs assessment for diesel PM was conducted between 1998 and 2000, which resulted in ARB staff developing and the Board approving a Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles (Diesel RRP) in 2000. The Diesel RRP presented information that identified the available options for reducing diesel PM and recommended control measures to achieve further reductions. The scope of the Diesel RRP was broad, addressing all categories of engines, both mobile and stationary, and included control measures for off-road diesel engines, such as those covered by the proposed regulation. The ultimate goal of the Diesel RRP is to reduce California's diesel PM emissions and associated cancer risks 85 percent from 2000 baseline levels by 2020. The proposed regulation would reduce diesel PM emissions and the local health impacts from main engines, auxiliary diesel and diesel-electric engines, and auxiliary boilers aboard ocean-going ships while operating in Regulated California Waters and would assist the Board with meeting the 2020 Diesel RRP goal.

Attainment of Ambient Air Quality Standards

The federal Clean Air Act (CAA) requires the U.S. Environmental Protection Agency (U.S. EPA) to establish National Ambient Air Quality Standards (national standards) for pollutants considered harmful to public health, including fine particulate matter (PM2.5) and ozone. Set to protect public health, the national standards are adopted based on a review of health studies by experts and a public process. Ambient PM2.5 is associated with premature mortality, aggravation of respiratory and cardiovascular disease, asthma exacerbation, chronic and acute bronchitis and reductions in lung function. Ozone is a powerful oxidant. Exposure to ozone can result in reduced lung function, increased respiratory symptoms, increased airway hyper-reactivity, and increased airway

inflammation. Exposure to ozone is also associated with premature death, hospitalization for cardiopulmonary causes, and emergency room visits for asthma.

Areas in the State that exceed the national standards are required by federal law to develop State Implementation Plans (SIPs) describing how they will attain the standards by certain deadlines. Diesel PM and PM emission reductions are needed because they contribute to ambient concentrations of PM2.5; NOx emission reductions are needed because NOx leads to formation in the atmosphere of both ozone and PM2.5; and SOx emission reductions are needed because SOx leads to the formation in the atmosphere of PM2.5. At this time, the South Coast Air Basin is required to attain the PM2.5 standard by 2015. U.S. EPA further requires that all necessary emission reductions be achieved one calendar year sooner – by 2014 – in recognition of the annual average form of the standard.

The ARB has adopted revisions to the South Coast ozone and PM2.5 SIPs and has submitted the SIPs to the U.S. EPA. Air quality modeling indicates that significant reductions in diesel PM, PM, NOx and SOx are needed to meet the PM2.5 standards. The strategy to achieve attainment of the PM2.5 standards in the South Coast Air Basin includes a 68 percent reduction in SOx emissions, a 55 percent reduction in NOx emissions, and a 15 percent reduction in direct PM2.5 emissions from 2006 baseline levels. The diesel PM, PM, NOx, and SOx, emission reductions from the proposed regulation would play an essential role in assisting the South Coast Air Basin with meeting its 2014 PM2.5 deadline as well as its future ozone deadlines.

As part of the submittal, ARB has also requested from U.S. EPA a reclassification of the South Coast Air Basin to "extreme" nonattainment for ozone, which will give the Basin until 2023 to attain the federal ozone standard. Air quality modeling indicated that by 2023, NOx emissions will need to be reduced by almost 90 percent – to 12 percent of the 2006 levels – to meet the current national 8-hour ozone standard.

The federal CAA permits states to adopt more protective air quality standards if needed, and California has set standards for particulate matter and ozone that are more protective of public health than respective federal standards. The Bay Area, South Coast, and San Diego areas are nonattainment for the State standards for ozone and PM2.5. Health and Safety Code section 40911 requires the local air districts to submit plans to the Board for attaining the State ambient air quality standards, and H&S section 40924 requires triennial updates of those plans. The NOx, SOx, and PM2.5 emission reductions from the proposed regulation will assist the districts in achieving attainment of the State ambient air quality standards.

Control of Emissions from Goods Movement-related Activities

In April 2006, the Board approved the Emission Reduction Plan for the Ports and Goods Movement in California (GMERP). The GMERP identifies strategies for reducing emissions created from the movement of goods through California ports and into other regions of the State. The GMERP is part of the broader Goods Movement Action Plan

(GMAP) being jointly carried out by the California Environmental Protection Agency and the Business, Transportation, and Housing Agency. Phase I of the GMAP was released in September 2005 and highlighted the air pollution impacts of goods movement and the urgent need to mitigate localized health risk in affected communities. The final GMAP was released in January 2007 and includes a framework that identifies the key contributors to goods movement-related emissions.

The GMERP identifies numerous strategies for reducing emissions from all significant emission sources involved in goods movement, including ocean-going vessels, commercial harbor craft, cargo handling equipment, locomotives, and trucks. The GMERP identifies several strategies for reducing emissions from ships, including the use of low sulfur fuels in ocean-going vessels. The proposed regulation would represent a significant step toward satisfying the GMERP goals by establishing fuel sulfur content limits for auxiliary diesel and diesel-electric engines, main engines, and auxiliary boilers beginning in 2009, with even lower sulfur content limits being required in 2012.

Authority

The ARB has authority under California law to adopt the proposed regulations. Health and Safety Code sections 43013(b) and 43018 provide broad authority for ARB to adopt emission standards and other regulations to reduce emissions from new and in-use vehicular, nonvehicular and other mobile sources. Under H&S sections 43013(b) and 43018, ARB is directly authorized to adopt emission standards and other regulations for marine vessels, as expeditiously as possible and to the extent permitted by federal law, to meet State ambient air quality standards. The ARB is further mandated by California law under H&S section 39666 to adopt ATCMs for new and in-use nonvehicular sources, including marine vessels such as ocean-going vessels, for identified TACs such as diesel PM.

Emission Reductions and Public Health Benefits Projected

The proposed regulation is expected to significantly reduce emissions of diesel PM, PM, NOx, and SOx from ocean-going vessel auxiliary diesel and diesel electric engines, main engines, and auxiliary boilers. Diesel PM emission reductions are needed to reduce cancer risk, premature mortality, and other adverse impacts from exposure to this TAC. The proposal would help achieve the 2020 goal set forth in the 2000 Diesel RRP of reducing diesel PM by 85 percent from 2000 baseline levels and the 2015 and 2020 goals of the GMERP.

Reductions in diesel PM, PM, NOx (which forms "secondary" nitrate PM in the atmosphere), and SOx (which forms "secondary" sulfate PM in the atmosphere) will also contribute to regional PM reductions that will assist in California's progress toward achieving State and federal air quality standards. Reductions in NOx, an ingredient in the formation of ozone pollution, will help reduce regional ozone levels. In 2010, the proposed regulation is expected to reduce diesel PM and PM emissions by about 13

tons per day (TPD), NOx emissions by about 10 TPD, and SOx emissions by about 110 TPD throughout California. Most of these reductions will be realized near ports, where environmental justice concerns are especially prevalent, and in coastal urban areas. Many of these coastal areas are non-attainment for the State and federal ambient air quality standards for PM10, PM2.5, and ozone.

Staff also evaluated the proposed regulation's impacts on greenhouse gas emissions. Based on a total fuel cycle analysis of the carbon dioxide (CO2) emissions associated with a switch to marine distillate fuels, ARB staff estimates that there potentially could be a slight 1-2% increase in global CO2 emissions. This net change in fuel-cycle CO2 emissions is primarily a function of the increased energy required at the refining stage to produce compliant distillate fuels. This offsets the decreased CO2 emissions from ship operations. The decrease in CO2 emissions from ship operations results primarily from the higher energy content of the distillate fuel, as compared to heavy fuel oil. But these results assume no effort by refineries to improve energy efficiency while maintaining, upgrading, or expanding their capacity to produce distillate fuels. Therefore, this potential fuel-cycle increase in CO2 emissions may be conservatively high.

Staff Report and Further Information

As described in more detail below, ARB staff has prepared as part of this rulemaking a Staff Report: Initial Statement of Reasons (Staff Report). Together with the needs assessment (i.e., the Diesel RRP), these two documents serve as the report on the need and appropriate degree of regulation for ocean-going ship main engines, auxiliary diesel and diesel-electric engines, and auxiliary boilers.

Description of the Proposed Regulatory Action:

Under the approach proposed by staff, the Board would approve adoption of two separate but essentially identical regulations, pursuant to its authority under H&S sections 43013(b) and 43018, which would apply to the emissions from auxiliary diesel and diesel-electric engines, main propulsion engines, and auxiliary boilers on ocean-going vessels operating within any of the Regulated California Waters (as defined in the proposal). The Board would also approve adoption of essentially identical provisions as an ATCM, pursuant to its authority under H&S section 39666, which would complement the regulation and provide maximum notice to the regulated community of the regulatory requirements on ocean-going vessels. These measures will hereinafter sometimes be referred to collectively as "the proposed regulations."

Applicability

The proposal applies to any person who owns, operates, charters, rents, or leases any ocean-going vessel that operates in any of the Regulated California Waters, regardless of the country in which the vessel is flagged or registered. The Regulated California Waters include all California internal waters, all California estuarine waters, all California ports, roadsteads, and terminal facilities, and all waters within 24 nautical miles of the

California baseline except for specified areas along the Southern California coastline (a more detailed description is provided in the regulatory proposal).

The proposed regulation includes language explicitly stating and clarifying that the proposal does not change or supersede any existing United States Coast Guard (USCG) regulations, and vessel owners and operators are responsible for ensuring that they meet all applicable USCG regulations, as well as the proposed regulation.

Exemptions

The proposed regulation includes several exemptions. First, the proposal does not apply to vessel voyages that are comprised of continuous and expeditious navigation through any Regulated California Waters for the purpose of traversing such bodies of water without entering California internal or estuarine waters or calling at a port, roadstead, or terminal facility. An exemption is included for steamships whose primary propulsion and electrical power are provided by steam boilers. The proposed regulation does not apply to vessels owned or operated by any branch of local, state, or federal government, or by a foreign government, when the vessels are operated on government non-commercial service. The proposed requirements exclude all emergency generators, and it also excludes auxiliary engines, main engines, and auxiliary boilers while such engines are using alternative fuel in Regulated California Waters. The proposed regulation does not apply if the vessel master reasonably and actually determines that compliance with the requirements would endanger the safety of the vessel, its crew, its cargo, or its passengers because of severe weather conditions, equipment failure, fuel contamination, or other extraordinary reasons beyond the master's reasonable control. Finally, the proposed requirements do not apply to vessels that have been granted a temporary experimental exemption by the Executive Officer for the duration of the approved exemption.

In-Use Operational Requirements

Staff's proposal would require vessel operators to ensure that their auxiliary diesel engines and diesel-electric engines operating in Regulated California Waters operate with either marine gas oil (MGO), with a maximum of 1.5 percent sulfur by weight, or marine diesel oil (MDO), with a maximum of 0.5 percent sulfur by weight, beginning upon the effective date of the regulation as approved by the Office of Administrative Law. Staff's proposal would require vessel operators to ensure that their main engines and auxiliary boilers operating in Regulated California Waters operate with either marine gas oil (MGO), with a maximum of 1.5 percent sulfur by weight, or marine diesel oil (MDO), with a maximum of 0.5 percent sulfur by weight, beginning July 1, 2009. Beginning on January 1, 2012, vessel operators would need to ensure that their auxiliary diesel and diesel-electric engines, main engines and auxiliary boilers operating in Regulated California Waters operate with either MGO or MDO, each limited to a maximum of 0.1 percent sulfur by weight. As noted below, vessel operators would be allowed under specified circumstances to pay a noncompliance mitigation fee for a limited duration in lieu of meeting the in-use operational requirements above.

Recordkeeping

Any person subject to the regulation will be required to maintain specified records in English for a minimum of three years. Staff has designed these requirements to minimize any impacts on vessel crews by relying on existing recordkeeping procedures to the extent possible. Additionally, the proposal requires records be retained and maintained documenting fuel switch over procedures.

Reporting, Monitoring, and Right of Entry

The information required to be recorded, as specified in the proposal, would have to be supplied in writing to the Executive Officer, but only upon request. Some of the recordkeeping required by the proposal may already be recorded to comply with other regulations or standardized practices. In these cases, the information may be provided to ARB in a format consistent with these regulations or practices, as long as the required information is provided. Ship owners or operators must also supply additional information as requested that may be necessary to determine compliance with the proposed regulations. To monitor compliance with the requirements of the proposal, vessel owners or operators would have to provide access to the records necessary to establish compliance with the requirements of the proposal, as well as access to fuel tanks or pipes for the purpose of collecting fuel samples for testing and analysis.

Other Provisions

The proposed regulation allows a vessel owner or operator, under restricted and specified circumstances, to pay a fee in lieu of complying with the in-use operational requirements. A vessel owner or operator using this mechanism would have to notify the Executive Officer of the vessel's noncompliance condition prior to the vessel entering Regulated California Waters. Also, the situations under which the fee provision could be used are limited to a finite set of specific circumstances, all of which must be documented (i.e., a "needs" demonstration). Further, the fee increases substantially with each subsequent port visit, which serves as an effective deterrent to continued use of the fee and an incentive to meet the in-use operational requirements as quickly as possible.

To use this option, the ship owner or operator would need to submit the required notification and mitigation fee, along with evidence demonstrating that the person meets the required conditions for participation in the program. The mitigation fees collected under this program may be deposited in the port's Noncompliance Fee Settlement and Air Quality Mitigation Fund to be used at the ports that are visited; emission reductions from marine and port related sources would be funded with these mitigation fees to benefit nearby affected communities. The fees would be disbursed pursuant to contracts entered into between the participating ports and ARB. If no such port fund exists, the fees would be deposited into the California Air Pollution Control Fund.

Through December 31, 2014, all or part of the fuel use requirements would be waived for vessels requiring essential modifications in order to use the specified fuel, provided certain criteria and documentation requirements are met and approved by the Executive Officer. Vessel operators would be required to use the low sulfur fuel to the maximum extent feasible without the need for essential modifications (e.g., closer to shore, in a subset of the ships engines, etc.).

Test Methods and Other Incorporated Documents

The proposal references International Standard ISO 8217, as revised in 2005 by the International Organization for Standardization (ISO). This standard includes the properties necessary for a fuel to qualify as DMX or DMA grade fuel (marine gas oil), or DMB grade fuel (marine diesel oil), and specifies the test methods for determining compliance with each of these properties. The proposal also references the test method (ISO 8754, as adopted in 2003) to be used for determining the sulfur level of these fuels, as well as the rounding method of ASTM Designation E 29-93a, Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications (published May 1993).

Violations

The proposal specifies that any violation of the requirements or other provisions would subject the person who committed the violation to the penalties, injunctive relief, and other remedies available under Health and Safety Code section 42400 et seq., other applicable sections of the Health and Safety Code, and other applicable provisions of California law for each violation. The proposal further specifies that each failure to meet a requirement, criteria, or provision of the regulation would constitute a single, separate violation for each hour that a person operates an ocean-going vessel within Regulated California Waters until the provision, criteria, or requirement has been met.

Sunset Provision

The "sunset" provision directs the Executive Officer to propose for the Board's consideration the termination of the proposed regulations under specified conditions. This would occur if the Executive Officer determines that the International Maritime Organization or the U.S. EPA has adopted regulations that will achieve equivalent benefits compared to the proposed regulation. This provision recognizes that, while California is authorized to require the use of low sulfur fuel on and regulate the emissions from ocean-going vessels, it would be preferable to regulate such emissions on a national or international basis.

Review of Baseline and Test Methods

This provision directs the Executive Officer to periodically review the California baseline determinations and conduct a public hearing to consider appropriate updates to the baseline. The definition for "Regulated California Waters" is based partly on the

definition of "baseline," which generally follows the California coastline but is subject to change due to erosion and accretion. The baseline is published on official charts authored by NOAA, and as NOAA modifies the charts, the Executive Officer can determine at that time whether revisions to the proposed regulation are necessary.

Similar to the baseline review, this provision also directs the Executive Officer to periodically review the test methods cited in the proposal and hold a public hearing to consider recommended changes to the Board as needed.

For the Executive Officer to conduct the hearings on the baseline and test methods specified, the Board will need to delegate such authority to the Executive Officer. The ARB staff intends to seek such express delegation as part of the Board resolution to this proposal.

Severability

This proposed regulation states that if any part of the regulation is held to be invalid, the remainder of the regulation shall continue to be effective.

COMPARABLE FEDERAL REGULATIONS

There are no current federal regulations that are comparable to the proposed regulation. The U.S. EPA adopted regulations – title 40, Code of Federal Regulations (CFR), parts 89 and 94 – that govern the emissions from "Category 2" (between 5 and 30 liters per cylinder displacement) and "Category 3" (at or above 30 liters per cylinder displacement) compression-ignition engines used on ocean-going vessels. While the U.S. EPA regulations apply to ocean-going vessels, they differ significantly from the staff's proposal in several ways. First, the federal regulations apply only to new engines to be installed on vessels, and only to engines installed on U.S.-flagged vessels. By contrast, the staff's proposal applies to in-use auxiliary diesel and diesel-electric engines, main diesel engines and auxiliary boilers on all ocean-going vessels that visit California ports, including both U.S. and foreign-flagged vessels. Further, the U.S. EPA regulation in 40 C.F.R., part 94, does not apply to the diesel PM or PM emissions from the regulated Category 3 engines, whereas the staff's proposal places a major emphasis on the control of toxic diesel PM emissions, as well as NOx and SOx, on all auxiliary diesel engines, diesel electric engines, main diesel engines, including Category 3 engines, and auxiliary boilers. Because of these differences, the federal regulations are not comparable to the staff's proposal.

AVAILABILITY OF DOCUMENTS AND AGENCY CONTACT PERSONS

The Board staff has prepared a Staff Report: Initial Statement of Reasons (ISOR) for the proposed regulatory action, which includes a summary of the potential environmental and economic impacts of the proposal. The ISOR is entitled, "Staff

Report: Initial Statement of Reasons for the Proposed Regulation for Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels within California Waters and 24 Nautical Miles of the California Baseline."

Copies of the Staff Report with the full text of the proposed regulatory language may be accessed on the ARB's web site listed below, or may be obtained from the Public Information Office, Air Resources Board, 1001 I Street, Visitors and Environmental Services Center, 1st Floor, Sacramento, CA 95814, (916) 322-2990, at least 45 days prior to the scheduled hearing on July 24, 2008.

Upon its completion, the Final Statement of Reasons (FSOR) will be available and copies may be requested from the agency contact persons in this notice, or may be accessed on the ARB's web site listed below.

Inquiries concerning the substance of the proposed regulations may be directed to the designated agency contact persons, Peggy Taricco, Manager of the Technical Analysis Section, at (916) 323-4882 or by email at ptaricco@arb.ca.gov, or Bonnie Soriano, Air Resources Engineer, at (916) 327-6888 or by email at bsoriano@arb.ca.gov.

Further, the agency representative and designated back-up contact persons to whom nonsubstantive inquiries concerning the proposed administrative action may be directed are Lori Andreoni, Manager, Board Administration & Regulatory Coordination Unit, (916) 322-4011, and Amy Whiting, Regulations Coordinator, (916) 322-6533. The Board has compiled a record for this rulemaking action, which includes all the information upon which the proposal is based. This material is available for inspection upon request to the contact persons.

This notice, the Staff Report, and all subsequent regulatory documents, including the FSOR, when completed, are also available on the ARB Internet site for this rulemaking at http://www.arb.ca.gov/regact/2008/fuelogv08/fuelogv08.htm.

COSTS TO PUBLIC AGENCIES AND TO BUSINESSES AND PERSONS AFFECTED

The determinations of the Board's Executive Officer concerning the costs or savings necessarily incurred by public agencies and private persons and businesses in reasonable compliance with the proposed regulations are presented below.

Costs to Local and State Government Agencies

Pursuant to Government Code section 11346.5(a)(5) and 11346.5(a)(6), the Executive Officer has determined that the proposed regulatory action would not create costs or savings to any state agency or in federal funding to the state, costs or mandate to any local agency or school district whether or not reimbursable by the state pursuant to Part 7 (commencing with section 17500), Division 4, Title 2 of the Government Code, except as discussed below, or other nondiscretionary savings to state or local agencies.

Costs to Businesses and Private Individuals

In developing this regulatory proposal, the ARB staff evaluated the potential economic impacts on representative private persons or businesses. The Executive Officer has determined that although most vessel owners will need to switch to more expensive marine distillate fuels while operating in Regulated California Waters in order to comply with the proposed regulation, these costs are a small fraction of the overall operating costs. We therefore expect no significant impacts on affected businesses. On average, we estimate the added annual fuel cost for a typical vessel operator to be about $300,000 to $700,000 per company depending on the year. For the entire ocean-going shipping fleet that visits California, we estimate an added annual fuel cost to range from about $140 million in 2009 (when the rule is implemented mid-year) to $360 million in 2014 (the final year of cost analysis). The added cost of the regulation represents about 1 percent of the total costs of a typical trans-Pacific voyage. We do not expect that the proposed regulation will result in significant capital costs to ship operators, since most vessels are unlikely to need to make modifications to use distillate fuel.

The Executive Officer has determined that, because the added costs of the proposed regulations are a small percentage of the overall operating costs, no significant impact on ship operators, businesses that import or export goods, California port competitiveness, or on individuals purchasing such goods is expected, even if all these costs were passed on to the consumer.

The Executive Officer has made an initial determination that the proposed regulatory action would not have a significant statewide adverse economic impact directly affecting businesses, including the ability of California businesses to compete with businesses in other states, or on representative private persons. A number of businesses are integrally linked to the goods that travel through California ports. However, we do not believe that the added costs of the proposed regulations are high enough for ship operators to consider alternative ports outside California.

In accordance with Government Code section 11346.3, the Executive Officer has determined that the proposed regulatory action would not affect the creation or elimination of jobs within the State of California, the creation of new businesses or elimination of existing businesses within the State of California, or the expansion of businesses currently doing business within the State of California. A detailed assessment of the economic impacts of the proposed regulatory action can be found in the ISOR.

The Executive Officer has also determined that, pursuant to title 1, CCR, section 4, the proposed regulatory action would not affect small businesses because we do not believe that the ship operators subject to this proposal would qualify as small businesses due to the large capital and operating costs associated with vessel operation.

The Executive Officer has also determined that there is a possibility the proposed regulatory action will result in a positive impact on business creation due to additional sales of marine fuels in California beginning in 2012, when vessel operators must use 0.1 percent sulfur marine gas oil or marine gas oil to meet the specified emission limits. This is because California is expected to have 0.1 percent sulfur fuel available and the regulation contains a provision that allow vessel operators, unable to obtain compliant fuel at a foreign port, to purchase compliant fuel upon arriving at a California port without having to pay a noncompliance fee.

In accordance with Government Code sections 11346.3(c) and 11346.5(a) (11), the Executive Officer has found that the reporting requirements of the regulations that apply to businesses are necessary for the health, safety, and welfare of the people of the State of California.

In accordance with H&S section 43013(a) and (b), the Executive Officer has determined that the standards and other requirements in the proposed regulations are necessary, cost-effective, and technologically feasible for auxiliary diesel and diesel-electric engines, main engines, and auxiliary boilers operated on ocean-going vessels within the Regulated California Waters.

Before taking final action on the proposed regulatory action, the Board must determine that no reasonable alternative considered by the agency or that has otherwise been identified and brought to the attention of the agency would be more effective in carrying out the purpose for which the action is proposed or would be as effective and less burdensome to affected private persons than the proposed action.

SUBMITTAL OF COMMENTS

The public may present comments relating to this matter orally or in writing at the hearing, and in writing or by e-mail before the hearing. To be considered by the Board, written submissions must be received **no later than 12:00 noon, Pacific Standard Time, July 23, 2008**, and addressed to the following:

- Postal mail: Clerk of the Board, Air Resources Board
  1001 I Street, Sacramento, California 95814
- Electronic submittal : http://www.arb.ca.gov/lispub/comm/bclist.php
- Facsimile submittal: (916) 322-3928

Please note that under the California Public Records Act (Government Code section 6250 et seq.), your written and oral comments, attachments, and associated contact information (e.g., you address, phone, email, etc.) become part of the public record and can be released to the public upon request. Additionally, this information may become available via Google, Yahoo, and other search engines.

The Board requests but does not require 30 copies of any written submission. The Board also requests that written, facsimile, and e-mail statements be filed at least 10 days prior to the hearing so that ARB staff and Board Members have time to fully consider each comment. The ARB encourages members of the public to bring to the attention of staff in advance of the hearing any suggestions for modification of the proposed regulatory action.

Additionally, the Board requests but does not require that persons who submit written comments to the Board reference the title of the proposal in their comments to facilitate review.

STATUTORY AUTHORITY AND REFERENCES

This regulatory action is proposed under the authority granted to ARB in sections 39600, 39601, 39658, 39659, 39666, 41510, 41511, 43013, and 43018, Health and Safety Code; and *Western Oil and Gas Ass'n v. Orange County Air Pollution Control District*, 14 Cal.3rd 411, 121 Cal.Rptr. 249 (1975). This regulatory action is proposed to implement, interpret, or make specific sections 39000, 39001, 39002, 39003, 39515, 39516, 39650, 39658, 39659, 39666, 41510, 41511, 43013, 43016, and 43018, Health and Safety Code; and *Western Oil and Gas Ass'n v. Orange County Air Pollution Control District*, 14 Cal.3rd 411, 121 Cal.Rptr. 249 (1975).

HEARING PROCEDURES

The public hearing will be conducted in accordance with the California Administrative Procedure Act, title 2, division 3, part 1, chapter 3.5 (commencing with section 11340) of the Government Code.

Following the public hearing, the ARB may adopt the regulatory language as originally proposed or with non-substantial or grammatical modifications. The Board may also adopt the proposed regulatory language with other modifications if the text as modified is sufficiently related to the originally proposed text that the public was adequately placed on notice that the regulatory language as modified could result from the proposed regulatory action. In the event that such modifications are made, the full regulatory text, with the modifications clearly indicated, will be made available to the public for written comment at least 15 days before it is adopted.

The public may request a copy of the modified regulatory text from the ARB's Public Information Office, Air Resources Board, 1001 I Street, Visitors and Environmental Services Center, 1st Floor, Sacramento, California 95814, (916) 322-2990.

CALIFORNIA AIR RESOURCES BOARD

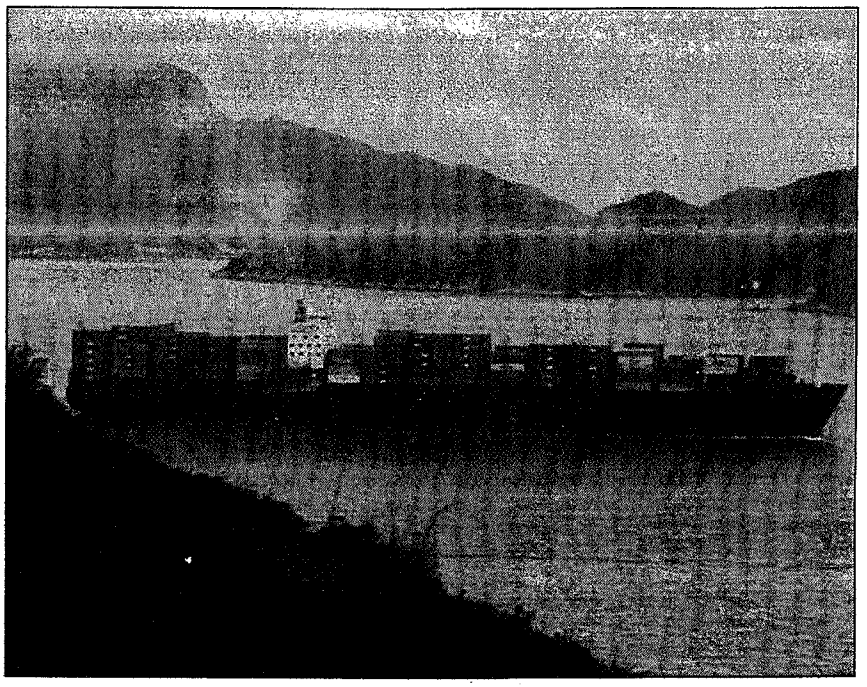
James N. Goldstene
Executive Officer

Date: May 27, 2008

California Environmental Protection Agency

AIR RESOURCES BOARD

INITIAL STATEMENT OF REASONS FOR PROPOSED RULEMAKING



FUEL SULFUR AND OTHER OPERATIONAL REQUIREMENTS FOR OCEAN-GOING VESSELS WITHIN CALIFORNIA WATERS AND 24 NAUTICAL MILES OF THE CALIFORNIA BASELINE

Stationary Source Division
Emissions Assessment Branch

June 2008

State of California
AIR RESOURCES BOARD

STAFF REPORT: INITIAL STATEMENT OF REASONS FOR PROPOSED RULEMAKING

Public Hearing to Consider

ADOPTION OF THE PROPOSED REGULATION FOR FUEL SULFUR AND OTHER OPERATIONAL REQUIREMENTS FOR OCEAN-GOING VESSELS WITHIN CALIFORNIA WATERS AND 24 NAUTICAL MILES OF THE CALIFORNIA BASELINE

To be considered by the Air Resources Board on July 24-25, 2008, at:

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State of California
AIR RESOURCES BOARD

PROPOSED REGULATION FOR FUEL SULFUR AND OTHER OPERATIONAL REQUIREMENTS FOR OCEAN-GOING VESSELS WITHIN CALIFORNIA WATERS AND 24 NAUTICAL MILES OF THE CALIFORNIA BASELINE

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EXECUTIVE SUMMARY

Air pollution from international trade and goods movement activities in California is a major public health concern at both regional and community levels. The diesel-powered vehicles and engines used to transport goods emit soot, or diesel particulate matter (PM), and other air pollutants that can increase health risks to nearby residents. Goods movement activities are also a significant source of sulfur oxides (SOx) and oxides of nitrogen (NOx) which can contribute to the formation of regional smog and fine particulate matter.

As one of many steps being taken to reduce emissions from goods movement activities, the Air Resources Board (ARB) staff is proposing a fuel quality regulation[1] to reduce emissions from ocean-going vessel auxiliary diesel and diesel-electric engines, main propulsion engines, and auxiliary boilers (OGV engines and auxiliary boilers). This proposed regulation is a key element of ARB's Diesel Risk Reduction Plan and Goods Movement Emission Reduction Plan (GMERP) and is essential to reducing exposures to PM emissions both regionally and in communities near maritime ports. (ARB, 2000; ARB, 2006a). Two recent health risk assessments by ARB staff have shown that diesel PM emissions from ocean-going vessels are one of the largest contributors of toxic pollutants and diesel PM in neighboring communities. (ARB, 2006b; ARB, 2008) The proposed regulation would reduce the emissions of diesel PM, PM, NOx, SOx, and "secondarily" formed PM (PM formed in the atmosphere from NOx and SOx) by requiring the use of cleaner marine distillate fuels in OGV engines and auxiliary boilers.

The proposed regulation would require both domestic and foreign flagged ocean-going vessels to use less polluting marine distillate fuel instead of heavy fuel oil when visiting California ports. The fuel requirement would be implemented in two phases with progressively more stringent fuel sulfur levels. Upon implementation of the Phase I requirement in 2009, there would be an immediate and substantial reductions in emissions. Specifically, for vessels currently using heavy fuel oil in their OGV engines and auxiliary boilers, we estimate a 74 percent reduction in PM (diesel PM and directly emitted PM from auxiliary boilers), 81 percent reduction in SOx, and 5 percent reduction in NOx. Compliance with Phase 2 in 2012 will result in an additional 9 percent reduction in PM and an additional 14 percent reduction in SOx. Overall, this translates into emission reductions of about 13 tons per day of PM statewide in 2010 and 15 tons per day in 2012.

This action will significantly reduce potential cancer risks in communities near ports. It will also reduce statewide premature deaths due to exposure to directly emitted particulate matter air pollution from OGV by 75 percent in 2010 and by 80 percent in 2012. Reductions in directly emitted PM alone would result in an estimated 2,000 fewer premature deaths in California between 2009 and 2015. In addition, the reductions in

[1] Two essentially identical regulations are being proposed to reflect the authorities granted to the ARB in the California Health and Safety Code to regulate sources of toxic air contaminants and to regulate marine vessel emissions. Throughout this report the regulations are collectively referred to as "the regulation."

diesel PM, PM, SOx and NOx will help ensure further progress towards achieving California's PM and ozone air quality goals.

In 2005, the ARB approved the Auxiliary Engine Regulation that, beginning on January 1, 2007, effectively required cleaner marine distillate fuels to be used in OGV auxiliary engines visiting California. Due to a successful legal challenge of that regulation as a preempted emissions standard, enforcement of the Auxiliary Engine Regulation was suspended in May 2008, and cannot resume until ARB obtains approval, called an authorization, from the United States Environmental Protection Agency (U.S. EPA) to implement state level emission standards under the Clean Air Act. Given the generally lengthy time and uncertainty involved in obtaining U.S. EPA approval of waiver and authorization requests, staff is proposing to incorporate requirements for the fuel used in auxiliary engines into this proposed regulation. Because California can implement fuel-only requirements without an authorization, this approach will address the courts' findings and allow implementation of the cleaner fuel-use requirements for auxiliary engines once again.[2]

Prior to the court ruling that an authorization was required, the Auxiliary Engine Regulation was successfully implemented for over 14 months demonstrating that the use of cleaner marine distillate fuels is feasible and that it does not impose undue burdens on the shipping industry. In fact, there are vessel operators who have said that they will continue to voluntarily comply with the suspended regulation. The proposed regulation for OGV main engines and auxiliary boilers builds on the auxiliary engine experience by requiring all OGV engines and auxiliary boilers to use the same low sulfur marine distillate fuel. Incorporating requirements for auxiliary engines, main engines, and auxiliary boilers into one rule will ensure that there are consistent requirements for all OGV engines and auxiliary boilers. This will help provide vessel operators, fuel producers, and fuel providers with certainty in what fuel needs to be provided and by when. Staff believes that this certainty will assist in implementation and enforcement, maximize the emission reduction benefits, and minimize the burden on OGV vessel operators.

While ARB has the authority to regulate ocean-going vessel emissions, we recognize that uniform national or international regulation of vessel emissions at an appropriate stringency level would be preferable, both to the ARB and to most vessel operators. This past year there has been positive movement at the International Maritime Organization (IMO) to strengthen international standards that would greatly reduce emissions from ships. While the final fuel sulfur limits being considered at IMO for

[2] On its face, the Auxiliary Engine Regulation was held to constitute an emissions standard that was preempted under section 209(e) of the Clean Air Act (CAA). ARB legal staff is therefore drafting a request for authorization for the suspended regulation under CAA section 209(e). The Auxiliary Engine Regulation can be found at title 13, California Code of Regulations (CCR), section 2299.1 "Emission Limits and Requirements for Auxiliary Diesel Engines and Diesel-Electric Engines Operated on Ocean-Going Vessels within California Waters and 24 Nautical Miles of the California Baseline" and the identical section title 17, CCR, section 93118 "Airborne Toxic Control Measure for Auxiliary Diesel Engines and Diesel-Electric Engines Operated on Ocean-Going Vessels within California Waters and 24 Nautical Miles of the California Baseline."

emission control areas (ECAs) mirror our proposed fuel sulfur levels, under the current proposal they could not be implemented until 2015 at the earliest. Given the large health impacts attributable to ship emissions, California cannot wait until 2015 to reduce emissions from OGV and we are proposing to act much sooner. However, to help California transition to national or international controls once they are established, the proposed regulation includes a provision that requires the Executive Officer to propose terminating or modifying the requirements of this proposal to the Board if the U.S. EPA or the IMO adopts regulations that will achieve equivalent benefits.

Presented below is an overview that briefly discusses the information presented in this document. For simplicity, the discussion is presented in question-and-answer format. It should be noted that this summary provides only brief discussions of the topics. The reader is directed to subsequent chapters in the main body of the report for more detailed information.

1. What is ARB proposing?

ARB staff is proposing a regulation to require operators of OGVs to use cleaner-burning marine distillate fuels in auxiliary diesel and diesel-electric engines, main propulsion engines and auxiliary boilers (OGV engines and auxiliary boilers) on vessels operating within a 24 nautical miles (nm) zone of the California coastline (Regulated California Waters). Unless vessel operators already use complying distillate fuels or choose to use distillate fuels on a permanent basis, they will need to switch from the use of heavy fuel oil to compliant marine distillate fuel prior to entering Regulated California Waters (RCW). The proposed regulation will apply to both U.S.-flagged and foreign-flagged vessels. The proposed regulation is implemented in two steps beginning in 2009 and requiring progressively more stringent fuel sulfur levels again in 2012. The proposed regulation would establish the most comprehensive and stringent marine fuel-use requirements for OGVs in the world.

2. Does ARB have the authority to regulate the emissions from ocean-going vessels as specified in the proposal?

Yes, under State and federal law, ARB can regulate both criteria pollutants and toxic diesel PM emissions from marine vessels. Health and Safety Code (H&S) sections 43013 and 43018 authorize ARB to regulate marine vessels to the extent such regulation is not preempted by federal law. Also, H&S section 39666 requires ARB to regulate emissions of toxic air contaminants (TAC) from nonvehicular sources, which include ocean-going vessels. The proposed regulation reduces or limits emissions of diesel PM, which is both a TAC and criteria pollutant, and PM, NOx and SOx, which are criteria pollutants.

The proposed regulation is neither preempted under federal law, nor does it violate the dormant Commerce Clause of the U.S. Constitution. Federal authorization under section 209(e) of the Clean Air Act (CAA) is required for regulating new nonroad engines and for requiring retrofits on existing engines. Ocean-going vessel engines, by

definition, fall within the category of nonroad engines. However, no federal authorization is required for implementing in-use operational requirements on existing marine vessels and their engines. The proposed regulation is an in-use operational requirement, rather than an emissions standard, because it does not apply a numerical emissions limit to be met (e.g., 10 grams NOx per brake horsepower-hour), does not require retrofits, or mandate design changes to the vessel. Rather, the regulation only requires that specified fuels be used on OGV engines and auxiliary boilers operating in Regulated California Waters.

Further, the proposed regulation does not conflict with the Ports and Waterways Safety Act (PWSA) and U.S. Coast Guard regulations. As a nondiscriminatory[3] regulation with substantial benefits, the proposed regulation does not violate the dormant Commerce Clause. And, federal and state cases support our assertion of authority to regulate both U.S. and foreign-flag vessels within the regulated California waters. Therefore, federal law does not preempt or otherwise prohibit the proposed regulation and its application in the waters off California's coast.

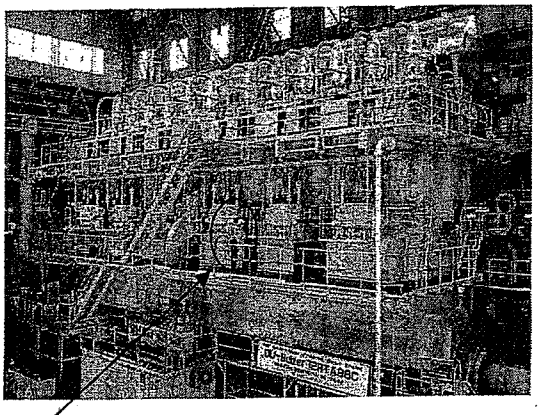
3. What is an ocean-going vessel?

Ocean-going vessels are very large vessels designed for deep water navigation. Ocean-going vessels include large cargo vessels such as container vessels, tankers, bulk carriers, and car carriers, as well as passenger cruise vessels. These vessels transport containerized cargo; bulk items such as vehicles, cement, and coke; liquids such as oil and petrochemicals; and passengers.

Ocean-going vessels travel internationally and may be registered by the U.S. Coast Guard (U.S.-flagged), or under the flag of another country (foreign-flagged). The majority of vessels that visit California ports are foreign-flagged vessels.

4. What is a main propulsion engine?

Main propulsion engines are diesel engines on ocean-going vessels that provide power for propulsion (except as noted below for diesel-electric vessels). Typically, a cargo vessel will have a single, very large, two-stroke main engine used for propulsion, and several smaller auxiliary "generator-set" engines. Passenger cruise vessels, and some tankers, use a different engine configuration that is referred to as "diesel-electric." These vessels use large four-stroke diesel generator sets to provide electrical power for both propulsion and ship-board electricity.



Marine Engineer

[3] The proposal treats regulated vessels equally, irrespective of whether they are based in California or not and whether they are U.S.-flagged or foreign-flagged.

Main engines on OGVs are designed to propel very large vessels. Not surprisingly, the engines themselves are also very large. For example, a nine cylinder K98MC-C MAN engine produces about 40 megawatts (MW), enough energy to power 30,000 houses for a year. The 65 feet long by 60 feet high engine is as tall as a 5-story building, weighs about 1,500 tons, and costs about 15 million dollars.

5. What are auxiliary engines?

Auxiliary engines are diesel engines on ocean-going vessels that provide power for uses other than propulsion (except as noted below for diesel-electric vessels). They are generally four-stroke diesel engines that are smaller than the main engines. Most OGVs have more than one auxiliary engine. Auxiliary engines are usually coupled to generators used to produce electrical power. On cargo vessels, most auxiliary engines are used to provide ship-board electricity for lighting, navigation equipment, refrigeration of cargo, and other equipment.

Passenger cruise vessels, and some tankers, use a different engine configuration that is referred to as "diesel-electric." These vessels use large diesel generator sets to provide electrical power for both propulsion and ship-board electricity. For the purposes of the proposed regulation, these large diesel generator sets are included in the definition of "auxiliary engines" because they are physically similar to auxiliary engines.

6. What is an auxiliary boiler?

Auxiliary boilers are fuel-fired combustion equipment designed primarily to produce steam for uses other than propulsion, such as heating of residual fuel and liquid cargo, heating of water for crew and passengers, powering steam turbine discharge pumps, freshwater generation, and space heating of cabins. Boilers used to provide propulsion (steam ships) are not included in the proposed regulation because there are very few steamships still in service.

7. What fuels do ocean-going vessel operators use in OGV engines and boilers?

Most vessel operators use heavy fuel oil (HFO or residual fuel) in their main propulsion engines and auxiliary boilers. HFO is a very viscous fuel that must be heated to allow it to flow through piping and be combusted in auxiliary engines. HFO is often referred to as residual fuel or bunker fuel. This fuel has high levels of sulfur, ash, and nitrogen containing compounds, and results in much higher emissions of PM and SOx than the use of marine distillate fuels. Marine distillate fuels include marine gas oil (MGO) and marine diesel oil (MDO). These distillate fuels are similar to the diesel fuel used by landside sources. According to an ARB survey of vessels visiting California ports, the majority of vessels calling California use HFO in their main engines and auxiliary boilers.

Prior to implementation of the Auxiliary Engine Regulation in 2007, 75 percent of vessels used HFO in their auxiliary engines. The remaining 25 percent used marine distillate fuels in their auxiliary engines. (ARB, 2005) During the 14 months that the Auxiliary Engine Regulation was in effect, vessels using HFO when visiting California switched to using marine distillate fuels in their auxiliary engines. Since the Auxiliary Engine Regulation was suspended in May 2008, we believe many vessel operators have switched back to using HFO in their auxiliary engines, but we are unsure of the exact number. However, two major vessel operators, Maersk and APL, have publically stated that they will continue to use marine distillate fuel in their auxiliary engines.

8. What emissions result from the main engines and auxiliary boilers used on ocean-going vessels?

The 2006 estimates of the statewide emissions of PM, NOx, SOx, carbon monoxide (CO), carbon dioxide (CO_2) and reactive organic gases (ROG) from OGV are presented in Table ES-1 below. These estimates include emissions that occur within the 24 nm zone of the California coast. Emissions that occur in California inland waters such as emissions from ocean-going vessels transiting to the ports of Stockton and Sacramento are also included in the estimate.

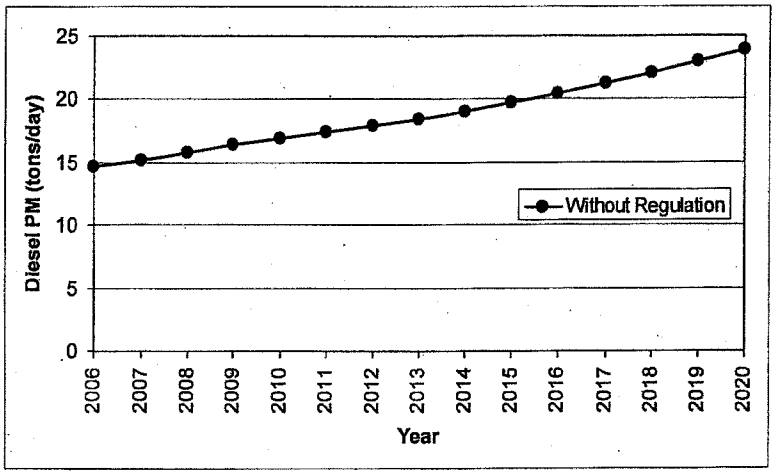
Table ES-1: 2006 Ocean-Going Vessel Emissions (tons/day) in California (24 nm zone)

Vessel Type	Vessels	Port Calls	PM_{10}	$PM_{2.5}$	SO_x	NO_x	CO	CO_2	ROG
Auto	234	1006	0.6	0.6	4.6	7.3	0.6	288	0.3
Bulk	475	983	0.7	0.7	5.1	7.9	0.6	323	0.3
Container	593	5038	8.4	8.1	60.1	94.2	7.7	3818	3.7
Cruise	52	770	1.2	1.1	9.0	12.0	0.9	616	0.4
General	147	371	0.3	0.3	2.1	3.3	0.3	133	0.1
Reefer	68	315	0.2	0.2	1.7	2.2	0.2	111	0.1
Ro-ro	28	112	0.1	0.1	0.5	0.7	0.1	31	0.0
Tanker	458	2391	3.2	3.1	34.1	29.5	2.4	2082	1.2
Total	**2055**	**10986**	**15**	**14**	**117**	**157**	**13**	**7402**	**6**

As shown in Table ES-1, there are over 2,000 ocean-going vessels that visited California's ports in 2006, and these vessels made nearly 11,000 port calls. Of those 2,000 vessels that visited California's ports, 30 percent were container vessels, and these vessels were responsible for more than 45 percent of the total port calls at California's ports.

The emissions from ocean-going vessels are projected to grow significantly over time as trade continues to increase. The projected diesel PM emission estimates up to 2020 are presented in Figure ES-1. As shown, OGV emissions will increase by about 60 percent in 2020 if left uncontrolled, relative to 2006 levels.

Figure ES-1: Ocean-Going Vessel Emissions Estimates Projected to Year 2020 (24 nm zone)

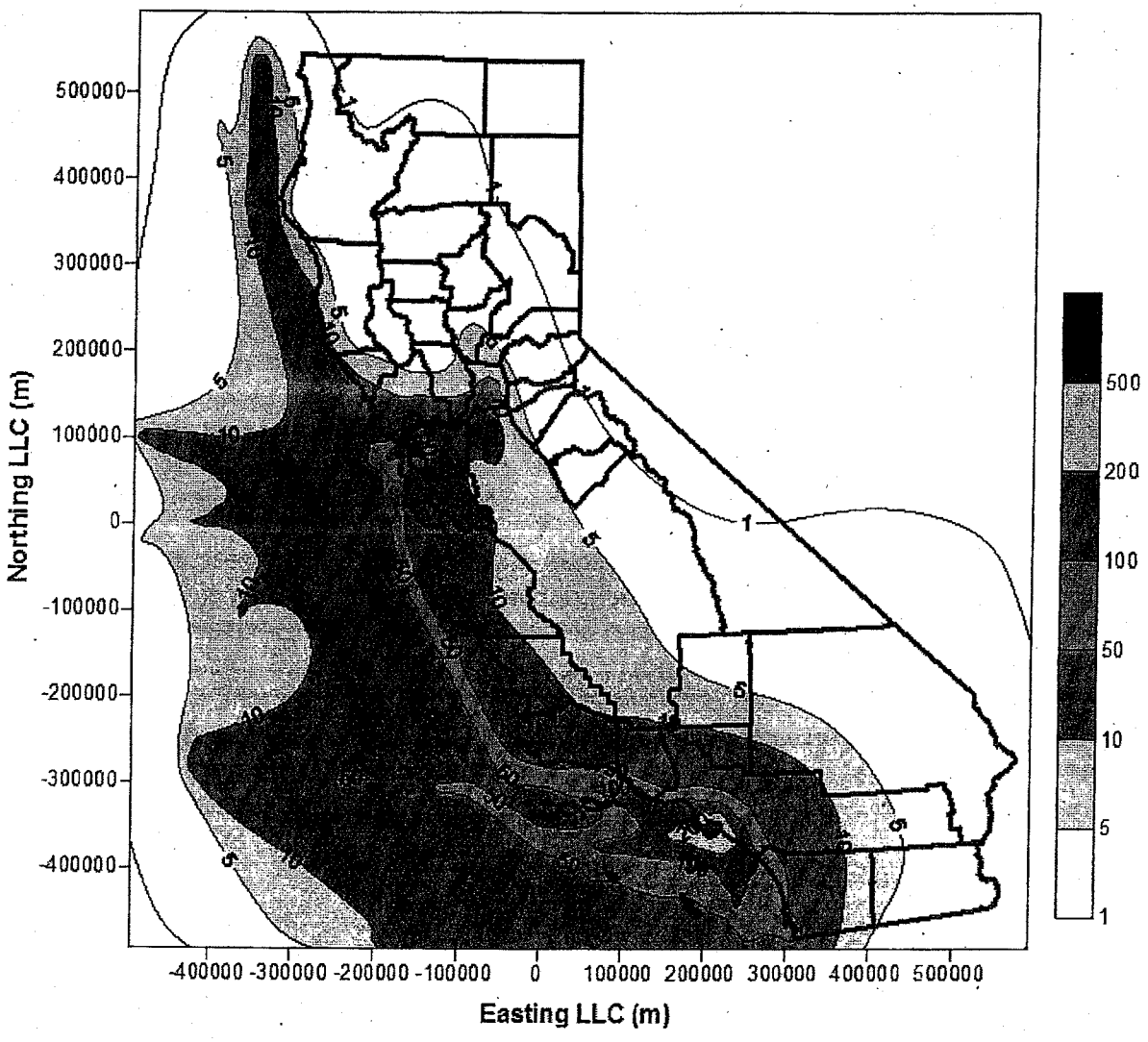


9. What are the exposures and potential health risks from ocean-going vessel emissions?

Most California ports and major shipping lanes are in or near urban areas and are located near where people live, work, and go to school. The operation of OGV results in substantial public exposures to PM and diesel PM emissions. Exposure to these emissions can result in increased cancer risk and non-cancer health impacts, such as premature mortality, PM-related cardiovascular effects, chronic bronchitis, asthma, and hospital admissions for pneumonia and asthma-related conditions. Staff generally uses potential cancer risk as an indicator of the severity of the impacts of diesel PM emissions on people living near the emission source. Estimates of premature deaths are generally used as an indicator of the severity of noncancer impacts due to PM emissions on a regional or statewide basis.

At the community level, OGV emissions also result in significant localized potential cancer risks. Using the recent health risk assessment work done in the West Oakland community, staff estimates that the potential cancer risk in the West Oakland community from OGVs operating in the San Francisco Bay is about 150 chances per million. This is about 12 percent of the estimated potential cancer risk in the West Oakland community due to all sources of diesel PM. At the statewide level, OGV emissions impact most Californians. Based on a modeling analysis done as part of this regulation development, staff determined that about 27 million people are exposed to OGV diesel PM emissions resulting in potential cancer risk levels of 10 chances in a million or greater. And, about 2.4 million people are exposed to potential cancer risk levels greater than 200 chances in a million due to diesel PM emissions from OGV (Figure ES-2).

Figure ES-2: Statewide Potential Cancer Risk Resulting from OGV Diesel PM (2005 Baseyear)



Direct PM emissions from OGV also result in significant contributions to noncancer health effects, including premature death. Statewide, staff estimates that in 2005, directly emitted PM from OGV results in:

- 300 premature deaths (80 – 510, 95% confidence interval (CI))
- 7,700 cases of asthma-related and other lower respiratory symptoms (3,000 – 12,500, 95% CI)
- 50,000 work loss days (43,000 – 58,000, 95% CI)
- 300,000 minor restricted activity days (241,000 – 351,000, 95% CI)

These are annual values and, as the emissions in OGV continue to grow unabated, each year the noncancer health impacts due to OGV emissions are expected to increase. If left uncontrolled, we estimate that in 2015, the number of premature deaths statewide due to OGV directly emitted PM emissions would be greater than 400. As mentioned, these are the noncancer health impacts due only to directly emitted PM. Impacts from secondary PM formed from SOx and NOx emissions have been quantified for the South Coast Air Basin and are discussed later in this report.

10. What are the key compliance requirements and dates in the proposed regulation?

Under the proposed regulation, vessel operators would be required to use cleaner-burning marine distillate fuels in their auxiliary and main engines and in their auxiliary boilers when operating within the California 24 nautical mile (nm) zone. Phase 1 would require vessel operators to use either marine gas oil (MGO), which typically averages 0.3% sulfur and is capped at 1.5% or marine diesel oil (MDO) with a sulfur limit of 0.5% or less when operating their engines and boilers within the 24 nm zone. For auxiliary engines, Phase 1 would begin on the effective date of the regulation (normally 30 days after approval by the Office of Administrative Law). For main propulsion engines and auxiliary boilers, Phase 1 would begin July 1, 2009.

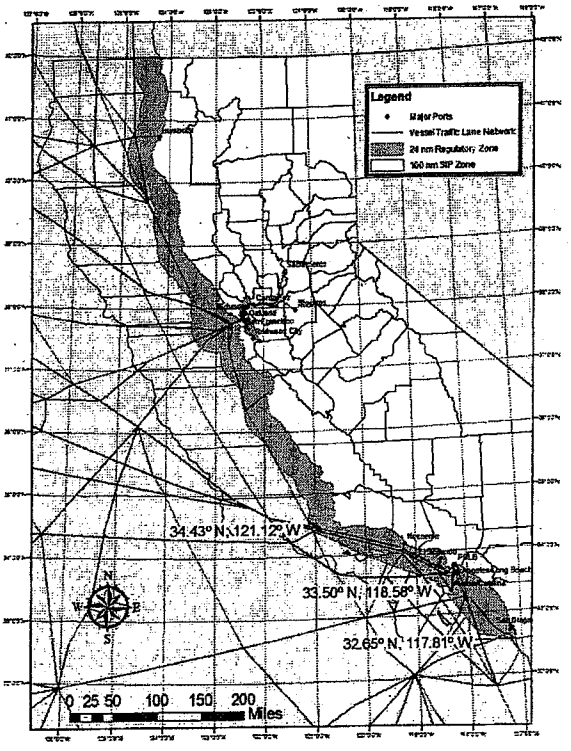
Phase 2 would require OGV operators to use either MGO meeting a 0.1% sulfur limit or MDO meeting a 0.1% sulfur limit in their auxiliary and main engines and auxiliary boilers when operating within the 24 nm zone. Phase 2 would begin January 1, 2012 for auxiliary and main engines and auxiliary boilers.

We recognize that most vessel operators would prefer uniform national or international regulation of vessel emission. So, we have included a provision in the proposed regulation that requires the Executive Officer to propose terminating or modifying the regulation if the U.S. EPA or the IMO implements regulations that will provide equivalent benefits to California citizens.

11. How far offshore are ocean-going vessels required to comply with the proposed regulation?

Under the proposed regulation, vessel operators would be required to use cleaner marine distillate fuels when operating in the 24 nm zone off the California baseline. The 24 nm zone boundary is shown as the gray area in Figure ES-3. Staff has proposed this 24 nm zone because it captures a large majority of the vessel emissions affecting the most heavily populated portions of California, it is consistent with the regulatory boundary selected for the previously adopted Auxiliary Engine Regulation, it minimizes the need for on-board tankage modifications to comply with the in-use fuel requirement, and it reduces fuel availability concerns. This boundary also reduces the cost of the regulation while still providing significant on-shore benefits in terms of reduced exposure to diesel PM. Approximately 68 percent of the PM emissions from OGV engines and auxiliary boilers occurring within 100 nm of the California coastline are emitted within the 24 nm boundary. The 24 nm boundary is also easily defined for vessel operators and is noted on most nautical charts. The boundary is aligned in Central and Northern California with the outer boundary of the Contiguous Zone, an internationally recognized boundary which extends approximately 24 nm out from the California coastline with a "bubble" that extends about 45 nm beyond the Golden Gate Bridge around the Farallon Islands. But, in Southern California, the boundary consists of straight line segments approximately 24 nm offshore of the mainland coastline. This approximation is used because the outer edge of the Contiguous Zone extends around the Channel Islands, up to 90 nm offshore the California coastline.

Figure ES-3: Offshore 24 Nautical Mile Boundary for Proposed Regulation



12. Are there potential benefits to extending the regulatory boundary farther offshore?

ARB staff has conducted detailed modeling and health risk assessments at California's major ports demonstrating the impacts of OGV emissions that occur within 100 nm on onshore air quality and public health. Based on the current emissions inventory, which estimates that approximately 68 percent of the emissions that occur within 100 nm are released within the 24 nm zone, ARB staff believes that this boundary will achieve a large portion of the heath and environmental benefits that can be realized from a fuel sulfur control program. Setting the boundary at 24 nm also improves the ability of the

shipping industry to procure and store the needed fuel supplies and comply in the timeframes required, and reduces the cost of the proposal. However, ARB staff believes that additional modeling and analysis may support setting boundaries farther offshore to realize additional health and environmental benefits. Analysis of other pollutants may also support a larger control area. Most of ARB's modeling efforts have focused primarily on directly emitted PM. However, other pollutants, such as NOx, SOx, and hydrocarbons, are involved in complex atmospheric reactions and can have impacts far from where they were released. For example, NOx and SOx can be converted to sulfate and nitrate-based PM. We believe that further study and modeling will help to determine whether boundaries farther offshore are appropriate considering these effects. We believe that these analyses are best conducted in conjunction with U.S. EPA as part of the application process for a Sulfur Emission Control Area (SECA) under current IMO MARPOL Annex VI protocols, or pending amendments that would create a similar process for Emission Control Areas (ECA).

13. Are the fuels specified in the proposed regulation available?

Yes. It is important that these fuels are or will be available at ports where California-bound vessels refuel. This is because vessel operators will need to use the marine distillate upon entering the 24 nm zone off California's coastline. The fuels specified for Phase 1, are MDO meeting a 0.5% sulfur limit or MGO.

MGO is widely available at ports worldwide. We are not proposing a sulfur limit for MGO, below the maximum allowed by specification (1.5% sulfur), because some foreign ports only have higher sulfur MGO available (i.e. higher than 0.5%). And with the proposals initial compliance date in 2009, ARB staff has concerns that there would not be sufficient time or incentive for fuel refiners and suppliers worldwide to provide very low sulfur MGO at all bunkering ports. However, we expect the average sulfur content of the MGO used in vessels visiting California ports to average at or below 0.3% sulfur, based on the results of the worldwide fuel sample data for 2007.

To provide additional flexibility to vessel operators, we are also allowing the use of MDO. This fuel tends to have slightly higher sulfur content than MGO, so we are limiting the use of this fuel to 0.5% sulfur. Vessel owners can choose between using MDO that meets the 0.5% sulfur limits or MGO that meets the allowable IMO specification limit.

Beginning January 1, 2012, Phase 2 would require the use of MGO or MDO, both meeting a 0.1% sulfur limit. While neither fuel with this sulfur content is currently available at all ports where California-bound vessels refuel, we believe they will become more readily available after 2010. As, the global trend toward lower sulfur fuels continues to expand, fuel suppliers will have more fueling infrastructures that will be capable of delivering the lower sulfur fuels.

14. What provisions are included in the proposed regulation if the specified fuels are not available at key fueling ports?

In the unlikely event a vessel operator cannot obtain the required fuel prior to coming to California, the proposed regulation includes a provision that allows the operator to pay a noncompliance fee subject to specified conditions. This is discussed in more detail in Question 15. Despite this provision, we do not anticipate extensive use of this fee, particularly during Phase I of the regulation. This is because MGO, and MDO with no more than 0.5% sulfur, are widely available at fueling ports throughout the world.

Our experience with implementing the Auxiliary Engine Regulation during 2007 and 2008 showed that very few vessel operators needed to use the noncompliance fee provision. Over the 14 months that the Auxiliary Engine Regulation was implemented, vessel operators paid a noncompliance fee only six times out of the estimated 13,000 vessel visits in California. Based on this experience we believe it is reasonable to expect the same outcome for Phase 1 of this proposal.

In contrast to Phase I, there is greater uncertainty of the worldwide availability of 0.1% sulfur MGO and MDO, either of which vessel operators will be required to use in California waters under Phase 2 starting on January 1, 2012. Because of this, we are proposing to include a provision to address the situation where 0.1% sulfur MGO or MDO is not available for an individual vessel on a specific voyage to California. Under this provision, the noncompliance fee will be waived for one vessel visit each calendar year until December 31, 2014. To use this provision, the vessel operator must acquire compliant fuel at the first California port visited on a voyage and use that fuel for the remainder of the voyage within the 24 nm zone. In addition, the vessel must be operated on either MGO or MDO (MDO has a sulfur limit of 0.5%) during the noncompliant, incoming portion of the voyage. This provision provides the vessel operator the option of purchasing compliant fuel in California if it was not available at other ports outside California.

15. What other provisions are included in the proposed regulation to accommodate special circumstances?

The proposed regulation exempts the master of the vessel from complying with the fuel sulfur and other specified requirements if the master determines that compliance would endanger the safety of the vessel, its crew, its cargo or its passengers because of severe weather conditions, equipment failure, fuel contamination, or other reasons beyond the master's reasonable control. It is important to note that, over the 14 months that the Auxiliary Engine Regulation was enforced, only 1 vessel operator requested the safety exemption. In this case, the vessel operator purchased fuel that when tested, did not meet the flashpoint specification for marine distillate fuels.

As noted, the proposed regulation also contains a Noncompliance Fee Provision that provides vessel operators with the flexibility to pay a fee in lieu of direct compliance with the fuel-use requirement in certain limited circumstances. We have designed the fees

such that they do not confer an economic advantage to participants relative to vessel operators who use the specified low sulfur fuels. This was achieved by graduating the fee schedule so that subsequent visits necessitating payment of the fees would result in substantially increasing fees.

This option can only be used when the vessel:

- is unexpectedly redirected to a California port;
- was not able to acquire a sufficient quantity of compliant fuel at the last fueling port;
- acquired fuel that was later found to be out of compliance after leaving the last bunkering port; or
- needs modifications and the modifications cannot be made prior to the effective date of the regulation or the vessel will make no more than four California port visits over the life of the vessel (after the regulation goes into effect).

The proposal also includes a provision for those relatively rare instances when a vessel, for unusual reasons, cannot use the specified low sulfur distillate fuels without essential modifications to the vessel. This provision provides an exemption from the fuel use requirement provided certain criteria are met. This provision will sunset December 31, 2014.

16. Will ocean-going vessels need to make modifications to comply with the proposed regulation?

We do not believe many vessels will need to make modifications to use the distillate fuels. OGV engines and boilers are designed to be able to use marine distillate and all vessels have some fuel storage dedicated to marine distillate. However, some vessel operators may choose to make modifications to provide for a more convenient fuel-switching operation since fuel-switching will occur more frequently than what is traditionally done. There may also be a small number of vessels, due to longer routes within the regulated zone or nonstandard tankage or fuel system designs, that may need to make modifications to comply with the proposal.

For the following reasons, we think in most cases modifications will not be necessary in most cases to comply with the in-use fuel requirement:

- All ocean going vessels already have the capability to store and use marine distillate fuels in their main engines and auxiliary engines. Current standard practice for vessel operators is to use marine distillate fuels to operate the main engine and auxiliary engines prior to going into dry-dock, prior to other large scale engine work, to assist with engine emergencies, and to comply with environmental regulations and programs such as port-lease requirements, California's Auxiliary Engine Regulation (suspended), and company voluntary environmental initiatives.

- Maersk, the world's largest shipping line, has reported that no capital investments were necessary to implement their voluntary program to use low-sulfur marine distillate fuel in the main engines of their vessels that visit California. Over a period from April 2006 to early 2008, Maersk vessels made over 517 fuel switches on over 105 different vessels with a variety of main engine makes, models and ages, and did not make any capital investments for ship modifications.
- For the Auxiliary Engine Regulation, the Pacific Merchant Shipping Association has stated in legal filings documents that none of their members' vessels needed modifications to comply with that regulation.
- In responding to an ARB survey conducted in 2007, some vessel operators reported that vessel modifications would be needed if marine distillate was required to be used in the main engine. However, based on additional evaluation of the responses and follow-up contacts, staff concluded that most vessels would not have to make modifications to use of the cleaner marine distillate fuels within the 24 nm regulated zone.
- Many shipping companies charter vessels from the world-wide fleet of over 40,000 vessels and can minimize the need for modifications by chartering vessels or rerouting vessels to California that do not need modifications to use the cleaner marine distillate fuel.

17. Is the proposal technically feasible?

Yes. Based upon ARB staff's analysis and discussions with numerous stakeholders, including the engine and auxiliary boiler manufacturers, staff believes that the requirements of the proposed regulation are technically feasible and achievable in the timeframes provided. Under the proposal, vessel operators will comply by using cleaner-burning marine distillate fuels in their OGV engines and auxiliary boilers instead of heavy fuel oils.

To meet the fuel requirements, vessel operators will need to ensure that they are using compliant marine distillate fuels prior to entering the 24 nm zone. In Phase 1, MGO or MDO at 0.5% sulfur or less would be required beginning in 2009. Staff found that fuel meeting the Phase 1 requirements is readily available at ports serving vessels coming to California. Staff found that technical issues including fuel viscosity/lubricity, lube oil compatibility, fuel switching, and fuel system leaks are manageable if attention is paid to fuel specification, engine and fuel system maintenance, and crew training. Furthermore, the 14 months of experience implementing the Auxiliary Engine Regulation provides additional evidence that the Phase 1 requirements are technically feasible.

In Phase 2, MGO or MDO (both having to meet a 0.1% sulfur limit) is required beginning in 2012. While fuel meeting the Phase 2 requirements is not currently available at the all the key ports serving vessels coming to California, we see this situation as improving over the next few years. We believe that by 2012, 0.1% sulfur MGO or MDO will be more readily available at ports serving vessels traveling to California. Staff believes that

the technical issues associated with 0.1% sulfur distillate are somewhat more pronounced than with Phase 1 distillate fuel. However, it is not clear if the technical issues are a result of lack of experience using the low sulfur fuel, the result of very low sulfur on-road diesel being used in marine applications, or the result of the sulfur content of the marine distillate being further reduced. We believe that the three year lead time before implementing Phase 2 requirements will provide sufficient time to identify and find solutions to the technical challenges associated with using 0.1% sulfur distillate.

18. Why is it important to have a two-phase implementation process?

We are proposing a two-step phase in of the fuel requirements to address a number of potential technical and safety issues. The requirement to use cleaner marine distillate in engines that have been designed to operate on heavy fuel oil present a number of significant challenges to the shipping industry. These challenges fall primarily into two areas: fuel management challenges to maintain the sulfur limits of the fuel and operational challenges.

Fuel management challenges come from procuring and maintaining fuel cleanliness with respect to the lower fuel sulfur limits. Cross contamination can occur both in the fuel delivery system and vessel fueling system. The bunkering industry has been providing heavy fuel oil, with sulfur levels in the 3 to 4% range. This proposal would require distillates in the 0.1 to 1.5% range. The challenges in both the procurement and on-board fuel management are significant for the vessel operators. Since OGV are not likely to be operated entirely on distillate fuel due to the significant cost differential between HFO and marine distillates, the on-board fuel management challenge is compounded by the potential for cross-contamination associated with storing and operating on two different fuels.

Operational challenges stem from running engines, designed to operate primarily on HFO, on a cleaner marine distillate that has very different physical properties than HFO. These differences include much lower viscosity and potentially lower lubricity. Because of the significant operational challenges, a number of stakeholders, including some shipping companies and the United States Coast Guard, recommended phasing in the fuel sulfur levels to reach the 0.1% sulfur marine distillate. During Phase 1, either MGO, typically below 0.5% sulfur and capped at 1.5% sulfur, or MDO, at or below 0.5%, is required. Maintaining the Phase 1 sulfur levels in both the delivery and on-board fuel delivery system will be somewhat easier to manage than the lower Phase 2 level, thus allowing the operators to focus on the operational challenges of using the distillate fuel in engines designed for heavy fuel oil. Because the sulfur levels are not as restrictive, the operators will have more flexibility in specifying viscosity levels when purchasing the fuel and may not have the possible lower lubricity issues that have been observed, to a very limited extent, in the very low sulfur distillate fuels.

Staff evaluated the trade-off between allowing the phase-in approach compared to requiring 0.1% sulfur level fuel in the first phase. Because the worldwide average sulfur

content of marine distillate is about 0.3%, the distillate fuels used in Phase 1 are expected to have much less sulfur than the 1.5% sulfur specification for MGO. Inspection results from the Auxiliary Engine Regulation have substantiated this finding showing that marine distillate fuels used to comply with similar fuel requirements were 0.3% sulfur, on average. Finally, staff believes that the small differences in reductions by having a phase-in requirement will be mitigated by providing the flexibility to the operators to successfully address the technical challenges presented by this proposed regulation.

19. How will ARB staff verify compliance with the proposed regulation?

Enforcement of the proposed regulation will be achieved through random inspections of records and fuel sampling and testing. To the extent feasible, ARB staff will coordinate vessel inspections with inspections conducted by other State agencies such as the California State Lands Commission. During vessel inspections, records will be reviewed to determine when vessels traveled within "Regulated California Waters" and the fuels used during this time. Records on the quantity of fuel purchased, the fuel type, and the sulfur content of the fuel will be reviewed to determine compliance. Fuel samples will be analyzed to ensure that they meet the ISO specifications for the fuel type and do not exceed the sulfur content limits under ISO or the proposed regulation, whichever is lower.

Based on our experience in enforcing the Auxiliary Engine Regulation, we expect to have a very active enforcement program for the proposed regulation. Over the 14 months of implementation for the Auxiliary Engine Regulation, ARB enforcement staff conducted over 200 vessel inspections.

20. What businesses and public agencies will be affected by the proposed regulation?

The proposed regulation would impact foreign and domestic businesses that own or operate large ocean-going vessels. This would include ocean shipping companies and passenger cruise vessel operators.

We do not expect significant impacts on "downstream" companies such as importers or exporters of goods, since the added costs imposed by the proposal are not expected to result in significant adverse impacts to vessel owners or operators. Similarly, we do not expect adverse impacts on California ports because we do not believe the added cost of the proposed regulation is great enough to induce vessel operators to divert cargos to ports outside California.

We do not predict any significant impact on public agencies. With the exception of military vessels, which are exempted from the requirements of the proposed regulation, public agencies in California do not operate ocean-going vessels as defined in the proposal.

21. What are the health and environmental impacts of the proposed regulation?

Upon implementation in 2009, the proposed regulation will result in immediate and significant reductions in emissions of diesel PM, PM, SOx, NOx, and "secondarily" formed particulate matter. Specifically, considering only the directly emitted emissions (not secondarily formed PM), the proposed regulation will result in estimated statewide emission reductions of approximately 13 tons per day (TPD) of diesel PM, 10 TPD of NOx, and 109 TPD of SOx in 2010. For perspective, the proposal would immediately upon implementation result in an estimated 74 percent reduction in diesel PM, 81 percent reduction in SOx, and a 5 percent reduction NOx from an engine that previously used heavy fuel oil.

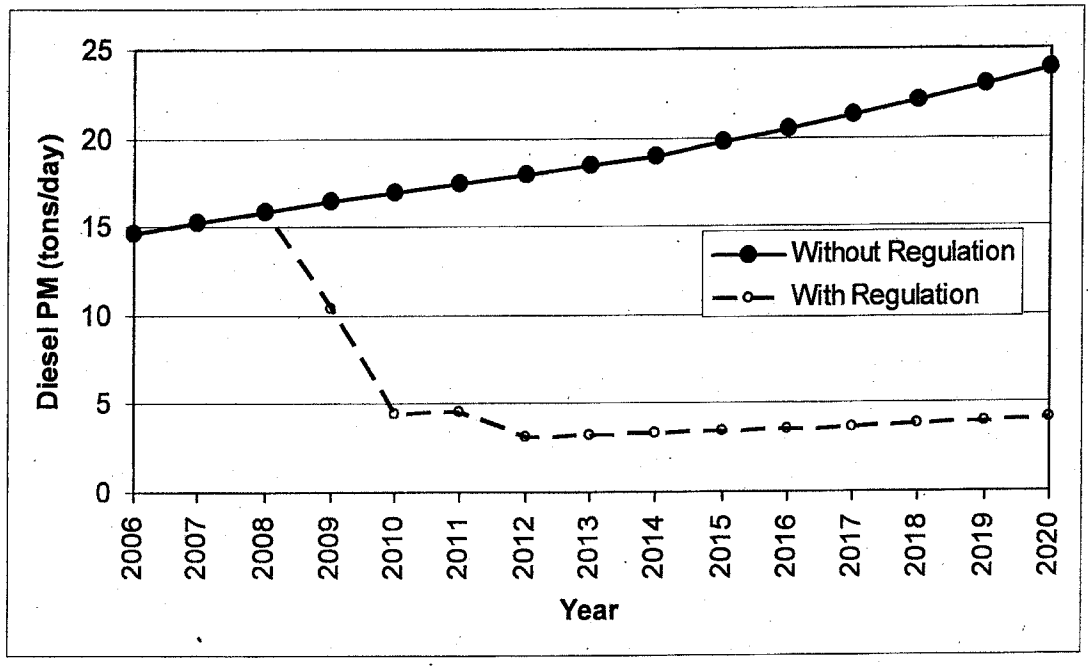
Beginning in 2012, the 0.1% sulfur limit will result in an additional 9 percent reduction in diesel PM and SOx. The estimated reductions for PM (which includes diesel PM), SOx and NOx, as shown in Table ES-2, reflect the use of the cleaner marine distillate fuels specified in the proposed regulation. The estimates do not reflect participation in the "noncompliance fee provision" in the proposal that allow shippers to pay a fee in lieu of using the low sulfur distillates because we cannot predict the rate of participation. However, from our experience implementing the Auxiliary Engine Regulation over 14 months, we would expect a very limited use of noncompliance fees under this proposal.

Table ES-2: Estimated Statewide Emission Reductions from Implementation of the Proposed Regulation (24 nm)

	Main Engine and Auxiliary Engine Emission Reductions (Tons per Day)		
Year	PM	NOx	SOx
2010	13	10	109
2012	15	11	135
2015	16	12	148
2020	20	15	178

The emission reductions shown for 2010 reflect the initial implementation, Phase 1, of the fuel sulfur requirements in the proposal, assuming that the average sulfur content of the fuel will be 0.5%. The 2012 and later reductions reflect the use of 0.1% sulfur MGO or MDO, as required under Phase 2 of the proposed regulation. Figure ES-4 shows the change in diesel PM emissions expected with implementation of the regulation.

Figure ES-4: Estimated Diesel PM Emissions in 24 nm Zone With and Without the Implementation of the Proposed Regulation

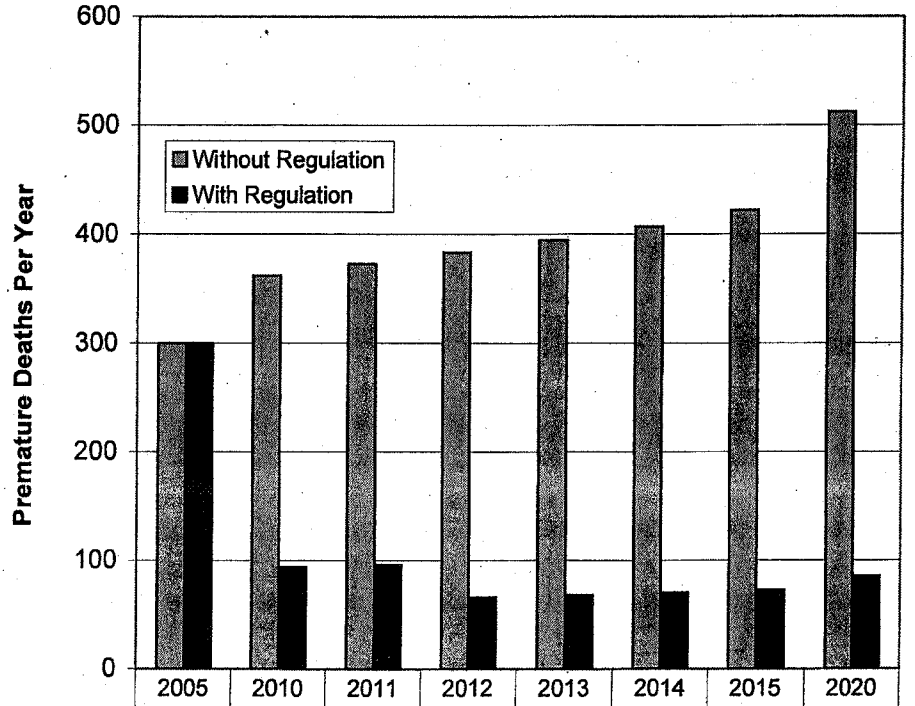


Significant air quality benefits are expected from the proposed regulation. The reductions in diesel PM, PM, NOx and SOx will help improve regional ambient air quality levels of PM and ozone. We also anticipate significant health benefits due to reduced incidences of cancer, premature mortality, PM-related cardiovascular effects, chronic bronchitis, asthma, and hospital admissions for pneumonia and asthma-related conditions. The diesel PM reductions are expected to reduce the number of premature deaths and other non-cancer health effects from air pollution in California. Staff estimates that the implementation of this regulation will avoid about 2,000 premature deaths between 2009 and 2015 due to reduction in diesel PM alone. (Figure ES-5).

With respect to potential cancer risk, there will be significant reductions in exposures and potential cancer risks to residents that live near ports in California. For example, based on an analysis of the predicted 2010 and 2015 ambient diesel PM levels statewide, we estimate that in 2010 there will be a 75 percent reduction in the population-weighted average risk relative to the predicted risk levels in 2010 from OGV diesel PM emissions and an 83 percent reduction in 2015.

ARB staff has concluded that, with the exception of CO_2 emissions, no significant adverse environmental impacts will occur from implementation of the proposed regulation. There will be no increase in emissions of diesel PM, PM, NOx, or SOx at any of the locations due to this proposed regulation. The locations experiencing the greatest emission reductions will be those areas nearest to the ports.

Figure ES-5: Estimated Statewide Premature Deaths from OGV Diesel PM Emissions With and Without the Proposed Regulation (# per year)



	2005	2010	2011	2012	2013	2014	2015	2020
Without Regulation	300	362	373	384	394	407	422	512
With Regulation	300	94	96	66	69	71	73	86

22. What are the impacts on greenhouse gas emissions?

Emissions of diesel PM, PM, NOx, SOx, and "secondarily" formed PM would be reduced by burning cleaner marine distillate fuels while globally, greenhouse gas (CO_2) emissions could increase slightly. Based on a total fuel cycle analysis of the CO_2 emissions associated with a switch to marine distillate fuels, ARB staff estimates that there potentially could be a slight one to two percent increase in global CO_2 emissions. (Corbett and Winebrake, 2008) This net change in fuel-cycle CO_2 emissions is primarily a function of the increased energy required at the refining stage to produce compliant distillate fuels. This offsets the decreased CO_2 emissions from ship operations. The decrease in CO_2 emissions from ship operations results primarily from the higher energy to carbon content of the distillate fuel, as compared to heavy fuel oil. But these results do not assume that refineries may be able to improve energy efficiency while maintaining, upgrading, or expanding their capacity to produce distillate fuels. Therefore, the referenced potential fuel-cycle increase in CO_2 emissions due to greater use of more highly refined fuels may be overestimated.

If CO_2 emissions associated with the fuel used by California-visiting ships do increase by one to two percent under this proposal, we project such an increase would result in

up to 50,000 tons per year of additional CO_2. While this is a very small increase relative to the overall CO_2 emissions from shipping, we nevertheless believe this may represent a significant adverse environmental impact. However, the very substantial health and environmental benefits from the proposal clearly constitute overriding considerations that amply justify the proposal. This is discussed in more detail later in the Environmental Impacts section of the Staff Report.

23. What are the economic impacts of the proposed regulation?

Under the proposed regulation, OGV (or "vessel") operators would comply through the use of distillate marine fuels. This requirement would apply when ships are within "Regulated California Waters," a zone that extends to approximately 24 nm off the California coastline.

Since the majority of vessels currently use heavy fuel oil in their engines and boilers, most vessel operators will need to switch to the more expensive marine distillate fuel in California. The costs resulting from the proposed regulation are estimated over a six year lifetime, from implementation in 2009 through 2014. Beginning in 2015, there is a possibility that an Emission Control Area (ECA) may be established under the International Maritime Organization that would require the use of 0.1% sulfur fuel off the California coastline (see Chapter V). If an ECA is established that achieves substantially equivalent benefits, then Air Resources Board staff will propose to the Board the termination of this regulation.

The added cost to businesses due to the higher cost of using distillate fuel can vary widely based on the amount of fuel they use in California. For example, a business that owns a single vessel which makes a single annual visit to a California port may incur an added cost of about $30,000. By contrast, an operator of a large fleet of vessels that make frequent California port visits may incur costs in the millions of dollars annually. On average, we estimate the annual additional fuel cost for a typical vessel operator at about $300,000 to $700,000 per company. For the entire ocean-going shipping fleet that visits California, we estimate an added annual fuel cost of about $140 to $360 million, or about $1.5 billion between 2009 and 2015. This added cost of the regulation represents less than one percent of the total costs of a typical trans-Pacific voyage. We also do not expect that the proposed regulation will result in significant capital costs to ship operators, since most vessel are unlikely to need to make modifications to use distillate fuel.

We do not expect significant economic impacts to the industry based on the added costs of the proposed regulation. As noted, the added costs of the regulation are relatively small compared to the overall operating expenses of these vessels. In addition, based on an analysis of the change in "return on owner's equity" (ROE) for typical businesses, the added costs of the proposed regulation would result in about a 1.5 percent decline in ROE. At this level, we would not anticipate a significant impact on profitability. Because the proposed regulation would not alter significantly the profitability of most businesses, we do not expect a noticeable change in employment,

business creation, elimination, or expansion, and business competitiveness in California. We also do not expect significant economic impacts on governmental agencies on the local, state, or federal level. As noted, local and State government agencies typically do not operate ocean-going vessels and military vessels are exempt from the proposed regulation.

We do not expect significant impacts on the customers served by ocean-going vessel operators, even assuming that all of the added costs are passed on to customers. Under a typical scenario we estimate that the added cost of the proposed regulation would add about six dollars per shipping container for importers or exporters shipping containerized goods overseas on a typical Asia to U.S, West Coast voyage. We estimate that this represents roughly one percent of the shipping cost. For passenger cruise ships, we estimate the added cost of the proposed regulation for a typical Los Angeles to Mexico cruise would be about $15 per passenger, representing about a 3 to 4 percent fare increase.

The overall cost-effectiveness of the proposed regulation, considering only reductions in diesel PM, is estimated to be about $63,000 per ton of diesel PM reduced ($32 per pound of diesel PM). However, the proposed regulation would also reduce emissions of NOx and SOx. Attributing half the cost of the proposed regulation to diesel PM, and half to NOx plus SOx, the cost-effectiveness would be about $31,000/ton ($16/pound) of diesel PM reduced. We estimate the cost-effectiveness of the combined NOx+SOx control at about $3,200/ton ($1.60/pound). The PM cost-effectiveness of the proposed regulation is similar to that of other regulations adopted by the Board to reduce diesel particulate matter.

Implementing the proposed regulation will achieve substantial health benefits. The diesel PM reductions between 2009 and 2015 will result in an estimated $15.4 billion (present value) cost savings due to estimated decreases in premature mortality. This would mean a benefits to cost ratio of 10 to 1.

24. How does the proposed regulation compare to other air quality regulations affecting ocean-going vessel main engines and auxiliary engines?

The U.S. EPA and IMO have adopted regulations designed to reduce the emissions from these engines. However, these regulations will achieve relatively modest diesel PM reductions compared to the proposed regulation. The U.S. EPA and IMO regulations and a comparison to the ARB proposed regulation are summarized below in Table ES-3.

Table ES-3: Summary of U.S. EPA and IMO Regulations

Regulation	Description of Regulation	Comparison to the ARB Staff Proposal
IMO Annex VI New Engine Standards	Establishes NOx exhaust standards for new marine engines. Engine manufacturers have complied since 2000.	▪Standards do not reduce PM and achieve modest NOx benefits
U.S. EPA 1999 Category 1&2 Engine Rule	Establishes NOx+HC, PM, and CO exhaust standards for new marine engines. Implementation starts in 2007 for most vessel auxiliary engines.	▪ Standards only apply to U.S.-flagged vessels which are a small percentage of the vessels that visit California ▪ Foreign trade exemption is provided that exempts most vessel auxiliary engines ▪ Benefits phase in slowly with vessel turnover
U.S. EPA 2003 Category 3 Engine Rule	Establishes NOx exhaust standards for new marine propulsion engines equivalent to IMO standards. Would apply large "auxiliary" engines on diesel-electric vessels. Implementation begins in 2004	▪ Standards only apply to U.S. flagged vessels ▪ Eliminates the foreign trade exemption for category 1 & 2 vessels (see above)
Annex VI IMO marine fuel sulfur limit	Establishes a fuel sulfur cap of 4.5%.	No reductions achieved by allowing fuel with a sulfur content this high.
EPA Nonroad diesel Rule	Establishes sulfur limits for diesel fuel used in marine applications	Exempts heavy fuel oil, and marine diesel oil.

In addition to the regulations summarized above (which apply to engines operated in the United States), the European Union countries have developed measures that will reduce emissions from oceangoing vessels. In November 2002, the European Commission adopted a European Union Strategy to reduce atmospheric emissions from seagoing ships. A step toward implementing this strategy is *Directive 2005/33/EC of the European Parliament and Council Modifying Directive 1999/32 as Regards the Sulfur Content of Marine Fuels* (Directive 2005/33/EC). Directive 2005/33/EC entered into force on August 11, 2005, and includes the following provisions:

- A 1.5% sulfur limit for marine fuels used by all seagoing vessels in the Baltic Sea starting May 19, 2006, and in the North Sea and English Channel starting in Autumn 2007;
- A 1.5% sulfur limit for marine fuels used by passenger vessels on regular services between EU ports, starting May 19, 2006; and
- A 0.1% sulfur limit on fuel used by inland vessels and by seagoing ships at berth in EU ports, starting January 1, 2010.

The provision regarding the use 0.1% sulfur fuel by inland vessels and seagoing ships at berth affects only the operation of OGV auxiliary engines and auxiliary boilers at berth – not main engines. This is because inland vessels are considered to be harborcraft such as ferries and fishing vessels. Like the staff's proposal, the EU control measure specifies a 0.1% sulfur limit. However, the staff's proposal extends out 24 nm, and will

reduce emissions from the operation of the main engine. Based on our emissions inventory, these emissions are about 70 percent of the total emissions from OGV in the 24 nm zone. In addition, because the EU control measure only applies at berth and the measure allows vessels to purchase the necessary fuel once in port, it is not necessary for vessels to obtain the fuel prior to coming to the EU.

25. How does the proposed regulation compare to the recently proposed amendments to International Maritime Organization's Annex VI of MARPOL and why doesn't California rely on an ECA to be implemented to reduce OGV emissions?

In spring 2008, the IMO's Marine Environmental Protection Committee (MEPC 57) agreed on amendments and revisions to MARPOL Annex VI (Prevention of Air Pollution from Ships) to reduce air emissions from ships. The amendments still have to be formally adopted at the next meeting of the MEPC in October 2008. If approved, the amendments will enter into force in February 2010.[4] The proposed amendments would establish new fuel sulfur limits for OGV fuels. Specifically, the proposal would require the following for fuel sulfur levels at open sea:

- 4.50% Prior to Jan 1, 2012
- 3.50% Jan 1, 2012
- 0.50% Jan 1, 2020

The proposal also includes a review process for the 0.50% standard in 2020 that will be conducted by group of experts by 2018 to determine the availability of such fuel. If that standard is determined as not possible or feasible, then the date becomes January 1, 2025.

The proposed amendments to Annex VI also allow for the creation of Emission Control Areas (ECA) which can be designated for any individual or combination of the three pollutants from ships - SOx, PM, and NOx. For ECAs, parties to the Annex can submit documentation that demonstrates the need for controls that would then be subject to approval by IMO. The sulfur limits applicable to an ECA are:

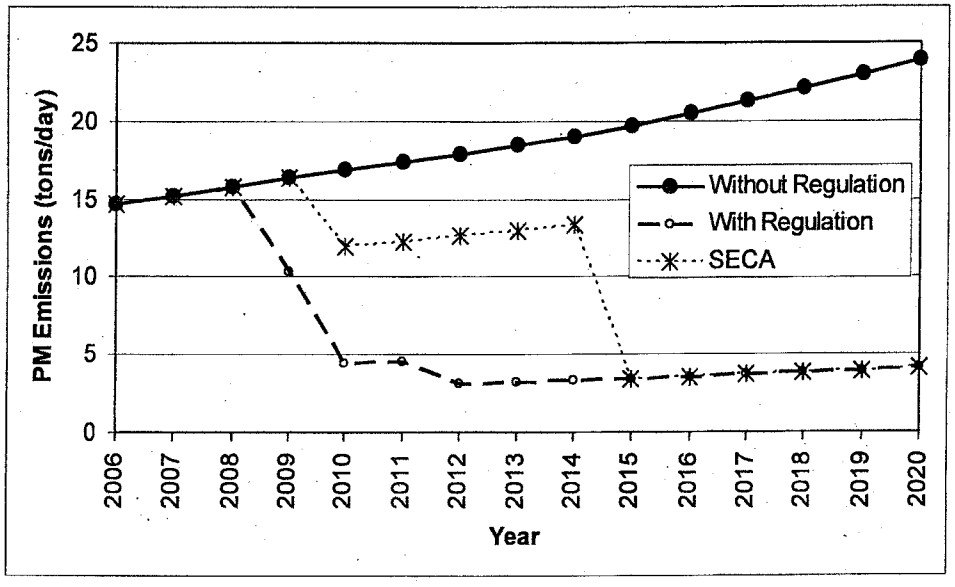
- 1.50% Prior to Mar 1, 2010
- 1.00% Jan 1, 2012
- 0.10% Jan 1, 2015

Although the regulations do not stipulate which fuels must be use to achieve these levels, distillates will be the most plausible way to achieve fuel sulfur levels below 1.0%. While this new proposal at IMO is very promising and we are hopeful that it will be adopted in October, ARB's proposed regulation differs from the recent IMO amendments in two aspects and will achieve significantly more emission reductions in the 2009-2015 timeframe. First, ARB's proposed regulation requires the use of distillate in all phases. Although Phase 1 of ARB's proposed regulation allows marine gas oil

[4] As with the existing MARPOL Annex VI, enabling legislation would likely need to be enacted before the amendments can enter into force in the U.S. This is expected to require additional time before the amendments, if passed, enter into force in the U.S.

with an upper sulfur limit of 1.5%, the average sulfur content is 0.3%, which is much lower than would be achievable with a heavy fuel oil with an upper limit of 1.5%. Second, ARB's proposed regulation contains a Phase 2 fuel requirement of 0.1% sulfur by January 1, 2012. As shown in Figure ES-6, the ARB proposed regulation will achieve significantly greater benefits in the 2009 through 2015 timeframe. For this reason, ARB cannot wait for an ECA to reduce emissions from OGVs.

Figure ES-6: Comparison of Diesel PM Emission Reductions Between the Proposed ARB Regulation and an ECA Provided for in the April 2008 Proposed Amendments to Annex VI



It is also important to acknowledge that, at this point in time, there is much uncertainty with respect to the possibility of implementing an ECA in the U.S. First, the U.S. is not yet a Party to MARPOL Annex VI and until that happens, cannot even vote on the current amendments to Annex VI. In the event the U.S. does become a Party to the treaty and the recent proposed amendments are approved by IMO, then the U.S. must develop documentation supporting the need to prevent, reduce, and control emissions in the ECA and obtain IMO approval. Nevertheless, ARB staff is optimistic that ultimately there will be progress at IMO and that the U.S. will become a Party to Annex VI. With that expectation in mind, ARB staff has been working closely with U.S. EPA staff on building the technical underpinnings for an ECA request. As mentioned earlier, the proposed California regulation includes a provision that would allow the ARB to sunset the rule in the event an international (or national) program is in place that will achieve equivalent benefits.

26. How is this proposed regulation affected by the Pacific Merchant Shipping Association (PMSA) lawsuit contending that ARB enforcement of the Auxiliary Engine Rule without US Environmental Protection Agency (EPA) approval violates the Clean Air Act?

The results of the PMSA lawsuit do not prohibit ARB from directly requiring the use of low sulfur distillate fuels in main and auxiliary ship engines, as set forth in the proposal. In December 2006, PMSA filed suit in federal district court challenging the Auxiliary Engine Regulation as preempted emission standards under Clean Air Act (CAA) section 209(e). PMSA also claimed that the Submerged Lands Act preempted the regulation to the extent the regulation was applied beyond 3 nm off the California coast. In May 2008, the 9th Circuit Court of Appeals upheld the lower court's granting of summary judgment against ARB and reinstated the lower court's injunction against ARB's enforcement of that regulation. The Court held that, on its face, the regulation constituted an emissions standard, which is preempted under CAA section 209(e) unless California obtains an authorization from U.S. EPA under the same section. In finding preemption under section 209(e), the Court did not reach the Submerged Lands Act issue.

The Court held that the Auxiliary Engine Regulation was an emissions standard because it allowed vessel operators to comply by showing equivalence to using the specified low sulfur distillates. To address this holding, we have incorporated into the proposal direct fuel-use requirements for main and auxiliary engines.[5] Under U.S. EPA implementing regulations for CAA section 209(e), direct fuel-sulfur limits do not constitute emission standards; instead, fuel sulfur limits are non-preempted in-use operational requirements, like limits on hours of operation and speed limits. Thus, we believe the proposed regulation's operational fuel-use requirements will survive another preemption challenge based on section 209(e).

27. Why is ARB proposing statewide implementation of this regulation?

We are proposing a statewide and uniform implementation of this regulation for practical reasons as well as ensuring that California employs state level consistent requirements with regard to regulating foreign-flag vessels. Under H&SC sections 43013 and 43018, ARB and the districts share concurrent jurisdiction over marine vessels, which are considered to be nonvehicular sources. In addition, H&SC section 39666(d) requires the districts to implement and enforce an ARB airborne toxic control measure (ATCM) or adopt and enforce an equally effective or more stringent ATCM. Thus, the districts are authorized under State law to regulate the main engines and auxiliary boilers on vessels, and each district can do so provided its regulations are equally effective or more stringent.

The districts' authority notwithstanding, we believe it is prudent for the districts to coordinate their efforts with those of ARB and have ARB to take the lead role in

[5] Auxiliary boilers are not affected by the PMSA lawsuit because boilers are not engines under CAA section 209(e).

implementing the ATCM. We believe this for several reasons. First, it is impractical for many districts to enforce an ATCM against ocean-going vessels, many of which make multiple visits to ports throughout California. Second, ARB has gained technical expertise over several years of developing this regulation, which would require a significant expenditure of district resources to replicate. Third, the districts are permitted but not required to adopt and enforce an equally effective or more stringent ATCM. By coordinating their efforts with ARB and having ARB take the primary lead in implementing the ATCM statewide, the districts will have met their statutory obligations under H&S section 39666(d).

Equally important to the practical concerns are the international foreign commerce concerns. Under the dormant Foreign Commerce Clause, regulations that interfere with a nation's ability to "speak with one voice when regulating commercial relations with foreign governments," may be held invalid. Having a patchwork of district regulations different from ARB's proposal may frustrate the efficient execution of the nation's foreign policy to speak with one voice. Thus, it would be in California's best interests to coordinate statewide efforts so that operators of foreign-flagged and U.S.-flagged vessels visiting California ports only need to understand and meet one set of statewide regulations.

28. How was this proposal developed?

In March, 2007, staff began a series of public workshops focused on the proposed regulation. Extensive efforts were made to ensure that the public and affected parties were aware of and had the opportunity to participate in the development of this proposal. Attendees included representatives from environmental organizations, community groups, port administration, vessel operators, engine manufacturers, fuel producers, the U.S. Coast Guard, local and federal air quality agencies, and other parties interested in marine emissions. These stakeholders participated both by providing data and reviewing draft regulations, and by participating in open forum workshops, in which staff directly addressed their concerns.

In July 2007, a Maritime Air Quality Technical Working Group (MWG) meeting was held to provide a forum for the presentation and discussion of the technical feasibility of using cleaner distillate fuel in the main engines and auxiliary boilers. Topics included the technical feasibility of fuel switching, greenhouse gas impacts, in-use experience with using distillate fuels in the main engines and worldwide availability of low sulfur marine distillates. Speakers included representatives from the two largest engine makers, MAN and Wärtsila, Herbert Engineering Corp., a naval architecture, and engineering firm, University of Delaware Marine and Earth Studies, the A.P. Moller-Maersk Group, BP Shipping, and DNV Petroleum Services, Inc.

More than 1,700 individuals and companies were notified for each workshop and the Maritime Working Group meeting through a series of mailings. Notices were posted to ARB's marine and public workshops web sites and e-mailed to subscribers of the marine electronic list server. As a way of inviting public participation and enhancing the

information flow between ARB and interested parties, staff created a commercial marine Internet website (http://www.arb.ca.gov/marine) in 2001. Since that time, staff has consistently made available on the website all related documents, including meeting presentations and draft versions of the proposed regulatory language. The website has also provided workshop and meeting notices and materials, other marine related information, and has served as a portal to other websites with related information.

29. How does the proposed regulation relate to the State Implementation Plan for Ozone and PM and the Goods Movement Emission Reduction Plan?

The federal Clean Air Act (CAA) requires the U.S. EPA to establish National Ambient Air Quality Standards (national standards) for pollutants considered harmful to public health, including fine particulate matter (PM2.5) and ozone. Areas in the State that exceed the national standards are required by federal law to develop State Implementation Plans (SIPs) describing how they will attain the standards by certain deadlines. Diesel PM and PM emission reductions are needed because they contribute to ambient concentrations of PM2.5; NOx emission reductions are needed because NOx leads to formation in the atmosphere of both ozone and PM2.5; and SOx emission reductions are needed because SOx leads to the formation in the atmosphere of PM2.5.

In particular, the proposed regulation is critical to assist the South Coast Air Quality Management District (SCAQMD) in attaining the national ambient air quality standard (NAAQS) for PM2.5 and to fulfill obligations in the State Implementation Plan (SIP). The South Coast Air Basin is required to attain the national standard for PM2.5 by April 5, 2015. Because the compliance with the standard is based on calendar annual averages, this effectively means that all reductions needed to meet the standard must be in place in 2014. The ARB has adopted revisions to the South Coast ozone and PM2.5 SIPs and has submitted the SIPs to the U.S. EPA. Air quality modeling indicates that significant reductions in diesel PM, PM, NOx and SOx are needed to meet the PM2.5 standards. The strategy to achieve attainment of the PM2.5 standards in the South Coast Air Basin includes a 68 percent reduction in SOx emissions, a 55 percent reduction in NOx emissions, and a 15 percent reduction in direct PM2.5 emissions from 2006 baseline levels. However, the modeling also indicates that reducing SOx emissions is the most effective strategy for attaining the standard. Preliminary modeling indicated that reducing one ton of SOx emissions was 10 times as effective in reducing ambient PM2.5 as reducing one ton of ROG, and over three times as effective as reducing one ton of NOx emissions. (Cassmassi, 2008) The diesel PM, PM, NOx, and SOx, emission reductions from the proposed regulation would play an essential role in assisting the South Coast Air Basin with meeting its 2014 PM2.5 deadline as well as its future ozone deadlines. The PM and SOx emission reductions from the proposal would meet the SIP reduction targets for ships, while the NOx emission reductions would assist other measures in making progress toward the NOx reduction targets.

The federal CAA permits states to adopt more protective air quality standards if needed, and California has set standards for particulate matter and ozone that are more protective of public health than respective federal standards. The Bay Area, South

Coast, and San Diego areas are nonattainment for the State standards for ozone and PM2.5. Health and Safety Code section 40911 requires the local air districts to submit plans to the Board for attaining the State ambient air quality standards, and H&S section 40924 requires triennial updates of those plans. The NOx, SOx, and PM2.5 emission reductions from the proposed regulation will assist the districts in achieving attainment of the State ambient air quality standards.

The proposed regulation is also an important element of the Goods Movement Emission Reduction Plan (GMERP) which outlines the measures necessary to achieve an 85 percent statewide diesel PM risk reduction. The PM and SOx emission reductions from the proposal would meet the GMERP targets for ships, while the NOx emission reductions would assist other measures in making progress toward the plan's targets.

30. How does the proposed regulation relate to ARB's goals for Environmental Justice?

Environmental Justice is defined as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies. ARB's Environmental Justice Policies are intended to promote the fair treatment of all Californians and cover the full spectrum of ARB's activities.

The proposed regulation is consistent with the environmental justice policy to reduce health risks from toxic air contaminants in all communities, including those with low-income and minority populations, regardless of location. The proposal will reduce diesel PM, PM, NOx and SOx emissions from ocean-going vessels for all communities near California ports and shipping lanes, particularly for communities near the ports of Los Angeles, Long Beach, San Diego, and Oakland. For example, in the West Oakland community ARB staff estimates about an 80 percent reduction in potential cancer risk due to exposures to diesel PM from OGV in 2015 from implementation of the proposed regulation.

31. What future activities are planned?

In addition to activities associated with monitoring and enforcement of the proposed regulation, staff recognizes the need to conduct a number of other activities. These activities include outreach to the vessel operators that only visit California ports occasionally to ensure that they are aware of the requirements of the proposal; and to continue to encourage the U.S. EPA and the IMO to take an active role in reducing emissions from ocean-going vessels. As discussed below, ARB staff intend to work closely with U.S. EPA on pursuing an ECA, continue to monitor fuel availability for marine distillate fuels specified in the proposed regulation, and undertake additional studies that will investigate the impacts of fuel-switching on marine engines and associated components.

IMO

ARB staff will continue to work with the U.S. EPA to establish a Sulfur Emission Control Area (SECA) or an Emission control Area (ECA) in the event the most recent amendments under consideration at IMO are approved and the U.S. enacts legislation to implement the treaty provisions.

Fuel Availability

While ARB staff believes the fuels specified in the proposed regulation will be available for OGV operators, we intend to monitor fuel availability as the regulation is implemented to ensure that vessel operators are able to obtain the necessary fuel in Pacific Rim fueling ports. Staff will determine if it is appropriate to propose amendments to the regulation under certain circumstances: (1) in the event we notice a significant increase in the number of noncompliance fees paid due to the inability to obtain the necessary fuel or, (2) if after 2012, a significant portion of the fleet finds it necessary to purchase fuel in California because it was not available at the prior fueling port.

Studies Evaluating Impacts of Marine Distillate Fuels

During the development of the proposed regulation, ARB staff determined that operating OGV engines and auxiliary boilers on marine distillate fuels is feasible. However, concerns were raised by engine manufacturers and vessel operators regarding impacts on fuel pumps and long-term engine maintenance when routinely switching from HFO to MGO or MDO. To provide further knowledge in these areas, ARB staff intends to undertake two additional studies to investigate the impacts of fuel switching in OGV main engines.

The first study will investigate the acceptable lower limits of fuel viscosity and lubricity in the fuel pumps. Some ship operators have expressed concern that use of low sulfur fuels (especially below 0.05% sulfur) would be damaging to fuel injection pumps because these fuels are low in viscosity and may be low in lubricity. In this study, ARB is partnering with the major marine engine manufactures to bench test low sulfur distillate fuels in a simulated "pump rig test". For this program, a fuel injection pump, typical of a large two-stroke, slow-speed engine, would be operated on a test stand. The pump will be operated with the designated fuel for a specified period of time and then disassembled and inspected for wear. The goal of this testing is to determine the lower limits of fuel lubricity and viscosity for marine fuel injection pumps used on large two-stroke, slow-speed OGV main engines.

The second study will investigate the long term impacts of fuel switching on main engine performance, component wear and failure rates. In this study, fuel switching between heavy fuel oil (HFO) and low sulfur, cleaner-burning distillate would be done on a select number of ocean-going vessel main engines. Currently, there have been no documented long term studies or demonstrations on the effect of low sulfur marine fuels on the long term performance and operation of modern two-stroke engines on ocean-

going vessels which routinely fuel switch between HFO and distillate fuels. In this program, the long term operation, such as engine performance, component failure rate, and component wear would be evaluated to determine the long term effects of fuel switching. Shipping companies and engine makers would provide in-kind services to partner with the ARB. In addition, emission testing for diesel PM, criteria pollutants and greenhouse gasses would be performed to determine emission benefits of fuel switching.

In addition, staff recognizes the need to achieve additional emission reductions from ocean-going vessels. ARB staff is currently studying the feasibility of implementing vessel speed reduction (VSR) including an evaluation of the technical and economic issues associated with VSR. Further, a clean ship measure is being developed to target strategies to reduce emissions in new ship builds. These and other potential emission reduction strategies are part of the SIP and GMERP.

32. What is staff's recommendation?

We recommend that the Board approve the proposed regulation presented in this report (Appendix A). The proposal will reduce emissions of diesel PM, PM, NOx, and SOx, resulting in significant health benefits to the public. In particular, communities near California's major ports and shipping lanes benefit from reduced exposure to the potential cancer risk from diesel PM. Staff believes that the proposal is technologically and economically feasible and necessary to carry out the Board's responsibilities under State law.

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I. INTRODUCTION

The California Air Resources Board's (ARB) mission is to promote and protect public health, welfare, and ecological resources through the effective and efficient reduction of air pollutants while recognizing and considering the effects on the economy of the state. Ocean-going vessel (OGV) auxiliary diesel and diesel electric engines, main propulsion engines, and auxiliary boiler (engines and auxiliary boilers) exhaust is a source of unhealthful air pollutants including particulate matter (PM), diesel PM, nitrogen oxides (NOx), and sulfur oxides (SOx). Emissions from OGV are a significant concern in communities near California ports. In this chapter, the Air Resources Board (ARB or Board) staff provides an overview of this staff report, discusses the purpose of the proposed regulation ("proposal"), and discusses the regulatory authority ARB has to adopt the proposed regulation. We also discuss the public outreach process used to include all interested stakeholders in the development of the proposal.

A. Overview

This report presents the proposed regulation to reduce emissions of diesel PM, PM, NOx, and SOx from OGV engines and auxiliary boilers used on ocean-going vessels within a 24 nautical mile zone of the California Coastline. A detailed summary of the requirements of the proposal are included in Chapter V. The report also shares the information that ARB staff used in developing the proposal. This information includes:

- the health effects associated with exposure to diesel PM, PM, NOx, and SOx emissions (Chapter II);
- a description of the affected industry (Chapter III);
- the emissions inventory and health risks posed by exhaust from OGV engines and boilers (Chapter IV);
- a summary of the provisions in the proposal, and a discussion of the regulatory alternatives to the proposal that were considered (Chapter V);
- a discussion of the technical feasibility of using the fuels specified in the proposal, (Chapter VI);
- the environmental impacts of implementing the proposal, including greenhouse gases, (Chapter VII); and
- the estimated costs to industry and the fiscal impacts of these costs (Chapter VIII).

The text of the proposal and other supporting information are found in the Appendices.

B. Purpose

The purposed regulation is designed to reduce emissions of diesel PM, PM, NOx, SOx, and "secondarily" formed PM (PM formed in the atmosphere from NOx and SOx emissions). Diesel PM emission reductions are needed to reduce the potential cancer risk. Diesel PM, PM from boilers, and secondarily formed PM reductions are needed to reduce premature mortality and other noncancer health impacts from PM exposures to people who live in the vicinity of California's major ports and shipping lanes. Reductions

in diesel PM, PM and secondary PM from SOx and NOx will also contribute to regional PM reductions that will assist in California's progress toward achieving State and federal air quality standards. Reductions in NOx, an ingredient in the formation of ozone pollution, will help reduce regional ozone levels and secondary nitrate PM. The health impacts of these pollutants are described in Chapter II.

C. Regulatory Authority

Under State and federal law, ARB can regulate both criteria pollutant and toxic diesel PM emissions from marine vessels. Health and Safety Code (H&SC) sections 43013 and 43018 authorize ARB to regulate marine vessels to the extent such regulation is not preempted by federal law. Also, H&SC § 39666 requires ARB to regulate emissions of toxic air contaminants (TAC) from nonvehicular sources, which include ocean-going vessels. The proposed regulation requires the use of lower sulfur marine distillate fuels that will result in reductions of diesel PM, which is both a TAC and criteria pollutant, and NOx, SOx, and PM which are criteria pollutants.

The proposed regulation is neither preempted under federal law, nor does it violate the Commerce Clause. Federal authorization under section 209(e) of the Clean Air Act (CAA) is required for regulating new nonroad engines and for requiring retrofits on existing engines. Ocean-going vessel engines, by definition, fall within the category of nonroad engines. However, no federal authorization is required for implementing in-use operational requirements on existing marine vessels and their engines.

Further, the proposed regulation does not conflict with the Ports and Waterways Safety Act (PWSA) and U.S. Coast Guard regulations. As a non-discriminatory regulation with substantial benefits, the proposed regulation does not violate the Commerce Clause. And federal and state cases support our authority to regulate both U.S. and foreign-flag vessels within California Coastal Waters. Therefore, federal law does not preempt the proposed regulation, nor does the regulation violate the requirements of the Commerce Clause.

The ARB's legal authority to promulgate the proposed regulation is discussed in more detail in Appendix B.

D. Public Outreach and Environmental Justice

ARB is committed to integrating environmental justice in all of its activities. On December 13, 2001, the Board approved "Policies and Actions for Environmental Justice," which formally established a framework for incorporating Environmental Justice into ARB's programs, consistent with the directive of California State law. Environmental Justice is defined as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies. These policies apply to all communities in California, but recognize that environmental justice issues have been raised more in the context of low-income and minority communities.

The Environmental Justice Policies (Policies) are intended to promote the fair treatment of all Californians and cover the full spectrum of ARB's activities. Underlying these Policies is a recognition that the agency needs to engage community members in a meaningful way as it carries out its activities. People should have the best possible information about the air they breathe and what is being done to reduce unhealthful air pollution in their communities. The ARB recognizes its obligation to work closely with all communities, environmental and public health organizations, industry, business owners, other agencies, and all other interested parties to successfully implement these Policies.

The proposal is consistent with the environmental justice policy to reduce health risks in all communities, including those with low-income and minority populations, regardless of location. The proposal will achieve the most significant reductions in emissions in the communities adjacent to the ports of Los Angeles, Long Beach, and Oakland, where the greatest shipping activity occurs. The proposal will also provide air quality benefits to other coastal regions, particularly near shipping lanes and the other ports.

Outreach Efforts

During the development process, ARB staff searched for opportunities to present information about the proposed regulation at places and times convenient to stakeholders. For example, the meetings were held at locations that encouraged public participation, including meetings at California ports. Attendees included representatives from environmental organizations, community groups, port administration, vessel operators, engine manufacturers, fuel producers and suppliers, the U.S. Coast Guard, local and federal air quality agencies, and other parties interested in marine emissions. These individuals participated both by providing data and reviewing draft regulations, and by participating in open forum workshops, in which staff directly addressed their concerns. Table I-1 below provides meeting dates that were made to apprise the public about the development of the proposed regulation. Over 1,700 individuals and/or companies were notified for each workshop through a series of mailings to the subscribers of the maritime electronic list server. In addition, all notices and meeting materials were posted to ARB's marine and public workshops web sites.

Table I-1: Public Workshops *

Date	Meeting	Location
March 20, 2007	Public Workshop	Port of Long Beach
June 13, 2007	Public Workshop	Cal/EPA Building, Sacramento
July 24, 2007	Maritime Working Group	Cal/EPA Building, Sacramento
September 24, 2007	Public Workshop	Cal/EPA Building, Sacramento
March 5, 2008	Public Workshop	Cal/EPA Building, Sacramento
May 13, 2008	Public Workshop	Cal/EPA Building, Sacramento

*All workshops and public meetings held at the Cal/EPA headquarters building were web-cast.

In addition to the public meetings presented in Table I-1, ARB staff and management participated in numerous meetings with industry, government agencies, community groups and environmental groups over the past two years. During these meetings, staff presented information on ARB's plans to regulate emissions from marine vessels, and incorporated the feedback from stakeholders. Some of the groups participating were the Pacific Merchant Shipping Association, Western States Petroleum Association, Ports of Los Angeles, Long Beach, Oakland, and San Francisco, the U.S. Maritime Administration, U.S. Environmental Protection Agency, U.S. Coast Guard, U.S. Navy, California Office of Spill Prevention and Response, San Francisco Harbor Safety Committee, California Maritime Academy, California State Lands Commission, South Coast Air Quality Management District, Santa Barbara County Air Quality Management District, Coalition for Clean Air, Environmental Defense, Natural Resources Defense Council, Union of Concerned Scientists and San Francisco Bar Pilots. Some of the shipping companies participating were the A.P. Moller-Maersk Group, Chevron Shipping Company, BP Shipping, APL, and Matson.

As a way of inviting public participation and enhancing the information flow between ARB and interested parties, staff created a commercial marine Internet web site (http://www.arb.ca.gov/marine) in 2001. Since that time, staff has consistently made available on the web site all related documents, including meeting presentations and draft versions of the proposed regulatory language. The web site has also provided workshop, meeting notices and materials, and other marine related information, along with serving as a portal to other web sites with related information.

Outreach efforts have also included hundreds of personal contacts via telephone, electronic mail, regular mail, surveys, facility visits, and individual meetings with interested parties. These contacts have included interactions with engine manufacturers and operators, emission control system manufacturers, local, national, and international trade association representatives, environmental, State agencies, military officials and representatives, and other federal agencies.

II. NEED FOR CONTROL OF EMISSIONS FROM OCEAN-GOING VESSELS

In 1998, the Air Resources Board identified diesel PM as a toxic air contaminant (TAC). Diesel PM is by far the most important TAC and contributes over 70 percent of the estimated risk from air toxic contaminants today. Since that time, there have been several initiatives undertaken to reduce exposures diesel PM. In September 2000, ARB approved the "Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles" (DRRP or Diesel Risk Reduction Plan). The DRRP established a goal of reducing diesel PM by 75 percent in 2010 and by 85 percent in 2020. In April 2006, the ARB approved the Emission Reduction Plan for Ports and Goods Movement in California (ARB, 2006) which outlines a comprehensive strategy to meet an 85 percent diesel PM risk reduction target from goods movement activities. In addition, the Office of Environmental Health Hazard Assessment (OEHHA) identified diesel PM in 2001 as one of the TACs that may cause children or infants to be more susceptible to illness, pursuant to the requirements of Senate Bill 25 (Stats. 1999, ch. 731). Senate Bill 25 also requires ARB to adopt control measures, as appropriate, to reduce the public's exposure to these special TACs (H&S section 39669.5). In the following sections, we describe the physical and chemical characteristics of diesel PM and discuss the adverse health and environmental impacts from the suite of pollutants emitted by diesel-fueled engines.

A. Physical and Chemical Characteristics of Diesel PM

Diesel engines emit a complex mixture of inorganic and organic compounds that exist in gaseous, liquid, and solid phases. The composition of this mixture will vary depending on engine type, age and horsepower, operating conditions, fuel, lubricating oil, and the presence of an emission control system. The primary gas or vapor phase components include typical combustion gases and vapors such as carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), oxides of nitrogen (NOx), reactive organic gases (ROG), water vapor, and excess air (nitrogen and oxygen).

Many of the diesel particles exist in the atmosphere as a carbon core with a coating of organic carbon compounds, or as sulfuric acid and ash, sulfuric acid aerosols, or sulfate particles associated with organic carbon (Beeson et al., 1998). The organic fraction of the diesel particle contains compounds such as aldehydes, alkanes and alkenes, and high-molecular weight polycyclic aromatic hydrocarbons (PAH), and PAH-derivatives. Many of these PAHs and PAH-derivatives, especially nitro-PAHs, have been found to be potent mutagens and carcinogens. Nitro-PAH compounds can also be formed during transport through the atmosphere by reactions of adsorbed PAH with nitric acid and by gas-phase radical-initiated reactions in the presence of oxides of nitrogen. Fine particles may also be formed secondarily from gaseous precursors such as SO_2, NOx, or organic compounds. Fine particles can remain in the atmosphere for days to weeks and travel through the atmosphere for hundreds to thousands of kilometers. Conversely, coarse particles deposit to the earth within minutes to hours and within tens of kilometers from the emission source.

The total diesel particle mass consists almost entirely of inhalable particles in the range of 10 microns or less in diameter (PM_{10}). Approximately 94 percent of the mass of these particles are less than 2.5 microns ($PM_{2.5}$) in diameter. Diesel PM can be distinguished from noncombustion sources of $PM_{2.5}$ by the high content of elemental carbon with the adsorbed organic compounds and the high number of ultrafine particles (organic carbon and sulfate).

The soluble organic fraction (SOF) consists of unburned organic compounds in the small fraction of the fuel and atomized and evaporated lube oil that escape oxidation. These compounds condense into liquid droplets or are adsorbed onto the surfaces of the elemental carbon particles. Several components of the SOF have been identified as individual toxic air contaminants.

B. Health Impacts of Exposure to Diesel PM, Ambient Particulate Matter, Ozone, and Sulfur Dioxide

The proposed regulation will reduce the public's exposure to diesel PM, which is a component of ambient particulate matter. In addition, the proposed regulation is expected to result in reductions in PM, NOx, and SOx. NOx is a precursor to the formation of ozone, and both NOx and SOx contribute to secondarily formed PM in the lower atmosphere. The primary health impacts of these air pollutants are discussed below.

Diesel Particulate Matter

Since most diesel exhaust particle mass consists of particles 2.5 microns or less in diameter, they can be inhaled deep into the lung. The majority of epidemiologic studies that have investigated the health effects of exposure to diesel exhaust are occupational studies, primarily railroad workers, truck drivers, or workers in mines, and the results generally support the view of an association between long-term exposure to diesel exhaust and lung cancer (Garshick et al., 2004; Garshick et al., 2006; Laden et al., 2006; Ris, 2007). Also other researchers (Hart et al., 2006) have reported that diesel exhaust exposure was associated with death from chronic obstructive pulmonary disease in railroad workers. There are no direct monitoring methods for diesel PM, and so exposure assessments have been typically based on job classification. On average, these studies found that long-term occupational exposures to diesel exhaust were associated with a 40 percent increase in the relative risk of lung cancer (ARB, 1998a) .

A potentially significant health effect of diesel exhaust exposure is its apparent ability to act as an adjuvant in allergic responses and possibly asthma (Diaz-Sanchez et al., 1996; Diaz-Sanchez et al., 1999; Riedl & Diaz-Sanchez, 2005). However, additional research is needed at diesel exhaust concentrations that more closely approximate current ambient levels before the role of diesel PM exposure in the increasing allergy and asthma rates is established.

Diesel PM was listed as a TAC by ARB in 1998 after an extensive review and evaluation of the scientific literature by OEHHA (ARB, 1998b). Using the cancer unit risk factor developed by OEHHA for the TAC program, it was estimated that for the year 2000, exposure to statewide average population-weighted ambient concentrations of diesel (1.8 $\mu g/m^3$) could be associated with a health risk of 540 potential cancer cases per million people exposed over a 70 year lifetime.

Ambient Particulate Matter

Ambient PM is a complex mixture of tiny particles that may consist of dry solid fragments, solid cores with liquid coatings, and small droplets of liquid. These particles vary greatly in shape, size, and chemical composition, and can consist of many different materials such as metals, soot, soil, and dust. As described above, PM can be directly emitted from sources, such as diesel PM, or can be produced indirectly from sources which emit precursors that are converted to PM by atmospheric processes. Particles 10 micrometers or less in diameter are defined as "respirable particulate matter" or "PM_{10}." PM_{10} and particles 2.5 micrometers or less in diameter ($PM_{2.5}$) can be inhaled deep into the lungs. $PM_{2.5}$ contributes significantly to regional haze and reduction of visibility in California. Besides reducing visibility, the acidic portion of PM (nitrates, sulfates) can harm crops, forests, aquatic and other ecosystems (ARB, 2002a). Ambient particulate matter includes diesel PM as an important component.

Considerable epidemiologic research over the past 15 years has investigated the responses of humans to PM. The principal health effects of ambient PM exposure are summarized below:

- Many studies have consistently found statistical associations between $PM_{2.5}$ and premature death with both long-term (Pope et al. 2004; Krewski et al., 2001; Pope et al., 2002; Laden et al., 2006) and daily exposures (Dominici, 2003, Dominici et al., 2005; Laden et al., 2000; Schwartz et al., 2003). The association with premature mortality is considerably stronger for annual average $PM_{2.5}$ exposure than for daily average $PM_{2.5}$. That is, long-term exposure appears to pose a greater risk of death than short-term exposure.

- A recent study suggests that long-term exposure to $PM_{2.5}$ may influence the risk of adverse cardiovascular events in women (Miller et al., 2007), including death from heart attack or stroke, and hospitalization for heart attack, stroke, or coronary artery angioplasty.

- Daily exposure to $PM_{2.5}$ has been associated with hospitalization for heart and lung related causes (Moolgavkar, 2003; Schwartz et al., 2003; Zanobetti et al., 2003). Others have found that exposure to $PM_{2.5}$ resulted in increased emergency room visits, exacerbation of asthma, and other respiratory diseases (Sheppard, 2003; Peel et al., 2005). Other research indicates that exposure to $PM_{2.5}$ leads to increased asthma medication usage (Gent et al., 2003) and increased asthma symptoms (Whittemore & Korn, 1980; Delfino et al., 2002).

Exposure to $PM_{2.5}$ has also been associated with increased work loss days (Ostro & Rothschild, 1989; Ostro et al., 1993).

- Older adults with preexisting chronic heart or lung disease are at greatest risk of experiencing adverse effects related to $PM_{2.5}$ exposure (Moolgavkar, 2003; Dominici et al., 2006; Symons et al., 2006).

- In May 2008, ARB released a draft report *Methodology for Estimating Premature Deaths Associated with Long-term Exposure to Fine Airborne Particulate Matter in California*. In this draft report, the relative risk of premature death due to PM2.5 exposure was reevaluated based on all relevant scientific literature, and a ne relative risk factor was developed. This new relative risk factor is a 10 percent increase in premature deaths per 10 $\mu g/m^3$ increase in PM2.5 exposures. (ARB, 2008)

There is some evidence suggesting that air pollution may have greater effects in children than in adults. This may be because they inhale more $PM_{2.5}$ per pound of body weight than do adults, and because they breathe more rapidly than adults. Adverse effects reported in children include reduced lung function growth in higher pollution areas (Gauderman et al., 2000; Gauderman et al., 2002; Gauderman et al., 2004) that may at least partially reverse if the child moves to an area with cleaner air (Avol et al., 2001); and increased asthma and bronchitis symptoms (McConnell et al., 1999; Gauderman et al., 2005).

Ozone

Diesel exhaust consists of hundreds of gas-phase, particle-phase, and semi-volatile organic compounds, including typical combustion products, such as CO_2, hydrogen, oxygen, and water vapor. Diesel exhaust also includes compounds resulting from incomplete combustion, such as CO, ROG, carbonyls, alkenes, aromatic hydrocarbons, PAHs, PAH derivatives, and SOx. Ozone (O_3) is formed by the reaction of ROG and NOx in the atmosphere in the presence of heat and sunlight. The highest levels of ozone are produced when both ROG and NOx emissions are present in significant quantities on hot, clear summer days.

Outdoor air often contains a sufficiently high concentration of O_3 to induce adverse responses in large segments of the population. Studies of human subjects exposed to controlled concentrations of O_3 have consistently shown that exposures at concentrations above 0.08 ppm for 6 to 8-hours or 0.12 ppm for one-hour consistently induce adverse responses in some individuals. The magnitude of effects depends on the inhaled dose of O_3, which is the product of ambient O_3 concentration, the volume of air breathed, and the duration of exposure (Silverman et al., 1976; Folinsbee et al., 1978; Adams et al., 1981; Drechsler-Parks et al., 1990). Acute effects of O_3 exposure include:

- Reductions in various measures of lung function (Folinsbee et al., 1977a; Folinsbee et al., 1977b; McDonnell et al., 1983; Kulle et al., 1985; Schelegle & Adams, 1986; Seal et al., 1993).
- Increased respiratory symptoms, such as cough, pain on deep breath, and difficulty taking a deep breath (Folinsbee et al., 1977a; Kulle et al., 1985; Schelegle & Adams, 1986; Seal et al., 1993; McConnell et al., 1999).

- Cellular and biochemical changes indicative of lung inflammation (Devlin et al., 1991; Aris et al., 1993; Balmes et al., 1996; Devlin et al., 1996).

The people most at risk for experiencing adverse acute responses to O_3 are those who inhale the most O_3, namely those who are active outdoors during the period of the day when the O_3 concentration is highest, particularly children, outdoor workers, and athletes (EPA 1996). Responsiveness to O_3 varies considerably between individuals (Adams et al., 1981; McDonnell et al., 1983; McDonnell et al., 1985; Aris et al., 1995; McDonnell et al., 1995), although the specific factor(s) that determine degree of responsiveness is (are) unknown (McDonnell et al., 1993; Frampton et al., 1997; Torres et al., 1997).

Some studies suggest that mild to moderate asthmatics have lung function and symptoms responses similar to those of nonasthmatics (Horstman et al., 1986; Koenig et al., 1987; Koenig et al., 1988), while others suggest that asthmatics may be more sensitive to O_3 than nonasthmatics (Scannell et al., 1996; Peden et al., 1997). Some asthmatics also have increased lung inflammatory responses to O_3 compared to healthy people (McBride et al., 1994; Peden et al., 1997), and enhanced allergic responses after O_3 exposure (Molfino et al., 1991; Peden et al., 1995; Kehrl et al., 1999), although the literature is inconsistent on this point (Ball et al., 1996; Hanania et al., 1998).

Epidemiological studies have reported statistically significant associations between outdoor O_3 concentrations and:

- Increased asthma and respiratory symptoms (Whittemore & Korn, 1980; Brunekreef et al., 1994; Devlin et al., 1996; Thurston et al., 1997; Mortimer et al., 2002; Gent et al., 2003; Millstein et al., 2004; Mudway et al., 2006; Romieu et al., 2006).

- Hospital admissions and emergency room visits, primarily for asthma or other respiratory causes including COPD and bronchitis (Schwartz, 1995; Anderson et al., 1997; Burnett et al., 1997; Delfino et al., 1997; Delfino et al., 1998; Sheppard et al., 1999; Peel et al., 2005; von Klot et al., 2005; Yang et al., 2005; Medina-Ramon et al., 2006).

- Increased school absenteeism for respiratory illnesses (Gilliland et al., 2001)

- Reduced lung function growth in children (Frischer et al., 1999; Rojas-Martinez et al., 2007; Oftedal et al., 2008).

- Increased risk of acquiring asthma for children who engage in three or more outdoor sports and live in high ozone areas (McConnell et al., 2002).

- Premature mortality (Ito & Thurston, 1996; Thurston & Ito, 2001; Bell et al., 2004; Gryparis et al., 2004; Bell et al., 2005; Levy et al., 2005).

Not only does ozone adversely affect human and animal health, but it also affects vegetation throughout most of California. These effects include reduced yield and quality in agricultural crops, disfiguration or unsatisfactory growth in ornamental vegetation, and damage to native plants. During the summer, ozone levels are often highest in the urban centers in Southern California, the San Joaquin Valley, and Sacramento Valley, which are adjacent to the principal production areas in the State's multibillion-dollar agricultural industry (USDA, 2006). ARB studies indicate that ozone pollution damage to crops is estimated to cost agriculture over $500 million dollars annually (ARB, 1987; 2006).

Sulfur Dioxide and Sulfates

Sulfur dioxide (SO_2) is a gaseous compound of sulfur and oxygen. SO_2 is formed when sulfur-containing fuel is burned by mobile sources, such as locomotives, marine vessels, and off-road diesel equipment. SO_2 is also emitted from several industrial processes, such as petroleum refining and metal processing.

Human exposure studies provide the most consistent data as to adverse health effects of SO_2. These studies have found that the population subgroups most likely to experience adverse responses to SO_2 at low levels include primarily asthmatics and some individuals with allergies and airway hyperresponsiveness (Sheppard et al., 1980; Koenig et al., 1981; Sheppard et al., 1981; Horstman et al., 1986; Linn et al., 1987; Nowak et al., 1997; Koenig, 1998). Even among asthmatics, there is wide variability in SO_2 susceptibility: one investigation of adult asthmatics suggests a seven-fold range of lung function responses to fixed levels of SO_2 exposures (Horstman et al., 1986). Low humidity and exercise (or voluntary hyperventilation) augment the responses observed in asthmatics (Sheppard et al., 1981; Linn et al., 1983; Bethel et al., 1984; Sheppard et al., 1984; Linn et al., 1985).

Some epidemiologic studies have suggested associations between ambient SO_2 levels and more serious categories of adverse health outcomes including mortality and various acute morbidities; however, the results are not consistent between studies. U.S. EPA (EPA, 2007) reviewed the existing literature on health effects related to SO_2, and concluded that there is a likely causal relationship between short-term SO_2 exposures (up to several hours) and acute respiratory effects such as symptoms, bronchoconstriction, and emergency department visits for respiratory causes, but that evidence for longer-term or more serious effects was inconclusive. Because ambient

SO_2 concentration is generally strongly correlated with other air pollutants originating from the same sources, such as $PM_{2.5}$, CO, and NO_2, it is difficult to determine whether observed effects are related to SO_2, or to one or more of these co-pollutants.

Sulfates (SO_4^{2-}) are the fully oxidized ionic form of sulfur. Sulfates occur in combination with metal and/or hydrogen ions. In California, emissions of sulfur compounds occur primarily from the combustion of petroleum-derived fuels (e.g., gasoline and diesel fuel) that contain sulfur. This sulfur is oxidized to sulfur dioxide (SO_2) during the combustion process and subsequently converted to sulfate compounds in the atmosphere. Conversion of SO_2 to sulfates takes place comparatively rapidly and completely in urban areas of California due to regional meteorological features. Ambient sulfates comprise a sub-fraction of ambient particulate matter, primarily in the $PM_{2.5}$ size category. Few studies have investigated health effects related specifically to sulfates exposure, although the consensus view is that the effects are comparable in nature and severity to those associated with $PM_{2.5}$ (ARB, 2002a).

C. Applicability of the Cancer Potency Factor for Diesel PM to Engines Using Marine Gas Oil, Marine Diesel Oil, or Marine Heavy Fuel Oil

ARB staff, in consultation with OEHHA, has concluded that particulate matter emissions from ocean-going vessel diesel (compression ignition) engines operating on marine gas oil (MGO), marine diesel oil (MDO), or marine heavy fuel oil (HFO) constitute "diesel particulate matter" emissions. As such, the cancer potency factor and chronic reference exposure level for exhaust emissions from diesel-fueled engines, approved by the Scientific Review Panel and adopted by the ARB in 1998, are applicable to exhaust emissions from ocean-going vessel diesel engines using MGO, MDO, or HFO. The basis for staff's conclusion is presented below.

Diesel Engines Using Marine Gas Oil and Marine Diesel Oil

For the following reasons, ARB staff believes the health values developed for diesel PM are appropriate for emissions from diesel engines using MGO and MDO:

- MGO and MDO are distillate fuels with most fuel properties nearly identical to diesel fuel.

Marine gas oil is generally the heavier middle fraction product from the atmospheric distillation of crude oil. Conventional diesel is the lighter middle fraction product from the atmospheric distillation of crude oil. The key fuel properties for marine distillate fuel (MGO and MDO) are very similar to conventional diesel fuel that is used for on-road and off-road diesel engines. The density, heating value, and hydrogen and carbon content for MGO, MDO and conventional diesel fuel are essentially the same. The viscosity of MGO and conventional diesel are very close to the same; while the viscosity of MDO is somewhat higher the MGO or conventional diesel fuel.

The main difference among these fuels is the sulfur content. Since diesel used in on-road and off-road applications are required to meet ARB and U.S. EPA sulfur content limits, conventional diesel fuel generally has lower sulfur content than MGO or MDO. As discussed earlier, the current average sulfur content for MGO used by vessels visiting California ports is about 0.5% (5000 ppm). Diesel fuel meeting ARB specification averages about 0.014% (140 ppm) and is scheduled to be reduced to 0.0015% (15 ppm) in 2006. Generally, MGO will be sold as MDO if it has come in contact with HFO.

- The fuel specifications for MGO and MDO are very similar to the diesel fuel specification that existed prior to 1993.

MGO and MDO fuel specifications are very similar to pre-1993 diesel fuel. Pre-1993 diesel fuels, compared to post-1993 diesel fuel in California, generally had higher aromatic content (33 vs. 20-25 vol. %), higher sulfur (<5000 vs. 100-150 ppm Wt.), lower cetane number (>40 vs. 50-55), higher PAHs (8 vs. 2-5 Wt. %) and higher nitrogen (300-600 vs. 40-500 ppm Wt.) (ARB, 1998). This is important in that one of the key health studies linking increases cancer risk with exposure to diesel exhaust emissions was based on railroad workers exposed to diesel exhaust emissions in the 1950s through 1970s.

Diesel Engines Using Heavy Fuel Oil

The health values developed for diesel PM are also appropriate for emissions from diesel engines using HFO since the basic fuel properties of HFO are similar to diesel fuel, and since emission characteristics from diesel engines using HFO are similar to diesel engines using diesel fuel.

- HFO is a blended petroleum product containing the same classes of hydrocarbons as diesel fuel

Heavy fuel oil, like diesel fuel, is comprised of a complex mixture of aliphatic, naphthenic, and aromatic hydrocarbons. With both types of fuel, the final product will contain varying amounts of these classes of hydrocarbons based on the crude oil used and the refinery process. Heavy fuel oil simply contains a higher proportion of heavier (higher molecular weight - typically having a carbon number from C_{20} to C_{50}) versions of the same hydrocarbon types, and higher levels of sulfur, metals, and other contaminants.

- Heavy fuel oil contains some diesel fuel

Marine fuels may be separated into two basic types of fuels: distillate and residual (EPA, 1999). Distillate fuel (e.g., diesel fuel and marine gas oil) is composed of the fractions of crude oil that are separated in a refinery by a boiling process, while the remaining fraction that did not boil is referred to as residual. To produce fuels that can be conveniently handled and stored in industrial and marine installations, and to meet

marketing specifications limits, the high viscosity residual components are normally blended with MGO or similar lower viscosity fractions. (CONCAWE, 1998) For example, the most common grades of marine heavy fuel oil (IFO-380 and IFO-180) are composed of a mixture of residual compounds and distillate components (EPA, 1999; FAMM, 2001). Specifically, typical heavy fuel oil has been estimated to contain as much as 12 percent distillate (EPA, 1999).

- The emission characteristics of a marine diesel engine using HFO are similar to those of a diesel engine using diesel fuel

The diesel engines covered by the proposed regulation are larger versions of typical land-based diesel engines. They operate on a compression-ignition "diesel" cycle similar to land-based diesel engines. Marine diesel engines are designed to burn HFO, MGO, or MDO. The combustion process is nearly identical for any of these fuels. The liquid petroleum based fuel is injected into the engine where it is compressed to the point of auto-ignition. The peak combustion temperatures are similar for all of the fuels. While the relative magnitude of the combustion products may vary with fuel; the relative percentage of organic material, elemental carbon, and ash are similar among the various fuels. The percent of sulfates and sulfate bound water is higher as the sulfur content of the fuel increases. As a result of the nearly identical combustion process, we would expect that the major combustion products of an engine burning HFO will be similar in chemical nature to an engine using diesel fuel.

- The general classes of PM exhaust components from a marine diesel engine using HFO are similar to a diesel engine using diesel fuel

The PM components emitted from OGV engines using heavy fuel oil are the same as those emitted from a typical diesel engine: elemental carbon, ash, soluble organic compounds, and a sulfate fraction (MAN B&W, 2005). However, the overall levels of PM will be significantly higher, and a greater proportion of the PM will be from sulfate. Specifically, as discussed in Chapter IV, we estimate that a typical vessel auxiliary or main engine running on 2.5% sulfur heavy fuel oil will emit about 1.5 g of PM per kW-hr. This compares to an emission factor of about 0.3 g/kw-hr for the same engine running on marine gas oil with a sulfur content of about 0.25%. Much of this difference is due to the sulfur content of the fuel, since sulfate PM is estimated to be directly related to fuel sulfur. The higher ash content and density of heavy fuel oil is also expected to play a role in the higher emissions from engines using heavy fuel oil (EPA 2002).

- The particle size distribution of the exhaust emissions from a marine diesel engine using HFO is similar to the particle size distribution from a diesel engine using diesel fuel

Testing performed in 2005 by the University of California, Riverside, CE-CERT, in association with Maersk and CARB, indicate that over 85 percent of the particulate matter emissions from a marine diesel engines burning HFO are less than 2.5 microns in size. These results are similar to results for diesel engines using diesel fuel where

95 percent of the particulate were found to be less than 2.5 microns in size. (ARB, 1998) These very small particles are more likely to be inhaled deep into the lung and, as a result, may pose more of a health issue than larger particles.

Boilers Using MGO, MDO, or HFO

ARB staff does not believe that the health values developed for diesel PM are appropriate for emissions from boilers using MGO, MDO, or HFO. Boilers are not internal combustions engines. The health studies for diesel PM were based on exposure to exhaust emissions from internal combustion, compression ignition engines. Boiler design, combustion characteristics, operating temperatures and pressure, residence time, and exhaust parameters are sufficiently different to questions the applicability of the diesel PM risk factor to boiler PM.

D. Health and Environmental Benefits from the Proposed Regulation

Reducing emissions from OGV engines and auxiliary boilers will have both public health and environmental benefits. The proposed regulation will reduce localized health risks associated with the operation of OGV engines and auxiliary boilers that are near receptors and will contribute to the reduction of the general exposures to PM that occurs on a region-wide basis due to collective emissions from OGV engines and auxiliary boilers. Additional benefits associated with the proposed regulation include further progress in meeting the ambient air quality standards for PM_{10}, $PM_{2.5}$, and ozone, and enhancing visibility.

Reduced Diesel PM Emissions

The estimated reductions in diesel PM emissions and the associated benefits from reduced exposure and risk are discussed in detail in Chapter VIII.

Reduced Ambient Particulate Matter Levels

Reducing diesel PM and PM from OGV will also help efforts to achieve the ambient air quality standards for particulate matter. Both the State of California and the U.S. EPA have established standards for the amount of PM_{10} and $PM_{2.5}$ in the ambient air. These standards define the maximum amount of PM that can be present in outdoor air. California's PM_{10} standards were first established in 1982 and updated June 20, 2002. It is more protective of human health than the corresponding national standard. Additional California and federal standards were established for $PM_{2.5}$ to further protect public health (Table II-1).

Table II-1: State and National PM Standards

California Standard		National Standard	
PM_{10}			
Annual Arithmetic Mean	20 $\mu g/m^3$	Annual Arithmetic Mean	50 $\mu g/m^3$
24-Hour Average	50 $\mu g/m^3$	24-Hour Average	150 $\mu g/m^3$
$PM_{2.5}$			
Annual Arithmetic Mean	12 $\mu g/m^3$	Annual Arithmetic Mean	15 $\mu g/m^3$
24-Hour Average	No separate State standard	24-Hour Average	65 $\mu g/m^3$

Particulate matter levels in most areas of California exceed one or more of current State PM standards. The majority of California is designated as non-attainment for the State PM_{10} standard (ARB, 2002b). Diesel PM and PM emission reductions from OGV engines and auxiliary boilers will help protect public health and assist in furthering progress in meeting the ambient air quality standards for both PM_{10} and $PM_{2.5}$.

The emission reductions obtained from this proposal will result in lower ambient particulate matter levels and significant reductions of exposure to primary diesel and secondary PM resulting from NOx and SOx emissions from OGV engines and auxiliary boilers. Lower ambient particulate matter levels and reduced exposure mean reduction of the prevalence of the diseases attributed to diesel PM, reduced incidences of hospitalizations, and prevention of premature deaths.

Reduced Ambient Ozone Levels

Emissions of NOx, a precursor to the formation of ozone in the lower atmosphere, will also be reduced by the proposed regulation. In California, most major urban areas and many rural areas are non-attainment for the State and federal 8-hour ambient air quality standard for ozone. Controlling emissions of ozone precursors would reduce the prevalence of the types of respiratory problems associated with ozone exposure and would reduce hospital admissions and emergency visits for respiratory problems. Ozone can also have adverse health impacts at concentrations that do not exceed the 8-hour NAAQS. Reducing NOx emissions will also reduce secondarily formed PM (nitrates).

Table II-2: State and National Ozone Standards

	California Standard	National Standard
1 hour	0.09 ppm (180 $\mu g/m^3$)	
8 hour	0.070 ppm (137 $\mu g/m^3$)	0.075 ppm (147 $\mu g/m^3$)

Improved Visibility

In addition to the public health effects of fine particulate pollution, inhalable particulates including sulfates, nitrates, organics, soot, and soil dust contribute to regional haze that impairs visibility.

In 1999, the U.S. EPA promulgated a regional haze regulation that calls for states to establish goals and emission reduction strategies for improving visibility in 156 mandatory Class I national parks and wilderness. California has 29 of these national parks and wilderness areas, including Yosemite, Redwood, and Joshua Tree National Parks. Reducing diesel PM from stationary diesel-fueled engines will help improve visibility in these Class I areas.

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III. INDUSTRY CHARACTERIZATION

Ocean-going vessels (or "vessels") that operate within the 24 nautical miles zone of the California coastline ("regulated waters") would be subject to the requirements of the proposed regulation. The requirements of the proposal would apply to both foreign-flagged and domestic vessels. However, exemptions are provided for military vessels and vessels passing through regulated waters without stopping at a California port ("innocent passage").

For the purposes of the proposed regulation, an ocean-going vessel is defined as a commercial, governmental, or military vessel that meets any one of the following criteria:

- a vessel greater than 400 feet in overall length;
- a vessel greater than or equal to 10,000 gross tons; or
- a vessel propelled by a marine compression ignition engine with a per cylinder displacement of greater than or equal to 30 liters.

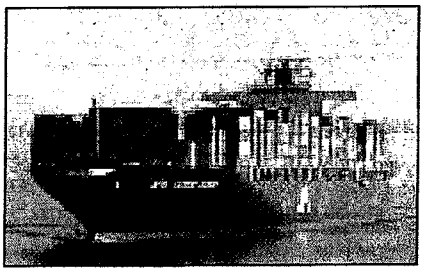
In this chapter, we provide examples of the types of ocean-going vessels, and also describe the engines and fuels currently being used by these vessels. Additional information on this industry can also be found in the U.S. EPA's Final Regulatory Support Document: Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder. (EPA, 2003).

A. Vessel Descriptions

Examples of the types of ocean-going vessels subject to the proposed regulation include container vessels, passenger cruise vessels, general cargo, reefers, RO-RO vessels, tanker vessels, and bulk carriers. Brief descriptions of these vessel types are provided below.

Container Vessels

Container vessels are cargo vessels that carry standardized truck-sized containers. These containers have capacities measured in TEUs (Twenty-foot Equivalent Units). One TEU refers to a container with external dimensions of 8'x8'x20'. Capacity is sometimes also measured by FEU's, forty-foot equivalents, 8'x8'x40', since the majority of containers used today are 40 feet in length. Many vessels also have a number of container slots that will accept refrigerated containers.

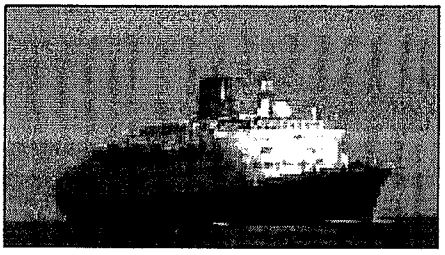


Container vessel capacity is often described in terms of the number of TEU's the vessel can hold. Due to economies of scale, container vessel capacity has increased over the

years. Currently, some large vessels are able to transport between 5,000 and 8,000 TEUs. This compares to older vessels built prior to 1970, which typically held less than 1,000 TEUs.

Most container vessels, like most ocean-going vessels, are propelled by large slow-speed two-stroke direct drive diesel engines. In addition, most container vessels have several smaller medium speed four-stroke auxiliary engines. The auxiliary engines, which are subject to the proposed regulation, provide electrical power for lighting, navigation equipment, and other ship-board uses.

Passenger Cruise Vessels



Passenger cruise vessels are passenger vessels used for pleasure voyages. These vessels typically stop at ports, where they coordinate activities for their passengers. Passenger cruise vessels also provide a number of entertainment options for their passengers while on the vessel. These vessels typically include swimming pools, exercise and recreation facilities, movie theaters, dance halls, casinos, and restaurants. As with other types of vessels, the size and capacity of these vessels has increased steadily over the years.

Table III-1: Typical Size of Passenger Cruise Vessels Over the Years

Year Built	Tonnage	Number of Passengers
1970	18,420	377 passengers
1980	37,600	707 passengers
1990	74,140	975 passengers
2000	137,300	1557 passengers

(Solentwaters, 2005)

Cruise ship propulsion is typically provided by several diesel engines coupled to generators. These generators produce electrical power that drives electric motors coupled to the vessel's propellers. This arrangement provides the option to run the vessel at a slower speed, while operating fewer engines at their peak efficiency, as opposed to a single engine at low, relatively inefficient loads. The same engines that are used for propulsion are also used to generate auxiliary power onboard the vessel for lights, refrigeration, etc.

Some vessels have the electric motor outside the ships hull in an azipod. This method eliminates the need for a rudder as the pod can be rotated to provide thrust in any direction. Some vessels also have a combination of a fixed propeller and azipods.

Reefer Vessels

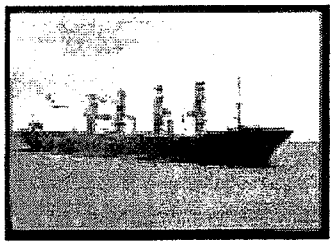
A Reefer vessel is a type of vessel typically used to transport perishable commodities which require temperature-controlled transportation, mostly fruits, meat, fish, vegetables, dairy products, and other foods. Reefer vessels are effectively large refrigerators, heavily insulated with glass fiber or similarly efficient insulation. They are vessels that tend to be divided into many more spaces than conventional dry cargo vessel, so that different commodities can be separated and carried, if required, at different temperatures. Below deck, a reefer vessel resembles a large modern warehouse, and cargo is usually carried and handled in palletized form, moved about on conveyors or by electric fork lift trucks.

RO-RO Vessels

A RO-RO vessel carries wheeled cargo such as automobiles, trailers or railway carriages. RO-RO is an acronym for "roll on/roll off". RO-RO vessels have built-in ramps, which allow the cargo to be "rolled on" and "rolled off" the vessel when in port. While smaller ferries that operate across rivers and other short distances often have these facilities, the term RO-RO is generally reserved for ocean-going vessels.

Typically new automobiles that are transported by vessel around the world are moved on RO-ROs. These large new-car carriers are commonly called Pure Car Carriers (PCCs) or Pure Car Truck Carriers (PCTCs). The largest PCC currently in service can carry over 7000 cars.

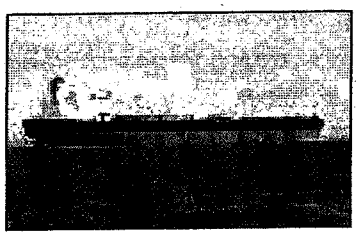
Bulk Carriers



Bulk carriers are vessels used to transport bulk items such as mineral ore, fertilizer, wood chips, or grain. They have large box-like hatches on their deck, designed to slide outboard for loading.

The bulk carriers primarily carry dry cargoes, which are shipped in large quantities and do not need to be carried in packaged form. The principal bulk cargoes are coal, iron ore, bauxite, phosphate, nitrate and grains such as wheat. The advantage of carrying such cargoes in bulk is that packaging costs can be greatly reduced and loading and unloading operations can be speeded up.

Tanker Vessel



Tanker vessels are vessels designed to transport liquids in bulk. Tankers can range in size from several hundred tons, designed for coastal service, to several hundred thousand tons, for transoceanic voyages. A wide range of products are carried by tankers, including:

- hydrocarbon products such as crude oil, LPG, and LNG
- chemicals, such as ammonia, chlorine, and styrene monomer; or
- fresh water

Different products require different handling and transport, thus special types of tankers have been built, such as "chemical tankers," "oil tankers," and "LNG carriers."

B. Vessels That Visit California Ports

California is a key player in international shipping. All of the vessel types described previously visit California ports delivering and receiving products used in California, the United States, and the rest of the world. As shown in Table III-2 below, container vessels accounted for nearly half of the California port visits in 2006, followed by tankers at 22 percent of port visits. The remaining six categories of vessels each account for less than ten percent of vessel visits.

Table III-2: 2006 California Port Calls by Vessel Type

Vessel Type	Number of Calls	Percentage of Total Calls
Auto Carriers	1,006	9%
Bulk Carriers	983	9%
Container	5,038	46%
Passenger Cruise Vessels	770	7%
General Cargo	371	3%
Reefer	315	3%
Ro-Ro	112	1%
Tanker	2,391	22%
Total	10,986	100%

(CSLC, 2006)

Table III-3 ranks California's ports by the number of vessel visits. As shown in the table, 50 percent of port calls occurred at the combined Ports of Los Angeles and Long Beach (which are adjacent to each other). The Port of Oakland accounted for about 18 percent of the port calls, and the remaining ports individually received 7 percent or less of the vessel calls.

Table III-3: 2006 Port Ranking by Vessel Visits

Port	Number of Calls	Percentage of Total Calls
Los Angeles/Long Beach	5,494	50%
Oakland	1,955	18%
Richmond	598	5%
Carquinez	794	7%
San Diego	550	5%
Hueneme	417	4%
San Francisco	306	3%
El Segundo	268	2%
Stockton	189	2%
All Other	415	4%
Total	10,986	100%

(CSLC, 2006)

C. Ocean-Going Vessel Engines and Fuels

The following sections describe the types of engines currently being used by ocean-going vessels. The information presented below was reported by vessel owners and operators in response to ARB's *Ocean-Going Ship Survey* or "Survey." The Survey requested information only for ocean-going vessels that visited California ports in 2006. The respondents provided Information on 761 vessels, their main engines, and approximately 2,500 auxiliary engines. For more detailed Ocean-Going Ship Survey data or information, see Appendix C. In addition, most vessels have auxiliary boilers used to produce steam. Information on boilers is provided later in this chapter.

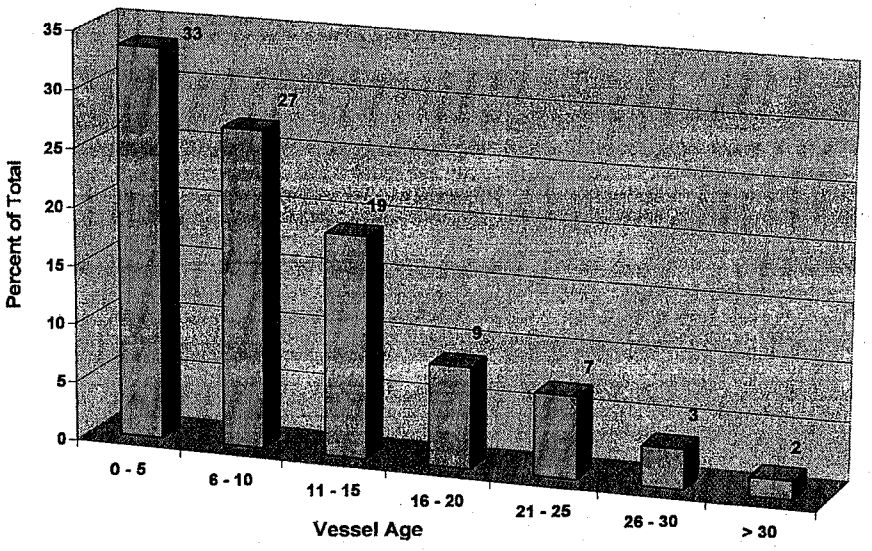
Ocean-going vessels subject to the proposed regulation have both main propulsion (main engines) and auxiliary diesel engines. The main engine for most vessels is a diesel-mechanical propulsion system, where the diesel engine is directly coupled to the propeller through a transmission. The exception is passenger cruise vessels and a few tankers, where the main engines are coupled to electric generators which provide electric power to electric motors which are directly coupled to the propellers. These are referred to as diesel-electric systems.

In most cases, the auxiliary engines provide power for uses other than propulsion. Most auxiliary engines are part of a diesel-electric system that is used to provide power for a variety of on-board systems including lighting systems, onboard cargo handling equipment, heating and air conditioning systems, and emergency power. Many passenger cruise vessels that have diesel-electric propulsion systems use the main engines to power electric motors that perform the same functions as auxiliary engines. Because of the relatively high electrical energy draw aboard a passenger cruise vessel, some also have gas turbine-electric systems aboard. Below we provide summaries of selected data collected from the Survey.

Vessel Age

The age of the vessels reported in the 2006 Survey ranged from 38 years old to new, with an average vessel age of about nine years. Approximately 80 percent of the vessels were less than 15 years old. The distribution of vessel age is shown in Figure III-1.

Figure III-1: Age Distribution of Vessels



Auxiliary Engines

Table III-4 summarizes the number of auxiliary engines reported in the Survey. As is shown, all vessels had at least one auxiliary engine. On average, vessels were reported to have 2-3 auxiliary engines.

Table III-4: Number of Auxiliary Engines

Vessel Type	Minimum	Maximum	Average	Engines
Auto Carrier/Ro-Ro	1	4	2	243
Bulk Carrier/General Cargo	1	4	2	405
Container Ship	1	6	2	1,052
Motor Ship/Container	1	5	3	24
Passenger	1	6	3	167
Product Carrier	1	3	2	3
Reefer	1	4	2	24
Tanker	1	6	2	582

Of the auxiliary engines reported in the Survey, 99 percent are four-stroke diesel-fueled engines. A four-stroke engine completes one power cycle for every two revolutions of the crankshaft. Therefore, there is one power stroke for every two revolutions of the crankshaft. The four-strokes include: intake, compression, power, and exhaust. Table III-5 presents the number and percent of the auxiliary engine diesel type reported.

Table III-5: Auxiliary Engine Type

Auxiliary Engine Diesel Type	Number of Engines Reporting in Survey	Percent of Total Engines
2 Stroke	28	1%
4 Stroke	2,381	99%

An earlier survey conducted by the ARB found that about 75 percent of auxiliary engines operated on heavy fuel oil, and 25 percent distillate (ARB, 2005). The 2006 Survey requested information on the fuel sulfur levels of the distillate fuels used to comply with the ARB's Auxiliary Engine regulation. Table III-6 provides the minimum, maximum, and average sulfur content of the distillate fuel type used to power the auxiliary engines when operating out to 24 nm from California shoreline.

Table III-6: Average Sulfur Content of Fuel Used in Auxiliary Engines

Fuel	Minimum Sulfur Content (%)	Maximum Sulfur Content (%)	Average Sulfur Content (%)
MDO	0.01	2.00	0.52
MGO	0.002	1.50	0.42

The manufacturers of the auxiliary engines were numerous, but six manufacturers accounted for almost 92 percent of the engines reported. These manufacturers are shown below in Table III-7.

Table III-7: Auxiliary Engine Manufacturers

Engine Maker	Number of Engines	Percent of Total Engines
MAN B&W	806	32
Daihatsu	691	28
Yanmar	375	15
Wartsila	309	12
Sulzer	71	3
MAK	56	2
Other	192	8

Figure III-2 shows the distribution in age of the auxiliary engines. It is interesting to note that a large percentage of the auxiliary engines are less than 10 years old. Typically, the auxiliary engines last the life of the vessel, so the age distribution of these engines is similar to the age distribution of vessels visiting California ports.

Figure III-2: Auxiliary Engine Age Distribution

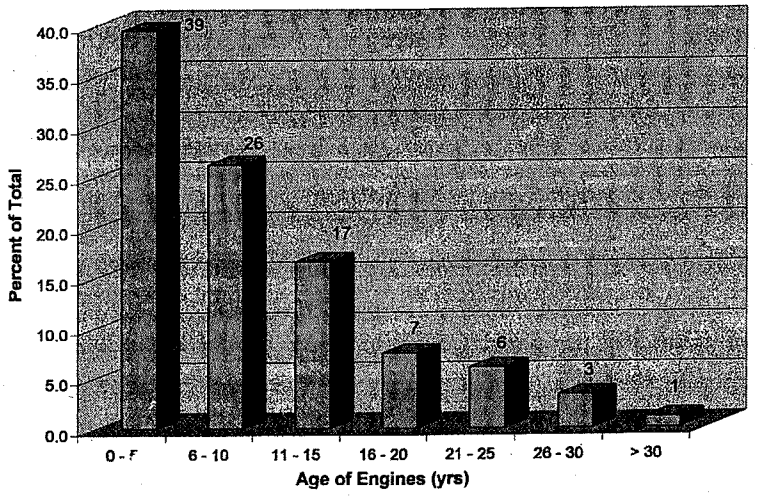


Table III-8 provides information on the average power generated by the auxiliary engines when vessels are hotelling (dockside), maneuvering at ports, and transiting at sea. The diesel generator set engines on passenger cruise vessels are defined as "auxiliary engines" for the purposes of the proposed regulation. The power generated by these engines is much higher than for other vessels because these engines produce electrical power for both propulsion and ship-board electricity.

Table III-8: Average Power Generated

Type of Vessel	Power Generated While Hotelling (kw)	Power Generated While Maneuvering (kw)	Power Generated While At Sea (kw)
Auto Carrier/Ro-Ro	600	1,000	600
Bulk Carrier/General	400	600	500
Container	1,100	2,300	1,400
Motor Ship/Container	1,200	3,200	1,400
Passenger	6,700	14,400	28,000
Product Carrier	500	1,000	800
Reefer	1,100	1,100	1,000
Tanker	600	1,400	1,700
Average of all Vessels	1,525	3,125	4,425

Main Engines

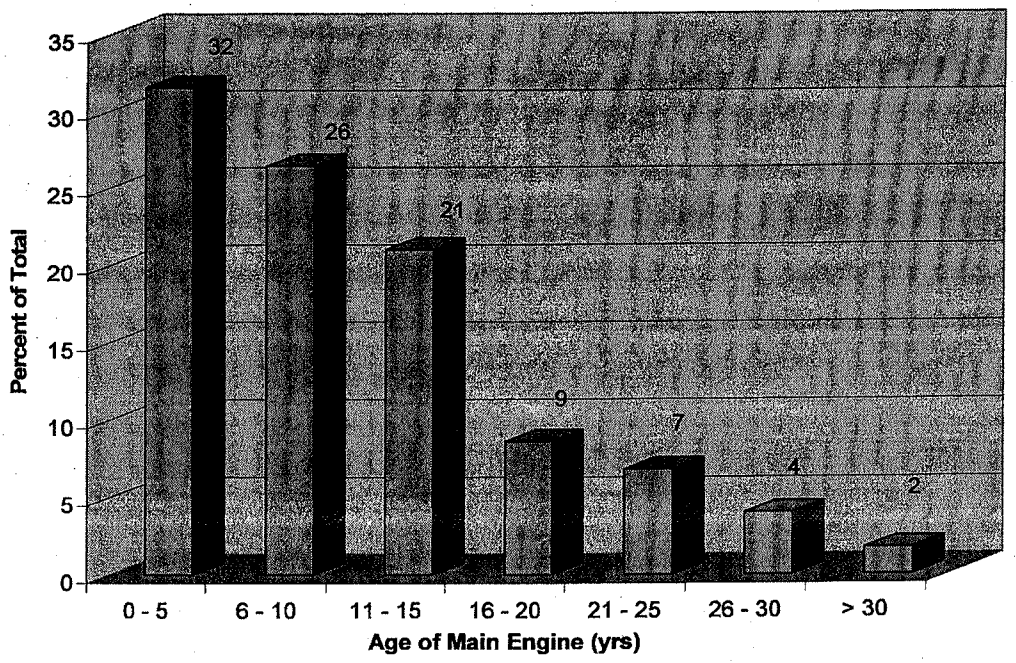
The 2006 Survey reported several different engine manufacturers; however three companies, Man B&W, Sulzer, and Mitsubishi were shown to make the majority of the engines. The Man B&W and Sulzer engines that are clearly identified are shown below. Most of the other engines are likely Man B&W or Sulzer designs produced by the shipyards under licensing agreements. Table III-9 provides the major manufacturers reported.

Table III-9: Main Engine Manufacturers

Engine Maker	Number of Engine Makes	Percent of Total Engines
Man B&W	479	66
Sulzer	117	16
Mitsubishi	88	12
Sulzer/Wartsila	14	2
General Electric	12	2
Other	13	2

Figure III-3 shows the age distribution of main engines, which reveals about 80 percent of the main engines are less than 15 years old, with 32 percent less than 5 years old, and the average age of a main engine is 12 years.

Figure III-3: Main Engine Age Distribution



According to the Survey, as reported in Table III-10, main engines are dominated by diesel engines, with only a small fraction being either gas or steam turbine. The diesel piston engines used on vessels are reciprocating internal combustion engines that operate on the same basic principles as land-based diesel engines. The main engine type results are shown below.

Table III-10: Main Engine Types

Engine Type	Number of Engines	Percent of Total Main Engines
Diesel Compression-Ignition	704	98
Steam Turbine	8	1
Gas Turbine	6	1

Additional information was gathered regarding whether the diesel engines were either two or four-stroke. As shown in Table III-11 below, 96 percent of the main engines on ocean-going vessels were reported to be two-stroke engines. Reciprocating internal combustion engines may operate in a two or four-stroke cycle, where a stroke is one complete movement of the piston from one end of the cylinder to the other. Two stoke engines have higher horsepower to weight ratio than four-stroke engines, but two-stroke engines tend to have higher NOx emissions. According to the survey, main engines use primarily heavy fuel oil.

Table III-11: Diesel Main Engine Types

Diesel Engine Type	Number of Engines	Percent of Total Diesel Engines
2-stroke	670	96
4-stroke	26	4

D. Auxiliary Boilers

Most ocean-going vessels have boilers. A boiler is a closed vessel in which water is heated under pressure to produce steam. In marine boilers, the steam is used for a variety of purposes such as: (1) heating residual fuel; (2) production of hot water and space heating for passengers or crew; (3) distillation of seawater to generate fresh water; (4) driving steam turbine pumps to offload crude oil or other petroleum products carried by tankers; and (5) driving steam turbines for ship propulsion on steamships. Marine boilers vary in size from the small "auxiliary boilers" used on most cargo vessels primarily to heat residual fuel, to the largest boilers used to propel steamships. This discussion focuses on auxiliary boilers, rather than the main boilers used to propel some steamships. Because there are very few steamships still in service, they are proposed to be exempt from the proposed regulation.

Auxiliary marine boilers may be categorized broadly based on function as follows: (1) relatively small auxiliary boilers used on most ocean-going vessels primarily to heat residual fuel; and (2) larger auxiliary boilers used on tankers to drive steam turbine pumps for crude oil.

Boiler output is typically rated in terms of steam capacity (weight of steam produced per hour at a given pressure). Cargo ship auxiliary boilers are typically rated in the 1-10 tonnes steam per hour range, while tankers, using boilers to power steam turbine discharge pumps, will typically be rated above 10 tonnes per hour. Boilers may also be rated by their thermal output (in terms of megawatts, horsepower, or Btu/hour). Table III-12 lists some models offered by major manufacturers and their output.

Table III-12: Typical Marine Boilers

Manufacturer	Model	Steam Capacity (tonne/hr)	Thermal Output (MW)	Typical Marine Application
Kangrim	MA Series	1-7 @ 6 bar	Not listed	cargo ship
Aalborg	UNEX-CHB	0.75-15 @ 10-18 bar	Up to 10	cargo ship
Aalborg	AQ-10/12W	0.6-6.3 @ 10 bar	Up to 4.4	cargo ship
Aalborg	Mission OS	1.6-6.5 @ 10 bar	Up to 4.6	cargo ship
Aalborg	Mission OM	8-20 @ 11 bar	5.6-14	tanker
Kangrim	MB Series	8-40 @ 16 bar	6-29	tanker
Aalborg	Mission OL	12.5-55 @ 18 bar	8.8-38.8	tanker

* Information from www.aalborg-industries.com and www.kangrim.com

Boiler Design: Marine boilers are similar to land-based industrial boilers except that they are generally smaller, less complex, and generally do not include heat recovery equipment. Marine boilers are manufactured in a variety of different configurations. Some are designed to burn fuel while others use main engine exhaust heat. In addition, there are differences in burner designs, and the physical heat exchange ("convection") surfaces. Control systems are also incorporated into the design, which handles the operation of pumps, fans, burners, and other equipment.

Marine boilers can be oil-fired, exhaust gas-fired, or combination ("composite") boilers. Oil-fired boilers have a burner which combusts fuel to supply heat for steam production. These boilers generally burn residual fuel (heavy fuel oil), although they can also use marine distillate fuels, and in some cases, waste oil or sludge. Exhaust gas-fired boilers (also called economizers) use heat from the exhaust of the main engine. Composite boilers can use either the main engine exhaust or fuel, depending on the operation of the vessel.

For most cargo ships, the main engine is turned off at dockside, and an auxiliary boiler(s) must continue to operate to keep the ship's heavy fuel oil warm. Therefore, an economizer alone is not sufficient, and most ships must have either separate oil-fired boilers and exhaust gas-fired boilers, or a combination boiler.

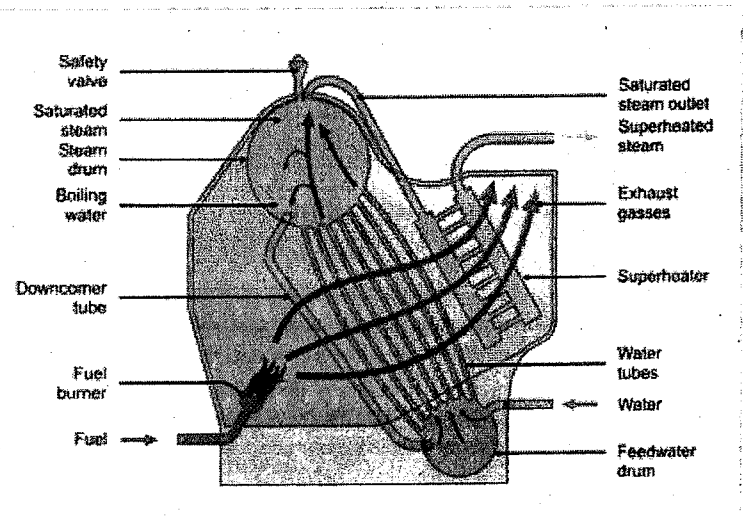
Burners are designed to atomize the fuel, mix it with air, and shape the flame for optimum efficiency as combustion gases flow through the furnace. In many cases, different burner options are available with the installation of a new boiler, and they may

be upgraded or replaced while leaving the rest of the boiler in place. Since most oil-fired boilers use heavy fuel oil, this fuel must be heated, and then atomized through high pressure or with the aid of steam. There are different burner designs including pressure jet burners, rotary cup burners, and steam atomizing burners. Pressure jet burners atomize fuel by passing it through burner nozzles at high pressure. Rotary cup burners use centrifugal force. Specifically, fuel oil is delivered into a spinning cup where centrifugal force moves the fuel forward until it is thrown off the cup rim as a fine, uniform film that is subsequently atomized by high velocity air discharged around the cup (Aalborg, 2008). Steam atomizing burners inject steam together with the fuel to help disperse the fuel. The steam can by injected together with the fuel at the nozzle tip, or the steam and fuel can be mixed inside the nozzle prior to injection.

Many marine boilers can be broadly classified as either fire tube (smoke tube), or water tube boilers. Fire tube boilers circulate hot combustion gases through tubes which are surrounded by water. Water tube boilers circulate water within tubes which are heated externally by exhaust gases. To improve the efficiency of heat transfer within a compact space, manufacturers seek to increase the total convective surface area on the gas side of the tubes. One such approach utilizes a "pin-tube" structure where water is contained within tubes that have numerous smaller "pins" projecting out radially from the tubes. One manufacturer claims that the addition of the pins expands the tube surface area such that the length of the tube can be reduced by a factor of eight compared to plain tubes (Aalborg, 2002). Other designs use "gilled" tubes with flat plates attached to the tubes (Aalborg, 2007a). Some modern boilers also use hybrid designs that are essentially water tubes within fire tubes (Aalborg, 2007b).

A diagram of a marine-type water tube boiler is shown in Figure III-4.

Figure III-4: Water Tube Boiler



As described below, the operation of marine auxiliary boilers varies with the type of vessel.

Cargo Ships
On most cargo vessels, the small auxiliary boilers are generally used to heat residual fuel, lubricating oil, main engine coolant, and water for use by crew (APL, 2007a; Matson, 2007). These boilers are generally only used when the main engine is not up to full operating temperature. This is when a vessel is at dockside, maneuvering, at anchorage, or approaching or leaving port (APL, 2007b; Matson, 2007). This is because the exhaust from the main engine generally provides enough waste heat when the main engine is at full operating temperature for the economizer to provide steam for heating residual fuel and other uses. The transition from the use of the economizer at sea to the auxiliary boiler when arriving (and the reverse on departure) will depend on the specific ship, port geography and vessel speed restrictions. Nevertheless, ship operators and other sources have reported relatively similar estimates for auxiliary boiler operation which include: (1) about an hour prior to picking up the pilot, and an hour after dropping of the pilot (APL, 2007b; MARAD, 2007); or (2) about an hour prior to maneuvering on arrival at port, and about an hour after maneuvering on departure (Matson, 2007).

Cruise Ships
Cruise ships use their auxiliary boilers for domestic hot water and space heating (for passengers and crew), and also to heat heavy fuel oil, heat pool water, and in the galley for dishwashers and soup kettles (Crystal Cruises, 2007). In addition, some cruise ships use their auxiliary boilers to generate freshwater by distilling seawater. Cruise ships use their boilers when the main engines are not up to full operating temperature, and, unlike cargo ships, may also use them when the vessel is transiting at sea (Crystal Cruises, 2007). Cruise ship boilers generally use more fuel than cargo ships because they need to more hot water and space heating for passenger cabins, in addition to keeping residual fuel warm.

Tankers
The operation of boilers on tankers varies widely with the type and function of the boilers on the individual vessel. Most tankers have much larger boilers than other ships because they drive high power steam driven centrifugal pumps used to discharge liquid cargo at dock. Therefore, during discharging of cargo, the boiler fuel consumption and emissions will be much greater than for other vessels. These tankers also use their boilers to heat residual fuel, certain viscous cargos (such as heavy petroleum crude and asphaltic roofing flux), and for hot water and space heating for crew. When not used for discharge pumps, the boiler fuel consumption and emissions may be similar to cargo ships, and at sea the economizer often provides sufficient steam. Tankers with large boilers for discharge pumping often also have a smaller boiler that provides steam for uses such as hot water for the ship's crew.

Not all tankers use steam driven pumps to discharge cargo. Some vessels use diesel auxiliary or main piston engines, or electric motors to drive the discharge pumps. For these ships, the boiler size and operation will be similar to other cargo ships.

There are numerous manufacturers of marine boilers. Table III-13 lists some of the major manufacturers.

Table III-13: Boiler Manufacturers

Aalborg Industries	Mitsubishi Heavy Industries
Hitachi Zosen Corporation	Mitsui Engineering and Shipbuilding
Ishikawajima-Harima Heavy Ind.*	Osaka Boiler Mfg. Company
Kawasaki Heavy Industries	Tortoise Engineering

* IHI no longer manufactures boilers, but some ships still use them

Aalborg Industries, with headquarters in Denmark, is the leading manufacturer of marine boilers (Aalborg, 2007b) and some of the other manufacturers make Aalborg designs under license. There are also many smaller manufacturers based near shipyards.

E. Vessel Fuels and Fuel Systems

As explained in Section C, most ocean-going vessels are propelled by a single large slow-speed two-stroke direct drive diesel engine, with smaller medium speed four-stroke auxiliary engines providing electrical power for lighting, navigation equipment, and other ship-board uses. For these vessels, the large main engine almost always operates on heavy fuel oil (HFO), while the smaller auxiliary engines generally run on HFO but some operate on marine distillate fuels such as marine gas oil or marine diesel oil. Vessels that use HFO in both their main and auxiliary engines are referred to as mono-fueled (or uni-fueled) vessels, while vessels that use distillate fuels in their auxiliary engines and HFO in their main engine are referred to as dual-fueled vessels.

Diesel-electric vessels such as passenger cruise vessels use very large four-stroke medium speed engines coupled to generators to provide electrical power for both propulsion and ship-board electrical power. These vessels generally use HFO, although some have reported using marine distillate fuels close to shore to reduce their emissions.

Fuel Types

The two basic types of marine fuels are distillate and residual. Distillate fuel is composed of the lighter fractions of crude oil that are separated in a refinery by a boiling process, while the remaining fraction that did not boil is referred to as residual.

Distillate Marine Fuels

The two most common types of marine distillate fuels are marine gas oil (MGO) and marine diesel oil (MDO). MGO is also referred to as DMA using official fuel specification terminology, where the "D" denotes a distillate fuel, the "M" indicates a marine fuel, and the "A" is the grade of fuel. MDO is similar to MGO, but may have a somewhat higher viscosity and sulfur content. This fuel is also referred to as DMB using official terminology, with the same nomenclature as for DMA fuel. MDO is generally MGO that contains a limited amount of residual fuel from storage in tanks or piping that previously held residual fuel. Other types of distillate marine fuels include DMX and DMC fuels. DMX fuel is special grade of fuel generally used only in emergency backup generators, while DMC is a distillate fuel like DMB, except that it is intentionally manufactured from heavier boiling fractions from a distillation process, or is blended from DMA and residual fuels. (EPA, 1999).

Residual Fuels

Marine residual fuel (also called "heavy fuel oil") is generally a mixture of residual and distillate fuels referred to as intermediate fuel oil (IFO). While there are numerous grades of marine residual fuels, the most common types are IFO-180 and IFO-380. Using this informal terminology, the numbers used in naming these fuels refers to the viscosity limits at the common fuel handling temperature of 50°C. Similar to the distillate fuels, there is also a parallel official terminology. For example, IFO-380 fuel is referred to as either RMG-35 or RMH-35. Using this terminology the "R" denotes a residual fuel, the "M" denotes a marine fuel, and the "35" is the maximum viscosity at 100°C. (EPA, 1999)

Listed below in Table III-14 are the common marine fuels discussed above, and the range in their allowable properties.

Table III-14: Selected ASTM Specifications for Marine Fuels

	Distillate Fuels		HFO/Residual Fuels	
Specification	**MGO (DMA)**	**MDO (DMB)**	**IFO 180 (RME/F-25)**	**IFO 380 RMG/H-35**
Min. Flash Pt. (°C)	60	60	60	60
Kinematic Viscosity (cSt@40°C)	1.5-6	11 max	25 *	35*
Max % Sulfur (wt.)	1.5	2.0	5.0**	5.0**
Max. % Ash (wt.)	0.01	0.01	0.10-0.15	0.15-0.2
% Distillate	100	99+	12	2

* Viscosity in centistokes at 100°C, ** IMO Annex VI limits sulfur to 4.5%.

On-Board Fuel Handling

Ocean-going vessels have complex fuel handling and processing systems that vary with the individual vessel. Most have multiple fuel storage tanks that can hold various grades of fuel, both distillate and HFO. Marine fuels undergo several processes before they are combusted in the engine. Typically, fuel from the storage tank is: (1) pumped to a settling tank; (2) pumped to a centrifuge for removal of water and sludge; (3) pumped to service (day) tank; and (4) pumped to the engine for consumption. Depending on the vessel, there are different ways these processes are handled, some with complete segregation of fuel processes for different grades of fuel, and some utilizing the same fuel processing components for different grades of fuel (Marintek, 2003). In addition, the complete fuel handling system will include additional filtration, venting, drainage, and other components.

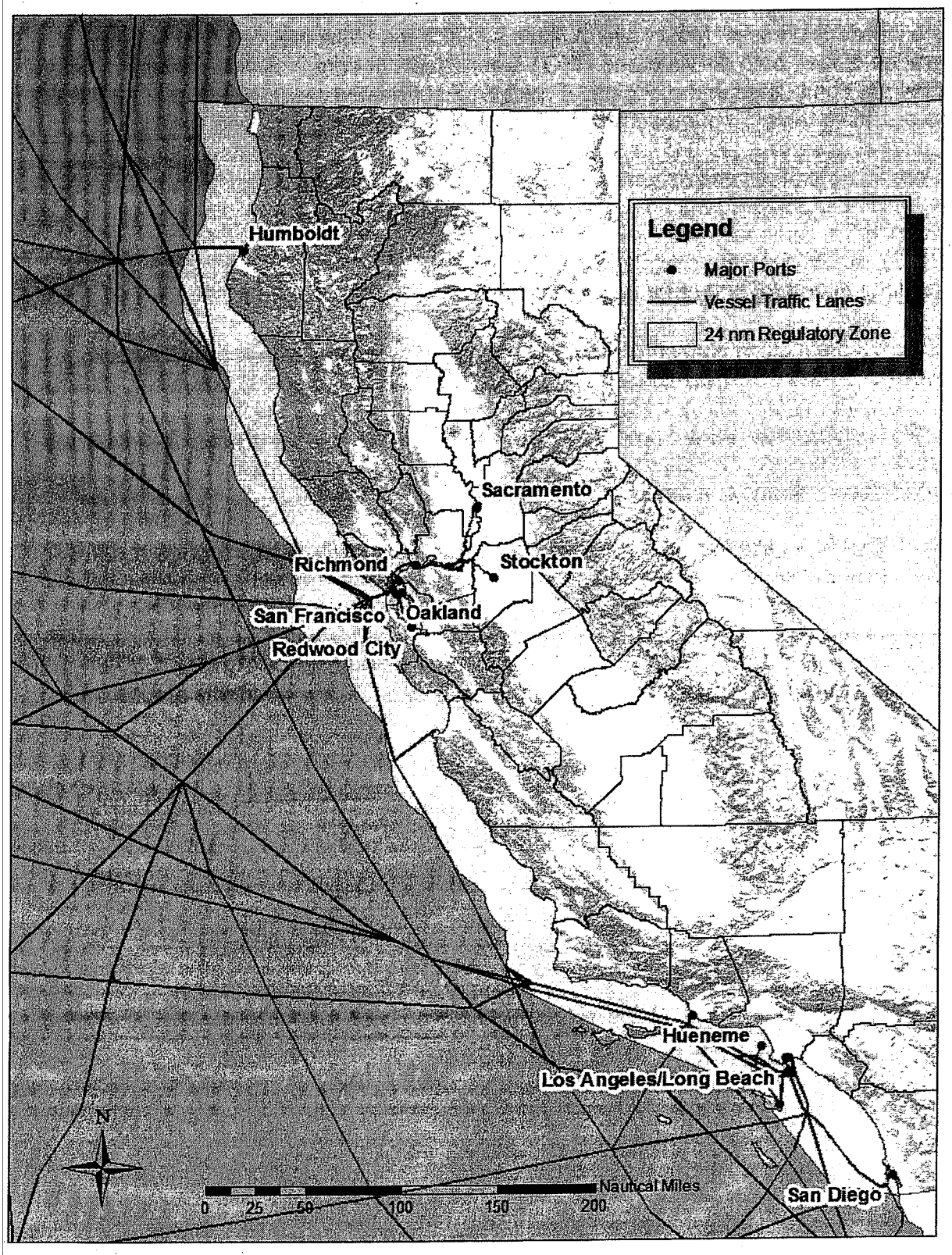
The fuel processing steps mentioned above apply to both HFO and distillate fuels. However, heavy fuel oil must also be heated to 100 to 200 degrees Celsius to reduce its viscosity to a point where it can be pumped and combusted in the engine. Because HFO is so viscous, vessel operators switch to distillate marine fuels prior to vessel dry-dock maintenance operations so that this fuel does not solidify in pipes and components when the engine is stopped.

F. The Shipping Lanes and Ocean-Going Vessel Activity off the Coast of California

The coastline of California stretches more than 800 miles, from Mexico in the south to Oregon in the north. In 2006, California's ports were visited by more than 2,000 ocean-going vessels. These vessels made approximately 11,000 visits to one or more of California's deep-water ports.

Ships typically travel in designated shipping lanes (similar to airplane flight paths) in high traffic areas near California's ports. For example, there are designated shipping lanes that ocean-going vessels use within the Santa Barbara Channel and approximately 25 nautical miles south of the Ports of Los Angeles and Long Beach. (MXSoCal, 2005). Similarly, there are designated shipping lanes within the San Francisco Bay and surrounding areas north to approximately Point Reyes, west to the Farallon Islands, and south to Half Moon Bay. (MXSF, 2005). Outside of the port areas, vessels are generally free to choose their routes, although certain vessel-specific requirements may apply. For these low traffic areas, approximations must be made of the most likely routes. To approximate the routes used by ocean-going vessels off California's coastline, including both designated traffic lanes and other areas, ARB staff used a network of vessel traffic lanes which was a composite of lane information from the United States Army Corps of Engineers (USACE) National Waterway Network, the Ship Traffic Energy and Environment Model (STEEM) developed by Dr. James Corbett, and data from ship automated instrumentation system (AIS) data. The vessel traffic lanes, major California ports, and the 24 nm regulatory zone are shown in Figure III-5.

Figure III-5: Vessel Shipping Lanes and the 24 nm Contiguous Zone



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IV. EMISSIONS, POTENTIAL EXPOSURES, AND RISK

This chapter provides a summary of the emissions inventory for ocean-going vessels (OGVs). Emissions were estimated within two distinct zones; a 24 nm zone which was used for implementation of the 2005 auxiliary engine regulation and development of the Goods Movement Emission Reduction Plan, and a 100 nautical mile zone that is used for ARB's emissions inventory system and the State Implementation Plan. In this chapter, the emissions inventory for the 24 nm zone is presented. The reader is directed to Appendix D for information on the emissions estimates within the 100 nm zone as well as for additional details on the methodology and contributions of OGVs emissions attributed to the main engine, auxiliary boilers, and auxiliary engines. In addition, this chapter includes a discussion on the impacts of OGV emissions on California air quality and the potential cancer and noncancer health risks that may occur due to the operation of these engines.

A. Estimated Emissions from Ocean-Going Vessels

ARB staff has updated the emissions inventory for OGVs to reflect new information and improved methodologies. This inventory is a revision of the 2005 emissions inventory developed by staff in 2005 in support of a number of programs, including the Auxiliary Engine Regulation. The main changes from the 2005 inventory include:

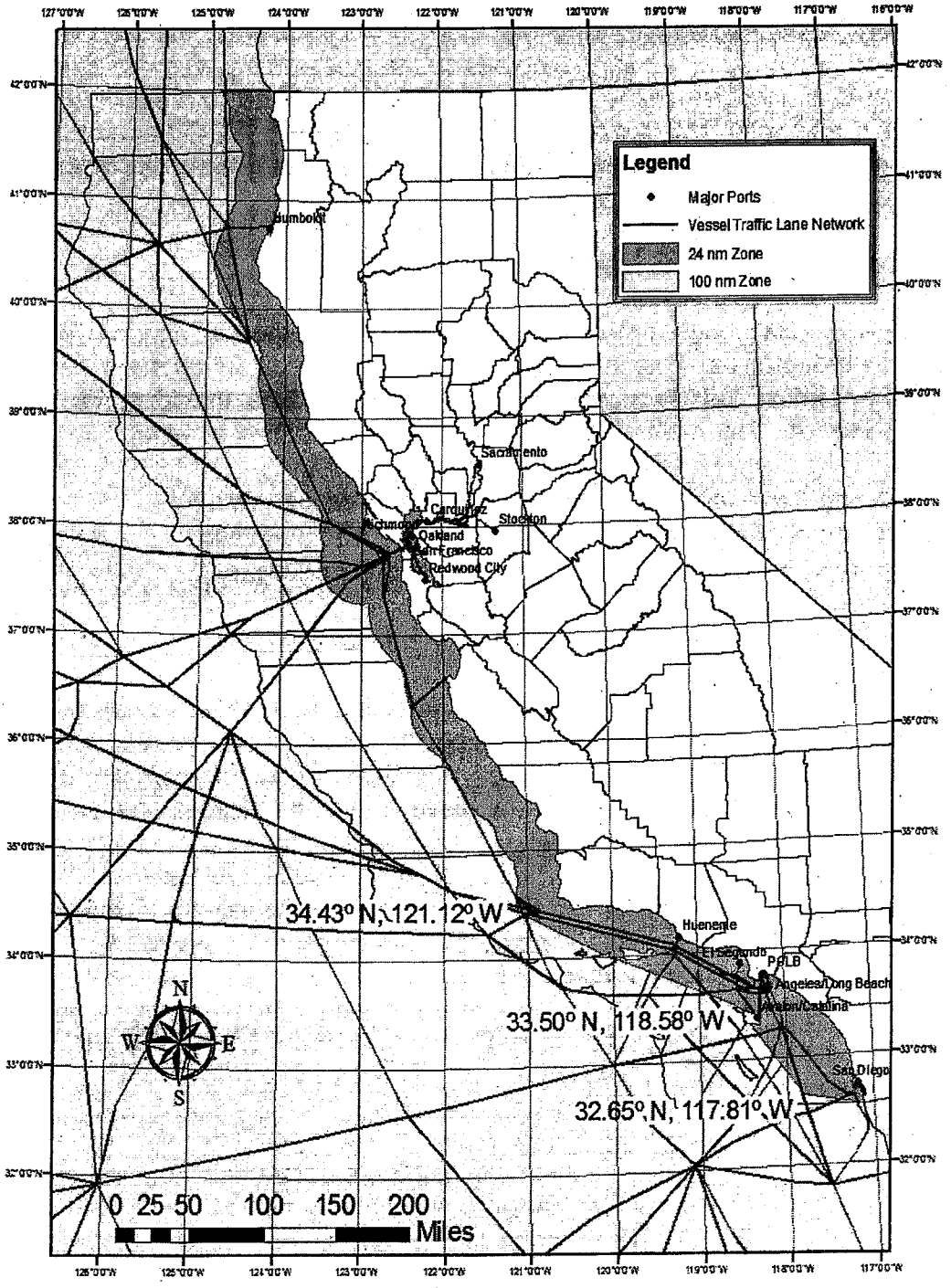
- Updating the inventory to reflect recent (2006) activity data
- Inclusion of more specific information on ship and port calls
- Alignment of the inventory to reflect recent port inventories
- Revision of growth assumptions and methods
- Assessment of the benefits of adopted regulations

The proposed inventory increases the specificity of the earlier inventory by including vessel specific characteristics and port call specific activity data, including port call specific hotelling times for individual vessel visits; vessel-specific power and speed ratings, and a more accurate shipping lane network. It is also based on more recent activity data: the earlier inventory used a 2004 base year; the new inventory uses a 2006 base year. The growth factors were updated with additional years of trend data, a port and vessel type specificity, and a more robust growth surrogate. Finally, existing control strategy emission reductions are built into the inventory model, rather than being applied from the forecasting database.

Emissions are calculated by estimating ship emissions on a ship by ship and a port call by port call basis, using actual ship engine power estimates, speeds, and actual ship hotelling times where possible. Base year emissions were forecasted using a set of growth factors specific to each port and each ship type. Emissions were estimated within two zones which differed by the distance from the California coastline wherein the emissions were counted. As shown in figure IV-1, emissions were estimated within 24 nm and 100 nm of the California coastline. On the figure, the outer black line, which mirrors the California coastline, represents the 100 nm emission inventory boundary

while the shaded gray area is the 24 nm zone emission inventory boundary. This area is also known as the "regulatory" boundary as it is within this region where the proposed regulation would be implemented.

Figure IV-1: Ocean-Going Vessel Emissions Inventory
24 nm and 100 nm Boundaries



The most recent year with activity data, 2006, was chosen as the base year. Base year emissions were forecasted by assessing trends in the growth of vessel net registered tonnage for the years 1994-2005. Net registered tonnage (NRT) is a measure of the volume of a ship's cargo capacity; the growth in NRT is directly proportional to the growth in installed power of a vessel's main propulsion engine. Controlled future year emissions for 2010 and 2020 were forecasted using the above methodology by including the benefits of adopted regulations including the 2007 Shore Power regulation. Details of the methodology are found in Appendix D. Based on the information available to date, we believe the methodology has resulted in a reasonable estimate of the emissions from OGVs.

Emission Estimates for Ocean-Going Vessels Operating in the 24 nm Zone

The emissions presented here include all OGV emissions within the 24 nautical mile regulatory zone. These include all emissions from the main engine, auxiliary boilers, and auxiliary engines used during transiting, maneuvering, at anchorage, or at berth. The updated emissions inventory and estimated future emissions inventories are presented for the years 2006, 2010, and 2020. The effects of adopted regulations and voluntary measures are also reflected in these estimates.[1]

Estimates of statewide 2006 PM_{10}, NOx, SOx, carbon monoxide, and reactive organic gases (ROG) from OGV within the 24nm zone are presented in Table IV-1. ARB staff estimates that the statewide PM_{10} emissions for OGVs operating within the 24 nm zone are approximately 15 tons per day or approximately 5,330 tons per year in 2006. As shown in Table IV-1, there are approximately 2,100 vessels that visited California's ports in 2006. Of these, about 30% were container vessels which represented more than 45% of the vessel port call visits to California's ports.

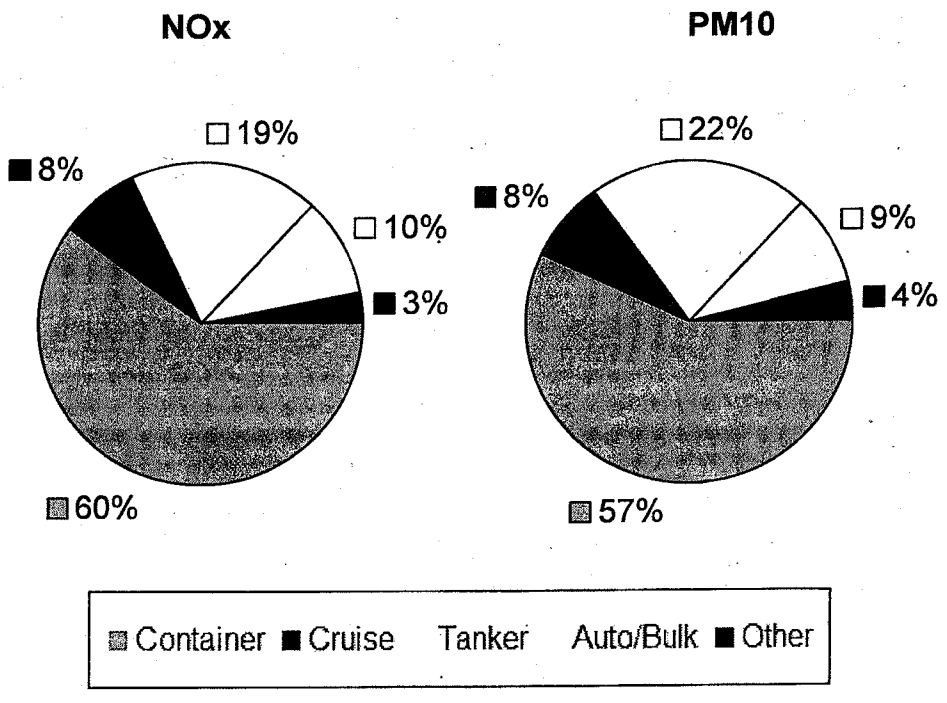
[1] The following regulations and measures are incorporated into the emission inventory projections: 1997 MARPOL Annex VI Emission Standards; 2004 Los Angeles/Long Beach Voluntary speed Reduction Zone; 2005 U.S. EPA Category 3 Engine Standards; 2007 Shore Power Regulation.

Table IV-1: Estimated Statewide 2006 Ocean-Going Vessel Emissions (24 nm)

Vessel Types	Numbers of Vessels	Numbers of Vessel Visits	2006 Pollutant Emissions, Tons/Day				
			NOx	ROG	CO	PM_{10}	SOx
Auto	234	1,006	7.2	0.3	0.6	0.6	4.6
Bulk	475	983	7.9	0.3	0.6	0.7	5.1
Container	593	5,038	94.2	3.7	7.7	8.4	60.1
Passenger	52	770	12.0	0.4	0.9	1.2	9.0
General	147	371	3.3	0.1	0.3	0.3	2.1
Reefer	68	315	2.2	0.1	0.2	0.2	1.7
Ro-Ro	28	112	0.7	<.1	0.1	0.1	0.5
Tanker	458	2,391	29.5	1.2	2.4	3.2	34.1
Totals	2,055	10,986	157	6	13	15	117

As shown in Figure IV-2, container vessels represent approximately 60% of all the PM_{10} and NOx emissions emitted by OGVs; followed by tankers, auto/bulk carriers, and cruise vessels.

Figure IV-2: 2006 PM_{10} and NOx Emission Distributions for Ocean-Going Vessels, 24 nm



The ARB staff also estimated district-specific emissions associated with OGVs. The allocation of these estimates is based on the length(s) of United States Army Corps of Engineers shipping lanes associated with a specific district. Table IV-2 presents a district-by-district estimate of emissions from OGVs operating in 24 nm zone.

Table IV-2: Estimated 2006 Ocean-Going Vessel Emissions by District (24 nm)

District	2006 Pollutant Emissions, Tons/Day				
	NOx	ROG	CO	PM_{10}	SOx
Bay Area AQMD	37.7	1.5	3.0	3.6	31.4
Mendocino County AQMD	6.8	0.3	0.5	0.6	4.2
Monterey Bay Unified APCD	20.1	0.8	1.6	1.7	12.3
North Coast Unified APCD	5.5	0.2	0.4	0.5	3.4
Northern Sonoma County APCD	3.9	0.1	0.3	0.3	2.4
San Diego County APCD	5.9	0.2	0.5	0.6	4.2
San Joaquin Valley Unified APCD	0.3	<.1	<.1	<.1	0.5
San Luis Obispo County APCD	2.8	0.1	0.2	0.2	1.7
Santa Barbara County APCD	22.0	0.9	1.7	1.9	13.4
South Coast AQMD	44.9	1.7	3.8	4.5	39.0
Ventura County APCD	7.3	0.3	0.6	0.6	4.8
Yolo/Solano AQMD	0.1	<.1	<.1	<.1	0.1
Total	157	6	13	15	117

Note: The following districts had no ocean-going auxiliary engine emissions allocated to them; Amador, Antelope Valley, Butte, Calaveras, Colusa, El Dorado, Feather River, Glenn, Great Basin Unified, Imperial, Kern, Lake, Lassen, Mariposa, Modoc, Mojave Desert, Northern Sierra, Placer, Sacramento, Shasta, Siskiyou, Tehama, and Tuolumne. Emissions attributed to Northern Sonoma air district are included in Bay Area pollutant totals. Total emissions in Table IV-2 may vary from values in Table IV-1 due to rounding.

The projected emission estimates within the 24 nm zone for the years 2010 and 2020 are presented in Table IV-3. Details of the growth assumptions used to determine growth rates are contained in Appendix D, Emissions Estimation Methodology for Ocean-Going Vessels.

Table IV-3: Ocean-Going Vessels Projected Year 2010 and 2020 Emission Estimates (24nm)

Vessel Types	2010 Emission, Tons per Day					2020 Emission, Tons per Day				
	NOx	ROG	CO	PM_{10}	SOx	NOx	ROG	CO	PM_{10}	SOx
Auto	7.6	0.3	0.6	0.7	4.9	9.3	0.4	0.7	0.8	6.0
Bulk	7.8	0.3	0.6	0.7	5.1	8.3	0.3	0.7	0.7	5.4
Container	114.9	4.5	9.5	10.2	73.5	175.7	7.0	14.6	15.8	114.3
Passenger	14.3	0.5	1.1	1.4	10.7	20.6	0.7	1.6	2.0	15.6
General	3.5	0.1	0.3	0.3	2.2	3.9	0.2	0.3	0.3	2.5
Reefer	2.5	0.1	0.2	0.2	1.8	3.4	0.1	0.3	0.3	2.5
Ro-Ro	0.8	<.1	0.1	0.1	0.5	0.9	<.1	0.1	0.1	0.6
Tanker	30.6	1.2	2.5	3.3	35.5	34.3	1.4	2.8	3.8	40.2
Totals	182	7	15	17	134	256	10	21	24	187

B. Transport of Offshore Ocean-Going Vessel Emissions and Impacts on California Air Quality

As discussed earlier in this staff report, OGV exhaust results in emissions of diesel PM, PM, NOx and SOx. In addition, NOx and SOx are transformed by atmospheric chemical and physical mechanisms resulting in the formation of secondary pollutants such as ozone and PM. During the development of the Auxiliary Engine Regulation, ARB staff provided extensive documentation to demonstrate that air pollution can be transported and that emissions from OGVs released offshore the California Coast can impact onshore air quality (ARB, 2005). Since that time, ARB staff has conducted additional analysis to further our understanding of the atmospheric impacts of these emissions, especially on regional air quality in California.

ARB staff conducted two studies in 2008 that evaluated the impacts of emissions from OGVs on California air quality. The first study - Air Quality Modeling Analysis of the Impacts of OGV Emissions on the South Coast Air Basin – used the CMAQ air quality photochemical model to estimate the impact of OGV emissions on secondary PM and ozone in the South Coast Air Basin (SCAB). The second study - Statewide CALPUFF Dispersion Modeling of Ocean-Going Vessel Emissions – used the CALPUFF dispersion model to estimate statewide diesel PM concentration due to OGV emissions. The reports are provided in Appendix E1 and E2.

For Southern California, the CMAQ air quality model was run for the year 2005 emission using two different emissions scenarios; one scenario included the emissions (PM, Reactive Organic Gases (ROG), NOx, SOx) from all sources in the SCAB and the other

was identical to the first except the emissions from OGV were excluded. In this study, the contribution from OGV to ambient levels of pollutants was calculated from the difference between the two emissions scenarios. In the summary provided below, the results of annual maximum 8-hour ozone (O_3) concentration, and the annual average concentrations of $PM_{2.5}$, primary $PM_{2.5}$, $PM_{2.5}$ sulfate (SO4), and $PM_{2.5}$nitrate (NO3) are reported.

The second study evaluated the impacts of OGV diesel PM emissions on statewide ambient levels of diesel PM. In this study the CALPUFF air dispersion was used along with the OGV 2005 diesel PM emissions and meteorological data from 2002. Statewide annual average concentrations of diesel PM due to OGV emissions were estimated.

Combined, the results of these two studies demonstrate that OGV emissions impact air quality in California and the control of OGV emissions is necessary to mitigate air pollution and protect public health. Below, we provide a summary of the key findings from the studies. Additional details are provided in Appendix E1 and E2.

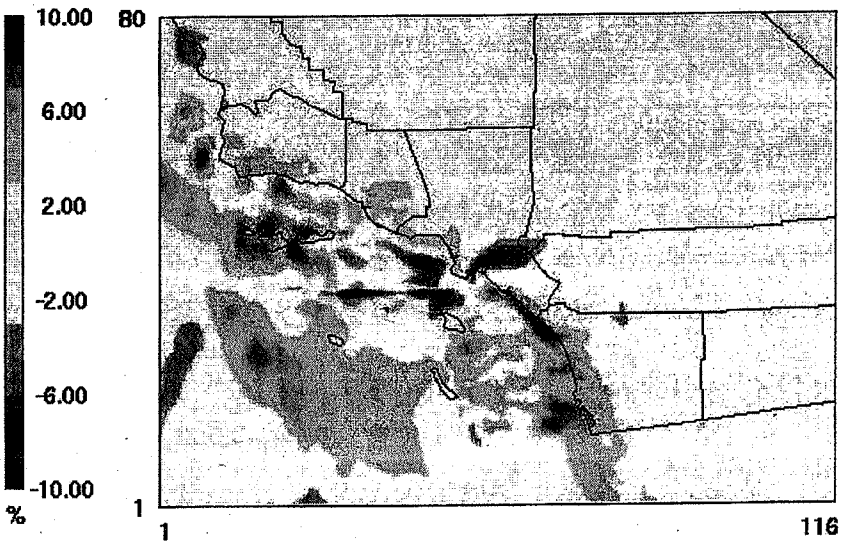
CMAQ OGV Modeling Analysis - Ambient Ozone Concentrations

Figure IV-3 provides the impacts on maximum 8-hr ozone background concentrations due to OGV emissions. In the figure, the relative (%) difference between ozone concentrations with all emissions (including OGVs), and concentrations resulting from non-OGV emissions only, are provided. Note that positive values indicate increases in concentrations due to OGV emissions, while negative values indicate decrease in concentrations due to OGV emissions.

The greatest positive percent changes (increase in ozone due to OGV emission) take place along the coast of Orange and San Diego counties. Increases in ozone are also seen in Santa Barbara, Ventura, and San Luis Obispo counties. Increases or decreases in ozone concentrations due to OGV emissions depend upon the intensity of local precursor emissions, especially NOx to ROG ratio, and other factors such as temperature. In the areas around the Ports of Los Angeles and Long Beach, the modeling shows relatively small increases or decreases in ozone concentrations from OGV emissions. This may be explained by the fact that these areas tend to be NOx rich, and further increases in NO_2 due to OGV emissions may lead to a decrease in ozone concentration. (Griffin et al., 2004)

Note: Figures IV-3 through IV-7 are best viewed in color as the legend encompasses the entire color spectrum, which, when presented in black and white obscures the data. The color versions of the figures can be found electronically at http://www.arb.ca.gov/regact/2008/fuelogv08/fuelogv08.htm.

Figure IV-3: Relative Change of Annual Maximum 8-Hour O_3 Concentrations Due to OGV Emissions
(only the relative changes > 4% and < -4% are shown in the plot)



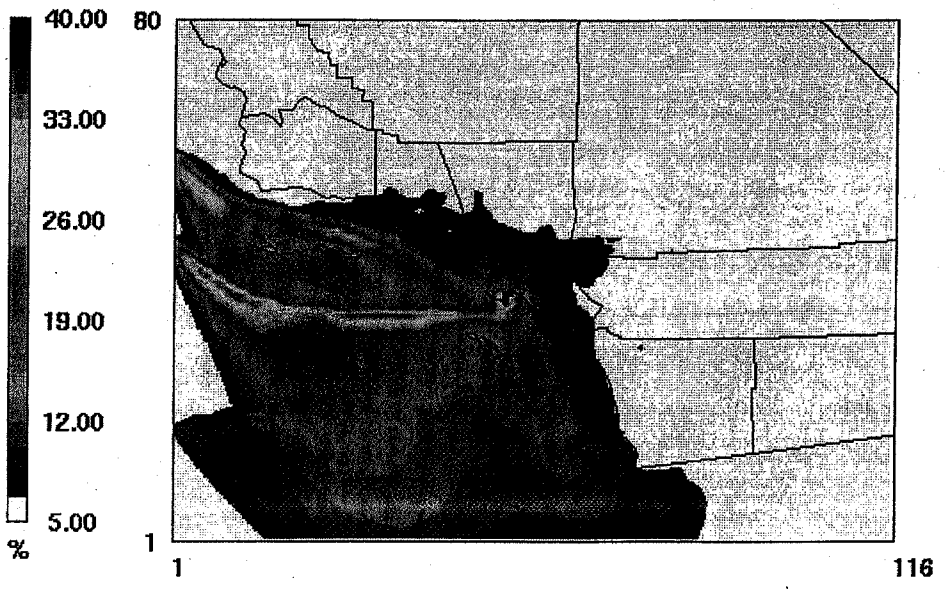
Min=-17.31 at (34,35), Max= 10.58 at (67,29)

CMAQ OGV Modeling Analysis - Ambient PM concentrations

The SCAB region exhibits some of the highest levels of ambient PM and experiences a large number of days with ambient PM concentrations exceeding the State and federal air quality standards (CARB, 2007). In addition to direct emission of particles from combustion and other sources, a significant fraction of fine PM is formed through secondary processes from gas-phase emissions. In this section, the relative contribution of OGV emissions to ambient PM is quantified by analyzing model predicted PM concentrations for modeling cases with and without OGV emissions.

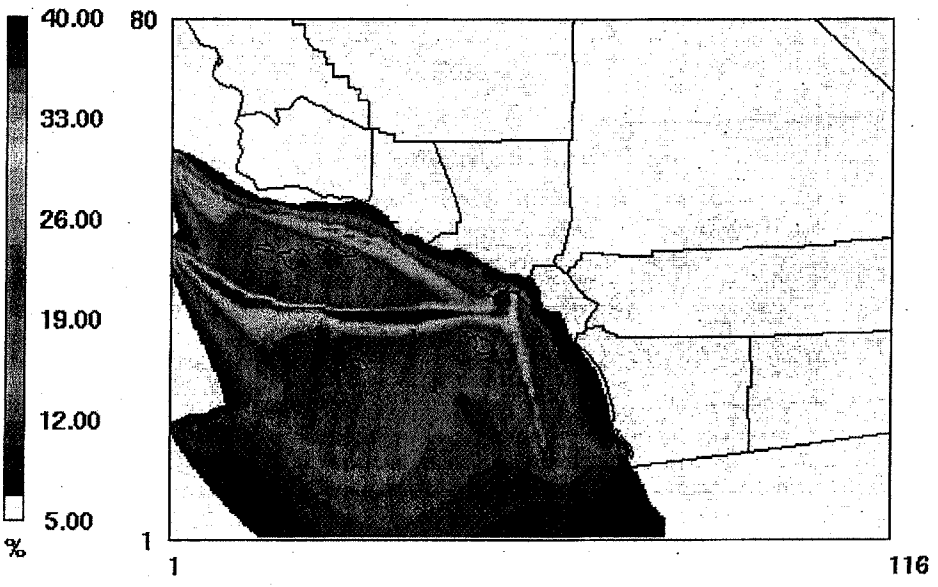
Figures IV-4, IV-5, IV-6, and IV-7 show the estimated relative contributions from OGV emissions for annual averaged total $PM_{2.5}$ (summation of primary and secondary $PM_{2.5}$), primary $PM_{2.5}$, $PM_{2.5}$ sulfate, and $PM_{2.5}$ nitrate. Since primary $PM_{2.5}$ is not explicitly defined in the CMAQ model, the summation of primary $PM_{2.5}$ sulfate and the non-reactive $PM_{2.5}$ species in the emissions inventory, including PM2.5 elemental carbon (EC), primary organic carbon, and unspeciated $PM_{2.5}$ was assumed to represent total primary $PM_{2.5}$. For this study, primary $PM_{2.5}$ sulfate included direct emissions and contributions from boundary and initial conditions. The primary $PM_{2.5}$ did not include concentrations of nitrate because it is not feasible to use the model to distinguish between the primary and secondary components of this species. This may not be a significant source of error since there are no significant amounts of primary nitrates in the emissions inventory (based on the ARB speciation profile, about 0.01% of direct PM is assumed to be nitrate). The total secondary $PM_{2.5}$ includes $PM_{2.5}$ NO_3, $PM_{2.5}$ NH_4, secondary $PM_{2.5}$ SO4 and organic carbon.

Figure IV-4: Estimated Relative Contributions of OGV Emissions to Annual Averaged Total $PM_{2.5}$



Min= 0.04 at (53,80), Max= 41.36 at (54,37)

Figure IV-5: Estimated Relative Contributions of OGV Emissions to Annual Averaged Primary $PM_{2.5}$

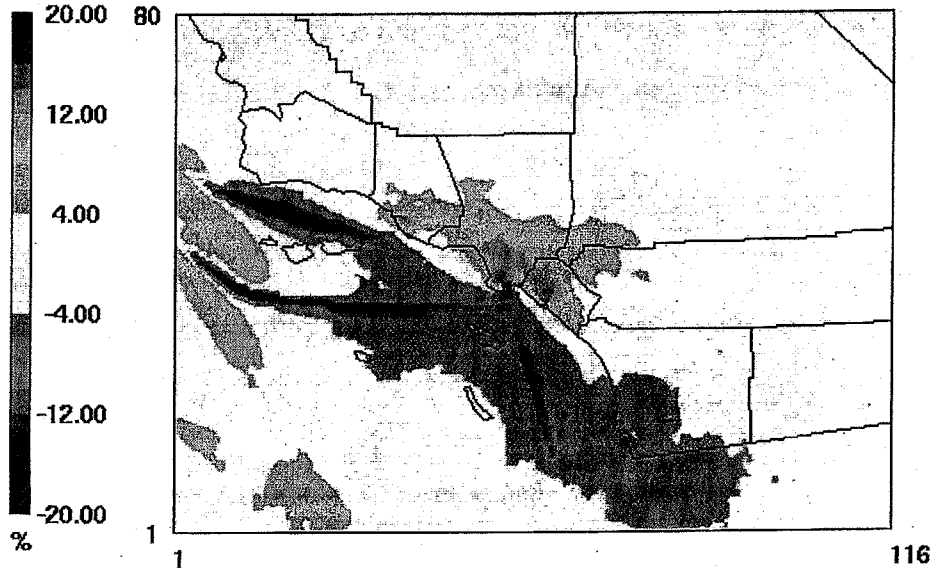


Min= 0.03 at (53,80), Max= 53.05 at (54,37)

Figure IV-6: Estimated Relative Contributions of OGV Emissions to Annual Averaged $PM_{2.5}$ Sulfate

Min= 0.07 at (53,80), Max= 57.16 at (54,37)

Figure IV-7: Estimated Relative Contributions of OGV Emissions to Annual Averaged $PM_{2.5}$ Nitrate



January 2,2005 0:00:00
Min=-32.14 at (11,38), Max= 16.40 at (53,39)

The greatest impact of OGVs on onshore $PM_{2.5}$ concentrations occurred in the vicinity of the Ports of Los Angeles and Long Beach, where emissions from OGVs accounted for approximately 25% of the $PM_{2.5}$ and 33% of the primary $PM_{2.5}$. The maximum relative contribution of OGV emissions to the total ambient PM2.5 is estimated to be

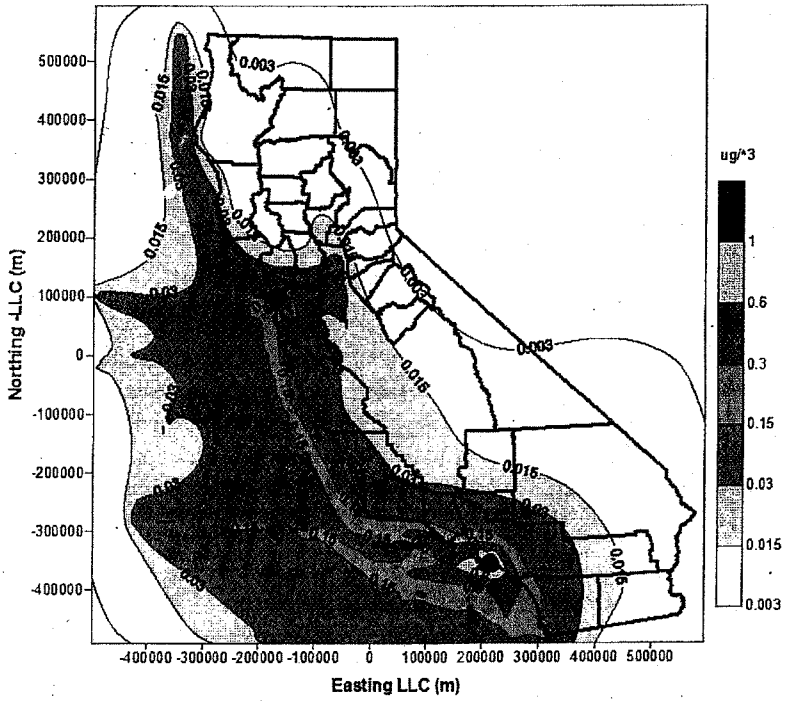
about 41% which occurs in the area of the Ports of Los Angeles and Long Beach. More than 40% of the difference in $PM_{2.5}$ in the Ports area was attributed to SO_4 concentrations. A broad area (>4% difference) of OGV impacts on SO_4 was predicted, covering most of the ocean area, coastline, and the Los Angeles Basin. For secondary $PM_{2.5}$ NO_3, the maximum relative contribution of OGV emissions is estimated to be about 16% which occurs at an area about 2-3 miles northwest of the Ports of Los Angeles and Long Beach. There is less impact of OGVs on NO_3 compared to SO_4. Overall a significant fraction of the contribution from OGV emissions to onshore PM comes as secondary PM from gas-phase emissions.

Researchers at UC Irvine conducted a similar modeling effort for investigating the effects of ship emissions on the Southern California air quality (Vutukurk, 2008). The study also showed that ship emissions impact Southern California air quality.

CALPUFF OGV Modeling Analysis - Ambient Diesel PM Concentrations

Figure IV-8 shows statewide annual average diesel PM concentrations resulting from OGV directly emitted diesel PM emissions. The CALPUFF modeling results estimate annual average diesel PM concentrations in the range of 0.03 to 1.0 $\mu g/m^3$ along the California coastline. These concentrations correspond to a 70-year cancer risk estimate of between 10 and 300 chances in a million. The highest concentrations are seen in areas near the Ports of Los Angeles and Long Beach and in the San Francisco Bay Area. These findings are consistent with the results from the Health Risk Assessments for the Ports of Los Angeles and Long Beach and the West Oakland Community.

Figure IV-8: Estimated Annual Average Concentrations of Diesel PM from OGV Emissions Statewide by CALPUFF ($\mu g/m^3$)



C. Potential Exposures and Health Risks from Ocean-Going Vessel Engine Diesel PM Emissions

This section examines the exposures and potential health risks associated with PM emissions from OGV. A brief qualitative discussion is provided on the potential exposures of Californians to the diesel PM emissions from OGV engine operations. In addition, a summary is presented of three health risk assessments conducted to determine the 70-year potential cancer risks associated with exposures to diesel PM emissions from OGV traveling in the California waterways and operating at the Port of Oakland, Port of Los Angeles, and Port of Long Beach. The noncancer health impacts resulting from the OGV PM emissions within the South Coast Air Basin were also investigated and are summarized in this section.

Exposures to Diesel PM

As discussed previously, OGVs visit California ports and travel in waters along the coastline of California and within certain inland waterways. The diesel PM emissions from OGV engines contribute to ambient levels of diesel PM emissions. Based on the most recent emissions inventory, there are about 11,000 vessel visits to California ports by OGVs each year. Most California ports are in urban areas and located near where people live, work, and go to school. This results in substantial exposures to diesel PM emissions from OGV operating in waters off the California coast and at the California ports. Because analytical tools to distinguish between ambient diesel PM emissions from OGVs and that from other sources of PM do not exist, we cannot measure the actual exposures to emissions from diesel-fueled vessel engines. However, modeling tools can be used to estimate potential exposures.

Health Risk Assessments

Risk assessment is a complex process that requires the analysis of many variables to simulate real-world situations. There are three key types of variables that can impact the results of a health risk assessment for cargo handling equipment: the magnitude of diesel PM emissions, local meteorological conditions, and the length of time of exposure. Diesel PM emissions are a function of the age and horsepower of the engine, the emissions rate of the engine, and the annual hours of operation. Older engines tend to have higher pollutant emission rates than newer engines, and the longer an engine operates, the greater the total pollutant emissions. Meteorological conditions can have a large impact on the resultant ambient concentration of diesel PM, with higher concentrations found along the predominant wind direction and under calm wind conditions. How close a person is to the emissions plume and how long he or she breathes the emissions (exposure duration) are key factors in determining potential risk, with longer exposures times typically resulting in higher risk.

To examine the potential cancer risks for OGV traveling in California waterway and the operations of OGV engines at California ports, ARB staff conducted three health risk assessments. The first assessment examined the statewide impact of diesel PM

emissions from OGV. The other two assessments look at the regional impacts of OGV activity in the San Francisco Bay Area and in the area surrounding the Ports of Los Angeles and Long Brach. The statewide assessment used the U.S. EPA air dispersion model – CALPUFF and the 2005 OGV emissions inventory. The San Francisco Bay Area analysis used the CALPUFF model and the 2005 emission inventory for OGV activity in the Bay Area to look at the impact of OGV emissions on the greater Bay Area. The Ports of Los Angeles and Long Beach assessment used the U.S. EPA ISCST3 air dispersion model and a 2002 emissions inventory for all sources of diesel PM emissions at the two ports.

The potential cancer risks for all of the assessments were estimated using standard risk assessment procedures based on the annual average concentration of diesel PM predicted by the model and a health risk factor (referred to as a cancer potency factor) that correlates cancer risk to the amount of diesel PM inhaled. The methodology used to estimate the potential cancer risks is consistent with the Tier-1 analysis presented in the Office of Environmental Health Hazard Assessment (OEHHA) Air Toxics Hot Spots Program Risk Assessment Guidelines (OEHHA, 2003; OEHHA, 2005). Following the OEHHA guidelines, we assumed that the most impacted individual would be exposed to modeled diesel PM concentrations for 70 years. This exposure duration represents an "upper-bound" of the possible exposure duration. The potential cancer risk was estimated by multiplying the inhalation dose by the cancer potency factor (CPF) of diesel PM (1.1 $(mg/kg\text{-}d)^{-1}$).

A brief summary of the results of the statewide assessment is presented below. The results of the two regional studies are discussed in Appendix E-3.

Cancer Risk Characterization – Statewide CALPUFF Modeling

Based on the 2008 statewide CALPUFF modeling, diesel PM emissions of OGVs have a significant health risk impact statewide. Figure IV-9 shows the risk isopleths for diesel PM emissions from all OGV emissions in California. We can see that OGV diesel PM emissions impact almost the entire state. The potential cancer risk level of 10 chances in a million extends inland at variable distances from the coastline. The area in which the potential cancer risks are predicted to exceed 10 chances in a million is about 22,100 square miles. The estimated population in this area is 27.3 million people or about 80 percent of the total California population. For potential cancer risk levels over 500 chances in a million, the impacted areas encompass about 80 square miles with an estimated population of 400,000. (see Table IV-4).

Figure IV-9: Estimated Potential Statewide Cancer Risk from OGV Diesel PM Emissions (chances in a million)

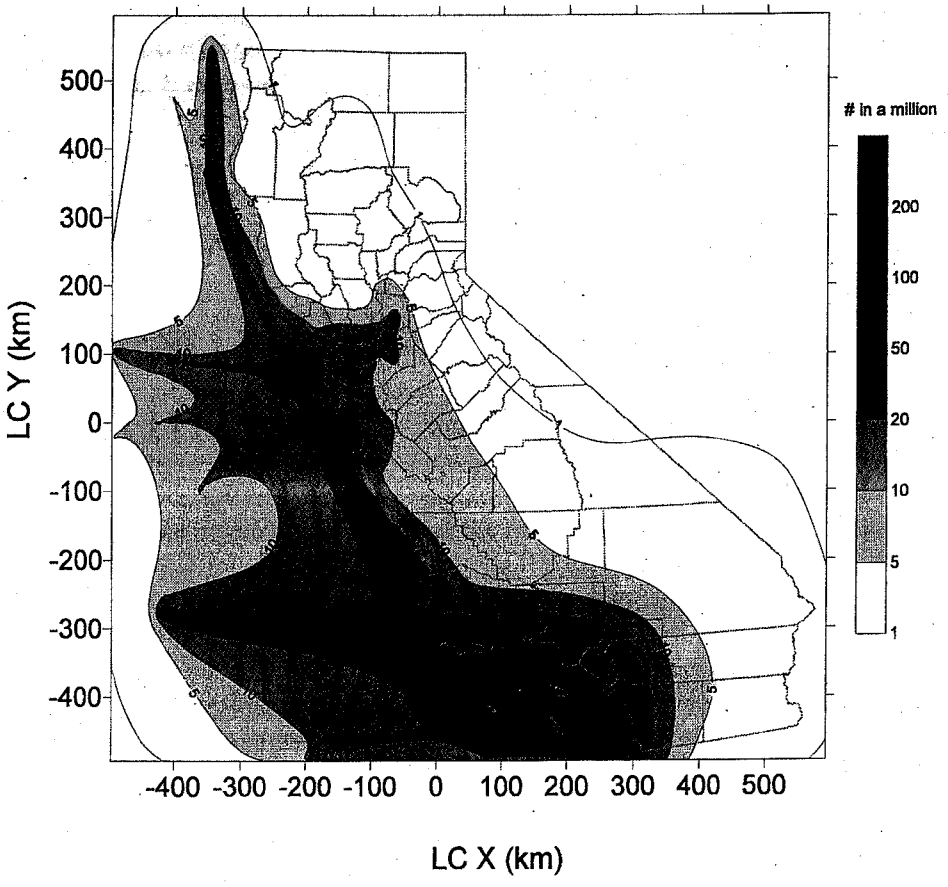


Table IV-4: Summary of Area Impacted and Population Affected by Risk Levels Statewide

Risk Level	Impacted Inland area (mile^2)	Affected population # (million)
Risk > 500	80	0.4
Risk > 200	400	2.4
Risk > 100	1,300	7.6
Risk > 10	22,100	27.3

Note: The population statistics is based on the U.S. Census Bureau's year 2000 census data

It also can be seen from Figure IV-9 that the highest impacts occur near the Ports of Los Angeles and Long Beach and the San Francisco Bay Area.

Non-Cancer Health Impacts

A substantial number of epidemiologic studies have found a strong association between exposure to ambient particulate matter (PM) and adverse health effects (ARB, 2002, 2006, 2008). As part of this assessment, ARB staff conducted an analysis of the

potential non-cancer health impacts associated with exposures to the model-predicted statewide ambient levels of directly emitted diesel PM (primary diesel PM) and secondary PM (from SOx and NOx) in the South Coast Air Basin resulting from OGV emissions. The noncancer health effects evaluated include premature death, hospital admissions, asthma-related and other lower respiratory symptoms, work loss days, and minor restricted activity days.

To assess the potential non-cancer health impacts associated with the OGV emissions (including primary diesel PM and the secondary PM), staff relied on four air dispersion and photochemical modeling studies that were discussed earlier. The four studies are the: (1) Statewide CALPUFF OGV modeling (2008), (2) San Francisco Bay Area CALPUFF modeling (2008), (3) Ports of Los Angeles and Long Beach ISCST3 modeling (2006), and (4) SCAB CMAQ photochemical modeling (2008). The first three studies estimated ambient concentrations of directly emitted diesel PM resulting from the OGV activities statewide, in the San Francisco Bay Area, and in the communities around the Ports of Los Angeles and Long Beach. The fourth study simulated the secondary PM resulting from OGV emissions in Southern California. The details of these studies can be found online at http://www.arb.ca.gov/ports/marinevess/documents/portstudy0406.pdf and in Appendix E.

To estimate the potential non-cancer health impacts, staff developed population exposure estimates using the model-predicted concentrations of directly emitted diesel PM (primary diesel PM) and secondary PM within each modeling grid cell to the population within the grid cell. The populations within each grid cell were determined from U.S. Census Bureau year 2000 census data.

ARB staff used the same PM-mortality relationship as were used in the Ports and Goods Movement Emission Reduction Plan (ARB, 2006). The methodology for estimating these health impacts is described in Appendix A of the Emission Reduction Plan for Ports and Goods Movement in California (ARB, 2006) and Methodology for Estimating the Premature Deaths Associated with Long-term Exposures to Fine Airborne Particulate Matter in California (ARB, 2008). We calculated the number of annual cases of death and other health effects associated with exposure to the PM concentration modeled for each of the grid cells. The totals over the entire modeling area were then calculated. For each grid cell, each health effect was estimated based on concentration-response functions derived from published epidemiological studies relating changes in ambient concentrations to changes in health endpoints, the population affected, and the baseline incidence rates. The selection of the concentration-response functions was based on the latest epidemiologic literature, as described in Emission Reduction Plan for Ports and Goods Movement in California (ARB, 2006).

Based on our analysis, we estimated the average numbers of cases per year for each study in the corresponding modeling areas. We estimated the statewide non-cancer health impacts due to directly emitted PM and the noncancer health impacts in the

South Coast Air Basin due to $PM_{2.5}$ nitrate and sulfate in the South Coast Air Basin. These estimates are presented in this section. The non-cancer health impacts due to directly emitted PM estimated from the regional modeling conducted for the Ports of Los Angeles and Long Beach and the San Francisco Bay Area are presented in Appendix E-3.

For direct emitted diesel PM from OGV activities statewide in 2005:

- 300 premature deaths (80 – 510, 95% CI)
- 7,700 cases of asthma-related and other lower respiratory symptoms (3,000 – 12,500, 95% CI)
- 100 hospital admissions – respiratory (25 to 170, 95% CI)
- 120 hospital admissions – cardiovascular (65 to 170, 95% CI)
- 650 acute bronchitis (0 to 1,400, 95% CI)
- 50,000 work loss days (43,000 – 58,000, 95% CI)
- 300,000 minor restricted activity days (241,000 – 351,000, 95% CI)

For $PM_{2.5}$ nitrate and sulfate due to OGV activities in the Southern California domain in 2005

- 770 premature deaths (210 – 1,300, 95% CI)
- 23,000 cases of asthma-related and other lower respiratory symptoms (8,800 – 37,000, 95% CI)
- 260 hospital admissions – respiratory (60 to 450, 95% CI)
- 300 hospital admissions – cardiovascular (170 to 440, 95% CI)
- 1,900 acute bronchitis (0 to 4,300, 95% CI)
- 140,000 work loss days (120,000 – 160,000, 95% CI)
- 800,000 minor restricted activity days (660,000 – 960,000, 95% CI)

Note that these estimated values for each study may not be comparable each other because of their different modeling selection, domain, emission inventory, population density, meteorological conditions, and other factors. For example, the estimates provided in Appendix E-3 for the Ports of Los Angeles and Long Beach were limited to a relative small domain of 20 mi x 20 mi and the smaller size of population (2 million) in the Southern California, while the study for the San Francisco Bay Area was applied to the domain of about 60 mi x 60 mi with the population size of about 5 million in Northern California.

In addition, in May 2008 ARB released a draft methodology for estimating premature deaths associated with long-term exposures to fine airborne particulate matter in California that proposes increasing the relative risk factor from 6% to 10% increase in premature death per 10$\mu g/m^3$ increase in PM2.5 exposures (ARB, 2008). Once this is finalized, the estimated premature deaths above could be increased by 67%.

Several key assumptions were used in our estimation. They involve the selection and applicability of the concentration-response functions to California data, exposure

estimation, subpopulation estimation, and baseline incidence rates. These are briefly described below.

- ARB staff assumed the model-predicted exposure estimates could be applied to the entire population within each modeling grid. That is, the entire population within each modeling grid was assumed to be exposed uniformly to modeled concentration. This assumption is typical of this type of estimation.

- ARB staff assumed the baseline incidence rates were uniform across each modeling grid and in many cases across each county. This assumption is consistent with methods used by the U.S. EPA for its regulatory impact assessment. The incidence rates match those used by U.S. EPA.

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V. SUMMARY OF THE PROPOSED REGULATION

In this chapter, we provide a plain English discussion of the key requirements of the proposed regulation for auxiliary engines, diesel-electric engines, main propulsion diesel engines and auxiliary boilers operated on ocean-going vessels (OGV engines and auxiliary boilers). This chapter begins with a general overview of the regulation and the approach taken in developing the requirements in the proposal. The remainder of the chapter follows the structure of the proposed regulation and provides an explanation of each major requirement of the proposal. This chapter is intended to satisfy the requirements of Government Code section 11346.2, which requires that a non-controlling "plain English" summary of the regulation be made available to the public.

A. Overview of the Proposed Regulation

The proposed regulation requires that operators of ocean-going vessels use marine distillate fuels in OGV engines and auxiliary boilers while operating within 24 nautical miles (nm) of the California coastline. Using cleaner burning marine distillate fuels will significantly reduce particulate matter (PM), diesel PM, nitrogen oxide (NOx), and sulfur oxide (SOx) emissions. The proposed regulation includes two phases of implementation with increasingly more stringent fuel sulfur limits on the marine distillate fuels required. For auxiliary engines and diesel-electric engines, the Phase 1 fuel requirements begin upon the effective date of the regulation (30 days after approval by the Office of Administrative Law). For main engines and auxiliary boilers, the Phase 1 fuel requirements begin July 1, 2009. For Phase 1, the operators must use either marine gas oil (MGO) or marine diesel oil (MDO). The MGO has a sulfur limit of 1.5% for Phase 1. The MDO has a sulfur limit of 0.5 percent in Phase 1. Phase 2, which begins on January 1, 2012, requires operators to use either MGO or MDO, both with a 0.1 percent sulfur limit, in the OGV engines and auxiliary boilers while operating within the 24 nm zone.

The proposed regulation includes several exemptions to accommodate special circumstances or situations where it may not be feasible or practical to use the required fuel. For example, a safety exemption is included for situations where the master of the vessel determines that compliance would endanger the safety of the vessel, crew, cargo or passengers. Exemptions are also provided for vessels that use alternative fuels, for military vessels, and for vessels that are evaluating technologies that will advance the state of knowledge pertaining to exhaust control technology or emissions characterization.

In the event a vessel owner needs to undertake essential modifications to enable the vessel to use the low sulfur distillate fuel within the 24 nm zone, the proposed regulation also includes a provision to grant an exemption from the fuel-use requirement provided certain criteria are met. If the operator elects not to use the exemption for essential modifications, the proposal also includes a noncompliance fee option where the operator, under special circumstances, is allowed to pay a fee in lieu of direct compliance with the fuel requirements. ARB staff believes these provisions will not be

used to a great extent, as most vessels will not require modifications to comply with the proposed regulation.

Because there is uncertainty about the availability marine distillate fuels that meet the 0.1 percent sulfur limit at fueling ports throughout the world, a provision is included to allow the purchase of the fuel in California. This provision will be implemented coinciding with the Phase 2 fuel requirements which are effective January 1, 2012.

B. Purpose

The purpose of this proposed regulation is to reduce emissions of diesel PM, PM, NOx, SOx, and "secondarily" formed PM (PM formed in the atmosphere from NOx and SOx). If adopted, the proposed regulation will achieve immediate, significant emission reductions upon implementation. Specifically, the proposed regulation will have the following benefits:

- diesel PM and PM emission reductions will reduce the potential cancer risk, premature mortality and other adverse health impacts from PM exposure to people who live in the vicinity of California's major ports and shipping lanes;
- diesel PM and PM emission reductions will reduce regional exposure to PM, and help continue progress toward State and federal ambient air quality standards for PM_{10} and $PM_{2.5}$;
- NOx emission reductions will reduce the formation of regional ozone and secondary nitrate PM; and
- reductions in SOx emissions will reduce the formation of secondary sulfate PM.

C. Applicability

This subsection explains who must comply with the proposed regulation. Except for the exemptions described below, the proposal applies to any person who owns or operates an ocean-going vessel within a 24 nm zone of the California coastline. The definition of ocean-going vessel is key to this section. In general, ocean-going vessels include large cargo vessels and passenger cruise vessels (see section on "Definitions" below). The regulation applies to both U.S.-flagged vessels and foreign-flagged vessels. Foreign-flagged vessels are vessels registered under the flag of a country other than the United States.

The proposed regulation includes language clarifying that the proposal does not change any applicable U.S. Coast Guard regulations and that vessel owners and operators are responsible for ensuring that they meet all applicable U.S. Coast Guard regulations.

D. Exemptions

The proposed regulation includes several exemptions. The proposal does not apply to vessels while in "innocent passage." Innocent passage generally means travel within the 24 nm zone off the California's coastline without stopping or anchoring, except in

limited situations such as when the vessel is in distress or must stop to comply with U.S. Coast Guard regulations. The proposal does not apply to emergency generators or to large boilers that are used to supply propulsion for a vessel (steamships). An exemption is also included for military and government vessels. Military vessels primarily use military specification distillate fuels that must be used on a consistent basis for military equipment globally. The proposal contains a safety exemption if the master determines that compliance would endanger the vessel, its crew, cargo or passengers due to severe weather conditions, equipment failure, fuel contamination or other reasons beyond the master's control. The proposal includes a temporary experimental or research exemption for experimental purposes as granted by the Executive Officer for up to three years with one two-year extension.

E. Definitions

The proposed regulation provides definitions for a number of terms that are not self-explanatory, or have specific meaning within the context of the proposed regulation. In this subchapter, we discuss some of the key definitions.

Auxiliary Boiler

An auxiliary boiler is defined as any fuel-fired combustion equipment designed primarily to produce steam for uses other than propulsion. The steam is typically used to heat residual fuel and liquid cargo, heating of water for crew and passengers, powering steam driven pumps, freshwater generation and space heating.

Auxiliary Engine

An auxiliary engine is defined as a diesel engine on an ocean-going vessel designed primarily to provide power for uses other than propulsion or emergencies, except that all diesel-electric engines shall be considered "auxiliary diesel engines" for purposes of this proposed regulation.

Baseline

The California "baseline" is the boundary line that divides the land and internal waters from the ocean. This boundary line is determined by the United States Baseline Committee and shown on the official United States nautical charts published by the National Oceanic and Atmospheric Administration (NOAA). Because the waterline rises and falls with the tide, the baseline is defined with respect to the tides. For this regulation, we have defined the baseline as the mean lower low water line along the California coast, as shown on the applicable NOAA Nautical Charts authored by the NOAA Office of Coast Survey. The NOAA routinely updates its nautical charts to update hazards to navigation and other information considered essential for safe navigation and any changes made to the baseline by the U.S. Baseline Committee. It is our understanding that NOAA will be updating the charts for the California coast in the near future. The California baseline is used in the definitions of "Territorial Sea" (which

extends to 12 nautical miles from the California Baseline) and "Contiguous Zone" (which extends to 24 miles from the California baseline).

Main Engine

A main engine is defined as a diesel engine on an ocean-going vessel designed primarily to provide propulsion. Main engines are typically slow-speed two-stroke diesel engines.

Marine Gas Oil

Marine Gas Oil (MGO) is a marine grade distillate fuel very similar to on-road diesel fuel except that it has a higher flash point requirement and often a much higher sulfur content. The International Organization for Standardization (ISO) sets standards for marine fuels under International Standard ISO 8217, including fuels designated DMX and DMA, which correspond to marine gas oil. For example, the maximum sulfur content for grade DMA fuel is 1.5 percent by weight, and the minimum flash point is 60 degrees Celsius. If a fuel meets all of the standards for DMA or DMX fuels in the applicable ISO standard, then it qualifies in the proposed regulation as "marine gas oil." In practice, on-road diesel fuel in California often meets the specifications for DMA fuel and is sold for marine use. In most cases, DMX grade fuel is primarily used only for emergency generators, so marine gas oil is generally DMA grade fuel.

Marine Diesel Oil

Marine Diesel Oil (MDO) is a marine grade distillate fuel very similar to marine gas oil except that it generally contains a small amount of marine residual fuel (heavy fuel oil) due to storage or transportation in tanks or piping that previously held marine residual fuels. The International Organization for Standardization (ISO) sets somewhat less stringent standards for MDO fuel, which corresponds to DMB grade fuel in ISO terminology. The sulfur content limit for DMB grade fuel is 2 percent, compared to 1.5 percent for DMA grade fuel (marine gas oil).

Ocean-Going Vessel

An ocean-going vessel is defined as a vessel meeting any of the following criteria:

- a vessel greater than or equal to 400 feet in length overall (LOA) as defined in the Code of Federal Regulations (50 CFR § 679.2, as adopted June 19, 1996);
- a vessel greater than or equal to 10,000 gross tons (GT ITC) per the convention measurement (international system) as defined in 46 CFR 69.51-.61, as adopted September 12, 1989; or
- a vessel propelled by a marine compression ignition engine with a per-cylinder displacement of greater than or equal to 30 liters.

The criteria in the definition of ocean-going vessel are designed to include the large vessels that travel domestically and internationally, such as container vessels, auto carriers, tankers, and passenger cruise vessels. The definition is also designed to exclude harbor craft such as tug boats, fishing boats and ferries, which are subject to more stringent fuel requirements. Currently, diesel fuel sold to harbor craft in California is required to meet California on-road "vehicular" standards.

Regulated California Waters

The Regulated California Waters (RCW) is a zone along the California coastline that extends approximately 24 nm off the California baseline.[1] North of Point Concepción, the zone extends to 24 nm offshore of the California mainland baseline and is aligned with the outer boundary of the Contiguous Zone, an internationally recognized boundary which is noted on most nautical charts. For the most part the contiguous zone extends 24 nm offshore the California mainland baseline, however, there is a "bubble" outside the Golden Gate where the Contiguous Zone extends out beyond the Farralon Islands and is approximately 45 nm from the Golden Gate Bridge. South of Point Concepción, a boundary approximately 24 nm off the shoreline is defined by straight line segments. We selected this linear boundary south of Point Concepción because extending the regulated waters around the Channel Islands, consistent with the Contiguous Zone, would bring the effective zone of the proposed regulation significantly beyond the intended boundary of approximately 24 nm offshore of the California mainland baseline – up to 90 nm offshore. RCW also includes California internal waters; estuarine waters, all California ports, roadsteads, and terminal facilities. It includes the all waters within 3, 12 and 24 nautical mile zones of the California coastline, starting at the California-Oregon border and ending at the California-Mexico border at the Pacific Ocean. By definition, RCW include all waters within the area, not including any islands, between the California baseline and a line starting at 34.43 degrees North, 121.12 degrees West; thence to 33.50 degrees North, 118.58 degrees West; thence to 32.65 degrees North, 117.81 degrees West; and ending at the California-Mexico border at the Pacific Ocean.

F. In-Use Operational Requirements

This section describes the fuels that must be used by operators of ocean-going vessels to comply with the requirements of the proposed regulation and the implementation dates. The proposed regulation requires vessels operating in Regulated California Waters to use the following fuel:

[1] The California "baseline" is the boundary line that divides the land and internal waters from the ocean. This boundary line is determined by the United States Baseline Committee and shown on the official United States nautical charts published by the National Oceanic and Atmospheric Administration. Because the waterline rises and falls with the tide, the baseline is defined with respect to the tides. For this regulation, we have defined the baseline as the mean lower low water line along the California coast.

Phase 1

For auxiliary engines and diesel-electric engines, the Phase 1 fuel requirements begin upon the effective date of the regulation (30 days after approval by the Office of Administrative Law). For main propulsion engines and auxiliary boilers, Phase 1 begins on July 1, 2009. The Phase 1 fuel requirements are as follows:

- marine gas oil (MGO) with a sulfur content of 1.5 percent or less, or
- marine diesel oil (MDO) with a sulfur content of 0.5 percent or less.

Phase 2

For auxiliary engines, diesel-electric engines, main engines and auxiliary boilers, Phase 2 begins January 1, 2012. The Phase 2 fuel requirements are as follows:

- MGO with 0.1 percent sulfur or less or
- MDO with 0.1 percent sulfur or less.

G. Recordkeeping and Reporting Requirements

Recordkeeping

Recordkeeping, in addition to ship-board inspections and fuel testing, is necessary for ARB enforcement staff to verify that a vessel operator is complying with the requirements of the proposed regulation. This section explains the recordkeeping requirements.

Beginning with the effective date of the regulation, any person who owns or operates an ocean-going vessel within RCW will be required to maintain certain records (in English) for a minimum of three years. These requirements do not apply to vessels that travel along California's coastline in "innocent passage," meaning traveling without stopping or anchoring, except in limited situations. The records that must be maintained are as follows:

- the date, time, and position (longitude and latitude) of the vessel for each entry into and departure from the region covered by the proposed regulation;
- the date, time, and position (longitude and latitude) of the vessel at the initiation and completion of any fuel switching procedures used to comply with the fuel requirements in the proposed regulation. Completion of fuel switching procedures means the moment at which auxiliary engines, diesel-electric engines, main engine and auxiliary boilers have completely switched from one fuel to another fuel;
- the date, time, and position (longitude and latitude) of the vessel at the initiation and completion of any fuel switching procedures within the region covered by the proposed regulation;
- the type of each fuel used (e.g. MDO or MGO) in the main engine and auxiliary boilers operated within the region covered by the proposed regulation; and

- the types and amounts of fuels purchased for use in the main engine and auxiliary boiler on the vessel, and the actual percent by weight sulfur content of such fuels as reported by the fuel supplier or a fuel testing firm.

Documentation of Fuel Switch Over Procedures

Beginning with the effective date of the regulation, any person who owns or operates an ocean-going vessel within 24 nm of the California coastline will be required to maintain records (in English) that document the fuel switch over procedures for the vessel. These requirements do not apply to vessels that travel along California's coastline in "innocent passage," meaning traveling without stopping or anchoring, except in limited situations. The records that must be maintained are as follows:

- A fuel system diagram that shows all storage, service, and mixing tanks, fuel handling, pumping, and processing equipment, valves, and associated piping. The diagram or other documentation shall list the fuel tank capacities and locations, and the nominal fuel consumption rate of the machinery at rated power;

- Description of the fuel switch over procedure with detailed instructions and clear identification of responsibilities; and

- The make, model, rated power, and serial numbers of all main engines and auxiliary engines and make, model, rated output and serial numbers of all auxiliary boilers subject to the proposed regulation.

Reporting and Monitoring Provisions

These provisions explain when the records described above will be provided (reported) to ARB. The provisions also explain that access to vessels shall be provided to allow enforcement staff to verify compliance with the proposed regulation. For example, enforcement staff may need to access the vessel to inspect records instead of requesting that they be mailed, or they may need to obtain a sample of fuel used by the vessels main engines and auxiliary boilers.

Under these provisions, the recordkeeping information specified in the proposed regulation must be supplied in writing to the Executive Officer upon request. Some of the recordkeeping required by the proposed regulation may already be recorded to comply with other regulations or standardized practices. In these cases, the information may be provided to ARB in a format consistent with these regulations or practices, as long as the required information is provided.

Vessel owners or operators may be requested to provide additional information needed to determine compliance with the proposed regulation on a case-by-case basis.

To monitor compliance with the requirements of the proposed regulation, these provisions require that vessel owners or operators provide access to the vessel to employees or officers of the Air Resources Board. This is to include access to records necessary to establish compliance with the requirements of the proposal and access to fuel tanks or pipes for the purpose of collecting fuel samples for testing and analysis.

H. Violations

Any person who is subject to this proposed regulation and commits a violation of any of the requirements is subject to penalties as specified in Health and safety codes as applicable under California law. Any noncompliance with the in-use fuel requirements, recordkeeping and other requirements shall amount to a separate violation for each hour that a person operates the vessel in Regulated California Waters until the requirements are met. Any person who is subject to this propped regulation is responsible and liable for meeting the requirement not withstanding any contractual requirement with a third-party.

I. Vessels Needing Essential Modifications to Comply

In the event a vessel owner needs to undertake essential modifications to enable the vessel to use the required low sulfur distillate fuel within the Regulated California Waters (RCW), the proposed regulation also includes a provision to grant an exemption from the fuel requirement provided certain criteria are met. This provision terminates December 31, 2014. After that date, vessels must meet the fuel use requirements. This provision has a notification requirement and a demonstration of need requirement. For the notification requirement, the operator must notify the Executive Officer, prior to entering RCW, that the vessel will not meet the fuel requirements. The demonstration of need requirement includes providing a written Essential Modification Report to the Executive Officer at least 45 days before entering RCW. The Essential Modification Report must address the following to the satisfaction of the Executive Officer:

- identifies the essential vessel modifications that are necessary to meet the fuel requirements,
- demonstrates that the modifications are essential, and
- identifies the extent to which the vessel can use the required fuel without essential vessel modifications (e.g. for a portion of the voyage or in any or all of the regulated OGV engines and auxiliary boilers).

The Executive Officer has 30 days to act on the Essential Modification Report. Additional information may be provided by the operator or requested by the Executive Officer. The Executive Officer has an additional 15 days to address any additional information.

While in Regulated California Waters, the vessel operator shall operate any OGV engines and auxiliary boilers on the required fuel to the maximum extent feasible and safe without the essential modifications.

J. Noncompliance Fee Option

The proposal contains a "Noncompliance Fee Option" to address the limited situations where a vessel operator may not be able to comply with the proposed regulation for reasons beyond their reasonable control, or it may be impractical to comply. Instead of providing exemptions for these situations, staff is proposing a provision that would allow a vessel owner or operator, under special circumstances, to pay a fee in lieu of direct compliance with the fuel requirement. The funds collected under this provision would be deposited in the Air Pollution Control Fund, with the goal of achieving equivalent or greater emission reductions near affected communities. Under this program, the vessel owners or operators would need to notify the Executive Officer that they will not meet the requirements of the regulation prior to entering the 24 nautical mile zone boundary (Regulated California Waters or 24 nm zone). The fees under this program are designed to ensure that participants will not receive an economic advantage over vessel operators that directly comply with the proposed regulation. The fee schedule is graduated such that later visits would result in increasing fee amounts.

This option could only be used in the following circumstances:

- Non-Compliance for Reasons Beyond Control
    - Unplanned Redirection: the vessel owner is unexpectedly redirected to a California port and the vessel does not have a sufficient quantity of fuel complying with the requirements of the proposed regulation;
    - Inadequate Fuel Supply: due to reasons beyond the vessel operator's control, the vessel was not able to acquire a sufficient quantity of fuel complying with the requirements of the proposed regulation. Note that an "offramp" provision has been included under this scenario, once the Phase 2 requirement begins January 1, 2012. This provision has been provided to account for the situation where MGO or MDO, both meeting 0.1% sulfur limit, is not available. Under this provision, the noncompliance fee will be waived once per vessel during each calendar year until December 31, 2014. To use this provision, compliant fuel must be acquired at the first California port and used the remainder of the voyage within RCW. In addition, the vessel must operate on fuel meeting the Phase 1 fuel requirement during the noncompliant portion of the voyage. This provision provides the vessel owner/operator the option of purchasing Phase 2 compliant fuel in California if it was not available at other ports outside California.
    - Defective Fuel: due to reasons beyond the vessel operator's control, fuel necessary to comply with the requirements of the proposed regulation was found to be contaminated or otherwise out of compliance after the vessel left the last bunkering port prior to a California port call;

If the operator elects not to use the exemption for essential modifications, discussed in subsection I, the proposed regulation includes a noncompliance fee provision for

circumstances where the vessel must go into dry-dock for modification or where infrequent visits and the need for modifications make it impractical to comply directly with the fuel requirements. Under this provision, the operator is allowed to pay a fee in lieu of direct compliance with the fuel requirements for the following cases:

- Vessels to be taken out of service for modifications
  - modifications to a vessel are required to comply with the proposed regulation and the vessel operator is not able to complete the modifications in time to meet the requirements in the proposal. The vessel operator must submit a Compliance Retrofit Report that identifies the modifications necessary and the date by which modifications will be completed.
- Modifications on Infrequent Visitors
  - modifications to a vessel are required to comply with the proposed regulation and the vessel will visit a California port a maximum of two times per calendar year, and four times over the life of the vessel after the effective date of the regulation. This provision terminates December 31, 2014.

The non-compliance fees would be paid to the port's Noncompliance Fee Settlement and Air Quality Mitigation Fund prior to leaving the port. If no such port fund exists, the person shall deposit the fees into the California Air Pollution Control Fund, as directed by the Executive Officer. The fee increases with each port visited while complying with this provision. The port visits are cumulative over the life of the vessel. For example, if a vessel visits a California port and uses the noncompliance fee option for the first time, the vessel's owner would pay a fee of $45,500. If that same vessel visits another California port sometime later and again uses the noncompliance fee option, the vessel owner would pay a fee of $91,000; since this was the second port visited under this provision. The fees are calculated based on the cost differential between heavy fuel oil and distillate for an average vessel visit. The noncompliance fee for the first port visit is 1.5 times the fuel differential cost. The noncompliance fee then increases for every additional port visited during a voyage. The fee schedule is shown in Table V-1, Noncompliance Fee Schedule.

Table V-1: Noncompliance Fee Schedule, Per Vessel

Noncompliance Fee Schedule	
Visit	**Fee (per vessel)**
1st Port Visited	$45,500
2nd Port Visited	$91,000
3rd Port Visited	$136,500
4th Port Visited	$182,000
5th or more Port Visited	$227,500

K. Test Methods

The proposed regulation includes test methods to determine whether fuels meet the requirements of the proposed regulation. Specifically, the proposed regulation references International Standard 8217 as adopted by the International Organization for Standardization in 2005. ISO 8217 includes the properties necessary for a fuel to qualify as DMX or DMA grade fuel (marine gas oil), or DMB grade fuel (marine diesel oil), and specifies the test methods to be used to determine compliance with each of these properties. The proposal also includes the test method to be used to determine the sulfur level of these fuels.

The proposed regulation allows the use of alternative test methods demonstrated to be equally accurate, as approved by the Executive Officer of ARB. For example, ASTM equivalent methods are available for many or all of the ISO test methods specified in ISO 8217.

L. Sunset and California Baseline Review Provisions

Sunset Provision

If the Executive Officer of the ARB determines that the IMO or the U.S. EPA adopts regulations that will achieve equivalent benefits from ocean-going vessels in California, compared to the benefits achieved by the proposed regulation, then the Executive officer will propose to the Board for its consideration terminating or modifying the requirements of the proposed regulation. This provision recognizes that it would be preferable to adopt regulations for ocean-going vessels on a national or international basis.

California Baseline Review

The proposed regulation requires the Executive Officer to periodically review the California baseline determinations by the National Oceanic and Atmospheric Administration to determine if updates to the baseline maps incorporated by reference in the regulation are necessary.

M. Severability

This provision states that if a particular section of the proposed regulation is held to be invalid, the remainder of the proposal shall continue to be effective.

N. Regulatory Alternatives

The Government Code section 11346.2 requires ARB to consider and evaluate reasonable alternatives to the proposed regulation and provide the reasons for rejecting those alternatives. ARB staff evaluated four alternative strategies to the current proposal. Based on the analysis, none of the alternative control strategies were

considered more effective in reducing emissions than the proposed regulation. Full implementation of the proposed regulation is necessary to make progress toward ARB's goals of: (1) reducing diesel PM by 85 percent in 2020, as described in the Diesel Risk Reduction Plan and the Goods Movement Emission Reduction Plan; and (2) achieving State and federal air quality standards for PM and ozone. This section discusses each of the four alternatives and provides reasons for rejecting those alternatives.

Alternative 1: Do Nothing

As discussed in Chapter VII, the proposed regulation will result in significant reductions in diesel PM, PM, NOx, and SOx emissions. The diesel PM reductions are an important element of the Diesel Risk Reduction Plan and the Goods Movement Emission Reduction Plan. The reductions from the proposed regulation, along with other regulations to be adopted by ARB, will reduce cancer and noncancer health risks to the public associated with inhalation exposure to emissions of diesel PM.

The emission reductions from the proposal are also necessary to make progress toward compliance with State and federal air quality standards for ozone and PM in nonattainment areas throughout the State. As discussed in Chapter IV, NOx and SOx emissions form "secondary" nitrate and sulfate PM in the atmosphere, while NOx emissions contribute to the formation of ozone.

In addition, ARB is required by H&S section 39658 to establish regulations for toxic air contaminants (TACs) such as diesel PM. Further, H&S sections 39666 and 39667 require the ARB to adopt measures to reduce emissions of TACs from nonvehicular and vehicular sources.

In consideration of ARB's statutory requirements and the recognized potential for adverse health impacts to the public resulting from exposure to diesel PM. PM, and ozone, staff rejected Alternative 1.

Alternative 2: Rely on U.S. Environmental Protection Agency (EPA) and International Maritime Organization (IMO) Regulations

As discussed in subsection L above, the proposed regulation includes a "sunset" provision which requires the Executive Officer of ARB to consider terminating the requirements of the proposed regulation if it is determined that the U.S. EPA or IMO adopts regulations that will achieve equivalent benefits compared to the proposed regulation. This provision recognizes that it would be preferable to adopt regulations for ocean-going vessels on a national or international basis. However, as discussed below, existing IMO and U.S. EPA regulations will not achieve the needed emission reductions from the proposal in the near term. Pending modifications to IMO regulations could provide a route for the necessary emission reductions in 2015. However, due to the significant public health impacts associated with OGV engines and boiler emissions, we believe it is appropriate to regulate this source at the state level until such time as U.S.

EPA or IMO implement regulations that will achieve equivalent benefits. The following is a brief summary of the status of IMO and U.S. EPA activities supporting our position that we cannot wait for IMO or U.S. EPA to act.

IMO Annex VI

IMO Annex VI ("Regulations for the Prevention of Air Pollution from Ships") of the MARPOL Convention was adopted in 1997, and established some relatively modest emission standards for ocean-going ships. Annex VI entered into force 12 months after being accepted by 15 countries with at least 50 percent of world merchant shipping tonnage. This occurred in May 2005, one year after ratification by Somoa. However, marine engine manufacturers have generally produced engines that comply with the IMO standards beginning in 2000.

Annex VI limits marine fuels to 4.5 percent fuel sulfur, and provides a process for the creation of sulfur emission control areas (SECAs), which require the use of 1.5 percent sulfur fuel (generally heavy fuel oil). Annex VI also establishes NOx standards for diesel engines greater than 130 kilowatts installed on vessels constructed on or after January 1, 2000. The 4.5 percent sulfur fuel limit has only a minor effect on ship SOx and PM emissions because marine fuels, even heavy fuel oils, rarely approach this level of sulfur. As discussed below, even the use of 1.5 percent sulfur fuel under a SECA would achieve far less emission reductions compared to the proposed regulation. We estimate that the engine NOx standards are achieving about a five percent NOx emission reduction compared to pre-2000 engines. Over ten years after original adoption in 1997, the U.S. has still not begun to implement it. Although the Senate has ratified Annex VI, the United States is still in the process of passing legislation necessary to enforce it.

Sulfur Emission Control Area (SECA)

The U.S. EPA, in association with the ARB and other air quality agencies, is currently investigating the creation of SECA's under a process provided by the IMO. Specifically, the IMO's Annex VI provides a mechanism to require the use of marine fuel (generally heavy fuel oil) with a 1.5 percent sulfur content limit in designated areas. Two such areas now exist, in the Baltic Sea and the North Sea. The formation of a SECA may provide significant and necessary PM and SOx emission reductions to California if a West Coast SECA is established. However, the benefits of such a program would not be comparable to the ARB staff proposal. The PM and SOx emission reductions achieved from the use of 1.5 percent sulfur heavy fuel oil are far less than the reductions that would be achieved by the use of the distillate fuels specified in the proposed regulation. Specifically, the U.S. EPA estimates an 18 percent PM reduction and a 44 percent SOx reduction from the use of 1.5 percent heavy fuel oil (EPA, 2002). We estimate the use of 0.5 percent sulfur distillate fuel will result in a 75 percent PM reduction, an 80 percent SOx reduction, and a 6 percent NOx reduction.

Pending Revisions to Annex VI

The Marine Environment Protection Committee (MEPC) of the IMO has approved proposed amendments that would significantly strengthen Annex VI. The United States was a significant participant in the discussions that led to this proposal. The revisions will be considered for adoption in October of 2008 at the 58th session of the MEPC in London. Among the more significant revisions would be progressive reductions in the sulfur content of fuel as follows:

- A 1% sulfur limit in "Emission Control Areas," beginning March 1, 2010 (reduced from the current 1.5% sulfur level in SECAs);
- A global sulfur limit of 3.5%, beginning January 1, 2012 (reduced from the current 4.5% sulfur)
- A 0.1% sulfur limit in "Emission Control Areas," beginning January 1, 2015;
- A global sulfur limit of 0.5%, beginning January 1, 2020 (subject to a feasibility review to be completed in 2018 that could shift implementation to 2025)
- A fuel availability provision would be introduced to outline the actions that should be taken if a ship operator is unable to obtain complying fuel.

The proposed revisions also specify a three tier system of NOx standards for new engines, as well as standards for existing engines, as follows:

- Tier I NOx standard of 17 g/kWh for slow speed engines (in existing Annex VI) would continue until January 1, 2011
- Tier II NOx standard of 14.4 g/kWh starting January 1, 2011
- Tier III NOx standard of 3.4 g/kWh starting January 1, 2016 within Emission Control Areas (tier II standard would apply outside of ECAs)
- Existing large engines (with a power output greater than 5,000 kW and a per cylinder displacement at or above 90 liters) installed on ships constructed between January 1, 1990 and January 1, 2000, would be subject to a 17 g/kWh NOx standard.

Assuming the amendments to Annex VI are adopted, the U.S. EPA could pursue an "Emission Control Area" (ECA) that would include California's coastline under the pending amendments to IMO Annex VI. Under an ECA, a one percent sulfur limit could be implemented starting in 2010, although implementation would likely start later depending on the time necessary to complete the process. Beginning January 1, 2015, a 0.1% sulfur limit could be implemented, which would be equivalent to the 2012 0.1% sulfur limit in the ARB proposed regulation.

The difference in PM and SOx emission reductions between the IMO ECA and the ARB proposal are shown in Table V-2 and Figure V-1. With regard to PM emissions, the ARB proposal achieves substantially greater emission reductions from 2009 to 2014. Specifically, for vessels currently using HFO in their OGV engines and auxiliary boilers, the ARB proposal would achieve an estimated 74 percent emission reduction when implementation begins in 2009, and about 83 percent in 2012, compared to an

estimated 30 percent PM emission reduction from the ECA. In total, the ARB proposal would achieve nearly 20,000 tons more emission reductions from 2009 to 2014. For SOx, the ARB proposal would achieve an estimated 80 percent emission reduction when implementation begins in 2009, and about 95 percent in 2012, compared to an estimated 60 percent SOx emission reduction from the ECA. In total, the ARB proposal would achieve nearly 100,000 tons more SOx emission reductions from 2009 to 2014. Moreover, as shown in Figure V-2, the number of premature deaths avoided will be significantly higher for the ARB proposed regulation (1355) compared to the IMO ECA proposal (396) from 2010 to 2015. In total, ARB's proposed regulation would avoid about 960 premature deaths compared to the IMO-ECA proposal. In 2015, the emission reductions of the two proposals will be similar with similar values for premature deaths avoided.

Table V-2: Comparison of Annual Costs and PM Emission Reductions Between an IMO ECA and the ARB Proposed Regulation

	Estimated SOx Reductions (tons/yr)			Estimated PM Reductions (tons/yr)		
Year	IMO ECA	ARB Proposal	Loss	IMO ECA	ARB Proposal	Loss
2009	0	19,285	19,285	0	2,192	2,192
2010	29,110	39,703	10,593	1,826	4,566	2,740
2011	29,950	40,835	10,885	1,863	4,712	2,849
2012	30,790	49,418	18,628	1,936	5,406	3,470
2013	31,667	50,806	19,139	1,972	5,552	3,580
2014	32,617	52,267	19,650	2,045	5,734	3,689
Total			98,180			18,520

Figure V-1: Comparison of Diesel PM Emission Reductions Between the Proposed ARB Regulation and an ECA Provided for in the April 2008 Proposed Amendments to Annex VI

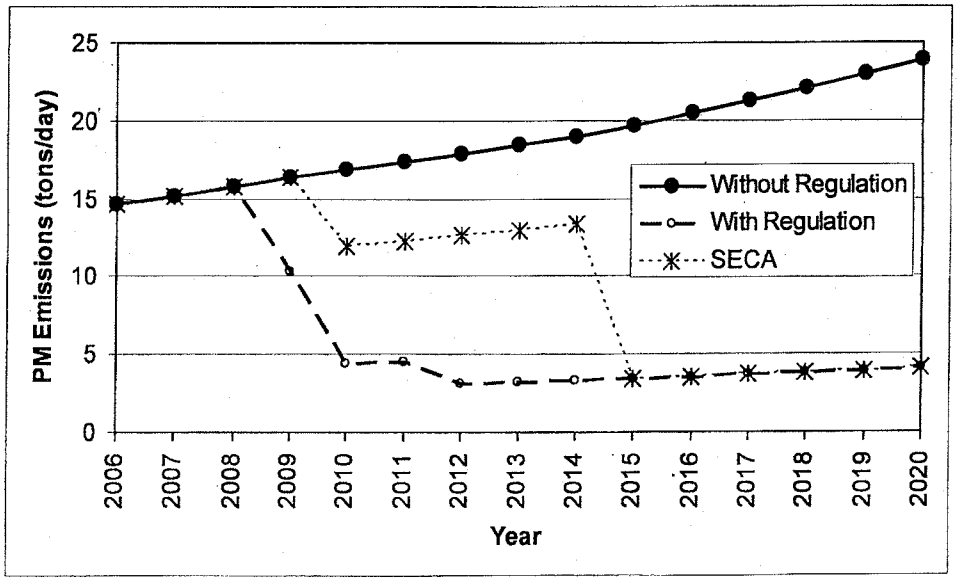
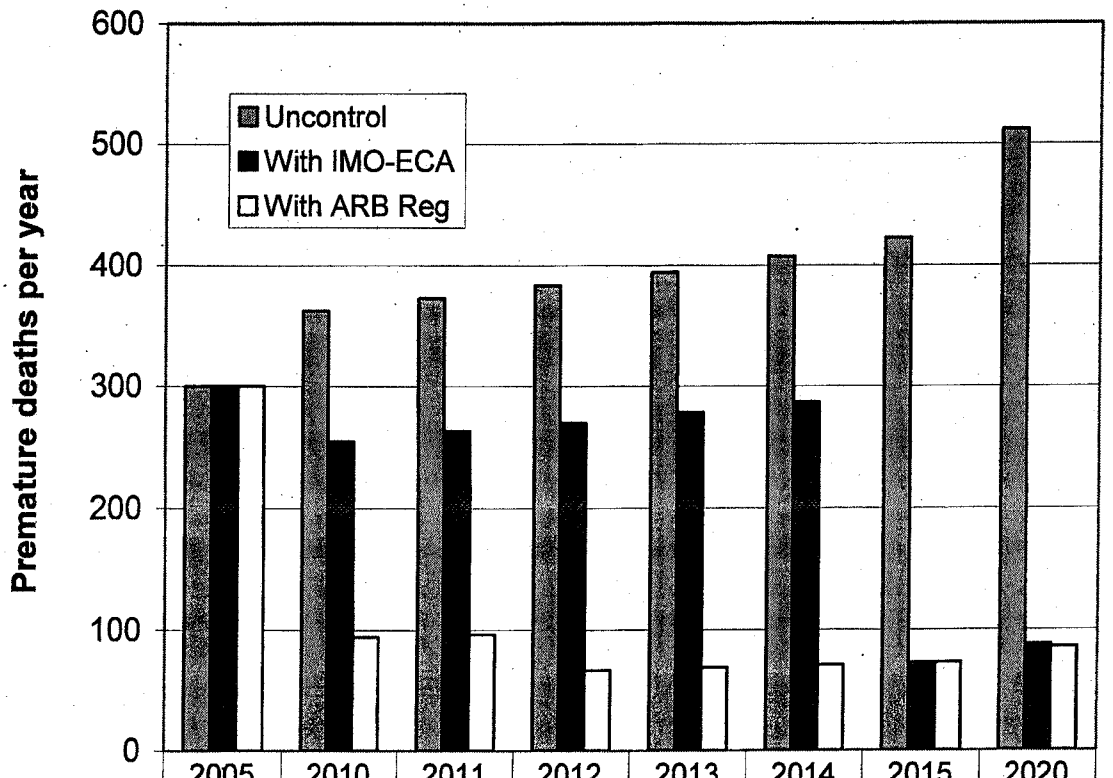


Figure V-2: Projection of Estimated Annual Statewide Premature Deaths Per Year Due to OGV PM Emissions Under Different Regulatory Scenarios



	2005	2010	2011	2012	2013	2014	2015	2020
Uncontrol	300	362	373	384	394	407	422	512
With IMO-ECA	300	255	264	270	279	287	73	88
With ARB Reg	300	94	96	66	69	71	73	86

U.S. EPA Category 1 & 2 Engine Standards

In 1999, U.S. EPA established "Tier II" standards for new "category 1 and 2" engines, those engines with a displacement less than 30 liters per cylinder (U.S. EPA considers the IMO Annex VI NOx standards as the "Tier I" standard). The U.S. EPA standards would apply to most auxiliary engines covered by the ARB staff proposal (if they are on U.S.-flagged vessels) because these engines are most often category 2 engines. The large diesel-electric engines used primarily on cruise ships are an exception because these engines are generally category 3 engines. This rule specifies standards for NOx plus hydrocarbons (combined), PM, and carbon monoxide. However, this rule only applies to new engines in U.S.-flagged vessels, which make up a small percentage of the auxiliary engines operating in California (most vessels visiting California ports are foreign-flagged vessels). There was originally a foreign-trade exemption for U.S.-flagged vessels, which would apply to auxiliary engines used on cargo ships, but this exemption was later removed in the U.S. EPA's 2003 rulemaking for category 3 engines (as discussed below).

In March, 2008, EPA issued a final rule establishing more stringent "Tier III," and "Tier IV" new engine standards for category 1 and 2 engines. The rule establishes standards for NOx, PM, and hydrocarbons. The Tier III standards will be implemented on new engines beginning 2009 to 2014, depending on the engine power and per cylinder displacement. The Tier IV standards, which reflect the use of high-efficiency exhaust treatment technology, will be implemented beginning 2014 to 2017, depending on the rated engine power. As with the 1999 rule, this rule only applies to U.S.-flagged vessels, which make up a small proportion of the vessels that visit California ports. In addition, vessel owners that routinely travel outside the United States can petition U.S. EPA for an exemption from the "Tier IV" standard. This is due to the need for ultra low sulfur diesel fuel (used in conjunction with after-treatment devices) to meet the Tier IV standards. Such fuel is not readily available in some regions outside the United States.

U.S. EPA Category 3 Engine Rules

In 2003, the U.S. EPA adopted NOx standards for new "category 3" engines, the large engines used for propulsion of ocean-going vessels. These standards would apply to engines manufactured on or after January 1, 2004. In terms of the engines covered in the proposed rule, these standards would apply to propulsion engines on cargo ships and the large generator set engines used on diesel-electric vessels, such as cruise ships. However, the standards are identical to the IMO Annex VI NOx standards and would only achieve modest NOx emission reductions and no PM reductions. In addition, they only apply to new engines on U.S.-flagged vessels, which represent a very small proportion of the engines operating in California.

In the 2003 rulemaking, U.S. EPA also addresses "category 1" and "category 2" engines with a displacement at or above 2.5 liters per cylinders but less than 30 liters per cylinder (typical of auxiliary engines used on ocean-going vessels). On U.S.-flagged vessels, these engines would be required to meet NOx standards equivalent to the IMO standards. In addition, beginning in 2007, new engines would be subject to the U.S. EPA's standards for category 1 and 2 engines as discussed above. To meet these standards, these engines will also need to use distillate fuels. In this rulemaking, U.S. EPA also eliminated the foreign trade exemption included in U.S. EPA's 1999 rule. However, all these requirements would only apply to U.S. flagged vessels, which represent a small proportion of the vessels that visit California ports.

In the 2003 rulemaking, U.S. EPA also set a deadline of April 2007 to promulgate more stringent Tier II standards for ships. However, U.S. EPA later released a rule to extend this deadline to December 2009, to allow more time for the IMO process to work and to further evaluate emission control technologies. However, these standards may again only apply to U.S.-flagged vessels, and may not address PM emissions. In addition, we estimate that such standards would not become effective for new engines until the 2011 timeframe at the earliest, and the emission reductions achieved by such a measure would phase in gradually as new vessels enter into service. As such, the measure would not be expected to achieve significant reductions until well after 2011.

EPA Nonroad Diesel Rule

Among other requirements, this rule would limit the sulfur content of diesel fuels for non-road applications. For marine use, the rule would limit the sulfur content in diesel fuel to 0.05 percent (500 ppm) in 2007, and 0.0015 percent (15 ppm) in 2012. However, this rule does not apply to marine diesel oil or heavy fuel oil. Since most ocean-going vessel engines use heavy fuel oil in the absence of a regulation, this would have little impact in reducing emissions from the engines covered in the ARB's proposed auxiliary engine rule.

Comparison of ARB staff proposal and IMO and U.S. EPA Rules

A comparison between the ARB staff proposal and the existing and potential regulations discussed in Alternative 2 are summarized in Table V-3. As shown, none of the existing regulations would achieve PM emission reductions comparable to the proposed ARB regulation for auxiliary engines. As discussed above, the potential revisions to IMO Annex VI might eventually achieve equivalent reductions in PM and SOx emissions, as well as greater NOx emission reductions, within defined Emission Control Areas. However, the potential implementation of these standards is not until 2015. Therefore, considering the adverse health impacts to the public resulting from exposure to diesel PM and ozone, we believe the best approach is to pursue the proposed regulation until IMO or U.S. EPA regulations achieve substantially equivalent emission reductions.

Table V-3: Comparison Between the ARB Staff Proposal and Existing and Potential IMO and U.S. EPA Rules

Regulation	Comparison to the ARB Staff Proposal
Proposed Amendments to IMO Annex VI	▪ Potential to achieve equivalent emission reductions in PM and SOx in 2015 within IMO "Emission Control Areas" ▪ Would achieve greater NOx emission reductions ▪ Results in 20,000 tons less PM and 100,000 tons less SOx reductions prior to 2015
Existing IMO Annex VI NOx Standards & Fuel Sulfur Limits	▪ Standards do not reduce PM or SOx significantly, achieve about a 5% NOx reduction
Potential IMO 1.5% Sulfur SECA off California Coast	▪ Significantly less reductions in diesel PM and SOx reductions ▪ No NOx benefit
U.S. EPA 1999 & 2008 Category 1&2 Engine Rule	▪ Standards only apply to U.S.-flagged vessels ▪ Benefits phase in slowly with engine turnover
U.S. EPA 2003 Category 3 Engine Rule	▪ Standards only apply to U.S.-flagged vessels ▪ Standards same as IMO and do not reduce PM significantly
Potential Tier II EPA Category 3 Standards (2009 adoption possible)	▪ Standards may only apply to U.S.-flagged vessels
U.S. EPA Nonroad Diesel Rule	▪ Specifies sulfur limits for diesel fuel used in marine applications, but exempts marine diesel oil & heavy fuel oil

In consideration of the significant public health impacts associated with OGV engines and boilers emissions and the uncertainty surrounding U.S. EPA or IMO regulatory efforts, ARB staff rejected Alternative 2.

Alternative 3: Implement the Regulation as Proposed Except Without the Lower Sulfur Limit of 0.1 Percent in 2012

Under this alternative, ocean-going vessels visiting California ports would be required to use the marine distillate fuels specified in the regulation for 2009-2011, but would not be required to meet the more stringent 0.1 percent sulfur limit in 2012. Instead, it would be anticipated that by 2015, a Sulfur Emission Control Area could be established under pending IMO Regulations that would require the use of 0.1 percent sulfur fuel or equivalent emission controls. As summarized in Table V-4, there would be about 600 less tons PM reduced annually under the proposed alternative from 2012 to 2014. This alternative would also reduce cost by over $50 million annually. Overall, the cost effectiveness of the proposed alternative is slightly lower than the original proposal. However, given the significant health impacts associated with PM, we recommend the proposed regulation.

Table V-4: Comparison of Annual Costs and PM Emission Reductions Between Alternative #3 and the Proposed Regulation

	Estimated Cost ($ millions)			Estimated Reductions (tons/yr)			Cost-Effectiveness ($/ton)	
Year	Alt. #3	Proposal	Savings	Alt. #3	Proposal	Loss	Alt. #3	Proposal
2012	$290.6	**$343.8**	$53.2	4,821	5,406	585	60,300	63,600
2013	$298.5	**$353.0**	$54.5	4,967	5,552	585	60,100	63,600
2014	$306.8	**$362.7**	$55.9	5,114	5,734	620	60,000	63,300

In consideration of the greater PM reductions from the ARB proposal (1790 tons) and the similar cost effectiveness, ARB staff rejected Alternative 3.

Alternative 4: Implement the Regulation Within 24 nm of California's Major Ports Rather than within 24 nm of the California Coastline

Under this alternative, ocean-going vessels visiting California ports would be required to use the marine distillate fuels specified in the proposed regulation only within 24 nautical miles of major ports, rather than along the entire coastline. This would reduce the transiting emission reductions by about 70 percent, while having little impact on the reductions that could be achieved from maneuvering and hotelling. Overall, the PM emissions subject to the proposed regulation would be reduced by about 53 percent. This alternative would retain emission reductions near California's major population centers, which are generally located near California's major ports, but would substantially decrease the emissions reduced in other coastal areas. This could be of particular concern to several coastal counties such as San Luis Obispo, Ventura, and

Santa Barbara Counties, which are impacted by ship emissions due to a major shipping line that traverses relatively close to their shoreline. In addition, statewide modeling conducted by ARB staff has shown that emissions from transiting along the coast can impact not only coastal areas but areas well inland as well. See Appendix E-1.

As summarized in Table V-5, with alternative #4, there would about 2,400 less tons PM reduced in year 2010 (the first full year of implementation), and an estimated $146 million cost reduction. Overall, the cost-effectiveness of the proposed alternative would remain the same because the costs and emission reductions are both reduced by the same percentage. Although this alternative would reduce costs and target emission reductions near population centers, the proposal would not achieve emission reductions in other coastal areas. In addition, pollutants from ships can be transported long distances, reaching sensitive areas. For these reasons, we recommend the proposed regulation.

Table V-5: Comparison of Annual Costs and PM Emission Reductions Between Alternative #4 and the Proposed Regulation for 2010

Estimated Cost ($ millions)			Estimated Reductions (tons/yr)			Cost-Effectiveness ($/ton)	
Alt. #4	Proposal	Savings	Alt. #4	Proposal	Loss	Alt. #4	Proposal
$129.3	$275	$146	2,146	4,566	2,420	60,200	60,200

In consideration of the greater PM reductions from the ARB proposal (2400 tons) and similar cost-effectiveness, ARB staff rejected Alternative 4.

REFERENCES

(EPA, 2002) United States Environmental Protection Agency, *Control of Emissions of Air Pollution from New Marine Compression-Ignition Engines at or Above 30 Liters/Cylinder*, Notice of Proposed Rulemaking, April 30, 2002, Table VI.F-1.

(EPA, 2003) United States Environmental Protection Agency Regulatory Announcement, *Emission Standards Adopted for New Marine Diesel Engines*, EPA420-F-03-001, January 2003.

(EPA, 2004) United States Environmental Protection Agency Fact Sheet, *Clean Air Nonroad Diesel Rule*, EPA420-F-04-032, May 2004.

VI. TECHNOLOGICAL FEASIBILITY OF THE PROPOSED REGULATION

In this chapter, we discuss the technological feasibility of the proposed regulation. In particular, we focus on the availability of the required fuels and the ability of ocean-going vessels (OGVs) to use those fuels in the auxiliary diesel and diesel-electric engines, main propulsion diesel engines, and auxiliary boilers. We also address safety and other issues that were raised during this rulemaking (similar to those raised in the rulemaking process for the Auxiliary Engine Regulation in 2005). ARB staff carefully analyzed the fuel availability, safety, operational, and other issues and concluded that the fuel sulfur limits and other requirements in the proposal are technologically feasible and can be met safely by vessel operators.

ARB staff is proposing a regulation to require operators of OGVs to use cleaner-burning marine distillate fuels in auxiliary diesel and diesel-electric engines, main propulsion engines and auxiliary boilers (OGV engines and auxiliary boilers) on vessels operating within a 24 nautical miles (nm) zone of the California coastline (Regulated California Waters). Unless they already use complying distillate fuels or choose to use distillate fuels on a permanent basis, vessel operators will need to switch from using heavy fuel oil to compliant marine distillate fuel prior to entering Regulated California Waters (RCW). The proposed regulation will apply to both U.S.-flagged and foreign-flagged vessels. As described previously in this report, the proposed regulation is implemented in two phases beginning in 2009 and requiring a more stringent fuel sulfur level again in 2012. The proposed regulation would establish the most comprehensive and stringent marine fuel-use requirement in the world.

The proposed regulation contains a safety exemption if the master of the vessel determines that compliance would endanger the safety of the vessel, crew, cargo or passengers. An exemption is also provided for ship operators that can demonstrate the need for essential modifications to comply.

A. Availability of Marine Distillate Fuels

ARB staff investigated the availability of low sulfur marine distillate fuels to meet both the Phase 1 and Phase 2 requirements. For the Phase 2 requirements, staff also considered two different implementation years – 2010, consistent with the Auxiliary Engine Regulation, and 2012, which is the Phase 2 implementation date for the proposed OGV Regulation. The investigation focused on the Pacific Rim ports where California-bound vessels would likely obtain the fuel necessary to comply with the proposed OGV Regulation. ARB staff relied on fuel test data provided by Det Norske Veritas (DNV) Petroleum Services, outreach to and feedback from fuel suppliers and providers, and other technical information regarding world refining markets to provide information that could provide indications regarding fuel availability. Our key findings are briefly summarized below, and additional details on the investigation can be found in Appendix F.

Overall, we believe the fuel specified in the proposed OGV Regulation will be available for vessel operators to purchase; however, there is some uncertainty in our findings, particularly with respect to the availability of fuels to meet the Phase 2 specifications. There are thousands of ports throughout the world where OGV can obtain fuel and, out of necessity, we focused our investigation on selected Pacific Rim ports and assumed that our findings also represent the ports not addressed.

While we have a reasonable basis for our belief that sufficient low sulfur marine distillate fuels will be available to comply with the proposal, reaching this conclusion was not without difficulty. First, it was difficult to obtain definitive fuel volume data, and many marine fuel suppliers' responses hinged on whether or not the demand would be sufficient to warrant a change in fueling infrastructure or supply from the refiners. In some cases, language barriers existed, and it is not certain if the fuel supplier fully understood our questions or discussions. At other times, some suppliers were somewhat hesitant in providing data due to confidentiality concerns.

Perhaps one of the more significant concerns is with Phase 2 of the proposal. Given the current global fuel and economic issues, constraints on supply, and uncertainty with the overall fuel markets, predicting marine fuel markets several years in the future is risky at best. But there are current market and regulatory trends that suggest the market for low sulfur marine distillate fuels may continue to expand. Indeed, some have suggested that the shipping industry may need to move away from bunker fuel, as refiners see diminishing returns with continuing to supply bunker fuel and instead switch to increasing production of higher value distillates.[1] Nevertheless, it will be important for ARB staff to monitor implementation of the regulation and be prepared to make mid-course adjustments in the event the fuel is not available or if the fuels available cannot meet the ISO specifications for marine distillate fuels.

Key Findings – Phase 1 Fuel Availability

- The amount of fuel needed to comply with the proposed regulation, about 1 million tons or about 1% of the worldwide volume of marine distillate fuels, is unlikely to have a significant impact on worldwide supply or demand for fuels that meet the Phase 1 fuel sulfur specifications.
- There is, and should continue to be a sufficient worldwide supply of MGO and MDO meeting the Phase 1 fuel specifications and this fuel should be available at all key fueling ports servicing California-bound OGVs. Most ports worldwide have MGO that meets the Phase 1 fuel specifications. About half of the ports worldwide have MDO that can meet the Phase 1 0.5% sulfur specification for MDO.
- Overall, we expect the average fuel sulfur content of MDO or MGO purchased to be about 0.3%.

[1] Unni Einemo, *Rude Awakening?*, quoting Dr. Rudy Kassinger of DNV (visited June 3, 2008) <http://www.sustainableshipping.com/news/2007/07/68368>. (SustainableShipping, 2007)

- There may be some limited logistical or spot supply issues in obtaining Phase 1 fuel at some ports. However, we expect the number of ports that do not have marine distillate fuels to be very small.

Key Findings – Phase 2 Fuel Availability in 2010

- We expect in 2010, the worldwide volume of MGO or MDO that can meet the Phase 2 fuel specifications will exceed the 1 million tons required for implementation of the proposed regulation.
- For 2010, there will not be sufficient supply of the Phase 2 (0.1% sulfur) MGO or MDO at key Pacific Rim ports serving California-bound OGVs.
- The average sulfur content of MGO and MDO in 2007 at 25 of the 31 Pacific Rim ports exceeded the Phase 2 fuel sulfur specifications.
- It is unlikely that a sufficient supply will be available prior to 2012 due to crude supply, refining capacity, and fueling infrastructure improvements that will be needed.

Key Findings – Phase 2 Fuel Availability in 2012

- For 2012, the issues outlined above for 2010 should be lessened due to the additional time for fuel providers and suppliers to develop and implement the necessary fueling infrastructure.
- We expect supplies of LSMDF across the world to increase as refinery upgrades are made to meet the increasing demands for cleaner diesel fuels for land-based equipment, including on- and off-road vehicles. However, while there will be increases in lower sulfur fuels for land-based equipment, we cannot assume that this same fuel could also be used for marine (due to specifications, price premium, and competition).
- There are significant refinery projects underway and planned that are expected to provide additional refining capacity near those bunkering ports where LSMDF will be in demand. Refineries have a strong economic incentive to produce higher-value products, such as LSDMF, over residual fuel as long as the demand is present.

B. Feasibility of Fuel Switching in Ocean-Going Vessel Engines

Currently, a majority of the vessels that will be subject to the proposed regulation use heavy fuel oil in their main engines, according to ARB's 2007 Ship Survey (2007 Survey). Because heavy fuel oil is a thick, viscous material at room temperature, it is heated to reduce its viscosity to the point where it can be pumped and injected into marine engines. Once liquefied, heavy fuel oil behaves much like ordinary diesel in the engine. By contrast, marine distillate fuels are liquid at room temperature, with properties already similar to typical on-road diesel fuel.

When an engine switches from one fuel to another, a transition period is generally needed to minimize rapid changes in temperature and viscosity. This helps reduce fuel

gassing; and ensure smooth, steady-state operation of the engine. To accomplish this transition period, vessel operators typically use a mixing tank. The operator steadily increases the ratio of distillate fuel to heavy fuel oil in the mixing tank, which eventually results in only distillate fuel being fed into the engine. The rate of mixing is controlled to limit the change in fuel temperature to approximately 1°F every 2 minutes (Morgante, 2008).

Considering the available information as discussed below, we believe that vessel operators can safely operate their main and auxiliary diesel engines and auxiliary boilers with compliant distillate fuels while operating within Regulated California Waters and fuel switch between to HFO and distillate upon entering and leaving the regulated waters.

Fuel Switching Procedures and Safety

As discussed above, main engines and auxiliary engines can operate continuously during transitions between heavy fuel oil and distillate fuels. Procedures for conducting these transitions are well known since vessel operators perform these transitions prior to dry-dock maintenance. Engine manufacturers and marine equipment suppliers publish guidance for vessel operators that explain the recommended procedures. (MAN B&W, 2001; Aalborg) These procedures are designed to ensure a transition period from one fuel to another that controls temperature changes and ensures minimum fuel viscosity levels are maintained. While the procedures for fuel switching are published and vessels currently fuel switch prior to dry-docking or major repair, fuels switching will occur more frequently due to the requirements of this proposed regulation.

For safety reasons, it is very important for all operators to ensure that their vessels have detailed fuel switching procedures available and that vessel personnel are all fully trained in the process. Because this is such an important safety issue, the proposed regulation requires documented fuel switch over procedures to be kept onboard the vessel. The fuel switch over procedures must include the following:

- a description and diagram of the fueling system,
- a description of the fuel switch over procedure with detailed instructions and clear identification of responsibilities; and
- information on all OGV engines and auxiliary boilers.

Engine manufacturers have commented that problems can occur if the transition is conducted too quickly, including fuel pump or injector scuffing, seizure, or cavitation, and fuel gassing. However, based on the fact that many vessels routinely transition from heavy fuel oil to distillate fuel, and virtually all vessels do this prior to dry-dock maintenance, we believe that vessel operators are well equipped to safely handle these transitions. We also note that equipment is available to vessel owners to automatically handle these fuel transitions.

As noted previously, we believe the safety of fuel transitions is amply demonstrated by the many vessels that routinely perform them. There are no problems reported for the vast majority of these fuel switches. However, there is a slight risk that temporary engine failure may occur if the vessel operator does not correctly follow procedures, possibly resulting in some loss of power to the vessel. For the case of an auxiliary engine, a vessel's emergency backup generators, which run solely on marine distillate fuel, would become operational.

The U.S. Coast Guard and shipping associations have recommended in some cases that fuel transitions in propulsion engines be performed away from confined areas. (PSSOA, 1999) This recommendation addresses the issue of compromised maneuverability in the case of loss of power. The Office of Spill Prevention and Response (OSPR) made a similar recommendation, during the rulemaking for the Auxiliary Engine Regulation, for any fuel switching during transit to be done at or beyond 24 nm offshore.[2] The proposed regulation is entirely consistent with these recommendations because the 24 nautical mile boundary in the regulation would generally result in fuel transitions being performed in open water. Arguably, switching fuels at or prior to entering the 24 nm boundary should provide a greater margin for safety than conducting the switch much closer to the ports, which is the practice for some vessels.

Existing Practice

Actual in-use experience demonstrates that marine vessels are able to operate both on HFO and low sulfur marine distillate fuel (MGO/MDO), and it is feasible to switch fuels during operation. Marine vessels currently perform the same type of fuel switches that are likely to occur under this regulation. Vessel operators perform many of these fuel switches prior to dry-dock maintenance operations to prevent heavy fuel oil from solidifying in fuel lines and engine components after engine shut down. In addition, these engines are certified by the manufacturer to International Maritime Organization nitrogen oxide emission standards through engine testing while the engine is operating on a distillate fuel, since heavy fuel oil properties are too variable. (IMO Annex VI)

The vast majority of ocean-going vessels visiting California ports during the 14 months that the Auxiliary Engine Regulation was enforced complied with the regulation by switching the fuel for their auxiliary engines to distillate fuel prior to entering within 24 nm of the California coastline. And no significant problems associated with the fuel switching were reported to ARB during that time. This not only confirmed ARB staff's

[2] California Air Resources Board, *Final Statement of Reasons for Rulemaking: Public Hearing to Consider the Adoption of Regulations to Reduce Emissions from Auxiliary Diesel Engines and Diesel-Electric Engines Operated on Ocean-Going Vessels within California Waters and 24 Nautical Miles of the California Baseline*, Dec. 8, 2005, pp. 69-70, (downloaded June 4, 2008) <http://www.arb.ca.gov/regact/marine2005/fsor.pdf>. (ARB, 2005b) The OSPR recommendation was based on the navigational risk analysis it conducted with other agencies and stakeholders. *West Coast Offshore Vessel Traffic Risk Management Project: Final Project Report and Recommendations*, Pacific States/British Columbia Oil Spill Task Force and the United States Coast Guard, July 2002. (OSPR, 2002)

belief during the auxiliary engine rulemaking that fuel switching to low sulfur distillate fuel is feasible and safe for auxiliary engines, but it also provides persuasive evidence that fuel switching can be successfully accomplished under the proposed regulation. While the Auxiliary Engine Regulation was being enforced, of the 234 ships that were boarded for compliance purposes, only 3 were cited for not using compliant fuel and 2 were cited for not switching at the required distance from the coastline. During this time there were only six vessels that opted to pay the non-compliance fee, as listed in Table VI-1 below.

Table VI-1: Ocean-Going Vessels and Associated Companies that Paid the Non-Compliance Fee (NCF)

Date Fee Paid	Vessel Type	Reason for Paying NCF
1/29/07	Tanker	Unable to find complying fuel
1/23/07	Cruise Ship	Infrequent Visitor Needs Modifications
2/9/07	Bulk Vessel	Unable to find complying fuel
6/28/07	Tanker	Unplanned redirection
2/08	Cruise Ship	Infrequent Visitor Needs Modifications
4/17/08	Tanker	Unable to find complying fuel

The diesel-electric engines on passenger vessels, which generally are large diesel generator sets that provide power for both propulsion and onboard electrical power, were subject to the Auxiliary Engine Regulation, and are an example of engines providing propulsive power which complied with this regulation without issue.

Further, some passenger liners regularly switched fuels in their diesel-electric engines for air quality reasons even before the Auxiliary Engine Regulation. For example, Carnival Cruise Lines, a major passenger cruise line, reported that it is company policy to switch to distillate MDO fuel when their vessels are within 3 miles of the California shore. (Carnival, 2005a; Carnival, 2005b) Another cruise line, Crystal Cruises, also reported that it switches to MDO near California ports to reduce smoke, and that cruise line has not had any operational problems with this practice. (Crystal Cruises, 2005)

There are also vessels that routinely switch from heavy fuel oil to distillate fuels in their main engines during California port visits. Specifically, A.P. Moller-Maersk Group, a major container ship operator, has a Pilot Fuel Switch West Coast Initiative (Maersk Pilot Program) where they are voluntarily using low (0.2% maximum) sulfur marine gas oil in their main engines within 24 nm of port. (Maersk, 2007) This is in addition to compliance with ARB's Auxiliary Engine Regulation that required them to operate their auxiliary engines on compliant distillate within 24 nm of the California coast while the

Auxiliary Engine Regulation was in effect. Maersk has indicated that they feel that the program has been successful and are happy with the results to date, it has come with a high price tag. Since March 2006, it has cost Maersk Line approximately $12 million dollars to use the low sulfur distillate. (Morgante, 2008)

The Maersk Pilot Program began in March 31, 2006, with the container ship Sine Maersk, and has included 577 fuel switches and 105 vessels, as of April 2008. The participating vessels have main engines manufactured by either MAN Diesel or Wärtsilä/Sulzer. Maersk's program includes using MGO with a sulfur level at or below 0.2% sulfur, for both the main engine and auxiliary engines. This is lower than the proposed requirements to use MGO or MDO (MDO with a 0.5% sulfur limit). In 2006, Maersk reported an average MGO fuel sulfur level of 0.17% for all participating visits in both the main and auxiliary engines. In 2007, the average MGO fuel sulfur level was 0.09%.

In Maersk's program, main engine fuel switching is completed by 24 nm from port. For the auxiliary engines, fuel switching is completed prior to the vessel entering the Regulated California Waters, 24 nm from the California coast, as required by ARB's Auxiliary Engine Regulation (until that regulation was suspended).[3] Because of ARB's requirement to use distillate within 24 nm of the coast, the auxiliary engines operate on distillate much longer, compared to the main engines under the Maersk Pilot Program. The auxiliary engines sometimes operate on distillate for as long as 5 days: as they approach the Ports of Los Angeles and Long Beach (POLA/POLB) and enter the 24 nm regulated waters at Point Conception (approximately 160 nm), as they hotel at port, and if they travel between POLA/POLB and the Port of Oakland within the regulated waters (approximately 430 nm).

The Maersk Pilot Program has included 105 different vessels and 577 successful fuel switches as of early 2008. The fleet of participating vessels is made up of a wide range of vessel build dates, and main engine make, model, model year and power rating. (*ARB, 2005a, Appendix C*) Out of the 105 participating vessels, Maersk has only reported issues related to fuel switching on 5 vessels. The issues are primarily associated with the fuel supply pumps that are used in the fuel delivery system. The issues in the fueling system have included leakage of booster and fuel feed pumps, failure of booster and fuel feed pump seals in two vessels and a crack in a fuel pump plunger in one vessel. In addition, two vessels required replacement and/or relapping of pump plunger components. (Morgante, 2008) None of these problems resulted in interruption or operational failure with the main engine.

In addition, the Maersk vessels are continuing to fuel switch when visiting California ports. There was one report concerning an auxiliary engine failure to start. It was determined that pump wear, combined with low fuel viscosity, was the cause. All of these issues were reported for vessels that had build dates in the 1990s and have Wärtsilä/Sulzer main and auxiliary engines.

[3] While the Auxiliary Engine Regulation was recently suspended due to the *PMSA* lawsuit, it is staff's understanding that Maersk remains committed to voluntarily meeting that regulation's requirements.

Maersk has indicated that a number of their chief engineers have concerns about the long term impacts of using distillate fuels in engines that were designed to operated on heavy fuel oil. They believe that it is still too early to determine what, if any, long term effects the fuel switch may have on their engines. (Morgante, 2008)

Maersk also reported that while running on low sulfur MGO, the main engines are operated on a BN 70 cylinder lubricant which is typically used with HFO, but with a lower feed rate than would be used for HFO operation. Maersk has not reported any excess cylinder wear or deposit build-up in the main engines as a result of fuel switching between the low sulfur MGO and heavy fuel oil. In addition, Maersk's fuel switching procedures include a maximum fuel temperature change of 1°F per every two minutes during fuel switch to minimize thermal impacts to the equipment and fuel viscosity.

Another example of fuel switching in the main engines involves four steel coil carrier vessels operated by USS-POSCO Industries. In these vessels, the operators switch from heavy fuel oil to ultra-low (less than 0.05%) sulfur diesel two to three hours prior to entering the Bay Area Air Quality Management District boundary on their regular routes between South Korea and Pittsburg, California. (McMahon) These fuel switches have been performed since the early 1990's to facilitate the use of on-board selective catalytic reduction emission control systems to reduce emissions of nitrogen oxides.

Finally, we should note that switching to distillate fuels upon entry to port was a standard practice for most diesel powered vessels in the past, when it was difficult for main engines to operate reliably on heavy fuel oil during maneuvering and low load operation. The use of less expensive heavy fuel oil in main engines during maneuvering is a relatively recent development made possible by improvements in fuel heating technology. (BMT, 2000)

C. Feasibility of Using Distillate Marine Fuels in Ocean-Going Vessel Main Propulsion Engines

Currently, a majority of the vessels that will be subject to the proposed regulation use heavy fuel oil in their main engines. To comply with the in-use fuel requirements for the proposed regulation, the operators can either use compliant fuel in main engines during all operation or can use compliant fuel in Regulated California Waters and switch to a lower cost HFO outside the regulated waters. The proposed regulation would likely result in ship operators using compliant fuel within Regulated California Waters and switching to HFO outside the regulated zone. The previous section addressed the feasibility of switching fuel. The following sections will concentrate on the feasibility of using compliant fuel in the Regulated California Waters.

Vessel Fuel Infrastructure Needs

Most vessel operators are equipped to run their main engines on distillate fuel as needed to comply with the proposed regulation. About 13 percent of the companies responding to our 2007 survey indicated the need for vessel modifications to use MGO/MDO in their main engines within 24 nm of the California coastline. Specifically, 168 out of 761 vessels (22 percent) were reported to need modifications to operate on distillate within 24 nm of the California coastline.[4] These changes may or may not require that the vessel be dry-docked. Dry-dock maintenance typically occurs every five years, while many other maintenance operations are performed while the vessel is at dockside.

For vessel operators that reported the need to modify their vessels, changes to the following types of equipment were reportedly necessary:

- fuel valves
- fuel piping and pumps
- fuel tank(s)
- cylinder lube oil system
- engine fuel pumps
- engine fuel injectors.

Several companies reported that they would need fuel tank modifications to use MGO/MDO in their main engines out to 24 nm. Of the vessels reporting, about half indicated that they would need fuel tank modifications. Most vessels have multiple fuel tanks and adequate MDO/MGO capacity to meet the requirements of this regulation. (Herbert, 2007). Some vessel operators may choose to make modifications to provide for a more convenient fuel-switching operation since fuel-switching will occur more frequently than what is traditionally done. If the vessels does need additional capacity, vessel owners may need to add new storage or day tanks, convert an existing heavy fuel oil tank to distillate, or segregate an existing tank to carry sufficient quantities of distillate.

If a new or segregated tank is desired, ancillary equipment such as pumps, piping, vents, filing pipes, gauges, and access would be required, as well as tank testing. (Entec, 2002) In addition, fuel processing systems include settling tanks, filters, and centrifuges may also be necessary. While some vessel operators may be able to use their existing processing systems, other operators have reported that they will need to add to these systems, along with increased fuel capacity or other modifications.

As noted previously, mixing tanks are used to assist in a gradual transition from one fuel to another to prevent sudden changes in fuel temperature or viscosity may cause damage to fuel pumps and injectors. (Wärtsilä, 2005a) Fuel coolers may be installed to

[4] As noted in later in this chapter, the Economic Impacts chapter (Ch. 9), and Appendix C, ARB staff believes this survey result overestimates the modifications needed, and the actual figure is likely to be substantially lower.

assist in controlling fuel temperatures and viscosity during fuel transitions. Furthermore, fuel coolers can be used to increase the viscosity of the compliant distillate fuels if the fuel viscosity is below the minimum, as specified by the engine manufacturer. (Herbert, 2007)

A small number of survey participants reported the need to modify engine components such fuel pumps, injectors, and nozzles. However, engine manufacturers have stated that, with certain caveats, the engines they designed for heavy fuel oil can also operate on MGO without these modifications. Additional information on the type of modifications reportedly needed is discussed in the summary of the survey results provided in Appendix C.

Staff believes that these figures may overestimate the number of vessels that will require essential modifications to comply with this proposal. All vessels are configured to switch to distillate fuel while going into dry-dock, in certain emergency conditions and prior to large-scale engine work. (Briers, 2008) Maersk, the world's largest shipping line, has reported that no capital investments were necessary to implement their voluntary program using marine distillate fuel in 105 vessel main engines while visiting California ports (Maersk, 2007). In addition, many ocean-going vessels that frequently visit California have been using distillate in their auxiliary engines to comply with ARB's Auxiliary Engine Regulation. Therefore, many of the fuel system modifications necessary to use distillate will have already been completed for compliance with the Auxiliary Engine Regulation.

Based on the survey, of the 168 vessels (22 percent of the total) that were reported to need modifications, approximately 62 vessels reported modifications for fuel system piping and pumps. These modifications most likely would have been performed to comply with the Auxiliary Engine Regulation. In addition, over half (90) of the 168 vessels were owned by two shipping companies. Neither company could provide follow-up information to confirm that these modifications were essential to comply with this regulation. Another vessel operator confirmed that the modifications they reported to be needed were to comply with potential Sulfur Emission Control Areas (SECA) requirements to use the distillate out over much larger regions.

Based on the reasons discussed above, ARB staff believes that the vast majority of vessels will not require modifications to comply with the proposed regulation. However, in the event that a vessel cannot use the low sulfur fuels without modifications, we have included in the proposal an exemption for vessel operators who can demonstrate the need for essential modifications to comply with the fuel-use requirements.

Technical and Safety Considerations

ARB staff met with the major manufacturers of main engines used on ocean-going vessels to determine whether these engines could operate on marine distillate fuel (marine gas oil or marine diesel oil). Engine manufacturers uniformly reported that their main engines, designed for use with heavy fuel oil, can also operate on distillate fuels. (Herbert, 2007) However, they noted that certain technical and safety considerations need to be observed with the use of distillate fuels and during the transition from one fuel to another. Given this, we believe that vessel operators already can and do safely use distillate fuels when they follow the engine manufacturers' recommendations. Each of the technical considerations is discussed below.

Fuel Compatibility: Engine manufacturers have commented that there is always a risk of fuel incompatibility when blending two fuels, particularly between heavy fuel oil and distillate fuels (especially very low sulfur distillate fuels which tend to be low in aromatic hydrocarbons). The main concern is that aromatic hydrocarbons in heavy fuel oil keep asphaltene compounds in solution, and the introduction of lower sulfur (often low aromatic) fuels may cause some asphaltene compounds to precipitate out of solution and clog fuel filters.

Much of the available information on this subject is focused on continuous blending of low sulfur distillate fuels with high sulfur heavy fuel oils to produce 1.5% sulfur fuel for Emission Control Areas in Europe. In these situations, there may be a greater potential for filter plugging to occur than during the temporary mixing of fuels that occurs during the switchover from one fuel to another. And manufacturers have stated that incompatibility problems are a concern during fuel transitions as well. However, while these concerns are theoretically possible, they have not translated to real-world problems under the Auxiliary Engine Regulation. Our experience implementing that regulation in 2007-2008 shows that fuel compatibility was not reported to be problematic when the vast majority of ocean-going vessels transitioned from heavy fuel oil to distillate prior to entering Regulated California Waters.

Some manufacturers have stated that the potential for incompatibility problems is more of a concern with the very low sulfur on-road fuels which tend to have the lowest aromatic levels. (CIMAC, 2004; MAN B&W, 2005) Again, based on experience from implementing the Auxiliary Engine Regulation, we know that some distillate fuels meeting the CARB on-road diesel sulfur limits (15 to 500 ppm) have been used in ship auxiliary engines. Even though such on-road fuels are not expressly designed for use in marine auxiliary engines, there have been no reports to date of compatibility issues with these very low-sulfur, on-road fuels.

Compatibility of Lubricants with Low Sulfur Fuels: Marine engine lubricants are matched to the expected sulfur content of fuel. Specifically, sulfur in fuel results in acidic compounds in the engine that need to be neutralized by alkaline calcium compounds in the engine lubricant. Higher "base number (BN)" lubricants are able to

neutralize higher sulfur fuels. When a relatively high BN lubricant is used with a low sulfur fuel, calcium deposits can form in the combustion chamber.

For two-stroke engines using lower sulfur fuels with a relatively high BN lubricant, problems are generally not expected unless low sulfur fuel is used for extended periods of time. One engine manufacturer recommends that their two-stroke engines can continue to use the same high BN lubricant when a heavy fuel oil engine alternates between heavy fuel oil and distillate fuel. (Wärtsilä, 2005b) Another manufacturer reported that their heavy fuel oil engines are expected to be able to operate for up to 300 hours on marine gas oil with high BN lubricants. We do not expect vessels to spend anywhere close to 300 hours of operation while traveling within 24 nm zone. This is because a vessel would only need 40 hours to travel at 20 knots along the entire 800 nm California coastline. In the Maersk Pilot Program, the BN 70 cylinder lubricant was not switched to a lower BN number lubricant due to the limited duration of distillate use in the main engine. The BN 70 feed rate was, however, decreased.

D. Feasibility of Using Marine Distillate Fuels in Ocean-Going Vessel Auxiliary Boilers

Feasibility of Using Distillate Marine Fuels

According to both ship operators and boiler manufacturers, ship auxiliary boilers can be safely operated on distillate fuels. As summarized below, most ship operators reported that a switch to distillate fuels in California could be easily implemented. However, as with the use of distillate fuels in auxiliary and main diesel piston engines, there are certain technical precautions that need to be considered. A few operators reported that evaluations of their boilers would be needed to determine if modifications would be necessary to ensure safe operation of their boilers on distillate fuels. However, the proposed regulation provides an exemption for vessel operators that can demonstrate the need for essential modifications to comply with the fuel requirements.

Ship Operators: Numerous ship operators were contacted to determine whether marine distillate fuels could be used in existing ship auxiliary boilers that normally use heavy fuel oil. Matson Navigation, a container shipping line, reported that the auxiliary boilers used on their vessels are not fuel sensitive, and can use either distillate or residual fuels (Matson, 2007). Matson also reported that they currently use distillate fuel at all times in some of their auxiliary boilers because it results in less fouling (buildup of soot deposits on boiler convective surfaces) compared to heavy fuel oil. They reported that use of distillate fuels does not introduce any additional safety concerns beyond the usual precautions with operation on heavy fuel oil. However, in some of their larger vessels, they reported that they may need to add more tank capacity and associated piping for distillate fuel if it were to be required in both the auxiliary engines and boilers.

Another large container shipping line, American Presidents Line (APL), reported that distillate fuels could be used in their boilers (APL, 2007). They did not expect that any modifications would be needed.

Crystal Cruises, a passenger cruise liner, reported that they already voluntarily use distillate fuel in or near California ports to ensure that they don't have any visible PM emissions (Crystal Cruises, 2007).

Tanker operators also reported that distillate fuel could be used in their boilers. However, they reported that their boilers may need modifications. Tankers are a special case because they have much larger auxiliary boilers because of the high power requirements to discharge crude and other products. Chevron Shipping Company (Chevron) reported that the use of distillate in new vessels would not be a concern, but it could be for older vessels. For one of their large auxiliary boilers, they are considering an upgraded combustion system and associated piping (Chevron, 2007). BP reported the need to evaluate each of their boilers on their tankers to determine if any modifications would be necessary to safely us the required distillate fuel. (BP, 2007)

Boiler Manufacturers: The leading manufacturer of marine auxiliary boilers, Aalborg-Industries, reported that their boilers can be used with distillate fuel (Aalborg, 2007). However, it was reported that the burners on older models would need to be adjusted for distillate fuel to achieve maximum efficiency (although you could still burn distillate without this adjustment). Specifically, they reported that their newer boilers, manufacturer after about 1993 or 1994, would automatically adjust their burners for maximum efficiency with distillate fuel without any manual input. For their earlier models, a manual adjustment would be needed to optimize the efficiency of the boiler.

Another boiler manufacturer, Osaka Boiler Manufacturing Company, reported that distillate fuel can be used without adjustment in all their boilers, with the exception that marine gas oil (DMA grade fuel) with a viscosity below 2.5 centistokes (cSt) would require the replacement of the fuel oil pump in boilers made prior to April, 2004 (Osaka, 2007).

Auxiliary Boilers: Marine auxiliary boilers can be operated on marine distillate fuels, as long as certain precautions are taken. Distillate fuel is a lighter, less viscous fuel with different properties than heavy fuel oil, and in some cases this will require some adjustments or modifications to marine boilers and fuel pumps. Table VI-2 below discusses some of the technical considerations identified by a marine boiler manufacturer (Aalborg, 2005) and ship classification society (DNV, 2005).

Table VI-2: Technical Considerations Associated with the Use of Marine Distillate Fuel (MGO) in Marine Auxiliary Boilers

Technical Issue	Solution
Distillate fuel has a slightly higher fuel heat value, which may result in a less than optimal air fuel ratio and an increase in smoke.	Readjust air/fuel ratio.
Distillate fuel has lower fuel viscosity, and associated lower lubricity. If the viscosity is below about 4-5 cSt it could result in damage to some boiler fuel pumps or the supply fuel pumps.	Shut off trace heating normally used with residual fuel. If necessary, install a fuel cooling system to increase viscosity of the fuel. Modify or replace fuel pump with a newer design more tolerant of low viscosity fuel. Modify the control system to turn off fuel pumps when boiler is on standby with distillate fuel.
Distillate fuel has a lower fuel density which means the amount of fuel to the burner will differ from the pre-set amount. This could result in increased smoke or ignition problems.	Readjust fuel flow based on lower density of fuel.
Distillate fuels have a lower flash point that is occasionally lower than the required 60C (140F). This presents a greater risk of fire.	Only purchase fuel meeting flash point requirements.
The lower viscosity of distillate fuel could result in an increase in the fuel input through pressure jet burner nozzles. This could increase smoke emissions.	Adjust fuel pressure or modify burner nozzles to avoid smoke. On steam atomizing burners.
Rotary cup burner compatibility with distillate fuel. Smoke. Accidental ignition of main burner when ignition flame out.	Install heat shield on rotary cup burners. Adjust control system for lighter fuels to ensure main burners do not accidentally ignite.
Steam atomizing burner compatibility with distillate fuel. Coke deposits on rotary cup burners. Accidental ignition of main burner when ignition flame out. Burner overfiring or fuel gassing with steam atomizing burners.	Adjust control system for lighter fuels to ensure main burners do not accidentally ignite.
Fuel gassing during changeover to distillate.	Use procedures that allow for gradual mixing to avoid large temperature changes.

E. Feasibility of Using Distillate Marine Fuels in Ocean-Going Vessel Auxiliary Engines

The feasibility of using distillate marine fuels in ocean-going vessel auxiliary engines is discussed in detail in the Initial Statement of Reasons for the Auxiliary Engine Regulation, which is incorporated by reference in this document. (ARB, 2005a) Like the proposal, the Auxiliary Engine Regulation also required the use of distillate marine fuels in ocean going vessel auxiliary engines. It was enforced for approximately 14 months starting in January 2007. As mentioned previously, the overwhelming compliance rate

of ocean-going vessels with that regulation amply demonstrates the feasibility for auxiliary engines.

Vessel Fuel Infrastructure Needs

Most vessels are equipped to run their auxiliary engines on either distillate fuel or heavy fuel oil. About 6 percent of the vessels that participated in the 2007 Survey reported the need for vessel modifications to use marine gas oil in their auxiliary engines. However, PMSA has admitted in its legal challenge to the Auxiliary Engine Regulation that no vessel changes are necessary for vessels to run their auxiliary engines on distillate and that engine manufacturers uniformly reported that their auxiliary engines designed for use with heavy fuel oil can also use compliant distillate fuels as long as proper fuel switching procedures are used. (PMSA, 2008) PMSA has also stated publicly that it requested its members to voluntarily comply with the Auxiliary Engine Regulation even though that regulation currently is not being enforced. (SustainableShipping, 2008)

Technical and Safety Considerations

We believe that vessel operators already can and do safely use distillate fuels when they follow the engine manufacturers' recommendations. Only one safety exemption was issued during the 14-month enforcement period of the Auxiliary Engine Regulation and that exemption was for fuel that was not within the fuel flashpoint specification. Issues related to the use of distillate fuels in auxiliary engines were addressed in the Initial Statement of Reasons for the Auxiliary Engine Regulation. (ARB, 2005a)

F. Impact of Reducing Marine Distillate Fuel Sulfur Levels

The process used to reduce the fuel sulfur levels during distillate processing may affect the physical properties such as lubricity, viscosity and flashpoint. While sulfur is not a lubricant, the process used to reduce the sulfur level can impact fuel lubricity (CIMAC, 2007). The viscosity of distillate fuel is already considerably lower than HFO. Concerns have been raised that the viscosity of distillate fuel will further decrease as the sulfur level decreased. In addition, stakeholders voiced concerns about the potential impacts on the availability marine fuels which have a higher flashpoint than on-road diesel fuels, since the distillate market is dominated by lower flashpoint on-road distillates. The following sections address both the distillate fuel properties and any differences in properties as a function of the fuel sulfur levels.

Lubricity: Lubricity can be defined as the ability to provide surface contact lubrication. Adequate levels of fuel lubricity are necessary to protect the internal contact points in fuel pumps and injection systems to maintain reliable performance. Natural lubricity of diesel fuel is dependent on the presence of trace levels of oxygen- and nitrogen-containing compounds that provide surface-active molecules that adhere to or combine with metallic surfaces to produce a protective film that reduces wear. (Nikanjam, 1993)

Several sources reported that lower sulfur fuels have lower lubricity, which could potentially cause fuel pump damage. (DNV, 2005; CIMAC, 2004; MAN B&W, 2005) Unlike low sulfur automotive diesel fuels, marine fuel standards do not include minimum lubricity standards. The California diesel fuel specification (Title 13, CCR, Sections 2281-2285 Title 17, CCR, Section 93114) requires a minimum level of lubricity. This is measured as a wear scar diameter (WSD) at 60°C of 520 µm or less using the ASTM D6079-02 method. The European diesel fuel specification (EN 590) requires a WSD at 60°C of 460 µm or less using the ISO 12156-1 method. (Dieselnet, 2006)

Desulfurization or hydrotreating processes, used to reduce the sulfur levels in the distillate fuel, have been reported to lower the lubricity of the fuels due to the reduction of trace surface-active molecules. (Nikanjam, 1993) When these fuels are sold into the marine market, there is no lubricity requirement to ensure a minimum level of fuel lubricity as would be required in the on-road distillate market.

Because there is limited experience using these hydrotreated low sulfur distillates in the main engine and there is very limited data on marine distillate lubricity, it is unknown what minimum level of lubricity would be required to prevent fuel pump problems. For example, one source states that sulfur levels below 0.05%, in conjunction with a viscosity below 2 cSt, could lead to fuel pump problems. (DNV, 2005, App. I) Another source reported that lubricity is not considered a problem for their four stroke engine fuel injectors as long as the sulfur content is above 0.01% (100 ppm) (*Wärtsilä, 2005b*). Still another source noted that lubricity additives could be added by the fuel manufacturer or marketer. (Wärtsilä, 2005b)

Information from a number of sources indicates that some of the compliant distillates may have very low sulfur levels, even in Phase 1 of the fuel requirements in the proposed regulation. The low levels of sulfur in the marine distillates are possibly due to the influence of automotive diesel sulfur standards of 0.0015% sulfur (15 ppm). For example, in California, the majority of marine distillate samples tested by DNV in 2007 were below their lowest detection limit of 0.05% sulfur. (DNV, 2007) ARB's Auxiliary Engine Regulation field inspections data found a number of marine distillate samples below 0.01% (100 ppm) sulfur. The International Council on Combustion Engines (CIMAC, 2007) guidelines indicate that if marine distillate fuels fulfill the limits of the European diesel fuel lubricity standard, having a WSD at 60°C of 460 µm or less, there is a high probability that these fuels will not cause lubricity problems. (CIMAC, 2007)

To gather data on the lubricity of lower sulfur in-use marine distillates, ARB conducted a study to test the lubricity, along with a number of other fuel properties, of a portion of the marine distillate samples taken during inspections. A total of 28 MGO and MDO samples, ranging from 0.007% to 1.5% sulfur, were tested in this study. Lubricity testing was performed at 25, 40 and 60°C, using the high-frequency reciprocating rig method per ASTM D 6079-04. Although 60°C is the standard test temperature, testing was performed at the three temperatures since the fuel temperatures at the inlet to the engine may vary, depending on fuel switching procedures and other operational parameters. Figure VI-1 shows the WSD diameter of all the samples tested for the

lubricity study. Table VI-3 lists the bunkering information and additional properties for each of the fuel samples.

Figure VI-1: HFRR Lubricity Results for Enforcement Samples (Wear Scar Diameter in Micrometers at 25, 40 and 60°C)

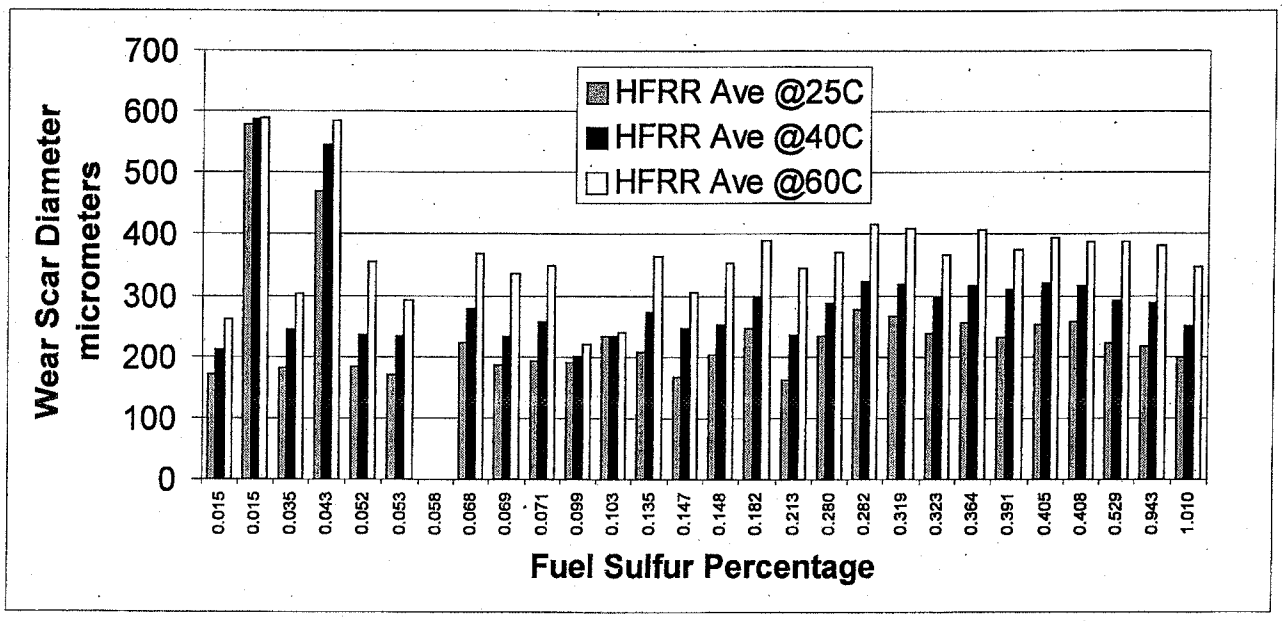


Table VI-3: Distillate Lubricity and Fuel Property Test Results for Inspection Samples

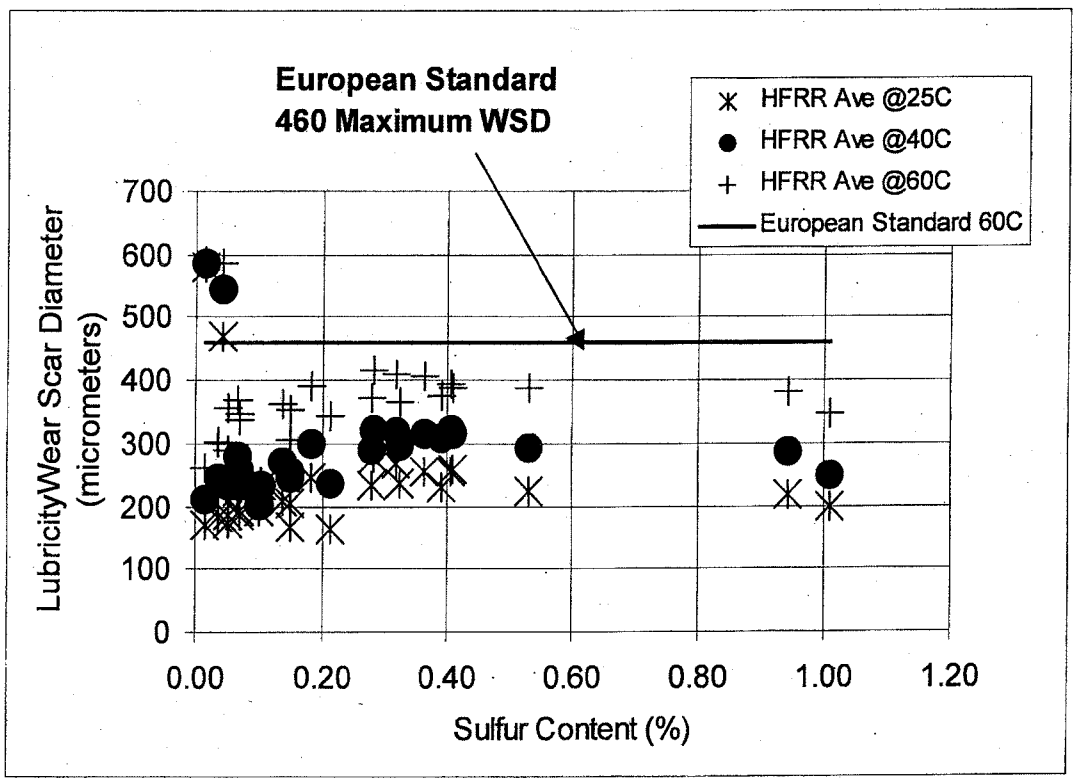
Bunker Location City/Port	Fuel Type	% Fuel Sulfur	Flash Point °F	Cetane Index	Kinematic Viscosity @°40C cSt	HFRR(1) Ave @25°C	HFRR Ave @40°C	HFRR Ave @60°C
Long Beach	MGO	0.02	178	41.9	3.0	172	213	262
Richmond	LSD	0.02	154	51.8	2.8	580	587	589
Tokyo	MGO	0.04	168	54.9	3.2	183	246	304
Manzanillo	MDO	0.04	146	52.7	3.8	470	547	585
Long Beach	MGO	0.05	178	44.7	3.2	185	237	356
Busan	MGO	0.05	156	51.7	2.8	172	233	292
Tokyo (2)	MDO	0.06	-	-	3.9	-	-	-
POLA	MGO	0.07	154	50.2	2.9	223	280	370
Tauranga	MGO	0.07	192	56.4	2.5	187	235	336
Tokyo (3)	MDO	0.07	158	47.5	2.8	194	258	348
POLA	MDO	0.10	150	53.0	3.8	192	203	222
Savannah	MGO	0.10	156	46.9	2.6	234	234	241
Busan	MGO	0.14	152	44.6	3.0	209	272	364
Busan	MGO	0.15	154	50.6	2.9	166	247	306
Zeebrugge	MGO	0.15	164	48.7	3.6	205	255	353
Ama	MGO	0.18	164	47.6	2.8	247	299	391
Singapore	MGO	0.21	166	52.8	3.6	164	236	345
Barcelona	MGO	0.28	178	48.5	3.7	234	289	371
Hong Kong	MGO	0.28	166	52.9	3.8	278	323	417
Long Beach	MGO	0.32	166	50.7	3.5	268	318	410
Busan	MGO	0.32	158	52.4	3.4	238	297	367
Singapore	MGO	0.36	176	51.4	3.5	255	317	407
Hong Kong	MGO	0.39	166	51.9	4.2	231	309	376
Hong Kong	MGO	0.41	170	51.0	4.2	255	322	394
Busan	MGO	0.41	158	52.9	3.7	258	317	389
Kokura	MGO	0.53	168	47.5	3.8	224	292	389
Rotterdam	MGO	0.94	186	46.0	4.3	217	289	383
Rotterdam	MGO	1.01	180	42.0	3.9	199	251	347

(1) Average of two tests at each temperature. Wear Scars are in micrometers.
(2) Sample was unstable due to water in fuel. Only partial analysis was completed.
(3) Fuel additive-Econofree 50liters /100 tons

The results from the lubricity study indicate that a majority of the marine distillates tested meet the more stringent European diesel fuel WSD standard of 460 µm, when tested at 60°C, as well as at the lower temperatures. This is shown in Figure VI-2 below. Although the two samples with WSDs higher than 460 um were measured for distillates with very low sulfur levels, there is no clear trend showing a relationship between fuel sulfur level and lubricity in this study. This data indicates that lubricity is

not likely to be a significant issue during the Phase 1 requirements, even if very low sulfur distillates are used in some instances. It does indicate that it may be a bigger concern in Phase 2, when only marine distillates at or below 0.1% sulfur are required. Ship operators can add lubricity additives at low cost if they feel it is necessary or they may be able to request a minimum lubricity level when purchasing fuel. ARB staff believes that a two phase approach, such as that contained in the proposal, will allow time to obtain more data on fuel lubricity and its impact on longer term engine performance.

Figure VI-2: HFRR Measured Lubricity Wear Scar Diameter vs. Sulfur Content



Low Viscosity: Both major main engine manufacturers, MAN and Wärtsilä, noted that the low viscosity of distillate marine fuels could potentially be a concern with some of their engines. One of the potential impacts of low fuel viscosity is greater internal leakage in fuel pumps and injectors, resulting in lower fuel pressures, and less fuel delivered. (DNV, 2005) Another potential impact is that the lower viscosity fuels may fail to provide a hydrodymanic film between moving components to prevent wear and damage in the fuel pumps. MAN has recommended a minimum of 1.5 to 2.5 cSt (cSt) at the inlet to the engine in order to ensure a hydrodynamic film between the wear surfaces. (Aabo, 2008). Wärtsilä has recommended minimum viscosities in the range of 1.8 to 3 cSt, depending on the engine model and whether the engine is 2-stroke or 4-stroke. (Wärtsilä, 2007)

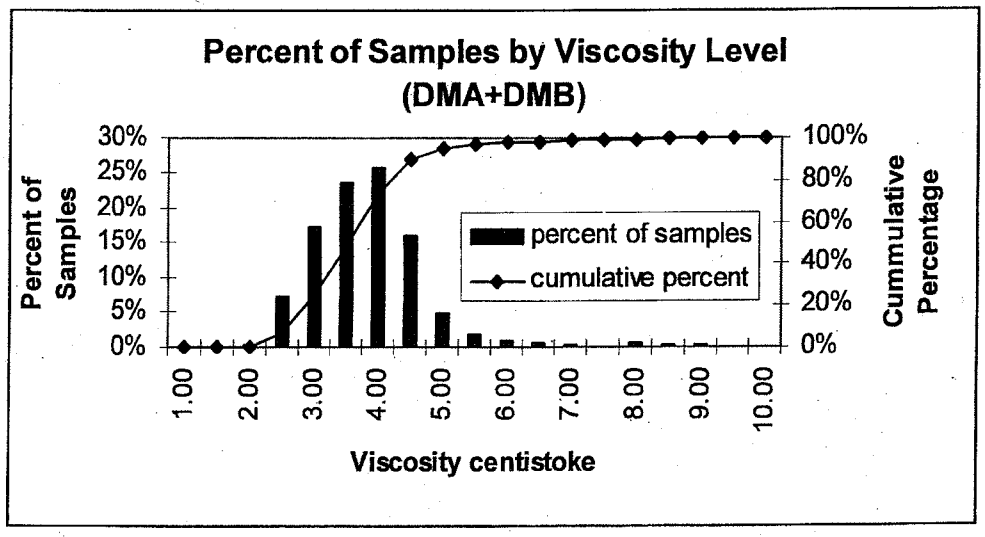
CIMAC has indicated that a minimum viscosity level of 2 cSt is recommended to avoid operational problems to the fuel equipment. (CIMAC, 2007) The minimum fuel viscosity for MGO per ISO 8217 is 1.5 cSt, which is below the CIMAC recommendation. As listed in Table VI-4, results from the analysis of the 2007 DNV fuel sample data indicate that the minimum viscosity of MGO is1.5 cSt and MDO is 1.97, both below the minimum recommended by CIMAC. However, the average viscosity of MGO (DMA) is 3.5 cSt and MDO (DMB) is 3.9 cSt, which is above both the CIMAC and engine manufacturers' recommendations.

As shown in Figure VI-3, the majority of samples analyzed are above 2.0 cSt and 50 percent of the samples analyzed are above 3.5 cSt. Because of these values, one engine manufacturer suggested that that a viscosity level could be specified when ordering distillate fuels. Another approach to control fuel viscosity would be to add a fuel cooler since lowering the fuel temperature will increase its viscosity. This modification could be installed at a ship's normal dry-docking. (Herbert, 2007)

Table VI-4: Range in Fuel Viscosity of Marine Distillate Fuels Analyzed (DNV, 2007)

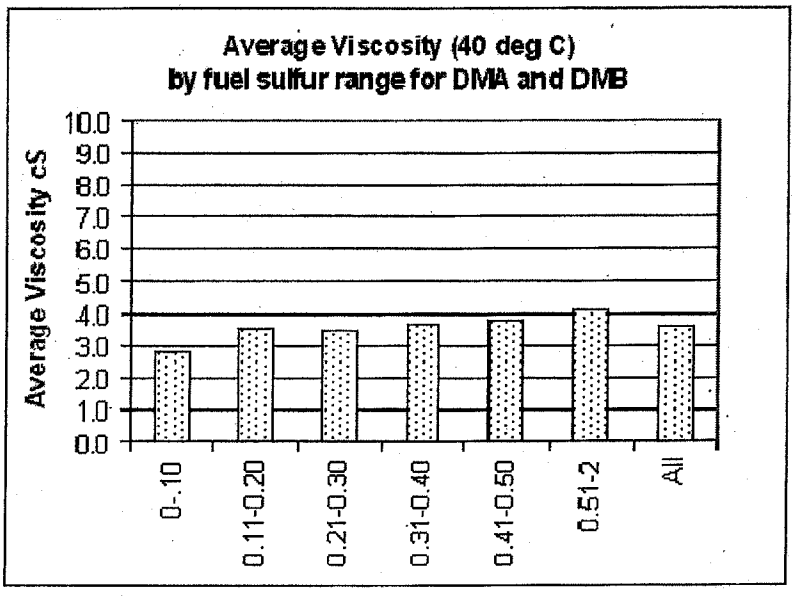
Fuel Type	Min cSt	Max cSt	Ave cSt
DMA	1.5	9.7	3.5
DMB	2.0	9.9	3.9
DMA+DMB	1.5	9.9	3.6

Figure VI-3: Fuel Viscosity Distribution of DMA and DMB Marine Distillate (DNV, 2007)



As shown in Figure VI-4, the average viscosity of fuels in the range of 0 to 0.1% sulfur is slightly lower than the average viscosity of fuels with higher sulfur content. However, there is no strong correlation in viscosity as a function of sulfur content for the distillate fuels, and all averages are above 2.0 cSt.

Figure VI-4: Average Fuel Viscosity by Sulfur Level for DMA and DMB Marine Distillate Fuels (DNV, 2007)



A two-phase approach will allow the operators more flexibility in managing fuel viscosity issues, specifically during the first phase of the rule implementation. Because the sulfur levels are not as restrictive in Phase 1, the operators will have more flexibility in specifying higher viscosity levels when purchasing the fuel. Operators and engine makers will have additional data and experience prior to Phase 2, where fuel availability of 0.1% sulfur MGO/MDO may make finding compliant fuels with higher viscosity more difficult.

Fuel Energy Content Differences: Marine distillate fuels have less energy than heavy fuel oils on a volume basis. Some manufacturers have commented that this will reduce the output of an engine by approximately 6-15 percent depending on the engine design and model. (Wärtsilä, 2005b; Yanmar, 2005; Pielstick, 2004) Depending on the engine, governor adjustments or a change in the fuel "rack" position may address this issue.

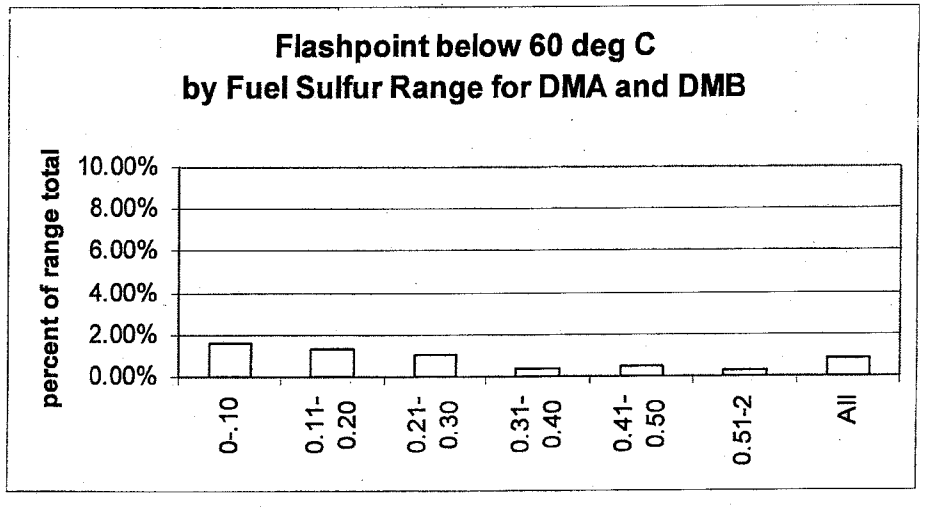
Flash Point: The flash point is the temperature at which a combustible liquid gives off just enough vapor to produce a vapor/air mixture that will ignite when a flame is applied. The importance of flash point is primarily related to safe handling of the product. If the flash point is too low, there could be a fire hazard. The minimum flash point for marine fuels is 60°C.

Marine fuels differ from land-based distillates in the minimum flash point specification. Marine fuels have a minimum flash point of 60°C, while land-based diesel fuels typically have a minimum flash point of 52°C. Analysis of the 2007 DNV distillate fuel properties indicate that less than 1 percent of all samples analyzed were below 60°C and that there was no correlation between sulfur level and flash point.

As shown in Figure VI-5, the DNV data shows a slightly higher percentage of below minimum flash point fuels in the range of 0 to 0.1% sulfur. (DNV, 2007) However, the percentage of below minimum flash point samples was below 2 percent for all the ranges analyzed. Since fuel flash point is tested for acceptance and the specified flash point is a requirement to sell, these fuels would be defective. These results indicate that in all sulfur level ranges, 98 percent of all samples meet the marine fuel specifications.

It should be noted that, while the larger on-road diesel market has not significantly impacted the availability of marine distillates meeting the higher flashpoint requirement, a sufficient supply of on-road diesel, with its lower flashpoint, does not insure sufficient quantities of low sulfur marine distillates meeting the 0.1% sulfur limit and higher flashpoint.

Figure VI-5: The Percent of Samples Below Minimum Flash Point (60°C) by Sulfur Level for DMA and DMB Marine Distillates (DNV, 2007)



Leakage: Use of less viscous marine distillate fuels, and temperature changes that occur during transitions between heated heavy fuel oil and non-heated distillate fuel have been reported to increase the likelihood of fuel leaks. However, such leaks would also be expected to occur during fuel transitions performed prior to dry-dock operations. Such leaks can be prevented through maintenance, such as replacement of deteriorated seals, gasket materials or o-rings, and tightening connections. Technical issues such as fuel system leaks are relatively manageable if attention is paid to fuel specification, maintenance, and training. A two-step implementation process will

provide the operators added flexibility, such as specifying and using higher viscosity fuels, to manage such leakage issues to the extent they may occur.

Further Studies

Engine makers and some ship operators have expressed concerns that use of very low sulfur MGO/MDO may cause damage to ocean-going vessel main engines because of low fuel viscosity and/or low fuel lubricity. While very low sulfur fuels, in the range of 15 ppm sulfur, are not a requirement of this regulation, they may make up a significant portion of the available compliant fuel used the meet the Phase 2, 0.1% sulfur requirement. Lubricity testing of fuel samples having sulfur levels above 0.1% shows that those fuels met the stringent European on-road diesel standard, and average viscosity values were higher for the ranges above 0.1% sulfur.

By contrast, the lubricity of the samples below 0.1% sulfur did not meet the stringent European on-road lubricity standard, in limited cases, and the average viscosity level was slightly lower than in the higher sulfur MGO/MDO. Furthermore, there is very limited information and data on the operation of these engines on very low sulfur distillates, and the impact of operating on very low sulfur MGO/MDO on the long-term performance of modern two-stroke ocean-going vessel main engines.

To further study these issues, ARB is performing two additional studies to investigate the impacts of fuel switching in OGV main engines. The first study investigates the acceptable lower limits of fuel viscosity and lubricity in the high pressure injection fuel pumps. The second study investigates the long term impacts of fuel switching on main engine performance, component wear and failure rates.

Investigate the Impacts of Using Low Sulfur Marine Distillate Fuels in Marine Fuel Injection Pumps

Some ship operators have expressed concern that use of low sulfur fuels (especially below 0.05% sulfur) would be damaging to fuel injection pumps because these fuels are low in viscosity and may be low in lubricity. In this study, ARB is partnering with the major marine engine manufactures to bench test low sulfur distillate fuels in simulated a "pump rig test." For this program, a fuel injection pump, typical of a large two-stroke, slow-speed engine, would be operated on a test stand. The pump will be operated with the designated fuel for a specified period of time and then disassembled and inspected for wear. The goal of this testing is to determine the lower limits of fuel lubricity and viscosity for marine fuel injection pumps used on large two-stroke, slow-speed OGV main engines.

Evaluate the Effect of Low Fuel Viscosity and Low Fuel Lubricity on Large Slow-Speed Two-Stroke Ocean-Going Vessel Main Engines

In this study, fuel switching between heavy fuel oil (HFO) and low sulfur-clean burning distillate would be done on a select number of ocean-going vessel main engines.

Currently, there have been no documented long term studies or demonstrations on the effect of low sulfur marine fuels on the long term performance and operation of modern two-stroke ocean-going vessels which routinely fuel switch between HFO and distillate. In this program, the long term operation, such as engine performance, component failure rate, and component wear would be evaluated to determine the long term effects of fuel switching. Shipping companies and engine makers would provide in-kind services to partner with the ARB. In addition, emission testing for diesel PM, criteria pollutants and greenhouse gasses would be performed to determine emission benefits of fuel switching.

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VII. ENVIRONMENTAL IMPACTS

This chapter describes the potential environmental impacts of this proposed regulation. The proposed regulation is intended to protect the health of California's citizens by reducing the exposure to the emissions from ocean-going vessels. An additional consideration is the impact that implementation of the proposed control measure may have on the environment. Based upon available information, ARB staff has determined that no significant adverse environmental impacts should occur as the result of the proposed regulation with the exception of a small, potential increase in greenhouse gas emissions. This chapter describes the potential impacts that the proposed regulation may have on water quality, hazardous waste disposal, air quality and greenhouse gas emissions

A. Legal Requirements

The California Environmental Quality Act (CEQA) and ARB policy require an analysis to determine the potential environmental impacts of proposed regulations. Because ARB's program involving the adoption of regulations has been certified by the Secretary of Resources pursuant to Public Resources Code section 21080.5, the CEQA environmental analysis requirements may be included in the Initial Statement of Reasons (ISOR) for this rulemaking. In the ISOR, ARB must include a "functionally equivalent" document, rather than adhering to the format described in CEQA of an Initial Study, a Negative Declaration, and an Environmental Impact Report. In addition, staff will respond, in the Final Statement of Reasons for the control measure, to all significant environmental issues raised by the public during the public review period or at the Board public hearing.

Public Resources Code section 21159 requires that the environmental impact analysis conducted by ARB include the following:

- an analysis of reasonably foreseeable environmental impacts of the methods of compliance;
- an analysis of reasonably foreseeable feasible mitigation measures; and
- an analysis of reasonably foreseeable alternative means of compliance with the control measure.

Regarding reasonably foreseeable mitigation measures, CEQA requires an agency to identify and adopt feasible mitigation measures that would minimize any significant adverse environmental impacts described in the environmental analysis.

Compliance with the proposed control measure is expected to directly affect air quality and potentially affect other environmental media as well. Our analysis of the reasonably foreseeable environmental impacts of the methods of compliance is presented below.

The proposed control measure is needed to reduce the risk from exposures to diesel PM as required by Health and Safety Code (H&S) section 39666 to meet the

requirements of H&S sections 43013(b) and 43018, and to fulfill the goals of the Diesel Risk Reduction Plan and the Goods Movement Emission Reduction Plan. The proposed regulation is also needed to reduce emissions of directly-emitted PM, NOx, and SOx; reduce secondarily-formed PM from NOx and SOx; and help with attaining the federal and State ambient air quality standards for PM_{10}, $PM_{2.5}$ and ozone. Alternatives to the proposed control measure have been discussed earlier in Chapter V of this report. ARB staff has concluded that there are no alternative means of compliance with the requirements of H&S section 39666 that would equivalent or greater diesel PM emission reductions at a lower cost.

B. Potential Water Quality Impact

ARB staff does not expect this regulation to have any adverse impacts on water quality. The proposed regulation's requirements, particularly the reduction in sulfur content of the engine fuels, should result in reduced formation of sulfuric acid, nitric acid and other harmful compounds to the extent the vessel emissions actually come into contact with ocean or inland waters. And because scrubbers and other exhaust treatment technologies are not allowable methods of compliance with this proposal, there are no impacts that might otherwise result from the byproducts of such methods (e.g., ash, salts, heavy metals from catalytic oxidizers, etc.).

C. Potential Hazardous Waste Impact

ARB staff does not expect this regulation to have any adverse impacts on hazardous wastes. The proposal is a straightforward low-sulfur fuel use requirement. And as noted previously, the proposal does not allow for alternative methods of compliance, such as the use of catalytic oxidizers or scrubbers. Thus, staff does not expect this regulation to have any adverse impacts on hazardous wastes.

D. Potential Air Quality Impact

The proposed regulation will provide diesel PM, PM, NOx, and SOx emissions reductions throughout California, especially in coastal urban areas many of which are non-attainment for the State and federal ambient air quality standards for PM10, PM2.5 and ozone. Air quality benefits will result from the reduction of SOx emissions as well because SOx secondarily forms PM in the atmosphere.

Emission Reduction Estimates

The emission reductions that would result from the proposed regulation were estimated based on the differences in emissions between the use of marine heavy fuel oil (HFO), and the cleaner burning marine distillate fuels specified in the regulation (marine gas oil (MGO) or marine diesel oil (MDO)). Specifically, from July 1, 2009 through 2011, we estimated the emission reductions that would occur from switching from 2.5% sulfur HFO to 0.5% sulfur marine distillate fuel. For 2012 and beyond, we estimated the

emission reductions from switch from 2.5% sulfur HFO to 0.1% sulfur marine distillate fuel, as specified in the regulation.

The 2.5% sulfur level assumed for HFO is based on ARB's 2005 Ship Survey (ARB, 2005), and ARB's more recent 2007 survey (ARB, 2007) indicates a similar sulfur level. The sulfur levels used for marine distillate fuels are based on the proposed regulation. Specifically, the proposed regulation requires the use of 0.5% sulfur MDO, or MGO with no limit in 2009. We are confident that the sulfur level for MGO will average below 0.5% sulfur without imposing a sulfur limit, based on enforcement samples taken for the auxiliary engine regulation that yielded an average sulfur level of about 0.3%.

Based on the results of ARB's 2007 survey and discussions with ship operators, we believe that the vast majority of main engines and auxiliary boilers use HFO. Therefore, we approximate the emissions from these sources assuming that they use HFO only. For auxiliary engines prior to regulation, we estimate that 78 percent use HFO, and 22 percent use marine distillate fuels. This is based on the ARB's 2005 ship survey (the ARB's 2007 survey was not used because in 2007 the use of distillate fuel was mandated by ARB in California).

When vessel operators switch from heavy fuel oil to distillate fuels, the PM emissions decrease, in large part, because of the lower sulfur content of distillate fuel, which in turn reduces the formation of sulfate PM. In addition, the lower ash content and lower density of distillate fuel also contributes to lower PM emissions (EPA, 2002). The lower sulfur content of distillate fuel also directly contributes to lower SOx emissions. For example, lowering the sulfur content from 2.5% to 0.5% (an 80 percent reduction in fuel sulfur) reduces SOx emissions by 80 percent. The lower nitrogen content of distillate fuels also results in a reduction in NOx emissions (EPA, 2002).

The estimated emission factors for main engines, auxiliary engines, and auxiliary boilers are shown in Table VII-1 below. Emission factors are used to estimate the average emissions for a class of engines or boilers under specified conditions; under the proposal, these factors are not used for compliance testing or for determining emissions from individual engines or boilers. While the emissions from an individual engine will vary significantly based on the engine model, engine condition, and specific fuel used, these emission factors represent our best overall estimates based on the available engine test data. We recognize that emissions test results for PM vary widely depending on the source of information, and others have estimate PM emission factors differently. These emission factors are discussed in more detail in Appendix D.

Table VII-1: Estimated Emission Factors (g/kw-hr)

Pollutant	HFO @ 2.5% sulfur	MGO @ 0.5% sulfur	MGO @ 0.1% sulfur
Main Engines (transiting)			
NOx	18.1	17.0	17.0
SOx	10.5	1.9	0.36
PM	1.5	0.38	0.25
Auxiliary Engines (all modes)			
NOx	14.7	13.9	13.9
SOx	11.1	2.1	0.4
PM	1.5	0.38	0.25
Auxiliary Boilers (all modes)			
NOx	2.1	2.0	2.0
SOx	16.5	3.0	0.6
PM	0.8	0.2	0.13

The estimated percent emission reductions from main engines, auxiliary engines, and auxiliary boilers that switch from HFO to distillate fuels are shown in Table VII-2 below. As shown, the emission reductions in PM and SOx are dramatic, while there is also a smaller NOx reduction.

Table VII-2: Estimated Emission Reductions for All Sources Switching from 2.5% Sulfur Heavy Fuel Oil to the Distillate Fuels

Pollutant	Percent Reduction: HFO to MGO @ 0.5% Sulfur	Percent Reduction: HFO to MGO @ 0.1% Sulfur
NOx	6%	6%
SOx	80%	96%
PM	75%	83%

Table VII-3 below shows the current and projected OGV emissions within the 24 nautical mile zone for main and auxiliary engines and auxiliary boilers. The future year projections are based on the growth assumptions discussed in Appendix D.

Table VII-3: Projected Emissions from OGV in 24 Nautical Mile Zone

Pollutant Source	2006	2010	2020
	PM (tons/day)		
Main Engine	10	12	18
Auxiliary Engine	3.4	3.9	4.2
Auxiliary Boiler	1.2	1.3	1.8
Total	15	17	24
	NOx (tons/day)		
Main Engine	115	133	203
Auxiliary Engine	39	45	48
Auxiliary Boiler	3.1	3.5	4.6
Total	157	182	256
	SOx (tons/day)		
Main Engine	68	79	120
Auxiliary Engine	25	28	31
Auxiliary Boiler	25	27	36
Total	118	134	187

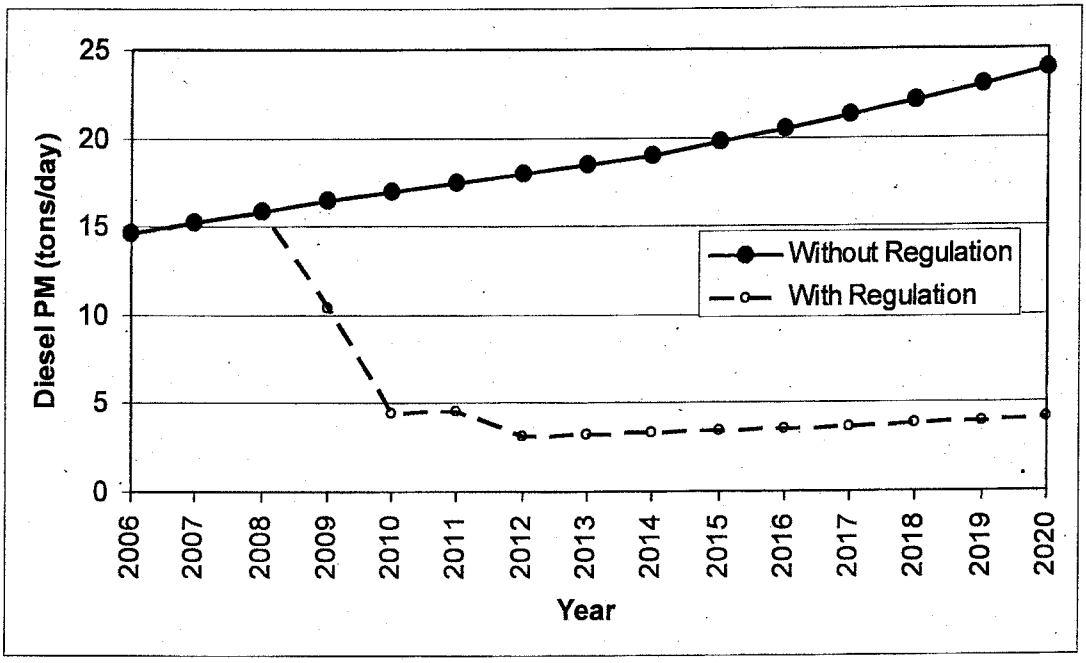
ARB staff estimates that implementation of the proposed regulation will result in immediate and substantial reductions in diesel PM, PM, NOx, and SOx emissions, as shown in Table VII-4 below. Upon the first full year of implementation in 2010, this represents a 74 percent reduction in PM emissions from the baseline emissions subject to the regulation (emissions within the 24 nautical mile zone). For 2012 and later, we estimate an overall 83 percent reduction in PM emissions

Table VII-4: Projected Reductions in OGV Emissions in 24 nm Zone Due to Proposed Control Measure

	Total Emission Reductions (Tons per Day)		
Year	PM	NOx	SOx
2010	13	10	109
2015	16	12	148
2020	20	15	178

Figure VII-1 illustrates how the PM emissions from ship auxiliary engines within the 24 nautical mile zone will grow with and without the proposed control measure. As shown, the proposed regulation will significantly reduce emissions as compared to the uncontrolled baseline.

FigureVII-1: Estimated Diesel PM Emissions in 24 nm Zone With and Without the Implementation of the Proposed Regulation



E. Potential Greenhouse Gas Impact

Impact of Proposed Regulation on CO_2 Emissions

Shipping is a relatively small but significant contributor to worldwide emissions of greenhouse gases (GHG). The primary GHG from shipping is carbon dioxide (CO_2) resulting from fuel combustion. By some estimates, shipping is responsible for about two percent of worldwide CO_2 emissions. (Marintek, 2000)

The proposed regulation would only cover a small percentage of the travel by ocean-going vessels worldwide (i.e., travel within 24 nautical miles of the California coastline). As a result, the CO_2 emissions from vessels traveling within 24 nautical miles of California are estimated to be less than one percent of worldwide shipping emissions. Nevertheless, we wanted to determine the overall impact of the proposed regulation on GHG emissions. The use of the marine distillate fuels specified in the proposed regulation would be expected to reduce CO_2 emissions in California because marine distillate fuels have a higher energy content by weight as compared to heavy fuel oil, resulting in lower fuel consumption. On the other hand, some sources have indicated that producing distillate fuels at the refinery requires more energy than heavy fuel oil, resulting in more CO_2 emissions.[1]

[1] Guy Wilson-Roberts, *Industry Rejects CO2 Arguments*, (visited June 2, 2008) <http://sustainableshipping.com/news/2007/09/69050>.

To examine the net impact of the proposed regulation on CO_2 emissions, ARB contracted with Dr. James Corbett and Dr. James Winebrake of Energy and Environmental Research Associates for a study of the total fuel-cycle emissions. The complete study can be found in Appendix H. Their analysis estimated the total fuel-cycle CO_2 and SOx emissions associated with fuel extraction, fuel processing, fuel distribution, and fuel consumption. To estimate the emissions at each stage, they used a modification of the peer-reviewed Total Energy & Emissions Analysis for Marine Systems (TEAMS) model, which was originally based on Argonne National Lab's GREET model (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation). The TEAMS model was modified to allow analyses for the particular set of fuels under study.

Corbett and Winebrake estimated that requiring a switch from residual fuel to the distillate fuels specified in the regulation would correspond to a net increase in CO_2 emissions of approximately 1 to 2 percent over the total fuel cycle (and an 86 to 97 percent decrease in SOx emissions). This slight increase in net fuel-cycle CO_2 emissions is primarily a function of the increased energy required at refineries that produce compliant distillate fuels. This offsets the localized decrease in CO_2 emissions from ship operations (fuel combustion) in California due to the higher energy content of the distillate fuel, as compared to heavy fuel oil. But this study assumes that refineries will make no efforts to improve energy efficiency while maintaining, upgrading, or expanding their capacity to produce distillate fuels. This is unlikely given rising energy costs and global efforts to reduce GHG.

Any potential increase due to the proposal may also be temporary, as pending amendments to IMO treaty protocols are likely to provide for the creation of Emission Control Areas, where equivalent fuel standards could be implemented by 2015 in sensitive regions worldwide. An ECA is functionally similar to the 24 nm jurisdictional zone under the proposed regulation, except that an ECA potentially can be much larger.

In addition, the study points out that the global refining industry is on a steady path toward greater production of higher value distillate fuels, and the modest increase in distillates produced by the proposal may already be accommodated by planned refinery upgrades. Therefore, the potential fuel-cycle increase in CO_2 emissions due to greater use of more highly refined marine distillate fuel may be overestimated.

If CO_2 emissions associated with the cleaner fuels specified in the proposal do increase by 1 to 2 percent under this proposal, we project such an increase could result in up to 50,000 metric tons per year of additional CO_2. While this is a very small increase relative to the overall CO_2 emissions from shipping, we nevertheless believe this may represent a significant adverse environmental impact.

Staff evaluated a number of alternatives to this proposal (see Chapter V, section N). However, staff was not able to identify any feasible alternatives that would substantially reduce the potential adverse impacts of this regulation while at the same time ensuring that the positive environmental impacts (e.g., the reduction in exposure to diesel PM,

PM, NOx, and SOx emissions) would be achieved. Staff was also unable to identify any feasible mitigation measures that could be incorporated into the proposed regulation that would substantially reduce the potential adverse impacts, while at the same time ensuring that the positive environmental impacts that would be achieved. However, other ARB programs will substantially reduce greenhouse gas emissions and will more than offset the potential increase in greenhouse gas emissions from this regulation. These programs are discussed below in the section entitled *Reasonable Foreseeable Mitigation Measures.*

Despite our finding of a potential significant adverse environmental impact, we believe the very substantial health and environmental benefits from the proposal clearly constitute overriding considerations that justify the proposal. Staff believes that reducing diesel PM and exposure to diesel PM, PM, NOx and SOx emissions as described in this Staff Report is a consideration that overrides the very small adverse impacts that may occur as a result of this proposed regulation.

Specifically, the potential 1 to 2 percent increase in CO_2 must be weighed against the benefits of the estimated 75-83 percent reduction in diesel PM, the 80-96 percent reduction in SOx, and the 6 percent reduction in NOx emissions. And as discussed in Section D below, these emission reductions are estimated to result in substantial reductions in premature death, asthma attacks, lost work days, and other health impacts. Thus, staff believes these substantial health and environmental benefits clearly outweigh and override the very small adverse impacts from a potential 1 to 2 percent increase in the shipping CO2 emissions associated with vessels that visit California.

Climate Change Impacts from Reductions in Non-CO_2 Emissions

In the above analysis, we discussed potential CO_2 impacts associated with the proposed regulation. The proposed regulation will significantly reduce several criteria air pollutants, including NOx, SOx, and fine PM, that may contribute to global warming or cooling. The science to quantify the net impact that changes in these pollutants will have on the global climate is still evolving and definitive estimates are not yet possible. However, the following section provides an overview of the current understanding of the potential climate impacts of these pollutants.

Nitrogen oxides (NO_X)

Through the production of tropospheric ozone, emissions of NO_X have a climate warming impact. However, by affecting the concentration of hydroxyl radical (OH) they reduce the levels of methane, providing a cooling effect. The net climate impact of changes in NO_X emissions will depend on whether ozone or methane production dominates. At this time, there is no consensus on which action is likely to dominate or on the overall magnitude of the impact due to changes in NOx emissions resulting from the regulation.

Sulfur oxides (SOx)

Sulfur dioxide is oxidized to sulfate, and about 3% of the annual atmospheric global sulfate load originates from ship emissions. Sulfate aerosols scatter sunlight, thus cooling the earth–atmosphere system. One would expect that reducing the sulfur content in marine fuel could have a net warming effect due to reductions in light-scattering sulfate aerosols. Currently it is not possible to estimate the magnitude of these effects.

Particulate Matter (PM)

PM from OGV engine exhaust is composed of combustion particles consisting of elemental and organic carbon, and sulfate, all of which can form aerosols. Atmospheric aerosols play an important role in the climate system through modifications of the global energy budget: directly, by the scattering and absorption of radiation; indirectly, by the modification of cloud properties.

Black carbon (BC), typically emitted as a fraction of PM from combustion processes, is the main light-absorbing component of aerosols and thereby causes global warming. In recent years there has been increased attention to BC for its global warming potential through direct and semi-direct effects. BC, as a short-lived GHG, is believed to have a net climate warming impact. Reductions in BC may be an effective means to reduce global warming in the near term. The light-scattering or light-absorbing properties of individual aerosol particles depend on the extent to which black carbon is mixed with primarily scattering aerosol components, such as sulfates and organics. Organic carbon PM, which is emitted along with BC and generally has a light-scattering effect, may act to offset some of the global warming impact of BC emissions.

In general, black carbon and sulfate particles are expected to have a strong impact on the atmospheric radiation budget. The magnitude of the overall direct climate impact of BC emitted from OGVs, the properties of particles emitted by OGVs, and their fate of the particles in the marine environment are not well known.

Aerosols emitted by OGV have also been known to contribute to the formation of clouds over the ocean. The interactions of aerosols and clouds have been identified as one of the most important uncertainties in understanding the rate of climate change, or global warming, because clouds reflect energy and thereby reduce the net warming effect of long-lived greenhouse gases. Since aerosols have a much shorter lifetime in the atmosphere -- about a week compared to decades and hundreds of years for greenhouse gases -- these effects have been difficult to quantify.

F. Estimating the Health Benefits Associated with the Reductions of Diesel PM Emissions

Reduced Ambient PM Levels

Implementing the proposed regulation will mitigate air quality impacts from OGVs emissions significantly. Staff estimated that ambient diesel PM concentrations resulting from OGV emissions will be decreased by 74% in 2010 and 83% in 2012. Similarly, ambient $PM_{2.5}$ SO_4 concentrations resulting from OGV emissions will be reduced by about 80% in 2010 and 95% in 2012. Staff also expects that implementing the proposed regulation would reduce ambient levels of $PM_{2.5}$ NO_3, and ozone.

Reduced Cancer Risk Levels

The proposed regulation would reduce diesel PM emissions from OGV activities substantially. Staff estimated that potential cancer risk level statewide will be decreased by almost 75% by 2010 and by over 80% in 2012. Staff estimates that the average statewide cancer risk due to diesel PM emissions from OGV will be reduce from 70 chances in a million in 2006 to 15 chances in million in 2012 with implementation of the proposed regulation.

Reduced Non-cancer Health Impacts

A substantial number of epidemiologic studies have found a strong association between exposure to ambient particulate matter (PM) and adverse health effects (ARB, 2002, 2006, 2008). For this report, ARB staff conducted a quantitative analysis of seven potential non-cancer health endpoints associated with the change in exposures to the model-predicted ambient levels of directly emitted diesel PM and $PM_{2.5}$ sulfate (primary and secondary). Below are the estimated non-cancer health impacts from direct PM avoided between 2009 and 2015 due to the proposed regulation.

- 1,650 premature deaths (450 to 2800, 95% CI)
- 42,000 asthma attacks (16,000 to 68,000, 95% CI)
- 540 hospital admission – respiratory (130 to 950, 95% CI)
- 640 hospital admission – cardiovascular (350 to 930, 95% CI)
- 3,600 acute bronchitis (0 to 8,000, 95% CI)
- 280,000 work loss days (240,000 to 300,000, 95% CI)
- 1,600,000 minor restricted activity days (1,300,000 to 1,900,000, 95% CI)

Below are the estimated non-cancer health impacts from PM2.5 sulfate (primary and secondary) avoided between 2009 and 2015 due to the proposed regulation.

- 1,920 premature deaths (520 to 3,300, 95% CI)
- 56,000 asthma attacks (21,000 to 90,000, 95% CI)
- 650 hospital admission – respiratory (160 to 1,100, 95% CI)
- 750 hospital admission – cardiovascular (400 to 1,100, 95% CI)

- 4,700 acute bronchitis (0 to 10,,000, 95% CI)
- 340,000 work loss days (290,000 to 390,000, 95% CI)
- 2,000,000 minor restricted activity days (1,600,000 to 2,300,000, 95% CI)

In May 2008 ARB released a draft methodology for estimating premature deaths associated with long-term exposures to fine airborne particulate matter in California that proposes increasing the relative risk factor from 6% to 10% increase in premature death per 10μg/m³ increase in PM2.5 exposures (ARB, 2008). The premature deaths avoided listed above were calculated using the 6% value. If the 10% value were used the estimates of premature deaths avoided would increase by 67%.

Methodology: The methodology used to estimate the health endpoints is discussed in Chapter IV with the following additions. To estimate the ambient concentrations of directly emitted PM and PM2.5 sulfate (primary and secondary) for different scenarios, we decreased the ambient concentration in each grid cell by the projection factor (or growth factor) and the ratio of the emission reductions anticipated from the proposed regulation to the estimated total emissions without the regulation for the pollutant of interest. We believe that this assumption of linearity between reduction in mass emission and reduction in ambient concentration is reasonable for direct PM and primary and secondary sulfate. However, we believe that this assumption is not appropriate for secondary nitrate since the fate of NOx is highly dependent on a number of factors including the concentration of other chemicals in the air and the environmental conditions during release and transport. Because of these uncertainties, and because the expected NOx reductions were about 5%, we did not estimate changes in the concentration of PM2.5 nitrate (or the associated health benefits) due to NOx reductions from the proposed regulation.

Assumptions and Limitations of Health Impacts Estimation: Several key assumptions were used in our estimation. They involve the selection and applicability of the concentration-response functions to California data, exposure estimation, subpopulation estimation, and baseline incidence rates. These are briefly described below.

- ARB staff assumed the model-predicted exposure estimates could be applied to the entire population within each modeling grid. That is, the entire population within each modeling grid was assumed to be exposed uniformly to modeled concentration. This assumption is typical of this type of estimation.

- ARB staff assumed the baseline incidence rates were uniform across each modeling grid and in many cases across each county. This assumption is consistent with methods used by the U.S. EPA for its regulatory impact assessment. The incidence rates match those used by U.S. EPA.

- The uncertainty in the mortality estimates are on the order of ±50 percent.

Value of Premature Deaths Avoided: The U.S. EPA has established $6.3 million (in 2000 $) for a 1990 income level as the mean value of avoiding one death (U.S. EPA, 2003). As real income increases, people may be willing to pay more to prevent

premature death. The U.S. EPA further adjusted the $6.3 million value to $8 million (in 2000 $) for a 2020 income level. ARB staff developed the valuation of avoiding various health effects, complied from ARB and U. S. EPA publications, updated to 2005 dollars (Table A-8, ARB, 2006). Based on the valuations, we calculated the cumulative health benefits (in 2005 dollars) resulting from avoiding premature deaths through this regulation from year 2009 to 2015 and projected to year 2008 to reflect current values.

Using these estimates, the total valuation of the avoided premature deaths (1650) due to directly emitted diesel PM emission reductions from the proposed rule is about $15 billion in 2008 dollars. For $PM_{2.5}$ sulfate emission reductions due to the proposed regulation the estimated total valuation of the avoided premature deaths in the SCAB is about $18 billion in 2008 dollars. Note that the values of certain non-mortality health effects, such as asthma attack, work loss day, and minor restricted activity day, are very small compared to the value of premature dearth. Mortality dominates the valuation of health effects. Because of this, we only estimated the valuation of the avoided premature deaths.

Conclusion: The health benefits of implementing the proposed OGV regulation are substantial. The estimated statewide benefit from reductions in directly emitted diesel PM from OGV over 2009 to 2014 is about $15 billion. The estimated health benefit from reductions in PM2.5 sulfate between 2009 and 2014 of reduced premature mortality is about $18 billion in the South Coast Air Basin. The total health benefits will be even greater since we have not considered the reductions in $PM_{2.5}$ sulfate in area outside of the SCAB. We also were not able to account for the heath benefits associated with reductions in $PM_{2.5}$ nitrate.

G. Reasonably Foreseeable Environmental Impacts as a Result of Potential Compliance Methods

While we expect the regulation to have substantial benefits for air quality improvements and some potentially significant adverse impacts on GHG emissions, there may be other air quality effects that can result if ship operators decide to alter current practices.

Use of Alternative Overwater Routes to Avoid Regulatory Requirements

It is possible that some vessel operators may use longer alternative routes to minimize the amount of travel within "Regulated California Waters (RCW)," which is approximately 24 nautical miles (nm) offshore of the California coastline. This is because many vessel operators currently travel significant distances along California's coastline within RCW, when alternative routes somewhat farther offshore (outside of the RCW) are possible. For example, cargo ships travelling to and from the Ports of Los Angeles and Long Beach (POLA/POLB) most often travel over 100 nm within RCW along the California coastline from Point Conception to the ports. Cargo ships traveling the 400 nm route between the POLA/POLB and the Port of Oakland also typically travel primarily within RCW. Cruise ships on the most common Mexico cruises typically travel roughly 100 nm within RCW from the ports to the overwater U.S./Mexico border.

In deciding whether to use alternative routes, ship operators will likely weigh the added fuel use and travel time associated with the longer alternative routes against the added cost of using the more expensive distillate fuels specified in the proposed regulation on existing routes. Ship operators will likely also consider company policies, safety, and other factors associated with alternative routes.

If vessel operators frequently choose alternative routes outside of RCW, there could be some potential environmental impacts. The existing shipping routes are primarily chosen to minimize the overwater distances, travel time and fuel use. If ship operators choose longer alternative routes, fuel use and associated emissions will increase. In addition, emissions will increase because the cleaner fuels will not be used outside of RCW. The associated emissions increase will be mitigated to some extent by the fact that the emissions are occurring farther offshore. However, for greenhouse gas emissions from the vessels, where the location of emissions is relatively unimportant, there would be a disbenefit.

Another potential impact is associated with U.S. Navy missile test ranges surrounding the Ports of Los Angeles and Long Beach (POLA/POLB). The Navy missile test ranges occupy vast overwater regions extending well offshore along the California coast from San Luis Obispo in the north, to San Diego and into international waters off the coast of Mexico in the south (U.S. Navy). This region is comprised of the Operating Area of Southern California Range Complex (SOCAL OPAREA), to the south of POLA/POLB, and the Point Mugu Sea Range, northwest of the POLA/POLB.

Although numerous vessels currently travel within these test ranges, the Navy has expressed concern that their weapons testing and training activities could be more difficult if there is a large increase in vessel traffic to routes that move outside the Channel Islands. Specifically, they said that most of their operations are conducted south and west of the Northern Channel Islands (San Miguel, Santa Rosa, Santa Cruz and Anacapa), and north and west of San Nicolas Island. The Navy has also said that such a route change could result in greater NOx emissions transported to California communities.

While some individual vessel operators may decide to change their existing routes, ARB staff does not expect that there will be a significant shift to alternative routes by the shipping lines. This potential existed during implementation of the Auxiliary Engine Regulation, and ARB staff did not see such a change when that regulation was in force for most of 2007. However, if the proposed regulation is adopted, ARB will monitor vessel traffic patterns. If there are significant shifts in vessel traffic to alternative routes that have significant environmental impacts, ARB will propose to the Board for its consideration modifications to the proposed regulation, including potential boundary changes, that will reduce the incentive for ship operators to use alternative routes. This should minimize or eliminate any possible adverse environmental impacts from this possibility.

Need for Additional Bunkering Tanks on Some Vessels

The regulation requires the use of marine distillate fuels. A vessel complying with the regulation will need more than one fuel tank if the vessel also operates on HFO. Most vessels already have multiple fuel tanks and are able to have multiple fuels on board. Historically, multiple fuel tanks were common. In those cases, one fuel tank generally was used to store distillate fuel that would be used for maneuvering and starting engines in the port.

In the event a vessel operator chooses to add an additional fuel tank to operate the vessel within RCW, it is possible, albeit unlikely, that the additional fuel tank will displace cargo space, resulting in additional vessel trips to deliver the same volume of cargo. We do not believe this is a likely scenario because the number of vessel operators indicating a desire to increase tankage represents only a very small fraction of the overall fleet.

In addition, the additional fuel tanks may require increased the fuel delivery to the ship increasing possibility of fuel spills. But we believe this is also an unlikely scenario, as refueling personnel can lower or minimize the possibility of fuel spills with training and following standard refueling operating procedures.

H. Reasonably Foreseeable Mitigation Measures

The ARB is required to do an analysis of reasonably foreseeable mitigation measures. Because staff identified a potentially significant adverse environmental impact on GHG emissions, an analysis of such measures is necessary.

As part of its climate change program, ARB is planning to develop programs to reduce GHG emissions from shipping operations in California; these programs are expected to more than offset whatever increase in CO2 emissions might occur under the proposed regulation. The ARB is required to develop a GHG Scoping Plan under AB 32 (Stats. 2006, ch. 488). The Scoping Plan[2], among other things, will identify strategies for reducing GHG emissions from various shipping-related sectors.[3] These include shore-power electrification for ships at berth[4], requirements for commercial harbor craft,[5] and vessel speed reduction measures. The shore-power measure alone will more than fully offset the potential 50,000 tons per year increase in GHG emissions under the proposal.[6]

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[2] AB 32 Scoping Plan is due to be proposed to the Board at its November 2008 hearing. Air Resources Board, *AB 32 Scoping Plan*, (visited June 3, 2008) <http://www.arb.ca.gov/cc/scopingplan/scopingplan.htm>.

[3] Air Resources Board, *Greenhouse Gas Sectors Portal*, (visited June 2, 2008) <http://www.arb.ca.gov/cc/ghgsectors/ghgsectors.htm>.

[4] Approved for adoption by the Board at the December 2007 hearing.

[5] Approved for adoption by the Board at the November 2007 hearing.

[6] The shore-power regulation is expected to reduce CO2 emissions from ships at berth in California by 122,000 to 242,000 metric tons by 2020. California Air Resource Board, *Regulations To Reduce*

Further, vessel speed reduction programs are currently being evaluated for possible control of CO_2 and NOx emissions. These programs have the potential to dramatically reduce fuel consumption and associated CO_2 emissions. For example, a ten percent reduction in speed can reduce CO_2 emissions by over 25 percent.

In addition, ARB is planning to develop "green ship" programs that will bring cleaner new and retrofitted vessels to California ports. Specifically, these programs would encourage ship operators frequenting California ports to reduce their GHG emissions and other pollutants through a variety of technologies and control strategies. Recent studies indicate that there are a number of technologies that can by used in new or existing vessels to reduce GHG emissions, including advanced heat recovery systems that capture main engine exhaust heat, new fuel injection systems, advanced hull and propeller designs, new hull coatings that reduce drag, and even wind assistive devices (Marintek, 2000).

Based on these reasons, we believe the reasonably foreseeable mitigation measures will more than offset the potential slight increase in GHG emissions that may result from the proposed regulation.

I. Reasonably Foreseeable Alternative Means of Compliance with the Proposed Regulation

The ARB is required to do an analysis of reasonable foreseeable alternative means of compliance with the proposed regulation. Alternatives to the proposed control measure are discussed in Chapter V of this report. ARB staff has concluded that the proposed regulation provides the most effective and least burdensome approach to reducing children's and the general public's exposure to emissions of diesel PM and other air pollutants emitted from main and auxiliary diesel engines and auxiliary boilers used on ocean-going vessels in Regulated California Waters.

J. Environmental Justice

The ARB is committed to evaluating community impacts of proposed regulations, including environmental justice concerns. As noted previously, many communities experience elevated exposures to toxic and criteria pollutants emitted from the regulated vessels. Because of this, it is a priority of ARB to ensure that full protection is afforded to all Californians. The proposed regulation is not expected to result in significant negative impacts in any community. Rather, the proposed regulation is designed to reduce emissions of diesel PM, PM, NOx and SOx from the regulated vessels, resulting in decreased exposures to these pollutants and lowering their associated potential health risks for all communities, particularly those located near the ports.

Emissions From Diesel Auxiliary Engines On Ocean-Going Vessels While At-Berth At A California Port, Staff Report: Initial Statement of Reasons for Proposed Rulemaking, (visited June 2, 2008) <http://www.arb.ca.gov/regact/2007/shorepwr07/isor.pdf>.

K. State Implementation Plan Impacts

As noted, the proposed regulation is expected to reduce emissions of diesel PM, PM, NOx, and SOx. Therefore, this regulation will contribute to progress toward compliance with the air quality standards for PM and ozone.

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VIII. ECONOMIC IMPACTS

In this chapter, we present the estimated costs and economic impacts associated with implementation of the proposed regulation to regulate the sulfur content of fuels used in main engines, auxiliary engines, and auxiliary boilers on ocean-going vessels that visit California (the "proposed regulation" or "proposal"). The estimated total annual costs are presented, as well as the cost-effectiveness of the proposed regulation. The economic impacts associated with the costs of the proposed regulation are also presented for typical businesses that operate ocean-going vessels.

This analysis is similar to the analysis conducted in 2005 for ARB's Auxiliary Engine Regulation[1], except that the analysis now includes main engines and auxiliary boilers in addition to auxiliary engines. Although the proposed rule requirements are very similar, fuel costs have increased significantly since 2005, increasing the costs of proposed regulation. In addition, for the reasons discussed in detail below, we estimate that capital costs for ship modifications will not be significant.

Legal Requirements

In this section, we will discuss the legal requirements that must be satisfied in analyzing the economic impacts of the proposal.

Section 11346.3 of the Government Code requires State agencies to assess the potential for adverse economic impacts on California business enterprises and individuals when proposing to adopt or amend any administrative regulation. The assessment shall include a consideration of the impact of the proposed regulation on California jobs, business expansion, elimination or creation, and the ability of California business to compete with businesses in other states.

In addition, the ARB is required under H&S section 43013(b) to adopt standards and regulations, consistent with H&S section 43013(a), for marine vessels to the extent permitted by federal law. Health and Safety Code section 43013(a) authorizes ARB to adopt and implement "motor vehicle emission standards, in-use performance standards, and motor vehicle fuel specifications...which the State board has found to be necessary, cost-effective, and technologically feasible..."

A literal reading of H&S section 43013(a) would lead one to conclude that the criteria "necessary, cost-effective, and technologically feasible" do not apply to a marine vessel regulation because marine vessels are nonvehicular by definition.[2] However, because the Legislature placed the authorization to regulate marine vessels in H&S section 43013(b), we will infer a legislative intent to require ARB to determine that its proposed regulations on marine vessels are "necessary, cost-effective, and technologically feasible."

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[1] Section 2299.1, title 13, California Code of Regulations (CCR) and section 93118, title 17, CCR.
[2] See H&S § 39039.

Also, State agencies are required to estimate the cost or savings to any State or local agency and school district in accordance with instructions adopted by the Department of Finance (DOF). The estimate must include any non-discretionary cost or savings to local agencies and the cost or savings in federal funding to the State.

Finally, H&S section 57005 requires the Air Resources Board to perform an economic impact analysis of submitted alternatives to a proposed regulation before adopting any major regulation. A major regulation is defined as a regulation that will have a potential cost to California business enterprises in an amount exceeding ten million dollars in any single year. The estimated cost of the proposed regulation exceeds ten million dollars in a single year, although much of the cost will be borne by businesses based outside of California. Nevertheless, we conducted the required economic impact analysis of submitted alternatives to the proposal.

A. Summary of the Economic Impacts

Methodology

The following is a description of the methodology used to estimate costs as well as ARB staff's analysis of the economic impacts on individuals, California businesses and State and local agencies.

Under the proposed regulation, ocean-going vessel (or "vessel") operators would comply by using cleaner burning distillate marine fuels in the regulated engines and boilers. This requirement would apply when ships are within "Regulated California Waters," a zone that extends to approximately 24 nautical miles (nm) off the California coastline.

Since the majority of vessels currently use heavy fuel oil in their OGV engines and auxiliary boilers, most vessel operators will need to switch to the more expensive marine distillate fuel in California. We estimated the costs of implementing the proposed regulation from 2009 through 2014. This is because in 2015 there is a possibility that an Emission Control Area (ECA) can be established under the pending amendments to the International Maritime Organization (IMO) MARPOL Annex VI protocol for reducing emissions from ships. Such an ECA would likely require the use of 0.1% sulfur fuel off the California coastline (see Chapter V). If an ECA is established that achieves substantially equivalent benefits to the proposed regulation, ARB staff will propose terminating or modifying this regulation to the Board at that time.

For the period from 2009 through 2011, we estimated the added costs for vessel operators to switch from the most common grade of heavy fuel oil (IFO 380) to the most common grade of marine distillate fuel, marine gas oil (MGO). For the three year period from 2012 through 2014, we estimated the added costs for vessels to switch from IFO 380 to MGO limited to 0.1% sulfur. These periods correspond to the first and second tiers, respectively, of fuel sulfur restrictions in the proposed regulation.

Costs to Businesses

The added cost to businesses due to the higher cost of using distillate fuel will vary widely based on the amount of fuel they use in California. For example, a business that owns a single vessel that makes a single annual visit to a California port may incur an added cost of about $30,000, while an operator of a large fleet of vessels that make frequent California port visits may incur costs in the millions of dollars annually. On average, we estimate the annual additional fuel cost for a typical vessel operator at about $300,000 to $700,000 per company. For the entire ocean-going shipping fleet that visits California, we estimate an added annual fuel cost of about $140 million to $360 million. We estimate the total present value cost of the regulation for the entire fleet at about $1.5 billion, assuming a regulation life from July 1, 2009 to the end of 2014. As discussed in detail below, we do not expect that the proposed regulation will result in significant capital costs to ship operators.

Impacts on Government Agencies and Business Competitiveness, Employment, Creation, Elimination or Expansion

We do not expect significant economic impacts to the industry based on the added costs of the proposed regulation. While the added costs of the regulation are substantial, they are relatively small compared to the overall operating expenses of these vessels. In addition, based on an analysis of the change in "return on owner's equity" (ROE) for typical businesses, the added costs of the proposed regulation would result in about a 1.5 percent decline in ROE. Generally, a decline of more than 10 percent in ROE suggests a significant impact on profitability.

Because the proposed regulation would not alter significantly the profitability of most businesses, we do not expect a noticeable change in employment, business creation, elimination, or expansion, and business competitiveness in California. We also do not expect significant economic impacts on governmental agencies on the local, state, or federal level. Military and government owned or operated vessels, used for government non-commercial purposes, are exempt from the proposed regulation.

Impacts on Individuals

We do not expect significant impacts on the customers served by ocean-going vessel operators, even assuming that all of the added costs are passed on to customers. Under a typical scenario, we estimate that the added cost of the proposed regulation would add about six dollars per shipping container for importers or exporters shipping containerized goods overseas. We estimate that this represents less than one percent of the shipping cost. For passenger cruise ships, we estimate the added cost of the proposed regulation for a typical Los Angeles to Mexico cruise would be about $15 per passenger, representing about a 3 to 4 percent fare increase.

Cost-Effectiveness and Value of Health Benefits

Cost effectiveness is the total annual costs of the proposal (including annualized costs) divided by the annual emission reductions of a specified pollutant or pollutants. This figure is generally expressed in terms of dollars per unit mass of pollutant reduced. The ARB uses cost-effectiveness values to compare the relative efficiency of a proposed measure with other measures already adopted by the Board (i.e., to compare how much "bang for the buck" each measure gets).

The overall cost-effectiveness of the proposed regulation, considering only reductions in diesel PM, is estimated to be about $63,000 per ton of diesel PM reduced ($32 per pound of diesel PM). However, the proposed regulation would also reduce emissions of nitrogen oxides (NOx) and sulfur oxides (SOx). Attributing half the cost of the proposed regulation to diesel PM, and half to NOx plus SOx, the cost-effectiveness would be about $31,000/ton ($16/pound) of diesel PM reduced. We estimate the cost-effectiveness of the combined NOx+SOx control at about $3,200/ton ($1.60/pound). The PM cost-effectiveness of the proposed regulation is similar to that of other regulations adopted by the Board to reduce diesel particulate matter.

The health benefits of implementing the proposed regulation are substantial. The estimated statewide benefit of reduced premature mortality is about $15.4 billion dollars for directly emitted PM only. This figure represents the present value of health benefits occurring from July 1, 2009 to the end of 2014.

B. Capital Costs

We do not expect that the proposed regulation will result in significant capital costs to ship operators. Ocean-going vessels already have the capability to store and use marine distillate fuels on board. Vessel operators need to use this fuel to operate their engines prior to going into dry-dock, to assist with engine emergencies, and to comply with environmental regulations and programs such as port-lease requirements and (until recently) California's Auxiliary Engine Regulation. Under the proposed regulation, they would simply be using the distillate fuels more frequently and for longer periods of time.

In the ARB surveys conducted in 2005 and 2007, most shipping lines reported that none of their vessels would need modifications to use distillate fuels. In addition, the world's largest shipping line, Maersk, has been voluntarily using low sulfur distillate fuels in California ports for over two years and has not needed to make modifications to their vessels. For the minority of shipping lines that have reported the need for modifications, we believe that most of these are either non-modifications (e.g., at least one company reported cleaning out a tank as a "modification") or nonessential changes made for more convenient fuel switching.

In addition, the proposed regulation includes an exemption for ships needing essential modifications, subject to verification by ARB. This provision would sunset in 2015, when equivalent IMO regulations are expected to be implemented. A more detailed

discussion of why we do not believe the proposal will result in significant capital costs for main engines, auxiliary engines, and auxiliary boilers is presented below.

Main Engines

The ARB 2007 Vessel Survey (ARB 2007a) was designed to collect information necessary to estimate the number of vessels requiring main engine modifications to use distillate fuel. In the Survey, we requested that the shipping lines identify whether their vessels would require modifications to use marine distillate fuel, and the nature and cost of the changes. The Survey requested information assuming the use of marine distillate fuel extended 24 nautical miles (nm), 50 nm, and 100 nm offshore. However, we only considered the information for the 24nm case here, because that is what is being proposed in the regulation.

Table VIII-1 below provides a summary of the survey responses regarding ships reported to need modifications. Individual company names are not provided because much of the survey data was designated as confidential. As shown in the table, 154 out of the 178 companies (87 percent) reported that none of their vessels visiting California would need modifications. In terms of the number of vessels, 168 out of 761 vessels (22 percent) were reported to need modifications to use distillate fuel. However, just two companies accounted for more than half of the vessels reported to need modifications.

ARB staff made several attempts to contact these companies to verify their survey data. One company reporting 57 ship modifications did not respond to our inquiries. The other company reporting 33 ship modifications did not provide information in the survey on the cost or nature of the modifications, and follow-up contacts with the company provided little additional information. Based on these results, we cannot assign much weight to the survey responses from these companies. We therefore believe that the overall survey data significantly overestimates the need for ship modifications.

Table VIII-1: Summary of Reported Ship Modifications by Company

Number of Companies	Ships Reported to Need Modifications
154	0
9	1
4	2
2	3
2	4
1	6
1	8
1	9
1	10
1	14
1	33
1	57
178	168

Nevertheless, even assuming all the information provided in the Survey is accurate, we estimated that the capital costs would not significantly alter the overall cost analysis. This is because the added fuel costs represent a much larger percentage of the overall cost of the proposal. Specifically, if we apply the (uncorrected) 22 percent of ships reported to need modifications from the Survey to the total number of vessels visiting California, and use the average cost of modifications reported in the survey, the resulting capital costs would total roughly $150 million in 2008 dollars. This represents about 10 percent of the present value cost of the proposed regulation ($1.5 billion) over a six year timeframe from 2009 to 2014, as described later in this chapter.

In addition, Maersk, the world's largest shipping line, has reported that no capital investments were necessary to implement their voluntary Pilot Program to use marine distillate fuel in the main engines of their vessels that visit California. The Maersk Pilot Program has included 105 different vessels and 438 successful fuel switches as of October 2007 (Maersk, 2007). Chapter VI provides a detailed discussion of this program.

Auxiliary Engines

For several reasons, we do not expect the proposed regulation to result in significant capital costs for auxiliary engines. Since the ARB's ship auxiliary engine regulation was in place for over a year, the vessels that regularly visit California would have already made modifications, if needed. In addition, many ship operators will be preparing to use distillate fuels in their auxiliary engines for other environmental regulations, including the European Union Directive 2005/33/EC, which requires ships to use 0.1% sulfur fuel at dockside in 2010. Ship operators have also been under pressure to make whatever changes are needed to use low sulfur distillate fuels because of the pending amendments to IMO's MARPOL Annex VI and U.S. EPA's marine diesel engine

standards (i.e., auxiliary engines on new U.S.-flagged vessels will need to be equipped to use distillate fuel at all times to meet U.S. EPA marine diesel engine emission standards).

In addition, ARB's ship surveys indicated that very few vessels would need modifications to use distillate fuel in auxiliary engines. ARB staff conducted a ship survey in 2005 (ARB, 2005a) that asked respondents whether fuel system modifications would be needed to use distillate fuel in their auxiliary engines. According to the survey, less than 10 percent of vessels were reported to need modifications. However, in ARB's retrospective follow-up 2007 Vessel Survey (ARB, 2007a), respondents were asked whether they actually made ship modifications to comply with the ship auxiliary engine rule, which was in place at the time.

Based on the 2007 follow up survey, only about six percent of vessels were reported to have been modified. Even though this is already a low percentage of the fleet, we believe this result still overestimates the actual number of vessels that need modifications to comply with the regulation. To illustrate, when we further questioned some respondents who initially reported needing modifications, they described their modifications as simply *using* distillate fuel. We are uncertain of the exact number of respondents who reported modifications that were clearly not modifications. However, it is clear that the survey may have overestimated the number of modifications actually made. The 2007 survey also indicated that modifications were less expensive than anticipated, averaging $50,000 per vessel (instead of $100,000 previously estimated for cargo vessel).

In addition, even if we assume as accurate the high rate of modifications reported from the 2005 survey, the capital costs would not significantly alter the overall cost analysis. Similar to the discussion for main engines above, this is because the added fuel costs represent a much larger percentage of the overall cost of the proposal. In the 2005 cost analysis performed for the auxiliary engine rule implemented in 2007 (using the higher costs and rate of modifications from the 2005 survey), the estimated capital costs ($10.5 to 17.1 million) were only about 10 percent of the added fuel costs ($154 million) even with the lower fuel cost estimates used in that earlier analysis.

Auxiliary Boilers

Based on discussions with ship operators and boiler manufacturers, we do not expect the proposed regulation to result in significant capital costs associated with auxiliary boilers. First, the large boilers used to propel steamships are not covered by the proposal. The smaller auxiliary boilers used on cargo ships can already use distillate fuel (Aalborg Industries, 2007a and 2007b; Crystal Cruises, 2007; Matson, 2007).

Tankers, which represent about 20 percent of the unique vessels visiting California, are a special case because their auxiliary boilers are larger than those on other vessels, and there are unique safety considerations on tankers. Tanker operators have reported that they will evaluate their auxiliary boilers to ensure that they are prepared to use

distillate fuel for longer periods of time (BP, 2007; Chevron, 2007). It is possible that some tanker operators may ultimately decide to modify their auxiliary boilers (e.g., to update burners or control systems). However, the capital costs associated with these potential modifications are not expected to be significant relative to the added fuel costs of the regulation. Assuming that half of the tankers visiting California (~225) made modifications costing $100,000 per vessel, the resulting $22.5 million capital cost would represent about 1.5 percent of the present value total cost of the proposed regulation ($1.5 billion), as described later in this chapter.

C. Recurring Costs

The recurring (on-going) costs associated with the proposed regulation are due to the higher incremental cost of using marine distillate fuel in California. We calculated these costs based on the difference between: (1) the current estimated fuel consumption and the price of the most common grade of heavy fuel oil (IFO 380); and (2) the estimated fuel consumption and price of the cleaner marine distillate fuels specified in the regulation. For years 2009-2011, we used the price differential between HFO and standard marine gas oil (MGO). For 2012 through 2014, we used the price differential between HFO and 0.1% sulfur marine gas oil (MGO), as specified in the proposed regulation. We did not attempt to forecast fuel price increases over the six years covered by this analysis given the highly volatile and unpredictable nature of petroleum prices. Our assumptions for fuel consumption rates and the price differential between MGO and HFO are described below.

Fuel Consumption Estimates

The estimated fuel consumption within the 24 nautical mile boundary is based on the ARB's Emissions Inventory, which is discussed in Appendix D. The estimate is based on: (1) the estimated energy consumed by vessels within 24 nm using vessel specific information and shipping lane distances within the 24 nm boundary; (2) the appropriate brake specific fuel consumption figures for medium-speed, four-stroke auxiliary engines and slow-speed, two-stroke main engines; and (4) estimated average auxiliary boiler fuel consumption by vessel type. This analysis also accounts for the impact of the voluntary vessel speed reduction program at the Ports of Los Angeles and Long Beach, which has a definite effect on fuel consumption and will continue to do so as long as that program is in effect.

For the pre-regulation base case, we assume that all fuel used by main engines and auxiliary boilers is heavy fuel oil. This is based on the ARB's 2007 Ship Survey, which indicates that over 90 percent of main engines operate on heavy fuel oil. For auxiliary engines under the base case without the proposed regulation, we assume that about 78 percent of the fuel used is heavy fuel oil (72 percent by cargo vessels and 92 percent by cruise ships) based on the ARB's 2005 Ship Survey (ARB, 2005a). We recognize that many shipping lines may be voluntarily using distillate fuel subsequent to the court injunction preventing ARB from enforcing the previous auxiliary engine rule. However, we cannot estimate the extent of this voluntary compliance.

As shown in Tables VIII-2 and VIII-3, based on these assumptions, we estimate the total annual fuel consumption in California is roughly 2600 to 3000 tons per day (about 860,000 to 980,000 tonnes[3] per year) from 2009 to 2014. To estimate the fuel consumption after implementation of the marine distillate fuel standards specified in the proposed regulation, we reduced the estimated fuel consumption figures for heavy fuel oil by five percent due to the higher energy content of marine distillate fuels on a weight basis (Entec, 2002). As shown in Tables VIII-2 and VIII-3, based on the use of marine distillate fuel (MGO), we estimate the total fuel consumption in California ranges from about 2500 to 2800 tons per day (840,000 to 930,000 tonnes per year).

Table VIII- 2: Fuel Use Estimates (Tons per Day)[1]

Fuel Use Scenario	2009	2010	2011	2012	2013	2014
Base Case w/o proposal[1]						
Main Engine HFO	1408	1463	1522	1583	1648	1717
Auxiliary Boiler HFO	490	502	515	528	543	558
Auxiliary Engine HFO	545	545	543	539	533	524
Auxiliary Engine MGO	154	154	153	152	150	148
Total Base Case HFO	2443	2510	2580	2650	2724	2799
Total Base Case MGO	154	154	153	152	150	148
Regulated Case[2] (All MGO/MDO)						
Main Engine	1373	1390	1446	1504	1566	1631
Auxiliary Boiler	478	477	489	502	516	530
Auxiliary Engine	685	671	669	664	656	646
Total Regulated	2536	2538	2604	2670	2738	2807

1. Base case includes ARB shore-side power regulation. Main engine and auxiliary boiler fuel use assumed to be 100% HFO. Auxiliary engine fuel use assumed to be 78% HFO, 22% distillate.
2. Regulated case includes shore-side power regulation and proposed regulation implemented starting July 1, 2009.

[3] 1 tonne = 1 metric ton

Table VIII- 3: Fuel Use Estimates (Tons per Year)

Emissions Scenario	2009	2010	2011	2012	2013	2014
Base Case[1] HFO	811,200	833,400	856,700	879,900	904,500	929,400
Base Case[1] MGO	51,100	51,100	50,900	50,500	49,900	49,100
Regulated Case[2] (MGO/MDO)	842,100	842,700	864,600	886,600	909,100	932,000

1. Base case includes ARB shore-side power regulation. Main engine and auxiliary boiler fuel use assumed to be 100% HFO. Auxiliary engine fuel use assumed to be 78% HFO, 22% distillate.
2. Regulated case includes shore-side power regulation and proposed regulation starting July 1, 2009.

Table VIII-4 provides a breakdown of the fuel use by vessel type for a representative year (2010). As shown, container ships are estimated to account for over half of the fuel consumed in California, followed by tankers and cruise ships.

Table VIII-4: 2010 Estimated Fuel Use by Vessel Type

Vessel Type	OGV Fuel Use (tons/day)	Percentage of Total Fuel Use
Auto Carrier	91	3.6%
Bulk	96	3.8%
Container	1396	55%
Cruise	220	8.7%
General	42	1.1%
Reefer	36	1.4%
RORO	10	0.4%
Tanker	648	25.5%
Total	2539	100%

Price Premium for Marine Distillate Fuel Compared to Heavy Fuel Oil

To determine the estimated price differential between heavy fuel oil and marine distillate fuels complying with the proposed regulation, we estimated the cost of the most common grade of heavy fuel oil, IFO-380, and the most common grade of marine distillate fuel, marine gas oil. Prices were averaged over seven months, October, 2007 through April, 2008, at five major bunkering ports: Singapore, Rotterdam, Fujairah, Busan, and Los Angeles (Bunkerworld, 2008b). The ports of Singapore, Rotterdam, and Fujairah were chosen because they are the world's largest bunkering ports by volume (Bunkerworld, 2008a). Busan and Los Angeles were chosen because they are major Pacific Rim bunkering ports for ships visiting California. As shown in Table VIII-5

below, the average price differential between IFO-380 and MGO was about $373 per metric ton (tonne). Fuel prices tend to be volatile and may change significantly in the future. However, we believe that the price differential between HFO and MGO will be less volatile than prices overall.

Table VIII-5: Marine Fuel Prices ($/tonne)*

Fuel	Los Angeles*	Busan	Singapore	Fujairah	Rotterdam	Average
MGO	891.57	860.36	839.71	845.00	850.50	857.43
IFO-380	494.93	513.07	478.50	482.29	453.50	484.46
Difference	396.64	347.29	361.21	362.71	397.00	372.97

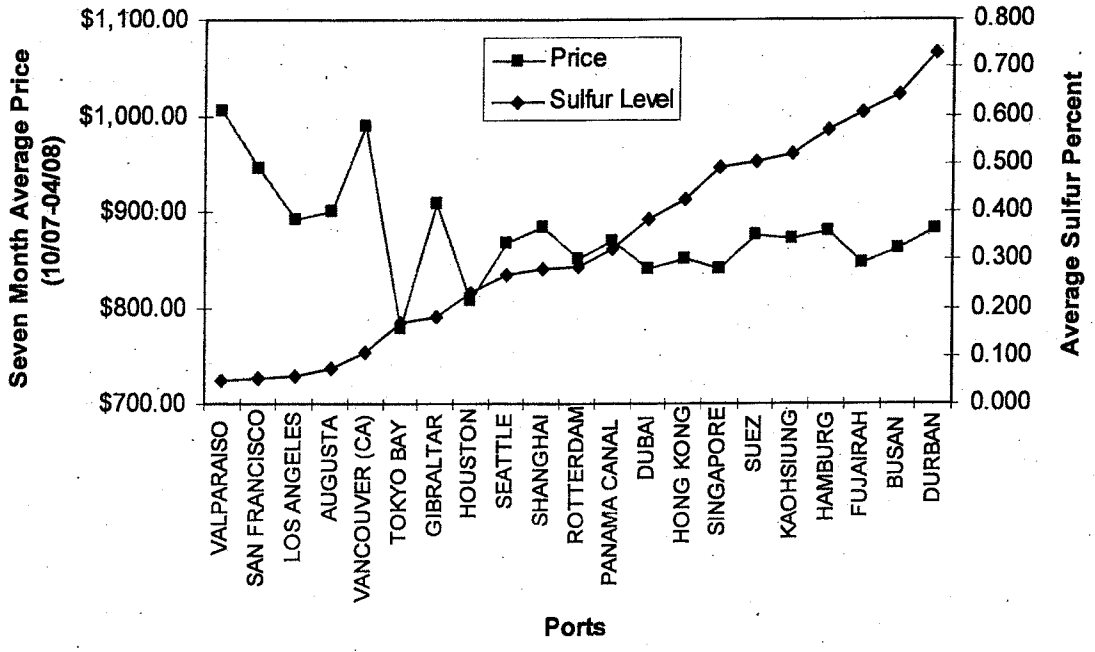
* Bunkerworld, 2008. Prices averaged from seven monthly reports from October, 2007 through April, 2008. Los Angeles marine distillate fuel is listed as MDO by Bunkerworld, but it is actually a mix of both MGO and MDO, with the majority of fuel expected to be MGO (Bunkerworld, 2008c).

Price Premium for 0.1% Sulfur Marine Distillate Fuel

To estimate the cost differential between standard marine gas oil and 0.1% marine distillate fuel (specified in the proposed regulation in 2012), we relied, in part, on existing estimates in the literature. A report prepared for the European Union (Beicip-Franlab, 2002) estimated the price premium for 0.1% sulfur marine gas oil compared to standard marine gas oil with no sulfur limit at 14-21 €/metric ton, or about $22 to $33/metric ton, using a current exchange rate of 0.63 Euros per U.S. dollar. While this information is dated, a more recent report prepared for the European Commission (IIASA, 2007) estimated the price premium for 0.1% sulfur fuel over 0.2% sulfur fuel at an extra 20 €/metric ton (~ $32/metric ton). However, this figure may underestimate the current premium between 0.1% sulfur and standard marine gas oil because it compares 0.1% sulfur fuel to 0.2% sulfur fuel rather than to standard marine gas oil.

Given that the information from the literature cited above is not definitive, we also examined the current price difference between ports selling high and low sulfur fuel. In particular, we wanted to examine the price of marine distillate fuels from ports where the average fuel is below 0.1% sulfur. To do this, we examined the average price from Bunkerworld.com over the same seven month period used in Table VIII-5 (from October, 2007 through April, 2008) and the average sulfur content from 2007 fuel testing performed by Det Norske Veritas Petroleum Services at 21 ports worldwide with a range in average sulfur content. As shown in Figure VIII-1 below, we did see a trend toward higher prices at ports offering lower sulfur fuel.

Figure VIII-1: Price vs. Distillate Fuel Sulfur Content at Selected Ports



Specifically, we found that the average price ($946/tonne) at the five ports selling low sulfur marine distillate fuel at or below 0.1% sulfur (Valparaiso, San Francisco, Los Angeles, Augusta, and Vancouver) was about $89 per tonne higher than the price ($857/tonne) at the16 ports selling fuel that averaged above 0.1% sulfur. This analysis does not necessarily indicate that there will be a premium on the order of $89 to purchase 0.1% sulfur fuel. For the ports that already sell marine distillate fuel that averages below 0.1% sulfur there may be little price premium. However, it does indicate that the lower sulfur fuel commands a higher price.

Considering the above information from the literature and our price versus sulfur content data, we assumed a $60 price premium for 0.1% sulfur fuel above standard marine distillate. This represents a midpoint between the low-end $32/tonne price premium based on the recent IIASA report mentioned above, and the upper-end $89/tonne figure cited above.

Table VIII-6 summarizes the estimated price premium we used for the cleaner fuels specified in the proposed regulation.

Table VIII-6: Estimated Fuel Price Differential Due to Proposed Regulation

Year	Fuel Change	HFO Price ($/tonne)	Distillate Fuel Price ($/tonne)	Price Premium ($/tonne)
2009 to 2011	IFO-380 to Standard MGO	484	857	+373
2012 to 2014	IFO-380 to 0.1% Sulfur MGO	484	917	+433

*Reflects data from Table VIII-5 above, and an estimated $60 premium for 0.1% sulfur MGO compared to standard MGO with no sulfur limit. A "tonne" equals a metric ton, or 2200 pounds.

Total Recurring (Fuel) Costs

The total annual recurring costs for 2009-2014 are provided in Table VIII-8. These estimates are based on the difference between the estimated fuel cost using primarily HFO (no regulation base case as shown in Table VIII-7) and the estimated fuel cost using the specified complying marine distillate fuels. The fuel consumption estimates are for the use of main engines, auxiliary engines, and auxiliary boilers, within 24 nm of the California Coastline, as specified in Tables VIII-2 and VIII-3. The fuel consumption figures for marine distillate fuel, as shown in Table VIII-8, are lower than those for HFO due to the higher energy content of marine distillate fuel on a mass basis. As shown in Table VIII-8, the added annual fuel costs are estimated to range from about $143 to $363 million, depending on the year.

Table VIII-7: Estimated Fuel Costs Without Proposed Regulation

Year	Total Estimated HFO Use (tonne/yr)	Total Estimated MGO Use (tonne/yr)	Estimated MGO Price ($/tonne)	Estimated HFO Price ($/tonne)	Total Estimated HFO Cost (millions)	Total MGO Cost (millions)	Total Fuel Cost (millions)
2009*	405,600	25,550	$857	$484	$196.3	$21.9	$218.2
2010	833,400	51,100	$857	$484	$403.4	$43.8	$447.2
2011	856,700	50,900	$857	$484	$414.6	$43.6	$458.2
2012	879,900	50,500	$857	$484	$425.9	$43.3	$469.2
2013	904,500	49,900	$857	$484	$437.8	$42.8	$480.6
2014	929,400	49,100	$857	$484	$449.8	$42.1	$491.9

*Covers half year starting July 1, 2009

Table VIII-8: Estimated Added Fuel Costs With Proposed Regulation

Year	Total Est. Distillate Use (tonne/year)	MGO Price ($/tonne)	Total Cost with Rule (millions)	Total Cost w/o Rule (millions)	Total Added Fuel Cost (millions)
2009*	421,100	$857	$360.8	$218.2	$142.6
2010	842,700	$857	$722.2	$447.2	$275.0
2011	864,600	$857	$741.0	$458.2	$282.8
2012	886,600	$917	$813.0	$469.2	$343.8
2013	909,100	$917	$833.6	$480.6	$353.0
2014	932,000	$917	$854.6	$491.9	$362.7

*Regulation would apply for a half year starting July 1, 2009

D. Total Industry Cost and Total Annual Cost

Total Industry Cost

We estimate the total statewide cost of the proposed regulation over the six year period from July 1, 2009 to the end of 2014 to be about $1.5 billion dollars. This estimated cost was derived from the present value of recurring (added fuel) costs shown in Table VIII-8 (see Appendix G).

Total Annual Cost

The total annual cost of the proposed regulation is the same as the add fuel costs shown in Table VIII-8 because we estimate no significant capital costs. In 2009, the cost is lower because the proposed regulation is implemented mid year in July. In 2012 and later years, the annual cost is higher due to the requirement to use 0.1% sulfur fuel.

E. Potential Additional Costs or Savings

There may be some other costs and potential cost savings that could be incurred under the proposed regulation, but data were not available to enable quantification of these possible impacts. Nevertheless, the net impact of these costs and savings is not expected to be significant. These are briefly described below.

Capital costs

Although we do not expect that the proposed regulation will result in significant capital costs, there will probably be some capital costs undertaken in response to the regulation. Nevertheless, even if we use upper-end estimates for these costs, as discussed in section B above, we would estimate that they would not increase the overall cost of the proposal by more than ten percent.

Distillate fuel may result in lower or higher maintenance costs

Marine distillate fuel has a lower sulfur and ash content than heavy fuel oil and may result in a permanent, ongoing reduction in engine maintenance in some engines and boilers due to a reduction in deposit formation (Croner, 2002; Matson, 2007). On the other hand, the use of lower viscosity distillate fuel may make leaks at weak pipe joints more likely than the use of heavier fuels, requiring additional maintenance. Because these effects, to the extent they may occur, are very engine and vessel-specific, we cannot quantify the overall potential savings or added costs from changes in maintenance costs. However, it is likely that at least some of this effect can be offset by the use of stronger pipe joints that are better suited to distillate fuels.

Crew time for fuel switching and recordkeeping

The proposed regulation would require vessel crews to perform fuel switches and keep certain records. For example, in a typical vessel visit to California, the crew would need to switch the OGV engines and auxiliary boilers from heavy fuel oil to complying distillate fuel upon entrance into Regulated California Waters, and then back again when exiting California. The crew time involved in the fuel switching operations would vary with the vessel. Some vessels have equipment to automate this process, requiring little crew time, while others use a manual process, requiring more crew time. While these activities will require additional crew time, we expect that in most cases these activities can be performed with existing crews.

Regarding recordkeeping, the proposed regulation would require records be kept of: (1) the date, time, and position of the vessel upon entry to and exit from the 24 nm boundary, and upon initiation and completion of fuel transitions; (2) fuel purchases, and the types of fuels used within the 24 nm boundary; and (3) documentation of fuel switchover procedures. The recording of fuel purchases and fuel use is already performed in accordance with standard practices as well as other regulations and Vessel Classification Society requirements. We also expect that documentation of the fuel switchover procedures would already be available on the vessel. Recording the date, time, and position of the vessel as required by the proposed regulation would be an added requirement, but we do not expect these activities to require significant time or costs to comply as these can easily be logged either manually or automatically. The proposed regulation does not require periodic reporting of records. Reporting is only required upon request.

Fueling costs

The proposed regulation may result in more frequent refueling because some vessels may use a smaller tank for the more expensive fuel that can be used to comply with the proposed regulation. However, we cannot predict the extent to which this would occur and the industry has not supplied estimates of these costs.

F. Estimated Cost to Businesses

The proposed regulation would primarily impact businesses that operate large ocean-going vessels. These costs are estimated below for typical (average) businesses. However, the cost to individual businesses will vary widely based on factors such as the following:

- number of vessels visiting California ports;
- number of California port visits per vessel; and
- power generated by engines, and thus fuel consumed.

For example, a business that owns a typical vessel that makes a single annual visit to a California port visit may incur an added fuel cost of about $30,000 dollars. On the other hand, a large vessel operator with several vessels making frequent California port visits would incur added fuel costs in the millions of dollars annually.

Table VIII-9 below provides a summary of the range of added fuel costs that could be incurred by shipping companies. As shown, most companies make relatively few visits and would incur proportionally lower costs, while a smaller number of large operators would incur costs in the millions of dollars annually. The average added fuel costs for travel in the 24 nm boundary associated with a California port visit (~$30,000/visit) was approximated by dividing the total annual industry recurring cost from Table VIII-8 ($275-363 million dollars, not counting 2009 with half year implementation) by the roughly 11,000 port visits to California ports.

Table VIII-9: Estimated Average Added Annual Fuel Cost to Vessel Operators*

Number of Companies	Number of California Port Calls	Estimated Added Fuel Cost @ $30,000 per Call
1	600-699	$18 to 21 million
1	500-599	$15 to 18 million
3	400-499	$12 to 15 million
3	300-399	$9 to 12 million
7	200-299	$6 to 9 million
10	100-199	$3 to 6 million
24	50-99	$1.5 to 3 million
71	10-49	$300,000 to1,470,000
70	5-9	$150,000 to 270,000
32	4	$120,000
55	3	$90,000
87	2	$60,000
160	1	$30,000
524 Total	~11,000 Total	--

* Company and port visit information based on 2006 California State Lands Commission data.

We do not believe that the vessel operators subject to this proposed regulation would qualify as small businesses due to the large capital and operating costs associated with vessel operation. Typical container vessels are estimated to cost on the order of $50 to $100 million (Mercator, 2005). In addition, Government Code section 11342.610 excludes businesses in transportation and warehousing with annual gross receipts exceeding one and a half million dollars from its definition of "small business." We believe that the annual gross receipts for a profitable vessel owner or operator would far exceed this level in order to be profitable. For example, a single Asia to U.S. West Coast voyage for a typical container vessel costs about $2 to $3 million. (*Ibid*) Therefore, we do not believe there are any small businesses directly affected by the proposed regulation. As such, we have only included costs in this analysis for typical businesses.

The recurring (fuel) costs to typical businesses are discussed below. The cost is based on the ongoing higher cost of marine distillate fuels that would be required by the proposed regulation. However, it should be noted that the total cost to a particular company will vary directly with the amount of fuel consumed by the company's vessels operated in California, as shown in Table VIII-9 above.

Recurring (Fuel) Costs to Typical Businesses

The recurring cost for a typical business is presented below. To determine the average annual recurring cost for a typical business, we divided the total annual recurring cost of the proposed regulation for all vessels by the number of shipping companies that operated ocean-going vessels in California in 2006, as reported by the California State

Lands Commission (CSLC, 2007). Specifically, we divided the total annual recurring cost of $142 to $363 million for years 2009-20014 as shown in Table VIII-8, by the approximately 524 ship companies reported by the California State Lands Commission. This resulted in an average added annual fuel cost per company of about $272,000 to $692,000.

Table VIII-10: Estimated Average Added Annual Fuel Costs per Company

Year	Annual Fuel Cost (millions)	Number of Operators	Average Annual Fuel Cost Per Company
2009*	$142.6	524	$272,100
2010	$275.0	524	$524,800
2011	$282.8	524	$539,700
2012	$343.8	524	$656,100
2013	$353.0	524	$673,700
2014	$362.7	524	$692,200

* Regulation would apply for a half year starting July 1, 2009

G. Potential Business Impacts

In this section, we analyze the potential impacts of the estimated costs of the proposed regulation on business enterprises. Section 11346.3 of the Government Code requires that, in proposing to adopt or amend any administrative regulation, State agencies shall assess the potential for adverse economic impact on California business enterprises and individuals. The assessment shall include a consideration of the impact of the proposed or amended regulation on the ability of California businesses to compete with businesses in other states, the impact on California jobs, and the impact on California business expansion, elimination, or creation.

This analysis is based on a comparison of the annual return on owner's equity (ROE) for affected businesses before and after the inclusion of the costs associated with the proposed regulation. The analysis also compares the estimated added costs of the proposed regulation to the overall operating costs of these vessels

ARB staff does not have access to financial records for many of these companies. However, it should be noted that many of these businesses are not California-based businesses. Many are foreign-owned enterprises, sometimes involving complicated ownership arrangements involving consortiums of investors.

As stated in Section E above, we do not believe that the businesses subject to this proposed regulation would qualify as small businesses due to the large capital and operating costs associated with vessel operation.

Analysis of Return on Owner's Equity (ROE)

In this section, we evaluate the potential economic impact of the proposed regulation on California businesses as follows:

(1) Typical businesses affected by the proposed regulation are identified from port visit data from the California State Lands Commission. The Standard Industrial Classification (SIC) codes associated with these businesses are listed in Table VIII-9 below;

(2) The annual costs of the proposed regulation are estimated for each of these businesses based on the SIC code. For ranges in cost estimates, the high end of the range was used;

(3) The total annual cost for each business is adjusted for both federal and state taxes; and

(4) The adjusted costs are subtracted from net profit data and the results used to calculate the ROE. The resulting ROE is then compared with the ROE before the subtraction of the adjusted costs to determine the impact on the profitability of the businesses. A reduction of more than 10 percent in profitability is considered to indicate a potential for significant adverse economic impacts. This threshold is consistent with the thresholds used by the U.S. EPA and others.

Using publicly available financial data from 2005 to 2007 for the representative businesses, staff calculated the ROEs, both before and after the subtraction of the adjusted annual costs, for the typical businesses from each industry category. These calculations were based on the following assumptions:

(1) All affected businesses are subject to federal and state tax rates of 35 percent and 9.3 percent, respectively; and

(2) Affected businesses neither increase the cost to their customers, nor lower their cost of doing business through cost-cutting measures due to the proposed regulation.

These assumptions, though reasonable, might not be applicable to all affected businesses.

The results of the analysis are shown in Table VIII-11 below. Using the ROE to measure profitability, we found that the ROE range for typical businesses from all industry categories would have declined by less than one percent due to the proposed regulation. This represents a small decline in the average profitability of the affected businesses. Overall, most affected businesses will be able to absorb the costs of the proposed regulation with no significant impacts on their profitability.

Table VIII-11: ROE Analysis of Businesses

SIC Code	Description of SIC Code	Percent Change in ROE
4412	Deep Sea Foreign Transportation of Freight	-0.24
4424	Deep Sea Domestic Transportation of Freight	-3.86
4481	Deep Sea Passenger Transportation	-0.30
Average		-1.47

Comparison of the Costs of the Proposed Regulation with Vessel Operating Costs

This analysis compares the added costs of the proposed regulation with the normal operating costs of large ocean-going vessels. While the costs of the proposed regulation are substantial, they are a small fraction of the overall operating costs for these businesses. For example, as discussed above, a typical vessel would be expected to incur added costs of about $30,000 per California port visit. We do not expect this cost to have a significant impact on vessel operators, or businesses that rely on the goods transported by these businesses, because the added fuel cost represents a minor percentage of the overall transportation cost. To put this in perspective, the total operating cost of a single Asia to U.S. West Coast voyage for a typical container vessel is estimated to be about 2 to 3 million dollars (Mercator, 2005). The $30,000 added cost represents about six dollars extra per shipping container for a 5,000 TEU (transport equivalent unit) vessel. This extra cost per TEU represents roughly one percent of the total trans-Pacific using a total oversea cost on the order of $500 per TEU, as estimated by Mercator. (*Ibid*) However, fuel costs and other fees have risen significantly since the Mercator report. Using a current cost estimate provided by a major shipping line, $2,200 to transport a 40 foot shipping container from Hong Kong to Los Angeles, the added six dollars per TEU would represent about a half percent of the voyage cost.

For a typical cruise ship, the added cost of the regulation would also be roughly $30,000 per California port visit. For a ship that carries about 2,000 passengers (Carnival, 2008), the added cost would be about $15 per passenger. For a relatively low cost 3 or 4 day Mexico cruise, about $400-500 (*Ibid*), a three to four percent increase in fare would be needed to offset the increased fuel cost.

Because the added costs of the proposed regulation are such as small percentage of the overall operating costs for both cargo and cruise vessels, we do not expect a significant impact on these businesses. There is also a possibility the proposed regulation will result in a positive impact on business creation due to additional sales of marine fuels in California beginning in 2012, when the 0.1% sulfur fuel requirement becomes effective. This is because California is expected to have 0.1% sulfur fuel available, whereas some ports worldwide may not.

H. Potential Impact on Business Competitiveness

The proposed regulation could potentially affect the ability of California ports and California based vessel operators to compete with ports and vessel operators outside California due to the slight increase in operating costs. However, we do not believe that the added costs of the proposed regulation are high enough for vessel operators to consider alternative ports outside California.

There are several reasons for this. First, many vessel operators utilize California ports because there is already a local market for their goods within California, or because California exporters choose to utilize California ports to transport their goods overseas. Second, other vessel operators find that the overall cost of transporting goods to their final destination beyond California is lowest by using California ports because of the ports' existing and well established infrastructure, including road and rail access. Third, in some cases, vessel operators would have to factor in the added costs of fuel and other costs of traveling greater distances to non-California ports, which may negate the cost savings in not purchasing the lower sulfur fuel. Finally, as stated previously, the added costs resulting from the proposed regulation are a small fraction of the overall operating costs of these vessels, and these costs are not expected to result in a significant adverse impact on the profitability of typical companies.

Most of the affected businesses that operate vessels are large businesses and can either absorb or pass-through the increased costs associated with the proposed regulation with no significant impact on their ability to compete with non-California businesses. For these reasons, we do not believe the relatively low costs of this proposed regulation are high enough to significantly affect the competitiveness of those businesses that are integrally linked to the movement of goods through California ports.

I. Potential Impact on Employment, Business Creation, Elimination, or Expansion

The proposed regulation is not expected to have a noticeable impact on employment, or business creation, elimination, or expansion. As stated above, the added costs of the proposed regulation are a small percentage of the overall operating costs for both cargo and cruise vessels. In addition, an analysis of the impact of the proposed regulation on the profitability of typical businesses indicated no significant adverse impacts.

There is also a possibility that the proposed regulation will result in a positive impact on business creation due to additional sales of marine fuels in California beginning in 2012, when the 0.1% sulfur fuel requirement becomes. This is because we expect to have 0.1% sulfur fuel available in California at that time, whereas some ports worldwide may not.

J. Potential Costs to Local, State, and Federal Agencies

Local Agencies

We do not expect any significant fiscal impacts on local agencies. We are not aware of any local government agency that operates an ocean-going vessel as defined in the proposed regulation. However, some minor impacts are possible on ports, which in California are established by state government and are operated by entities such as port authorities and departments of municipal governments.

The proposed regulation will increase costs for vessels visiting California ports. As such, some vessel operators could potentially choose to utilize alternative ports outside of California. However, as discussed in detail in section H above, we do not believe that this will occur to any significant degree.

We do not expect significant fiscal impacts on local air pollution control agencies due to the proposed regulation because ARB intends to enforce the provisions of the proposal statewide.

State Agencies

We do not expect any significant fiscal impacts on State agencies. Government owned or operated vessels are exempted from the regulation. In addition, ARB staff was already enforcing the previous auxiliary engine rule with existing resources. However, additional resources will be needed as the implementation of this and other port-related measures occur, and the industry grows.

Federal Agencies

We are not aware of any impacts on federal agencies. Military and government vessels are exempted from the requirements of the proposed regulation.

K. Cost-Effectiveness

For the purposes of this section, cost-effectiveness is defined as the ratio of the cost of compliance per ton of pollution reduced. Cost-effectiveness figures allow different regulations to be compared to determine the most economic way to reduce a given amount of emissions.

In this section, we calculate the cost-effectiveness in two ways. First, we attribute the total annual cost of the proposed regulation to each pollutant individually. This results in the highest cost-effectiveness values, and may overestimate the overall cost-effectiveness of the proposed regulation. For example, a regulation that resulted in the same costs and diesel PM emission reductions, but no reductions in other pollutants, would have the same cost-effectiveness in terms of diesel PM as the proposed regulation. Therefore, as an alternative, we also calculate the cost-effectiveness by

attributing half of the costs of the proposed regulation to diesel PM reductions, and the other half to reductions in NOx and SOx.

Cost-Effectiveness of the Proposed Regulation: Attributes All Costs to Each Pollutant Individually

The estimated cost-effectiveness of the proposed regulation is shown in Table VIII-12 below. The cost-effectiveness is expressed in terms of dollars per ton of NOx, diesel PM, and SOx removed, with the total annual cost attributed to each pollutant individually. As shown, the average cost effectiveness is estimated at about $63,000 per ton of PM reduced, $84,000 per ton of NOx reduced, and about $7,000 per ton of SOx reduced. The cost-effectiveness values in 2012 are slightly higher due to the higher cost of the 0.1% sulfur fuel.

Table VIII-12: Cost-Effectiveness of the Proposed Regulation (Attributes All Costs to Each Pollutant Individually)

Year	Total Annual Cost ($ millions)	Emission Reductions* (tons per year)			Cost-Effectiveness ($/ton)		
		NOx	PM	SOx	NOx	PM	SOx
2009	$142.6	1,498	2,192	19,285	95,200	65,100	7,400
2010	$275.0	3,689	4,566	39,703	74,500	60,200	6,900
2011	$282.8	3,799	4,712	40,835	74,400	60,000	6,900
2012	$343.8	3,908	5,406	49,418	88,000	63,600	7,000
2013	$353.0	4,054	5,552	50,806	87,100	63,600	7,000
2014	$362.7	4,164	5,734	52,267	87100	63,300	6,900
Average Cost Effectiveness					84,400	62,600	7,000

* The emission reductions are based on the ARB Marine Emissions Model Version 2.1, updated May 22, 2008.

Cost-Effectiveness of the Proposed Regulation: Attributes Half the Costs to PM and Half to NOx plus SOx

In Table VIII-13 below, we calculate the cost-effectiveness by attributing half of the costs of the proposed regulation to PM reductions, and the other half to reductions in nitrogen oxides (NOx) and sulfur oxides (SOx). This may reflect the overall cost-effectiveness more accurately in that it accounts for the multiple benefits of the proposed regulation. As shown, the average cost-effectiveness is estimated at about $31,300 per ton of PM reduced, and about $3,200 per ton of combined NOx and SOx emissions reduced.

Table VIII-13: Cost-Effectiveness of the Proposed Regulation (Attributes Half of the Costs to PM and Half to NOx+SOx)

Year	Half of Total Annual Cost (millions)	Emission Reductions* (tons per year)		Cost-Effectiveness ($/ton)	
		PM	NOx+SOx	PM	NOx+SOx
2009	$71.3	2,192	20,783	32,500	3,400
2010	$137.5	4,566	43,392	30,100	3,200
2011	$141.4	4,712	44,634	30,000	3,200
2012	$171.9	5,406	53,326	31,800	3,200
2013	$176.5	5,552	54,860	31,800	3,200
2014	$181.4	5,734	56,431	31,600	3,200
Average Cost Effectiveness				31,300	3,200

* The emission reductions are based on the ARB's 2008 Emissions Inventory.

As shown in Table VIII-14 below, the cost-effectiveness values of the proposed regulation for PM (as calculated in Table VIII-13) are similar to other regulations recently adopted by the Board. For comparison purposes, all cost-effectiveness estimates shown attribute half of the regulation costs to PM and half to NOx or other pollutants, except for the In-Use Off-road Diesel Vehicle Rule, as noted.

Table VIII-14: PM Cost-Effectiveness of the Proposal and Other Diesel Regulations (Attributes Half of All Costs to PM)

Regulation or Airborne Toxic Control Measure	PM Cost-Effectiveness		Source of Estimate
	Dollars/Ton	Dollars/pound	
Public Fleets Rule	$320,000	$160	ARB, 2005b
In-Use Off-road Diesel Vehicle Rule[1]	$80,000	$40	ARB, 2007b
Solid Waste Collection Vehicle Rule	$64,000	$32	ARB, 2003a
Cargo Handling ATCM	$42,000	$21	ARB, 2005c
Ship Main/Aux/Boiler Proposal (2008)	**$31,300**	**$16**	**Staff Report**
Ship Auxiliary Engine Regulation (2005)	$26,000	$13	ARB, 2005a
Stationary Diesel Engine ATCM	$15,400	$7.70	ARB,2003b

1. Attributes all regulation costs associated with diesel emission controls to PM and splits other regulation costs equally between PM and NOx.

L. Analysis of Alternatives

In this section, we compare the cost-effectiveness of the proposed regulation to two of the four alternative control options discuss in Chapter V. We do not discuss the cost-effectiveness of two additional alternatives discussed in Chapter V ("Do Nothing" and "Rely on existing U.S. EPA and IMO Regulations") because there are no ARB imposed costs associated with them.

Alternative 1: Implement the Regulation as Proposed Except Without the Lower 0.1% Sulfur Limit in 2012

Under this alternative, ocean-going vessels visiting California ports would be required to use the marine distillate fuels specified in the regulation for 2009-2011, but would not be required to meet the more stringent 0.1% sulfur limit in 2012. Instead, it would be anticipated that by 2015, an Emission Control Area could be established under pending amendments to IMO Regulations that would require the use of 0.1% sulfur fuel or equivalent emission controls. As summarized in Table VIII-15, there would about 600 fewer tons PM reduced annually under the proposed alternative from 2012 to 2014. This alternative would also reduce cost by over $50 million annually. Overall, the cost effectiveness of the proposed alternative is slightly lower than the original proposal. However, given the significant health impacts associated with PM, we recommend the proposed regulation.

Table VIII-15: Comparison of Annual Costs and PM Emission Reductions Between Alternative #1 and the Proposed Regulation

	Estimated Cost ($ millions)			Estimated Reductions (tons/yr)			Cost-Effectiveness ($/ton)	
Year	Alt. #1	Proposal	Savings	Alt. #1	Proposal	Loss	Alt. #1	Proposal
2012	$290.6	$343.8	$53.2	4,821	5,406	585	60,300	63,600
2013	$298.5	$353.0	$54.5	4,967	5,552	585	60,100	63,600
2014	$306.8	$362.7	$55.9	5,114	5,734	620	60,000	63,300

Alternative 2: Implement the Regulation Within 24 nm of California's Major Ports Rather than within 24 nm of the California Coastline

Under this alternative, ocean-going vessels visiting California ports would be required to use the marine distillate fuels specified in the proposed regulation only within 24 nautical miles of major ports, rather than along the entire coastline. This would reduce the transiting emission reductions by about 70 percent, while having little impact on the reductions that would be achieved from maneuvering and hotelling. Overall, the PM emissions subject to the proposed regulation would be reduced by about 53 percent. This alternative would retain emission reductions near California's major population centers, which are generally located near California's major ports, but would substantially decrease the emissions reduced in other coastal areas. This could be of particular concern to California coastal counties such as Santa Barbara, Ventura, and San Luis Obispo, which are impacted by ship emissions due to a major shipping line that traverses relatively close to their shorelines.

As summarized in Table VIII-16, with alternative #2, there would about 2,400 less tons PM reduced in year 2010 (a representative year), and an estimated $146 million cost reduction. Overall, the cost-effectiveness of the proposed alternative would remain the same because the reduction in costs and emission reductions are both reduced by the

same percentage. Although this alternative would reduce costs and target emission reductions near population centers, the proposal would not achieve emission reductions in other coastal areas. In addition, pollutants from ships can be transported long distances, reaching sensitive areas. For these reasons, we recommend the proposed regulation.

Table VIII-16: Comparison of Annual Costs and PM Emission Reductions Between Alternative #2 and the Proposed Regulation for 2010

Estimated Cost ($ millions)			Estimated Reductions (tons/yr)			Cost-Effectiveness ($/ton)	
Alt. #2	Proposal	Savings	Alt. #2	Proposal	Loss	Alt. #2	Proposal
$129.3	$275	$146	2,146	4,566	2,420	60,200	60,200

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TITLE 13. CALIFORNIA AIR RESOURCES BOARD

NOTICE OF PUBLIC HEARING TO CONSIDER AMENDMENTS TO THE CURRENT SPARK-IGNITION MARINE ENGINE AND BOAT REGULATIONS

The Air Resources Board (the Board or ARB) will conduct a public hearing at the time and place noted below to consider adoption of amendments to the California regulations and test procedures for new spark-ignition marine engines and boats, to the California regulations for in-use compliance regarding new spark-ignition marine engines and boats, and to the California procedures for exemption of add-on and modified parts for new spark-ignition marine engines and boats. The purposes of staff's proposed amendments are to provide greater compliance flexibility to the regulated industry, specifically manufacturers of high performance sterndrive/inboard engines, and to enhance alignment with proposed United States Environmental Protection Agency (U.S. EPA) regulations. A summary of the amendments proposed by staff is provided in the section "Description of the Proposed Regulatory Action" later in this notice.

DATE: July 24, 2008

TIME: 9:00 a.m.

PLACE: California Environmental Protection Agency
Air Resources Board
Byron Sher Auditorium
1001 I Street
Sacramento, CA 95814

This item will be considered at a two-day meeting of the Board, which will commence at 9:00 a.m., July 24, 2008, and may continue at 8:30 a.m., July 25, 2008. This item may not be considered until July 25, 2008. Please consult the agenda for the meeting, which will be available at least 10 days before July 24, 2008, to determine the day on which this item will be considered.

If you have a disability-related accommodation need, please go to http://www.arb.ca.gov/html/ada/ada.htm for assistance or contact the ADA Coordinator at (916) 323-4916. If you are a person who needs assistance in a language other than English, please contact the Bilingual Coordinator at (916) 324-5049. TTY/TDD/Speech-to-Speech users may dial 7-1-1 for the California Relay Service.

INFORMATIVE DIGEST OF PROPOSED ACTION AND POLICY STATEMENT OVERVIEW

Sections Affected: Proposed adoption of amendments to sections 2111, 2112, and Appendix A, within Chapter 2, Article 2.1, Title 13, California Code of Regulations (13 CCR); section 2139 within Chapter 2, Article 2.3, 13 CCR, section 2147 within Chapter 2, Article 2.4, 13 CCR; sections 2440, 2441, 2442, 2443.1, 2443.2, 2443.3,

2444.1, 2444.2, and 2445, and proposed repeal of Section 2448, within Chapter 9, Article 4.7, 13 CCR; and proposed adoption of amendments to the following documents incorporated by reference in Section 2447, 13 CCR: "California Exhaust Emission Standards and Test Procedures for 2001 Model Year and Later Spark-Ignition Marine Engines," as last amended September 22, 2006, and in Section 2474, 13 CCR: "Procedures for Exemption of Add-On and Modified Parts for Off-Road Categories," as adopted July 14, 2000.

Background: Health and Safety Code sections 43013 and 43018 direct ARB to achieve the maximum feasible and cost effective emission reductions from all mobile source categories, including spark-ignition marine engines, through the setting of emission standards and other requirements.

The U.S. EPA first promulgated exhaust emission standards for new outboard and personal watercraft (OB/PWC) engines in 1996. However, the benefits of the federal rulemaking were insufficient to meet California's air quality goals and State Implementation Plan (SIP) requirements. Therefore, ARB adopted exhaust emission regulations for these OB/PWC spark-ignition recreational marine engines in 1998. At that time the Board approved regulations that accelerated the 2006 federal standards to begin in 2001 in California. The regulations also set more stringent standards for these engines to be implemented in 2004 and 2008. As of this current year 2008, OB/PWC engines in California will meet exhaust emission standards that are numerically 65 percent less (i.e., more stringent) than federal exhaust emission standards.

On July 26, 2001, the Board approved amendments to the spark-ignition marine regulations (Title 13, CCR, section 2440 et seq.) to include new sterndrive and inboard (SD/I) engines. Those amendments included the adoption of two sets of exhaust standards and the incorporation of on-board diagnostics (OBD-M) for SD/I engines. The first set of standards capped hydrocarbons plus oxides of nitrogen (HC+NOx)[1] emissions at 16.0 grams per kilowatt-hour (g/kW-hr) for all 2003 through 2006 model year engines. This is equivalent to California's most stringent exhaust standard for OB/PWC engines. The second set of standards required the phase-in of a catalyst-based 5.0 g/kW-hr HC+NOx standard from 2007-2009 (45/75/100 percent) and OBD-M.

On November 17, 2005, the Board approved amendments to the original SD/I regulations to provide engine manufacturers with an emissions neutral option to delay the 2007 introduction of engines meeting the catalyst-based second tier standards by one year in exchange for full product line compliance in 2008 and limited evaporative permeation control. The Board also provided temporary relief to manufacturers of high performance SD/I engines greater than 373 kilowatts (>373 kW) by delaying the second tier standard (5.0 g/kW-hr HC+NOx) for these engines until 2009, and by allowing them to meet the standard through averaging. The Board adopted other relief provisions during this rulemaking such as revised durability periods and default certification levels for high performance engines. The Board also directed staff to track U.S. EPA's

[1] Includes only the nonmethane portion of hydrocarbons.

progress and to consider proposing CO standards and to consider harmonizing with other U.S. EPA requirements if appropriate for California.

Description of the Proposed Regulatory Action:

Staff's proposed amendments to the emission standards and test procedures for spark-ignition marine engines are meant to address issues that have developed since the Board's 2005 rulemaking and to enhance alignment with other ARB and U.S. EPA regulations. Primarily, staff is proposing to modify the high performance (>373 kW) SD/I engine exhaust emissions standards to address concerns regarding the use of catalytic converters on high performance engines and to address the resulting change in emissions benefits by considering other measures, including enhanced evaporative controls for those engines.

Staff is also proposing to streamline the regulations by incorporating additional compliance flexibility provisions and by harmonizing requirements with U.S. EPA to the extent feasible while allowing California to attain its goals for improved air quality.

Staff's proposed amendments are of two general types, those:

1) To Be Harmonized with U.S. EPA, including
- Total Hydrocarbon Standards (all spark-ignition marine categories)
- Not-To-Exceed Limits (all spark-ignition marine, except SD/I > 373 kW)
- Revised Definitions for OB/PWC and SD/I Engines
- Revised Jet Boat Engine Standards
- Standardized Engine Rebuilding Practices (all spark-ignition marine categories)

For this group of amendments, staff is proposing that the Board direct staff to align with the final federally promulgated regulations (described in next section) where appropriate.

2) To Retain California-Specific Provisions, including
- Carbon Monoxide Standards (all spark-ignition marine categories)
- Revised High Performance Engine Requirements (SD/I >373 kW)
- Revised OBD-M Requirements (SD/I engines)
- Hardship Allowance Provisions (SD/I engines)
- Voluntary Five-Star Standards (all spark-ignition marine categories)
- Replacement Engine Provisions (all spark-ignition marine categories)
- Clarifications and Miscellaneous Requirements

For this group of amendments, staff is proposing that the Board direct staff to review the final federally promulgated regulations and align the final California regulations where possible while maintaining California-specific provisions.

A more detailed description of staff's proposal is included in the Staff Report: Initial Statement of Reasons for Rulemaking to Consider Amendments to the Current Spark-Ignition Marine Engine and Boat Regulations.

COMPARABLE FEDERAL REGULATIONS

U.S. EPA promulgated regulations in 1996 for OB/PWC engines; however, this regulation did not apply to SD/I pleasurecraft. On May 18, 2007, U.S. EPA published a Notice of Proposed Rulemaking (NPRM) in the Federal Register for nonroad spark-ignition engines and equipment that would institute a federal SD/I regulation generally harmonizing with the existing California exhaust standards for OB/PWC and SD/I engines. The NPRM also proposed the adoption of CO standards and evaporative control requirements for OB/PWC and SD/I engines and boats. Furthermore, the NPRM proposed to include the methane component of hydrocarbon in its certification standard for gasoline fueled engines and to incorporate general relief provisions for unforeseen technical and economic hardships that may befall engine or equipment manufacturers. U.S. EPA is expected to promulgate a final rulemaking for OB/PWC and SD/I standards this year.

BENEFITS OF THE PROPOSAL

Staff's objectives in recommending the revisions proposed herein to California's spark-ignition marine regulations and test procedures are to provide harmonization with proposed federal requirements and to address technical concerns regarding the use of catalytic converters on high performance engines. Because the proposal would be no more expensive to industry as a whole than meeting the current 2009 requirements, the estimated maximum California cost-effectiveness would remain at $2.08 to 3.39/lb HC+NOx reduced for all SD/I engines as calculated for the 2001 rulemaking. This cost-effectiveness continues to be well within the range of other control measures adopted by the Board. The cost effectiveness for OB/PWC engines would also remain unchanged by this proposal at $0.32 to $3.57 per pound of NMHC+NOx reduced since no additional control technologies would be required to meet the proposed CO and NTE standards.

AVAILABILITY OF DOCUMENTS AND AGENCY CONTACT PERSONS

The Board staff has prepared a Staff Report: Initial Statement of Reasons (ISOR) for the proposed regulatory action, which includes a summary of the economic and environmental impacts of the proposal. The report is entitled: "Staff Report: Initial Statement of Reasons for Rulemaking, Public Hearing to Consider Amendments to the Current Spark-Ignition Marine Engine and Boat Regulations."

Copies of the ISOR and the full text of the proposed regulatory language, in underline and ~~strikeout~~ format to allow for comparison with the existing regulations, may be accessed on the ARB's web site listed below, or may be obtained from the Public Information Office, Air Resources Board, 1001 I Street, Visitors and Environmental

Services Center, 1st Floor, Sacramento, CA 95814, (916) 322-2990 at least 45 days prior to the scheduled hearing on July 24, 2008.

Upon its completion, the Final Statement of Reasons (FSOR) will be available and copies may be requested from the agency contact persons in this notice, or may be accessed on the ARB's web site listed below.

Inquiries concerning the substance of the proposed regulation may be directed to the designated agency contact persons, Mr. Scott Rowland, at (626) 575-6676 or srowland@arb.ca.gov, or Mr. Jeff Lowry, at (626) 575-6841 or jlowry@arb.ca.gov.

Further, the agency representative and designated back-up contact persons to who nonsubstantive inquiries concerning the proposed administrative action may be directed are Ms. Lori Andreoni, Board Administration & Regulatory Coordination Unit, (916) 322-4011, or Ms.Trini Balcazar, Regulations Coordinator, (916) 445-9564. The Board has compiled a record for this rulemaking action, which includes all the information upon which the proposal is based. This material is available for inspection upon request to the contact persons.

This notice, the ISOR and all subsequent regulatory documents, including the FSOR, when completed, are available on the ARB Internet site for this rulemaking at www.arb.ca.gov/regact/2008/marine08/marine08.htm

COSTS TO PUBLIC AGENCIES AND TO BUSINESSES AND PERSONS AFFECTED

The determinations of the Board's Executive Officer concerning the costs or savings necessarily incurred by public agencies and private persons and businesses in reasonable compliance with the proposed regulations are presented below.

Pursuant to Government Code sections 11346.5(a)(5) and 11346.5(a)(6), the Executive Officer has determined that the proposed regulatory action would not create costs or savings to any state agency or in federal funding to the state, costs or mandate to any local agency or school district whether or not reimbursable by the state pursuant to part 7 (commencing with section 17500), division 4, title 2 of the Government Code, or other nondiscretionary cost or savings to state or local agencies. The ARB may incur additional implementation or enforcement costs at some future time.

In developing this regulatory proposal, the ARB staff evaluated the potential economic impacts on representative private persons or businesses. The ARB is not aware of any cost impacts that a representative private person or business would necessarily incur in reasonable compliance with the proposed action.

The Executive Officer has made an initial determination that the proposed regulatory action would not have a significant statewide adverse economic impact directly affecting businesses, including the ability of California businesses to compete with businesses in other states, or on representative private persons.

In accordance with Government Code section 11346.3, the Executive Officer has determined that the proposed regulatory action would not affect the creation or elimination of jobs within the State of California, the creation of new businesses or elimination of existing businesses within the State of California, or the expansion of businesses currently doing business within the State of California. A detailed assessment of the economic impacts of the proposed regulatory action can be found in the ISOR.

The Executive Officer has also determined, pursuant to title 1, CCR, section 4, that the proposed regulatory action would not affect small businesses because there will be no incremental cost, or an insignificant cost, associated with staff's proposal in addition to those already needed to comply with current regulations.

In accordance with Government Code sections 11346.3(c) and 11346.5(a)(11), the Executive Officer has found that the reporting requirements of the regulation which apply to businesses are necessary for the health, safety, and welfare of the people of the State of California.

Before taking final action on the proposed regulatory action, the Board must determine that no reasonable alternative considered by the board or that has otherwise been identified and brought to the attention of the board would be more effective in carrying out the purpose for which the action is proposed or would be as effective and less burdensome to affected private persons than the proposed action. A detailed assessment of the economic impacts of the proposed regulatory action can be found in the ISOR.

SUBMITTAL OF COMMENTS

Interested members of the public may also present comments orally or in writing at the meeting, and in writing or by e-mail before the meeting. To be considered by the Board, written comments submissions not physically submitted at the meeting must be received **no later than 12:00 noon, July 24, 2008,** and addressed to the following:

Postal mail: Clerk of the Board, Air Resources Board
1001 I Street, Sacramento, California 95814

Electronic submittal : http://www.arb.ca.gov/lispub/comm/bclist.php

Facsimile submittal: (916) 322-3928

Please note that under the California Public Records Act (Government Code section 6250 et seq.), your written and oral comments, attachments, and associated contact information (e.g., your address, phone, email, etc.) become part of the public record and can be released to the public upon request. Additionally, this information may become available via Google, Yahoo, and any other search engines.

The Board requests but does not require that 30 copies of any written statement be submitted and that all written statements be filed at least 10 days prior to the hearing so that ARB staff and Board Members have time to fully consider each comment. The board encourages members of the public to bring to the attention of staff in advance of the hearing any suggestions for modification of the proposed regulatory action.

STATUTORY AUTHORITY AND REFERENCES

This regulatory action is proposed under that authority granted in Health and Safety Code, sections 39600, 39601, 43013, 43018, 43101, 43102, 43104, and 43105. This action is proposed to implement, interpret and make specific sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5, and 43210-43212.

HEARING PROCEDURES

The public hearing will be conducted in accordance with the California Administrative Procedure Act, title 2, division 3, part 1, chapter 3.5 (commencing with section 11340) of the Government Code.

Following the public hearing, the Board may adopt the regulatory language as originally proposed, or with non-substantial or grammatical modifications. The Board may also adopt the proposed regulatory language with other modifications if the text as modified is sufficiently related to the originally proposed text that the public was adequately placed on notice that the regulatory language as modified could result from the proposed regulatory action; in such event the full regulatory text, with the modifications clearly indicated, will be made available to the public, for written comment, at least 15 days before it is adopted.

The public may request a copy of the modified regulatory text from the ARB's Public Information Office, Air Resources Board, 1001 I Street, Visitors and Environmental Services Center, 1st Floor, Sacramento, CA 95814, (916) 322-2990.

CALIFORNIA AIR RESOURCES BOARD

James N. Goldstene
Executive Officer

Date: 5/27/2008

The energy challenge facing California is real. Every Californian needs to take immediate action to reduce energy consumption. For a list of simple ways you can reduce demand and cut your energy costs see our Web –site at www.arb.ca.gov.

State of California
AIR RESOURCES BOARD

STAFF REPORT: INITIAL STATEMENT OF REASONS FOR RULEMAKING

PUBLIC HEARING TO CONSIDER AMENDMENTS TO THE CURRENT SPARK-IGNITION MARINE ENGINE AND BOAT REGULATIONS

Date of Release: **June 6, 2008**
Scheduled for Consideration: **July 24, 2008**

This report has been reviewed by the staff of the California Air Resources Board and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Air Resources Board, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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EXECUTIVE SUMMARY

The amendments proposed herein to the California emissions regulations and test procedures for new spark-ignition marine engines and boats are intended to address issues that have developed since the Air Resources Board (Board or ARB) last considered the regulations (November 2005) and to enhance alignment with other ARB and United States Environmental Protection Agency (U.S. EPA) regulations.

Staff is foremost proposing that the Board modify the existing requirements for high performance engines (sterndrive/inboard (SD/I) engines > 373 kilowatts) to address technical barriers to the use of catalytic converters on these engines by relaxing the exhaust standards in this category for small volume manufacturers. To offset the potential emissions increases, staff is proposing to require the incorporation of enhanced evaporative technology (i.e., activated carbon canisters and low permeation tanks and hoses) on all vessels in which high performance engines are used beginning in 2009. Staff proposes to retain the existing exhaust emission standards for large volume manufacturers that produce both high performance and standard performance engines (SD/I engines ≤ 373 kilowatts). Such dual category manufacturers would be able to meet the standards through averaging. Optionally, these manufacturers would be allowed to certify high performance engines to the same exhaust and evaporative standards as proposed for small volume manufacturers. They would then be required to ensure the installation of enhanced evaporative technology on a portion of the vessels in which their standard performance SD/I engines are installed. In either case, all high performance engines beginning in 2009 would be accompanied with enhanced evaporative controls. These proposed changes would result in the same total combined hydrocarbon and oxides of nitrogen emissions as retaining the existing standards.

Staff is also proposing to streamline the regulations and harmonize with U.S. EPA to the extent feasible.

Staff's other proposed amendments are of two general types, those:

Harmonizing with U.S. EPA, including
- Total Hydrocarbon Standards (all spark-ignition marine categories)
- Not-To-Exceed Limits (all spark-ignition marine, except SD/I > 373 kW)
- Revised Jet Boat Engine Standards
- Standardized Engine Rebuilding Practices (all spark-ignition marine categories)
- Revised Definitions for Outboard, Personal Watercraft, and SD/I Engines

Provisions Specific to and Retained for California, including
- Carbon Monoxide Standards (all spark-ignition marine categories)
- Revised High Performance Engine Certification Requirements (SD/I >373 kW)
- Revised On-Board Diagnostics Marine (OBD-M) Requirements (SD/I engines)
- Hardship Allowance Provisions (SD/I engines)
- Voluntary Five-Star Standards (all spark-ignition marine)
- Replacement Engine Provisions (all spark-ignition marine)

- Clarifications and Miscellaneous Requirements

A more in depth description of staff's proposal is included in Chapter 3 of this report.

Staff recommends that the Board adopt this proposal.

1. INTRODUCTION

This report describes the rationale and details of staff's proposal to amend California's existing regulations for new spark-ignition marine engines and boats. In chapter 8 of the Air Resources Board's (Board or ARB) Initial Statement of Reasons (staff report) dated September 30, 2005, staff committed to return to the Board prior to the commencement of the 2009 model year regarding the certification of, and the incorporation of catalysts on, high performance sterndrive and inboard (SD/I) engines (i.e., those with rated power greater than 373 kilowatts) for manufacturers without sufficient product volume to make use of existing fleet averaging provisions (ARB 2005a). For reasons detailed in chapter 4 of this report, several technical issues have surfaced that would make it problematic to properly engineer a three-way catalytic converter for effective use on high performance engines. Furthermore, chapter 8 of the 2005 staff report also describes staff's intent to return to the Board prior to 2009 to adopt carbon monoxide (CO) standards and evaporative requirements, and to align as appropriate with the future requirements of the United States Environmental Protection Agency (U.S. EPA) pertaining to spark-ignition marine engines and boats. The changes proposed herein are meant to address these issues and to facilitate compliance with the California regulations.

2. BACKGROUND

This section provides information on the history of emissions control for spark-ignition marine engines, California's authority to set standards for off-road mobile sources including spark-ignition marine engines and boats, the current emissions inventory for spark-ignition marine engines in California, the existing spark-ignition marine regulations, and the steps taken to make the public and stakeholders aware of staff's proposal to amend California's current regulations.

2.1. History

Only in recent years has government regulatory activity been undertaken to control exhaust emissions from spark-ignition marine engines. The U.S. EPA first promulgated exhaust emission standards to reduce emissions of hydrocarbon (HC) and oxides of nitrogen (NOx) from new outboard and personal watercraft (OB/PWC) engines in 1996 (U.S. EPA 1996). However, the benefits of the federal rulemaking were not sufficient to meet California's air quality goals and State Implementation Plan (SIP) requirements. Therefore, in 1998 ARB adopted exhaust emission regulations for spark-ignition marine engines that accelerated the 2006 federal standards to begin in 2001 in California (ARB 1998a). The regulations also set more stringent standards for these engines to be implemented in 2004 and 2008. As of this current year 2008, personal watercraft and outboard engines in California will meet exhaust emission standards that are numerically 65 percent less (i.e., more stringent) than existing federal exhaust emission standards. The Board also adopted a star rating system for these engines depicting their relative cleanliness through a visible display of one, two, or three stars, with three representing the most stringent standards in California at that time.

On July 26, 2001, the Board amended the spark-ignition marine regulations (Title 13, California Code of Regulations, section 2440 et seq.) to include new SD/I engines (ARB 2001). Although OB/PWC engines dominate the emissions inventory with respect to spark-ignition marine engines, ARB modeling showed that SD/I engines also contributed significantly to ozone-forming emissions in California.

Accordingly, manufacturers of inboard and sterndrive engines were required to demonstrate compliance with an NMHC[1]+NOx exhaust emissions standard of 16.0 grams per kilowatt-hour (g/kW-hr) beginning with the 2003 model year. This standard is roughly equivalent to California's most stringent exhaust standard for OB/PWC engines, which, for those engines, was not required until 2008.

The SD/I regulations at that time also required compliance with a more stringent NMHC+NOx standard beginning in 2007 on a portion of engines. Since inboard and sterndrive marine engines are generally similar to automobile engines, for which a number of effective emission control technologies already exist, transference of automotive control technologies (catalysts specifically) to the marine sector makes a more stringent standard feasible. In fact, the majority of SD/I engines with rated power less than 373 kW are almost exclusively General Motors truck engines that have been marinized[2] for use on lakes and the ocean. Accordingly, the Board adopted a 5.0 g/kW-hr NMHC+NOx standard for these engines, which was based on the demonstrated use of three-way catalytic converters and oxygen sensor feedback control. Engines complying with the 5.0 g/kW-hr NMHC+NOx standard were eligible for a new four-star rating on environmental labels and hang tags to visually depict the most stringent marine engine standards currently available at that time. Also required beginning in 2007 was the incorporation of on-board diagnostics for all engines required to comply with the 5.0 g/kW-hr NMHC+NOx standard.

On November 17, 2005, the Board amended the original SD/I regulations by providing engine manufacturers with an emissions neutral option to delay the introduction of engines meeting the catalyst-based second tier standards by one year in exchange for full product line compliance in 2008 and limited evaporative permeation control. The Board adopted other provisions during this rulemaking such as revised durability periods and default certification levels for high performance engines. The Board also provided a temporary reprieve for high performance engine manufacturers by delaying the second tier standard (5.0 g/kW-hr NMHC+NOx) for these engines until 2009, and by allowing them to meet the standard through averaging. Finally, the Board directed staff to investigate the incorporation of future CO standards for spark-ignition marine engines and the harmonization of requirements that were under development by U.S. EPA.

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[1] The non-methane component of hydrocarbons.

[2] Marinization is the process of modifying an existing automobile engine to operate reliably in a marine environment. Some typical modifications include upgrading the composition of exhaust components to be more resistive against rust and corrosion, incorporating a water jacket within the exhaust manifolds to reduce temperatures, and providing better insulation for electrical contacts that might otherwise be exposed to corrosive sea water.

On May 18, 2007, U.S. EPA published its Notice of Proposed Rulemaking to harmonize federal exhaust standards for OB/PWC and SD/I engines with those already in effect in California (U.S. EPA 2007). Additionally, U.S. EPA proposed the adoption of CO standards, evaporative control requirements, Not-To-Exceed (NTE) standards, and other minor changes. U.S. EPA is expected to promulgate a final rulemaking in June 2008.

2.2. Authority

The Board's regulatory authority to control air pollution is set forth in Divisions 25.5 and 26 of the Health & Safety Code (H&SC), including sections 39600 and 39601. Health & Safety Code §39903 identifies ARB (the actual acronym used is CARB) as:

> "... the state agency charged with coordinating efforts to attain and maintain ambient air quality standards, to conduct research into the causes of and solutions to air pollution, and to systematically attack the serious problem caused by motor vehicles, which is the major source of air pollution in many areas of the state."

Provisions in Division 26 of the H&SC authorize CARB to control the emissions of criteria pollutants (and their precursors) from specific source categories.

In addition to more general grants of authority, the California Clean Air Act, as codified in Health and Safety Code section 43013, directs the ARB to regulate off-road mobile sources of emissions. Health and Safety Code section 43018 further mandates ARB "to achieve the maximum degree of emission reduction possible" from mobile sources of pollution in order to attain California's ambient air quality standards. These off-road mobile sources include, but are not limited to, marine vessels, locomotives, utility engines, off-road motorcycles, and off-highway vehicles. This regulation focuses on new spark-ignition (gasoline) marine engines, typically found in recreational boats such as ski boats or family fishing boats.

2.3. Existing Regulations

The existing California, federal, and international spark-ignition marine requirements are briefly discussed in this subsection.

2.3.1. California's Spark-Ignition Marine Regulations

The current spark-ignition marine regulations require that new engines comply with NMHC+NOx exhaust standards and that certification and environmental labels be attached to engines and/or boats to provide prospective engine owners, current engine owners, and enforcement personnel with information about the relative cleanliness of the engine.

The OB/PWC section of the regulations requires three phases (or tiers) of progressively more stringent exhaust standards from 2001 through 2008 culminating in a final emissions level of approximately 16 g/kW-hr NMHC+NOx for a typical 75 kW OB/PWC

engine. The test procedures for OB/PWC engines adopted by the Board were largely aligned with those already promulgated by U.S. EPA, but ARB's regulations required more stringent long term emission standards for California engines.

Table 2.1 shows the current range of standards for SD/I engines. The first tier standard of 16.0 g/kW-hr NMHC+NOx was required for all new SD/I engines with rated power less than or equal to 373 kW (500 horsepower) beginning in 2003. The second tier standard requires engines to meet a 5.0 g/kW-hr NMHC+NOx emissions level beginning on a portion of engines in 2007 and 2008, or optionally on all engines beginning in 2008 and thereafter, provided supplemental measures were taken to ensure equivalent emissions. Manufacturers choosing to wait until 2008 before introducing 5.0 g/kW-hr NMHC+NOx engines must use 15 grams per meter squared per day low-permeation fuel line supply hoses in 2007 and thereafter. SD/I engines with rated power greater than 373 kW do not have to comply with the emission standards until 2009.

The SD/I regulations also established durability periods for engines certified to the 5.0 g/kW-hr NMHC+NOx standard to ensure compliance with the standard throughout the engines' useful lives.

Table 2.1 - SD/I Exhaust Standards and Permeation Requirements

MODEL YEAR	RATED POWER [kilowatts]	COMPLIANCE OPTION[1]	DURABILITY [hours / years]	EXHAUST STANDARD NMHC[2]+NOx [grams per kilowatt-hour]	EXHAUST STANDARD TYPE[3]	SUPPLEMENTAL MEASURE[4]
2003 - 2006	kW ≤ 373	N/A	N/A	16.0	AVE	None
2007	kW ≤ 373	OPT 1	N/A	16.0 (55%)	AVE	None
			480 / 10	5.0 (45%)	FIXED	
		OPT 2	N/A	14.0	FIXED	Low-Permeation Fuel Line Hoses
2008	kW ≤ 373	OPT 1	N/A	16.0 (25%)	AVE	None
			480 / 10	5.0 (75%)	FIXED	
		OPT 2	480 / 10	5.0	FIXED	Low-Permeation Fuel Line Hoses
2009 and later	kW ≤ 373	N/A	480 / 10	5.0[6]	FIXED	Carryover[7]
	373 < kW ≤ 485		150[5] / 3	5.0[6]	AVE	
	kW > 485		50[5] / 1	5.0[6]	AVE	

Notes:
1. Once a manufacturer has chosen an option, that option must continue to be used exclusively across product lines
2. The non-methane component of hydrocarbon
3. Corporate averaging (AVE) may be used to demonstrate compliance with the exhaust emission standard, except where a FIXED standard is required
4. Supplemental measures may be different than shown, but must provide equal and verifiable emission reductions to those indicated
5. For the purpose of durability testing, engine components that have been approved with an hourly warranty period shorter than the full hourly durability period per § 2445.1 (c)(3)(C)4. may be replaced at the specified warranty interval
6. All engines ≤ 373 kW must meet a 5.0 g/kW-hr NMHC+NOx capping standard. For engines > 373 kW, the standard may be met by sales-averaging with engines equal to or less than 373 kW
7. The same or better supplemental emission control hardware used to meet the standard in 2007 must be used every model year thereafter

Additionally, the regulations require manufacturers to employ on-board diagnostics marine (OBD-M) on SD/I engines and boats complying with the 5.0 g/kW-hr NMHC+NOx standard to continuously monitor emission control components for proper performance and to alert the vessel operator via a dashboard light or audio alert device after a malfunction has been identified. The OBD-M system makes consumers aware when a component or system fails anytime in-use, which in turn provides incentive for the consumer to have the problem corrected in a timely manner especially should the malfunction occur during the warranty period. Furthermore, OBD-M facilitates the repair of the malfunctioning component by providing a detailed description of the problem to the service technician via a generic scan tool, and a confirmation that the repair has been performed correctly.

The spark-ignition marine regulations also provide selective enforcement auditing, in-use compliance testing, consumer labeling to identify emissions performance relative to other spark-ignition marine engines, and a defects warranty program to protect

consumers against poor quality products and to ensure that engines continue to perform as designed throughout their entire useful lives.

2.3.2. Federal Regulations

On May 18, 2007, U.S. EPA published a Notice of Proposed Rulemaking (NPRM) in the Federal Register for nonroad spark-ignition engines and equipment that would generally harmonize federal and California exhaust standards for OB/PWC and SD/I engines (U.S. EPA 2007). The NPRM also proposed the adoption of CO standards and evaporative control requirements for OB/PWC and SD/I engines and boats. Furthermore, the NPRM proposed to include the methane component of hydrocarbon in the federal certification standard for gasoline fueled engines and to incorporate compliance facilitation provisions for unforeseen technical and economic hardships that may befall engine or equipment manufacturers. Although on-board diagnostics for SD/I engines were proposed in the NPRM, they were far less comprehensive and rigorous that the OBD-M requirements already in effect for California.

2.4. Emissions Inventory

Table 2.2 shows the statewide baseline inventories for the reactive organic gas (ROG) component of hydrocarbons, NOx, and CO from spark-ignition marine engines in 2009, 2010, and 2020. These baseline estimates are annual averages and include the effects of all currently adopted State and federally promulgated regulations, including the 5.0 g/kW-hr NMHC+NOx standard for high performance SD/I engines schedule to begin in 2009. All emissions estimates are from the ARB's off-road emissions inventory database as of May 2008.

Table 2.2 - Baseline Spark-Ignition Marine Exhaust Emission Inventories Statewide Annual Averages

ENGINE TYPE		POLLUTANT	EMISSIONS INVENTORY (tons per day)		
			2009	2010	2020
OUTBOARD		ROG	42.6	40.0	20.4
		NOx	3.6	3.6	3.3
		CO	85.6	80.8	45.3
PERSONAL WATERCRAFT		ROG	25.3	24.2	22.4
		NOx	4.0	4.2	7.4
		CO	43.9	42.3	40.1
STERNDRIVE / INBOARD	≤ 373 KW	ROG	19.0	18.7	17.3
		NOx	24.1	23.8	22.3
		CO	538.3	541.8	629.3
	> 373 KW	ROG	0.9	0.9	0.7
		NOx	0.3	0.3	0.2
		CO	18.9	19.6	27.5

As shown in the table, ozone precursors from these engines are projected to decrease over time as a result of the Board's previous actions. Between 2009 and 2020, ROG+NOx[3] emissions are projected to decrease by 22 tons per day for OB/PWC engines and about 3.8 tons per day for SD/I engines. Although not currently regulated, CO emissions for outboard engines and personal watercraft are also projected to decrease over time as a corollary effect of the Board's previous actions to control ozone precursors. Paradoxically, total estimated CO emissions for sterndrive and inboard engines continue to increase despite the incorporation of CO reducing three-way catalytic converters on these engines in 2007 and 2008. Although the catalytic converters reduce engine-out CO by 40 - 60 percent, the increasing population of engines appears to cancel out these gains resulting in a net loss over time[4].

Table 2.2 only shows half the story, however. To provide the complete picture, Table 2.3 illustrates the emissions inventories for the same categories of spark-ignition marine engines during summer weekends. Boats with spark-ignition marine engines are used most frequently on summer weekends when the temperature is hot and smog levels are high. Exhaust emission levels associated with summer weekend operation are approximately 143[3] percent higher than corresponding annual average levels due to increased boating activity during the summer months. This is especially relevant since the potential for ozone formation is highest during the summer months.

Table 2.3 - Baseline Spark-Ignition Marine Exhaust Emission Inventories Statewide Summer Weekend

ENGINE TYPE		POLLUTANT	EMISSIONS INVENTORY (tons per day)		
			2009	2010	2020
OUTBOARD		ROG	103.5	97.1	49.6
		NOx	8.8	8.9	8.1
		CO	208.1	196.4	110.1
PERSONAL WATERCRAFT		ROG	61.4	58.9	54.4
		NOx	9.7	10.2	18.1
		CO	106.8	102.7	97.3
STERNDRIVE / INBOARD	≤ 373 KW	ROG	46.3	45.4	41.9
		NOx	58.6	57.9	54.2
		CO	1308.0	1316.6	1529.1
	> 373 KW	ROG	2.1	2.1	1.6
		NOx	0.7	0.7	0.6
		CO	46.0	47.7	66.8

[3] Estimated 2020 benefits are based on May 2008 off-road emissions inventory data, and differ somewhat from earlier calculations due to modeling refinements after the 2001 adoption of the existing regulation.
[4] The CO emissions inventory estimate is not as fully developed as that for ozone precursors. As more data become available with certification, the emissions inventory will be improved.

This table shows that ROG+NOx emissions are projected to decrease by about 53 tons per day for OB/PWC engines and about 9.4 tons per day for SD/I engines between 2009 and 2020 due to the Board's previous actions. CO emissions are also projected to decrease for OB/PWC engines and to increase for SD/I engines accordingly.

2.5. Public Process

In developing its proposal, staff has remained in close contact with the regulated marine industry in order to follow industry's progress regarding the spark-ignition marine engine and boat regulations and to be kept apprised of any issues that might delay compliance efforts. A list of specific outreach efforts is provided in Appendix A at the end of this report.

3. SUMMARY OF PROPOSED REGULATIONS

The amendments herein proposed address issues that have developed since 2005, when the Board last considered the regulations, and are meant to enhance alignment with other ARB and U.S. EPA regulations by harmonizing requirements where possible and by streamlining certification requirements. Staff is also proposing to revise the exhaust standard for high performance SD/I engines certified by small volume manufacturers to a level that would no longer be based on the use of three-way catalytic converters. Additionally, to make up for lost emission benefits resulting from this proposed relaxation of the standards, all high performance SD/I engine manufacturers would be required to ensure the proper installation of canister-based evaporative emission controls on all vessels using high performance engines in order to preserve the overall benefit of the existing 5.0 g/kW-hr HC+NOx exhaust standard. This amendment is necessary because using catalytic converters on high performance engines has turned out to be a difficult challenge.

Staff's other proposed amendments include the adoption of CO standards and Not-To-Exceed (NTE) limits for all categories of spark-ignition marine engines, the incorporation of general and hardship related compliance facilitation provisions for all engines, modifications to OBD-M and replacement engine requirements for SD/I engines, and the adoption of voluntary standards allowing manufacturers the option of a new five-star certification rating for any spark-ignition marine engine. Staff is also proposing to harmonize several existing and new definitions with those proposed by U.S. EPA and to align with U.S. EPA regarding the assignment of total hydrocarbons, rather than non-methane hydrocarbons, for its exhaust standards for all categories of spark-ignition marine engines. Staff is proposing other non-substantial modifications to the regulations and test procedures to correct grammatical and typographical errors, to correct references and citations, and to improve clarity. The following subsections describe the major provisions of staff's proposals in greater detail.

3.1. Definitions

Staff intends to revise or adopt definitions for the following terms to enhance harmonization with the requirements proposed by U.S. EPA in its May 18, 2007, NPRM and Regulatory Impact Analysis (RIA) documents:

- "High Performance Engine"
- "Jet boat"
- "Large Volume Dual Category Manufacturer"
- "Marinize"
- "Maximum Engine Power"
- "Maximum Test Speed"
- "New Propulsion Marine Engine" or "New Engine"
- "Nontrailerable Boat"
- "Outboard Engine"
- "Personal Watercraft"
- "Personal Watercraft Engine"
- "Spark-ignition"
- "Sterndrive/Inboard Engine" or "Sterndrive/Inboard Marine Engine"

These terms are defined in § 2441 of the proposed regulation order in Attachment A.

3.2. Emission Standards

3.2.1. Total Hydrocarbon plus Oxides of Nitrogen (HC+NOx) Standards

Title 13 of the California Code of Regulations (CCR), Section 2442(b) (13 CCR 2442(b)), requires spark-ignition marine engines to comply with NMHC+NOx standards as a condition of certification and sale in California. Only the non-methane component of hydrocarbon was included in those standards because the intent of the regulation was to control ozone and methane does not contribute to ozone formation in the atmosphere. However, methane has been identified as one of the greenhouse gases responsible for manmade global warming; therefore, staff intends to propose that all future marine standards reflect the total hydrocarbon species. Additionally, such action would harmonize the form of California's spark-ignition marine standards with that proposed by U.S. EPA for gasoline fuel certification. However, in practice this requirement is not expected to have a significant impact on compliance or change the projected reductions of ozone precursors in California. Virtually all currently regulated spark-ignition marine manufacturers in California already voluntarily submit total hydrocarbon measurements in their certification applications to eliminate having to speciate emission samples. Furthermore, the methane component is only about one percent of the total hydrocarbon species for gasoline and would not constitute much of a change in ozone precursor reductions regardless. From this point forward, all references in this staff report to combined hydrocarbons and oxides of nitrogen (HC+NOx) should be read to include methane.

3.2.2. Carbon Monoxide Standards

The CO standards proposed in this report are intended to lower the risk of asphyxiation during boating activities such as wakeboarding and teak surfing where boaters may be in close or direct proximity to a vessel's exhaust, but also to protect vessel occupants exposed to lesser concentrations that can cause diminished cerebral capacity leading to

accidents as a result. The California Department of Boating and Waterways reports ten deaths between 2001 and 2006 in California directly attributable to the inhalation of carbon monoxide during recreational boating activities[5]. Other fatalities or injuries not quantified in this tally may have occurred indirectly (e.g., drowning or loss of balance).

The proposed CO standards would apply separately to OB/PWC and SD/I engines and would essentially cap CO emissions at current measured levels; therefore, compliance with the proposed standards should not require the incorporation of any additional technology not already required by existing California regulation. Staff does, however, recognize that more stringent standards will likely be necessary to better protect the health of boaters in the future, and is committed to developing such standards (see subsection 5.3), but for now believes it important to ensure that CO levels not be allowed to increase above current levels. The proposed California standards differ slightly from the proposed federal standards for OB/PWC and SD/I engines in that the California standards would apply discretely to each engine family whereas the proposed federal standards could be met using averaging. As such, some manufacturers may need to adjust engine calibrations on some applications to comply with the proposed California standards, but such modifications are expected to be rare and minor. Staff's proposal does not provide for CO averaging in California because of the immediate risk from CO poisoning that higher emitting engines would pose to vessel occupants, not to mention the added complexity that would be added to the State's enforcement efforts should multiple emissions configurations become applicable (via averaging) to engines whose final point-of-sale destinations are not always predictable.

Staff is also proposing an optional CO standard and alternate certification cycle for larger displacement standard performance SD/I engines to facilitate compliance. For SD/I engines greater than or equal to 6.0 liters in displacement, but less than 373 kW maximum power, staff is proposing an optional CO standard of 25 g/kW-hr that would only use the weighted emission measurements from modes 2 through 5 of the E4 test cycle[6]. This standard discounts CO emissions at wide open throttle (Mode 1) where the risk of CO exposure from large displacement boats is expected to be low due to the unlikelihood of tow sports or other near-exhaust proximity activities such as wakeboarding and teak surfing being performed at maximum engine speeds and accelerations. Staff is not proposing to extend this alternate CO standard to high performance engines because the proposed standard for these engines is not expected to result in any compliance issues.

U.S. EPA had considered the promulgation of an identical standard in Chapter 4 of its Regulatory Impact Analysis (RIA 2007), but has not yet decided whether to include it in the final rulemaking since the proposed federal rule would permit CO averaging, which

[5] Annual safety reports are found collectively at http://www.dbw.ca.gov/Reports/SafetyReports.aspx

[6] Universally accepted 5-mode steady-state test cycle for spark-ignition marine engines defined in the International Organization for Standardization document "(ISO) 8178-4. Reciprocating Internal Combustion Engines, Exhaust Emissions Measurement, Part 4: Test Cycles for Different Engine Applications. Test cycle E4—Spark-ignited pleasure-craft less than 24 m length." Originally developed by the International Committee of Marine Industry Associations (ICOMIA Standard 36, 1988)

industry believes is sufficient to account for the few SD/I engine families that are expected to exceed the proposed 75.0 g/kW-hr CO standard.

Table 3.1, below, summarizes staff's proposed CO standards.

Table 3.1 - Proposed CO Standards for OB/PWC & SD/I Engines

ENGINE CATEGORY	MODEL YEAR	MAXIMUM POWER[a] *[kilowatts]*	CO STANDARD[b] *[grams per kilowatt-hour]*
OB/PWC	2009 and later	kW ≤ 40	500 – 5 x P[c]
		kW > 40	300.0
SD/I	2009 and later	kW ≤ 373	75.0[d]
		kW > 373	350.0

a Maximum Power may be interpreted as maximum rated power prior to 2010, but must be interpreted as maximum engine power for 2010 models and thereafter.
b All standards are fixed.
c P is defined as Maximum Engine Power in kilowatts (kW).
d An alternative standard of 25 g/kW-hr over modes 2 - 5 of the E4 cycle is provided for engines ≥ 6.0 L displacement.

3.2.3. High Performance (> 373 kW) SD/I Engine Standards

California's existing spark-ignition marine regulations require high performance SD/I engines to comply with a 5.0 g/kW-hr HC+NOx exhaust standard in 2009. The existing regulation allows standard performance (i.e., ≤ 373 kW) and high performance engine family emission levels to be averaged within a manufacturer's product line as a means to facilitate compliance.

However, due to technical obstacles regarding the effective use of catalytic converters on high performance engines and the competitive disadvantage that averaging would place on small volume manufacturers without enough standard performance engines to generate offsets (discussed in detail in Section 4.1, below), staff believes that sufficient reason exists for the Board to modify the high performance engine requirements.

Staff proposes that the Board relax the 2009 and later HC+NOx exhaust standard for small volume manufacturers of high performance engines from 5.0 g/kW-hr HC+NOx to the levels shown in Table 3.2 below. Any large volume dual category manufacturer (i.e., a manufacturer that produces both high performance and standard performance engines in California in combined quantities greater than 75 units annually)[7] would continue to be required to meet the existing 5.0 g/kW-hr HC+NOx exhaust standard, and could also avail themselves of averaging, if they so choose, beginning in 2009.

[7] Currently, only one large volume manufacturer of high performance and standard performance engines is know to exist (Mercury Marine).

Table 3.2
Proposed Exhaust Standards for SD/I engines

MODEL YEAR	MAXIMUM[a] POWER *[kilowatts]*	HC+NOx STANDARD *[grams per kilowatt-hour]*		CO STANDARD *[grams per kilowatt-hour]*
		Small Volume Single/Dual Category or Large Volume Single Category Manufacturer[b]	Large Volume Dual Category Manufacturer	
2009 - 2010	kW ≤ 373	5.0	5.0[b]	75.0[c]
	373 < kW ≤ 485	16.0	5.0[d]	350.0
	kW > 485	25.0		
2011 and later	kW ≤ 373	5.0	5.0[b]	75.0[c]
	373 < kW ≤ 485	16.0	5.0[d]	350.0
	kW > 485	22.0		

a Maximum Power may be interpreted as maximum rated power prior to 2010, but must be interpreted as maximum engine power for 2010 models and thereafter.
b These standards are fixed except for engines certified under the discontinuation allowance in subsection 3.4.1.
c Standard performance engines ≥ 6.0 liter displacement may alternatively meet a 25 g/kW-hr standard based on Modes 2-5 of the E4 test cycle.
d This standard may be met using averaging within the high performance category and/or between standard performance and high performance categories. Alternatively, manufacturers may instead comply with the exhaust standards for single category manufacturers provided a sufficient number of vessels with standard performance engines are equipped with carbon canister based evaporative systems.

To compensate for the shortfall in emission benefits from the change in exhaust standards, the staff proposal would also require all boats using 2009 and later high performance SD/I engines (regardless of whether the engine is produced by a small or large volume manufacturer) to incorporate enhanced evaporative controls, including evaporative control canisters (i.e., activated carbon canisters) and low permeation fuel tanks and hoses. The proposed evaporative requirements are based on national data compiled by U.S. EPA and rely in part on the analyses presented in the May 18, 2007, NPRM and its incorporated Regulatory Impact Analysis (RIA 2007). The proposed U.S. EPA standards are included in Table 3.3 below as guidance for industry. Staff is at this time proposing only a design-based requirement, not testing of individual evaporative control configurations. ARB staff is in the process of developing more comprehensive evaporative standards and test procedures specific to California's spark-ignition marine engines; therefore, the currently proposed evaporative requirements will be updated when staff's independent development work is complete and more comprehensive standards are considered for adoption in California.

Table 3.3
Proposed 2009 and Later Evaporative Control Design Specifications / Proposed U.S. EPA Standards

PERMEATION STANDARDS *[grams per square meter per day]*		DIURNAL STANDARD[a] *[grams per gallon per day]*
Hose[b]	Tank[c]	
15.0	1.5	0.40[d]

a Diurnal testing requires fuel with 9 pounds per square inch (psi) Reid Vapor Pressure volatility and a 24 hour fuel temperature cycle of 27.6 ° to 30.2 ° Celsius.
b Fuel line permeation testing requires gasoline fuel with 10% ethanol content and must be performed at a test temperature of 23 ± 2 ° Celsius.
c Fuel tank permeation testing requires gasoline fuel with 10% ethanol content and must be performed at a test temperature of 28 ± 2 ° Celsius.
d This standard is for trailerable boats; non-trailerable boats must meet a 0.16 grams per gallon per day diurnal standard over a fuel temperature cycle of 25.6 ° to 32.2 ° Celsius.

Staff additionally proposes that any large volume dual category manufacturer be given an option to certify high performance engines to the less stringent 16.0 g/kW-hr HC+NOx standard, but be required to recover the lost emission benefits by expanding the use of evaporative controls on standard performance engines. This option is explained in further detail in subsection 4.1.

The proposal would not change the levels associated with the required environmental labels. High performance engines achieving the existing 5.0 g/kW-hr standard without averaging would receive a four-star rating on environmental labels and hang tags. High performance engines certified to the 16.0 g/kW-hr HC+NOx standard and possessing enhanced evaporative controls would receive a three-star rating on environmental labels and hang tags, and high performance engines certified to either the 25.0 g/kW-hr or 22.0 g/kW-hr HC+NOx standards would receive a two-star rating.

3.2.4. Optional Test Cycle for High Performance Engines

Staff is also proposing an optional certification test cycle for all high performance SD/I engines. The optional cycle would be similar to the currently required E4 steady-state test cycle, but instead of measuring emissions at "no load" idle, manufacturers would test at 15 percent load. Staff has learned that high performance engines typically operate at loaded idle since much of their operation occurs while going through numerous zones near docks and swimming areas with five mile per hour "no wake" speed limits. Loaded idle operation is therefore more representative of high performance engine operation than "no load" idle operation and should be reflected in the certification test cycle.

3.2.5. Not-To-Exceed Limits

Staff proposes that the Board harmonize with federal NTE requirements for OB/PWC engines and SD/I engines with rated power less than or equal to 373 kW. The NTE

requirements would ensure emissions control in modes of engine operation that are not fully represented by the certification test cycle. No additional testing beyond that required by the federal requirements would be required; however, engine manufacturers would be required to certify separately in California and would be subject to all applicable State provisions pertaining to in-use compliance and enforcement.

3.2.6. Voluntary Standards

Staff is proposing a fifth tier of voluntary emission standards for spark-ignition marine engines. Engines certified to these voluntary requirements would be eligible for a new five-star emissions rating. Although intended for SD/I engines primarily, the five-star rating would be available to any category of spark-ignition marine engine certified to the voluntary standards throughout its useful life. The proposed five-star label is shown below:

The proposed voluntary five-star emission levels are shown below in Table 3.4:

Table 3.4 – Five-Star Voluntary Standards

$HC+NO_X$ STANDARD *[grams per kilowatt-hour]*	CO STANDARD *[grams per kilowatt-hour]*	PERMEATION STANDARDS *[grams per square meter per day]*		DIURNAL STANDARD *[grams per gallon per day]*
		Hose	Tank	
2.50	50.0	15.0	1.5	0.4

In addition to complying with the five-star emissions levels, which represent a fifty percent decrease in exhaust emissions compared to a four-star engine family, an eligible five-star engine family would also need to possess a fully complaint OBD-M system complete with functioning misfire monitoring capability. Labels and hang-tags for engine families certified to the voluntary standards must indicate a five-star rating. Manufacturers may, however, continue to use existing stocks of labels with only four stars for engines that are not certified to the voluntary standards.

3.3. Certification Requirements for High Performance Engines

3.3.1. Portable Measurement Systems

For the certification of high performance SD/I engines manufactured in extremely low volumes, staff proposes that the Board adopt, as an option to engine dynamometer testing, the use of portable emissions measurement systems (PEMS) for measurements in the laboratory or in the field. Eligible PEMS must comply with generally the same specifications and verifications as the laboratory instrumentation described in the spark-ignition marine engine test procedures, but with added flexibility per the incorporation of the provisions for portable measurement systems from sections 1065.901 through 1065.940 of Title 40, Code of Federal Regulations. A determination of compliance for the PEMS would be based on an overall demonstration of comparable accuracy and reliability relative to laboratory measurements occurring over multiple repetitions of the certification test cycle or an equivalent manufacturer-defined duty cycle. An acceptable duty cycle must have several individual field-test intervals against which a PEMS is compared to the laboratory system. The proposed test procedure amendments also specify procedures for preparing and conducting a field test and for correcting emission analyzer drift by taking into account a number of known measurement techniques. Additional provisions and conditions would apply when using PEMS in an engine dynamometer laboratory. Staff proposes that the PEMS option be limited to manufacturers that produce no more than 75 engines per year nationally (roughly 10% of which end up in California) to ensure a reasonable mix of dynamometer and PEMS data for comparison. Such an amendment would greatly reduce the cost of compliance for the many small volume manufacturers in the high performance sector.

3.3.2. Assigned Deterioration Factors

Staff is also proposing the optional use of assigned deterioration factors for high performance engines regardless of production volumes. Emissions deterioration over a high performance engine's useful life is expected to be relatively small considering an engine's 50-hour or 150-hour rebuild frequency; therefore, the assignment of reasonable deterioration factors provides a cost effective and low-risk alternative to the traditional method of determining deterioration factors. Staff anticipates the assignment of conservative deterioration factors in the early years of implementation, most likely extrapolated from the largest standard performance engines prior to the incorporation of catalytic converters. However, as more data become available, staff intends to revise deterioration factors as necessary to better reflect real world engine performance. Manufacturers opting to certify with assigned deterioration factors would be required to indicate this in their applications for certification, and engines so certified would be subject to the same requirements, penalties, and corrective actions for in-use compliance as would be the case for engines certified using traditionally derived deterioration factors.

3.4. Compliance Assistance Provisions

Engine marinizers have requested corporate averaging as a means for addressing unforeseen circumstances, primarily the unanticipated discontinuation of engines by the base engine supplier[8] and the lack of development time necessary to develop reliable emission control systems for the engines that replace them. While staff recognizes that unforeseen circumstances beyond the control of the engine marinizer can and do occur, it does not believe that corporate averaging is the most appropriate solution for the California market. As discussed previously with respect to CO emissions, averaging does not address the immediate risk to vessel occupants from CO poisoning that engines certified to higher family emission limits would pose. Furthermore, since manufacturers are not able to guarantee the ultimate destination of their engines, they cannot guarantee that California would not receive more than its fair share of higher emitting engines should ARB agree to participate in the national averaging program. Additionally, corporate averaging would complicate ARB's ability to enforce the regulations in that compliant SD/I engines would no longer be readily distinguished from noncompliant engines in the field by ARB inspectors. Further, should ARB attempt to implement corporate averaging within State boundaries, rather than as a participant in the federal program, U.S. EPA has the right to deny federal credits for any engines certified in California, which would serve as a disincentive for manufacturers to introduce their cleanest engines in California. Consequently, ARB would have to adopt significantly more stringent standards than currently required or proposed to achieve the same air quality benefits as from fixed standards.

3.4.1. Engine Discontinuation Allowance for SD/I Engines

In lieu of providing relief through corporate averaging for SD/I engines that will no longer be produced by the base engine supplier, staff proposes to allow manufacturers to certify one engine family (or other logical grouping) per year to current emission levels. This approach, hereafter known as the engine discontinuation allowance (EDA), would require one or more of the remaining engine families in a manufacturer's SD/I product line to be certified to emission levels more stringent than the existing fixed exhaust standards to make up for the deficit of the higher emitting engine family.

In addition to the typical stipulations of an averaging program, such as calculation methodology, records keeping, and reporting requirements as documented in 13 CCR 2442(b)(2), staff intends that the following criteria also be applicable with respect to its SD/I EDA proposal:

- Only one engine family (or other approved logical grouping of engines) per year per manufacturer may be certified with emission levels less stringent than the standards;
  - ➢ The engine family may be carried over for three subsequent years;

[8] In 2006, General Motors announced the end of production runs for two of the five base engines (4.3 liter and 8.1 liter engine families) frequently marinized by standard performance SD/I manufacturers.

- Previously certified engine families may not subsequently be certified to less stringent standards; however, normal fluctuations in certification levels due to superseded component use would be permitted unless the fluctuations resulted in an exceedance of the standards to which the engine family was previously certified;

- First time certified engine families certified less stringent than the standards must still comply with applicable OBD-M requirements and evaporative control standards;

3.4.2. Hardship Compliance Assistance for All Spark-Ignition Marine Engines

Staff is also proposing a separate provision applicable to all spark-ignition marine engines granting the Executive Officer discretion to issue additional compliance assistance for matters of extreme hardship for which the engine discontinuation allowance may not be completely adequate. Such compliance assistance would not be automatically available to the manufacturer; the manufacturer would be required to show proof that the situation necessitating Executive Officer intervention was completely beyond its control, and that the manufacturer had done everything feasible to resolve the situation under existing provisions. The following would be considered by the Executive Officer in determining whether or not to grant the compliance assistance:

- Proof must be provided showing that the hardship was beyond the control of the engine or boat manufacturer;
- All existing compliance flexibility provisions have been exhausted;
- The manufacturer has a plan to make up for any lost emission benefits.

3.5. On-Board Diagnostics-Marine (OBD-M)

Staff proposes that misfire monitoring become a mandatory component of the OBD-M requirements for SD/I engines beginning in 2010. Currently misfire monitoring is only required when ARB or the certifying manufacturer determines that engine misfire would cause the catalyst to fail before the emissions durability period of the engine had elapsed (e.g., 480 hours or 10 years for standard performance engines certified with a catalyst). When the OBD-M requirements were originally adopted, industry believed that catalyst construction would have to be far more robust than that of existing automotive catalysts to meet the 5.0 g/kW-hr NMHC+NOx standard and remain durable in a water environment. By virtue of that assumption, industry contended that misfire would not be an issue regarding catalyst durability and ARB agreed to make misfire monitoring a conditional OBD-M requirement. However, now that manufacturers have begun certifying SD/I engines in California, all have voluntarily included misfire monitoring as part of their OBD-M systems, presumably, at least in part, because they have found ways to incorporate conventionally designed catalytic converters that are susceptible to damage from engine misfire. As such, and because misfire monitoring has already been introduced voluntarily, staff believes that mandatory misfire monitoring should be a requirement for all future OBD-M systems. Audio/visual alert device suppression provisions would remain in effect per existing provisions. Staff is also proposing to ease the transition to OBD-M for manufacturers of high performance

engines by extending compliance dates to allow for the deployment of more sophisticated on-board computers and/or by temporarily relaxing the requirement for audio/visual alert device (i.e., malfunction indicator light) activation.

3.6. Replacement Engine Provisions

Part I, Section 8, of the "California Exhaust Emission Standards and Test Procedures for 2001 Model Year and Later Spark-Ignition Marine Engines" currently requires new SD/I replacement engines to comply with current model year emission standards. This unintentionally necessitates that a catalyst-equipped engine be used to replace the engine in an older model boat that may not be properly designed to accommodate or support a catalyst-equipped engine (e.g., limited engine compartment space, incompatible wiring harnesses, etc.). Accordingly, staff proposes to revise this provision to require installation of the cleanest engine currently available that can be installed in a boat without unreasonable modifications when replacing an existing engine. If no cleaner engine is available or compatible with the boat, a less stringent new replacement engine would be allowed so long as its emissions performance is at least as stringent as that of the engine being replaced.

3.7. Standardized Engine Rebuilding Practices

Staff proposes the incorporation of language to standardize procedures for rebuilding spark-ignition marine engines. The proposed language is in alignment with the engine rebuilding practices for other off-road categories in California and is virtually identical to that proposed by U.S. EPA for spark-ignition marine engines (40 CFR 1068.120). The incorporation of this requirement is necessary to prevent the downgrading of emission system performance during an engine rebuild.

3.8. Hang Tag Durability Requirements

Staff proposes to add a general statement of durability regarding the construction of hang tag labels. The requirements for environmental labels in § 2443.3 mandate a non-permanent label (i.e., hang tag) to be displayed on marine engines at the time of sale, but provide no material specifications for the construction of the hang tag. To address longevity concerns raised by a California dealership, staff had considered proposing an amendment to standardize components of the hang tag's construction such as reinforced grommets and surface lamination. However, several members of the regulated industry expressed opposition to more specific requirements citing that existing hang tags were sufficiently durable and replacements were available upon request should they ever be needed. After examining samples from several engine manufacturers, staff has concluded that the reviewed hang tags appear robust enough to survive under most conditions that should be encountered in a boat show room. However, to ensure that this is always the case and for every manufacturer, staff proposes that the Executive Officer be given discretion to require a demonstration of durability for any hang tag submitted per the provisions of § 2443.3 (d) that is suspected of being too fragile to remain viable for a period of no less than two years displayed under normal conditions. Recent legislation (Assembly Bill 695) now requires hang tags be submitted to the Department of Motor Vehicles with the registration application for

new boats with SD/I engines produced on or after July 1, 2008, further illustrating the importance of hang-tag durability.

3.9. Executive Officer Discretion for Technical Changes

Staff proposes that the Board additionally delegate to the Executive Officer the discretion to make technical changes to the regulations and test procedures without the need to return to the Board. This discretion is needed to ensure harmonization with the U.S. EPA, as its program has not yet been finalized. The staff envisions these changes being on the order of modifying definitions and technical specifications, particularly with regards to the test procedures and the NTE program. In these cases, the staff proposes alignment with U.S. EPA for the benefit of industry, but the final form of the requirements is not yet determined. Without such delegation, the marine industry may be subject to differing requirements until the Board could amend the regulation itself.

3.10. Aftermarket Exemption Procedures Clarification

To correct an oversight dating back to the adoption of the SD/I regulations in 2001, staff proposes to remove the exclusion of eligibility for an aftermarket exemption for SD/I parts found in section V, subsection D, of the "Procedures for Exemption of Add-On and Modified Parts for Off-Road Categories," incorporated in § 2472 of California's aftermarket regulations (13 CCR Article 7). As such, these procedures are in conflict with the applicability section of the aftermarket regulations (13 CCR 2470), which grants exemption applicability to all off-road engines subject to California or federal emission standards. The statement excluding SD/I engines in the aftermarket procedures was added in 2000, when only OB/PWC engines were subject to California's spark-ignition marine engine emission requirements, and was meant to provide reinforcement to readers that an exemption was not needed for pre-controlled engines, specifically SD/I engines at that time. However, after emission standards were adopted for SD/I engines in 2001, a corresponding adjustment to the aftermarket exemption procedures did not occur. Nonetheless, there has been no consequence to this apparent conflict in practice since applicability to SD/I engines is provided for in the aftermarket regulations, which establish regulatory requirements while incorporated test procedures detail the more nuts and bolts of demonstrating compliance to the regulations, and the regulations take precedence over incorporated documents. Staff's proposal to include SD/I engines in the aftermarket exemption procedures would therefore be a clarification of existing requirements.

4. DISCUSSION

4.1. High Performance Engines

The high performance engine sector in California consists of a relatively small number of manufacturers that cumulatively sell between 200 - 250 new engines Statewide each year. Despite this small number of engines, the emissions contribution from this category is not trivial. Additionally, the overwhelming majority of high performance engine sales are from a single manufacturer (Mercury Marine) that also has the distinction of being the only manufacturer that produces both standard and high

performance engines. As such, this manufacturer has a significant competitive advantage under the existing regulation in that it would be the only manufacturer able to certify high performance engines at current emission levels by averaging them together with lower-emitting standard performance engines.

Furthermore, additional information has indicated that the existing 2009 and later HC+NOx standard of 5.0 g/kW-hr presents a difficult challenge for high performance engines. Unlike the standard performance engines which have successfully met the 5.0 g/kW-hr emissions standard, high performance engines are typically operated at wide-open throttle for extended periods, and as such are calibrated to run fuel-rich most of the time. This is done primarily to reduce combustion temperatures preventing exhaust valve failure due to the high temperatures and cylinder pressures generated within the engines. Conversely, three-way catalytic converters, the technology of choice utilized almost exclusively on standard performance engines to comply with the standard, only achieve optimal performance at or near stoichiometric air/fuel ratios. Three-way catalysts can be engineered to retain some oxygen for use during fuel-rich operation; however, as the Manufacturers of Emissions Controls Association (MECA) noted in a letter regarding the staff's proposal, (See Appendix B), the oxygen storage materials used in three-way catalysts need periods of lean operation in order to replenish the stored oxygen. Typical usage of high-performance marine engines would not reliably offer the necessary periods of lean operation.

A key consideration in the development of staff's proposal was the potential impact of leaving the regulation unchanged. As mentioned above, the existing regulation gives an unfair competitive advantage to the sole dual category manufacturer. As a result, this manufacturer, already the dominant provider of high performance engines, would have a virtual monopoly of the high performance market in California. This would severely impact the small, California-based high performance engine manufacturers, as California sales form a significant part of their small market share. California dealers and boat builders currently supplied by high performance engine manufacturers without compliant product for 2009 would also be adversely affected. Furthermore, staff anticipates that many affluent Californians intent on owning a high performance boat would not be deterred by the lack of product in California and could purchase and register boats out of State, but use them in California anyway, despite legislation prohibiting the practice (Chapter 609, Statutes of 2007, Assembly Bill No. 695, Vehicle Code Sections 9852.9, 9853.7, and 9853.8). Should this scenario come to fruition, the result of the existing regulation with averaging would be job loss with less than optimal emission reductions.

While the original rulemaking included standard and high performance engines together, standard performance engines have been able to meet the 5.0 g/kW-hr HC+NOx standard, so requiring further emissions reductions from manufacturers participating solely in that market to make up for relaxed standards in the high performance market would not make sense. Any emissions reductions to make up for the relaxation should reasonably come from manufacturers in the high-performance market.

However, due to the composition of the market, most manufacturers have neither any standard performance engines with which to average, nor the resources to develop a plan to make up the shortfall. Requiring these small businesses, many of which are located in California, to make up the shortfall would be tantamount to shutting them down. For these reasons, staff investigated alternatives to the existing standard that could provide equivalent emissions benefits.

After examining and rejecting various alternatives (See Section 7), staff determined that the current proposal most fairly balanced the competing issues. The staff's proposal to relax the 2009 and later HC+NOx exhaust standard for small volume manufacturers of high performance engines from 5.0 g/kW-hr HC+NOx to the levels shown in Table 3.2, combined with the requirement that any large volume dual category manufacturer be required to meet the existing 5.0 g/kW-hr HC+NOx exhaust standard beginning in 2009 (likely using averaging), and the requirement that all boats using 2009 and later high performance SD/I engines (regardless of whether the engine is produced by a small or large volume manufacturer) incorporate enhanced evaporative controls, would preserve the emissions benefits of the regulation adopted in 2001.

The presence of only a single large volume dual category manufacturer, Mercury Marine, in the market has caused staff to consider alternatives that would allow for less expensive ways to comply with the requirements. Thus, staff additionally proposes an option that a large dual category manufacturer may certify high performance engines to the same exhaust and evaporative standards as proposed for small volume manufacturers. If a manufacturer chooses that option, staff proposes that it would then be required each year to expand the use of enhanced evaporative control technology on its standard performance engines to compensate for the emissions benefit shortfall that would otherwise occur. Staff also proposes that the Executive Officer be given discretion to allow other methods for recovering lost emission benefits should such methods provide equivalent and verifiable emissions benefits as the options identified.

It could be argued that the proposal thus increases the cost of the standard performance boats that are either used to generate a lower average exhaust emissions level or equipped with enhanced evaporative controls. However, since the requirement applies only to dual category manufacturers, that manufacturer would have the option of absorbing those costs in the purchase price of the high performance engine, an option the other manufacturers would not have. Furthermore, it should be noted that any other manufacturer that offers product in both the high-performance and standard performance markets in the future would be subject to the same requirements.

4.2. Technological Feasibility

The technological feasibility of the existing spark-ignition marine regulations has already been established by staff in its reports to the Board during the 1998, 2001, and 2005 rulemakings and follow-up test programs at Southwest Research Institute (SwRI). Namely, the technologies such as four-stroke and direct injection two-stroke technologies, leaner air-fuel calibration, electronic fuel injection, oxygen sensor

feedback fuel control, catalytic converters, and on-board diagnostics have all been determined to be feasible and appropriate for marine applications.

Staff's proposal does introduce additional evaporative emission controls that were not evaluated during those rulemakings. However, controls such as evaporative carbon canisters and low-permeation hoses are well-established, and have been used successfully by the automotive industry (ARB 1998b) for many years and are currently required for use on other off-road applications including some lawnmowers (ARB 2003a). U.S. EPA has also demonstrated the feasibility of carbon canisters and low-permeation hoses in marine applications as part of its current proposed rulemaking for spark-ignition marine engines (RIA 2007). The carbon canisters and hoses suggested in this report as a means to satisfy the proposed compliance requirement for high performance SD/I engines are expected to have similar material specifications as those mentioned in the referenced studies, and are indeed the same as those on which staff's and U.S. EPA's proposals are based.

4.3. "Sterndrive/Inboard Engine" and "Jet Boat" Definitions

Staff's proposed alignment with the federal definitions for "Sterndrive/inboard engine" and "Jet boat" would require several manufacturers that currently certify jet boat engines to the OB/PWC standards to begin certifying them to the more stringent SD/I standards. Staff believes this change is appropriate since jet boats typically compete in the same market as boats with sterndrive engines, and is necessary to prevent a potential shift in the sterndrive market favoring greater production and sales of higher emitting OB/PWC engines. U.S. EPA intends to allow manufacturers of jet boats with OB/PWC engines to comply federally using banked emission credits until 2012. However, ARB regulations do not permit the banking of emission credits and thus, these manufacturers would be required to make the transition immediately in California in the absence of additional action by the Board to grant compliance assistance. Therefore, to help facilitate transitioning to the SD/I standards for manufacturers currently certifying jet boat engines to the OB/PWC standards, staff proposes the following amendments:

- Jet boat engine families previously certified to the OB/PWC standards may continue to be certified to the OB/PWC standards until 2012;

- Beginning in 2010, newly introduced jet boat engine families must comply with the SD/I requirements upon introduction, but same-year offsets from any other jet boat or OB/PWC engine family may be used to comply with the HC+NOx standards through averaging until 2012. Compliance with the proposed CO standards would need to be met without averaging. Engine families certified to the OB/PWC HC+NOx standards in prior years, but not used in jet boat applications until 2010 would be considered newly introduced jet boat families;

- Jet boat engines previously certified in the same engine family as OB/PWC engines must be certified separately and in a unique engine family beginning in 2010 if newly introduced, or in 2012 otherwise.

Additionally, OBD-M would apply to new jet boat engine families beginning in 2010 and to all jet boat engine families beginning in 2012. The engine discontinuation allowance (EDA) would apply to these engine families beginning in 2012, but only engines used in jet boat applications would be considered in determining the final EDA emissions limit (i.e., engines from the same family as a jet boat engine, but installed in a PWC, cannot generate EDA offsets).

4.4. "New Engine" Definition

Staff's proposed alignment with the federal definition for "New Propulsion Marine Engine or New Engine" is meant to ensure consistency between federal and State regulations regarding applicability to specific engine configurations. This definition also makes explicit that any engine installed for sale in a new vessel, whether the engine is rebuilt, remanufactured, or used, must comply with the emission requirements in effect for new engines at the time the engine was installed.

4.5. Safety Concerns

The marine industry has not raised any safety-related issues at this time regarding staff's proposed amendments to the regulation. The proposed diurnal and permeation standards for high performance SD/I engines are based on the use of passive purge control carbon canister systems which do not violate United States Coast Guard prohibitions against fuel storage in pressurized containers.

5. ENVIRONMENTAL IMPACTS AND COST-EFFECTIVENESS

The proposed amendments are intended to provide limited regulatory relief while maintaining reductions of ozone precursor emissions assumed in the current regulations. An additional consideration is the impact that the proposed amendments may have on both ambient and localized concentrations of carbon monoxide in the environment. In consideration of the data analyses performed herein, staff has determined that no significant adverse environmental impacts should occur as a result of adopting these amendments. This chapter describes the potential impacts that the proposed amendments may have on the environment.

5.1 Legal Requirements

The California Environmental Quality Act (CEQA) and CARB policy require an analysis be performed to determine the potential adverse environmental impacts of proposed regulations. In addition, ARB's regulations require Staff Reports to assess significant beneficial and adverse environmental impacts. (Title 17 California Code of Regulations, Section 60005(b).) To meet these requirements, CARB must assess the extent and severity of reasonably foreseeable environmental impacts, evaluate potential environmental benefits of both the proposed action and of alternatives, and respond (in writing) to all significant environmental issues raised in the public review period and at the Board hearing. At present, CARB's regulatory program is certified by the Secretary of Resources (cf. Public Resources Code §21080.5), which allows CARB to include an

environmental analysis in the Initial Statement of Reasons (ISOR) instead of preparing an environmental impact report or negative declaration. Written responses to significant environmental issues raised by the public will be included in the Final Statement of Reasons (FSOR) for the proposed amendments.

Public Resources Code §21159 requires that the environmental analysis prepared by CARB include analyses of the following "reasonably foreseeable" items:

- Impacts of the methods of compliance;
- Feasible mitigation measures; and
- Alternate means of compliance with the proposed amendments (see subsection 5.2.3).

With respect to mitigation measures, CEQA requires state agencies to identify and adopt feasible mitigation measures that would minimize any significant adverse environmental impacts described in the environmental analysis.

The impact of the proposed action (i.e., the regulations as proposed here) on criteria pollutant emissions generally has been discussed above. However, both the proposed action and alternatives to it can also affect carbon monoxide emissions levels that have a more direct impact on human health and welfare near marine engines and equipment in operation; therefore, ARB must also evaluate the relative effects of the proposed action and alternatives on these more direct impacts. Staff believes that the proposed action will provide additional and direct benefits for many individuals by reducing their exposure to CO.

5.2. Projected ROG+NOx Emission Benefits

The focal point of staff's proposal is to provide industry with compliance options (explained in subsection 4.1.1) for high performance SD/I engines that preserves the emissions reduction goals of the existing regulation (I.e., is emissions-neutral with respect to the existing regulations). As shown in Table 5.1, no adverse environmental impacts are expected as a result of staff's proposal.

Table 5.1 -
Projected Emission Benefits for High Performance SD/I Engines
Statewide Summer Weekend

MODEL YEAR	POLLUTANT	EMISSION BENEFITS [tons per day]	
		Existing	Staff proposal
2009	ROG+NOx	0.19	0.19
2010	ROG+NOx	0.36	0.36
2020	ROG+NOx	2.03	2.03

5.3. Carbon Monoxide (CO)

5.3.1. Benefits of the Proposal

Although CO is not an ozone precursor, it is a criteria pollutant and has been known to cause fatalities in high concentration through asphyxiation. The United States Coast Guard and the National Institute for Occupational Safety and Health warn against the practices of wakeboarding and teak surfing because of the potential for these activities to result in serious injury or death as a result of CO inhalation from close proximity to the boat engine's exhaust. Typically, CO poisoning occurs while wakeboarders and teak surfers hold on to the back of the boat at idle or low cruising speeds. From approximately 1990-2007, there were 52 boat-related CO poisoning cases in California according to an updated Boating Accident Report from the Double Angel Foundation (DBLA 2007) using data commissioned by the United States Coast Guard. The California Department of Boating and Waterways reports 10 deaths between 2001 and 2006 in California associated with the inhalation of carbon monoxide during boating activities.

While as previously stated in subsection 3.2.2 of this report, staff's proposed CO standards would essentially cap emission levels at current levels, the incorporation of three-way catalytic converters on SD/I engines in California beginning in 2007 to reduce HC and NOx has also significantly reduced engine-out CO levels from those same engines compared to previous generations without catalytic converters. Staff estimates that reductions in CO on the order of 40 to 60 percent below previous engine-out levels have been achieved and the proposed standards will ensure the continuation of these reductions into the future. Conversely, staff's proposal to allow relaxed exhaust standards for high performance engines would result in a theoretical loss of CO benefits for those engines compared to the existing regulation, which does not mandate CO emission levels. However, the loss would be slight since the number of high performance engines in the California inventory is relatively small and, as previously mentioned, there would not be an increase in exposure risk because wakeboarding and other tow sports are not typically performed at maximum engine speeds behind high performance boats. CO reductions for OB/PWC engines have also occurred as an indirect result of the Board's previous action to control ozone precursors and will be ensured by staff's proposed CO standards.

As noted in Section 5.2.1, inhalation of CO during boating activities was associated with 10 deaths in California between 2001 and 2006. Additionally, CO may be a contributing factor in an associated with the unknown number of other marine–related deaths or injuries that are otherwise classified as being due to drunkenness or drowning.

Because of the dangers of carbon monoxide poisoning, the California Legislature made it illegal to teak surf[9]. AB 2222 (Stats. 2004, Chap. 565), effective as of January 1, 2005, imposes a fine of up to $100 on anyone who operates a vessel's engine or

[9] "Teak surfing" or "platform dragging," involves pulling a person through the boat's wake while the person holds on to the back of the boat.

generator while a person is holding on to the swim platform, swim ladder, or swim step on a boat. The passage of AB 2222, the Legislature declared its intent to, among other items:

> (c) Urge manufacturers of motorboats to invest in research and development to do both of the following:
>
> (1) Reduce the carbon monoxide emissions from their engines as soon as possible.
>
> (2) Design a motorboat that would better protect boaters from all CO emissions.

Although staff cannot quantify the impact of the CO standards in the proposed action on premature deaths and poisonings avoided, tests conducted by the National Institute for Occupational Safety and Health (NIOSH) indicate that a catalyzed SD/I system reduced CO exposures to boat occupants more than 90 percent. NIOSH concluded that "catalytic technology can greatly reduce the CO poisoning hazard to occupants of boats that have gasoline-powered engines." (NIOSH, 2007).

Because the subject marine engines are currently unregulated for CO, and because both the proposed actions and alternatives considered here all require at least some CO reduction from marine engines neither the proposed action nor the alternatives considered can be considered to cause an adverse impact. However, the proposed action would reduce continued adverse impacts on vessel operators and occupants. By contrast, the alternatives considered that would involve less stringent CO standards could result in continued adverse environmental impacts on vessel operators and occupants, and could require mitigation. Staff will continue to evaluate CO emissions and potential ways to reduce emissions further when possible.

5.3.2. Reasonably Foreseeable Feasible Mitigation Measures

Because the proposed amendments hold ozone precursor emissions constant, and because there is currently no CO standard and the proposed CO standard is set at or below current engine emissions levels, staff concludes that no significant adverse environmental impacts would occur from implementing the proposed amendments. As no adverse impacts are anticipated, no mitigation measures would be needed.

5.3.3. Reasonably Foreseeable Alternative Means of Compliance

The use of various types of emissions controls such as catalysts or evaporative controls to reduce hydrocarbon emissions constitutes the alternative means of compliance with the proposed amendments. Both technologies are well understood, and have been used successfully in other applications such as automobiles for decades. Neither technology would increase CO emissions; catalysts would decrease CO emissions.

5.4. State Implementation Plan (SIP)

The original spark-ignition marine engine regulations were adopted by the Board in 1998 for OB/PWC and in 2001 for SD/I engines and have been included as part of the

missions inventory baseline for SIP revisions since 2002. The emissions from engines in this source category are most significant during the summer ozone season. Since the proposal retains the overall ROG+NOx emissions benefits from the 2001 regulation, the changes proposed by staff should not significantly alter SIP commitments.

There is a possibility that the projected relative emission levels of HC and NOx would change due to the substitution of evaporative emissions control for exhaust control. However, as noted, the high performance engines run extremely rich, so it is likely that even if the 5.0 g/kW-hr HC+NOx standard were somehow to be met, that the majority of emissions reduced would be HC emissions. Thus, staff believes the change in relative HC and NOx reductions due to the proposal would be negligible.

5.5. Environmental Justice

State law defines environmental justice as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies (Senate Bill 115, Solis; Stats 1999, Ch. 690; Government Code § 65040.12(c)). The Board has established a framework for incorporating environmental justice into ARB's programs consistent with the directives of State law. The policies developed apply to all communities in California, but recognize that environmental justice issues have been raised more in the context of low income and minority communities, which sometimes experience higher exposures to some pollutants as a result of the cumulative impacts of air pollution from multiple mobile, commercial, industrial, area-wide, and other sources. Over the past twenty years, ARB, local air districts, and federal air pollution control programs have made substantial progress towards improving the air quality in California. However, some communities continue to experience higher exposures than others as a result of the cumulative impacts of air pollution from multiple mobile and stationary sources and thus may suffer a disproportionate level of adverse health effects. Since the same ambient air quality standards apply to all regions of the State, all communities, including environmental justice communities, will benefit from the air quality benefits associated with the proposal. As additional relevant scientific evidence becomes available, the spark-ignition SD/I marine engine standards will be reviewed again to make certain that public health is protected with an adequate margin of safety.

To ensure that everyone has had an opportunity to stay informed and participate fully in developing these proposed amendments to the spark-ignition inboard and sterndrive marine engine standards, staff has had meetings and has participated in public forums as described in Appendix A to this report.

5.6. Cost-Effectiveness

The cost-effectiveness for OB/PWC engines found in the 1998 rulemaking was $0.32 to $3.57 per pound of NMHC+NOx reduced (ARB 1998a) and for SD/I engines in the 2001 rulemaking was $2.08 to 3.39/lb NMHC+NOx reduced (ARB 2001). Staff expects no net change in cost-effectiveness from that found in the prior rulemakings, because the proposed amendments allow high performance engine manufacturers to comply with

non-catalyst based exhaust standards, and otherwise generally align with proposed federal requirements for other SD/I and OB/PWC engines.

If carbon canisters and low-permeation evaporative control hoses are utilized as a means of complying with the regulation (virtually all vessels that use high performance engines in California already possess metal, thus low permeation, tanks), the increase in costs to the manufacturer ($0.40 to $0.60 per foot hose length and $50.00 to $150.00 per carbon canister on average) would be offset by the savings resulting from the relaxation of requirements to introduce high performance engines meeting the catalyst-based 5.0 g/kW-hr HC+NOx exhaust standard in 2009 and thereafter. For comparison, in the original 2001 Initial Statement of Reasons, the incremental cost of complying with the catalyst-based standard was estimated to be $756 to $1231 per engine (ARB 2001).

6. ECONOMIC IMPACTS

The proposed regulatory amendments are not expected to result in net additional costs above the costs to comply with the existing regulation or for manufacturers to comply with federal requirements. Adoption of staff's proposal is actually expected to benefit high performance engine manufacturers by providing them with a less expensive alternative to the catalyst-based 5.0 g/kW-hr HC+NOx exhaust standard that they would not otherwise have under the existing regulation. Additionally, the proposed CO standards, NTE limits, and jet boat requirements are nearly identical to those proposed federally and would not necessitate additional costs or efforts above those required to comply with the federal requirements. Therefore, staff maintains that the proposed amendments would have no adverse impacts on business competitiveness, California employment, or on business creation, elimination, and expansion. Furthermore, if any manufacturer determines that compliance with the existing regulation is more economically advantageous than staff's proposed amendments for high performance manufacturers, that manufacturer is still able to choose to comply with the exhaust emission standards of the existing regulation. This section discusses, in greater detail, the potential cost and economic impacts of staff's proposed amendments.

6.1. Legal Requirement

Sections 11346.3 and 11346.5 of the Government Code require State agencies to assess the potential for adverse economic impacts on California business enterprises and individuals when proposing to adopt or amend any administrative regulation. The assessment shall include a consideration of the impact of the proposed regulation on California jobs, business expansion, elimination, or creation, and the ability of California business to compete.

State agencies are required to estimate the cost or savings to any state or local agency, and school districts. The estimate is to include any nondiscretionary cost or savings to local agencies and the cost or savings in federal funding to the state.

6.2. Affected Businesses

Staff does not expect any business to be adversely affected by the proposed amendments to the regulation, including those pertaining to farm or agriculture. Staff's amendments would provide greater flexibility for any high performance marine engine manufacturer or boat builder to comply with the regulation. Boat owners are not likely to be adversely affected because vessels with high performance engines are primarily used in recreational applications and are not typically employed to support the livelihood of California residents. The amendments are directed at manufacturers, so docks, ports, and fishing and boating stores are not expected to be adversely affected by staff's proposal; in fact, the amendments may indirectly benefit them since the amendments are meant to facilitate compliance for the marine industry.

6.2.1. Estimated Costs to Engine Manufacturers

An additional cost to the manufacturer would occur from the incorporation of carbon canisters ($50.00 to $150.00 per carbon canister on average) and low-permeation evaporative tubing ($0.40 to $0.60 per foot hose length on average). However, these incremental costs will be more than offset by the relaxation of requirements to introduce high performance engines that comply with the 5.0 g/kW-hr HC+NOx exhaust standard (i.e., most probably equipped with catalytic converters, which were estimated in the 2001 action to cost from $756 to $1231 per engine (ARB 2001)).

6.2.2. Potential Impacts on Business

Staff does not expect any business to be adversely affected by the proposed amendments to the regulation. The evaporative control technology to be incorporated is readily available, generally inexpensive compared to catalytic converters, and would not require special expertise. The proposed amendments are likely to benefit manufacturers because they generally facilitate compliance and are a potentially less expensive alternative for complying with the regulation. High performance marine engines are primarily used in recreational applications and do not typically support the livelihood of California residents. As mentioned above, the amendments are directed at manufacturers, so docks, ports, and fishing and boating stores are not expected to be adversely affected by staff's proposal. Staff's proposal to adopt CO standards and NTE limits is the same as the federal proposal. For all these reasons, no adverse effect on businesses would occur.

6.2.3. Potential Impact on Business Competitiveness

The proposed amendments are not expected to have a significant impact on the ability of California businesses to compete with businesses in other states since any engine produced in, or imported into, the State must comply with the proposed requirements. Furthermore, the recent enactment of AB 695 by the California Department of Motor Vehicles to modify the boat registration process in California promotes a level playing field for California dealerships by denying the registration of boats purchased outside the State with engines not certified for sale in California. Staff does not expect that any business will suffer a competitive disadvantage from the proposed amendments. The

evaporative control technologies are readily available and/or easily implementable, comparatively inexpensive, and would not require special expertise. High performance marine engines are primarily used in recreational applications and do not typically support the livelihood of California residents. As noted previously, docks, ports, and fishing and boating stores are not expected to be adversely affected by staff's proposal, since the amendments are directed at manufacturers. To the extent that the amendments reduce compliance costs to the marine industry, the docks, ports, and fishing and boating stores could also benefit.

6.2.4. Potential Impact on Employment

The proposed amendments are not expected to cause a noticeable change in California employment. In fact, they could help preserve California jobs to some extent, by making it easier for small California business to continue to compete in the high performance SD/I market. The evaporative control technologies and supplemental measures required are readily available and/or easily implementable, comparatively inexpensive, and would not require special expertise. The adoption of staff's proposal is expected to benefit manufacturers who would otherwise have to comply with a more expensive option or stop selling engines in California.

6.2.5. Potential Impact on Business Creation, Elimination or Expansion

The proposed amendments are not expected to have a noticeable impact on the status of California business creation, elimination, or expansion. The evaporative control technologies and supplemental measures required are readily available and/or easily implementable, comparatively inexpensive, and would not require special expertise.

6.2.6. Potential Impact on Small Businesses

The proposed amendments are not expected to have a noticeable impact on the status of California businesses including small businesses; however, adherence to the existing requirements for high performance engines with averaging could result in severe financial hardship for some small businesses (see subsection 4.1). The evaporative control technologies and supplemental measures required are readily available and/or easily implementable, comparatively inexpensive, and would not require special expertise.

6.3. Potential Costs to Local and State Agencies

Staff believes the proposed requirements are the most cost-effective means of achieving emission reductions of the same magnitude as the existing regulation. Staff is proposing amendments that would allow greater flexibility for businesses (high performance engine manufacturers specifically) to comply with the regulation at reduced cost and without a reduction in emission benefits as required by the existing regulation. The only costs to State government as a result of the proposed amendments would be to ARB for implementing the new regulatory requirements and possibly for additional staff time to evaluate aftermarket replacement parts for SD/I marine engines. We anticipate that the implementation costs could be absorbed within the existing ARB

budget for the current fiscal year 2008/2009; however, an additional 1¼ to 1½ PY could be needed for future fiscal years 2009/2010 and 2010/2011 to address a potential increase in the number of new applications to be reviewed. This would result in an estimated range of $150K to $180K using the current basis of $120K per PY. Although ARB is already responsible for verifying the implementation of the existing regulations for spark-ignition marine engines, an undetermined number of additional manufacturers will begin complying for the first time in 2009; thus, the hiring of additional staff could be necessary if significant increases to workload occur as a result of staff's proposed compliance flexibility option and alignment with new U.S. EPA requirements. The proposed amendments are not expected to result in an overall increase in costs for local agencies.

7. REGULATORY ALTERNATIVES

The staff evaluated various alternatives to the current proposal. A brief description of the alternatives and staff's rationale for finding them unsuitable follows below.

7.1. Preserve Existing High Performance Engine Requirements

The first alternative to this proposal would be to not modify the existing California spark-ignition marine engine regulations. As noted in Section 4.1.1., the existing regulation contains an averaging provision that unintentionally puts small volume high performance engine manufacturers at a competitive disadvantage that could result in their businesses closing. Therefore, staff rejected this alternative.

7.2. Wait for the Adoption of Federal Regulations

Although U.S. EPA has published a Notice of Proposed Rulemaking for inboard and sterndrive engine standards, including CO standards and NTE limits, the federal requirements are not expected to be implemented until 2010 at the earliest. Furthermore, the emission requirements being considered federally for high performance engines would be less stringent than those already adopted by California or the alternatives proposed in this staff report. Considering that California has had regulations for high performance engines in place since 2001, and that staff's proposed amendments preserve the emission benefits of those requirements in the absence of a federal requirement (at least through 2010), postponing these amendments would only serve to deny reasonable compliance flexibility to the regulated industry.

The advantage of a national regulation is harmonization. Manufacturers would have to comply with only one set of regulations for all nationwide sales. The disadvantage of relying on the federal rulemaking is largely one of uncertainty and timing with the likelihood of lost benefits in the high performance engine sector. Staff fully intends to continue working with U.S. EPA in its development of a federal rule to ensure consistency of standards and other requirements to the extent feasible and appropriate. However, delaying action until the federal regulation is finalized would unnecessarily burden the marine industry by requiring it to comply with a California standard for high performance engines for the 2009 model year that, by and large, the marine industry appears unable to meet. Conversely, if the action was to repeal the existing standards

and rely on U.S. EPA, the result would be a loss of emission benefits. Therefore, staff rejected this alternative.

7.3. Exempt Small Volume High Performance Engine Manufacturers

Although relatively few in number, high performance engines have high exhaust rates and their impact on air quality in California is not trivial, especially during the summer season. Since the overwhelming majority of these engines are produced by a single manufacturer, staff considered an option to exempt the remaining small volume manufacturers from compliance with the 5.0 g/kW-hr HC+NOx standard while continuing to require the single large volume manufacturer to meet the standard in 2009. While this would address any issues of a competitive disadvantage for the small volume manufacturers, it would not fully constitute an emissions neutral solution compared to the existing requirements. Furthermore, U.S. EPA has not proposed to exempt small volume manufacturers from complying with the federal standards in part because high performance engines are discretionary products and already expensive to purchase, making the cost of emissions control more absorbable and easier to pass on to the customer (albeit U.S. EPA is not likely to require catalyst-based standards for these engines). Therefore, staff rejected this alternative.

7.4. Require All High-Performance SD/I Manufacturers to Make up Emissions Shortfall

Staff considered proposing changes that would have allowed all high-performance SD/I manufacturers to meet relaxed HC+NOx emissions standards, equip high-performance boats with enhanced evaporative controls, and also require the individual manufacturers to submit plans for making up the remaining emissions shortfall with supplemental measures. Upon review, staff determined that although this alternative would theoretically be emissions-neutral, implementation would be overly burdensome. Without clarity on exactly what measures would be needed and acceptable to the Executive Officer, manufacturers could have spent an enormous amount of resources developing measures only to have them rejected. In the case of the small-volume manufacturers who participate only in the high-performance market, their alternatives for achieving additional emissions reductions would be severely constrained, placing them at a competitive disadvantage with the dual-category manufacturer. Furthermore, even the dual-category manufacturer would be subject to uncertainty regarding product planning. Therefore, staff rejected this alternative

8. CONCLUSIONS AND RECOMMENDATIONS

Staff's objectives in recommending the revisions proposed herein to California's spark-ignition marine regulations and test procedures are to provide harmonization with proposed federal requirements, and to provide another compliance path for larger, high performance engines that avoids a potential technical barrier in using catalysts, and avoids an unanticipated competitive disadvantage to small volume manufacturers of these engines. The cost-effectiveness of the changes remains positive, and manufacturers will be required to offset the small loss of emission reductions resulting from the revised tailpipe standards. A new CO standard applicable to both inboard and outboard recreational marine engines will help assure no individual engine will expose wakeboarders to excess concentrations of CO.

No alternative considered by the agency would be more effective in carrying out the purpose for which the amended regulation is proposed, or would be as effective as, or less burdensome, to affected private persons than the proposed regulation. Therefore, staff recommends that the Board accepts staff's proposed adoption of amendments to sections 2111, 2112, and Appendix A, within Chapter 2, Article 2.1, Title 13, California Code of Regulations (13 CCR); section 2139 within Chapter 2, Article 2.3, 13 CCR, section 2147 within Chapter 2, Article 2.4, 13 CCR; sections 2440, 2441, 2442, 2443.1, 2443.2, 2443.3, 2444.1, 2444.2, and 2445, and proposed repeal of Section 2448, within Chapter 9, Article 4.7, 13 CCR; and proposed adoption of amendments to the following documents incorporated by reference in Section 2447, 13 CCR: "California Exhaust Emission Standards and Test Procedures for 2001 Model Year and Later Spark-Ignition Marine Engines," as last amended September 22, 2006, and in Section 2474, 13 CCR: "Procedures for Exemption of Add-On and Modified Parts for Off-Road Categories," as adopted July 14, 2000.

9. REFERENCES

ARB 1998a: California Air Resources Board, Public Hearing to Consider Adoption of Emission Standards and Test Procedures for New 2001 and Later Model Year Spark-Ignition Marine Engines, October 23, 1998 (Staff Report).

ARB 1998b: California Air Resources Board, Proposed Amendments to California Exhaust and Evaporative Emission Standards and Test Procedures for Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles, September 18, 1998 (Staff Report).

ARB 2001: California Air Resources Board, Public Hearing to Consider Adoption of Emission Standards and Test Procedures for New 2003 and Later Spark-Ignition Inboard and Sterndrive Marine Engines, June 8, 2001 (Staff Report).

ARB 2003a: California Air Resources Board, Public Hearing to Consider the Adoption of Exhaust and Evaporative Emission Control Requirements for Small Off-Road Equipment and Engines Less Than or Equal To 19 kW, August 8, 2003 (Staff Report).

ARB 2003b: California Air Resources Board, Public Hearing to Consider Adoption of the Heavy-Duty Diesel Engine Software Upgrade Regulation (Chip Reflash), September 5, 2003 (Staff Report).

ARB 2005a: California Air Resources Board, Public Hearing to Consider Amendments to the Current Inboard and Sterndrive Boat Regulations, September 30, 2005 (Staff Report).

ARB 2005b: California Air Resources Board, Notice of Public Hearing to Consider Requirements to Reduce Idling Emissions from New and In-Use Trucks, Beginning in 2008, September 1, 2005 (Staff Report).

Assembly Bill 695: California Statutes of 2007, Chapter 609, Adds Sections 9852.9, 9853.7, and 9853.8 to the VC, Karnette, Betty, 54th District, October 13, 2007

DBLA 2007: Double Angel Foundation, Boat-Related Carbon Monoxide (CO) Poisonings, Updated: April 2007.

ISO 8178-4: International Organization for Standardization, Reciprocating Internal Combustion Engines, Exhaust Emissions Measurement, Part 4: Test Cycles for Different Engine Applications.

NIOSH 2007: National Institute for Occupational Safety and Health, Report EPHB 289-12a, Evaluation of Carbon Monoxide Concentration With and Without Catalytic Emission Controls From Gasoline Propulsion Engines, April 2007

RIA 2007: United States Environmental Protection Agency, Control of Emissions from Marine SI and Small SI Engines, Vessels, and Equipment, Draft Regulatory Impact Analysis, April 2007.

U.S. EPA 1996: United States Environmental Protection Agency, Control of Air Pollution; Final Rule for New Gasoline Spark-Ignition Marine Engines, Exemptions for New Nonroad Compression-Ignition Engines at or Above 37 Kilowatts and New Nonroad Spark-Ignition Engines at or Below 19 Kilowatts; Final Rule, 61 Federal Register 52088-52169, October 4, 1996.

U.S. EPA 2007: United States Environmental Protection Agency, Control of Emissions from Nonroad Spark-Ignition Engines and Equipment; Proposed Rule, 72 Federal Register 28098-28393, May 18, 2007.

APPENDIX A: SPECIFIC OUTREACH AND PUBLIC PROCESS REGARDING THE DEVELOPMENT OF STAFF'S PROPOSAL TO AMEND THE SPARK-IGNITION MARINE REGULATIONS

The following is a chronological listing of meetings and other instances of dialog with the public, regulated industries, and associated organizations:

2005 Public Board Hearing

On November 17, 2005, staff proposed and the Board adopted amendments to the spark-ignition marine regulations for SD/I engines and boats. Included in those amendments was a provision allowing engine manufacturers to certify high performance engines through corporate averaging with standard performance engines. Representatives from the National Marine Manufacturer's Association (NMMA) commented at that time that corporate averaging in itself might not be sufficient for all high performance engine manufacturers since many of them only produce high performance engines and therefore do not have standard performance engines to average. Staff had previously acknowledged this potential deficiency in the staff report for the November 17, 2005, rulemaking, and indicated its commitment to develop a long-term solution prior to the commencement of emission requirements for these engines in 2009.

Meeting with Southern California Marine Dealers Association (SCMA)

On January 16, 2007, staff met with the Board of Directors of SCMA to discuss how ARB's recreational marine regulations could affect California dealerships. SCMA was concerned that the addition of catalysts and sophisticated electronic controls on SD/I engines could cause California boats so equipped to significantly increase in price compared to similar out-of-State boats without catalysts. In response, staff identified several major marketing incentives for buying a California certified inboard or sterndrive marine engine despite the prospect of a price increase. The incentives were that the catalyzed California engine is covered by mandatory warranty and durability by the manufacturer, it must incorporate on-board diagnostics that quickly and accurately identify malfunctions and facilitate repairs, it must have a four-star label that lake authorities could use to restrict the use of boats in the future, has an environmentally friendly engine that appeals to many Californians like hybrid electric cars have, and is safer to operate because of reduced carbon monoxide emissions.

Participation in the Development of Assembly Bill No. 695 (AB 695)

AB 695 was legislation authored by State Assemblywoman Betty Karnette, 54th District, and sponsored by SCMA, to protect California marine dealers from unfair competition due to the higher cost of California boats equipped with catalytic converters versus similar out-of-State boats without them. AB 695 proposed to add §§ 9852.9, 9853.7, and 9853.8 to the California Vehicle Code (VC) to make it generally illegal for a person to purchase a marine vessel outside of California for use in California without a valid California-certified engine. AB 695 was signed into law on October 13, 2007, and as of July 1, 2008, new boat owners are required to submit proof that their boats contain a California-certified engine when applying for registration and a vessel identification

number. AB 695 was amended several times since its introduction in February 2007, and ARB staff routinely provided input throughout the various stages of its development.

2007 Los Angeles Boat Show

On February 7, 2007, staff attended the 51st Annual Los Angeles Boat Show. The show is presented each year by SCMA and staff attended by invitation of Ilmor Marine Engines, LLC, a manufacturer of high performance marine engines, and was provided complimentary passes by SCMA. The purpose of the visit was to converse with the represented boat dealers, educate them on the benefits of California engines versus federal engines, and to get a first hand look at some of the new recreational marine offerings for 2007. In particular, staff focused its attention on dealers selling boats with high performance engines since these engines will be regulated for the first time beginning with the 2009 model year.

Meetings with High Performance Marine Engine Manufacturers

In addition to frequent conference calls and meetings with NMMA and SCMA to discuss high performance related issues, staff met individually with representatives from Mercury Marine and Ilmor Marine Engines, LLC, several times between February 2007 and April 2008. During each of those meetings staff heard the manufacturer's concerns regarding compliance with the existing catalyst-based standards (5.0 g/kW-hr NMHC+NOx) set to begin with the introduction of 2009 model year engines. These meetings were informative and helped guide the development of staff's proposed amendments to the existing regulations for high performance engines.

Certification and Enforcement Guidance Meetings

On March 14, 2007, staff from ARB's regulatory, certification, legal, and enforcement groups met with NMMA collectively and individually to discuss the legality of business practices related to in-State and out-of-State engine and boat sales and distribution, engine vs. boat manufacturer liability issues, the expectations and time constraints of the certification process for catalyst equipped engines and on-board diagnostics, and to hear industry's concerns regarding new replacement engines, which according to existing regulation are required to comply with current year exhaust emission standards. Several member companies made presentations on the unique elements of its business practices.

Meeting with SCMA on High Performance Engines

On September 11, 2007, SCMA leadership and several member companies that exclusively manufacture high performance engines met with ARB staff to lobby for a relaxation of the 5.0 g/kW-hr NMHC+NOx catalyst-based standard scheduled to begin in 2009. SCMA asked for a relaxation of the exhaust standard for high performance engines and a component-based approach to emissions control rather than the traditional performance-based approach. Staff replied that it was open to both concepts, but that any lost emissions would need to be made up via other means.

Conference Calls with U.S. EPA
On October 30, 2007, and throughout the development of the proposals in this staff report, ARB staff conferred with U.S. EPA staff regarding changes to, and alignment with, the federal proposal for spark-ignition marine engines and boats. Included among the discussion topics were high performance engine standards, production line testing, OBD-M, NTE standards, and the extension of catalyst-based standards to jet boat applications.

Meeting with NMMA
On December 17-18, 2007, staff met with NMMA management and several member companies to discuss high performance engine standards and remediation methods for any loss of benefits resulting from a relaxed exhaust standard. Some of the remediation methods discussed included an early introduction of evaporative standards proposed by U.S. EPA for high performance engines and the in-use replacement of fuel hoses with low-permeation hoses. Also discussed was the lifecycle extension of the base 4.3 liter engine by General Motors.

Workshop Notice
On February 21, 2008, ARB emailed listserv subscribers and posted a document on its website at http://www.arb.ca.gov/msprog/mailouts/msc0803/msc0803.pdf announcing that a public workshop had been scheduled for March 18, 2008, to discuss proposed changes to the spark-ignition marine engine and boat regulations. The document went into some detail regarding the changes being considered by staff and provided the logistics for the meeting and outlined the processes for commenting on staff's proposal.

Meetings with Jet Boat Manufacturers
In separate meetings on March 11, 2008, staff spoke with representatives from Bombardier and Yamaha to discuss proposed changes to California's spark-ignition marine engine and boat regulations that would require jet boat engines previously certified to the applicable OB/PWC standards to be certified to the significantly more stringent SD/I standards.

NMMA Pre-Workshop Conference Call
On March 13, 2008, staff received verbal feedback from NMMA regarding the regulatory revisions proposed by staff in the February 21, 2008, workshop notice. Staff used this information to fine tune its proposal prior to the workshop.

2008 Public Workshop (Webcast)
On March 18, 2008, staff held a public workshop to discuss modifications to California's existing spark-ignition marine engine and boat regulations. The workshop was webcast to reach a wider audience than was able to attend in person. The discussion included a presentation by staff of proposed changes to the exhaust standards for high performance engines, an early introduction of evaporative control requirements for high performance engines, the incorporation of CO standards and NTE limits, adoption of general and hardship compliance assitance provisions, revised new replacement engine provisions, and more. Additional presentations were made by both the manufacturer

and supplier of carbon canisters that could be made available to the industry in the timeframe required for compliance with staff's new proposals. A copy of staff's presentation may be found at http://www.arb.ca.gov/msprog/offroad/recmarine/si_marine_workshop_03182008.pdf.

Certification Outreach Meeting

On April 22, 2008, ARB staff held a meeting to educate manufacturers of high performance engines on the various aspects of certifying their engines for the 2009 model year and beyond. The majority of high performance engine manufacturers are small business operations that sell less than fifty engines per year in California and have no previous experience with the certification process. Since many of these manufacturers do not have the resources to hire dedicated certification staff, ARB staff felt it warranted to provide outreach to this segment of the industry to facilitate compliance with the certification process.

APPENDIX B: LETTER FROM THE MANUFACTURERS OF EMISSION CONTROLS ASSOCIATION REGARDING HIGH PERFORMANCE ENGINES

Manufacturers of Emission Controls Association

1730 M Street, NW
Suite 206
Washington, DC 20036-5603
(202) 296-4797 FAX: (202) 331-1388

May 16, 2008

Scott Rowland
Mobile Source Control Division
California Air Resources Board
9528 Telstar Ave.
El Monte, CA 91731

Dear Mr. Rowland:

This letter is in response to your request regarding ARB's proposed emission regulations for new spark-ignited marine engines and boats that were presented at the March 18th workshop. MECA has reviewed the latest proposal and participated in the March workshop. MECA supports ARB's approach to harmonize California's spark-ignition marine standards with those proposed by U.S. EPA for gasoline certification of THC + NOx. We also believe that the proposed CO limits for stern drive and inboard (SD/I) engines above and below 373 kW are reasonable and can be met with the same three-way catalyst (TWC) converters already used on California engines.

With respect to high performance engines (> 373 kW), we agree with staffs proposed approach to relax the 5.0 g/kW-hr exhaust standard for NMHC + NOx in exchange for the incorporation of evaporative control systems on vessels equipped with high performance engines beginning in 2009. Evaporative control technology has been successfully incorporated on passenger vehicles for over 30 years and has advanced to allow automobiles to meet the zero evaporative emissions required by California's LEV II PZEV emission limits. We see no reason why these performance marine vessels can not benefit from the same technology as other SI vehicles and engines to achieve ultra low evaporative emissions.

MECA agrees with Staff's conclusion that the operating conditions of these high performance engines are not ideal for optimal performance of three-way catalysts. TWC catalysts are designed for peak conversion efficiencies of all three major criteria pollutants (HC, CO and NOx) at or near the stoichiometric air/fuel ration of 14.65. Although advances in catalyst technologies designed with improved oxygen storage capacity have facilitated the broadening of this high conversion window, the range for > 90% conversion efficiencies remains between an air/fuel ratio of 14.5 to 14.7. Automotive engine combustion control has also advanced to control air/fuel operation within this narrow range. The wide-open throttle and high speed operation of high performance marine engines has required engine calibrations in the fuel-rich side of the stoichiometric air/fuel ratio. Although this is ideal for the reduction of NOx with a TWC, the oxidation of HC and CO is likely to be compromised making it difficult to meet the proposed HC + NOx combined target. Furthermore, the oxygen storage materials used in TWCs require periods of lean A/F operation in order to allow the oxygen storage function to regenerate. Long term operation on either side of the stoichiometric A/F ratio provides challenges for high TWC conversion of all three criteria pollutants. We believe that the proposed trade-off of exhaust emissions in exchange for equal reductions of evaporative emissions for this specialized class of marine vessels is a good approach that MECA and our members support.

We hope this information is helpful and please feel free to contact me if we can be of further assistance.

Best regards,

Dr. Rasto Brezny
Deputy Director

ATTACHMENT A

PROPOSED REGULATION ORDER

Title 13 California Code of Regulations

PROPOSED REGULATION ORDER

Proposed Amendments to the California Regulations for New 2009 and Later Spark-Ignition Marine Engines and Boats

NOTE: This document is written in a style to indicate changes from the existing provisions. All existing language is indicated by plain text. All additions to language are indicated by underlined text. All deletions to language are indicated by ~~strikeout~~. Only those portions containing the suggested modifications from existing provisions are included. All other portions remain unchanged and are indicated by the symbol "* * * * *" for reference.

Amend sections 2111, 2112, Appendix A to Article 2.1, 2139, 2147, 2440, 2441, 2442, 2443.1, 2443.2, 2443.3, 2444.1, 2444.2, 2445.1, 2445.2, and 2446, and delete section 2448, title 13 California Code of Regulations, to read as follows:

Chapter 2. Enforcement of Vehicle Emission Standards and Surveillance Testing

Article 2.1. Procedures for In-Use Vehicle Voluntary and Influenced Recalls

§ 2111. Applicability.

(a) These procedures shall apply to:

* * * * *

(4) California-certified 2008 model year spark-ignition sterndrive/inboard marine engines with maximum rated power less than or equal to 373 kilowatts complying with the Option 2 requirements in Section 2442(b)(1) and all California-certified 2009 and subsequent model-year spark-ignition sterndrive/inboard ~~and~~ marine engines. ~~complying with the Option 1 requirements in Section 2442(b)(1) and California-certified 2008 and subsequent model-year spark-ignition inboard and sterndrive marine engines complying with the Option 2 requirements in Section 2442(b)(1).~~

* * * * *

Note: Authority cited: Sections 39600, 39601, 43013, 43018 and 43105, Health and Safety Code.
Reference: Sections 43000, 43009.5, 43013, 43018, 43101, 43104, 43105, 43106, 43107 and 43204-43205.5, Health and Safety Code.

§ 2112. Definitions.

(a) "Capture rate" means ...

* * * * *

(l) "Useful life" means, for the purposes of this article:

* * * * *

(20) For 2004 and subsequent model-year heavy heavy-duty diesel engines, 2004 and subsequent model-year heavy-duty diesel urban buses, 2004 and subsequent model-year heavy-duty diesel engines to be used in urban buses, and 2004 and subsequent model year hybrid-electric urban buses for carbon monoxide, particulate, and oxides of nitrogen plus non-methane hydrocarbon emissions standards, a period of use of 10 years or 435,000 miles, or 22,000 hours, whichever first occurs, or any alternative useful life period approved by the Executive Officer, except as provided in paragraphs ~~(19)(i)~~(20)(A) and ~~(19)(ii)~~(20)(B).

~~(i)~~
(A) The useful life limit of 22,000 hours in paragraph (19) of this definition is effective as a limit to the useful life only when an accurate hours meter is provided by the manufacturer with the engine and only when such hours meter can reasonably be expected to operate properly over the useful life of the engine.

~~(ii)~~
(B) For an individual engine, if the useful life hours limit of 22,000 hours is reached before the engine reaches 10 years or 100,000 miles, the useful life shall become 10 years or 100,000 miles, whichever occurs first, as required under Clean Air Act section 202(d) (42 U.S.C. 7521(d)).

* * * * *

(23) (A) For California-certified ~~2009~~2008 and subsequent model year spark-ignition sterndrive/inboard ~~and sterndrive~~ marine engines with maximum rated power less than or equal to 373 kilowatts and complying with the ~~Option 1~~2 requirements in Section 2442(b)(1), and for California-certified ~~2008~~2009 and subsequent model-year spark-ignition sterndrive/inboard ~~and sterndrive~~ marine engines ~~complying with the Option 2 requirements in Section 2442(b)(1)~~with a maximum rated or maximum engine power less than or equal to 485 kilowatts, a period of ten years or 480 hours, whichever first occurs. ~~for engines 485 kilowatts and less.~~

(B) For California-certified 2009 and subsequent model year spark-ignition sterndrive/inboard marine engines greater than 485 kilowatts, a period of one year or 50 hours, whichever first occurs. Manufacturers of spark-ignition sterndrive/inboard marine engines greater than 485 kilowatts may petition the Executive Officer for a approval of a shorter period when appropriate.

* * * * *

Appendix A to Article 2.1

California In-Use Vehicle Emission-Related Recall Procedures, Enforcement Test Procedures, and Failure Reporting Procedures for 1982 and Subsequent Model-Year Passenger Cars, Light-Duty Trucks, Medium-Duty Vehicles, Heavy-Duty Vehicles and Engines, Motorcycles, 1997 and Subsequent Model-Year Off-Road Motorcycles and All-Terrain Vehicles, 2000 and Subsequent Model-Year Off-Road Compression-Ignition Engines, and 2008 and Subsequent Model-Year Spark-Ignition ~~Inboard and~~ Sterndrive/Inboard Marine Engines.

Vehicle and Engine Parameters, Components, and Specifications

I. Passenger Car, Light-Duty Truck, Medium-Duty Vehicle, Motorcycle, and Inboard and Sterndrive Parameters and Specifications.

* * * * *

F. Engine Cooling System: Thermostat calibration.
~~456~~
G. Exhaust Emission Control system.

* * * * *

Note: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43104, 43105 and 43806, Health and Safety Code; and Section 28114, Vehicle Code.
Reference: Sections 39002, 39003, 39500, 43000, 43009.5, 43013, 43018, 43100, 43101, 43101.5, 43102, 43104, 43105, 43106, 43107, 43202, 43204-43205.5, 43206,

43210, 43211, 43212, 43213 and 43806, Health and Safety Code; and Section 28114, Vehicle Code.

(Operative <*Insert Date*>)

Chapter 2. Enforcement of Vehicle Emission Standards and Surveillance Testing

Article 2.3. In-Use Vehicle Enforcement Test Procedures

§ 2139. Testing.

* * * * *

(h) For spark-ignition ~~inboard and~~ sterndrive/inboard marine engines, in-use compliance tests shall be performed pursuant to section 2442, Title 13, California Code of Regulations. The in-use compliance testing shall use the same test procedure utilized for the specific engine's original certification testing.

* * * * *

Note: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43104 and 43105, Health and Safety Code.
Reference: Sections 39002, 39003, 43000, 43009.5, 43013, 43018, 43100, 43101, 43101.5, 43102, 43103, 43104, 43105, 43106, 43107, 43204-43205.5 and 43211-43213, Health and Safety Code.

Chapter 2. Enforcement of Vehicle Emission Standards and Surveillance Testing

Article 2.4. Procedures for Reporting Failures of Emission-Related Components

* * * * *

§ 2147. Demonstration of Compliance with Emission Standards.

* * * * *

(b) A manufacturer may test properly maintained in-use vehicles with the failed emission-related component pursuant to the applicable certification emission tests specified in Title 13, California Code of Regulations, Section 1960.1 or 1961, as applicable, for passenger cars, light-duty trucks and medium-duty vehicles, Section 1956.8 for heavy-duty engines and vehicles, Section 1958 for motorcycles, and Section 2442 for ~~inboard and~~ sterndrive/inboard marine engines. The emissions shall be projected to the end of the vehicle's or engine's useful life using in-use deterioration factors. The in-use deterioration factors shall be chosen by the manufacturer from among the following:

* * * * *

Note: Authority cited: Sections 39600, 39601 and 43105, Health and Safety Code. Reference: Sections 43000, 43009.5, 43018, 43101, 43104, 43105, 43106, 43107 and 43204-43205.5, Health and Safety Code.

Chapter 9. Off-Road Vehicles and Engines Pollution Control Devices

Article 4.7. Spark-Ignition Marine Engines

§ 2440. Applicability.

(a)

* * * * *

(3) Spark-ignition ~~inboard and~~ sterndrive/inboard marine engines produced by the engine manufacturer to be used solely for competition are exempt from the requirements of this article, except section 2443.1, provided that the marine watercraft in which the engine is installed is designed, built, and used solely for competition. Marine watercraft not registered with a nationally-recognized organization that sanctions professional competitive events or used for amateur or occasional competition do not meet the competition exemption criteria.

* * * * *

Note: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2441. Definitions.

(a)

* * * * *

(5) "Boat manufacturer," as it applies in Section 2442(b), means any person or business entity engaged in the manufacturing, assembling, or importing of new vessels equipped with ~~inboard or~~ sterndrive/inboard engines for sale in California, or engaged in the sale, offer for sale, introduction, delivery or importation of such vessels into California for introduction into commerce. Included are those who act for and are under the control of any such person or business entity in connection with the distribution of such vessels. The term boat manufacturer does not include any person or business entity whose sole activities are the direct sale of said vessels to ultimate purchasers or the servicing of said vessels.

* * * * *

(21) "Enhanced Evaporative Control System" means an integration of evaporative control hardware including activated carbon canisters, low permeation fuel hoses, and non permeable fuel tanks designed to comply with the diurnal and permeation standards in Table 2.2 of § 2442(b)(2).

(~~21~~22) "Exhaust emissions" means matter emitted into the environment from any opening downstream from the exhaust port of a spark-ignition marine engine.

(~~22~~23) "Executive Officer" means the Executive Officer of the Air Resources Board or his or her authorized representative.

(~~23~~24) "Executive Order" means an order issued by the Executive Officer certifying engines for sale in California.

(~~24~~25) "Family Emission Limit" means an emission value assigned by a marine engine manufacturer to an engine family for the purpose of complying with a corporate average exhaust emission standard. The Family Emission Limit (FEL) must not exceed the limit specified in this Article.

(~~25~~26) "Fuel system" means all components involved in the transport, metering, and mixture of the fuel from the fuel tank to the combustion chamber(s) including, but not limited to the following: fuel tank, fuel tank cap, fuel pump, fuel lines, oil injection metering system, carburetor or fuel injection components, and all fuel system vents.

(~~26~~27) "Fuel trim" refers to feedback adjustments to the base fuel schedule. Short-term fuel trim refers to dynamic or instantaneous adjustments. Long-term fuel trim refers to much more gradual adjustments to the fuel calibration schedule

than short-term trim adjustments. These long-term adjustments compensate for engine differences and gradual changes that occur over time.

(~~27~~28) "Functional check" for an output component means verification of proper response to a computer command. For an input component, functional check means verification of the input signal being in the range of normal operation, including evaluation of the signal's rationality in comparison to all available information.

(29) "High Performance Engine" or "High Performance SD/I Engine" means a spark-ignition sterndrive/inboard marine engine with maximum engine power greater than 373 kilowatts.

~~(28) "Inboard Engine" means a four-stroke spark-ignition marine engine not used in a personal watercraft that is designed such that the propeller shaft penetrates the hull of the marine watercraft while the engine and the remainder of the drive unit is internal to the hull of the marine watercraft.~~

(~~29~~30) "Inspection criteria" means the pass and fail numbers associated with a particular sampling plan.

(31) "Jet boat" means a vessel that uses an installed internal combustion engine powering a water jet pump as its primary source of propulsion and is designed with open area for carrying passengers.

(32) "Large Volume Dual Category Manufacturer" means an engine manufacturer that produces both high performance and standard performance sterndrive/inboard engines for sale in California in combined quantities greater than 75 units annually.

~~(30)~~(33) "Low-permeation ~~fuel line (or supply)~~ hose" means a fuel hose that does not exceed a 15.0 grams per square meter per day permeation rate on CE10 fuel at 23° Celsius~~, as tested~~ per SAE J1527.

~~(31)~~(34) "Malfunction" means the inability of an emission-related component or system to remain within design specifications. Further, malfunction refers to the deterioration of any of the above components or systems to a degree that would likely cause the emissions of an aged engine with the deteriorated components or systems present at the beginning of the applicable certification emission test to exceed the $HC+NO_x$ emission standard by more than 50 percent, unless otherwise specified, as applicable pursuant to Subchapter 1 (commencing with Section 1900), Chapter 3 of Title 13.

~~(32)~~(35) "Marine engine manufacturer" means any person engaged in the manufacturing or assembling of new spark-ignition marine engines or the importing of such engines for resale, or who acts for and is under the control of any such person in connection with the distribution of such engines. A spark-ignition marine engine manufacturer does not include any dealer with

respect to new spark-ignition marine engines received by such person in commerce.

~~(33)~~(36) "Marine warm-up cycle" means sufficient engine operation such that the coolant temperature has risen by at least 40 degrees Fahrenheit from engine starting and reaches a minimum temperature of at least 140 degrees Fahrenheit.

~~(34)~~(37) "Marine watercraft" means every description of boat, ship or other artificial contrivance used, or capable of being operated on water.

(38) "Marinize" means to modify an existing automobile engine to operate reliably in a marine environment. Some typical modifications include upgrading the composition of exhaust components to be more resistive against rust and corrosion, incorporating a water jacket within the exhaust manifolds to reduce temperatures, and providing better insulation for electrical contacts that might otherwise be exposed to corrosive sea water.

(39) "Maximum Engine Power" means the maximum brake power point on the nominal power curve for the engine configuration. The nominal power curve of an engine configuration is the relationship between maximum available engine brake power and engine speed for an engine, using the mapping procedures of 40 CFR part 1065, based on the manufacturer's design and production specifications for the engine. This information may also be expressed by a torque curve that relates maximum available engine torque with engine speed. The nominal power curve must be within the range of the actual power curves of production engines considering normal production variability. The power value should be rounded to the nearest whole kilowatt. Except as indicated below in paragraphs (A) and (B) of this definition, the maximum engine power for an engine family is the weighted average value of maximum engine power for each engine configuration within the engine family based on the total California production volume of engines produced from the engine family. Alternately:

(A) For outboard or personal watercraft engines, maximum engine power is the greatest value for maximum engine power from all the different configurations within the engine family to determine the appropriate emission standard under § 2442(a).

(B) For sterndrive/inboard engines, maximum engine power is the smallest value for maximum engine power from all the different configurations within the engine family to determine the standards and other requirements that apply under § 2442(b).

~~(35)~~(40) "Maximum Rated Power" means the maximum brake kilowatt output of an engine at rated speed, as stated in the manufacturer's application for certification.

(41) "Maximum Test Speed" means:

(A) the engine speed during sustained operation with maximum operator demand when testing other than a two-stroke engine installed in a vessel, or

(B) the same as defined in 40 CFR 1045.501 and 40 CFR 1065.1001 when testing a two-stroke engine installed in a vessel or any engine on an engine dynamometer.

For the purposes of laboratory testing, the declared maximum test speed must be within 500 revolutions per minute of the measured value for maximum test speed specified in the test procedures.

~~(36)~~(42) "Model year" means the engine manufacturer's annual new model production period which includes January 1 of the calendar year for which the model year is named, ends no later than December 31 of the calendar year, and does not begin earlier than January 2 of the previous calendar year. Where an engine manufacturer has no annual new model production period, model year means the calendar year.

~~(37) "New," for purposes of this Article, means a spark-ignition marine engine or watercraft the equitable or legal title to which has never been transferred to an ultimate purchaser. Where the equitable or legal title to the engine or watercraft is not transferred to an ultimate purchaser until after the engine or watercraft is placed into service, then the engine or watercraft will no longer be new after it is placed into service. A spark-ignition marine engine or watercraft is placed into service when it is used for its functional purposes. With respect to imported spark-ignition marine engines or watercraft, the term "new" means an engine or watercraft that is not covered by an Executive Order issued under this Article at the time of importation, and that is manufactured after the effective date of a section in this Article which is applicable to such engine or watercraft, or which would be applicable to such engine or watercraft had it been manufactured for importation into the United States.~~

(43) "New Propulsion Marine Engine" or "New Engine" or "New," – for purposes of this Article, means any of the following:

(A) A freshly manufactured propulsion marine engine for which the ultimate purchaser has never received the equitable or legal title. This kind of engine might commonly be thought of as "brand new." In the case of this paragraph (A), the engine is new from the time it is produced until the ultimate purchaser receives the title or the product is placed into service, whichever comes first.

(B) An engine intended to be used as a propulsion marine engine that was originally manufactured as a motor vehicle engine, a nonroad engine that is not a propulsion marine engine, or a stationary engine. In this case, the

engine is no longer a motor-vehicle, nonpropulsion, or stationary engine and becomes a "new propulsion marine engine." The engine is no longer new when it is placed into marine service.

(C) A propulsion marine engine that has been previously placed into service in an excluded application, where that engine is installed in a vessel subject to the requirements of these regulations. The engine is no longer new when it is placed into marine service covered by these regulations. For example, this would apply to an auxiliary marine engine that becomes a propulsion marine engine.

(D) An engine not covered by paragraphs (A) through (C) of this definition that is intended to be installed in a new vessel. This generally includes installation of used engines in new vessels. The engine is no longer new when the ultimate purchaser receives a title for the vessel or the product is placed into service, whichever comes first.

(E) An imported marine engine determined by federal regulations to be new per the criteria defined in 40 CFR 1045.801 for imported propulsion marine engines.

~~(38)~~(44) "Nonconformity" or "Noncompliance," for purposes of Title 13, California Code of Regulations, section 2444.1, means that:

(A) a significant number, determined by the Executive Officer, of a class of engines, although properly maintained and used, experience a failure of the same emission-related component(s) within their useful lives which, if uncorrected, results in the engines' failure to comply with the emission standards prescribed under section 2442 which are applicable to the model year of such engines; or

(B) a class of engines that at any time within their useful lives, although properly maintained and used, on average does not comply with the emission standards prescribed under section 2442 which are applicable to the model year of such engines.

(45) "Nontrailerable boat" means a vessel equal to or greater than 8 meters in length and 2.6 meters or more wide.

~~(39)~~(46) "Operating cycle" consists of engine startup, engine run, and engine shutoff.

~~(40)~~(47) "Original equipment manufacturer" means a manufacturer who purchases engines for installation in its equipment for sale to ultimate purchasers.

~~(41)~~(48) "Outboard engine" means ~~a spark-ignition marine engine that, when properly mounted on a marine watercraft in the position to operate, houses the~~

~~engine and drive unit external to the hull of the marine watercraft~~ an assembly of a spark-ignition marine engine and drive unit used to propel a vessel from a properly mounted position external to the hull of the vessel. An outboard drive unit is partially submerged during operation and can be tilted out of the water when not in use.

(49) "Personal watercraft" means a vessel less than 4.0 meters (13 feet) in length that uses an installed internal combustion engine powering a water jet pump as its primary source of propulsion and is designed with no open load carrying area that would retain water. The vessel is designed to be operated by a person or persons positioned on, rather than within the confines of the hull. A vessel using an outboard engine as its primary source of propulsion is not a personal watercraft.

~~(42)~~(50) "Personal watercraft engine" means ~~a spark-ignition marine engine that does not meet the definition of outboard engine, inboard engine or sterndrive engine, except that the Executive Officer may, in his or her discretion, classify a personal watercraft engine as an inboard or sterndrive engine if it is comparable in technology and emissions to an inboard or sterndrive engine~~ a spark-ignition engine used to propel a personal watercraft.

~~(43)~~(51) "Production-line tests" are emission tests performed on a sample of production engines produced for sale in California and conducted in accordance with Title 13, California Code of Regulations, section 2446(a).

(52) "Rebuild" or "Rebuilding" refers to a major overhaul in which the engine's pistons or power assemblies are replaced or other changes that significantly increase the service life of the engine are made. It also includes replacing or rebuilding an engine's turbocharger or aftercooler or the engine's systems for fuel metering or electronic control so that it significantly increases the service life of the engine. For these provisions, rebuilding may or may not involve removing the engine from the equipment. Rebuilding does not normally include scheduled emission-related maintenance that the standard-setting part allows during the useful life period (such as replacing fuel injectors) or unscheduled maintenance that occurs commonly within the useful life period.

~~(44)~~(53) "Redline engine speed" means the engine manufacturer recommended maximum engine speed as normally displayed on instrument panel tachometers, or the engine speed at which fuel shutoff occurs.

~~(45)~~(54) "Response rate," with regards to oxygen sensors, refers to the delay (measured in milliseconds) between a switch of the sensor from lean to rich or vice versa in response to a change in fuel/air ratio above and below stoichiometric.

~~(46)~~(55) "Sales" or "Eligible sales" means the actual or calculated sales of an engine family in California for the purposes of corporate averaging and production-line testing. Upon Executive Officer approval, an engine

manufacturer may calculate its eligible sales through market analysis of actual federal production or sales volumes.

~~(47)~~(56) "Scheduled maintenance" means any adjustment, repair, removal, disassembly, cleaning, or replacement of components or systems required by the engine manufacturer to be performed on a periodic basis to prevent part failure or marine watercraft or engine malfunction, or those actions anticipated as necessary to correct an overt indication of malfunction or failure for which periodic maintenance is not appropriate.

(57) "Spark-ignition" means relating to a gasoline-fueled engine or any other type of engine with a spark plug (or other sparking device) and with operating characteristics significantly similar to the theoretical Otto combustion cycle. Spark-ignition engines usually use a throttle to regulate intake air flow to control power during normal operation.

~~(48)~~(58) "Spark-ignition marine engine" means any engine used to propel a marine watercraft, and which utilizes the spark-ignition combustion cycle; including, but not limited to personal watercraft, outboard, ~~inboard~~ and sterndrive/inboard engines.

(59) "Standard Performance Engine" or "Standard Performance SD/I Engine" means a spark-ignition sterndrive/inboard marine engine with maximum engine power less than or equal to 373 kilowatts.

~~(49) "Sterndrive engine" means a four-stroke spark-ignition marine engine not used in a personal watercraft that is designed such that the drive unit is external to the hull of the marine watercraft, while the engine is internal to the hull of the marine watercraft.~~

(60) "Sterndrive/inboard engine" or "sterndrive/inboard marine engine" means a spark-ignition engine that is used to propel a vessel, but is not an outboard engine or a personal watercraft engine. This includes engines on propeller driven vessels, jet boats, air boats, and hovercraft.

~~(50)~~(61) "Test engine" means the engine or group of engines that an engine manufacturer uses during certification, production-line and in-use testing to determine compliance with emission standards.

~~(51)~~(62) "Test Procedures" means the document entitled "California Exhaust Emission Standards and Test Procedures for 2001 Model Year and Later Spark-Ignition Marine Engines," which includes the standards and test procedures applicable to 2001 and later spark-ignition personal watercraft, outboard, ~~inboard~~ and sterndrive/inboard marine engines, as adopted October 21, 1999, and as last amended ~~September 22, 2006~~[insert date]. This document is incorporated by reference herein.

~~(52)~~(63) "Ultimate purchaser" means, with respect to any new spark-ignition marine engine, the first person who in good faith purchases such new spark-ignition marine engine for purposes other than resale.

~~(53)~~(64) "U.S.C." means United States Code.

~~(54)~~(65) "Used solely for competition" means exhibiting features that are not easily removed and that would render its use other than in competition unsafe, impractical, or highly unlikely.

~~(55)~~(66) "Useful life" for spark-ignition marine engines means nine years for personal watercraft engines and sixteen years for outboard, ~~sterndrive,~~ and sterndrive/inboard engines.

~~(56)~~(67) "Warranty period" means the period of time the engine or part is covered by the warranty provisions.

~~(57)~~(68) "Warranty station" means any dealer, service center or other agent that is authorized by the engine manufacturer to perform diagnostic labor, repairs or replacements of warranted engine components.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2442. Emission Standards.

(a) Model year 2001 and later model year spark-ignition personal watercraft and outboard marine engines:

(1) Exhaust emissions from new spark-ignition marine engines manufactured for sale, sold, or offered for sale in California, or that are introduced, delivered or imported into California for introduction into commerce must not exceed the hydrocarbon plus oxides of nitrogen ($HC+NO_x$) exhaust emission standards listed in Table 1.1 nor the carbon monoxide (CO) exhaust emission standards listed in Table 1.2 during its designated useful life:

Table 1.1

~~Article I.~~ Corporate Average Emission Standards by Implementation Date $HC+NO_x$ (g/kW-hr)			
Model Year	Max. Family Emission Limit (FEL)	**$P_{tx} < 4.3$ kW[1]**	**$P_{tx} \geq 4.3$ kW[1]**
2001-2003	Not Applicable	81.00	$(0.25 \times (151+557/P_{tx}^{0.9})) + 6.0$
2004-2007	80	64.80	$(0.20 \times (151+557/P_{tx}^{0.9})) + 4.8$
2008 and Later[2]	44	30.00	$(0.09 \times (151+557/P_{tx}^{0.9})) + 2.1$

1. For 2010 and subsequent model years, an engine or engine family's power category is based on maximum engine power; otherwise maximum rated power may be used.
2. For 2010 and subsequent model years, standards are measured in total hydrocarbons plus oxides of nitrogen.

Table 1.2

Outboard and Personal Watercraft Carbon Monoxide Standards

ENGINE CATEGORY	MODEL YEAR	POWER CATEGORY[a] *[kilowatts]*	CO STANDARD *[grams per kilowatt-hour]*
OB/PWC[b]	2009 and later	kW ≤ 40	500 - 5 x P[c]
		kW > 40	300.0

a For 2010 and subsequent model years, an engine or engine family's power category is based on maximum engine power; otherwise maximum rated power may be used.
b Abbreviation for "Outboard and Personal Water Craft" engines
c P is defined as maximum rated power or maximum engine power (see footnote a) in kilowatts (kW)

where:

P_{tx} is the average power in kilowatts (kW) (sales-weighted) of the total number of spark-ignition marine engines produced for sale in California in model year x. Engine power must be calculated using the Society of Automotive Engineers (SAE) standard J1228, November 1991, incorporated herein by reference. Engine manufacturers must not determine P_{tx} by combining the power outputs of outboard engines with the power outputs of personal watercraft engines.

(2) An engine manufacturer may comply with the standards directly on an individual engine family basis. Consequently in Table 1.1, FELs are not applicable for any model year and P_{tx} means the average power in kW (sales-weighted) of the subject engine family produced for sale in California in model year x.

Compliance with the HC+NOx standards on a corporate average basis is determined as follows:

$$\frac{\sum_{j=1}^{n}(PROD_{jx})(FEL_{jx})(P_{jx})}{\sum_{j=1}^{n}(PROD_{jx})(P_{jx})} = STD_{ca}$$

where:

n = Total number of engine families (by category)

$PROD_{jx}$ = Number of units each engine family j produced for sale in California in model year x.

FEL_{jx} = The Family Emission Limit (FEL) for engine family j in model year x, which must be determined by the engine manufacturer subject to the following conditions: (1) no individual engine family FEL shall exceed the maximum allowed value as specified in Table 1.1; (2) no engine family designation or FEL shall be amended in a model year unless the engine family is recertified; and (3) prior to sale or offering for sale in California, each engine family must be certified in accordance with the test procedures referenced in section 2447 and must meet the engine manufacturer's FEL as a condition of the Executive Order. Before certification, the engine manufacturer must also submit estimated production volumes for each engine family to be offered for sale in California.

P_{jx} = The average power in kW (sales-weighted) of engine family j produced for sale in California in model year x. Engine power must be calculated using SAE standard J1228, November 1991, incorporated herein by reference.

STD_{ca} = An engine manufacturer's calculated corporate average $HC+NO_x$ exhaust emissions from those California spark-ignition marine engines subject to the California corporate average $HC+NO_x$ exhaust emission standard determined from Table 1.1, as established by an Executive Order certifying the California production for the model year. This Executive Order must be obtained prior to the issuance of certification Executive Orders for individual engine families for the model year.

(A) For purposes of compliance under this paragraph, engine manufacturers must not corporate average outboard engine families in combination with personal watercraft engine families.

(B) During the engine manufacturer's production year, for each engine family, the engine manufacturer shall provide the Executive Officer within 45 days after the last day in each calendar quarter the total number of spark-ignition marine engines produced for sale in California and their applicable FEL(s).

(C) The Executive Order certifying the California production for a model year must be obtained prior to the issuance of

certification Executive Orders for individual engine families for the model year.

(D) The engine manufacturer's average HC+NO_x exhaust emissions must meet the corporate average standard at the end of the engine manufacturer's production for the model year. At the end of the model year, the manufacturer must calculate a corrected corporate average using sales or eligible sales rather than projected sales.

(E) Production and sale of spark-ignition marine engines that result in noncompliance with the California standard for the model year shall cause an engine manufacturer to be subject to: revocation or suspension of Executive Orders for the applicable engine families; enjoinment from any further sales, or distribution, of such noncompliant engine families, in the State of California pursuant to section 43017 of the Health and Safety Code; and all other remedies available under Part 5, Division 26 of the Health and Safety Code. Before seeking remedial action against the engine manufacturer, the Executive Officer will consider any information provided by the equipment manufacturer.

(F) For each model, the engine manufacturer shall submit California sales data ninety (90) days after the end of the model year.

(b) Model year 2003 and later model year spark-ignition ~~inboard and sterndrive~~ sterndrive/inboard marine engines:

(1) Exhaust emissions from all new model year 2003 and later spark-ignition ~~inboard and sterndrive~~ sterndrive/inboard marine engines must not exceed the ~~exhaust~~ emission standards listed in Table 2.1(a) and/or 2.1(b) for the designated emission durability test period.

(A) Prior to Model Year 2007 certification, each engine manufacturer must select either Option 1 (OPT 1) or Option 2 (OPT 2) for its entire production of standard performance engines for the 2007 and 2008 model years.

Table 2.1(a)
Standard Performance ~~Inboard/~~Sterndrive/Inboard Marine Engine Standards

MODEL YEAR	~~RATED~~ POWER CATEGORY[1] [kilowatts]	COMPLIANCE OPTION[12]	DURABILITY [hours / years]	EXHAUST STANDARDS ~~NMHC[23]+NOx~~ [grams per kilowatt-hour]	TYPE[34]	CO [grams per kilowatt-hour]	SUPPLEMENTAL MEASURE[45]
2003 - 2006	kW ≤ 373	N/A	N/A	16.0	AVE[6]	N/A	None
2007	kW ≤ 373	OPT 1	N/A	16.0 (55%)	AVE[6]		None
			480 / 10	5.0 (45%)	FIXED		
		OPT 2	N/A	14.0	FIXED		Low-Permeation Fuel Line Hoses
2008	kW ≤ 373	OPT 1	N/A	16.0 (25%)	AVE[6]		None
			480 / 10	5.0 (75%)	FIXED		
		OPT 2	480 / 10	5.0	FIXED		Low-Permeation Fuel Line Hoses
2009 and later	kW ≤ 373	N/A	480 / 10	5.0[6,7,8]	FIXED	75.0[7,9]	Carryover[710]
	~~373 < kW ≤ 485~~		~~150[5] / 3~~	~~5.0[6]~~	~~AVE~~		
	~~kW > 485~~		~~50[5] / 1~~	~~5.0[6]~~	~~AVE~~		

Notes:
1. For 2010 and subsequent model years, an engine or engine family's power category is based on maximum engine power; otherwise maximum rated power may be used
~~1~~2. Once a manufacturer has chosen an option, that option must continue to be used exclusively across product lines
~~2~~3. ~~The non-methane component of hydrocarbon~~For 2010 and subsequent model years, standards are measured in total hydrocarbons plus oxides of nitrogen; however, the non-methane component of hydrocarbon may be substituted in prior years
~~3~~4. Corporate averaging (AVE) may be used to demonstrate compliance with the exhaust emission standard, except where a FIXED standard is required
~~4~~5. Supplemental measures may be different than shown, but must provide equal and verifiable emission reductions to those indicated
~~5. For the purpose of durability testing, engine components that have been approved with an hourly warranty period shorter than the full hourly durability period per § 2445.1 (c)(3)(C)4. may be replaced at the specified warranty interval~~
6. The corporate average calculation may be met with or without power weighting for these years
~~6~~7. ~~All engines ≤ 373 kW must meet a 5.0 g/kW-hr NMHC+NOx capping standard. For engines > 373 kW, the standard may be met by sales averaging with engines equal to or less than 373 kW~~A single engine family certified under the discontinuation allowance in Title 13, California Code of Regulations, § 2442(g)(2) may continue to meet current certification levels for HC+NOx and no more than 150 g/kW-hr for CO over the engine's useful life provided that the manufacturer certifying such an engine family also certifies one or more engine families to family emissions limits sufficiently low to enable compliance on a corporate average basis
8. Large volume dual category manufacturers are required to certify one or more engine families to a family emissions limit lower than the HC+NOx standard when complying with high performance engines on a corporate average basis .
9. Standard performance engines ≥ 6.0 liter displacement may alternatively meet a 25 g/kW-hr standard for Modes 2-5 of the ISO 8178-4 E4 marine test cycle
~~7~~10. The same or better supplemental emission control hardware used to ~~meet the standard~~ comply in 2007 must be used every model year thereafter and all fuel hoses (i.e., not just the fuel line hose) must be low-permeation hoses

(B) At the time of, or prior to, Model Year 2009 certification, each Large Volume Dual Category Manufacturer must declare whether it will comply with the high performance exhaust standard of 5.0 g/kW-hr HC+NOx through averaging or whether it will comply with the less stringent small volume high performance HC+NOx exhaust standard through the incorporation of enhanced evaporative control systems on vessels using standard performance engines for 2009 and subsequent model year engine production.

Table 2.1(b)
High Performance Sterndrive/Inboard Marine Engine Standards

MODEL YEAR	POWER[a] CATEGORY *[kilowatts]*	HC[b]+NOx STANDARD *[grams per kilowatt-hour]*		CO STANDARD *[grams per kilowatt-hour]*
		Small Volume or Large Volume Single Category Manufacturer	Large Volume Dual Category Manufacturer	
2009 - 2010	373 < kW ≤ 485	16.0[c]	5.0[d]	350.0[c]
	kW > 485	25.0[c]		
2011 and later	373 < kW ≤ 485	16.0[c]	5.0[d]	350.0[c]
	kW > 485	22.0[c]		

a For 2010 and subsequent model years, an engine or engine family's power category is based on maximum engine power; otherwise maximum rated power may be used

b For 2010 and subsequent model years, standards are measured in total hydrocarbons plus oxides of nitrogen; however, the non-methane component of hydrocarbon may be substituted in prior years

c These standards are fixed except that engine families certified under the discontinuation allowance in Title 13, California Code of Regulations, § 2442(g)(2) may continue to meet current certification levels for HC+NOx over the engine's useful life provided that the manufacturer certifying such an engine family also certifies one or more engine families to family emissions limits sufficiently low to enable compliance on a corporate average basis

d This standard may be met on a corporate average basis between high performance engines and/or between standard performance and high performance engines. Alternately, large volume dual category manufacturers may comply with the exhaust standards for small volume manufacturers provided a sufficient number of vessels with the manufacturer's standard performance engines are equipped with enhanced evaporative control systems as noted in Title 13, California Code of Regulations, § 2442(b)(5). Manufacturers must declare their intent to use this alternative prior to certifying engines for the 2009 model year and must continue to certify future model year engines using this alternative exclusively across product lines

(C) No crankcase emissions shall be discharged into the ambient atmosphere from 2003 and later spark-ignition ~~inboard and~~ sterndrive/inboard marine engines.

(D) Production and sale of spark-ignition marine engines that result in noncompliance with the California standard for the model year shall cause an engine manufacturer to be subject to: revocation or suspension of Executive Orders for the applicable engine families; enjoinment from any further sales, or distribution, of such noncompliant engine families, in the State of California pursuant to section 43017 of the Health and Safety Code; and all other remedies available under Part 5, Division 26 of the Health and Safety Code. Before seeking remedial action against the engine manufacturer, the Executive Officer will consider any information provided by the equipment manufacturer.

(E) For each engine family, the engine manufacturer shall submit the total number of engines produced for sale in California, or the total number of engines produced for sale nationally, ninety (90) days after the end of the model year.

(2) Evaporative Requirements for All High Performance Engine Manufacturers and Boat Manufacturers:

(A) For 2009 and subsequent model year engines, each engine manufacturer must provide written instructions, as part of the installation materials provided to boat manufacturers, to use enhanced evaporative control systems on any boat that is manufactured for sale, sold, or offered for sale in California, or that is introduced, delivered or imported into California for introduction into commerce. The engine manufacturer shall also provide evidence that the supplier(s) of the enhanced evaporative control system has designed the system components to meet or exceed the diurnal and permeation design specifications listed in Table 2.2 throughout the useful life of the engine.

Table 2.2 Sterndrive/Inboard Marine Evaporative Design Specifications

	PERMEATION STANDARDS[1] *[grams per square meter per day]*	DIURNAL STANDARD[2] *[grams per gallon per day]*	TEST TEMPERATURES *[degrees Celsius]*
Fuel Hoses	15.0	—	23 ± 2
Fuel Tank	1.5	—	28 ± 2
Trailerable Boat	—	0.40	25.6 – 32.2
Nontrailerable Boat	—	0.16	27.6 – 30.2

1. Fuel hoses and tank permeation testing requires fuel with 10% ethanol content.
2. Diurnal testing requires fuel with 9 pounds per square inch (psi) Reid Vapor Pressure volatility and a 24-hour fuel temperature cycle.

(B) For 2009 and subsequent model year engines, each boat manufacturer must install an enhanced evaporative control system on every boat that is manufactured for sale, sold, or offered for sale in California that uses a high performance engine.

(3) ~~(2)~~ Compliance with the standards on a corporate averaging basis is calculated as follows:

$$\frac{\sum_{j=1}^{n}(PROD_{jx})(EL_{jx})}{\sum_{j=1}^{n}(PROD_{jx})} = \textit{Corporate Average}$$

$$\frac{\sum_{j=1}^{n}(PROD_{jx})(EL_{jx})(P_{jx})}{\sum_{j=1}^{n}(PROD_{jx})(P_{jx})} = \text{Corporate Average}$$

where:

n = Total number of engine families available for averaging

$PROD_{jx}$ = Number of engines in engine family j produced for sale in California in model year x.

EL_{jx} = The measured ~~NM~~HC+NOx emission levels for engine family j in model year x~~; or for engines > 485 kW, the manufacturer may choose to use 30 g/kW-hr as per paragraph (F) below~~.

P_{jx} = The average power in kW (sales-weighted) of engine family j produced for sale in California in model year x. Engine power must be calculated using SAE standard J1228, November 1991, incorporated herein by reference.

(A) During the engine manufacturer's production year, for each engine family, the engine manufacturer shall provide the Executive Officer within 45 days after the last day in each calendar quarter the total number of spark-ignition marine engines produced for sale in California and their applicable EL(s).

(B) The Executive Order certifying the California production for a model year must be obtained prior to the issuance of certification Executive Orders for individual engine families for the model year.

(C) The engine manufacturer's average ~~NM~~HC+NO_x exhaust emissions must meet the corporate average standard at the end of the engine manufacturer's production for the model year. At the end of the model year, the manufacturer must calculate a corrected corporate average using sales or eligible sales rather than projected sales.

(D) Production and sale of spark-ignition marine engines that result in noncompliance with the California standard for the model year shall cause an engine manufacturer to be subject to: revocation or suspension of Executive Orders for

the applicable engine families; enjoinment from any further sales, or distribution, of such noncompliant engine families, in the State of California pursuant to section 43017 of the Health and Safety Code; and all other remedies available under Part 5, Division 26 of the Health and Safety Code. Before seeking remedial action against the engine manufacturer, the Executive Officer will consider any information provided by the engine manufacturer.

(E) For each engine family, the engine manufacturer shall submit California sales data within one hundred eighty (180) days after the end of the model year.

~~(F) Engines exceeding 485 kilowatts maximum rated power: In lieu of exhaust emission testing, manufacturers may certify using a default exhaust emissions level of 30.0 grams per kilowatt-hour of NMHC+NO_x in their corporate averaging calculation.~~

~~(3)~~

(4) Alternate Requirements for Standard Performance Manufacturers:

(A) Requirements of engine manufacturers and boat manufacturers under Option 2 and using Low Permeation Fuel Line Hose:

~~(A)~~

1. Each engine manufacturer that chooses Option 2 must provide written instructions, as part of the installation materials provided to purchasers of the engine, to use Low Permeation Fuel Line Hose for the primary fuel line connecting the fuel tank to the engine of any boat that is manufactured for sale, sold, or offered for sale in California, or that is introduced, delivered or imported into California for introduction into commerce.

~~(B)~~

2. Each boat manufacturer must install Low Permeation Fuel Line Hose for the primary fuel line connecting the fuel tank to the engine of any boat that is manufactured for sale, sold, or offered for sale in California that uses an engine from a manufacturer that chooses Option 2.

~~(4)~~ (B) Supplemental Measures. Prior to Model Year 2007 certification, manufacturers choosing Option 2 may request Executive Officer approval of a supplemental measure as an alternative to meeting the requirements of paragraph (b)(3).

In determining whether to approve a request, the Executive Officer will consider the following:

~~(A)~~ 1. Whether the proposed supplemental measure would achieve reductions in ~~NM~~HC+NO_x equivalent to using Low-Permeation Fuel Line Hoses,

~~(B)~~ 2. The engine manufacturer's measures to ensure successful implementation of the proposed supplemental measure,

~~(C)~~ 3. The durability of the proposed supplemental measure, and

~~(D)~~ 4. Any additional information the Executive Officer deems relevant.

(5) Alternate Requirements for Large Volume Dual Category Manufacturers.

In lieu of complying with the 5.0 g/kW-hr HC+NOx exhaust standard in Table 2.1(b) for high performance engines, large volume dual category engine manufacturers may certify high performance engines to the same HC+NOx exhaust standards as required for small volume manufacturers in Table 2.1(b) provided that a sufficient number of boats using standard performance engines are equipped with enhanced evaporative control systems to fully compensate for the change in emission benefits from allowing compliance to the less stringent standard. Unless a lower percentage is demonstrated sufficient by the certifying manufacturer, a minimum of fifteen percent annually of the large volume dual category manufacturer's standard performance engine production for California must be installed in boats equipped with enhanced evaporative control systems. Beginning with the 2009 model year and for all model years thereafter, the following would apply:

A. Each engine manufacturer must provide written instructions, as part of the installation materials provided to purchasers of the engine, to use enhanced evaporative control systems on any boat that is manufactured for sale, sold, or offered for sale in California, or that is introduced, delivered or imported into California for introduction into commerce that uses a standard performance engine intended to qualify the engine manufacturer to certify its high performance engines using the HC+NOx standards intended for small volume high performance manufacturers in Table 2.1(b) of this section. The engine manufacturer shall also provide evidence that

the supplier(s) of the enhanced evaporative control system has designed the system components to meet or exceed the diurnal and permeation design specifications listed in Table 2.2 throughout the useful life of the engine.

B Each boat manufacturer shall install an enhanced evaporative control system on every boat that is manufactured for sale, sold, or offered for sale in California that uses a standard performance engine intended to qualify the engine manufacturer to certify its high performance engines using the HC+NOx standards intended for small volume high performance manufacturers in Table 2.1(b) of this section.

(c) Not-to-Exceed (NTE) Limits

(RESERVED)

{Note to commenters: Upon promulgation by the United States Environmental Protection Agency of Not-to-Exceed (NTE) requirements for spark-ignition marine engines, the Executive Officer shall have the authority to adopt the same NTE requirements for California; such that, for engines subject to these regulations, California would have full authority to enforce the NTE limits independently of the federal government. The federal NTE proposal can be found at "Control of Emissions from Nonroad Spark-Ignition Engines and Equipment," Federal Register Volume 76, Number 92, Friday, May 18, 2007, 28098, at pages 28279-28281, as discussed at pp. 28121-28124. There will be no additional demonstrations of NTE compliance unique to California beyond those of the federally promulgated requirements.}

(d) Voluntary Standards. Model Year 2009 and later spark-ignition marine engines:

(1) Manufacturers may voluntarily certify their engines to the full useful life exhaust and evaporative emission standards in Table 3 below.

(2) Marine vessels powered by engines certified to the voluntary standards in Table 3 below and equipped with a fully compliant OBD-M system (see § 2444.2) shall display a five-star consumer/environmental emission label (see § 2443.2 and § 2443.3).

Table 3 - Voluntary Standards

HC^1+NO_x STANDARD *[grams per kilowatt-hour]*	CO STANDARD *[grams per kilowatt-hour]*	PERMEATION STANDARDS *[grams per square meter per day]*		DIURNAL STANDARD[2] *[grams per gallon per day]*
		Hose[3]	Tank[4]	
2.50	50.0	15.0	1.5	0.4

1. The exhaust standard includes total hydrocarbons
2. Diurnal testing assumes a trailerable boat and requires fuel with 9 pounds per square inch (psi) volatility and a 24 hour fuel temperature cycle of 25.6 to 32.2 °Celsius
3. Fuel line permeation testing requires gasoline fuel with 10% ethanol content and must be performed at a test temperature of 23 ± 2 °Celsius
4. Fuel tank permeation testing requires gasoline fuel with 10% ethanol content and must be performed at a test temperature of 28 ± 2 °Celsius

(3) Spark-ignition marine engines certified to the voluntary standards are subject to the same in-use compliance and recall requirements as engines certified to the required exhaust and evaporative standards.

(e) New Replacement Engine Requirements for Engine Manufacturers. A new spark-ignition marine engine produced solely to replace an engine originally manufactured in accordance with the requirements of § 2422 shall be identical in specifications to the most stringent certified emissions configuration currently available that can be installed in a vessel or personal watercraft without unreasonable modifications, as determined by the Executive Officer. A new replacement engine with emissions performance less than maximum stringency shall be allowed only if all engines of greater stringency are incompatible with the vessel or personal watercraft and so long as the emissions performance of the new replacement engine is at least as stringent as that of the engine being replaced. New replacement engines that do not comply with current year emission requirements must be labeled as follows:

"SALE OR INSTALLATION OF THIS ENGINE FOR ANY PURPOSE OTHER THAN TO REPLACE AN ENGINE OF SIMILAR OR LESS STRINGENT EMISSIONS PERFORMANCE IS A VIOLATION OF CALIFORNIA LAW SUBJECT TO CIVIL PENALTY."

~~(e)~~(f) The test equipment and test procedures for determining compliance with these standards are set forth in Parts III and IV, respectively, of the "Test Procedures."

(g) Special Provisions for Engine and/or Vessel Manufacturers

(1) Jet Boat Engines

(A) Jet boat engine families previously certified to the HC+NOx standards for outboard engines and personal watercraft in

§ 2442(a) may continue to be certified to those standards until 2012 with the additional requirement for 2009 and subsequent model years to comply with the applicable carbon monoxide standards for OB/PWC engines in Table 1.2.

(B) Beginning in 2010, all new jet boat engine families shall comply with the standards for sterndrive/outboard engines in § 2442 (b) upon introduction, except that these new jet boat engine families may be cross-category averaged with any other jet boat or personal watercraft engine family to comply with those standards until 2012. An engine family certified to the § 2442 (a) standards prior to 2010, but not previously used in a jet boat application would be considered a new jet boat engine family in 2010.

(C) Jet boat engines previously certified in the same engine family with personal watercraft engines must be certified separately and to a unique engine family beginning in 2010 if new, or in 2012 otherwise.

(D) The OBD-M requirements in § 2444.2 would apply to new jet boat engine families in 2010 and to all jet boat engine families in 2012.

(2) Discontinuation of Marinized Sterndrive/Inboard Engines.

Sterndrive/inboard engine manufacturers who marinize base engines produced by another manufacturer may request a discontinuation allowance from the Executive Officer, subject to the following:

(A) The base engine manufacturer has announced that it plans to discontinue the base engine.

(B) Each marinizer may have a discontinuation allowance for only one engine family in effect at any time. As an alternative to the "one engine family" stipulation, manufacturers may petition the Executive Officer to allow a modified grouping of engines based on factors that logically link the engines to be discontinued including, but not necessarily limited to, the pre-marinized base configuration of the engines (e.g., the same base engine offered in one family with fuel injection and another family with carburetion).

(C) The discontinuation allowance would allow the marinizing manufacturer to continue to certify the engine family to be discontinued to emission levels that are less stringent than

the standards otherwise required for sterndrive/inboard engines in § 2442 (b) for a total of four model years, provided that on a corporate average basis, the manufacturer meets the required standards in § 2442 (b).

(D) Manufacturers shall not certify engine families to emission levels less stringent than those in effect for previous model year versions of the same or similar engine family. Fluctuations in certification levels from year to year due to component variation would not violate this prohibition unless the fluctuations result in an exceedance of the standards to which the engine family was previously certified.

(E) Manufacturers shall comply with all applicable OBD-M and evaporative requirements in effect for:

1. any previously uncertified engine family certified for the first time under paragraph (g)(2) of this section to emission levels that are less stringent than the standards otherwise required for sterndrive/inboard engines in § 2442 (b); and

2. any current production engine family that has previously been certified with OBD-M or evaporative systems.

(F) The applicable requirements of §§ 2442(b)(3), 2443.1, and 2443.2, including averaging, records keeping, reporting, and labeling, shall be applicable to manufacturers employing the discontinuation allowance provisions of this paragraph (g)(2).

(3) General Hardship Relief Provision

Manufacturers may petition the Executive Officer at any time to issue temporary relief from any of the requirements of this Article that would result in extreme financial or technical hardship to the manufacturer. The Executive Officer shall consider the following in determining whether or not to grant the manufacturer's request for relief and the extent to which relief is provided:

(A) The manufacturer could not have reasonably anticipated the situation for which relief is requested and has substantiated that the circumstances resulting in the hardship were beyond its control to avert; and

(B) The manufacturer has exhausted all existing relief provisions in trying to remedy the situation; and

(C) The manufacturer has proposed an effective, implementable, and enforceable plan to make up for any emission benefits that would be lost should the requested relief be provided.

(4) Executive Officer Discretion for Technical Changes.

The Executive Officer may revise or incorporate specific technical requirements with respect to the test procedures incorporated at § 2441(a)(58) of these regulations. For the purposes of this subparagraph (4), "technical requirements" includes revisions to test procedures, test methodology, or any requirement to enhance alignment with similar federal regulations promulgated after the amendments to this Article 4.7, as noticed June 6, 2008, are adopted. Such technical requirements shall be electronically noticed to listserv subscribers, shall be made available to the public via appropriate ARB webpage postings, and shall be noticed in the California Regulatory Notice Register. Such technical requirements will become effective 30 days after notice, unless any person notifies the Executive Offier in writing that they object to any part of the technical requirements noticed.

(h) Practices for Rebuilding Engines. The rebuilding practices described in Part I, Section 7 of the incorporated test procedures shall apply to all spark-ignition marine engines subject to the requirements of § 2422 that are rebuilt after December 31, 2009, including those engines that were originally manufactured on, or prior to, December 31, 2009.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2443.1. Emission Control Labels - Model Year 2001 and Later Spark-Ignition Marine Engines.

(a) * * * * *

(b) Applicability. This section applies to:

(1) Model year 2001 and later spark-ignition personal watercraft and outboard marine engines and model year 2003 and later spark-ignition ~~inboard and~~ sterndrive/inboard marine engines, which have been certified to the applicable emission standards pursuant to Health and Safety Code section 43013;

* * * * *

(c) Engine Label and Location.

* * * * *

(2)

(B) ~~Inboard and~~ Sterndrive/Inboard Engines. In selecting an acceptable location, the engine manufacturer must consider visibility and the possibility of accidental damage (e.g., possibility of tools or sharp instruments coming in contact with the label). The engine label must be affixed in such a manner that it cannot be removed without destroying or defacing the label. The engine label must contain the unique identification number that has been assigned to the engine, pursuant to subsection (a) of this section. If the engine manufacturer claims there is inadequate space to attach the label, the Executive Officer will determine a suitable location.

* * * * *

(4) The engine label must contain the following information:

(A) * * * * *

(B) The full corporate name or trademark of the engine manufacturer.

~~(i)~~

1. An engine manufacturer may request the Executive Officer's approval to delete its name and trademark, and substitute the name and trademark of another engine

manufacturer, original equipment manufacturer or third-party distributor.

~~(ii)~~

2. Approval under paragraph (4)(B)~~(i)~~1. above does not relieve the engine manufacturer granted an engine family Executive Order of any requirements imposed by these provisions on the applicable engines.

* * * * *

(D) Identification of the Exhaust and/or Evaporative Emission Control System(s) (Abbreviations may be used and must conform to the nomenclature and abbreviations provided in the latest revision of the Society of Automotive Engineer's (SAE) procedure J1930, "Electrical/Electronic Systems Diagnostic Terms, Definitions, Abbreviations and Acronyms", and as specified in section 1977, Title 13, California Code of Regulations).

* * * * *

(G) An unconditional statement of compliance with the appropriate model year California regulations. For example, "THIS ENGINE CONFORMS TO (model year) CALIFORNIA EMISSION REGULATIONS FOR SPARK-IGNITION MARINE ENGINES." For an engine family certified in California with an FEL different from the FEL assigned federally for the engine family, the following statement shall be appended to the unconditional statement of compliance: "...AND IS CERTIFIED TO (specify FEL) g/kW-hr HC+NO_x ENGINE FAMILY EXHAUST EMISSION STANDARD IN CALIFORNIA."

(H) The engine and evaporative family identification(s) (i.e., engine and, where applicable, evaporative family name(s)). The engine and evaporative family identification(s) shall be in accordance with the current format(s) used by the United States Environmental Protection Agency.

* * * * *

(d) For ~~Inboard and~~ Sterndrive/Inboard Engines used solely for Competition.

* * * * *

(4) * * * * *

(B) The full corporate name or trademark of the engine manufacturer.

~~(i)~~
1. An engine manufacturer may request the Executive Officer's approval to delete its name and trademark, and substitute the name and trademark of another engine manufacturer, original equipment manufacturer or third-party distributor.

~~(ii)~~
2. Approval under paragraph (4)(B)~~(i)~~1. above does not relieve the engine manufacturer granted an engine family Executive Order of any requirements imposed by these provisions on the applicable engines.

* * * * *

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2443.2. Consumer / Environmental Label Requirements.

(a) * * * * *

(b) Applicability. This section applies to:

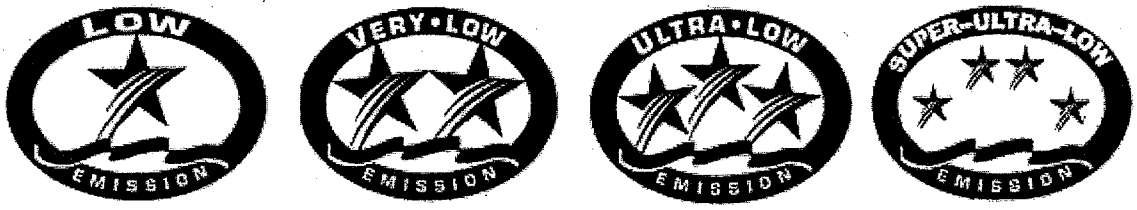
(1) Model year 2001 and later spark-ignition personal watercraft and outboard marine engines and model year 2003 and later spark-ignition ~~inboard and~~ sterndrive/inboard marine engines, which have been certified to the applicable emission standards pursuant to Health and Safety Code section 43013;

* * * * *

(c) * * * * *

(1) Facsimiles of the label format are shown in Figure 1.

Figure 1



(NOTE: Labels are not to scale.)

(A) The engine manufacturer must ensure that the label has the following characteristics:

~~(i)~~
1. Oval shape;

~~(ii)~~
2. Dimensions of no less than three inches wide by two and a half inches high, except that it may be no less than

two inches by one and two-thirds inches high for engines that have power outputs of 11.2 kW (15 hp) or less;

~~(iii)~~
3. Watermark

(i) For all except five star labels, ~~A~~a watermark as shown in Figure 2 that is a clear laminate. The watermark must cover the entire label and be screened at no less than fifteen percent; and

(ii) For five star labels, a colored or black and white watermark consisting of the central portion of the California State flag as shown in the five star label format in Figure 1. The watermark must cover the entire label and be screened at no less than fifteen percent; and

~~(iv)~~
4. All written information required by paragraph (c)(4)(B) must be in the English language and the font must be sans serif. The characters must be a minimum of two (2) millimeters in height except as specified in paragraph ~~(b)(1)(B)(i)(d)~~(c)(1)(B)5., and of a color that contrasts with the background on which it is displayed.

Figure 2

(B) Multiple levels of cleanliness. Progressively clean engines shall carry the following notations (as applicable):

~~(i)~~
1. An engine that has an FEL or that has been certified at or below the hydrocarbon plus oxides of nitrogen standard listed in Table 1 of this section for Tier 1 must include the phrase "LOW EMISSION" and a single star symbol as shown in Figure 1.

~~(ii)~~
2. An engine that has an FEL or that has been certified at or below the hydrocarbon plus oxides of nitrogen standard listed in Table 1 of this section for Tier 2 must include the phrase "VERY LOW EMISSION" and two star symbols as shown in Figure 1.

~~(iii)~~
3. An engine that has an FEL or that has been certified at or below the hydrocarbon plus oxides of nitrogen standard listed in Table 1 of this section for Tier 3 must include the phrase "ULTRA LOW EMISSION" and three star symbols as shown in Figure 1.

~~(iv)~~
4. An engine that has an FEL or that has been certified at or below the hydrocarbon plus oxides of nitrogen standard listed in Table 1 of this section for Tier 4 must include the phrase "SUPER ULTRA LOW EMISSION" and four star symbols as shown in Figure 1.

5. An engine that has an FEL or that has been certified at or below the hydrocarbon plus oxides of nitrogen standard listed in Table 1 of this section for Tier 5 must include the phrase "LEVEL FIVE EXTREMELY CLEAN" and five star symbols as shown in Figure 1.

Table 1.

Hydrocarbon plus Oxides of Nitrogen Standards (in g/kW-hr)		
Tier	***P < 4.3***	***P ≥ 4.3***
1	81.00	$(0.25 \times (151+557/P^{0.9})) + 6.0$
2	64.80	$(0.20 \times (151+557/P^{0.9})) + 4.8$
3	30.00	$(0.09 \times (151+557/P^{0.9})) + 2.1$
4	5.0	5.0
5	2.5	2.5

Where P means the average power in kW (sales-weighted) of the subject engine family.

~~(iv)~~
6. All phrases encircling the top portion must have block characters that are a minimum of five (5) millimeters in height except that the characters may be three (3) millimeters for labels sized as allowed pursuant to paragraph (c)(1)(A)~~(i)~~2. for engines that have power outputs of 11.2 kW (15 hp) or less.

(C) Language other than that specified in paragraph (b)(1)(B) must not be used unless permitted by the Executive Officer.

(D) The color of the outer oval and stars on the labels must contrast with the engine cover or watercraft hull. The color of the interior oval (i.e., background for the stars) must contrast with the color of the outer oval and stars.

(2) Label Location. For outboard engines, a single label must be permanently affixed to the back of the engine cover or cowling. For personal watercraft, a single label must be affixed two to three inches to the right of the required location of the California Assigned Vessel Number displayed on the port side of the hull. For ~~inboard and~~ sterndrive/inboard engines, labels must be affixed to the engine and to the port side of the hull, either to the right or left and in close proximity to the required location of the California Assigned Vessel Number. Each label must be manufactured and permanently affixed so that it cannot be removed without destroying or defacing the label, must be readily visible and must not be affixed to any location that is likely to be replaced during the engine's useful life. For the purposes of this paragraph, readily visible means that the label's shape and number of stars are discernible from a distance of 100 feet.

* * * * *

(5) For ~~Inboard and~~ Sterndrive/Inboard Marine Engines:

* * * * *

(e) Replacement engines installed in hulls, cowlings or watercraft that had been previously labeled in accordance with these specifications must have identical or improved emissions to that of the original certified engine in accordance with the provisions in § 2442 (e).

* * * * *

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2443.3. Environmental Label/Consumer Notification Requirements.

(a) Applicability. This section applies to model year 2001 and later spark-ignition personal watercraft and outboard marine engines and model year 2003 and later spark-ignition ~~inboard and~~ sterndrive/inboard marine engines, which have been certified to the applicable emission standards pursuant to Health and Safety Code section 43013.

(b) A nonpermanent label (i.e., hang tag) must be attached to each personal watercraft or outboard engine, as applicable, at time of sale. A nonpermanent label (i.e., hang tag) produced and supplied by the engine manufacturer must be attached, by the seller, to each ~~inboard and~~ sterndrive/inboard engine or watercraft, as applicable, when introduced for sale to ultimate purchasers. Environmental labels pursuant to this section shall include a copy of the following:

Front of Hang Tag:

The Star Label means Cleaner Marine Engines

This engine has been certified as a:

☐ ☒ ☐ ☐ ☐

(<Check appropriate box.>)

The Symbol for Cleaner Marine Engines:

Cleaner Air and Water – for a healthier lifestyle and environment.

Better Fuel Economy – burns up to 30 - 40 percent less gas and oil than conventional carbureted two-stroke engines, saving money and resources.

Longer Emissions Warranty – protects consumer for worry free operation.

Back of Hang Tag:

<facsimile of the one-star label>

One Star – Low Emission
The one-star label identifies engines that meet the Air Resources Board's Personal Watercraft and Outboard marine engine 2001 exhaust emission standards. Engines meeting these standards have 75% lower emissions than conventional carbureted two-stroke engines. These engines are equivalent to the U. S. EPA's 2006 standards for marine engines.

<facsimile of the two-star label>

Two Stars – Very Low Emission
The two-star label identifies engines that meet the Air Resources Board's Personal Watercraft and Outboard marine engine 2004 exhaust emission standards. Engines meeting these standards have 20% lower emissions than One Star – Low Emission engines.

<facsimile of the three-star label>

Three Stars – Ultra Low Emission
The three-star label identifies engines that meet the Air Resources Board's Personal Watercraft and Outboard marine engine 2008 exhaust emission standards or the Sterndrive and Inboard marine engine 2003-2008 exhaust emission standards. Engines meeting these standards have 65% lower emissions than One Star – Low Emission engines.

<facsimile of the four-star label>

Four Stars – Super Ultra Low Emission
The four-star label identifies engines that meet the Air Resources Board's Sterndrive and Inboard marine engine 2009 exhaust emission standards. Personal Watercraft and Outboard marine engines may also comply with these standards. Engines meeting these standards have 90% lower emissions than One Star – Low Emission engines.

<facsimile of the five-star label>

Five Stars - Level Five Extremely Clean
The five-star label identifies engines that meet the Air Resources Board's Voluntary Standards for spark-ignition marine engines. Engines meeting these standards have 50% lower emissions than Four Stars – Super Ultra Low Emission engines.

<White Space for dealer or manufacturer identification or additional information>

Cleaner Watercraft – Get the Facts
1-800-END-SMOG
www.arb.ca.gov

(1) * * * * *

(2) For outboard engines greater than 130 horsepower, facsimiles of only the "Low Emission Engine" and "Very Low Emission Engine" labels described in sections 2443.2(c)(1)(B)~~(i)~~1. and ~~(ii)~~2. need to be displayed on the nonpermanent label until the earlier of:

* * * * *

(3) For personal watercraft, facsimiles of only the "Low Emission Engine" and "Very Low Emission Engine" labels described in sections 2443.2(c)(1)(B)~~(i)~~1. and ~~(ii)~~2. need to be displayed on the nonpermanent label until the earlier of:

* * * * *

(4) For any spark-ignition marine engine or personal watercraft not certified to the voluntary standards in § 2442(d), facsimiles of only the "Low Emission Engine," "Very Low Emission Engine," "Ultra Low Emission Engine," and "Super Ultra Low Emission Engine" labels described in §§ 2443.2(c)(1)(B)1. through 2443.2(c)(1)(B)4. need to be displayed on the nonpermanent label, except as permitted in (b)(2) and (b)(3) of this section:

~~(4)~~

(5) All textual information (i.e., characters and/or lettering) required by this section must be no smaller than two (2) millimeters in height.

(c) * * * * *

(d) Samples of all labels produced pursuant to this section must be submitted to the Executive Officer with the applicable certification application. The Executive Officer may require a demonstration of durability for any hang tag, submitted per the provisions of this section, that s/he believes may become illegible, damaged, or otherwise not intact at the time of sale, for a period of two years, when displayed under normal conditions.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2444.1. In-Use Compliance Testing and Recall Regulations – Model Year 2001 and Later Spark-Ignition Marine Engines.

(a) Applicability. This section applies to model year 2001 and later spark-ignition personal watercraft and outboard marine engines, which have been certified to the applicable emission standards pursuant to Health and Safety Code section 43013. Spark-ignition ~~inboard and~~ sterndrive/inboard marine engines shall comply with the in-use compliance testing and recall requirements found in Title 13, California Code of Regulations, Sections 2111 through 2140 and 2147.

(b) * * * * *

(3) * * * * *

(B) * * * * *

~~(i)~~
1. A minimum of two (2) engines per family provided that no engine fails any standard. For each failing engine, two (2) more engines must be tested until the total number equals ten.

~~(ii)~~
2. For engine families of less than 50 engines (California sales) for the identified model year or for engine manufacturers who make less than or equal to 200 engines (California sales) for that model year, a minimum of one engine per family provided that this engine does not fail any standard. If this engine fails, two (2) more engines shall be tested. For each additional engine failure, the engine manufacturer must continue testing two (2) additional engines until the total number equals eleven.

~~(iii)~~
3. If an engine family was certified using carryover emission data and has been previously tested under paragraph (b)(3)(B) without an ordered recall, then only one engine for that family must be tested. If this engine fails any standard, testing must be conducted as outlined in paragraphs (b)(3)(B), as applicable.

* * * * *

(E) * * * * *

~~(i)~~

1. engine family production in California is less than or equal to 20 per year; or

~~(ii)~~

2. engines cannot be obtained for testing because they are used substantially in watercraft that are not conducive to engine removal such as large watercraft where the engine cannot be removed without dismantling either the engine or the watercraft; or

~~(iii)~~

3. other compelling circumstances associated with the structure of the industry and uniqueness of spark-ignition marine engine applications. Such alternatives shall be designed to determine whether the engine family is in compliance in-use.

(F) * * * * *

(G) * * * * *

~~(i)~~

1. A test engine must have a maintenance and use history representative of actual in-use conditions.

   a. The engine manufacturer must obtain information from the end users regarding the accumulated usage, maintenance, operating conditions and storage of the test engines.

   b. Documents used in the procurement process must be maintained as required by section 30 of the Test Procedures.

~~(ii)~~

2. The engine manufacturer may perform minimal "set-to-specification" maintenance on components of a test engine that are not subject to parameter adjustment. Maintenance may include only that which is listed in the owner's manual for engines with the amount of service and age of the acquired test engine. Documentation shall be maintained and retained as required by section 30 of the Test Procedures.

~~(iii)~~

3. At least one valid emission test, performed according to the test procedures outlined in Part IV of the Test Procedures is required for each in-use engine.

~~(iv)~~
4. The Executive Officer may waive portions or requirements of the test procedures, if any, that are not necessary to determine in-use compliance.

~~(v)~~
5. If a selected in-use engine fails to comply with any applicable emission standard, the engine manufacturer must determine the reason for noncompliance. The engine manufacturer must report all such reasons of noncompliance within fifteen days of completion of testing.

* * * * *

(e) * * * * *

(4) Record keeping and Reporting Requirements.

(A) * * * * *

~~(i)~~
1. Engine family and emission recall campaign number designated by the engine manufacturer.

~~(ii)~~
2. Date engine/watercraft owner notification was begun, and date completed.

~~(iii)~~
3. Number of engines involved in the voluntary or ordered recall campaign.

~~(iv)~~
4. Number of engines known or estimated to be affected by the nonconformity and an explanation of how this number was determined.

~~(v)~~
5. Number of engines inspected pursuant to the voluntary or ordered recall plan.

~~(vi)~~
6. Number of inspected engines found to be affected by the nonconformity.

~~(vii)~~
7. Number of engines receiving repair under the recall plan and a listing of these engines' engine identification numbers.

~~(viii)~~
8. Number of engines determined to be ineligible for recall action due to removed or modified parts.

~~(ix)~~
9. A copy of any service bulletins transmitted to dealers or other authorized repair facilities which pertain to the nonconformity to be corrected and that have not previously been reported.

~~(x)~~
10. A copy of all communications transmitted to engine/watercraft owners that relate to the nonconformity and that have not previously been submitted.

(B) If the engine manufacturer determines that any of the information submitted pursuant to paragraph (4)(A) above has changed or was incorrect, revised information and an explanation must be submitted. Responses to subsections (4)(A)~~(v)~~5.,~~(vi)~~6.,~~(vii)~~7.,(viii)8. and ~~(ix)~~9. above shall be cumulative totals.

(C) * * * * *

~~(i)~~
1. To whom notification was given;

~~(ii)~~

2. Whose engines were repaired or inspected under the recall plan; and

~~(iii)~~
3. Whose engines were determined not to qualify for repair due to removed or modified components.

(D) * * * * *

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2444.2. On-Board Engine Malfunction Detection System Requirements - Model Year 2007 and Later Spark-Ignition ~~Inboard and~~ Sterndrive/Inboard Marine Engines.

(a) (1) Engines certified under Option 1 of Section 2442(b)(1):

All 2007 and 2008 model year spark-ignition ~~inboard and~~ standard performance sterndrive/inboard marine engines certified to the 5.0 grams per kilowatt-hour HC+NOx standard shall comply with the requirements for subsections (b) through (i) below, except as noted. For all 2009 model year and later spark-ignition ~~inboard and~~ standard performance sterndrive/inboard marine engines, the requirements in *italics* shall also apply.

(2) Engines certified under Option 2 of Section 2442(b)(1):

All 2008-2009 model year spark-ignition ~~inboard and~~ standard performance sterndrive/inboard marine engines shall comply with the requirements for subsections (b) through (i) below, except as noted. For all 2010 model year and later spark-ignition standard performance ~~inboard and~~ sterndrive/inboard marine engines, the requirements in italics shall also apply.

(3) High Performance Engines

All 2009-2010 model year spark-ignition high performance sterndrive/inboard marine engines shall comply with the requirements for subsections (b) through (i) below, except as noted and applicable. For all 2011 model year and later spark-ignition high performance sterndrive/inboard marine engines, the requirements in italics shall also apply.

This section shall be implemented according to the provisions of the following subsections or by means determined by the Executive Officer to be equivalent in meeting the requirements of this section.

~~This section shall be implemented according to the provisions of the following subsections or by means determined by the Executive Officer to be equivalent in meeting the requirements of this section.~~

(b) General requirements.

(1) Spark-ignition sterndrive ~~and inboard~~/inboard marine engines sold as new shall be equipped with an integrated malfunction detection and notification system, hereinafter known as On-~~b~~Board Diagnostics-Marine (OBD-M) system, to identify emission-related malfunctions of the catalyst, fuel system, primary oxygen sensors used for feedback fuel control, secondary oxygen sensors (if

equipped) used for catalyst monitoring, computer-sensed comprehensive components, and the on-board computer itself, by means of diagnostic trouble codes stored in non-volatile computer memory. For this section, a computer-sensed comprehensive component is any electronic device that:

(A) provides information to the on-board computer and significantly impacts emissions when malfunctioning; or

(B) is used to enable or disable any other OBD-M monitoring strategy.

(2) For model years 2010 and subsequent, t~~T~~he OBD-M system shall ~~not~~ be required to identify engine misfire per the provisions in subsection (c)(5) ~~unless such monitoring is determined necessary by the Executive Officer to preserve or protect the catalyst system~~ except as otherwise permitted in these regulations. ~~The Executive Officer shall (as part of the in-water testing and development program to be conducted in conjunction with U.S. EPA, the U.S. Coast Guard, the marine industry, and catalyst manufacturers) identify whether, and to what extent, misfire in spark-ignition inboard and sterndrive marine engines may affect catalyst durability and performance. If the Executive Officer determines that engine misfire is a significant factor in reducing the durability and/or performance of marine catalysts, engine manufacturers shall be required to incorporate appropriate misfire detection diagnostics into the OBD-M system. In that case, the provisions in subsection (c)(5) shall be considered sufficient for satisfying the obligation to monitor misfire.~~ Alternate misfire monitoring strategies shall be considered by the Executive Officer and may be implemented in lieu of subsection (c)(5) if demonstrated by the engine manufacturer to provide an equivalent degree of catalyst protection. Otherwise the provisions of that subsection shall be voluntary. ~~In making a determination, the Executive Officer shall consider the cost effectiveness of requiring additional monitoring to address the concerns identified by the test program in addition to the leadtime necessary to modify existing hardware and software, to add misfire detection hardware (e.g., sensors) if necessary, and to develop engine-specific calibrations to accommodate misfire monitoring. Notwithstanding, misfire monitoring shall not be required prior to the 2009 model year, and may be delayed beyond that date pending Executive Officer discretion.~~

(3) The OBD-M system shall not be required to detect any emissions-related malfunction that prevents the engine from starting. The OBD-M system shall not be required to monitor any emissions-related component or system if the only reliable way to accomplish such monitoring would either significantly impair

engine/vessel operability or decrease the safety involved with operating the engine/vessel.

(4) OBD-M systems shall have the capability to activate an audio or visual alert device located on the marine vessel to inform vessel occupants in the event of a malfunction, and to transmit diagnostic information locally via a standardized data link connector.

(5) Spark-ignition sterndrive ~~and~~ /inboard marine vessels shall be equipped with an audio alert device and/or visual alert device that is compatible with the activation function of the OBD-M system on the installed engine.

(A) If equipped, the audio alert device shall provide sufficient volume and intensity to be readily perceptible to vessel occupants during normal modes of vessel operation and occupant activity, but shall not exceed applicable maximum noise levels as set by authorized federal or State agencies. Further, the audio alert device shall in no way impede the function of required sound-signaling devices, or other safety-related devices, already present on the vessel. The audio alert device shall sound briefly in the engine-run key position before engine cranking to indicate that the audio alert device is functional.

(B) If equipped, the visual alert device shall provide sufficient activation and be located such that it is readily visible under normal lighting conditions, but shall in no way impede the function of any visual distress-signaling device, fog signal, or navigational light. The visual alert device shall activate in the engine-run key position before engine cranking to indicate that the visual alert device is functional and shall, when activated, display the phrase "Service Required" or an equivalent standardized phrase or symbol to be determined as specified in Subsection (h).

(6) Malfunction thresholds for catalyst, misfire, fuel system, oxygen sensor, and computer-sensed comprehensive component diagnostics shall be determined by the engine manufacturer. However, the engine manufacturer must demonstrate that the determination of these thresholds is sufficient for detecting emission-related malfunctions in a timely and meaningful manner subject to Executive Officer approval (see Subsection (f)(2)).

(7) Regarding diagnostic system monitoring and audio/visual alert device activation requirements, engine manufacturers are required to define monitoring conditions that are representative of typical

in-use operation, and which will result in the routine execution and completion of all OBD-M diagnostics in-use.

(8) For model years 2007-2008 on engines complying with paragraph (a)(1) of this section, ~~and~~ for model years 2008-2009 on engines complying with paragraph (a)(2) of this section, and for model years 2009-2010 on engines complying with paragraph (a)(3) of this section, activation of the audio/visual alert device upon detection of excessive engine misfire or a catalyst, fuel system, or oxygen sensor malfunction shall be optional. However, there are no exemptions from storing diagnostic trouble codes in non-volatile computer memory during these model years for any malfunction. The OBD-M must be capable of fully communicating stored information to a generic scan tool via the standardized data link connector.

(9) Engine manufacturers may employ alternate statistical audio/visual alert device activation and diagnostic trouble code storage protocols to those specified in these requirements, subject to Executive Officer approval, based on comparable timeliness in detecting a malfunction and evaluating system performance.

(10) Should emission control devices/strategies be introduced on the engine in addition to those identified herein as requiring monitoring (e.g., exhaust gas recirculation), the engine manufacturers shall notify the Executive Officer and submit a plan for monitoring the new device/strategy prior to its incorporation into the OBD-M system. This would not apply to carbon canisters, non permeable fuel tanks, or low-permeation hoses ~~should they be~~ used to comply with the ~~supplemental emission reduction requirements of~~ evaporative requirements for high performance engines in § 2442(b)(2), the Option 2 requirements for standard performance engines in § 2442(b)(4), or the alternative requirements for large volume dual category manufacturers in § 2442(b)(5) ~~in Section 2442(b)(1)~~.

(11) Engine manufacturers may request Executive Officer approval to disable any diagnostic strategy at ambient engine starting temperatures below forty (40) degrees Fahrenheit (low ambient temperature conditions may be determined based on intake air or engine coolant temperature at engine starting), and at elevations above six thousand five hundred (6,500) feet above sea level provided the engine manufacturer submits data and/or an engineering evaluation which adequately demonstrate that monitoring would be unreliable when such conditions exist. Notwithstanding, diagnostic system disablement may be requested at other ambient engine starting temperatures if the engine manufacturer adequately demonstrates with data and/or an

engineering evaluation that misdiagnosis would occur due to the impact of such ambient temperatures on the performance of the component itself.

(12) Engine manufacturers may disable individual monitors that can be affected by running out of fuel, provided disablement will not occur when the fuel level is above fifteen percent of the nominal capacity of the fuel tank.

(13) The Executive Officer may grant an extension for compliance with the requirements of this section, with respect to an engine model or engine family, if the engine manufacturer demonstrates that a present electronic control system cannot be modified in time for the 2007, ~~or~~ 2008, or 2009 model year, as applicable per subsection (a) of this section, because major design changes, not consistent with the engine manufacturer's projected changeover schedule, would be needed to comply with the provisions of the regulation. The period of extension shall not exceed that period of time necessary to enable modification of the electronic control system in accordance with the engine manufacturer's projected changeover schedule, or a period of two years, whichever first occurs. Engine manufacturers requesting an extension shall, no later than six months prior to the applicable model year, submit to the Executive Officer a written request for exemption, setting forth the required demonstration and specifying the period for which the extension is requested.

(14) All engines certified to the 5.0 gram per kilowatt-hour ~~NM~~HC+NOx standard, including those engines certified using the corporate averaging provisions in 2442(b) and discontinuation allowance in 2442(g)(2), must be equipped with OBD-M for the engine's emission-related components. Notwithstanding, current production engines not yet required to possess an OBD-M system would not be required to incorporate OBD-M under the discontinuation allowance until the allowance had expired.

(c) Monitoring requirements.

(1) Catalyst monitoring.

(A) Purpose and scope:

~~(i)~~

1. The diagnostic system shall monitor the catalyst system on spark-ignited marine engines to ensure that the performance of the catalyst has not been compromised due to engine misfire or other factors that can decrease catalyst durability.

~~(ii)~~

2. Manufacturers of spark-ignited lean-burn marine engines may request that the Executive Officer exempt such applications from these catalyst monitoring requirements if it can be demonstrated that a reliable monitoring technology is not available. The Executive Officer shall approve such a request upon determining that all reasonable monitoring technologies have been considered to the extent possible.

(B) Malfunction~~ing~~ criteria:

~~(i)~~

1. The catalyst system shall be considered malfunctioning when the temperature of the measured catalyst(s) exceeds a threshold value, as determined by the engine manufacturer, indicating abnormally high operating temperature; or when the catalyst temperature fails to reach a minimum value, as determined by the engine manufacturer, indicating "light-off" of the catalyst after a manufacturer-specified time interval has elapsed.

~~(ii)~~

2. Subject to executive officer approval, alternate malfunction criteria (e.g., correlating oxygen sensor frequencies to catalyst conversion efficiency) may be employed by the engine manufacturer if the alternate criteria are appropriate and would provide for enhanced monitoring capability.

(C) Monitoring conditions:

~~(i)~~

1. The engine manufacturer shall define conditions for monitoring the catalyst with the constraints that the check shall:

   a. be conducted at the earliest acceptable opportunity encountered after the beginning of each operating cycle; and

   b. the monitoring system shall operate at least once per in-use operating cycle during which the engine manufacturer-defined monitoring conditions are met.

(D) Malfunction~~ing~~ notification and diagnostic trouble code storage:

~~(i)~~
1. Upon detection of a catalyst malfunction, the audio/visual alert device shall be activated and a diagnostic trouble code stored no later than the end of the next operating cycle during which monitoring occurs provided the malfunction is again present.

~~(ii)~~
2. The diagnostic system shall temporarily disable catalyst monitoring when a malfunction exists that could affect the proper evaluation of catalyst efficiency.

~~(iii)~~
3. The monitoring method for the catalyst(s) shall be capable of detecting when a catalyst trouble code has been cleared (except diagnostic system self-clearing), but the catalyst has not been replaced (e.g., catalyst over-temperature approaches may not be acceptable).

(2) Fuel system monitoring.

(A) Purpose and scope:

The diagnostic system shall monitor the fuel delivery system for its ability to dynamically adjust fuel delivery.

(B) Malfunction criteria:

The engine manufacturer shall establish malfunction criteria to monitor the fuel delivery system. If the engine is equipped with fuel trim circuitry, the engine manufacturer shall include as one of the malfunction criteria the condition where the trim circuitry has used up all of the trim adjustment allowed within the engine manufacturer's selected limit(s). Engine manufacturers may compensate the criteria limit(s) appropriately for changes in altitude or for other similar identifiable operating conditions when they occur.

(C) Monitoring conditions:

The fuel system shall be monitored continuously for the presence of a malfunction.

(D) Malfunction notification and diagnostic trouble code storage:

~~(i)~~

1. For fuel systems with short-term trim only capability, the diagnostic system shall store a diagnostic trouble code after the fuel system has attained the criteria limit for an engine manufacturer-defined time interval sufficient to determine a malfunction. If the malfunction criteria limit and time interval are exceeded, the audio/visual alert device shall be activated and a diagnostic trouble code stored no later than the end of the next operating cycle in which the criteria and interval are again exceeded; unless operating conditions similar to those under which the problem was originally detected (manufacturer-defined conditions) have been encountered without such an exceedance, in which case the initial temporary code and stored conditions may be erased. Furthermore, if similar operating conditions are not encountered during forty (40) operating cycles subsequent to the initial detection of a malfunction, the initial temporary code and stored conditions may be erased.

~~(ii)~~

2. For fuel systems with long-term fuel trim capability, upon attaining a long-term based malfunction criteria limit independent of, or in combination with, the short-term trim system status, the audio/visual alert device shall be activated and a diagnostic trouble code stored no later than the end of the next operating cycle if the malfunction is again detected. If the malfunction is not detected during the second operating cycle, the audio/visual alert device shall be activated and a diagnostic trouble code stored no later than the next operating cycle in which the malfunction is again detected; unless operating conditions similar to those under which the problem was originally detected (manufacturer-defined conditions) have been encountered without an indication of a malfunction, in which case the initial temporary code and stored conditions may be erased. Furthermore, if similar operating conditions are not encountered during forty (40) operating cycles subsequent to the initial detection of a malfunction, the initial temporary code and stored conditions may be erased.

(3) Oxygen sensor monitoring.

(A) Purpose and scope:

~~(i)~~

1. The diagnostic system shall monitor the output voltage and response rate of all primary (fuel control) oxygen (lambda) sensors for malfunction. It shall also monitor secondary oxygen sensors when used as a monitoring device for proper output voltage and/or response rate. Response rate is the time required for the oxygen sensor to switch from lean-to-rich once it is exposed to a richer than stoichiometric exhaust gas mixture or from rich-to-lean when exposed to a leaner than stoichiometric exhaust gas mixture. As a precaution, measuring oxygen sensor switching frequency may not be an adequate indicator of oxygen sensor response rate, particularly at low speeds.

~~(ii)~~

2. Either the lean-to-rich or both the lean-to-rich and rich-to-lean response rates shall be checked. Response rate checks shall evaluate the portions of the sensor's dynamic signal that are most affected by sensor malfunctions such as aging or poisoning.

   Engine manufacturers may observe the voltage envelope of the sensor when cycled at a frequency of 1.5 Hertz or greater, as determined by the engine manufacturer, to evaluate a slow response rate sensor (i.e., a slow sensor cannot achieve maximum and/or minimum voltage as will a good sensor, given a properly chosen switching frequency and fuel step change for the check). With Executive Officer approval, engine manufacturers may use alternative parameters to comply with this requirement such as voltage ranges and fuel-air switching frequencies based on a determination that the modifications will result in an accurate and timely evaluation of the sensor.

~~(iii)~~

3. For sensors with different characteristics, the engine manufacturer shall submit data and an engineering evaluation to the Executive Officer for approval based on showing equivalent evaluation of the sensor.

(B) Malfunction criteria:

An oxygen sensor shall be considered malfunctioning when the voltage, response rate, or other criteria, as determined by the engine manufacturer, are exceeded, or when sensor output characteristics are no longer sufficient (e.g., lack of sensor switching) for use as a diagnostic system monitoring device (e.g., for catalyst efficiency monitoring).

(C) Monitoring conditions:

~~(i)~~
1. The engine manufacturer shall define conditions for monitoring the oxygen sensor(s) with the constraints that the check shall:

a. be conducted at the earliest acceptable opportunity encountered after the beginning of each operating cycle; and

b. operate at least once per in-use operating cycle during which the engine manufacturer-defined monitoring conditions are met.

~~(ii)~~
2. For primary oxygen sensors(s) used for fuel control, the response rate and output voltage shall be monitored for malfunction after the engine has commenced closed-loop operation. If the oxygen sensor(s) is used as part of the monitoring strategy for the catalyst, the oxygen sensor(s) diagnostics should be scheduled to execute before the catalyst diagnostics begin.

(D) Malfunction notification and diagnostic trouble code storage: Upon detection of any oxygen sensor malfunction, the diagnostic system shall store a diagnostic trouble code and the audio/visual alert device shall activate no later than the end of the next operating cycle during which monitoring occurs provided the malfunction is again present.

(4) Computer-sensed comprehensive component monitoring.

(A) Purpose and scope:

The diagnostic system shall monitor for malfunction any computer-sensed electronic engine components not otherwise described in this subsection that provide input to

(directly or indirectly) the on-board computer, and that~~:~~ ~~1)~~ can affect emissions during any reasonable in-use operating condition~~,~~ or ~~2)~~ are used as part of the diagnostic strategy for any other monitored system or component.

~~(i)~~
1. The monitoring system shall have the capability of detecting, *at a minimum*, lack of circuit continuity *and out of range values to ensure proper operation of the input device. The determination of out of range values shall include logic evaluation of available information to determine if a component is operating within its normal range (e.g., a low throttle position sensor voltage would not be reasonable at a high engine speed with a high mass airflow sensor reading). To the extent feasible, said logic evaluation shall be "two-sided" (i.e., verify a sensor output is not inappropriately high or low).*

~~(ii)~~
2. Computer-sensed comprehensive components may include, but are not limited to, the engine speed sensor, crank angle sensor, knock sensor, throttle position sensor, coolant temperature sensor, cam position sensor, and other electronic components such as sensors and fuel injectors.

~~(iii)~~
3. *The coolant temperature sensor shall be monitored for achieving a stabilized minimum temperature level that is needed to achieve closed-loop operation within an engine manufacturer-specified time interval after starting the engine. The time interval shall be a function of starting engine coolant temperature and/or a function of intake air temperature. Engine manufacturers may suspend or delay the diagnostic if the engine is subjected to conditions which could lead to false diagnosis (e.g., engine operation at idle for more than 50 to 75 percent of the warm-up time).*

(B) Malfunction criteria:

Computer-sensed comprehensive components shall be considered malfunctioning when, *at a minimum,* lack of circuit continuity *or engine manufacturer-specified out-of-range values occurs.*

(C) Monitoring conditions:

Computer-sensed components shall be monitored continuously for *proper range of values and* circuit continuity.

For rationality monitoring (where applicable), engine manufacturers shall define appropriate operating conditions that are representative of typical in-use operation and will result in the routine execution and completion of all diagnostics in-use. Rationality monitoring shall occur at least once per operating cycle during which the engine manufacturer-defined monitoring conditions are met.

(D) Malfunction notification and diagnostic trouble code storage:

Upon detecting a malfunction, the diagnostic system shall store a diagnostic trouble code and activate the audio/visual alert device no later than the end of the next operating cycle during which monitoring occurs provided the malfunction is again detected.

(5) Misfire monitoring.

~~The provisions in this subsection shall be considered voluntary unless otherwise determined by the Executive Officer according to subsection (b)(2) above.~~

(A) Purpose and scope:

The diagnostic system shall identify the occurrence of engine misfire that can result in damage to the catalyst system. Identification of the misfiring cylinder is not required, however all patterns of misfire must be identified regardless of whether it occurs in a single or multiple number of cylinders.

(B) Malfunctioning criteria:

The diagnostic system shall identify a malfunction when the total number of misfires evaluated in 200 crankshaft-revolution increments for each engine speed and load condition exceeds a percentage (determined by the engine manufacturer to cause damage to the catalyst system) of the total number of firing events in each increment. These threshold percentages shall be provided in the certification documentation. Subject to Executive Officer approval, an interval longer than 200 crankshaft-revolutions may be used. The engine manufacturer shall submit in the certification documentation catalyst temperature data versus percent misfire over the full range of engine speed and load conditions. Alternatively, catalyst temperature data may be submitted for every 500 rpm increment along the Propeller Law curve beginning

at engine idle and continuing throughout the "Not to Exceed Zone" for marine propulsion engines with Fixed- and Variable-pitch propellers, as defined in 40 CFR, section 94.106, (July 1, 2001), which is incorporated by reference herein. The data shall be obtained from a representative cross section (from small to large displacements) of an engine manufacturer's production. Up to three such engine evaluations shall be documented per engine manufacturer, though an engine manufacturer may submit more data, if desired. An engineering evaluation shall be provided for establishing malfunction criteria for the remainder of engine families in the engine manufacturer's product line. The Executive Officer shall waive the evaluation requirement each year if, in the judgment of the Executive Officer, technological changes do not affect the previously determined malfunction criteria.

(C) Monitoring conditions:

~~(i)~~

1. Monitoring for misfire shall be continuous from engine starting under all steady-state positive torque engine speeds and load conditions.

~~(ii)~~

2. As an exception to monitoring misfire during all positive torque operating conditions, engine manufacturers may disable misfire monitoring in the engine operating region bound by the positive torque line (i.e., engine load with the transmission in neutral), and the two following engine operating points:

   a. an engine speed of 3,000 rpm with the engine load at the positive torque line; and

   b. the redline engine speed (defined in section 2441) with the engine's manifold vacuum at four inches of mercury lower than that at the positive torque line.

   Misfire detection systems unable to detect all misfire patterns under all required conditions shall be evaluated for compliance by the Executive Officer based on, but not limited to, the following factors:

   c. the magnitude of the region(s) in which misfire detection is limited,

d. the degree to which misfire detection is limited in the region(s) (i.e., the probability of detection of misfire events),

e. the frequency with which said region(s) are expected to be encountered in-use,

f. the type of misfire patterns for which misfire detection is troublesome, and

g. demonstration that the monitoring technology employed is not inherently incapable of detecting misfire under required conditions (i.e., compliance can be achieved on other engines).

The evaluation shall be based on the following misfire patterns:

h. equally spaced misfire occurring on randomly selected cylinders,

i. single cylinder continuous misfire; and

j. paired cylinder (cylinders firing at the same crank angle) continuous misfire.

Further, with Executive Officer approval, the engine manufacturer may disable misfire monitoring or employ higher malfunction criteria when misfire cannot be distinguished from other effects (e.g., turbulence causing the propeller to alternately emerge from then re-submerge into the water.) when using the best reasonably available monitoring technology. The engine manufacturer shall present data and/or an engineering evaluation to the Executive Officer to justify the proposed action. Executive Officer approval shall be based on the extent to which monitoring is expected to be disabled in relation to the capabilities of the best available monitoring technologies as applied to other engines. However, any such disablement occurring within the first 5 seconds after engine starting shall not require Executive Officer approval. Additionally, for engines with greater than eight cylinders, the Executive Officer shall waive the requirements of this section provided the engine manufacturer submits data and/or an engineering evaluation which adequately

demonstrates that misfire detection throughout the required operating region cannot be achieved when employing proven monitoring technology (i.e., a technology that provides for compliance with these requirements on other engines) and provided misfire is detected to the fullest extent permitted by the technology.

(D) Malfunction notification and diagnostic trouble code storage:

~~(i)~~

1. Upon detection of the level of misfire specified in subsection (b)(5)(B) above, the following criteria shall apply for audio/visual alert device activation and diagnostic trouble code storage:

a. A temporary diagnostic trouble code shall be stored no later than after the third exceedance of the specified misfire level when operating in the region bound by modes 2 through 5 of the spark-ignition marine engine test cycle and no later than after the first exceedance of the specified misfire level when operating at any other engine speed and load condition during a single operating cycle. If the level of misfire is exceeded again (a single exceedance) during the following operating cycle, or the next operating cycle in which similar conditions are encountered (manufacturer defined conditions), the audio/visual alert device shall activate, a diagnostic trouble code shall be stored, and the audio/visual alert device shall remain continuously activated, even if the misfire ceases. The initial temporary code and stored conditions may be erased if misfire is not detected during the following operating cycle and similar conditions have been encountered without an exceedance of the specified misfire level. The code and conditions may also be erased if similar operating conditions are not encountered during forty operating cycles subsequent to the initial detection of a malfunction.

b. Notwithstanding, in engines that provide fuel shutoff and default fuel control to prevent over fueling during misfire conditions, the audio/visual alert device need not activate

provided that the fuel shutoff and default control shall be activated as soon as misfire is detected. Fuel shutoff and default fuel control may be deactivated only to permit fueling outside of the misfire range.

(d) Additional audio/visual alert device activation and diagnostic trouble code storage protocol.

(1) Audio/visual alert device activation: For all emission-related components/systems, upon final determination of a malfunction, the OBD-M system shall activate an audio or visual alert device.

(A) If so equipped, visual alert devices shall remain activated continuously whenever a malfunction has been identified by the OBD-M system, and may be deactivated only according to the provisions in paragraph (2) below, or with a scan tool after appropriate repairs have been effected.

(B) If so equipped, audio alert devices may remain activated continuously when a malfunction has been identified by the OBD-M system; however, the Executive Officer shall consider alternative strategies in which the audio alert is activated on a discontinuous, but repetitive, basis. To be acceptable, discontinuous audio alert strategies must convey a sense of urgency to vessel operators regarding the presence of OBD-M malfunctions.

Upon fulfillment of the standardization processes referred to in subsection (g) below, a protocol for audio alert device activation shall be specified authorizing only discontinuous activation. A standardized notification format is necessary to facilitate consumer association of the audio alert pattern with the identification of an OBD-M malfunction independent of manufacturer or platform. OBD-M system designers are encouraged to cooperate fully with each other and the ARB early on in this endeavor to minimize the redesigning of OBD- M audio alert activation algorithms once a standardized protocol has been finalized.

(C) The diagnostic system shall store a diagnostic trouble code whenever the audio/visual alert device is activated. The diagnostic system shall activate the audio/visual alert device and shall store a diagnostic trouble code whenever the engine enters a default or "limp home" mode of operation. The diagnostic system shall activate the audio/visual alert device and shall store a diagnostic trouble code whenever the engine control system fails to enter closed-loop operation

(if employed) within an engine manufacturer specified minimum time interval.

(2) Audio/visual alert device deactivation:

(A) *Misfire and* Fuel System Malfunctions: For *misfire or* fuel system malfunctions, the audio/visual alert device may be deactivated if the fault does not recur when monitored during three subsequent sequential operating cycles in which conditions are similar to those under which the malfunction was first determined.

(B) All Other Malfunctions: For all other faults, the audio/visual alert device may be deactivated after three subsequent sequential operating cycles during which the monitoring system responsible for activating the audio/visual alert device functions without detecting the malfunction and if no other malfunction has been identified that would independently activate the audio/visual alert device according to the requirements outlined above.

(3) Erasing a diagnostic trouble code: The diagnostic system may erase a diagnostic trouble code if the same fault is not re-registered in at least forty (40) engine warm-up cycles, and the audio/visual alert device is not activated for that diagnostic trouble code.

(e) Tampering protection: Computer-coded engine operating parameters shall not be changeable without the use of specialized tools and procedures (e.g. soldered or potted computer components or sealed (or soldered) computer enclosures). Subject to Executive Officer approval, engine manufacturers may exempt from this requirement those product lines that are unlikely to require protection. Criteria to be evaluated in making an exemption include, but are not limited to, current availability of performance chips, high performance capability of the engine, and sales volume.

(f) Certification documentation: The engine manufacturer shall submit the following documentation for each engine family at the time of certification. With Executive Officer approval, one or more of the documentation requirements specified in this section may be waived or altered if the information required would be redundant or unnecessarily burdensome to generate:

(1) A written description of the functional operation of each monitoring strategy within the diagnostic system.

(2) A table providing the following information for each monitored component or system (either computer-sensed or -controlled) of the emission control system:

(A) corresponding diagnostic trouble code.

(B) monitoring method or procedure for malfunction detection.

(C) primary malfunction detection parameter and its type of output signal.

(D) fault criteria limits used to evaluate output signal of primary parameter.

(E) other monitored secondary parameters and conditions (in engineering units) necessary for malfunction detection.

(F) monitoring time length and frequency of checks.

(G) criteria for activating the audio/visual alert device.

(3) A logic flowchart describing the general method of detecting malfunctions for each monitored emission-related component or system. To the extent possible, abbreviations in SAE J1930 "Electrical/Electronic Systems Diagnostic Terms, Definitions, Abbreviations, and Acronyms," May 1998, shall be used. J1930 is incorporated by reference herein. The information required in the ~~chart~~ table under (2) above may instead be included in this flow chart, provided all of the information required in (2) is included.

(4) A listing and block diagram of the input parameters used to calculate or determine calculated load values and the input parameters used to calculate or determine fuel trim values.

(5) Any other information determined by the Executive Officer to be necessary to demonstrate compliance with the requirements of this section.

(g) Confirmatory testing: The ARB may perform confirmatory testing of engine manufacturers' diagnostic systems for compliance with requirements of this section in accordance with malfunction criteria submitted in the engine manufacturer's approved certification documentation. The ARB or its designee may install appropriately deteriorated or malfunctioning components in an otherwise properly functioning test engine (or simulate a deteriorated or malfunctioning component response) in order to test the fuel system, oxygen sensor, catalyst system, and misfire (if applicable) monitors for compliance with the applicable constraints in this section.

Diagnostic systems of a representative sample of engines that uniformly fail to meet the requirements of this section may be recalled for correction.

(h) Standardization: The spark-ignition ~~inboard and~~ sterndrive/inboard marine industry, in cooperation with ARB, will develop and adhere to standardized specifications for the implementation of OBD-M, including diagnostics trouble code formats, communication, and scan tool protocols.

(i) Implementation schedule.

(1) These OBD-M requirements, unless otherwise specified, shall be implemented beginning with the 2007 model year for engines complying with (a)(1) of this section, ~~and~~ with the 2008 model year for engines complying with (a)(2) of this section, and with the 2009 model year for engines complying with (a)(3) of this section.

(2) All engine manufacturers shall meet these OBD-M requirements by the 2009 model year for engines complying with (a)(1) of this section, ~~and~~ the 2010 model year for engines complying with (a)(2) of this section, and the 2011 model year for engines complying with (a)(3) of this section.

(3) The Executive Officer, upon receipt of an application from the engine manufacturer, may certify the engines in question even though said engines may not comply with one or more of the requirements of these subsections. Such certification is contingent upon the extent to which these requirements are satisfied overall on the engine applications in question and a demonstrated good-faith effort to meet these requirements in full by evaluating and considering the best available monitoring technology. Each incident of non-compliance will be recorded as a deficiency.

(A) Engine manufacturers of non-complying systems shall be subject to fines pursuant to section 43016 of the California Health and Safety Code for each deficiency identified subject to the following limitations:

~~(i)~~
1. The specified fines shall apply to the third and subsequently identified deficiencies, with the exception that fines shall apply to all monitoring system deficiencies wherein a required monitoring strategy is completely absent from the OBD-M system; and

~~(ii)~~
2. Engine manufacturers may not carry over monitoring system deficiencies for more than two model years

unless it can be adequately demonstrated that substantial engine hardware modifications and additional lead time beyond two years would be necessary to correct the deficiency, in which case the deficiency may be carried over for three model years.

(B) For the third deficiency and every deficiency thereafter identified in an engine model, the fines shall be in the amount of $25 per deficiency per engine for non-compliance with any of the monitoring requirements specified in this section. Total fines per engine under this section shall not exceed $250 per engine and shall be payable to the State Treasurer for deposit in the Air Pollution Control Fund.

NOTE: Authority cited: Sections 39515, 39600, 39601, 43013, 43018, 43104, and 44036.2, Health and Safety Code; Sections 27156 and 38395 Vehicle Code. Reference: Sections 39002, 39003, 39667, 43000, 43004, 43008.6, 43013, 43016, 43018, 43100, 43101, 43101.5, 43102, 43104, 43105, 43106, 43204, and 44036.2, Health and Safety Code; Sections 27156, 38391, and 38395, Vehicle Code.

§ 2445.1. Defects Warranty Requirements for Model Year 2001 and Later Spark-Ignition Marine Engines.

(a) Applicability. This section applies to model year 2001 and later spark-ignition personal watercraft and outboard marine engines, and to model year 2003 and later spark-ignition ~~inboard and~~ sterndrive/inboard marine engines. The warranty period begins on the date the engine or equipment is delivered to an ultimate purchaser or first placed into service (e.g., a demonstration engine or watercraft).

(b) * * * * *

(c) * * * * *

(1) For model year 2001 and later spark-ignition personal watercraft and outboard marine engines, a period of 4 years or 250 hours of use, whichever first occurs ~~first~~.

(2) For model year 2003-2005 spark-ignition ~~inboard and~~ sterndrive/inboard marine engines, a period of 2 years.

(3) For model year 2006 and later spark-ignition ~~inboard and~~ sterndrive/inboard marine engines:

* * * * *

(e) * * * * *

~~(10)~~
(10) Evaporative System

(A) Carbon Canister(s)
(B) Fuel Tank(s)
(C) Purge Valve(s)

(11) Miscellaneous Items Used in Above Systems

(A) Hoses, clamps, fittings, tubing, sealing gaskets or devices, and mounting hardware
(B) Pulleys, belts and idlers
(C) Vacuum, temperature, check, and time sensitive valves and switches
(D) Electronic Controls

* * * * *

(g) Exclusions.

(1) * * * * *

(2) Engine manufacturers must warrant engines for the yearly warranty period specified in paragraph (c). For Outboard and Personal Watercraft engines, and for ~~inboard/~~sterndrive/inboard engines greater than 485 kilowatts, manufacturers may warrant engines for the hour warranty period if the engines:

(A) are equipped with hour meters; (an ECM-integrated hour meter for ~~inboard/~~sterndrive/inboard engines)

* * * * *

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2445.2. Emission Control Warranty Statements.

(a) Each engine manufacturer must provide a verbatim copy of the following statement with each new 2001 model year and later spark-ignition personal watercraft and outboard marine engine and with each new 2003 model year and later spark-ignition ~~inboard and~~ sterndrive/inboard marine engine, using those portions of the statement applicable to the engine.

CALIFORNIA EMISSION CONTROL WARRANTY STATEMENT
YOUR WARRANTY RIGHTS AND OBLIGATIONS

The California Air Resources Board (and engine manufacturer's name, optional) is (are) pleased to explain the emission control system warranty on your (model year)(~~inboard,~~ sterndrive/inboard, outboard, or personal watercraft) engine. In California, new (~~inboard,~~ sterndrive/inboard, outboard, or personal watercraft) engines must be designed, built and equipped to meet the State's stringent anti-smog standards. (Engine manufacturer's name) must warrant the emission control system on your (~~inboard,~~ sterndrive/inboard, outboard, or personal watercraft) engine for the periods of time listed below provided there has been no abuse, neglect or improper maintenance of your (~~inboard,~~ sterndrive/inboard, outboard or personal watercraft) engine.

Your emission control system may include parts such as the carburetor or fuel injection system, the ignition system, and catalytic converter. Also included may be hoses, belts, connectors and other emission-related assemblies.

Where a warrantable condition exists, (engine manufacturer's name) will repair your (~~inboard,~~ sterndrive/inboard, outboard or personal watercraft) engine at no cost to you, including diagnosis, parts and labor.

MANUFACTURER'S WARRANTY COVERAGE:

(For spark-ignition personal watercraft and outboard marine engines:)
Select emission control parts from model year 2001 and later (outboard or personal watercraft) engines are warranted for 4 years, or for 250 hours of use, whichever first occurs ~~first~~.

(For 2003 - 2005 spark-ignition ~~inboard and~~ sterndrive/inboard marine engines:)
Select emission control parts from model year 2003 - 2005 (~~inboard or~~ sterndrive/inboard) engines are warranted for 2 years.

(For 2006 - 2008 spark-ignition ~~inboard and~~ sterndrive/inboard marine engines certified according to Option 1 in Section 2442(b)(1):)
Select emission control parts from model year 2006 - 2008 (~~inboard or~~ sterndrive/inboard) engines are warranted for 2 years.

(For 2006 - 2007 spark-ignition ~~inboard and~~ sterndrive/inboard marine engines certified according to Option 2 in Section 2442(b)(1):)
Select emission control parts from model year 2006 - 2007 (~~inboard or~~ sterndrive/inboard) engines are warranted for 2 years.

(For 2008 spark-ignition ~~inboard and~~ sterndrive/inboard marine engines certified according to Option 2 in Section 2442(b)(1):)
Select emission control parts from model year 2008 (~~inboard or~~ sterndrive/inboard) engines are warranted for 3 years or 480 hours, whichever first occurs.

(For 2009 and later spark-ignition ~~inboard and~~ sterndrive/inboard marine engines 373 kilowatts and less:)
Select emission control parts from model year 2009 and later (~~inboard or~~ sterndrive/inboard) engines are warranted for 3 years or 480 hours, whichever first occurs.

(For 2009 and later spark-ignition ~~inboard and~~ sterndrive/inboard marine engines greater than 373 kilowatts, but less than or equal to 485 kilowatts:)
Select electronic emission-related control parts from model year 2009 and later (~~inboard or~~ sterndrive/inboard) engines are warranted for 3 years or 480 hours, whichever first occurs. Select mechanical emission-related components are warranted for 3 years or 150 hours of operation, whichever first occurs.

(For 2009 and later spark-ignition ~~inboard and~~ sterndrive/inboard marine engines greater than 485 kilowatts:)
Select electronic emission-related control parts from model year 2009 and later (~~inboard or~~ sterndrive/inboard) engines are warranted for 3 years or 480 hours, whichever first occurs. Select mechanical emission-related components are warranted for 1 year or 50 hours of operation, whichever first occurs.

However, warranty coverage based on the hourly period is only permitted for engines that are equipped with hour meters as defined in s 2441(a)(13) or their equivalent. If any emission-related part on your engine is defective under warranty, the part will be repaired or replaced by (engine manufacturer's name).

OWNER'S WARRANTY RESPONSIBILITIES:

– As the (~~inboard,~~ sterndrive/inboard, outboard or personal watercraft) engine owner, you are responsible for the performance of the required maintenance listed in your owner's manual. (Engine manufacturer's name) recommends that you retain all receipts covering maintenance on your (~~inboard,~~ sterndrive/inboard, outboard or personal watercraft) engine, but (engine manufacturer's name) cannot deny warranty solely for the lack of receipts or your failure to ensure the performance of all scheduled maintenance.

– As the (~~inboard,~~ sterndrive/inboard, outboard or personal watercraft) engine owner, you should however be aware that (engine manufacturer's name) may deny you warranty coverage if your (~~inboard,~~ sterndrive/inboard, outboard or personal watercraft) engine or a part has failed due to abuse, neglect, improper maintenance or unapproved modifications.

– You are responsible for presenting your (~~inboard,~~ sterndrive/inboard, outboard or personal watercraft) engine to a (engine manufacturer's name) distribution center as soon as a problem exists. The warranty repairs will be completed in a reasonable amount of time, not to exceed 30 days.

If you have any questions regarding your warranty rights and responsibilities, you should contact (Insert chosen contact of engine manufacturer) at 1-XXX-XXX-XXXX.

* * * * *

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2446. 2001 and Later Model Year Production-Line Test Procedures and Selective Enforcement Auditing Regulations for Spark-Ignition Marine Engines.

(a) Applicability. This section applies to 2001 and later spark-ignition personal watercraft and outboard marine engines. The allowable methods of production-line testing are specified in subsections (b) and (c), unless the engine manufacturer can satisfactorily provide an alternate method that shows an equivalent assurance of compliance to that of subsection (b). The engine manufacturer must choose only one method for each model year and submit its method of production-line testing to the Executive Officer for approval no later than 90 days prior to the start of the subject model year production. The 2003 and later spark-ignition ~~inboard and~~ sterndrive/inboard marine engines are only subject to the selective enforcement audit requirements specified within subsections (d) and (e) of this section. ~~Inboard and sterndrive engines certified using the provision in Section 2442(b)(2)(F) are exempt from this Section~~.

(b) 2001 and Later Model Year Quality-Audit Production Line Test Procedures

* * * * *

(4) * * * * *

(B) * * * * *

~~(i)~~
1. The total production and sample size for each engine family.

~~(ii)~~
2. Engine identification numbers and explanation of the identification code.

~~(iii)~~
3. The applicable emissions standards or Family Emission Levels for each engine family.

~~(iv)~~
4. A description of each test engine or equipment (i.e., date of test, engine family, engine size, engine or equipment identification number, fuel system, dynamometer power absorber setting in horsepower or kilowatts, engine code or calibration number, and test location).

~~(v)~~
5. The exhaust emission data for HC+NOx for each test engine or equipment. The data reported shall provide two significant figures beyond the number of significant figures in the applicable emission standard.

~~(vi)~~
6. The retest emissions data, as described in Paragraph (~~v~~5.) above for any engine or unit of equipment failing the initial test, and description of the corrective measures taken, including specific components replaced or adjusted.

~~(vii)~~
7. A statistical analysis of the quality-audit test results for each engine family stating:

~~1.~~
a. Number of engines or units of equipment tested.

~~2.~~
b. Average emissions and standard deviations of the sample for $HC+NO_x$.

~~(viii)~~
8. Every aborted test data and reason for the aborted test.

~~(ix)~~
9. The applicable quarterly report shall include the date of the end of the engine manufacturer's model year production for an engine family.

~~(x)~~
10. The required information for all engine families in production during the quarter regardless of sample size.

~~(xi)~~
11. The start and stop dates of batch-produced engine family production.

* * * * *

(c) * * * * *

(1) * * * * *

(A) * * * * *

~~(i)~~
1. For newly certified engine families: After two (2) engines are tested, the engine manufacturer will calculate the required sample size for the model year according to the Sample Size Equation in paragraph (c)(1)(B) of this section.

~~(ii)~~
2. For carry-over engine families: After one engine is tested, the engine manufacturer must combine the test with the last test result from the previous model year and then calculate the required sample size for the model year according to the Sample Size Equation in paragraph (B) of this section.

~~(iii)~~
3. The engines must be representative of the engine manufacturer's California sales. Each engine will be selected from the end of the assembly line. All engine models within the engine family must be included in the sample pool. Each selected engine for quality-audit testing must pass the inspection test, by being equipped with the appropriate emission control systems certified by the ARB. The procedure for randomly selecting engines or units of equipment must be submitted to the Chief, Mobile Source Operations Division, P.O. Box 8001, 9528 Telstar Avenue, El Monte, CA, 91734-8001, before the start of production for the first year of production.

~~(iv)~~
4. a. Prior to the beginning of the 2001 model year, if an engine manufacturer cannot provide actual California sales data, it must provide its total production and an estimate of California sales at the end of the model year. The engine manufacturer must also provide supporting material for its estimate.

b. For the 2001 and later model years, engine manufacturers must provide actual California sales, or other information acceptable to the Executive Officer, including, but not limited to, an estimate based on market analysis and federal production or sales.

(B) ~~(i)~~1. Engine manufacturers must calculate the required sample size for the model year for each engine family using the Sample Size Equation below. N is calculated from each test result. The number N indicates the number of tests required for the model year for an engine family. N is recalculated after each test. Test results used to calculate the variables in the Sample Size Equation must be final deteriorated test results as specified in paragraph (c)(3)(C).

$$N = \left[\frac{(t_{95} * \sigma)}{(x - FEL_{jx})} \right]^2 + 1$$

where:

N = Required sample size for the model year.

T_{95} = 95% confidence coefficient. It is dependent on the actual number of tests completed, n, as specified in the table in paragraph (c)(1)(B)~~(ii)~~2. of this section. It defines one-tail, 95% confidence intervals.

FEL_{jx} = Family Emission Limit

σ = Actual test sample standard deviation calculated from the following equation:

$$\sigma = \sqrt{\frac{\sum (X_i - x)^2}{n - 1}}$$

where:

X_i = Emission test result for an individual engine

x = Mean of emission test results of the actual sample

n = The actual number of tests completed in an engine family

~~(ii)~~2. Actual Number of Tests (n) and 1-tail Confidence Coefficients (t_{95}) are listed in Table 3 below:

Table 3

~~Actual Number of Tests (n) and 1-tail Confidence Coefficients (t_{95})~~

n	t_{95}	n	t_{95}	n	t_{95}
2	6.31	12	1.80	22	1.72
3	2.92	13	1.78	23	1.72
4	2.35	14	1.77	24	1.71
5	2.13	15	1.76	25	1.71
6	2.02	16	1.75	26	1.71
7	1.94	17	1.75	27	1.71
8	1.90	18	1.74	28	1.70
9	1.86	19	1.73	29	1.70
10	1.83	20	1.73	30	1.70
11	1.81	21	1.72	∞	1.645

~~(iii)~~
3. An engine manufacturer must distribute the testing of the remaining number of engines needed to meet the required sample size N, evenly throughout the remainder of the model year.

~~(iv)~~
4. After each new test, the required sample size, N, is recalculated using updated sample means, sample standard deviations and the appropriate 95% confidence coefficient.

~~(v)~~
5. An engine manufacturer must continue testing and updating each engine family's sample size calculations according to paragraphs (c)(1)(B)~~(i)~~1. through (c)(1)(B)~~(iv)~~4. of this section until a decision is made to stop testing as described in paragraph (c)(1)(B)~~(vi)~~6. of this section or a noncompliance decision is made pursuant to paragraph (c)(2)(A)~~(v)~~5. of this section.

~~(vi)~~
6. If, at any time throughout the model year, the calculated required sample size, N, for an engine family is less than or equal to the actual sample size, n, and the sample mean, x, for each regulated pollutant is less than or equal to the FEL for that pollutant, the engine manufacturer may stop testing that engine family except as required by paragraph (c)(2)(A)~~(vi)~~6..

~~(vii)~~

7. If, at any time throughout the model year, the sample mean, x, for any regulated pollutant is greater than the FEL, the engine manufacturer must continue testing that engine family at the appropriate maximum sampling rate.

~~(viii)~~

8. The maximum required sample size for an engine family (regardless of the required sample size, N, as calculated in paragraph (c)(1)(B)~~(i)~~1. of this section) is thirty (30) tests per model year.

~~(ix)~~

9. Engine manufacturers may elect to test additional randomly chosen engines. All additional randomly chosen engines tested in accordance with the testing procedures specified in the Test Procedures must be included in the Sample Size and Cumulative Sum equation calculations as defined in paragraphs (c)(1)(B)~~(i)~~1. and (c)(2)(A)~~(i)~~1. of this section, respectively.

* * * * *

(2) * * * * *

(A) * * * * *

~~(i)~~

1. Engine manufacturers must construct the following Cumulative Sum Equation for each regulated pollutant for each engine family. Test results used to calculate the variables in the Cumulative Sum Equation must be final deteriorated test results as defined in paragraph (c)(3)(C).

$$C_i = \max[0 \text{ or } (C_{i-1} + X_i - (FEL_{jx} + F))]$$

where:

C_i = The current Cumulative Sum statistic

C_{i-1} = The previous Cumulative Sum statistic. Prior to any testing, the Cumulative Sum statistic = 0 (i.e., $C_0 = 0$)

X_i = The current emission test result for an individual engine

FEL_{jx} = Family Emission Limit

F = $0.25 \times \sigma$

After each test, C_i is compared to the action limit, H, the quantity that the Cumulative Sum statistic must exceed, in two (2) consecutive tests, before the engine family may be determined to be in noncompliance for purposes of paragraphs (a)(2)(A)~~(iv)~~4. and (a)(2)(A)~~(v)~~5.

H = The Action Limit. It is $5.0 \times \sigma$ and is a function of the standard deviation, σ.

σ = The sample standard deviation and is recalculated after each test.

~~(ii)~~

2. After each engine is tested, the Cumulative Sum statistic must be promptly updated according to the Cumulative Sum Equation in paragraph (c)(2)(A)~~(i)~~1. of this section.

~~(iii)~~

3. If, at any time during the model year, an engine manufacturer amends the application for certification for an engine family as specified in Part I, section 28 or 29 of the Test Procedures by performing an engine family modification (i.e., a change such as a running change involving a physical modification to an engine, a change in specification or setting, the addition of a new configuration, or the use of a different deterioration factor), all previous sample size and Cumulative Sum statistic calculations for the model year will remain unchanged.

~~(iv)~~

4. A failed engine is one whose final deteriorated test results pursuant to paragraph (c)(3)(C), for a regulated pollutant exceeds the FEL for that pollutant.

~~(v)~~

5. An engine family may be determined to be in noncompliance if, at any time throughout the model year, the Cumulative Sum statistic, C_i, for a regulated pollutant is greater than the action limit, H, for two (2) consecutive tests.

~~(vi)~~

6. The engine manufacturer must perform a minimum of two tests per engine family per quarter, regardless of whether the conditions of paragraph (c)(1)(B)~~(vi)~~6. have been met. The Executive Officer may waive the requirement of this paragraph if the engine manufacturer does not have a failing engine family in the prior two model years of testing.

~~(vii)~~

7. All results from previous quarters of the same model year must be included in the on-going Cumulative Sum analysis, provided that the engine family has not failed (e.g., if three engines of a family were tested in the first quarter, the first test of the second quarter would be considered as the fourth test).

~~(viii)~~

8. If the Cumulative Sum analysis indicates that an engine family has failed, the engine manufacturer must notify the Chief of the Mobile Source Operations Division, in writing and by telephone, within ten working days. Corrective action will be taken as noted in paragraph (c)(4)(E).

~~(ix)~~

9. If an engine manufacturer performs corrective action on a failed engine family and then resumes production, all previous tests will be void, and Cumulative Sum analysis will begin again with the next test.

* * * * *

(3) * * * * *

(D) If, at any time during the model year, the Cumulative Sum statistic exceeds the applicable action limit, H, in two (2) consecutive tests, the engine family may be determined to be in noncompliance and the engine manufacturer must notify the Chief of the Mobile Source Operations Division ~~and the Manager of the New Vehicle Audit Section, P.O. Box 8001, 9528 Telstar Avenue, El Monte, CA, 91734-8001,~~ within ten working days of such exceedance by the Cumulative Sum statistic.

(E) * * * * *

~~(i)~~

1. The location and description of the engine manufacturer's or other's exhaust emission test facilities that were utilized to conduct testing reported pursuant to this section;

~~(ii)~~
2. Total production and sample sizes, N and n, for each engine family;

~~(iii)~~
3. The applicable emissions standards for each engine family;

~~(iv)~~
4. A description of the process to obtain engines on a random basis;

~~(v)~~
5. A description of the test engines or equipment (i.e., date of test, engine family, engine size, engine or equipment identification number, fuel system, dynamometer power absorber setting in horsepower or kilowatts, engine code or calibration number, and test location);

~~(vi)~~
6. The date of the end of the engine manufacturer's model year production for each engine family;

~~(vii)~~
7. For each test conducted,

a. A description of the test engine, including:

~~1.~~
(i) Configuration and engine family identification,

~~2.~~
(ii) Year, make, and build date,

~~3.~~
(iii) Engine identification number and explanation of the identification code, and

~~4.~~
(iv) Number of hours of service accumulated on engine prior to testing;

b. Location where service accumulation was conducted and description of accumulation procedure and schedule;

c. Test number, date, test procedure used, initial test results before and after rounding, and final test results

for all exhaust emission tests, whether valid or invalid, and the reason for invalidation, if applicable;

d. The exhaust emission data for CO, NO_x and HC for each test engine or watercraft. The data reported must provide two (2) significant figures beyond the number of significant figures in the applicable emission standard.

e. The retest emissions data, as described in paragraph (b)(4)(B)~~(vi)~~6. of this section, for any engine or watercraft failing the initial test, and description of the corrective measures taken, including specific components replaced or adjusted.

f. A complete description of any adjustment, modification, repair, preparation, maintenance, and/or testing that was performed on the test engine, was not reported pursuant to any other part of this article, and will not be performed on all other production engines;

g. A Cumulative Sum analysis, as required in paragraph (c)(2)(A)~~(i)~~1. of this section, of the production line test results for each engine family;

h. Any other information the Executive Officer may request relevant to the determination whether the new engines being manufactured by the engine manufacturer do in fact conform with the regulations with respect to which the Executive Order was issued;

~~(viii)~~
8. For each failed engine as defined in paragraph ~~(vii)~~7.d., above, a description of the remedy and test results for all retests;

~~(ix)~~
9. Every aborted test data and reason for the aborted test;

~~(x)~~
10. The start and stop dates of batch-produced engine family production; and

~~(xi)~~
11. The required information for all engine families in production during the quarter regardless of sample size.

* * * * *

(d) Test Procedures Applicable to All Production-Line and Selective Enforcement Audit Testing.

* * * * *

(3) * * * * *

(D) If an engine manufacturer determines that the emission test results of an engine or watercraft are invalid, the engine or equipment must be retested. Emission results from all tests must be reported. The engine manufacturer must include a detailed report on the reasons for each invalidated test in the quarterly report for all production-line testing, or as required by the ~~Execurive~~Executive Officer for selective enforcement audit testing.

* * * * *

(5) * * * * *

(A) The Executive Order is automatically suspended with respect to any engine failing pursuant to paragraph (b)(3)(D) or (c)(2)(A)~~(iv)~~4. or whose test results for a regulated pollutant exceed the emission standards effective from the time that testing of that engine is completed.

(B) The Executive Officer may suspend the Executive Order for an engine family that is determined to be in noncompliance pursuant to paragraphs (b)(3)(C) or (c)(2)(A)~~(v)~~5. This suspension will not occur before fifteen (15) days after the engine family is determined to be in noncompliance.

(C) If the results of testing pursuant to these regulations indicate that engines of a particular family produced at one plant of an engine manufacturer do not conform to the regulations with respect to which the Executive Order was issued, the Executive Officer may suspend the Executive Order with respect to that family for engines manufactured by the engine manufacturer at all other plants.

(D) Notwithstanding the fact that engines described in the application for certification may be covered by an Executive Order, the Executive Officer may suspend such Executive Order immediately in whole or in part if the Executive Officer finds any one of the following infractions to be substantial:

~~(i)~~
1. The engine manufacturer refuses to comply with any of the requirements of this section.

~~(ii)~~
2. The engine manufacturer submits false or incomplete information in any report or information provided to the Executive Officer under this section.

~~(iii)~~
3. The engine manufacturer renders inaccurate any test data submitted under this section.

~~(iv)~~
4. An ARB enforcement officer is denied the opportunity to conduct activities authorized in this section.

~~(v)~~
5. An ARB enforcement officer is unable to conduct activities authorized in paragraph (d)(2) of this section

because an engine manufacturer has located its facility in a foreign jurisdiction where local law prohibits those activities.

(E) The Executive Officer will notify the engine manufacturer in writing of any suspension or revocation of an Executive Order in whole or in part. A suspension or revocation is effective upon receipt of the notification or fifteen (15) days from the time an engine family is determined to be in noncompliance pursuant to paragraph (d)(1), except that the Executive Order is immediately suspended with respect to any failed engines as provided for in paragraph (b)(3)(D) or (c)(2)~~(iv)~~4. of this section.

(F) The Executive Officer may revoke an Executive Order for an engine family after the Executive Order has been suspended pursuant to paragraphs (d)(5)(B) or (C) of this section if the proposed remedy for the nonconformity, as reported by the engine manufacturer to the Executive Officer, is one requiring a design change or changes to the engine and/or emission control system as described in the application for certification of the affected engine family.

(G) Once an Executive Order has been suspended for a failed engine, as provided for in paragraph (d)(5)(A) of this section, the engine manufacturer must take the following actions before the Executive Order is reinstated for that failed engine:

~~(i)~~
1. Remedy the nonconformity;

~~(ii)~~
2. Demonstrate that the engine conforms to its applicable FEL by retesting the engine in accordance with these regulations; and

~~(iii)~~
3. Submit a written report to the Executive Officer, after successful completion of testing on the failed engine, that contains a description of the remedy and test results for each engine in addition to other information that may be required by this part.

(H) Once an Executive Order for a failed engine family has been suspended pursuant to paragraphs (d)(5)(B), (C) or (D) of this section, the engine manufacturer must take the following actions before the Executive Officer will consider reinstating the Executive Order:

~~(i)~~

1. Submit a written report to the Executive Officer that identifies the reason for the noncompliance of the engines, describes the proposed remedy, including a description of any proposed quality control and/or quality assurance measures to be taken by the engine manufacturer to prevent future occurrences of the problem, and states the date on which the remedies will be implemented.

~~(ii)~~

2. Demonstrate that the engine family for which the Executive Order has been suspended does in fact comply with the regulations of paragraphs (b) or (c), as applicable, by testing as many engines as needed so that the Cumulative Sum statistic, as calculated in paragraph (c)(2)(A)~~(i)~~1., falls below the action limit, or the average emissions from the Quality-Audit testing as calculated in paragraph (b)(3)(A) remains below the FEL, as applicable. Such testing must comply with the provisions of paragraphs (b) or (c), as applicable. If the engine manufacturer elects to continue testing individual engines after suspension of an Executive Order, the Executive Order is reinstated for any engine actually determined to be in conformance with the emission standards through testing in accordance with the applicable test procedures, provided that the Executive Officer has not revoked the Executive Order pursuant to paragraph (d)(5)(F) of this section.

(I) Once the Executive Order has been revoked for an engine family, if the engine manufacturer wants to introduce into commerce a modified version of that family, the following actions must be taken before the Executive Officer may issue an Executive Order for that modified family:

~~(i)~~

1. If the Executive Officer determines that the proposed change(s) in engine design may have an effect on emission performance deterioration, the Executive Officer will notify the engine manufacturer, within five (5) working days after receipt of the report in paragraph (d)(5)(H)~~(i)~~1. of this section, whether subsequent testing under this section will be sufficient to evaluate the proposed change or changes or whether additional testing will be required; and

~~(ii)~~

2. After implementing the change or changes intended to remedy the nonconformity, the engine manufacturer

must demonstrate that the modified engine family does in fact conform with the regulations of paragraphs (b) or (c), as applicable, by testing as many engines as needed from the modified engine family so that the Cumulative Sum statistic, as calculated in paragraph (c)(2)(A)~~(i)~~1., falls below the action limit, or the average emissions from the Quality-Audit testing as calculated in paragraph (b)(3)(A) remains below the FEL, as applicable. When this requirement is met, the Executive Officer will reissue the Executive Order or issue a new Executive Order, as the case may be, to include that family. The revocation of engine family executive orders issued based on Cumulative Sum testing results remains in effect as long as the Cumulative Sum statistic remains above the action limit.

(J) At any time after the suspension of an Executive Order for a test engine under to paragraph (d)(5)(A)of this section, but not later than fifteen (15) days (or such longer period as may be allowed by the Executive Officer) after notification of the Executive Officer's decision to suspend or revoke an Executive Order in whole or in part pursuant to paragraphs (d)(5)(B), (C) or (F) of this section, an engine manufacturer may request a hearing pursuant to subchapter 1.25, Title 17, California Code of Regulations, as to whether the tests have been properly conducted or any sampling methods have been properly applied.

(K) Any suspension of an Executive Order under paragraph (d)(5)(D) of this section:

~~(i)~~
1. must be made only after the engine manufacturer concerned has been offered an opportunity for a hearing pursuant to subchapter 1.25, Title 17, California Code of Regulations, and;

~~(ii)~~
2. does not apply to engines no longer in the possession of the engine manufacturer.

* * * * *

(e) Selective Enforcement Auditing Regulations.

(1) Test Orders.

(A) A test order addressed to the engine manufacturer is required for any testing under paragraph (e).

(B) The test order is signed by the Executive Officer or his or her designee. The test order must be delivered in person by an ARB enforcement officer or ARB authorized representative to a company representative or sent by registered mail, return receipt requested, to the engine manufacturer's representative who signed the application for certification submitted by the engine manufacturer, pursuant to the requirements of the applicable portions of Title 13, California Code of Regulations, section 2447. Upon receipt of a test order, the engine manufacturer must comply with all of the provisions of this subsection and instructions in the test order.

(C) Information included in test order.

~~(i)~~
1. The test order will specify the engine family to be selected for testing, the engine manufacturer's engine assembly plant or associated storage facility or port facility (for imported engines) from which the engines must be selected, the time and location at which engines must be selected, and the procedure by which engines of the specified family must be selected. The test order may specify the configuration to be audited and/or the number of engines to be selected per day. Engine manufacturers are required to select a minimum of four engines per day unless an alternate selection procedure is approved pursuant to paragraph (e)(2)(A), or unless total production of the specified configuration is less than four engines per day. If total production of the specified configuration is less than four engines per day, the engine manufacturer selects the actual number of engines produced per day.

~~(ii)~~
2. The test order may include alternate families to be selected for testing at the Executive Officer's discretion in the event that engines of the specified family are not available for testing because those engines are not being manufactured during the specified time or are not being stored at the specified assembly plant, associated storage facilities, or port of entry.

~~(iii)~~
3. If the specified family is not being manufactured at a rate of at least two (2) engines per day in the case of engine manufacturers specified in paragraph (e)(4)(G)(i) of this section, or one engine per day in the case of engine manufacturers specified in paragraph (e)(4)(G)(ii) of this section, over the expected duration of the audit, the Executive Officer or her or his designated representative may select engines of the alternate family for testing.

~~(iv)~~
4. In addition, the test order may include other directions or information essential to the administration of the required testing.

(D) An engine manufacturer may submit a list of engine families and the corresponding assembly plants, associated storage facilities, or (in the case of imported engines) port facilities from which the

engine manufacturer prefers to have engines selected for testing in response to a test order. In order that an engine manufacturer's preferred location be considered for inclusion in a test order for a particular engine family, the list must be submitted prior to issuance of the test order. Notwithstanding the fact that an engine manufacturer has submitted the list, the Executive Officer may order selection at other than a preferred location.

(E) Upon receipt of a test order, an engine manufacturer must proceed in accordance with the provisions of paragraph (e).

(2) Testing by the Executive Officer.

(A) The Executive Officer may require by test order under paragraph (e)(1) that engines of a specified family be selected in a manner consistent with the requirements of paragraph (e)(3) and submitted to the Executive Officer at the place designated for the purpose of conducting emission tests. These tests will be conducted in accordance with paragraph (e)(4) to determine whether engines manufactured by the engine manufacturer conform with the regulations with respect to which the certificate of conformity was issued.

(B) Designating official data.

~~(i)~~
1. Whenever the Executive Officer conducts a test on a test engine or the Executive Officer and engine manufacturer each conduct a test on the same test engine, the results of the Executive Officer's test are the official data for that engine.

~~(ii)~~
2. Whenever the engine manufacturer conducts all tests on a test engine, the engine manufacturer's test data are accepted as the official data, provided that if the Executive Officer makes a determination based on testing conducted under paragraph (e)(2)(A) of this section that there is a substantial lack of agreement between the engine manufacturer's test results and the Executive Officer's test results, no engine manufacturer's test data from the engine manufacturer's test facility will be accepted for purposes of this subsection.

(C) If testing conducted under paragraph (e)(1) is unacceptable under paragraph (B)~~(ii)~~2. of this subsection, the Executive Officer must:

~~(i)~~

1. Notify the engine manufacturer in writing of the Executive Officer's determination that the test facility is inappropriate for conducting the tests required by this subsection and the reasons therefore; and

~~(ii)~~

2. Reinstate any engine manufacturer's data upon a showing by the engine manufacturer that the data acquired under paragraph (e)(2) were erroneous and the engine manufacturer's data was correct.

(D) The engine manufacturer may request in writing that the Executive Officer reconsider the determination in paragraph (B)(ii) of this section based on data or information indicating that changes have been made to the test facility and these changes have resolved the reasons for disqualification.

(3) Sample selection.

(A) Engines comprising a test sample will be selected at the location and in the manner specified in the test order. If an engine manufacturer determines that the test engines cannot be selected in the manner specified in the test order, an alternative selection procedure may be employed, provided the engine manufacturer requests approval of the alternative procedure before starting test sample selection, and the Executive Officer approves the procedure.

(B) The engine manufacturer must produce and assemble the test engines of the family selected for testing using its normal production and assembly process for engines to be distributed into commerce. If, between the time the engine manufacturer is notified of a test order and the time the engine manufacturer finishes selecting test engines, the engine manufacturer implements any change(s) in its production or assembly processes, including quality control, which may reasonably be expected to affect the emissions of the engines selected, then the engine manufacturer must, during the audit, inform the Executive Officer of such changes. If the test engines are selected at a location where they do not have their operational and emission control systems installed, the test order will specify the manner and location for selection of components to complete assembly of the engines. The engine manufacturer must assemble these components onto the test engines using normal assembly and quality control procedures as documented by the engine manufacturer.

(C) No quality control, testing, or assembly procedures will be used on the test engine or any portion thereof, including parts and subassemblies, that have not been or will not be used during the production and assembly of all other engines of that family, unless the Executive Officer approves the modification in production or assembly procedures pursuant to paragraph (B) of this subsection.

(D) The test order may specify that an ARB enforcement officer(s) or authorized representative(s), rather than the engine manufacturer, select the test engines according to the method specified in the test order.

(E) The order in which test engines are selected determines the order in which test results are to be used in applying the sampling plan in accordance with paragraph (e)(5).

(F) The engine manufacturer must keep on hand all untested engines, if any, comprising the test sample until a pass or fail decision is reached in accordance with paragraph (e)(5)(E). The engine manufacturer may ship any tested engine which has not failed the requirements as set forth in paragraph (e)(5)(B). However, once the engine manufacturer ships any test engine, it may not conduct retests as provided in paragraph (e)(4)(I).

(4) Test procedures.

(A) ~~(i)~~ 1. For spark-ignition marine engines subject to the provisions of this subsection, the prescribed test procedures are the test procedures as specified in Part IV of the Test Procedures.

~~(ii)~~ 2. The Executive Officer may, on the basis of a written application by an engine manufacturer, prescribe test procedures other than those specified in paragraph ~~(i)~~1. for any spark-ignition marine engine he or she determines is not susceptible to satisfactory testing using the procedures specified in paragraph ~~(i)~~1.

(B) ~~(i)~~ 1. The engine manufacturer may not adjust, repair, prepare, or modify the engines selected for testing and may not perform any emission tests on engines selected for testing pursuant to the test order unless this adjustment, repair, preparation, modification, and/or tests are documented in the engine manufacturer's engine assembly and inspection procedures and are actually performed or unless these adjustments and/ or tests are required or

permitted under this subsection or are approved in advance by the Executive Officer

~~(ii)~~ 1. The Executive Officer may adjust or cause to be adjusted any engine parameter that the Executive Officer determines subject to adjustment for certification and Selective Enforcement Audit testing in accordance with Part I, section 18 of the Test Procedures, to any setting within the physically adjustable range of that parameter, as determined by the Executive Officer in accordance with section 18, prior to the performance of any tests. However, if the idle speed parameter is one which the Executive Officer has determined to be subject to adjustment, the Executive Officer may not adjust it to any setting that causes a lower engine idle speed than would have been possible within the physically adjustable range of the idle speed parameter if the engine manufacturer had accumulated 12 hours of service on the engine under paragraph (C) of this section, all other parameters being identically adjusted for the purpose of the comparison. The engine manufacturer may be requested to supply information needed to establish an alternate minimum idle speed. The Executive Officer, in making or specifying these adjustments, may consider the effect of the deviation from the engine manufacturer's recommended setting on emission performance characteristics as well as the likelihood that similar settings will occur on in-use engines. In determining likelihood, the Executive Officer may consider factors such as, but not limited to, the effect of the adjustment on engine performance characteristics and information from similar in-use engines.

(C) Service Accumulation. Before performing exhaust emission testing on a selective enforcement audit test engine, the engine manufacturer may accumulate on each engine a number of hours of service equal to the greater of 12 hours or the number of hours the engine manufacturer accumulated during certification on the emission data engine corresponding to the family specified in the test order.

~~(i)~~
1. Service accumulation must be performed in a manner using good engineering judgment to obtain emission results representative of normal production engines. This service accumulation must be consistent with

the new engine break-in instructions contained in the applicable owner's manual.

~~(ii)~~
2. The engine manufacturer must accumulate service at a minimum rate of 6 hours per engine during each 24-hour period, unless otherwise approved by the Executive Officer.

a. The first 24-hour period for service begins as soon as authorized checks, inspections, and preparations are completed on each engine.

b. The minimum service accumulation rate does not apply on weekends or holidays.

c. If the engine manufacturer's service or target is less than the minimum rate specified (6 hours per day), then the minimum daily accumulation rate is equal to the engine manufacturer's service target.

~~(iii)~~
3. Service accumulation must be completed on a sufficient number of test engines during consecutive 24-hour periods to assure that the number of engines tested per day fulfills the requirements of paragraphs (G)~~(i)~~1. and (G)~~(ii)~~2. below.

(D) The engine manufacturer may not perform any maintenance on test engines after selection for testing, nor may the Executive Officer allow deletion of any engine from the test sequence, unless requested by the engine manufacturer and approved by the Executive Officer before any engine maintenance or deletion.

(E) The engine manufacturer must expeditiously ship test engines from the point of selection to the test facility. If the test facility is not located at or in close proximity to the point of selection, the engine manufacturer must assure that test engines arrive at the test facility within 24 hours of selection. The Executive Officer may approve more time for shipment based upon a request by the engine manufacturer accompanied by a satisfactory justification.

(F) If an engine cannot complete the service accumulation or an emission test because of a malfunction, the engine manufacturer may request that the Executive Officer authorize either the repair of that engine or its deletion from the test sequence.

(G) Whenever an engine manufacturer conducts testing pursuant to a test order issued under this subsection, the engine manufacturer must notify the Executive Officer within one working day of receipt of the test order as to which test facility will be used to comply with the test order. If no test cells are available at a desired facility, the engine manufacturer must provide alternate testing capability satisfactory to the Executive Officer.

~~(i)~~
1. An engine manufacturer with projected spark-ignition marine engine sales for the California market for the applicable year of 20 or greater must complete emission testing at a minimum rate of two (2) engines per 24-hour period, including each voided test.

~~(ii)~~
2. An engine manufacturer with projected spark-ignition marine engine sales for the California market for the applicable year of less than 20 must complete emission testing at a minimum rate of one engine per 24-hour period, including each voided test.

~~(iii)~~
3. The Executive Officer may approve a lower daily rate of emission testing based upon a request by an engine manufacturer accompanied by a satisfactory justification.

(H) The engine manufacturer must perform test engine selection, shipping, preparation, service accumulation, and testing in such a manner as to assure that the audit is performed in an expeditious manner.

(I) Retesting.

~~(i)~~
1. The engine manufacturer may retest any engines tested during a Selective Enforcement Audit once a fail decision for the audit has been reached in accordance with paragraph (e)(5)(E).

~~(ii)~~
2. The Executive Officer may approve retesting at other times based upon a request by the engine manufacturer accompanied by a satisfactory justification.

~~(iii)~~

3. The engine manufacturer may retest each engine a total of three times. The engine manufacturer must test each engine or vehicle the same number of times. The engine manufacturer may accumulate additional service before conducting a retest, subject to the provisions of paragraph (C) of this paragraph (4).

(J) An engine manufacturer must test engines with the test procedure specified in Part IV of the Test Procedures to demonstrate compliance with the exhaust emission standard (or applicable FEL) for $HC+NO_x$. If alternate procedures were used in certification pursuant to Part 1, section 20(c) of the Test Procedures, then those alternate procedures must be used.

(5) Compliance with acceptable quality level and passing and failing criteria for selective enforcement audits.

(A) The prescribed acceptable quality level is 40 percent.

(B) A failed engine is one whose final test results for $HC+NO_x$ pursuant to paragraph (b)(3)(D) or (c)(2)~~(iv)~~4., as applicable, exceed the applicable family emission level or whose test results for a regulated pollutant exceed the emission standards.

* * * * *

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2448. ~~Sunset Review of the California Regulations for 2001 and Later Model Year Spark-Ignition Marine Engines.~~ [Reserved.]

~~Within five years from the effective date of adoption or date of implementation, whichever comes later, the Air Resources Board, in consultation with the Secretary for Environmental Protection, shall review the provisions of this Article to determine whether they should be retained, revised or repealed.~~

~~Note: Authority cited: Sections 39600, 39601, 43013 and 43018, Health and Safety Code.~~
~~Reference: Sections 39600 and 39601, Health and Safety Code.~~

~~(Operative 01-07-2000)~~

ATTACHMENT B

CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES
FOR 2001 MODEL YEAR AND LATER
SPARK-IGNITION MARINE ENGINES

State of California
AIR RESOURCES BOARD

CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR 2001 MODEL YEAR AND LATER SPARK-IGNITION MARINE ENGINES

Adopted: October 21, 1999
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CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES
FOR 2001 MODEL YEAR AND LATER SPARK-IGNITION MARINE ENGINES

Part I. Emission Regulations for 2001 and Later New Spark-Ignition Marine Engines, General Provisions.

1. General Applicability.

(a) (1) This rule applies to model year 2001 and later spark-ignition (SI) marine engines, unless otherwise indicated.

(2) Every new spark-ignition marine engine that is manufactured for sale, sold, or offered for sale in California, or that is introduced, and delivered or imported into California for introduction into commerce, and which is subject to any of the standards prescribed in this article must be covered by an Executive Order, issued pursuant to this article.

(3) Spark-ignition inboard and sterndrive marine engines produced by the engine manufacturer to be used solely for competition are exempt from the requirements of this document, provided that the marine watercraft in which the engine is installed is designed, built, and used solely for competition. Marine watercraft used for amateur or occasional competition do not meet the competition exemption criteria.

(b) Each part of this article is severable, and in the event that any part of this chapter is held to be invalid, the remainder of this article remains in full force and effect.

(c) (1) For purposes of this article, military tactical vehicles or equipment means vehicles or equipment owned by the U.S. Department of Defense and/or the U.S. military services and used in combat, combat support, combat service support, tactical or relief operations, or training for such operations.

(2) This article shall not apply to engines used in off-road military tactical vehicles or equipment which have been exempted from regulations under the federal national security exemption, 40 CFR, subpart J, section 90.908, which is incorporated by reference herein. It shall also not apply to those vehicles and equipment covered by the definition of military tactical vehicle that are commercially available and for which a federal certificate of conformity has been issued under 40 CFR Part 91, subpart B, which is incorporated by reference herein.

(3) On January 1, 1997, the U.S. Department of Defense shall submit to the ARB a list of all vehicles and equipment that are exempted under the above provisions and which are located in the State of California. If any additional vehicle and equipment types are added to the list during any calendar year after January 1,

1997, the U.S. Department of Defense shall update the list and submit it to the ARB by January 1 of the following year.

2. Definitions.

The definitions in section 2441, Chapter 9, Title 13 of the California Code of Regulations apply with the following additions:

"Engine Family" is a subclass of a basic engine based on similar emission characteristics. The engine family is the grouping of engines that is used for the purposes of certification, and is determined in accordance with section 17.

"Engine-Displacement-System Combination" or "Engine Family Displacement Emission Control System Combination" is a subclass of an engine family based on engine displacement and specific emission control system components, and is used for purposes of test engine selection.

"Engine Model" or "Engine Code" is a subclass of an engine-displacement system combination on the basis of the engine calibration (e.g., carburetor jet size, valve timing, etc.), and other parameters that may be designated by the Executive Officer.

"Gross Power" means the power measured at the engine crankshaft (or equivalent) and produced by an engine that is equipped with only the accessories that are necessary for engine operation.

"Hang-up" means the situation whereby hydrocarbon molecules are absorbed, condensed, or otherwise removed from the sample flow prior to the instrument detector; and any subsequent desorption of the molecules into the sample flow when such molecules are assumed to be absent.

"Incomplete Engine Assembly" is a basic engine assembly that does not include all of the components necessary for designation as a complete engine assembly, and is marketed in order to be a part of, and assembled into, a new unit of equipment.

"Oxides of Nitrogen" means the sum of the nitric oxide and nitrogen dioxide contained in a gas sample as if the nitric oxide were in the form of nitrogen dioxide.

"Rated Power" means the maximum brake power output (in kilowatts) of an engine as specified by an engine manufacturer.

"Rated Speed" means the engine speed (revolutions per minute [rpm]) at which the manufacturer specifies the maximum rated power of an engine.

"Rebuild" or "Rebuilding" refers to a major overhaul in which you replace the engine's pistons or power assemblies or make other changes that significantly increase the service life of the engine. It also includes replacing or rebuilding an engine's

turbocharger or aftercooler or the engine's systems for fuel metering or electronic control so that it significantly increases the service life of the engine. For these provisions, rebuilding may or may not involve removing the engine from the equipment. Rebuilding does not normally include scheduled emission-related maintenance that the standard-setting part allows during the useful life period (such as replacing fuel injectors) or unscheduled maintenance that occurs commonly within the useful life period. For example, replacing a water pump is not rebuilding an engine.

"Span gas" means a gas of known concentration that is used routinely to set the output level of any analyzer.

"Special Tool" means a tool or fixture specified by an engine manufacturer that is intended to perform only a specific function with respect to an engine; and the effective usage of the tool or fixture requires special expertise.

3. Abbreviations.

ARB	—	California Air Resources Board
AECD	—	Auxiliary emission control device
ASME	—	American Society of Mechanical Engineers
ASTM	—	American Society for Testing and Materials
C	—	Carbon
C	—	Celsius
C_3H_8	—	Propane
cc	—	Cubic centimeter(s)
cfm	—	Cubic feet per minute
cfh	—	Cubic feet per hour
CLD	—	chemiluminescent detector
cm	—	Centimeter(s)
CO	—	Carbon monoxide
CO_2	—	Carbon Dioxide
conc	—	Concentration

cu.	—	Cubic
CVS	—	Constant Volume Sample
EGR	—	Exhaust gas recirculation
EP	—	End point
F	—	Fahrenheit
FEL	—	Family Emission Limit
g	—	Gram(s)
g/kW-hr	—	gram(s) per kilowatt hour
h	—	hour
HC	—	Hydrocarbon(s.)
HCLD	—	heated chemiluminescent detector
HFID	—	heated flame ionization detector
Hg	—	Mercury
hp	—	Horsepower
HSC	—	Health and Safety Code
H_2O	—	Water
in.	—	Inch(es)
K	—	Kelvin
kg	—	Kilogram(s)
km	—	Kilometer(s)
kPa	—	Kilopascals
kW	—	kilowatt
lb	—	Pound(s)

m	—	meter(s)
mph	—	Miles per hour
mm	—	Millimeter(s)
N	—	Newton
N_2	—	Nitrogen
NDIR	—	non-dispersive infrared analyzer
NGPA	—	Natural Gas Processors Association
NIST	—	National Institute of Standards and Testing
NO	—	Nitric Oxide
NO_2	—	Nitrogen Oxide
NO_x	—	Oxides of nitrogen
No.	—	Number
O_2	—	Oxygen
OB	—	Outboard engine(s)
Pa	—	Pascals
pb	—	Lead
PMD	—	Paramagnetic detector
ppm	—	Parts per million by volume
psi	—	Pounds per square inch
psig	—	Pounds per square inch gauge
PWC	—	Personal watercraft
R	—	Rankine
rpm	—	Revolutions per minute

SI	—	Spark-ignition
U.S.C.	—	United States Code
VOC	—	Volatile organic compounds
wt	—	Weight
ZROD	—	Zirconium dioxide sensor
°	—	Degree(s)
%	—	Percent

4. Measurement System.

These provisions utilize the International System of Units.

5. General Standards; Increase in Emissions; Unsafe Conditions.

(a) Any emission control system installed on or incorporated in a new spark-ignition marine engine to enable such an engine to conform to standards imposed by these provisions:

(1) Must not in its operation or function cause the emission into the ambient air of any noxious or toxic substances that would not be emitted in the operation of such engine without such emission control system, except as specifically permitted by regulation; and,

(2) Must not in its operation, function, malfunction result in any unsafe condition endangering the equipment, its user(s), or persons or property in close proximity to the equipment.

(b) Every manufacturer of new spark-ignition marine engines subject to any of the standards imposed by these provisions must test, or cause to be tested, engines in accordance with good engineering practice to ascertain that such test engines will meet the requirements of this section for the useful life of the engine.

6. Defeat Devices, Prohibition.

(a) No spark-ignition marine engine may be equipped with a defeat device.

(b) Defeat device means any element of design that:

(1) Senses temperature, engine RPM, manifold vacuum, or any other parameter for the purpose of activating, modulating, delaying or deactivating the operation of any part of the emission control system; and,

(2) Reduces the effectiveness of the emission control system under conditions that may reasonably be expected to be encountered in normal equipment operation and use, unless:

~~(i)~~(A) Such conditions are substantially included in the test procedure; or,

~~(ii)~~(B) The need for the device is justified in terms of protecting the spark-ignition marine engine against damage or accident; or,

~~(iii)~~(C) The device does not go beyond the requirements of engine starting or warm-up.

~~7. [Reserved].~~

7. **Practices for Rebuilding Engines.**

(a) These requirements apply to anyone rebuilding an engine subject to this part, but the recordkeeping requirements in paragraphs (h) and (i) of this section apply only to businesses. For maintenance or service that is not rebuilding, including any maintenance related to evaporative emission controls, changes may not be made that might increase emissions of any pollutant, but recordkeeping is not required.

(b) Anyone rebuilding an engine or engine system must have a reasonable technical basis for knowing that the rebuilt engine's emission control system performs as well as, or better than, it performs in its certified configuration. The model year of the resulting engine configuration must be identified. A reasonable technical basis is met under two main conditions:

(1) Install parts—new, used, or rebuilt—so a person familiar with engine design and function would reasonably believe that the engine with those parts will control emissions of all pollutants at least to the same degree as with the original parts. For example, it would be reasonable to believe that parts performing the same function as the original parts (and to the same degree) would control emissions to the same degree as the original parts.

(2) Adjust parameters or change design elements only according to the original engine manufacturer's instructions. To differ from these instructions requires verifiable data or some other technical basis to show that an increase in in-use emissions would not result.

(c) If the rebuilt engine remains installed or is reinstalled in the same piece of equipment, it must be rebuilt to the original configuration or another certified configuration of the same or later model year.

(d) If the rebuilt engine replaces another certified engine in a piece of equipment, it must be rebuilt to a certified configuration of the same model year as, or a later model year than, the engine being replaced.

(e) Emission-related codes or signals from onboard monitoring systems must not be erased or reset without diagnosing and responding appropriately to any diagnostic codes. This requirement applies regardless of the manufacturer's reason for installing the monitoring system and regardless of its form or interface. Upon returning the rebuilt engine into service, clear any codes from the diagnostic systems. Do not disable a diagnostic signal without addressing its cause.

(f) When rebuilding an engine, check, clean, adjust, repair, or replace as needed all emission-related components (listed in § 2445.1., title 13, CCR) according to the original manufacturer's recommended practice. In particular, replace oxygen sensors, replace the catalyst if there is evidence of malfunction, clean gaseous fuel-system components, and replace fuel injectors (if applicable), unless there exists a reasonable technical basis for believing that any of these components do not need replacement.

(g) When installing an engine that was rebuilt by another source, the installer must check all emission-related components listed in § 2445.1., title 13, CCR, as needed, according to the original manufacturer's recommended practice.

(h) Businesses must keep at least the following records:

(1) Identify the hours of operation (or mileage, as appropriate) at time of rebuild.

(2) Identify the work done on the engine or any emission-related control components, including a listing of parts and components used.

(3) Describe any engine parameter adjustments.

(4) Identify any emission-related codes or signals responded to and reset.

(i) Records must be available or made available upon request. Records must be kept for at least two years after rebuilding an engine. Records may be kept in any format that is readily reviewable.

(1) Keeping information that is not reasonably available through normal business practices is not expected..

(2) Keeping records of what other companies do is not necessary.

(3) Keeping records based on families rather than individual engines is allowable.

8. Replacement Engines.

~~No new spark-ignition marine engines may be produced for sale to replace spark-ignition marine engines in pre-2001 model year equipment after the 2004 model year, unless those engines comply with the 2001 model year emission standards.~~

A new spark-ignition marine engine produced solely to replace an engine originally manufactured in accordance with the requirements of § 2422 shall be identical in specifications to the most stringent certified emissions configuration currently available that can be installed in a vessel or personal watercraft without unreasonable modifications, as determined by the Executive Officer. A new replacement engine with emissions performance less than maximum stringency shall be allowed only if all engines of greater stringency are incompatible with the vessel or personal watercraft and so long as the emissions performance of the new replacement engine is at least as stringent as that of the engine being replaced. New replacement engines that do not comply with current year emission requirements must be labeled as follows:

"SALE OR INSTALLATION OF THIS ENGINE FOR ANY PURPOSE OTHER THAN TO REPLACE AN ENGINE OF SIMILAR OR LESS STRINGENT EMISSIONS PERFORMANCE IS A VIOLATION OF CALIFORNIA LAW SUBJECT TO CIVIL PENALTY."

9. Exhaust Emission Standards for 2001 and Later Spark-Ignition Marine Engines

(a) Model year 2001 and later model year spark-ignition personal watercraft and outboard marine engines:

(1) Exhaust emissions from new spark-ignition marine engines manufactured for sale, sold, or offered for sale in California, or that are introduced, delivered or imported into California for introduction into commerce, must not exceed the following standards:

Table 1.1
Corporate Average Emission Standards by Implementation Date
$HC+NO_x$ (g/kW-hr)

Model Year	Max. Family Emission Limit (FEL)	$P_{tx} < 4.3$ kW[1]	$P_{tx} \geq 4.3$ kW[1]
2001-2003	Not Applicable	81.00	$(0.25 \times (151+557/P_{tx}^{0.9})) + 6.0$
2004-2007	80	64.80	$(0.20 \times (151+557/P_{tx}^{0.9})) + 4.8$
2008 and Later[2]	44	30.00	$(0.09 \times (151+557/P_{tx}^{0.9})) + 2.1$

1. For 2010 and subsequent model years, an engine or engine family's power category is based on maximum engine power; otherwise maximum rated power may be used.
2. For 2010 and subsequent model years, standards are measured in total hydrocarbons plus oxides of nitrogen.

Table 1.2
Carbon Monoxide Exhaust Emission Standards

ENGINE CATEGORY	MODEL YEAR	POWER CATEGORY[1] *[kilowatts]*	CO STANDARD *[grams per kilowatt-hour]*
OB/PWC[2]	2009 and later	kW ≤ 40	500 - 5 x P[3]
		kW > 40	300.0[3]

1. For 2010 and subsequent model years, an engine or engine family's power category is based on maximum engine power; otherwise maximum rated power may be used.
2. Abbreviation for "Outboard and Personal Water Craft" engines
3. P is defined as maximum rated power or maximum engine power (see footnote 1) in kilowatts (kW)

where:

> P_{tx} is the average power in kilowatts (kW) (sales-weighted) of the total number of spark-ignition marine engines produced for sale in California in model year x. Engine power must be calculated using the Society of Automotive Engineers (SAE) standard J1228, November 1991, incorporated herein by reference. Engine manufacturers must not determine P_{tx} by combining the power outputs of personal watercraft engines.

(2) An engine manufacturer may comply with the standards directly on an individual engine family basis. Consequently in Table 1.1, FELs are not applicable for any model year and P_{tx} means the average power in kW

(sales-weighted) of the subject engine family produced for sale in California in model year x.

Compliance with the HC+NOx standards on a corporate average basis is determined as follows:

$$\frac{\sum_{j=1}^{n}(PROD_{jx})(FEL_{jx})(P_{jx})}{\sum_{j=1}^{n}(PROD_{jx})(P_{jx})} = STD_{ca}$$

where:

n	=	total number of engine families (by category)
$PROD_{jx}$	=	number of units each engine family j produced for sale in California in model year x.
FEL_{jx}	=	the Family Emission Limit (FEL) for engine family j in model year x, which must be determined by the engine manufacturer subject to the following conditions: (1) no individual engine family FEL shall exceed the maximum allowed value as specified in Table 1; (2) no engine family designation or FEL shall be amended in a model year unless the engine family is recertified; and (3) prior to sale or offering for sale in California, each engine family must be certified in accordance with the test procedures referenced in section 2447 and must meet the engine manufacturer's FEL as a condition of the Executive Order. Before certification, the engine manufacturer must also submit estimated production volumes for each engine family to be offered for sale in California.
P_{jx}	=	the average power in kW (sales-weighted) of engine family j produced for sale in California in model year x. Engine power must be calculated using SAE standard J1228, November 1991, incorporated herein by reference.
STD_{ca}	=	an engine manufacturer's calculated corporate average $HC+NO_x$ exhaust emissions from those California spark-ignition marine engines subject to the California corporate average $HC+NO_x$ exhaust emission standard determined from Table 1.1, as

established by an Executive Order certifying the California production for the model year. This Executive Order must be obtained prior to the issuance of certification Executive Orders for individual engine families for the model year.

(A) For purposes of compliance under this paragraph, engine manufacturers must not corporate average outboard engine families in combination with personal watercraft engine families.

(B) During engine manufacturer's production year, for each engine family, the manufacturer shall provide to the Executive Officer within 45 days after the last day in each calendar quarter: The total number of spark-ignition marine engines produced for sale in California and their applicable FEL.
(C)The Executive Order certifying the California production for a model year must be obtained prior to the issuance of certification Executive Orders for individual engine families for the model year.

(D)The engine manufacturer's average pollutant exhaust emissions must meet the corporate average standard at the end of the manufacturer's production for the model year. No later than 90 days after the end of the model year, the manufacturer must calculate a corrected corporate average using actual rather than projected sales.

(E) Production and sale of spark-ignition marine engines which result in non-compliance with the California standard for the model year shall cause an engine manufacturer to be subject to civil penalties, per engine, pursuant to section 43017 of the Health and Safety Code, and subject to all other remedies available under Part 5, Division 26 of the Health and Safety Code. All excess emissions resulting from non-compliance with the California standard must be made up in the following model year.

(F) For each model the engine manufacturer shall submit California sales data.

(b) Model year 2003 and later model year spark-ignition inboard and sterndrive marine engines:

(1) Exhaust emissions from all new model year 2003 and later spark-ignition ~~inboard and sterndrive~~ sterndrive/inboard marine engines must not exceed the ~~exhaust~~ emission standards listed in Tables 2.1(a) and /or 2.1(b) for the designated emission durability test period.

(A) Prior to Model Year 2007 certification, each engine manufacturer must select either Option 1 (OPT 1) or Option 2 (OPT 2) for its entire production of standard performance engines for the 2007 and 2008 model years.

Table 2.1(a)
Standard Performance ~~Inboard/~~Sterndrive/Inboard Marine Engine Standards

MODEL YEAR	~~RATED~~ POWER CATEGORY[1] [kilowatts]	COMPLIANCE OPTION[12]	DURABILITY [hours / years]	EXHAUST STANDARDS ~~NMHC[23]~~+NOx [grams per kilowatt-hour]	TYPE[34]	CO [grams per kilowatt-hour]	SUPPLEMENTAL MEASURE[45]
2003 - 2006	kW ≤ 373	N/A	N/A	16.0	AVE[6]	N/A	None
2007	kW ≤ 373	OPT 1	N/A	16.0 (55%)	AVE[6]		None
			480 / 10	5.0 (45%)	FIXED		
		OPT 2	N/A	14.0	FIXED		Low-Permeation Fuel Line Hoses
2008	kW ≤ 373	OPT 1	N/A	16.0 (25%)	AVE[6]		None
			480 / 10	5.0 (75%)	FIXED		
		OPT 2	480 / 10	5.0	FIXED		Low-Permeation Fuel Line Hoses
2009 and later	kW ≤ 373	N/A	480 / 10	5.0[6,7,8]	FIXED	75.0[7,9]	Carryover[710]
	~~373 < kW ≤ 485~~		~~150[5] / 3~~	~~5.0[6]~~	~~AVE~~		
	~~kW > 485~~		~~50[5] / 1~~	~~5.0[6]~~	~~AVE~~		

Notes:
1. For 2010 and subsequent model years, an engine or engine family's power category is based on maximum engine power; otherwise maximum rated power may be used
~~4~~2. Once a manufacturer has chosen an option, that option must continue to be used exclusively across product lines
~~2~~3. ~~The non-methane component of hydrocarbon~~For 2010 and subsequent model years, standards are measured in total hydrocarbons plus oxides of nitrogen; however, the non-methane component of hydrocarbon may be substituted in prior years
~~3~~4. Corporate averaging (AVE) may be used to demonstrate compliance with the exhaust emission standard, except where a FIXED standard is required
~~4~~5. Supplemental measures may be different than shown, but must provide equal and verifiable emission reductions to those indicated
~~5. For the purpose of durability testing, engine components that have been approved with an hourly warranty period shorter than the full hourly durability period per § 2445.1 (c)(3)(C)1. may be replaced at the specified warranty interval~~
The corporate average calculation may be met with or without power weighting for these years
~~All engines ≤ 373 kW must meet a 5.0 g/kW-hr NMHC+NOx capping standard. For engines > 373 kW, the standard may be met by sales averaging with engines equal to or less than 373 kWA single engine family certified under the discontinuation allowance in § 2442(g)(2) may continue to meet current certification levels for HC+NOx and no more than 150 g/kW-hr for CO over the engine's useful life provided that the manufacturer certifying such an engine family also certifies one or more engine families to family emissions limits sufficiently low to enable compliance on a corporate average basis~~
8. Large volume dual category manufacturers are required to certify one or more engine families to a family emissions limit lower than the HC+NOx standard when complying with high performance engines on a corporate average basis
9. Standard performance engines ≥ 6.0 liter displacement may alternatively meet a 25 g/kW-hr standard for Modes 2-5 of the ISO 8178-4 E4 marine test cycle
~~7~~10. The same or better supplemental emission control hardware used to ~~meet the standard~~ comply in 2007 must be used every model year thereafter and all fuel hoses (i.e., not just the fuel line hose) must be low-permeation hoses

(B) At the time of, or prior to, Model Year 2009 certification, each Large Volume Dual Category Manufacturer must declare whether it will comply with the high performance exhaust standard of 5.0 g/kW-hr HC+NOx through averaging or whether it will comply with the less stringent small volume high performance HC+NOx exhaust standard through the incorporation of enhanced evaporative control systems on vessels using standard performance engines for 2009 and subsequent model year engine production.

Table 2.1(b)
High Performance Sterndrive/Inboard Marine Engine Standards

MODEL YEAR	POWER[a] CATEGORY *[kilowatts]*	HC[b]+NOx STANDARD *[grams per kilowatt-hour]*		CO STANDARD *[grams per kilowatt-hour]*
		Small Volume or Large Volume Single Category Manufacturer	Large Volume Dual Category Manufacturer	
2009 - 2010	373 < kW ≤ 485	16.0[c]	5.0[d]	350.0[c]
	kW > 485	25.0[c]		
2011 and later	373 < kW ≤ 485	16.0[c]	5.0[d]	350.0[c]
	kW > 485	22.0[c]		

a For 2010 and subsequent model years, an engine or engine family's power category is based on maximum engine power; otherwise maximum rated power may be used

b For 2010 and subsequent model years, standards are measured in total hydrocarbons plus oxides of nitrogen; however, the non-methane component of hydrocarbon may be substituted in prior years

c These standards are fixed except that engine families certified under the discontinuation allowance in § 2442(g)(2) may continue to meet current certification levels for HC+NOx over the engine's useful life provided that the manufacturer certifying such an engine family also certifies one or more engine families to family emissions limits sufficiently low to enable compliance on a corporate average basis

d This standard may be met on a corporate average basis between high performance engines and/or between standard performance and high performance engines. Alternately, large volume dual category manufacturers may comply with the exhaust standards for small volume manufacturers provided a sufficient number of vessels with the manufacturer's standard performance engines are equipped with enhanced evaporative control systems as noted in § 2442(b)(5). Manufacturers must declare their intent to use this alternative prior to certifying engines for the 2009 model year and must continue to certify future model year engines using this alternative exclusively across product lines

~~(A)~~(C) No crankcase emissions shall be discharged into the ambient atmosphere from 2003 and later spark-ignition sterndrive/inboard ~~and sterndrive~~ marine engines.

~~(B)~~(D) Production and sale of spark-ignition marine engines that result in noncompliance with the California standard for the model year shall cause an engine manufacturer to be subject to: revocation or suspension of Executive Orders for the applicable engine families; enjoinment from any further sales, or distribution, of such noncompliant engine families, in the State of California pursuant to section 43017 of the Health and Safety Code; and all other remedies available under Part 5, Division 26 of the Health and Safety Code. Before seeking remedial action against the engine manufacturer, the Executive Officer will consider any information provided by the equipment manufacturer.

~~(C)~~(E) For each engine family, the engine manufacturer shall submit the total number of engines produced for sale in California, or the total number of engines produced for sale nationally, ninety (90) days after the end of the model year.

(2) Evaporative Requirements for All High Performance Engine Manufacturers and Boat Manufacturers:

(A) For 2009 and subsequent model year engines, each engine manufacturer must provide written instructions, as part of the installation materials provided to boat manufacturers, to use enhanced evaporative control systems on any boat that is manufactured for sale, sold, or offered for sale in California, or that is introduced, delivered or imported into California for introduction into commerce. The engine manufacturer shall also provide evidence that the supplier(s) of the enhanced evaporative control system has designed the system components to meet or exceed the diurnal and permeation design specifications listed in Table 2.2 throughout the useful life of the engine.

Table 2.2 Sterndrive/Inboard Marine Evaporative Design Specifications

	PERMEATION STANDARDS[1] *[grams per square meter per day]*	DIURNAL STANDARD[2] *[grams per gallon per day]*	TEST TEMPERATURES *[degrees Celsius]*
Fuel Hoses	15.0	—	23 ± 2
Fuel Tank	1.5	—	28 ± 2
Trailerable Boat	—	0.40	25.6 – 32.2
Nontrailerable Boat	—	0.16	27.6 – 30.2

1. Fuel hoses and tank permeation testing requires fuel with 10% ethanol content.
2. Diurnal testing requires fuel with 9 pounds per square inch (psi) Reid Vapor Pressure volatility and a 24-hour fuel temperature cycle.

(B) For 2009 and subsequent model year engines, each boat manufacturer must install an enhanced evaporative control system on every boat that is manufactured for sale, sold, or offered for sale in California that uses a high performance engine.

(3)~~(2)~~ Compliance with the standards on a corporate averaging basis is calculated as follows:

$$\frac{\sum_{j=1}^{n}(PROD_{jx})(EL_{jx})}{\sum_{j=1}^{n}(PROD_{jx})} = \text{Corporate Average}$$

$$\frac{\sum_{j=1}^{n}(PROD_{jx})(EL_{jx})(P_{jx})}{\sum_{j=1}^{n}(PROD_{jx})(P_{jx})} = \text{Corporate Average}$$

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where:

n = Total number of engine families available for averaging.

$PROD_{jx}$ = Number of engines in engine family j produced for sale in California in model year x.

EL_{jx} = The measured ~~NM~~HC+NO_x emission levels for engine family j in model year x~~; or for engines > 485 kW, the manufacturer may choose to use 30 g/kW-hr as per paragraph (F) below~~.

P_{jx} = The average power in kW (sales-weighted) of engine family j produced for sale in California in model year x. Engine power must be calculated using SAE standard J1228, November 1991, incorporated herein by reference.

(A) During the engine manufacturer's production year, for each engine family, the engine manufacturer shall provide the Executive Officer within 45 days after the last day in each calendar quarter the total number of spark-ignition marine engines produced for sale in California and their applicable EL(s).

(B) The Executive Order certifying the California production for a model year must be obtained prior to the issuance of certification Executive Orders for individual engine families for the model year.

(C) The engine manufacturer's average ~~NM~~HC+NO_x exhaust emissions must meet the corporate average standard at the end of the engine manufacturer's production for the model year. At the end of the model year, the manufacturer must calculate a corrected corporate average using sales or eligible sales rather than projected sales.

(D) Production and sale of spark-ignition marine engines that result in noncompliance with the California standard for the model year shall cause an engine manufacturer to be subject to: revocation or suspension of Executive Orders for the applicable engine families; enjoinment from any further sales, or distribution, of such noncompliant engine families, in the State of California pursuant to section 43017 of the Health and Safety Code; and all other remedies

available under Part 5, Division 26 of the Health and Safety Code. Before seeking remedial action against the engine manufacturer, the Executive Officer will consider any information provided by the engine manufacturer.

(E) For each engine family, the engine manufacturer shall submit California sales data within one hundred eighty (180) days after the end of the model year.

~~(F) Engines exceeding 485 kilowatts maximum rated power: In lieu of exhaust emission testing, manufacturers may certify using a default exhaust emissions level of 30.0 grams per kilowatt-hour of NMHC+NO_x in their corporate averaging calculation.~~

~~(3)~~ (4) Alternate Requirements for Standard Performance Manufacturers:

(A) Requirements of engine manufacturers and boat manufacturers under Option 2 and using Low Permeation Fuel Line Hose:

~~(A)~~1. Each engine manufacturer that chooses Option 2 must provide written instructions, as part of the installation materials provided to purchasers of the engine, to use Low Permeation Fuel Line Hose for the primary fuel line connecting the fuel tank to the engine of any boat that is manufactured for sale, sold, or offered for sale in California, or that is introduced, delivered or imported into California for introduction into commerce.

~~(B)~~2. Each boat manufacturer must install Low Permeation Fuel Line Hose for the primary fuel line connecting the fuel tank to the engine of any boat that is manufactured for sale, sold, or offered for sale in California that uses an engine from a manufacturer that chooses Option 2.

~~(4)~~(B) Supplemental Measures. Prior to Model Year 2007 certification, manufacturers choosing Option 2 may request Executive Officer approval of a supplemental measure as an alternative to meeting the requirements of paragraph (b)(3). In determining whether to approve a request, the Executive Officer will consider the following:

~~(A)~~1. Whether the proposed supplemental measure would achieve reductions in ~~NM~~HC+NO_x equivalent to using Low Permeation Fuel Line Hoses,

~~(B)~~2. The engine manufacturer's measures to ensure successful implementation of the proposed supplemental measure,

~~(C)~~3. The durability of the proposed supplemental measure, and

~~(D)~~4. Any additional information the Executive Officer deems relevant.

(5) Alternate Requirements for Large Volume Dual Category Manufacturers.

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In lieu of complying with the 5.0 g/kW-hr HC+NOx exhaust standard in Table 2.1(b) for high performance engines, large volume dual category engine manufacturers may certify high performance engines to the same HC+NOx exhaust standards as required for small volume manufacturers in Table 2.1(b) provided that a sufficient number of boats using standard performance engines are equipped with enhanced evaporative control systems to fully compensate for the change in emission benefits from allowing compliance to the less stringent standard. Unless a lower percentage is demonstrated sufficient by the certifying manufacturer, a minimum of fifteen percent annually of the large volume dual category manufacturer's standard performance engine production for California must be installed in boats equipped with enhanced evaporative control systems. Beginning with the 2009 model year and for all model years thereafter, the following would apply:

A. Each engine manufacturer must provide written instructions, as part of the installation materials provided to purchasers of the engine, to use enhanced evaporative control systems on any boat that is manufactured for sale, sold, or offered for sale in California, or that is introduced, delivered or imported into California for introduction into commerce that uses a standard performance engine intended to qualify the engine manufacturer to certify its high performance engines using the HC+NOx standards intended for small volume high performance manufacturers in Table 2.1(b) of this section. The engine manufacturer shall also provide evidence that the supplier(s) of the enhanced evaporative control system has designed the system components to meet or exceed the diurnal and permeation design specifications listed in Table 2.2 throughout the useful life of the engine.

B. Each boat manufacturer shall install an enhanced evaporative control system on every boat that is manufactured for sale, sold, or offered for sale in California that uses a standard performance engine intended to qualify the engine manufacturer to certify its high performance engines using the HC+NOx standards

intended for small volume high performance manufacturers in Table 2.1(b) of this section.

(c) Not-to-Exceed (NTE) Limits

(RESERVED)

{Note to commenters: Upon promulgation by the United States Environmental Protection Agency of Not-to-Exceed (NTE) requirements for spark-ignition marine engines, the Executive Officer shall have the authority to adopt the same NTE requirements for California; such that, for engines subject to these regulations, California would have full authority to enforce the NTE limits independently of the federal government. The federal NTE proposal can be found at "Control of Emissions from Nonroad Spark-Ignition Engines and Equipment," Federal Register Volume 76, Number 92, Friday, May 18, 2007, 28098, at pages 28279-28281, as discussed at pp. 28121-28124. There will be no additional demonstrations of NTE compliance unique to California beyond those of the federally promulgated requirements.}

(d) Voluntary Standards. Model Year 2009 and later spark-ignition marine engines:

(1) Manufacturers may voluntarily certify their engines to the exhaust and evaporative emission standards in Table 3 below.

(2) Marine vessels powered by engines certified to the voluntary standards in Table 3 below and equipped with a fully compliant OBD-M system (see § 2444.2) shall display a five-star consumer/environmental emission label (see § 2443.2 and § 2443.3).

Table 3 - Voluntary Standards

HC^1+NO_X STANDARD *[grams per kilowatt-hour]*	CO STANDARD *[grams per kilowatt-hour]*	PERMEATION STANDARDS *[grams per square meter per day]*		DIURNAL STANDARD[2] *[grams per gallon per day]*
		Hose[3]	Tank[4]	
2.50	50.0	15.0	1.5	0.4

1. The exhaust standard includes total hydrocarbons
2. Diurnal testing assumes a trailerable boat and requires fuel with 9 pounds per square inch (psi) volatility and a 24 hour fuel temperature cycle of 25.6 to 32.2 °Celsius
3. Fuel line permeation testing requires gasoline fuel with 10% ethanol content and must be performed at a test temperature of 23 ± 2 °Celsius
4. Fuel tank permeation testing requires gasoline fuel with 10% ethanol content and must be performed at a test temperature of 28 ± 2 °Celsius

(3) Spark-ignition marine engines certified to the voluntary standards are subject to the same in-use compliance and recall requirements as engines certified to the required exhaust and evaporative standards.

(e) Special Provisions for Engine and/or Vessel Manufacturers

(1) Jet Boat Engines

(A) Jet boat engine families previously certified to the HC+NOx standards for outboard engines and personal watercraft in § 2442(a) may continue to be certified to those standards until 2012 with the additional requirement for 2009 and subsequent model years to comply with the applicable carbon monoxide standards for OB/PWC engines in Table 1.2.

(B) Beginning in 2010, all new jet boat engine families shall comply with the standards for sterndrive/outboard engines in § 2442 (b) upon introduction, except that these new jet boat engine families may be cross-category averaged with any other jet boat or personal watercraft engine family to comply with those standards until 2012. An engine family certified to the § 2442 (a) standards prior to 2010, but not previously used in a jet boat application would be considered a new jet boat engine family in 2010.

(C) Jet boat engines previously certified in the same engine family with personal watercraft engines must be certified separately and to a unique engine family beginning in 2010 if new, or in 2012 otherwise.

(D) The OBD-M requirements in § 2444.2 would apply to new jet boat engine families in 2010 and to all jet boat engine families in 2012.

(2) Discontinuation of Marinized Sterndrive/Inboard Engines.

Sterndrive/inboard engine manufacturers who marinize base engines produced by another manufacturer may request a discontinuation allowance from the Executive Officer, subject to the following:

(A) The base engine manufacturer has announced that it plans to discontinue the base engine.

(B) Each marinizer may have a discontinuation allowance for only one engine family in effect at any time. As an alternative to the "one engine family" stipulation, manufacturers may petition the Executive Officer to allow a modified grouping of engines based on factors that logically link the engines to be discontinued including, but not necessarily limited to, the pre-marinized base configuration of the engines (e.g., the same base engine offered in one family with fuel injection and another family with carburetion).

(C) The discontinuation allowance would allow the marinizing manufacturer to continue to certify the engine family to be discontinued to emission levels that are less stringent than the standards otherwise required for sterndrive/inboard engines in § 2442 (b) for a total of four model years, provided that on a corporate average basis, the manufacturer meets the required standards in § 2442 (b).

(D) Manufacturers shall not certify engine families to emission levels less stringent than those in effect for previous model year versions of the same or similar engine family. Fluctuations in certification levels from year to year due to component variation would not violate this prohibition unless the fluctuations result in an exceedance of the standards to which the engine family was previously certified.

(E) Manufacturers shall comply with all applicable OBD-M and evaporative requirements in effect for:

1. any previously uncertified engine family certified for the first time under paragraph (g)(2) of this section to emission levels that are less stringent than the standards otherwise required for sterndrive/inboard engines in § 2442(b); and

2. any current production engine family that has previously been certified with OBD-M or evaporative systems.

(F) The applicable requirements of §§ 2442(b)(3), 2443.1, and 2443.2, including averaging, records keeping, reporting, and labeling, shall be applicable to manufacturers employing the discontinuation allowance provisions of this paragraph (g)(2).

~~(e)~~(f) In 2001 and subsequent model years, fire and police departments, and other entities that specialize in emergency response may purchase emergency equipment powered by a non-California-certified spark-ignition marine engine only when such

equipment with a California-certified spark-ignition marine engine is not available. For purposes of this section, a request to purchase emergency equipment powered by a non-California-certified engine must be submitted for approval to the Executive Officer.

10. Maintenance and Warranty Instructions.

Maintenance and warranty instructions must conform to the requirements pursuant to sections 2445.1 and 2445.2, Title 13, California Code of Regulations.

11. Labeling.

Labeling required pursuant to sections 2443.1, 2443.2 and 2443.3, Title 13 of the California Code of Regulations must conform to the requirements specified therein.

12. Submission of Engine Identification Number.

(a) The manufacturer of any spark-ignition marine engine covered by an Executive Order must furnish to the Executive Officer, at the beginning of each model year, information and an explanation about the engine identification number system pursuant to section 2443.1(e), Title 13 of the California Code of Regulations that identifies production engines that are covered by an Executive Order.

(b) Within 30 days of receiving a request by the Executive Officer, the manufacturer of any spark-ignition marine engine covered by an Executive Order must identify such engines by their identification number system provided under the requirements of paragraph (a) above.

13. [Reserved].

14. Application for Certification.

(a) The Executive Officer may request notification, sixty (60) days prior to the initial model year submission of an engine manufacturer's certification application(s), of the engine manufacturer's intent to seek engine family certification (i.e., a letter of intent) so that the Executive Officer can adequately allocate resources required for reviewing such certification applications in a timely manner. Such letters of intent must provide the engine manufacturer's best estimate of general information for the applicable model-year certification, such as identification of each engine family, date of expected submission, etc.

(b) New spark-ignition marine engines are covered by the following:

(1) Manufacturers of new spark-ignition marine engines must complete and submit to the Executive Officer a written application, in the English language, requesting an Executive Order that certifies such engines be issued. The engine

manufacturer must update and correct by amendment such applications whenever changes are made to engines that are delineated in the certification application (see section 28). An engine manufacturer must include within a single application for certification all engine models within an engine family (see section 17 to determine what an engine family is). The application must describe each applicable engine model in the engine family. An engine manufacturer may, however, choose to apply separately for certification of part of its engine product line. The selection of test engines and the computation of emission test results must be determined by the Executive Officer for each separate and individual engine family certification application.

(2) The certification application must be signed by an authorized representative of the engine manufacturer. The certification application must include the following:

~~(i)~~(A) Identification and description of the engines covered by the engine family certification application; descriptions of the engine designs (e.g., combustion chamber, valves, etc.); and, identifications (i.e., part numbers) and descriptions of the emission control system and components, auxiliary emission control devices, fuel system and components, air inlet system and components, exhaust system and components, and any optional equipment. For purposes of this section, "auxiliary emission control device" means any element of design that senses temperature, engine RPM, manifold vacuum, or any other parameter for the purpose of activating, modulating, delaying, or deactivating the operation of any part of the emission control system.

~~(ii)~~(B) Emission control warranty information as set forth in section 10.

~~(iii)~~(C) Emission control and consumer/environmental label information as set forth in section 11, including actual production labels and descriptions of all applicable label attachment locations.

~~(iv)~~(D) Identification and description (i.e., range, value, etc.) of any adjustable engine parameters (e.g., idle fuel/air, ignition timing, etc.); and a description of the method used to ensure that the emission characteristics of the certification test engines remain representative of those of the production engines with respect to any adjustments of such engine parameters.

~~(v)~~(E) Projected California sales data of the engine family for which certification is requested. Where applicable, the sales for each engine model within the engine family should be provided. Such estimated sales data must include an explanation of the method used to make the estimate.

~~(vi)~~(F) A description of the facility and equipment used to test the engines for certification including (as applicable) specifications about the dynamometers, gas analyzers, data collection devices, etc.

~~(vii)~~(G) Information about the certification test fuels and lubricants, and information about the commercially available fuels and lubricants recommended for use in the production engines.

~~(viii)~~(H) A description of the proposed certification test engine service accumulation (e.g., break-in) procedure and the certification test engine maintenance schedule.

~~(ix)~~(I) A statement of recommended periodic and anticipated procedures for maintenance necessary to assure that the engine covered by an Executive Order conforms to the regulations. The statement must include a listing of the fuels and lubricants recommended for use by the ultimate purchaser and a description of the training program for personnel who will perform such maintenance, and the equipment required to perform such maintenance

~~(x)~~(J) The engine family's FEL and an estimate of the overall corporate average emissions for that model year.

~~(xi)~~(K) Information about high-altitude adjustments, and an engineering evaluation of one engine family within the manufacturer's line that demonstrates emissions compliance at high altitudes.

(3) Completed copies of the engine family certification application and of any amendments thereto, and all notifications under sections 28 and 29 must be submitted in such multiple copies as the Executive Officer requires.

15. Approval of Application for Certification.

(a) After a review of the complete engine family application for certification and any other information that the Executive Officer requires, the Executive Officer will approve the application if all the foregoing conditions are satisfied.

(b) The Executive Officer may disapprove an engine family application for certification, in whole or in part, for reasons including, but not limited to, being incomplete, inaccurate, or providing inappropriate information regarding proposed break-in procedures, maintenance, test equipment, label content or locations, test fuel or lubricant. It may also be disapproved if the described engines incorporate any defeat devices. If an engine family certification application or part thereof is rejected, the Executive Officer will notify the engine manufacturer in writing and set forth the reasons for such rejection.

16. Engine Displacement of Spark-Ignition Marine engines.

Engine displacements must be calculated using nominal engine values and rounded to the nearest tenth of a cubic centimeter, in accordance with ASTM E 29-93a, (May 1993), incorporated by reference herein.

17. Engine Families and Engine Family Groups.

(a) Certification applications submitted by engine manufacturers must divide engines covered therein into groupings that are expected to have similar emission characteristics throughout their useful life. Each group of engines with similar emission characteristics must be defined as a separate engine family.

(b) In order to be included within the same engine family, engines must be identical in all of the following specifications:

(1) The combustion cycle.

(2) The cooling mechanism.

(3) The cylinder block configuration (i.e., inline, vee, opposed, bore spacings, etc.).

(4) The number of cylinders.

(5) The method of air aspiration.

(6) The number, location, volume, and composition of any catalytic converters.

(7) The thermal reactor characteristics.

(8) The number of carburetors, as applicable.

(9) The prechamber characteristics.

(10) The exhaust port(s) and cylinder design of two-stroke engines.

(c) At the engine manufacturer's option, reciprocating engines identical in all the specifications listed in paragraph (b) of this section may be further divided into different engine families if the Executive Officer determines that they may be expected to have different emission characteristics. This determination will be based upon consideration of factors such as:

(1) The bore and stroke.

(2) The combustion chamber configuration.

(3) The intake and exhaust timing method of actuation (i.e., poppet valve, reed valve, rotary valve, etc.).

(4) The intake and exhaust valve or port sizes, as applicable.

(5) The fuel system.

(6) The exhaust system.

18. Test Engines.

(a) Test engines will be selected by the engine manufacturer to represent each engine-displacement-system combination. The engine manufacturer will select the engine configuration (i.e., air inlet system, exhaust system, engine calibration, etc.) of each engine-displacement-system combination in the engine family that is expected to have the greatest probability of exceeding the emission standards. The Executive Officer will make the final determination whether the test engines selected by the engine manufacturer may be used for certification testing. At the manufacturer's option, the criterion for selecting the worst case engine may be that engine configuration which has the highest weighted brake-specific fuel consumption over the engine test cycle described in section 20(b)(5).

(b) A test engine must be a complete engine assembly with all emission control systems and components that are specified in the certification application installed and functional for test purposes.

(c) Concurrent with the selection of an engine family test engine, the Executive Officer will determine the engine parameters subject to adjustment for certification, assembly-line quality-audit and compliance tests. The Executive Officer will also evaluate the adequacy of the limits, stops, seals, or other methods utilized to control, restrict or inhibit adjustment, and will evaluate resultant adjustable ranges of each parameter. The Executive Officer will notify the engine manufacturer of each determination.

(1) The Executive Officer will consider an engine parameter to be subject to adjustment if the parameter is capable of adjustment and the adjustment may significantly affect emissions.

(2) In order to determine if an engine parameter is subject to adjustment, the Executive Officer will consider the in-use probability that the parameter may be changed from the values, or beyond the positions, specified in the engine family certification application (i.e., misadjustment). The Executive Officer may evaluate this probability on the basis of factors such as: ease of access to the parameter, damage to the engine or equipment that may result from an attempt to misadjust the parameter, consequence with respect to emissions of a misadjustment, information provided in the preliminary engine family application,

and information obtained from any compliance-related activities that are, or may be, required.

(3) The Executive Officer will determine an adjustable parameter to be adequately inaccessible when either or both of the following apply:

~~(i)~~(A) The physical device that controls the adjustable parameter can be accessed only by the disassembly of the engine or equipment, and this disassembly requires the use of special tools.

~~(ii)~~(B) Adequate deterrence to restrict access to an adjustable parameter will not be demonstrated by the necessity to remove an engine component that is routinely removed in maintenance, or that is required to be removed in order to perform an adjustment.

(4) The Executive Officer shall determine an adjustable parameter to be adequately controlled or restricted when one or more of the following apply:

~~(i)~~(A) The device that controls the adjustable parameter is restricted from adjustment beyond the range or values specified in the engine family certification application.

~~(ii)~~(B) The restriction may be circumvented only through the use of special tools.

~~(iii)~~(C) Attempts to misadjust the parameter would result in breakage of the restrictive device and/or the parameter and thereby result in unsatisfactory engine operation.

(5) The Executive Officer may also determine an adjustable parameter to be adequately controlled or restricted when either one or both of the following apply:

~~(i)~~(A) Attempts to misadjust the parameter are ineffective. For example, an adjustment beyond the values or positions specified in the engine family certification application would not alter significantly the engine performance; hence, the emission levels as projected in certification are representative of in-use engine family emissions.

~~(ii)~~(B) Any solid-state memory devices that control or monitor emission control systems or components are protected adequately against unauthorized or inappropriate changes.

(d – f) Reserved.

(g) In lieu of testing an engine and submitting data thereon, an engine manufacturer may, with the prior written approval of the Executive Officer, submit exhaust emission data on a similar engine for which certification has previously

been obtained or for which all applicable data have previously been submitted (i.e., carryover).

(h) All engines must have closed crankcases. For purposes of this section, "crankcase" means the housing for the crankshaft and other related internal parts.

19. Executive Officer's Engines.

The Executive Officer may require additional tests on the engines selected in accordance with section 18 and tested in accordance with section 20.

20. Test Procedures, General Requirements.

(a) For each engine family, engine manufacturers must determine a deterioration factor for each regulated pollutant pursuant to Part II.

(b) Certification testing of exhaust emissions.

(1) Manufacturers of spark-ignition marine engines must use the test procedures outlined in Part IV.

(2) The exhaust emission test consists of prescribed sequences of engine operating conditions to be conducted on an engine dynamometer. The exhaust gases generated during engine operation are sampled either raw or dilute (as required), and specific components are analyzed through the exhaust gas analytical system. The test is designed to measure (as applicable) the concentration of hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO_2), oxides of nitrogen (NO_x), exhaust volume, temperature, fuel flow, and the gross power output. The measured values are weighted and used to calculate the brake-specific emissions of each pollutant (in g/kW-hr).

(3) For engines with adjustable parameters, the Executive Officer may adjust or require to be adjusted those adjustable parameters to any specification within the adjustable range during testing to determine compliance with the requirements of this Part.

(4) The exhaust emission test uses prescribed sequences of engine operation as indicated in Table 20-1.

Table 20-1.
Spark-Ignition Marine Engine Test Cycle

Mode Number	1	2	3	4	5
Speed (%)	100	80	60	40	Idle
Torque (%)	100	71.6	46.5	25.3	0[1]

Weighting Factor	0.06	0.14	0.15	0.25	0.40

1. For high performance engines (i.e., engines greater than 373 kilowatts), manufacturers have the option of measuring the emissions under mode 5 with a 15 percent torque load applied.

(5) Engine power (in kilowatts) must be calculated using the Society of Automotive Engineers (SAE) standard J1228, November 1991, incorporated herein by reference.

(c) In lieu of the test procedures in Part IV, manufacturers of SI sterndrive/inboard marine engines that produce no more than 75 engines per year nationally may use portable emissions measurement systems (PEMS) to demonstrate compliance of their engines greater than 373 kilowatts to the exhaust emission standards. The test procedures for using a PEMS are contained in Title 40, Code of Federal Regulations, Subpart J, Sections 1065.901 through 1065.940, and are incorporated by reference herein. These measurements can be performed in the laboratory or in the field.

~~(c)~~(d) The Executive Officer will prescribe emission test procedures for any spark-ignition marine engine that the Executive Officer determines is not susceptible to satisfactory testing by the methods set forth in the test procedures.

~~(d)~~(e) The Executive Officer may revise these test procedures on a case-by-case basis when a request to do so is supported by data and results, or other information, showing the necessity for the revision.

21. Service Accumulation Procedures; Test Engines.

(a) The service accumulation (i.e., break-in) procedure for an emission test engine must be the procedure specified by the engine manufacturer, and must be approved by the Executive Officer before the accumulation of hours.

(b) During the service accumulation period, engine manufacturers must not operate engines for a total of more than 12 hours unless an allowance to do so is approved by the Executive Officer. Engine shutdowns are permitted during the operating sequence; however, the periods of shutdown must not be included in the 12 hour total.

22. Scheduled Maintenance; Test Engines.

(a) Engine manufacturers may schedule and perform break-in maintenance on the emission test engine and its emission control and fuel systems only at the same time intervals specified in the engine manufacturer's break-in maintenance instructions furnished to the ultimate purchaser.

(b) During service accumulation, an engine manufacturer must be restricted to inspecting, replacing, cleaning, adjusting and servicing of the following items:

(1) idle speed and idle air/fuel mixture; and,

(2) spark plugs. Such procedures must be conducted in a manner consistent with service instructions and specifications provided by the engine manufacturer for use by the ultimate purchaser. Such procedures must not render the certification test engines unrepresentative of the emission characteristics of the engine family production engines.

(c) The Executive Officer may specify, within the physically available range, the ignition timing, idle air/fuel mixture and other fuel system adjustments to be used at each tune-up.

(d) Engine manufacturers may perform periodic changes of engine oil, and may change or service oil, air and fuel filters at the time intervals specified in the engine manufacturer's break-in maintenance instructions that are furnished to the ultimate purchaser.

(e) Engine manufacturers may request from the Executive Officer authorization to perform service accumulation maintenance of emission control related components not specifically authorized by this section, and for anticipated maintenance, before to the beginning of the service accumulation period. The Executive Officer will approve the performance of such maintenance, if the engine manufacturer makes a satisfactory showing that the maintenance will be performed by and/or for the ultimate purchaser on engines in use and that the maintenance is reasonable and necessary.

23. Unscheduled Maintenance; Test Engines.

(a) Engine manufacturers must not perform any unscheduled engine, emission control system, or fuel system adjustment, repair, removal, disassembly, cleaning, or replacement on engines without the advance approval of the Executive Officer.

(1) In the case of unscheduled maintenance the Executive Officer will approve such maintenance if the Executive Officer:

~~(i)~~(A) Has made a preliminary determination that part failure or system malfunction, or the repair of such failure or malfunction, does not render the engine unrepresentative of engines in use, and does not require direct access to the combustion chamber, except for spark plug, fuel injection component, or removable prechamber removal or replacement; and

~~(ii)~~(B) Has made a determination that the need for maintenance or repairs is indicated by an overt indication of malfunction such as persistent misfire, engine stall, overheating, fluid leakage, loss of oil pressure, or charge indicator warning.

(2) Emission measurements must not be used as a means of determining the need for unscheduled maintenance under paragraph (a)(1)~~(i)~~(A) of this section.

(b) Engine manufacturers may perform repairs of engine components of test engines, other than the engine, emission control system, or fuel system, only as a result of part failure or with the prior approval of the Executive Officer.

(c) The Executive Officer must be given the opportunity to verify the extent of any overt indication of part failure (e.g., misfire, stall), or an activation of an audible and/or visual signal, before the engine manufacturer performing any maintenance related to such overt indication or signal.

(d) Unless approved by the Executive Officer before use, engine manufacturers must not use any equipment, instruments, or tools to identify malfunctioning, maladjusted, or defective engine components unless the same or equivalent equipment, instruments, or tools will be available at dealerships and other service outlets; and:

(1) Are used in conjunction with scheduled maintenance on such components; and,

(2) Are used subsequent to the identification of an engine malfunction, as provided in paragraph (a)(1) of this section for emission data engines.

(e) If the Executive Officer determines that part failure or system malfunction occurrence and/or repair rendered the engine unrepresentative of engines in use, the engine must not be used as a test engine.

(f) Unless waived by the Executive Officer, complete emission tests are required before and after any engine maintenance that may reasonably be expected to affect emissions.

24. Engine Failure.

Engine manufacturers must not use as a test engine any test engine that incurs major mechanical failure requiring disassembly of the engine. This prohibition does not apply to failures that occur after completing the service accumulation period.

25. Data Submission.

(a) Engine manufacturers must submit the test engine emission data and results for all emission data tests (including voided tests) that were conducted on the test engines.

(b) The engine manufacturer must furnish to the Executive Officer, with the submission of the information required by paragraph (a), explanations of the cause for any voided emission tests. The Executive Officer will determine if voiding the test was appropriate based upon the explanation given by the engine manufacturer.

(c) When unscheduled or unanticipated maintenance is performed, the engine manufacturer must furnish to the Executive Officer a complete record of all pertinent maintenance, including the malfunction diagnosis, the corrective action taken, and the test data obtained.

(d) A complete record of all maintenance that was performed on any test engines must be furnished to the Executive Officer as part of the certification application.

26. Testing by the Executive Officer.

(a) At the conclusion of the service accumulation procedure and emission tests, the engine manufacturer must submit the test engine data and results to the Executive Officer in accordance with the requirements of section 25. After reviewing the test data and results, the Executive Officer may conduct emission testing on the test engine(s) (i.e., confirmatory testing) to verify the engine manufacturer's test results, and to determine that the test engine emission characteristics are representative of production engines.

(b) As part of the test data and results submission, an engine manufacturer may request that the Executive Officer not conduct confirmatory testing of the test engine(s) (i.e., test-waiver request), and that the engine manufacturer's test data and results be accepted as officially representative of production engines (i.e., projected emission levels).

(c) The Executive Officer will consider an engine manufacturer's test-waiver request by evaluating information submitted under the requirements of section 25, information contained in the engine family application, and other certification-related information. The Executive Officer will determine whether or not to conduct confirmatory emission testing on the basis of, but not limited to, such factors as:

(1) Marginal compliance with the applicable emission standards;

(2) Demonstrated capability of the engine manufacturer's prior certification-related activities;

(3) Use of new or different technologies that may affect engine emission characteristics, or that may not be compatible with existing procedures; and,

(4) Reasonableness of emission test data and results.

(d) Whenever the Executive Officer determines that confirmatory testing is not warranted, the engine manufacturer's test data and results will be accepted as the official test data and results for purposes of the certification review specified in section 27(a)(2)~~(i)~~(A).

(e) Whenever the Executive Officer determines that confirmatory testing is warranted, the Executive Officer will notify the engine manufacturer to submit one or more of the test engines, at such a place or places as the Executive Officer may designate, for purposes of conducting confirmatory testing. The data and results from that test will, unless subsequently invalidated by the Executive Officer, comprise the official test engine(s) data and results for purposes of the certification review specified in section 27(a)(2)~~(i)~~(A).

(f) The engine manufacturer may request a retest. The results of the retest will be used to determine compliance with the applicable emission standards.

(g) If any emission test result exceeds the applicable standard, the Executive Officer will deny certification.

27. Certification.

(a) New spark-ignition marine engines produced by a manufacturer are covered by the following certification requirements:

(1) The engine manufacturer must submit to the Executive Officer a statement that the test engine for which data have been submitted has been tested in accordance with the applicable test procedures, that it meets the requirements of such tests, and that, on the basis of such tests, it conforms to the requirements of this Part. If such statements cannot be made with respect to any engine tested, the engine must be identified, and all pertinent test data relating thereto must be supplied.

(2)~~(i)~~(A) If, after review of the test reports and data submitted by the engine manufacturer, data derived from any inspection carried out under section 31, and any other pertinent data or information, the Executive Officer determines that a test engine(s) meets the requirements of section 43013 of the California Clean Air Act and of these provisions, the Executive Officer will issue an Executive Order certifying such engine(s) except for engines covered by section 32.

~~(ii)~~(B) The engine family certification will be granted only for the model-year engine production as specified by the Executive Officer in the Executive Order; and upon such terms as the Executive Officer may deem necessary to assure that any new spark-ignition marine engine covered by the Executive Order will meet the requirements of these provisions.

~~(iii)~~(C) The Executive Order will apply to all engines within the engine family represented by the test engine and will certify compliance with no more than one set of applicable standards.

~~(iv)~~(D) The engine manufacturer may, at its option, proceed with any of the following alternatives with respect to engines represented by a test engine(s) determined not to be in compliance with applicable standards:

~~(A)~~(i) Delete from the application for certification engines that were represented by the failed test engine. The Executive Officer will then select in place of each failed engine an alternate engine chosen in accordance with the selection criteria that were employed in selecting the engine that failed; or,

~~(B)~~(ii) Repair and retest the failed engine to demonstrate that it meets the applicable standards. The engine manufacturer must then test a second engine that is in all material respects the same as the first engine (as repaired) in accordance with the applicable test procedures.

~~(v)~~(E) If the engine manufacturer does not submit the data required under paragraphs (2)~~(i)~~(A), ~~(ii)~~(B) and ~~(iii)~~(C) of this section, the Executive Officer will deny certification.

28. Amendments to the Application.

(a) The engine manufacturer must inform the Executive Officer by written amendment to the certification application of any proposed changes to engines that are in production or will be produced. The Executive Officer will, if appropriate, select a new test engine. Except as provided in section 29, the engine manufacturer must not institute any changes until approved by the Executive Officer.

(b) The Executive Officer may allow reduced testing with respect to the requirements of this section.

29. Alternative Procedure for Notification of Additions and Changes.

(a) (1) If the engine manufacturer determines that a change in an engine family model will not result in failure of the subject engines to continue to meet applicable emission standards, an engine manufacturer may elect to notify the Executive Officer at the time such a change is made rather than in advance as required by section 28.

(2) Such notification must include a full description of the addition or change and any supporting documentation provided by the engine manufacturer to support its determination that the addition or change does not cause noncompliance.

(3) The engine manufacturer's determination that the addition or change does not cause noncompliance must be based on an engineering evaluation of the addition or change and/or testing.

(b) (1) The Executive Officer may require that additional emission testing be performed to support the engine manufacturer's original determination submitted in accordance with paragraph (a) of this section.

(2) If additional testing is required, the Executive Officer will proceed as in section 28.

(3) If the Executive Officer requests additional test data, the engine manufacturer must provide such data within 30 days of the request or the engine manufacturer must rescind the addition or change immediately after the expiration of the 30 day period.

(4) The Executive Officer may grant additional time to complete testing if additional testing is required.

(5) If based on this additional testing or any other information, the Executive Officer determines that the engines affected by the addition or change do not meet the applicable standards, the Executive Officer will notify the engine manufacturer to rescind the addition or change immediately upon receipt of the notification, and to cease selling engines affected by such addition or change.

(c) If an engine manufacturer elects to produce engines under this section, the engine manufacturer, upon notification from the ARB that engines that it has produced do not meet the standards set forth herein, will be subject to being enjoined from any further sales of such products in the State of California pursuant to section 43017 of the Health and Safety Code. Prior to seeking to enjoin an engine manufacturer, the Executive Officer will consider any information provided by the engine manufacturer.

30. Maintenance of Records.

(a) The manufacturer of any spark-ignition marine engine subject to any of the standards or procedures prescribed in these provisions must establish, maintain and retain the following adequately organized and indexed records;

(1) General records.

~~(i)~~(A)

~~(A)~~(i) Identification and description of all certification engines for which testing is required under this Part.

~~(B)~~(ii) A description of all emission control systems that are installed on or incorporated in each certification engine.

~~(C)~~(iii) A description of all procedures used to test each certification engine.

~~(ii)~~(B) A properly completed application, following the format prescribed by the California Air Resources Board for the appropriate year of production, must fulfill each of the requirements set forth in paragraph (a)(1)~~(i)~~(A) of this section.

(2) Individual records.

~~(i)~~(A) A brief history of each spark-ignition marine engine used for certification under these provisions including:

~~(A)~~(i)~~(1)~~a. In the case where a current production engine is modified for use as a certification engine, a description of the process by which the engine was selected and of the modification made.

~~(2)~~b. In the case where the certification engine is not derived from a current production engine, a general description of the build-up of the engine (e.g., experimental heads were cast and machined according to supplied drawings, etc.).

~~(3)~~c. In both of the above cases, a description (as applicable) of the origin and selection process for the carburetor, fuel system, emission control system components, and exhaust aftertreatment device must be included. The required description must specify the steps taken to assure that the certification engine is representative of production engines with respect to its fuel system, emission control system components, exhaust aftertreatment device, or any other device or component that can reasonably be expected to influence exhaust emissions. The description must also state that all components and/or engine construction processes, component inspection and selection techniques, and assembly techniques employed in constructing such engines are reasonably likely to be implemented for production engines, or that they are as closely analogous as practicable to planned construction and assembly processes.

~~(B)~~(ii) A complete record of all certification emission tests performed (except tests performed by ARB directly) including test results, and the date and purpose of each test, and the hours accumulated on the engine.

~~(C)~~(iii) The date of each service accumulation procedure.

~~(D)~~(iv) [Reserved].

~~(E)~~(v) A record and description of all maintenance and other service performed, including the date of the maintenance or service and the reason for it.

~~(F)~~(vi) A record and description of each test performed to diagnose engine or emissions control system performance, giving the date and time of the test and the reason for it.

~~(G)~~(vii) [Reserved].

~~(H)~~(viii) Each such history must state the date that any of the selection or build-up activities in paragraph (a)(2)~~(i)(A)~~(A)(i) of this section occurred with respect to the certification engine. The history must be updated each time the operation status of the engine changes or additional work is performed on it.

(3) All records, other than routine emission test records, required to be maintained under these provisions must be retained by the engine manufacturer for a period of six (6) years after the issuance of all Executive Orders to which they relate. Routine emission test records must be retained by the manufacturer for a period of one (1) year after issuance of all Executive Orders to which they relate. Records may be retained as hard copy or reduced to rewritable compact disc, microfilm, punch cards, etc., depending on the record retention procedures of the engine manufacturer, provided, in every case, all the information contained in the hard copy must be retained.

31. Right of Entry.

(a) Any engine manufacturer subject to these emission standards and test procedures, upon receipt of prior notice must admit or cause to be admitted during operating hours any ARB Enforcement Officer that has presented proper credentials to any of the following:

(1) Any facility where tests or procedures or activities connected with such tests or procedures are or were performed.

(2) Any facility where any new spark-ignition marine engine is present and is being, has been, or will be tested.

(3) Any facility where a manufacturer constructs, assembles, modifies, or builds-up an engine into a certification engine that will be tested for certification.

(4) Any facility where any record or other document relating to any of the above is located.

(b) Upon admission to any facility referred to in paragraph (c)(1) of this section, any ARB Enforcement Officer must be allowed:

(1) To inspect and monitor any part or aspect of such procedures, activities, and testing facilities, including, but not limited to, monitoring engine preconditioning, emissions tests and break-in, maintenance, and engine storage procedures.

(2) To verify correlation or calibration of test equipment; and,

(3) To inspect and make copies of any such records, designs, or other documents; and,

(4) To inspect and/or photograph any part or aspect of any such certification engine and any components to be used in the construction thereof.

(c) To permit an ARB determination whether production spark-ignition marine engines conform in all material respects to the design specifications that apply to those engines described in the Executive Order certifying such engines and to standards prescribed herein, engine manufacturers must, upon receipt of prior notice, admit any ARB Enforcement Officer, upon presentation of credentials, to:

(1) Any facility where any document design, or procedure relating to the translation of the design and construction of engines and emission related components described in the application for certification or used for certification testing into production engines is located or carried on; and,

(2) Any facility where any spark-ignition marine engines to be introduced into commerce are manufactured or assembled.

(3) Any California retail outlet where any spark-ignition marine engine is sold.

(d) On admission to any such facility referred to in this section, any ARB Enforcement Officer must be allowed:

(1) To inspect and monitor any aspects of such manufacture or assembly and other procedures;

(2) To inspect and make copies of any such records, documents or designs; and,

(3) To inspect and photograph any part or aspect of any such new spark-ignition marine engine and any component used in the assembly thereof that are reasonably related to the purpose of the ARB Enforcement Officer's entry.

(e) Any ARB Enforcement Officer must be furnished by those in charge of a facility being inspected with such reasonable assistance as may be necessary to discharge any function listed in this section. Each applicant for or recipient of certification is required to cause those in charge of a facility operated for its benefit to furnish such reasonable assistance without charge to the ARB irrespective of whether or not the applicant controls the facility.

(f) The duty to admit or cause to be admitted any ARB Enforcement Officer applies whether or not the applicant owns or controls the facility in question and applies both to domestic and foreign engine manufacturers and facilities. The ARB will not attempt to make any inspections that it has been informed that local law forbids. However, if local law makes it impossible to insure the accuracy of data generated at a facility, no informed judgment that an engine is certifiable or is covered by an Executive Order can properly be based on the data. It is the responsibility of the engine manufacturer to locate its testing and manufacturing facilities in jurisdictions where this situation will not arise.

(g) For purposes of this section:

(1) "Presentation of credentials" means a display of a document designating a person to be an ARB Enforcement Officer.

(2) Where engine, component, or engine storage areas or facilities are concerned, "operating hours" means all times during which personnel are at work in the vicinity of the area or facility and have access to it.

(3) Where facilities or areas other than those covered by paragraph (g)(2) of this section are concerned, "operating hours" means all times during which an assembly line is in operation or during which testing, maintenance, break-in procedure, production or compilation of records, or any other procedure or activity is being conducted related to certification testing, translation of designs from the test stage to the production stage, or engine manufacture or assembly.

(4) "Reasonable assistance" includes, but is not limited to, providing clerical, copying, interpretation and translation services; making personnel available upon request to inform the ARB Enforcement Officer of how the facility operates and to answer questions; and performing requested emissions tests on any engine that is being, has been, or will be used for certification testing. Such tests must be nondestructive, but may require appropriate break-in. Upon written request from the Executive Officer for the appearance of any employee of a facility, and service of such request upon the engine manufacturer, the ARB may compel an engine manufacturer to cause the personal appearance of any employee at such a facility before an ARB Enforcement Officer. Any such employee who has been instructed by the engine manufacturer to appear will be entitled to be accompanied, represented, and advised by counsel.

32. Denial, Revocation, or Suspension of Certification.

(a) Notwithstanding the fact that any engine(s) tested for certification may comply with the provisions set forth herein, the Executive Officer may withhold or deny the issuance of an Executive Order (or suspend or revoke any such Executive Order that has been issued) with respect to any such engine(s) if:

(1) The engine manufacturer submits false or incomplete information in its application for certification; or,

(2) The engine manufacturer renders inaccurate or invalid any test data that it submits pertaining to the certification or otherwise circumvents the intent of section 43013 of the California Clean Air Act or of these provisions with respect to such engine; or,

(3) Any ARB Enforcement Officer is denied access on the terms specified in section 31 to any facility that contains any of the following:

~~(i)~~(A) The engine;

~~(ii)~~(B) Any components used or considered for use in its modification or build-up into a certification engine;

~~(iii)~~(C) Any production engine that is or will be claimed by the engine manufacturer to be covered by the certificate;

~~(iv)~~(D) Any step in the construction of an engine described in paragraph (c) of this section;

~~(v)~~(E) Any records, documents, reports, or histories required by this Part to be kept concerning any of the above.

(4) Any ARB Enforcement Officer is denied "reasonable assistance" in examining any of the items listed in paragraph (a)(3) of this section.

(b) The sanctions of withholding, denying, revoking, or suspending of an Executive Order may be imposed for the reasons in paragraph (a) of this section only when the infraction is substantial.

(c) In any case in which an engine manufacturer knowingly submits false or inaccurate information, or knowingly renders inaccurate or in valid any test data, or commits any fraudulent acts and such acts contribute substantially to the Executive Officer decision to issue an order, the Executive Officer may deem such Executive Order void ab initio.

(d) In any case in which certification of an engine is proposed to be withheld, denied, revoked, or suspended under paragraph (a)(3) or (4) of this section, and in which the Executive Officer has presented to the engine manufacturer involved reasonable evidence that a violation of section 31 has occurred, the engine manufacturer, will have the burden of establishing any contention to the satisfaction of the Executive Officer, that even though the violation occurred, the engine in question was not involved to such a degree that would warrant withholding, denial, revocation, or suspension of certification under either paragraph (a)(3) or (4) of this section.

(e) Any revocation or suspension of certification under paragraph (a) of this section may also subject the manufacturer to penalties to the extent permissible under Part 5, Division 26 of the Health and Safety Code.

33. Adjudicatory Hearing.

Parties affected by an Executive Officer's determination may file for an adjudicatory hearing pursuant to Subchapter 1.25, Title 17, California Code of Regulations. The provisions of Subchapter 1.25, Title 17, California Code of Regulations, apply fully to filings made under these provisions.

Part II. Spark-Ignition Marine Engines - Determination of Deterioration Factors.

34. Definitions.

The definitions in Part I, section 2 apply to this Part.

35. Acronyms and Abbreviations.

The acronyms and abbreviations in Part I, section 3 apply to this Part.

36. Deterioration Factor.

(a) The manufacturer must determine the deterioration factor for each engine family and pollutant based on good engineering judgment and/or test data. For personal watercraft and outboard spark-ignition marine engines, this deterioration factor must be based on the designated useful life of the engine family. For inboard and sterndrive spark-ignition marine engines, the deterioration factor must be based on a designated test period of 480 hours.

(b) For SI marine engines not utilizing aftertreatment technology (e.g., catalytic converters, exhaust gas recirculation), the sum of the exhaust emission results from each test engine added to the deterioration factor is the emissions certification value for that engine family and pollutant. If the deterioration factor is less than zero, it is considered zero for the purposes of this Part.

(c) For SI marine engines utilizing aftertreatment technology (e.g., catalytic converters, exhaust gas recirculation), the product of the exhaust emission results from each test engine multiplied by the deterioration factor is the emissions certification value for that engine family and pollutant. If the deterioration factor is less than one, it is considered to be one for the purposes of this Part.

(d) For SI sterndrive/inboard engines greater than 373 kilowatts, manufacturers have the option to use an ARB-assigned deterioration factor. Use of this option must be indicated in the manufacturer's application for certification.

Part III. Emission Test Equipment Provisions.

37. Scope; Applicability.

(a) This Part describes the equipment required to perform exhaust emission tests on new spark-ignition marine engines subject to the provisions of Part I, section 1.

(b) Exhaust gases are sampled while the test engine is operated using a steady state test cycle on an engine dynamometer. Exhaust gas sampling may be performed using either the raw gas sampling method or the constant volume sampling (CVS) method. The exhaust gases receive specific component analysis determining concentration of pollutants, exhaust volume, temperature, the fuel flow, and the power output during each mode. Emissions are reported on a gram per brake-kilowatt hour (g/kW-hr). See Part IV for a complete description of the test procedure.

38. Definitions.

The definitions in Part I, section 2 apply to this Part.

39. Acronyms and Abbreviations.

The acronyms and abbreviations in Part I, section 3 apply to this Part.

40. Test Equipment Overview.

(a) All engines subject to this Part are tested for exhaust emissions. Engines are operated on dynamometers meeting the specification given in section 5.

(b) The exhaust is tested for gaseous emissions using either a constant volume sampling (CVS) system as described in Part IV, section 14, or using the raw gas sampling system as described in Part IV, section 21. Both systems require analyzers (see paragraph (c) of this section) specific to the pollutant being measured.

(c) Analyzers used are a non-dispersive infrared detector (NDIR) absorption type for carbon monoxide and carbon dioxide analysis; paramagnetic detector (PMD), zirconia (ZRDO), or electrochemical type (ECS) for oxygen analysis; a flame ionization detector (FID) or heated flame ionization detector (HFID) type for hydrocarbon analysis; and a chemiluminescent detector (CLD) or heated chemiluminescent detector (HCLD) for oxides of nitrogen analysis.

41. Dynamometer Specifications and Calibration Accuracy.

(a) Dynamometer specifications.

(1) The dynamometer test stand and other instruments for measurement of engine speed and torque must meet the accuracy requirements shown in Table 1

in Appendix A to this Part. The dynamometer must be capable of performing the test cycle described in Part I, section 20.

(b) Dynamometer calibration accuracy.

(1) The dynamometer test stand and other instruments for measurement of engine torque and speed must meet the calibration frequency shown in Table 1 in Appendix A to this Part.

(2) A minimum of three calibration weights for each range used is required. The weights must be equally spaced and traceable to within 0.5 percent of National Institute of Standards and Testing (NIST) weights. Laboratories located in foreign countries may certify calibration weights to local government bureau standards.

42. Dynamometer Torque Cell Calibration.

(a) (1) Any lever arm used to convert a weight or a force through a distance into a torque must be used in a horizontal position for horizontal shaft dynamometers (± five degrees). For vertical shaft dynamometers, a pulley system may be used to convert the dynamometer's horizontal loading into the vertical plane.

(2) Calculate the indicated torque (IT) for each calibration weight to be used by:

IT = Moment Arm (meters) X Calibration Weight (Newtons)

(3) Attach each calibration weight specified in Part III, section 5(b)(2) to the moment arm at the calibration distance determined in paragraph (a)(2) of this section. Record the power measurement equipment response (N-m) to each weight.

(4) Compare the torque value measured to the calculated torque.

(5) The measured torque must be within two percent of the calculated torque.

(6) If the measured torque is not within two percent of the calculated torque, adjust or repair the system. Repeat steps in paragraphs (a)(1) through (a)(6) of this section with the adjusted or repaired system.

(b) Option. A master load-cell or transfer standard may be used to verify the torque measurement system.

(1) The master load-cell and read out system must be calibrated with weights specified in Part III, section 5(b)(2).

(2) Attach the master load-cell and loading system.

(3) Load the dynamometer to a minimum of three equally spaced torque values as indicated by the master load-cell for each in-use range used.

~~(3)~~
(4) The in-use torque measurement must be within two percent of the torque measured by the master system for each load used.

(5) If the in-use torque is not within two percent of the master torque, adjust or repair the system. Repeat steps in paragraphs (b)(2) through (b)(4) of this section with the adjusted or repaired system.

(c) Calibrated resistors may not be used for dynamometer torque transducer calibration, but may be used to span the transducer before engine testing.

(d) Other engine dynamometer system calibrations such as speed are performed as specified by the dynamometer manufacturer or as dictated by good engineering practice.

43. Engine Cooling System.

An engine cooling system is required with sufficient capacity to maintain the engine at normal operating temperatures as prescribed by the engine manufacturer. Auxiliary fan(s) may be used to maintain sufficient engine cooling during dynamometer operation.

44. Lubricating Oil and Test Fuel.

(a) Lubricating oil.

(1) Use the engine lubricating oil which meets the engine manufacturer's requirements for a particular engine and intended usage. Record the specifications of the lubricating oil used for service accumulation and the certification test.

(2) For two-stroke engines, the fuel/oil mixture ratio must be that which is recommended by the manufacturer. If the flow rate of the oil in the engine is greater than two percent of the fuel flow rate, then the oil supplied to the engine must be added to the fuel flow in the emission calculations described in Part IV, section 19 and section 26. Good engineering judgment may be used to estimate oil flow when oil injection is used.

(b) Test fuels – certification.

(1) Petroleum-based fuels. The manufacturer must use gasoline having the specifications or substantially equivalent specifications approved by the Executive Officer, as specified in Table 8-1 below for exhaust emission testing of

gasoline fueled engines. As an alternative, the manufacturer may use the fuel specifications as outlined in the California Code of Regulations, Title 13, section 1960.1, and the latest amendment of the "California Exhaust Emission Standards and Test Procedures for 1988 and Subsequent Model Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles," incorporated herein by reference. The test fuel specification in either case should remain consistent from batch to batch. The specification range of the fuel to be used under this paragraph must be reported in accordance with Part I, section 14(b)(2)~~(vi)~~(F).

Table 8-1
Test Fuel Specifications

Item	Property	Tolerance	Procedure (ASTM)[1]
Sulfur, ppm max.	1000	—	D 2622
Benzene, max. percent	1.5	—	D 3606
RVP, psi	8.6	±0.6	D 323
Octane, R+M/2	89.9	±3.1	D 2699 D 2700
IBP, ℃	32.8	±11.0	D 86
10% point, ℃	53.3	±5.5	D 86
50% point, ℃	101.7	±8.3	D 86
90% point, ℃	160.0	±11.1	D 86
End Point, max. ℃	212.8	—	D 86
Phosphorus, g/l, max.	0.02	—	D 3231
Lead, g/l, max.	0.02	—	—
Manganese, g/l, max.	0.004	—	—
Aromatics, max. percent	35	—	D 1319
Olefins, max. percent	10	—	D 1319
Saturates, percent	remainder	—	D 1319

1. All ASTM Procedures in this table have been incorporated by reference.

(2) Alcohol-based fuels. Alcohol-based fuels must be allowed for emission test purposes when the appropriate emission standards with respect to such fuels are a part of these provisions. Such fuels must be as specified in paragraph (b)(1) above.

(c) Test fuels – service accumulation.

(1)(A) Gasoline. Unleaded gasoline representative of commercial gasoline which will be generally available through retail outlets must be used in service accumulation for spark-ignition marine engines. As an alternative, the certification test fuels specified under paragraph (b) of this section for engine service accumulation. Leaded fuel may not be used during service accumulation.

(B) The octane rating of the gasoline used may not be higher than 4.0 research octane numbers above the minimum recommended by the manufacturer and have a minimum sensitivity of 7.5 octane numbers, where sensitivity is defined as research octane number minus motor octane number.

(C) The Reid Vapor Pressure of a gasoline must be characteristic of the engine fuel during the season in which the service accumulation takes place in the outdoors, or must be characteristic of the engine fuel appropriately suited to the ambient conditions of an indoor test cell in which the entire service accumulation takes place.

(2) Alternative fuels.

(A) Liquefied petroleum gas meeting the ASTM D1835 or NGPA HD-5 specifications must be used for service accumulation.

(B) Natural gas representative of commercial natural gas that will be generally available through retail outlets must be used in service accumulation.

(d) Other fuels may be used for testing provided:

(1) They are commercially viable,

(2) Information, acceptable to the Executive Officer, is provided to show that only the designated fuel would be used in customer service;

(3) Use of a fuel listed under paragraph (b) of this section would have a detrimental effect on emissions or durability; and

(4) The Executive Officer provides written approval of the fuel specifications before the start of testing.

45. Engine Intake Air Temperature Measurement.

(a) Engine intake air temperature measurement must be made within 100 cm of the air-intake of the engine. The measurement location must be either in the supply system or in the air stream entering the engine.

(b) The temperature measurements must be accurate to within ± 2 degrees Celsius.

46. Engine Intake Air Humidity Measurement.

This section refers to engines which are supplied with intake air other than the ambient air in the test cell (i.e., air which has been plumbed directly to the engine air intake system). For engines which use ambient test cell air for the engine intake air, the ambient test cell humidity measurement may be used.

(a) Humidity conditioned air supply. Air that has had its absolute humidity altered is considered humidity-conditioned air. For this type of intake air supply, the humidity measurements must be made within the intake air supply system, and after the humidity conditioning has taken place.

(b) Unconditioned air supply. Humidity measurements in unconditioned intake air supply must be made in the intake air stream entering the engine. Alternatively, the humidity measurements can be measured within the intake air stream entering the supply system.

47. Test Conditions.

(a) General requirements.

(1) Ambient temperature levels encountered by the test engine throughout the test sequence may not be less than 20 degrees Celsius nor more than 30 degrees Celsius.

(2) Calculate all volumes and volumetric flow rates at standard conditions for temperature and pressure. Use these conditions consistently throughout all calculations. Standard conditions for temperature and pressure are 25 degrees Celsius and 101.3 kilopascals.

(b) Engine test conditions. Measure the absolute temperature (designated as T and expressed in degrees Kelvin) of the engine air at the inlet to the engine and the dry atmospheric pressure (designated as p_s and expressed in kilopascals. Determine the parameter *f* according to the following provisions:

(1) Naturally aspirated and mechanically supercharged engines:

$$f = \frac{99}{P_s} x \left(\frac{T}{298} \right)^{0.7}$$

(2) Turbocharged engine with or without cooling of inlet air:

$$f = \left(\frac{99}{P_s} \right)^{0.7} x \left(\frac{T}{298} \right)^{1.5}$$

(3) For a test to be recognized as valid, the parameter *f* must be between the limits as shown below:

$$0.96 < f < 1.04$$

48. Analytical Gases.

(a) The shelf life of a calibration gas may not be exceeded. Record the expiration date stated by the gas supplier for each calibration gas.

(b) Pure gases. The required purity of the gases is defined by the contamination limits given in parenthesis. The following gases must be available for operation.

(1) Purified nitrogen, also referred to as "zero-grade nitrogen"
(Contamination < 1 ppm C, < 1 ppm CO, < 400 ppm CO_2, < 0.1 ppm NO)

(2) Purified oxygen (Purity 99.5 percent vol O_2)

(3) Hydrogen-helium mixture (40 ± 2 percent hydrogen, balance helium)
(Contamination < 1 ppm C, < 400 ppm CO)

(4) Purified synthetic air, also referred to as "zero gas"
(Contamination < 1 ppm C, < 1 ppm CO, < 400 ppm CO_2, < 0.1 ppm NO)
(Oxygen content between 18-21 percent vol.)

(c) Calibration and span gases.

(1) Calibration gas values are to be derived from NIST "Standard Reference Materials" (SRM's) or other local gas standards and are to be single blends as specified in this subsection.

(2) Mixtures of gases having the following chemical compositions must be available:

C_3H_8 and purified synthetic air (dilute measurements); C_3H_8 and purified nitrogen (raw measurements); CO and purified nitrogen; NO_x and purified nitrogen (the amount of NO_2 contained in this calibration gas must not exceed five percent of the NO content); CO_2 and purified nitrogen.

Note: For the HFID or FID, the manufacturer may choose to use as a diluent span gas and the calibration gas either purified synthetic air or purified nitrogen. Any mixture of C_3H_8 and purified synthetic air which contains a concentration of propane higher than what a gas supplier considers to be safe may be substituted with a mixture of 8 C_3H_8 and purified nitrogen. However, the manufacturer must be consistent in the choice of diluent (zero air or purified nitrogen) between the calibration and span gases. If a manufacturer chooses to use C_3H_8 and purified nitrogen for the calibration gases, then purified nitrogen must be the diluent for the span gases.

(3) The true concentration of a span gas must be within ± two percent of the NIST gas standard. The true concentration of a calibration gas must be within ± one percent of the NIST gas standard. The use of precision blending devices (gas dividers) to obtain the required calibration gas concentrations is acceptable. Give all concentrations of calibration gas on a volume basis (volume percent or volume ppm).

(4) The gas concentrations used for calibration and span may also be obtained by means of a gas divider, diluting with purified N_2 or with purified synthetic air. The accuracy of the mixing device must be such that the concentration of the diluted gases may be determined to within ± two percent.

(d) Oxygen interference check gases must contain propane with 350 ppmC ± 75 ppmC hydrocarbon. Determine the concentration value to calibration gas tolerances by chromatographic analysis of total hydrocarbons plus impurities or by dynamic blending. Use nitrogen as the predominant diluent with the balance oxygen.

(e) Fuel for the hydrocarbon flame ionization detector (HC-FID) must be a blend of 40 ± 2 percent hydrogen with the balance being helium. The mixture shall contain less than one ppm equivalent carbon response; 98 to 100 percent hydrogen fuel may be used with advance approval of the Executive Officer.

(f) Hydrocarbon analyzer burner air. The concentration of oxygen must be within one mole percent of the oxygen concentration of the burner air used in the latest oxygen interference check (percent O_2I), see Part III, section 16(d). If the difference in oxygen concentration is greater than one mole percent, then the oxygen interference must be checked and the analyzer adjusted if necessary, to meet the percent O_2I requirements. The burner air must contain less than two ppmC hydrocarbon.

49. Analyzers Required.

(a) Analyzers. Analyze measured gases with the following instruments:

(1) Carbon monoxide (CO) analysis.

~~(i)~~(A) The carbon monoxide analyzer must be of the non-dispersive infrared (NDIR) absorption type.

~~(ii)~~(B) The use of linearizing circuits is permitted.

(2) Carbon dioxide (CO_2) analysis.

~~(i)~~(A) The carbon dioxide analyzer must be of the non-dispersive infrared (NDIR) absorption type.

~~(ii)~~(B) The use of linearizing circuits is permitted.

(3) Oxygen (O_2) analysis. Oxygen (O_2) analyzers may be of the paramagnetic (PMD), zirconia (ZRDO) or electrochemical type (ECS).

(4) Hydrocarbon (HC) analysis.

~~(i)~~(A) For Raw Gas Sampling, the hydrocarbon analyzer must be of the heated flame ionization (HFID) type. For constant volume sampling, the hydrocarbon analyzer may be of the flame ionization (FID) type or of the heated flame ionization (HFID) type.

~~(ii)~~(B) For the HFID system, if the temperature of the exhaust gas at the sample probe is below 190 degrees Celsius, the temperature of the valves, pipe work, and so forth, must be controlled so as to maintain a wall temperature of 190 degrees Celsius ± 11 degrees Celsius. If the temperature of the exhaust gas at the sample probe is above 190 degrees Celsius, the temperature of the valves, pipe work, and so forth, must be controlled so as to maintain a wall temperature greater than 180 degrees Celsius.

~~(iii)~~(C) For the HFID analyzer, the detector, oven, and sample handling components within the oven must be suitable for continuous operation at temperatures to 200 degrees Celsius. It must by capable of maintaining temperature within ± 5.5 degrees Celsius of the set point.

~~(iv)~~(D) Fuel and burner air must conform to the specifications in Part III, section 12.

~~(v)~~(E) The percent of oxygen interference must be less than three percent, as specified in Part III, section 16(d).

(5) Oxides of nitrogen (NO_X) analysis.

~~(i)~~(A) This analysis device consists of the following items:

~~(A)~~(i) A NO_2 to NO converter. The NO_2 to NO converter efficiency must be at least 90 percent.

~~(B)~~(ii) An ice bath located after the NO_X converter (optional).

~~(C)~~(iii) A chemiluminescent detector (CLD) or heated chemiluminescent detector (HCLD).

~~(ii)~~(B) The quench interference must be less than three percent as measured in Part III, section 25.

(b) Other gas analyzers yielding equivalent results may be used with advance approval of the Executive Officer.

(c) The following requirements must be incorporated as indicated in systems used for testing under this Part.

(1)Carbon monoxide and carbon dioxide measurements must be made on a dry basis (for raw exhaust measurement only). Specific requirements for the means of drying the sample can be found in section 13(e).

(2) Calibration or span gases for the NO_X measurement system must pass through the NO_2 to NO converter.

(d) The electromagnetic compatibility (EMC) of the equipment must be on a level as to minimize additional errors.

(e) Gas drying. Chemical dryers are not an acceptable method of removing water from the sample. Water removal by condensation is acceptable. If water is removed by condensation, the sample gas temperature or sample dew point must be monitored either within the water trap or downstream and its temperature must not exceed 7 degrees Celsius. A water trap performing this function is an acceptable method. Means other than condensation may be used only with prior approval from the Executive Officer.

50. Analyzer Accuracy and Specifications.

(a) Measurement accuracy – general. The analyzers must have a measuring range which allows them to measure the concentrations of the exhaust gas sample pollutants with the accuracies shown in Table 1 in Appendix A to this Part.

(1) Precision. The precision of the analyzer must be, at worst, ± one percent of full-scale concentration for each range used. The precision is defined as 2.5 times the standard deviation(s) of 10 repetitive responses to a given calibration or span gas.

(2) Noise. The analyzer peak-to-peak response to zero and calibration or span gases over any 10-second period may not exceed two percent of full-scale chart deflection on all ranges used.

(3) Zero drift. The analyzer zero-response drift during a one-hour period must be less than two percent of full-scale chart deflection on the lowest range used. The zero-response is defined as the mean response including noise to a zero-gas during a 30-second time interval.

(4) Span drift. The analyzer span drift during a one-hour period must be less than two percent of full-scale chart deflection on the lowest range used. The analyzer span is defined as the difference between the span-response and the zero-response. The span-response is defined as the mean response including noise to a span gas during a 30-second time interval.

(b) Operating procedure for analyzers and sampling system. Follow the start-up and operating instructions of the instrument manufacturer. Adhere to the minimum requirements given in Part III, sections 16 through 25 and Part IV, section 9.

(c) Emission measurement accuracy – Bag sampling.

(1) Good engineering practice dictates that exhaust emission sample analyzer readings below 15 percent of full scale chart deflection should generally not be used.

(2) Some high resolution read-out systems, such as computers, data loggers, and so forth, can provide sufficient accuracy and resolution below 15 percent of full scale. Such systems may be used provided that additional calibrations are made to ensure the accuracy of the calibration curves. The following procedure for calibration below 15 percent of full scale may be used:

Note: If a gas divider is used, the gas divider must conform to the accuracy requirements as follows: The use of precision blending devices (gas dividers) to obtain the required calibration gas concentrations is acceptable, provided that the blended gases are accurate to within ± 1.5 percent of NIST gas standards or

other gas standards which have been approved by the Executive Officer. This accuracy implies that primary gases used for blending must be "named" to an accuracy of at least ± 1 percent, traceable to NIST or other approved gas standards.

~~(i)~~(A) Span the full analyzer range using a top range calibration gas. The span gases must be accurate to within ± 2 percent of NIST gas standards or other gas standards which have been approved by the Executive Officer.

~~(ii)~~(B) Generate a calibration curve according to, and meeting the requirements of the sections describing analyzer calibrations which are found in sections 16, 17, 18, and 20 of this Part.

~~(iii)~~(C) Select a calibration gas (a span gas may be used for calibrating the CO_2 analyzer) with a concentration between the two lowest non-zero gas divider increments. This gas must be "named" to an accuracy of ± 2 percent of NIST gas standards, or other standards approved by the Executive Officer.

~~(iv)~~(D) Using the calibration curve fitted to the points generated in paragraphs (c)(2)~~(i)~~(A) and ~~(ii)~~(B) of this section, check the concentration of the gas selected in paragraph (c)(2)~~(iii)~~(C) of this section. The concentration derived from the curve must be within ± 2.3 percent (± 2.8 percent for CO_2 span gas) of the gas' original named concentration.

~~(v)~~(E) Provided the requirements of paragraph (c)(2)~~(iv)~~(D) of this section are met, use the gas divider with the gas selected in paragraph (c)(2)~~(iii)~~(C) of this section and determine the remainder of the calibration points. Fit a calibration curve per sections 16, 17, 18, and 20 of this chapter for the entire analyzer range.

(d) Emission measurement accuracy – continuous sampling. Analyzers used for continuous analysis must be operated such that the measured concentration falls between 15 and 100 percent of full scale chart deflection. Exceptions to these limits are:

(1) The analyzer's response may be less than 15 percent or more than 100 percent of full scale if automatic range change circuitry is used and the limits for range changes are between 15 and 100 percent of full scale chart deflection;

(2) The analyzer's response may be less than 15 percent of full scale if:

~~(i)~~(A) Alternative in paragraph (c)(2) of this section is used to ensure that the accuracy of the calibration curve is maintained below 15 percent; or

~~(ii)~~(B) The full scale value of the range is 155 ppmC or less; or

~~(iii)~~(C) The emissions from the engine are erratic and the integrated chart deflection value for the cycle is greater than 15 percent of full scale; or

~~(iv)~~(D) The contribution of all data read below the 15 percent level is less than 10 percent by mass of the final test results.

51. Analyzer Initial Calibration.

(a) Warming-up time. Follow the warm-up time according to the recommendations of the manufacturer. If not specified, a minimum of two hours should be allowed for warming up the analyzers.

(b) NDIR and HFID analyzer. Tune and maintain the NDIR analyzer per the instrument manufacturer recommendations. The combustion flame of the HFID analyzer must be optimized in order to meet the specifications in Part III, section 16(b).

(c) Zero setting and calibration. Using purified synthetic air (or nitrogen), set the CO, CO_2, NO_X and HC analyzers at zero. Connect the appropriate calibrating gases to the analyzers and record the values. The same gas flow rates shall be used as when sampling exhaust.

(d) Rechecking of zero setting. Recheck the zero setting and, if necessary, repeat the procedure described in paragraph (c) of this section.

52. Hydrocarbon Analyzer Calibration.

(a) Calibrate the FID and HFID hydrocarbon analyzer as described in this section. Operate the HFID to a set point ± 5.5 degrees Celsius between 185 and 197 degrees Celsius.

(b) Initial and periodic optimization of detector response. Prior to introduction into service and at least annually thereafter, adjust the FID and HFID hydrocarbon analyzer for optimum hydrocarbon response as specified by this paragraph. Alternative methods yielding equivalent results may be used, if approved in advance by the Executive Officer.

(1) Follow good engineering practices for initial instrument startup and basic operating adjustment using the appropriate fuel (see Part III, section 12) and purified synthetic air or zero-grade nitrogen.

(2) One of the following procedures is required for FID or HFID optimization:

~~(i)~~(A) The procedure outlined in Society of Automotive Engineers (SAE) paper No. 770141, "Optimization of Flame Ionization Detector for Determination of Hydrocarbons in Diluted Automobile Exhaust"; author, Glenn D. Reschke. This procedure has been incorporated by reference.

~~(ii)~~(B) The HFID optimization procedures outlined in Title 40, Code of Federal Regulations, section 86.331-79 [July 1, 1997], incorporated herein by reference.

~~(iii)~~(C) Alternative procedures may be used if approved in advance by the Executive Officer.

(3) After the optimum flow rates have been determined, they are recorded for future reference.

(c) Initial and periodic calibration. Prior to introduction into service and monthly thereafter, or within one month before the certification test, calibrate the FID or HFID hydrocarbon analyzer on all normally used instrument ranges, using the steps in this paragraph. Use the same flow rate and pressures as when analyzing samples. Introduce calibration gases directly at the analyzer.

(1) Adjust analyzer to optimize performance.

(2) Zero the hydrocarbon analyzer with purified synthetic air or zero-grade nitrogen.

(3) Calibrate on each used operating range with calibration gases having nominal concentrations between 10 and 90 percent of that range. A minimum of six evenly spaced points covering at least 80 percent of the 10 to 90 percent range (64 percent) is required (see following table).

Example calibration points	Acceptable for calibration?
20, 30, 40, 50, 60, 70	No, range covered is 50 percent, not 64 percent.
20, 30, 40, 50, 60, 70, 80, 90	Yes.
10, 25, 40, 55, 70, 85	Yes.
10, 30, 50, 70, 90	No, though equally spaced and entire range covered, a minimum of six points is needed.

(4) For each range calibrated, if the deviation from a least squares best-fit straight line is two percent or less of the value at each data point, calculate concentration values by use of a single calibration factor for that range. If the deviation exceeds two percent at any point, use the best-fit non-linear equation which represents the data to within two percent of each test point to determine concentration.

(d) Oxygen interference optimization. Choose a range where the oxygen interference check gases will fall in the upper 50 percent. Conduct the test, as outlined in this paragraph, with the oven temperature set as required by the instrument manufacturer. Oxygen interference check gas specifications are found in Part III, section 12(d).

(1) Zero the analyzer.

(2) Span the analyzer with the 21 percent oxygen blend.

(3) Recheck zero response. If it has changed more than 0.5 percent of full scale repeat paragraphs (d)(1) and (d)(2) of this section to correct the problem.

(4) Introduce the five percent and 10 percent oxygen interference check gases.

(5) Recheck the zero response. If it has changed more than ± one percent of full scale, repeat the test.

(6) Calculate the percent of oxygen interference (designated as percent O_2I) for each mixture in paragraph (d)(4) of this section according to the following equation:

$$percent\ O_2I = \frac{B\ Analyzer\ response\ (ppmC)}{B} x(100)$$

Where:

$$analyzer\ response = \left(\frac{A}{\%\ of\ fullscale\ analyzer\ response\ (A)} \right) x\ (\%\ of\ fullscale\ analyzer\ response\ (B))$$

A = hydrocarbon concentration (ppmC) of the span gas used in paragraph (d)(2) of this section.

B = hydrocarbon concentration (ppmC) of the oxygen interference check gases used in paragraph (d)(4) of this section.

(7) The percent of oxygen interference (designated as percent O_2I) must be less than ± three percent for all required oxygen interference check gases before testing.

(8) If the oxygen interference is greater than the specifications, incrementally adjust the air flow above and below the manufacturer's specifications, repeating paragraphs (d)(1) through (d)(7) of this section for each flow.

(9) If the oxygen interference is greater than the specification after adjusting the air flow, vary the fuel flow and thereafter the sample flow, repeating paragraphs (d)(1) through (d)(7) of this section for each new setting.

(10) If the oxygen interference is still greater than the specifications, repair or replace the analyzer, FID fuel, or burner air before testing. Repeat this section with the repaired or replaced equipment or gases.

53. Carbon Monoxide Analyzer Calibration.

(a) Calibrate the NDIR carbon monoxide analyzer described in this section.

(b) Initial and periodic interference check. Prior to its introduction into service and annually thereafter, check the NDIR carbon monoxide analyzer for response to water vapor and CO_2:

(1) Follow good engineering practices for instrument start-up and operation. Adjust the analyzer to optimize performance on the most sensitive range to be used.

(2) Zero the carbon monoxide analyzer with either purified synthetic air or zero-grade nitrogen.

(3) Bubble a mixture of three percent CO_2 in N_2 through water at room temperature and record analyzer response.

(4) An analyzer response of more than one percent of full scale for ranges above 300 ppm full scale or more than three ppm on ranges below 300 ppm full scale requires corrective action. (Use of conditioning columns is one form of corrective action which may be taken.)

(c) Initial and periodic calibration. Calibrate the NDIR carbon monoxide analyzer before its introduction into service and monthly thereafter.

(1) Adjust the analyzer to optimize performance.

(2) Zero the carbon monoxide analyzer with either purified synthetic air or zero-grade nitrogen.

(3) Calibrate on each normally used operating range with carbon monoxide-in-N_2 calibration gases having nominal concentrations between 10 and 90 percent of that range. A minimum of six evenly spaced points covering at least 80 percent of the 10 to 90 range (64 percent) is required (see following table).

Example calibration points	Acceptable for calibration?
20, 30, 40, 50, 60, 70	No, range covered is 50 percent, not 64 percent.
20, 30, 40, 50, 60, 70, 80, 90	Yes.
10, 25, 40, 55, 70, 85	Yes.
10, 30, 50, 70, 90	No, though equally spaced and entire range covered, a minimum of six points is needed.

(4) Additional calibration points may be generated. For each range calibrated, if the deviation from a least-squares best-fit straight line is two percent or less of the value at each data point, concentration values may be calculated by use of a single calibration factor for that range. If the deviation exceeds two percent at any point, use the best-fit non-linear equation which represents the data to within two percent of each test point to determine concentration.

54. Oxides of Nitrogen Analyzer Calibration.

(a) Calibrate the chemiluminescent oxides of nitrogen analyzer as described in this section.

(b) Initial and periodic interference. Prior to its introduction into service, and monthly thereafter, check the chemiluminescent oxides of nitrogen analyzer for NO_2 to NO converter efficiency. Figure 2 in Appendix B of this Part is a reference for the following paragraphs:

(1) Follow good engineering practices for instrument start-up and operation. Adjust the analyzer to optimize performance.

(2) Zero the oxides of nitrogen analyzer with purified synthetic air or zero-grade nitrogen.

(3) Connect the outlet of the NO_X generator to the sample inlet of the oxides of nitrogen analyzer which has been set to the most common operating range.

(4) Introduce into the NO_X generator analyzer-system an NO-in-nitrogen (N_2) mixture with an NO concentration equal to approximately 80 percent of the most common operating range. The NO_2 content of the gas mixture must be less than 5 percent of the NO concentration.

(5) With the oxides of nitrogen analyzer in the NO mode, record the concentration of NO indicated by the analyzer.

(6) Turn on the NO_X generator O_2 (or air) supply and adjust the O_2 (or air) flow rate so that the NO indicated by the analyzer is about 10 percent less than indicated in paragraph (b)(5) of this section. Record the concentration of NO in this $NO+O_2$ mixture as value "c."

(7) Switch the NO_X generator to the generation mode and adjust the generation rate so that the NO measured on the analyzer is 20 percent of that measured in paragraph (b)(5) of this section. There must be at least 10 percent unreacted NO at this point. Record the concentration of residual NO as value "d."

(8) Switch the oxides of nitrogen analyzer to the NO_X mode and measure total NO_X. Record this value as "a."

(9) Switch off the NO_X generator but maintain gas flow through the system. The oxides of nitrogen analyzer will indicate the NO_X in the $NO+O_2$ mixture. Record this value as "b."

(10) Turn off the NO_X generator O_2 (or air) supply. The analyzer will now indicate the NO_X in the original NO-in-N_2 mixture. This value should be no more than 5 percent above the value indicated in paragraph (b)(4) of this section.

(11) Calculate the efficiency of the NO_X converter by substituting the concentrations obtained into the following equation:

Where:

$$percent\ efficiency = \left(1 + \frac{ab}{cd}\right) x\,100$$

a = concentration obtained in paragraph (b)(8) of this section,

b = concentration obtained in paragraph (b)(9) of this section,

c = concentration obtained in paragraph (b)(6) of this section,

d = concentration obtained in paragraph (b)(7) of this section.

(c) Initial and periodic calibration. Prior to its introduction into service, and monthly thereafter, calibrate the chemiluminescent oxides of nitrogen analyzer on all normally used instrument ranges. Use the same flow rate as when analyzing samples. Proceed as follows:

(1) Adjust analyzer to optimize performance.

(2) Zero the oxides of nitrogen analyzer with zero-grade air or zero-grade nitrogen.

(3) Calibrate on each normally used operating range with NO-in-N_2 calibration gases with nominal concentrations between 10 and 90 percent of that range. A minimum of six evenly spaced points covering at least 80 percent of the 10 to 90 percent range (64 percent) is required (see following table).

Example calibration points	Acceptable for calibration?
20, 30, 40, 50, 60, 70	No, range covered is 50 percent, not 64 percent.
20, 30, 40, 50, 60, 70, 80, 90	Yes.
10, 25, 40, 55, 70, 85	Yes.
10, 30, 50, 70, 90	No, though equally spaced and entire range covered, a minimum of six points is needed.

(4) Additional calibration points may be generated. For each range calibrated, if the deviation from a least-squares best-fit straight line is two percent or less of the value at each data point, concentration values may be calculated by use of a single calibration factor for that range. If the deviation exceeds two percent at any point, use the best-fit non-linear equation which represents the data to within two percent of each test point to determine concentration.

55. NO_X Converter Check.

(a) The efficiency of the converter used for the conversion of NO_2 to NO is tested as given in paragraphs (a)(1) through (a)(8) of this section (see Figure 2 in Appendix B to this Part).

(1) Using the test setup as shown in Figure 2 in Appendix B to this Part (see also Part III, section 18 of this chapter) and the procedures described in paragraphs

(a)(2) through (a)(8) of this section, test the efficiency of converters by means of an ozonator.

(2) Calibrate the HCLD in the most common operating range following the manufacturer's specifications using zero and span gas (the NO content of which must amount to about 80 percent of the operating range and the NO_2 concentration of the gas mixture less than five percent of the NO concentration). The NO_X analyzer must be in the NO mode so that the span gas does not pass through the converter. Record the indicated concentration.

(3) Calculate the efficiency of the NO_X converter as described in Part III, section 18(b).

(4) Via a T-fitting, add oxygen continuously to the gas flow until the concentration indicated is about 20 percent less than the indicated calibration concentration given in paragraph (a)(2) of this section. Record the indicated concentration as "c." The ozonator is kept deactivated throughout the process.

(5) Activate the ozonator to generate enough ozone to bring the NO concentration down to about 20 percent (minimum 10 percent) of the calibration concentration given in paragraph (a)(2) of this section. Record the indicated concentration as "d." Note that if, with the analyzer in the most common range the NO_X converter cannot give a reduction from 80 percent to 20 percent, then use the highest range which will give the reduction.

(6) Switch the NO analyzer to the NO_X mode, which means that the gas mixture (consisting of NO, NO_2, O_2 and N_2) now passes through the converter. Record the indicated concentration as "a."

(7) Deactivate the ozonator. The mixture of gases described in paragraph (a)(6) of this section passes through the converter into the detector. Record the indicated concentration as "b."

(8) Switched to NO mode with the ozonator deactivated, the flow of oxygen or synthetic air is also shut off. The NO_X reading of the analyzer may not deviate by more than ± five percent of the theoretical value of the figure given in paragraph (a)(2) of this section.

(b) The efficiency of the converter must be tested before each calibration of the NO_X analyzer.

(c) The efficiency of the converter may not be less than 90 percent.

56. Carbon Dioxide Analyzer Calibration.

(a) Prior to its introduction into service, and monthly thereafter, or within one month before the certification test, calibrate the NDIR carbon dioxide analyzer as follows:

(1) Follow good engineering practices for instrument start-up and operation. Adjust the analyzer to optimize performance.

(2) Zero the carbon dioxide analyzer with either purified synthetic air or zero-grade nitrogen.

(3) Calibrate on each normally used operating range with carbon dioxide-in-N_2 calibration or span gases having nominal concentrations between 10 and 90 percent of that range. A minimum of six evenly spaced points covering at least 80 percent of the 10 to 90 percent range (64 percent) is required (see following table).

Example calibration points	Acceptable for calibration?
20, 30, 40, 50, 60, 70	No, range covered is 50 percent, not 64 percent.
20, 30, 40, 50, 60, 70, 80, 90	Yes.
10, 25, 40, 55, 70, 85	Yes.
10, 30, 50, 70, 90	No, though equally spaced and entire range covered, a minimum of six points is needed.

(4) Additional calibration points may be generated. For each range calibrated, if the deviation from a least-squares best-fit straight line is two percent or less of the value at each data point, concentration values may be calculated by use of a single calibration factor for that range. If the deviation exceeds two percent at any point, use the best-fit non-linear equation which represents the data to within two percent of each test point to determine concentration.

57. NDIR Analyzer Calibration.

(a) Detector optimization. If necessary, follow the manufacturer's instructions for initial start-up and basic operating adjustments.

(b) Calibration curve. Develop a calibration curve for each range used as follows:

(1) Zero the analyzer.

(2) Span the analyzer to give a response of approximately 90 percent of full-scale chart deflection.

(3) Recheck the zero response. If it has changed more than 0.5 percent of full scale, repeat the steps given in paragraphs (b)(1) and (b)(2) of this section.

(4) Record the response of calibration gases having nominal concentrations between 10 and 90 percent of full-scale concentration. A minimum of six evenly spaced points covering at least 80 percent of the 10 to 90 percent range (64 percent) is required (see following table).

Example calibration points	Acceptable for calibration?
20, 30, 40, 50, 60, 70	No, range covered is 50 percent, not 64 percent.
20, 30, 40, 50, 60, 70, 80, 90	Yes.
10, 25, 40, 55, 70, 85	Yes.
10, 30, 50, 70, 90	No, though equally spaced and entire range covered, a minimum of six points is needed.

(5) Generate a calibration curve. The calibration curve must be of fourth order or less, have five or fewer coefficients, and be of the form of equation ~~(1)~~(A) or ~~(2)~~(B). Include zero as a data point. Compensation for known impurities in the zero gas can be made to the zero-data point. The calibration curve must fit the data points within two percent of point or one percent of full scale, whichever is less.

(A) $$y = Ax^4 + Bx^3 + Cx^2 + Dx + E \quad (1)$$

(B) $$y = \frac{x}{Ax^4 + Bx^3 + Cx^2 + Dx + E} \quad (2)$$

y = concentration

x = chart deflection

(6) Option. A new calibration curve need not be generated if:

~~(i)~~(A) A calibration curve conforming to paragraph (b)(5) of this section exists;

~~(ii)~~(B) The responses generated in paragraph (b)(4) of this section are within one percent of full scale or two percent of point, whichever is less, of the responses

predicted by the calibration curve for the gases used in paragraph (b)(4) of this section.

(7) If multiple range analyzers are used, the lowest range used must meet the curve fit requirements below 15 percent of full scale.

(c) Linear calibration criteria. If any range is within two percent of being linear, a linear calibration may be used. To determine if this criterion is met:

(1) Perform a linear least-square regression on the data generated. Use an equation of the form y = mx, where x is the actual chart deflection and y is the concentration.

(2) Use the equation z = y/m to find the linear chart deflection (designated as z) for each calibration gas concentration (designated as y).

(3) Determine the linearity (designated as percent L) for each calibration gas by:

$$percent\ L = \frac{(zx)}{Full\ scale\ linear\ chart\ deflection}(100)$$

(4) The linearity criterion is met if the percent L is less than ± two percent for each data point generated. For each emission test, use a calibration curve of the form y = mx. The slope (designated as m) is defined for each range by the spanning process.

58. Calibration of Other Equipment.

Calibrate other test equipment as often as required by the test equipment manufacturer or as necessary according to good engineering practice.

59. Analyzer Bench Checks.

(a) Prior to initial use and after major repairs, verify that each analyzer complies with the specifications given in Table 1 to this Part.

(b) If a stainless steel NO_2 to NO converter is used, condition all new or replacement converters. The conditioning consists of either purging the converter with air for a minimum of four hours or until the converter efficiency is greater than 90 percent. The converter must be at operational temperature while purging. Do not use this procedure before checking converter efficiency on in-use converters.

60. Analyzer Leakage Check.

(a) Vacuum side leak check.

(1) Check any location within the analysis system where a vacuum leak could affect the test results.

(2) The maximum allowable leakage rate on the vacuum side is 0.5 percent of the in-use flow rate for the portion of the system being checked. The analyzer flows and bypass flows may be used to estimate the in-use flow rates.

(3) The sample probe and the connection between the sample probe and valve V2 (see Figure 1 in Appendix A of this Part) may be excluded from the leak check.

(4) Pressure side leak check. Substantial leaks of the sample on the pressure side of the system may impact sample integrity if the leaks are of sufficient magnitude. As a safety precaution, it is good engineering practice to perform periodic pressure side leak checks on the sampling system.

61. Analyzer Interference Checks.

(a) Gases present in the exhaust other than the one being analyzed can interfere with the reading in several ways. Positive interference occurs in NDIR and PMD instruments when the interfering gas gives the same effect as the gas being measured, but to a lesser degree. Negative interference occurs in NDIR instruments by the interfering gas broadening the absorption band of the measured gas, and in CLD instruments by the interfering gas quenching the radiation. The interference checks described in this section are to be made initially and after any major repairs that could affect analyzer performance.

(b) CO analyzer water and CO_2 interference checks. Bubble through water at room temperature a CO_2 span gas having a concentration of between 80 percent and 100 percent inclusive of full scale of the maximum operating range used during testing and record the analyzer response. For dry measurements, this mixture may be introduced into the sample system before the water trap. The analyzer response must not be more than one percent of full scale for ranges equal to or above 300 ppm or more than three ppm for ranges below 300 ppm.

(c) NO_X analyzer quench check. The two gases of concern for CLD (and HCLD) analyzers are CO_2 and water vapor. Quench responses to these two gases are proportional to their concentrations and, therefore, require test techniques to determine quench at the highest expected concentrations experienced during testing.

(1) NO_X analyzer CO_2 quench check.

~~(i)~~(A) Pass a CO_2 span gas having a concentration of 80 percent to 100 percent of full scale of the maximum operating range used during testing through the CO_2 NDIR analyzer and record the value as "a."

~~(ii)~~(B) Dilute the CO_2 span gas approximately 50 percent with NO span gas and pass through the CO_2 NDIR and CLD (or HCLD). Record the CO_2 and NO values as "b" and "c," respectively.

~~(iii)~~(C) Shut off the CO_2 and pass only the NO span gas through the CLD (or HCLD). Record the NO value recorded as "d."

~~(iv)~~(D) Calculate the percent CO_2 quench as follows, which may not exceed three percent:

$$percent\ CO_2\ quench = 100\ x\left(1 - \frac{(c\ x\ a)}{(d\ x\ a)(d\ x\ b)}\right) x\left(a/b\right)$$

Where:

a	=	Undiluted CO_2 concentration (percent)
b	=	Diluted CO_2 concentration (percent)
c	=	Diluted NO concentration (ppm)
d	=	Undiluted NO concentration (ppm)

(2) NO_X analyzer water quench check.

~~(i)~~(A) This check applies to wet measurements only. Pass an NO span gas having a concentration of 80 percent to 100 percent of full scale of a normal operating range through the CLD (or HCLD). Record the response as D. Bubble through water at room temperature the NO span gas and pass it through the CLD (or HCLD). Record the analyzers response as AR. Determine and record the analyzers absolute operating pressure and the bubbler water temperature. (It is important that the NO span gas contains minimal NO_2 concentration for this check. No allowance for absorption of NO_2 in water has been made in the following quench calculations.)

~~(ii)~~(B) Calculations for water quench must consider dilution of the NO span gas with water vapor and scaling of the water vapor concentration of the mixture to that expected during testing. Determine the mixture's saturated vapor pressure (designated as Pwb) that corresponds to the bubbler water temperature. Calculate the water concentration (Z1", percent) in the mixture by the following equation:

$$Z1 = 100\ x\left(Pwb/GP\right)$$

Where:

GP = the analyzer's standard operating pressure (pascals)

~~(iii)~~(C) Calculate the expected dilute NO span gas and water vapor mixture concentration (designated as "D1") by the following equation:

$$D1 = D\ x\left(1Z1/100\right)$$

62. Pre- and Post-test Analyzer Calibration.

Calibrate the operating range of each analyzer used during the test before and after each test in accordance with the following procedure (A chronic need for parameter adjustment can indicate a need for instrument maintenance.):

(a) Make the calibration using a zero gas and a span gas whose nominal value is between 80 percent and 100 percent of full scale, inclusive, of the measuring range.

(b) Use the same analyzer(s) flow rate and pressure as that used during exhaust emission test sampling.

(c) Warm-up and stabilize the analyzer(s) before the calibration is made.

(d) If necessary, clean and/or replace filter elements before calibration is made.

(e) Calibrate analyzer(s) as follows:

(1) Zero the analyzer using the appropriate zero gas. Adjust analyzer zero if necessary. Zero reading should be stable.

(2) Span the analyzer using the appropriate span gas for the range being calibrated. Adjust the analyzer to the calibration set point if necessary.

(3) Recheck zero and span set points.

(4) If the response of the zero gas or span gas differs more than one percent of full scale, then repeat paragraphs (e)(1) through (3) of this section.

63. Sampling System Requirements.

(a) Sample component surface temperature. For sampling systems which use heated components, use engineering judgment to locate the coolest portion of each component (pump, sample line section, filters, and so forth) in the heated portion of the sampling system that has a separate source of power or heating element. Monitor the temperature at that location. If several components are within an oven, then only the surface temperature of the component with the largest thermal mass and the oven temperature need be measured.

(b) If water is removed by condensation, monitor the sample gas temperature or sample dew point either within the water trap or downstream. It may not exceed 7 degrees Celsius.

64. Measurement Equipment Accuracy/Calibration Frequency Table.

(a) The accuracy of measurements must be such that the maximum tolerances shown in Table 1 in Appendix A to this Part are not exceeded.

(b) Calibrate all equipment and analyzers according to the frequencies shown in Table 1 in Appendix A to this Part.

(c) Prior to initial use and after major repairs, bench check each analyzer (see Part III, section 23).

(d) Calibrate as specified in Part III, section 6 and sections 15 through 22.

(e) At least monthly, or after any maintenance which could alter calibration, perform the following calibrations and checks.

(1) Leak check the vacuum side of the system (see Part III, section 24(a)).

(2) Verify that the automatic data collection system (if used) meets the requirements found in Table 1 in Appendix A of this Part.

(3) Check the fuel flow measurement instrument to insure that the specifications in Table 1 in Appendix A to this Part are met.

(f) Verify that all NDIR analyzers meet the water rejection ratio and the CO_2 rejection ratio as specified in Part III, section 25.

(g) Verify that the dynamometer test stand and power output instrumentation meet the specifications in Table 1 in Appendix A to this Part.

65. Catalyst Thermal Stress Test.

(a) Oven characteristics. The oven used for thermally stressing the test catalyst must be capable of maintaining a temperature of 500 degrees Celsius ± 5 degrees Celsius and 1000 degrees Celsius ± 10 degrees Celsius.

(b) Evaluation gas composition.

(1) A synthetic exhaust gas mixture is used for evaluating the effect of thermal stress on catalyst conversion efficiency.

(2) The synthetic exhaust gas mixture must have the following composition:

Constituent	Volume Percent	Parts per million
Carbon Monoxide[1]	1	—
Oxygen	1.3	—
Carbon Dioxide	9	—
Water Vapor	10	—
Sulfur Dioxide	—	20
Oxides of Nitrogen	—	280
Hydrogen	—	3500
Hydrocarbon[1,2]	—	4000
Nitrogen=Balance	—	—

1 Alternatively, the carbon monoxide and hydrocarbon proportions of the mixture may be changed to 1.2% and 4650 ppm, respectively (using one of these concentrations requires that the other be used simultaneously.
2 Propylene/propane ratio = 2/1.

Appendix A to Part III.

Table 1.
Measurement Accuracy Calibration Frequency

No.	Item	Permissible deviation from reading[1]		Calibration frequency
		non-idle	idle	
1	Engine speed	± 2%	± 2%	Monthly
2	Torque	± 5%	—	Monthly
3	Fuel consumption	± 1%	± 5%	Monthly
4	Air consumption	± 2℃	± 5%	As required
5	Coolant temperature	± 2℃	Same	As required
6	Lubricant temperature	± 2%	Same	As required
7	Exhaust backpressure	± 5%	Same	As required
8	Inlet depression	± 5%	Same	As required
9	Exhaust gas temperature	± 15%	Same	As required
10	Air inlet temperature (combustion air)	± 2℃	Sam e	As required
11	Atmospheric pressure	± 0.5%	Same	As required
12	Humidity (combustion air) (relative)	± 3.0%	Same	As required
13	Fuel temperature	± 2℃	Same	As required
14	Temperature with regard to dilution system	± 2℃	Same	As required
15	Dilution air humidity	± 3.0% absolute	Same	As required
16	HC analyzer	± 2%[2]	Same	Monthly
17	CO analyzer	± 2%[2]	Same	Monthly
18	NO_x analyzer	± 2%[2]	Same	Monthly
19	NO_x converter check	90%	Same	Monthly
20	CO_2 analyzer	± 2%[2]	Same	Monthly

1. All accuracy requirements pertain to the final recorded value, which is inclusive of the data acquisition system.
2. If reading is under 100 ppm then the accuracy shall be ± 2 ppm.

Appendix B to Part III – Figures.

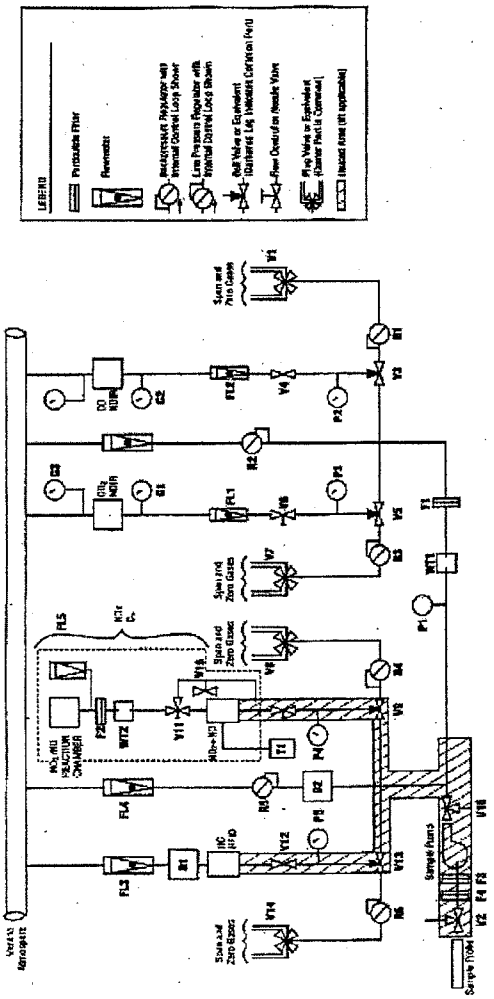

Figure 1. — Exhaust Gas Sampling and Analytical Train, Continuous Sampling

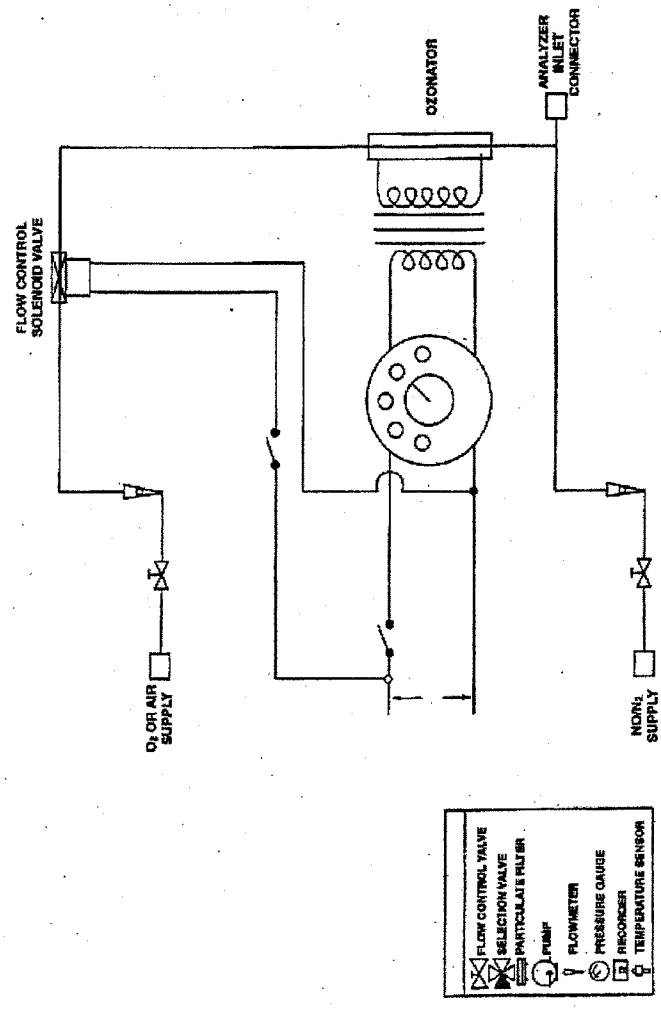

Figure 2. — NOx Converter Efficiency Detector

Part IV. Gaseous Exhaust Test Procedures

66. Scope; Applicability.

(a) This Part describes the procedures to follow in order to perform exhaust emission tests on new spark-ignition marine engines subject to the provisions of Part I. Provisions specific to raw gas sampling are in Part IV, sections 14 through 19, provisions specific to constant volume sampling are in Part IV, sections 20 through 26. All other sections in this Part apply to both raw gas sampling and constant volume sampling unless indicated otherwise.

(b) Requirements for emission test equipment and calibrating this equipment as required to perform the procedures in this Part are found in Part III.

67. Definitions.

The definitions in Part I, section 2 apply to this Part.

68. Abbreviations.

The abbreviations in Part I, section 3 apply to this Part.

69. Test Procedure Overview.

(a)The test consists of prescribed sequences of engine operating conditions to be conducted on an engine dynamometer or equivalent load and speed measurement device. The exhaust gases generated during engine operation are sampled either raw or dilute, and specific components are analyzed through the analytical system.

(b)The tests are designed to determine the brake-specific emissions of hydrocarbons, carbon monoxide, and oxides of nitrogen. The test consists of one idle mode and four power modes with an exponential relationship between torque and speed which span the typical operating range of spark-ignition marine engines. These procedures require the determination of the concentration of each pollutant, fuel flow, and the power output during each mode. The measured values are weighted and used to calculate the grams of each pollutant emitted per brake kilowatt hour (g/kW-hr).

(c) (1) When an engine is tested for exhaust emissions the complete engine is tested, with all emission control devices installed and functioning.

(2) Additional accessories (for example, oil cooler, alternators, and so forth) may be installed, but such accessory loading will be considered parasitic in nature and observed power is used in the emission calculation.

(d) All emission control systems installed on or incorporated in the application must be functioning during all procedures in this Part. In cases of component malfunction or

failure, no maintenance is allowed without prior approval from the Executive Officer in accordance with Part I, section 23.

70. Recorded Information.

(a) Record the information described in this section for each test where applicable.

(b) Test data; general.

(1) Engine identification number.

(2) Engine emissions control system.

(3) Test operator(s).

(4) Number of hours of operation accumulated on the engine before beginning the warm-up portion of the test (to the nearest tenth hour).

(5) Fuel identification.

(6) For two-stroke engines, fuel/oil mixture ratio.

(7) Date of most recent analytical assembly calibration.

(8) All pertinent instrument information such as tuning, gain, serial numbers, detector number, and calibration curve numbers. As long as this information is traceable, it may be summarized by system number or analyzer identification numbers.

(c) Test data; pre-test.

(1) Date and time of day.

(2) Test number.

(3) Barometric pressure; as an option, barometric pressure can be measured as a modal measurement instead of or in addition to a pre- and post-test measurement.

(4) Recorder chart or equivalent. Identify for each test segment zero traces for each range used, and span traces for each range used.

(d) Test data; modal.

(1) Recorder chart or equivalent. Identify for each test mode the emission concentration traces and the associated analyzer range(s).

(2) Observed engine torque.

(3) Observed engine rpm.

(4) Engine intake air flow, if applicable.

(5) Test cell temperature and humidity for each mode.

(6) For raw gas testing; fuel flow for each mode. Fuel flow measurement is not required for dilute testing but is allowed. If the fuel flow measurement is a volume measurement system, record the fuel temperature in the measurement system for fuel density corrections to the mass flow rate. If the fuel temperature is within 3 degrees Celsius of the calibration temperature, no density correction is required.

(7) Engine intake temperature and humidity for each mode, if applicable.

(8) Exhaust sample line temperature, if applicable.

(e) Test data; post-test.

(1) Recorder chart or equivalent. Identify the hang-up check.

(2) Recorder chart or equivalent. Identify the zero traces for each range used and the span traces for each range used.

(3) Total number of hours of operation accumulated on the engine (to the nearest tenth hour).

(4) Barometric pressure, post-test segment.

71. Engine Parameters to be Measured and Recorded.

Measure or calculate, then record, the engine parameters in the table below:

Parameter	Units
Airflow rate (dry), if applicable	g/h
Fuel flow rate	g/h
Engine speed	rpm
Engine torque output	N-m
Power output	kW
Air inlet temperature	℃
Air humidity	mg/kg
Coolant temperature (liquid cooled)	℃
Exhaust mixing chamber surface temperature, if applicable	℃
Total accumulated hours of engine operation	H
Barometric pressure	kilopascals

72. Engine Inlet and Exhaust Systems.

(a) The engine manufacturer is liable for emission compliance over the full range of restrictions that are specified by the engine manufacturer for that particular engine.

(b) The air inlet filter system and exhaust muffler system combination used on the test engine must be the systems expected to yield the highest emission levels.

73. Pre-test Procedures.

(a) Engine service accumulation and stabilization procedure. Use the service accumulation procedure determined by the manufacturer for exhaust emission stabilizing of an engine, consistent with good engineering practice (see Part 1, section 21).

(1) The manufacturer determines, for each engine family, the number of hours at which the engine exhaust emission control system combination is stabilized for emission testing. However, this stabilization procedure may not exceed 12 hours. The manufacturer must maintain, and provide to the Executive Officer upon request, a record of the rationale used in making this determination. If the manufacturer can document that, at some time before the full 12 hour service

accumulation period, the engine emissions are decreasing for the remainder of the 12 hours, the service accumulation may be completed at that time. The manufacturer may elect to accumulate 12 hours on each test engine within an engine family without making this determination.

(2) During service accumulation, the fuel and lubricants specified in Part III, section 8 must be used.

(3) Engine maintenance during service accumulation is allowed only in accordance with Part I, section 22.

(b) Engine pre-test preparation.

(1) Drain and charge the fuel tank(s) with the specified test fuel (see Part III, section 8) to 50 percent of the tank's nominal capacity. If an external fuel tank is used, the engine fuel inlet system pressure must be typical of what the engine will see in use.

(2) Operate the engine on the dynamometer measuring the fuel consumption (fuel consumption required only for raw gas sampling method) and torque before and after the emission sampling equipment is installed, including the sample probe, using mode 1 from Table 1-1 in Part 1, section 20. The emission sampling equipment may not significantly affect the operational characteristics of the engine (typically, the results should agree within five percent).

(c) Analyzer pre-test procedures.

(1) If necessary, warm up and stabilize the analyzer(s) before calibrations are performed.

(2) Replace or clean the filter elements and then vacuum leak check the system per Part III, section 24(a). If necessary, allow the heated sample line, filters, and pumps to reach operating temperature.

(3) Perform the following system checks:

(A) If necessary, check the sample-line temperature. Heated FID sample line temperature must be maintained between 110 degrees Celsius and 230 degrees Celsius, a heated NO_X sample line temperature must be maintained between 60 degrees Celsius and 230 degrees Celsius.

(B) Check that the system response time has been accounted for before sample collection data recording.

(C) A hang-up check is permitted.

(4) Check analyzer zero and span before and after each test at a minimum. Further, check analyzer zero and span any time a range change is made or at the maximum demonstrated time span for stability for each analyzer used.

(d) Check system flow rates and pressures and reset if necessary.

74. Engine Dynamometer Test Run.

(a) Engine and dynamometer start-up.

(1) Only adjustments in accordance with Part I, section 17, may be made to the test engine before starting a test.

(2) If necessary, warm up the dynamometer as recommended by the dynamometer manufacturer or in accordance good engineering practice.

(3) At the manufacturer's option, the engine can be run with the throttle in a fixed position or by using the engine's governor (if the engine is manufactured with a governor). In either case, the engine speed and load must meet the requirements specified in paragraph (b)(12) of this section.

(b) Each test consists of the following:

(1) Record the general test data as specified in section 5 of this Part.

(2) Precondition the engine in the following manner;

~~(i)~~(A) Operate the engine at idle for 2 to 3 minutes;

~~(ii)~~(B) Operate the engine at a power greater than or equal to 50 percent power at the rated speed for 5 to 7 minutes;

~~(iii)~~(C) Operate the engine at rated speed and maximum power for 25 to 30 minutes;

~~(iv)~~(D) Option. For four-stroke engines, where appropriate, it is permitted to precondition the engine at rated speed and maximum power until the oil and water temperatures are stabilized. The temperatures are defined as stabilized if they are maintained within 2 percent of point for 2 minutes. The engine must be operated a minimum of 10 minutes for this option. This optional procedure may be substituted for step in paragraphs (b)(2)~~(iii)~~(C) of this section;

~~(v)~~(E) Option. If the engine has been operating on service accumulation for a minimum of 40 minutes, the service accumulation may be substituted for steps in paragraphs (b)(2)~~(i)~~(A) through ~~(iii)~~(C) of this section.

(3) Record all pre-test data specified in Part IV, section 5(c).

(4) Start the test cycle (see Part IV, section 10) within 10 minutes of the completion of the steps required by paragraph (b)(2) of this section.

(5) During the first mode calculate the torque corresponding to 71.6, 46.5, and 25.3 percent of the maximum observed torque for the rated speed.

(6) Once engine speed and load are set for a mode, run the engine for a sufficient period of time to achieve thermal stability. At the manufacturers option, determine and document the appropriate criterion for thermal stability for each engine family.

(7) Record all modal data specified in Part IV, section 5(e) for a minimum time period of the last two minutes of each mode. Longer averaging periods are acceptable, but the data averaged must be from a continuous time period. The duration of time during which this data is recorded is referred to as the "sampling period." The data collected during the sampling period is used for modal emission calculations.

(8) Continuously record the analyzer's response to the exhaust gas during the sampling period.

(9) Modes may be repeated.

(10) If a delay of more than one hour occurs between the end of one mode and the beginning of another mode, the test is void and must be restarted as described at paragraph (b)(1) of this section.

(11) The engine speed and load must be maintained within the requirements of Part IV, section 10 during the sampling period for each mode. If this requirement is not met, the mode is void and must be restarted.

(12) If at any time during a mode, the test equipment malfunctions or the specifications in Part IV, section 10 can not be met, the test is void, and must be aborted. Corrective action should be taken and the test restarted.

(13) Fuel flow and air flow during the idle condition may be determined just before or immediately following the dynamometer sequence, if longer times are required for accurate measurements. If the dilute sampling method (Constant Volume Sampling) is used, neither fuel flow nor air flow measurements are required.

(c) Exhaust gas measurements.

(1) Measure HC, CO, CO_2, and NO_X concentration in the exhaust sample.

(2) Each analyzer range that may be used during a test segment must have the zero and span responses recorded before the start of the test. Only the range(s) used to measure the emissions during the test is required to have its zero and span recorded after the completion of the test. Depending on the stability of each individual analyzer, more frequent zero checks or spans between modes may be necessary.

(3) It is permitted to change filter elements between test segments.

(4) A leak check is permitted between modes.

(5) A hang-up check is permitted between modes (see Part IV, section 13).

(6) If, during the emission measurement portion of a mode, the value of the gauges downstream of the NDIR analyzer(s) G3 or G4 (See Figure 1 in Appendix B of Part III) differs by more than ± 0.5 kilopascals, the mode is void.

75. Engine Test Cycle.

(a)The 5-mode cycle specified in Part I, section 20 shall be followed in dynamometer operation tests of spark-ignition marine engines.

(b)During each non-idle mode the specified speed and load shall be held to within ± 50 rpm or ± two percent of point, whichever is greater. During each idle mode the engine speed shall be held within ± 75 rpm or ± five percent of the manufacturers specified idle speed, whichever is greater. For direct drive products (no neutral gear), it is acceptable to have an accessory load on the engine during the idle mode provided that the engine speed is within ± five percent of the manufacturers specified idle speed and the accessory load is representative of in use operation.

(c) If the operating conditions specified in paragraph (b) of this section for modes 2, 3, 4, and 5 cannot be maintained, the Executive Officer may authorize deviations from the specified load conditions. Such deviations shall not exceed 10 percent of the maximum torque at the test speed. The minimum deviations, above and below the specified load, necessary for stable operation shall be determined by the manufacturer and approved by the Executive Officer before the test run.

(d) Do not include power generated during the idle mode (mode 5) in the calculation of emissions results.

76. Post-test Analyzer Procedures.

(a) Perform a hang-up check within 60 seconds of the completion of the last mode in the test. Use the following procedure:

(1) Introduce a zero-grade gas or room air into the sample probe or valve V2 (see Figure 1 in Appendix B of Part III) to check the hangup zero response. Simultaneously start a time measurement.

(2) Select the lowest HC range used during the test.

(3) Within four minutes of beginning the time measurement in paragraph (a)(1) of this section, the difference between the zero gas response and the hang-up zero response shall not be greater than 5.0 percent of full scale or 10 ppmC whichever is greater.

(b) Begin the analyzer span checks within six minutes after the completion of the last mode in the test. Record for each analyzer the zero and span response for each range used during the preceding test or test segment.

(c) If during the test, the filter element(s) were replaced or cleaned, a vacuum check must be performed per Part III, section 24(a) immediately after the span checks. If the vacuum side leak check does not meet the requirements of Part III, section 24(a) the test is void.

(d) Read and record the post-test data specified in Part IV, section 5(e).

(e) For a valid test, the analyzer drift between the before-segment and after-segment span checks for each analyzer must meet the following requirements:

(1) The span drift (defined as the change in the difference between the zero response and the span response) must not exceed two percent of full-scale chart deflection for each range used.

(2) The zero response drift must not exceed two percent of fullscale chart deflection for each range used above 155 ppm (or ppm C), or three percent of full-scale chart deflection for each range below 155 ppm (or ppm C).

77. Data Logging.

(a) A computer or any other automatic data collection (ADC) device(s) may be used as long as the system meets the requirements of this Part.

(b) Determine from the data collection records the analyzer responses corresponding to the end of each mode.

(c) Record data at a minimum of one Hz (one time per second).

(d) Determine the final value for power by averaging the individually calculated power points for each value of speed and torque recorded during the sampling period. As an

alternative, the final value for power can be calculated from the average values for speed and torque, collected during the sampling period.

(e) Determine the final value for CO_2, CO, HC, and NO_X concentrations by averaging the concentration of each point taken during the sample period for each mode.

78. Exhaust Sample Procedure – Gaseous Components.

(a) Automatic data collection equipment requirements. The analyzer response may be read by automatic data collection (ADC) equipment such as computers, data loggers, etc. If ADC equipment is used the following is required:

(1) For dilute grab ("bag") analysis, the analyzer response must be stable at greater than 99 percent of the final reading for the dilute exhaust sample bag. A single value representing the average chart deflection over a 10-second stabilized period shall be stored.

(2) For continuous analysis systems, a single value representing the average integrated concentration over a cycle shall be stored. Alternatively, the ADC may store the individual instantaneous values collected during the measurement period.

(3) The chart deflections or average integrated concentrations required in paragraphs (a)(1) and (a)(2) of this section may be stored on long-term computer storage devices such as computer tapes, storage discs, punch cards, and so forth, or they may be printed in a listing for storage. In either case a chart recorder is not required and records from a chart recorder, if they exist, need not be stored.

(4) If ADC equipment is used to interpret analyzer values, the ADC equipment is subject to the calibration specifications of the analyzer as if the ADC equipment is part of analyzer system.

(b) Data records from any one or a combination of analyzers may be stored as chart recorder records.

(c) Grab sample analysis. For dilute grab sample analysis perform the following sequence:

(1) Calibrate analyzers using the procedure described in Part III, section 26.

(2) Record the most recent zero and span response as the preanalysis value.

(3) Measure HC, CO, CO_2, and NO_X background concentrations in the sample bag(s) and background sample bag(s) using the same flow rates and pressures.

(4) Good engineering practice dictates that analyzers used for continuous analysis should be operated such that the measured concentration falls between 15 percent and 100 percent of full scale.

(5) A post-analysis zero and span check of each range must be performed and the values recorded. The number of events that may occur between the pre and post checks is not specified. However, the difference between pre-analysis zero and span values (recorded in paragraph (c)(5) or (c)(6) of this section) versus those recorded for the post-analysis check may not exceed the zero drift limit or the span drift limit of 2 percent of full scale chart deflection for any range used. Otherwise the test is void.

(d) Continuous sample analysis. For continuous sample analysis, perform the following sequence:

(1) Calibrate analyzers using the procedures described in Part III, section 26.

(2) Leak check portions of the sampling system that operate at negative gauge pressures when sampling, and allow heated sample lines, filters, pumps, and so forth to stabilize at operating temperature.

(3) Option: Determine the hang-up for the FID or HFID sampling system:

(A) Zero the analyzer using zero air introduced at the analyzer port.

(B) Flow zero air through the overflow sampling system. Check the analyzer response.

(C) If the overflow zero response exceeds the analyzer zero response by two percent or more of the FID or HFID full-scale deflection, hang-up is indicated and corrective action must be taken (see paragraph (e) of this section).

(D) The complete system hang-up check specified in paragraph (f) of this section is recommended as a periodic check.

(4) Obtain a stable zero reading.

(5) Good engineering practice dictates that analyzers used for continuous analysis should be operated such that the measured concentration falls between 15 percent and 100 percent of full scale.

(6) Record the most recent zero and span response as the preanalysis values.

(7) Collect background HC, CO, CO_2, and NO_X in a sample bag (for dilute exhaust sampling only, see Part IV, section 22).

(8) Perform a post-analysis zero and span check for each range used at the conditions specified in paragraph (d)(1) of this section. Record these responses as the post-analysis values.

(9) Neither the zero drift nor the span drift between the preanalysis and post-analysis checks on any range used may exceed three percent for HC, or two percent for NO_X, CO, and CO_2, of full scale chart deflection, or the test is void. (If the HC drift is greater than three percent of full-scale chart deflection, hydrocarbon hang-up is likely.)

(10) Determine background levels of NO_X, CO, or CO_2 (for dilute exhaust sampling only) by the grab ("bag") technique outlined in paragraph (c) of this section.

(e) Hydrocarbon hang-up. If HC hang-up is indicated, the following sequence may be performed:

(1) Fill a clean sample bag with background air.

(2) Zero and span the HFID at the analyzer ports.

(3) Analyze the background air sample bag through the analyzer ports.

(4) Analyze the background air through the entire sample probe system.

(5) If the difference between the readings obtained is two ppm or more, clean the sample probe and the sample line.

(6) Reassemble the sample system, heat to specified temperature, and repeat the procedure in paragraphs (e)(1) through (e)(5) of this section.

79. Raw Gaseous Exhaust Sampling and Analytical System Description.

(a) Schematic drawing. An example of a sampling and analytical system which may be used for testing under this Part is shown in Figure 4 in Appendix A of this Part. All components or parts of components that are wetted by the sample or corrosive calibration gases shall be either chemically cleaned stainless steel or inert material (e.g., polytetrafluoroethylene resin). The use of "gauge savers" or "protectors" with nonreactive diaphragms to reduce dead volumes is permitted.

(b) Sample probe.

(1) The sample probe shall be a straight, closed end, stainless steel, multi-hole probe. The inside diameter shall not be greater than the inside diameter of the sample line + 0.03 cm. The wall thickness of the probe shall not be greater than 0.10 cm. The

fitting that attaches the probe to the exhaust pipe shall be as small as practical in order to minimize heat loss from the probe.

(2) The probe shall have a minimum of three holes. The spacing of the radial planes for each hole in the probe must be such that they cover approximately equal cross-sectional areas of the exhaust duct. The angular spacing of the holes must be approximately equal. The angular spacing of any two holes in one plane may not be 180 deg. ± 20 deg. (i.e., section C-C of Figure 1 in Appendix A of this Part). The holes should be sized such that each has approximately the same flow. If only three holes are used, they may not all be in the same radial plane.

(3) The exhaust gas probe must be located in a position which yields a well mixed, homogeneous sample of the engine exhaust. The probe must extend radially through the exhaust duct before where the exhaust mixes with the cooling water. The cooling water flow may be rerouted if necessary to obtain an emission sample provided that the modification has no significant effect on the performance or emissions characteristics of the engine. The probe must pass through the approximate center and must extend across at least 80 percent of the diameter of the duct. The exact position of the probe may vary from engine family to engine family.

(c) Sample transfer line.

(1) The maximum inside diameter of the sample line shall not exceed 1.32 cm.

(2) If valve V2 in Figure 1 of Appendix B of Part III is used, the sample probe must connect directly to valve V2 in Figure 1 of Appendix B of Part III. The location of optional valve V2 may not be greater than 1.22 m from the exhaust duct.

(3) The location of optional valve V16 in Figure 1 of Appendix B of Part III may not be greater than 61 cm from the sample pump. The leakage rate for this section on the pressure side of the sample pump may not exceed the leakage rate specification for the vacuum side of the pump.

(d) Venting. All vents including analyzer vents, bypass flow, and pressure relief vents of regulators should be vented in such a manner to avoid endangering personnel in the immediate area.

(e) Any variation from the specifications in this Part including performance specifications and emission detection methods may be used only with prior approval by the Executive Officer.

(f) Additional components, such as instruments, valves, solenoids, pumps, switches, and so forth, may be employed to provide additional information and coordinate the functions of the component systems.

(g) The following requirements must be incorporated in each system used for raw testing under this Part.

(1) Take the sample for all components with one sample probe and split it internally to the different analyzers.

(2) Heat the sample transport system from the engine exhaust pipe to the HC analyzer for the raw gas sampling method as indicated in Figure 1 in Appendix B of Part III. The NO_X analyzer for the raw gas sampling method may be heated as indicated in Figure 1 in Appendix B of Part III. The HC analyzer and the NO_X analyzer for the dilute sampling method may be heated as indicated in Figure 1 in Appendix B of Part III.

80. Raw Gaseous Sampling Procedures.

Fit all heated sampling lines with a heated filter to extract solid particles from the flow of gas required for analysis. The sample line for HC measurement must be heated. The sample line for CO, CO_2, and NO_X may be heated or unheated.

81. Intake Air Flow Measurement Specifications.

(a) If used, the engine intake air flow measurement method used must have a range large enough to accurately measure the air flow over the engine operating range during the test. Overall measurement accuracy must be ± two percent of full-scale value of the measurement device for all modes except the idle mode. For the idle mode, the measurement accuracy shall be ± five percent or less of the full-scale value. The Executive Officer must be advised of the method used before testing.

(b) When an engine system incorporates devices that affect the air flow measurement (such as air bleeds, air injection, pulsed air, and so forth) that result in understated exhaust emission results, make corrections to the exhaust emission results to account for such effects.

82. Fuel Flow Measurement Specifications.

(a) Fuel flow measurement is required only for raw testing but is allowed for dilute testing.

(b) The fuel flow rate measurement instrument must have a minimum accuracy of ± two percent of full-scale flow rate for each measurement range used.

83. Data Evaluation for Gaseous Emissions.

For the evaluation of the gaseous emissions recording, record the last two minutes of each mode and determine the average values for HC, CO, CO_2, and NO_X during each mode from the average concentration readings determined from the corresponding calibration data.

84. Raw Emission Sampling Calculations.

(a) Derive the final test results through the steps described in this section.

(b) Air and fuel flow method. If both air and fuel flow mass rates are measured, the following equations are used to determine the weighted emission values for the test engine:

$$W_{HC} = (G_{AIRD} + G_{FUEL})\, x \frac{M_{HC_{exh}}}{M_{exh}}\, x\, WHX\, x \frac{1}{10^6}$$

$$W_{NO_x} = (G_{AIRD} + G_{FUEL})\, x \frac{M_{NO_2}}{M_{exh}}\, x\, WNO_x\, x\, K_H\, x \frac{1}{10^6}$$

Where:

W_{HC} = Mass rate of HC in exhaust [g/hr],

G_{AIRD} = Intake air mass flow rate on dry basis [g/hr],

G_{FUEL} = Fuel mass flow rate [g/hr],

$$W_{CO} = (G_{AIRD} + G_{FUEL})\, x \frac{M_{CO}}{M_{exh}}\, x\, WCO\, x \frac{1}{10^6}$$

M_{HCexh} = Molecular weight of hydrocarbons in the exhaust; see the following equation:

$$M_{HC_{exh}} = 12.01 + 1.008 x \alpha$$

Where:

α = Hydrocarbon/carbon atomic ratio of the fuel.

M_{exh} = Molecular weight of the total exhaust; see the following equation:

$$M_{exh} = \frac{M_{HC_{exh}} x WHC}{10^6} + \frac{28.01 x WCO}{10^2} + \frac{44.1 x WCO_2}{10^2} + \frac{46.01 x WNO_x}{10^6} + \frac{2.016 x WH_2}{10^2} + 18.01 x (1-K) +$$

$$28.01 x \frac{\left[100 - \frac{WHC}{10^4} - WCO - WCO_2 \frac{WNO_x}{10^4} - WH_2 - 100 x (1-K)\right]}{10^2}$$

Where:

WHC = HC volume concentration in exhaust, ppmC wet

WCO = CO percent concentration in the exhaust, wet

DCO = CO percent concentration in the exhaust, dry

WCO_2 = CO_2 percent concentration in the exhaust, wet

DCO_2 = CO_2 percent concentration in the exhaust, dry

WNO_X = NO volume concentration in exhaust, ppm wet

WH_2 = H_2 percent concentration in exhaust, wet

K = correction factor to be used when converting dry measurements to a wet basis. Therefore, wet concentration = dry concentration x K, where K is:

$$\frac{1}{1 + 0.005 x (DCO + DCO_2) x \alpha - 0.01 x DH_2}$$

DH_2 = H2 percent concentration in exhaust, dry, calculated from the following equation:

$$DH_2 = \frac{0.5 x \alpha x DCO x (DCO + DCO_2)}{DCO + (3 x DCO_2)}$$

W_{CO} = Mass rate of CO in exhaust, [g/hr]

M_{CO} = Molecular weight of CO = 28.01

W_{NOx} = Mass rate of NO_X in exhaust, [g/hr]

M_{NO2} = Molecular weight of NO_2 = 46.01

K_H = Factor for correcting the effects of humidity on NO_2 formation for four-stroke gasoline engines; see the equation below:

$$K_H = \frac{1}{1 - 0.0329\,x\,(H - 10.71)}$$

Where:

H = specific humidity of the intake air in grams of moisture per kilogram of dry air.

For two-stroke gasoline engines, K_H should be set to 1.

(c) Fuel flow method. The following equations are to be used when fuel flow is selected as the basis for mass emission calculations using the raw gas method.

$$W_{HC} = \frac{G_{FUEL}}{TC}\,x\,\frac{WHC}{10^4}$$

$$W_{CO} = \frac{M_{CO}}{M_F}\,x\,\frac{G_{FUEL}}{TC}\,x\,WCO$$

$$W_{NO_x} = \frac{M_{NO_x}}{M_F}\,x\,\frac{G_{FUEL}}{TC}\,x\,\frac{WNO_x}{10^4}\,x\,K_H$$

Where:

W_{HC} = Mass rate of HC in exhaust, [g/hr]

M_F = Molecular weight of test fuel; see following equation:

$$M_F = 12.01 + 1.008\,x\,\alpha$$

G_{FUEL} = Fuel mass flowrate, [g/hr]

TC = Total carbon; see following equation:

$$TC = WCO + WCO_2 + \frac{WHC}{10^4}$$

WHC = HC volume concentration in exhaust, ppmC wet

WCO = CO percent concentration in the exhaust, wet

DCO = CO percent concentration in the exhaust, dry

WCO_2 = CO_2 percent concentration in the exhaust, wet

DCO_2 = CO_2 percent concentration in the exhaust, dry

WNO_x = NO volume concentration in exhaust, ppm wet

WH_2 = H_2 percent concentration in exhaust, wet

K = correction factor to be used when converting dry measurements to a wet basis. Therefore, wet concentration = dry concentration x K, where K is:

$$K = \frac{1}{1 + 0.005\,x\,(DCO + DCO_2)\,x\,\alpha - 0.01\,x\,DH_2}$$

DH_2 = H_2 percent concentration in exhaust, dry, calculated from the following equation:

$$DH_2 = \frac{0.5\,x\,\alpha\,x\,DCO\,x\,(DCO + DCO_2)}{DCO + (3\,x\,DCO_2)}$$

W_{CO} = Mass rate of CO in exhaust, [g/hr]

M_{CO} = Molecular weight of CO = 28.01

W_{NOx} = Mass rate of NO_X in exhaust, [g/hr]

M_{NO2} = Molecular weight of NO_2 = 46.01

K_H = Factor for correcting the effects of humidity on NO_2 formation for four-stroke gasoline engines; see the equation below:

$$K_H = \frac{1}{1 - 0.0329\,x\,(H - 10.71)}$$

Where:

H = specific humidity of the intake air in grams of moisture per kilogram of dry air.

For two-stroke gasoline engines, KH should be set to 1.

(d) The final reported emission test results must be computed by using the following formula for each individual gas component:

$$Y_{wm} = \frac{\sum (W_i \, x \, f_i)}{\sum (P_i \, x \, f_i)}$$

Where:

Y_{wm} = Weighted mass emission level (HC, CO, NO_x) for a test [g/kW-hr].

W_i = Average mass flow rate (W_{HC}, W_{CO}, W_{NOx}) of an emission from the test engine during mode i, [g/hr].

f_i = Weighting factors for each mode according to Part IV, section 10(a).

P_i = Average power measured during mode i, [kW], calculated according to the formula given in Part IV, section 23(b). Power for the idle mode shall always be zero for this calculation.

(e) The final reported weighted brake-specific fuel consumption (WBSFC) shall be computed by use of the following formula:

$$WBSFC = \frac{\sum (F_i \, x \, f_i)}{\sum (P_i \, x \, f_i)}$$

Where:

WBSFC = Weighted brake-specific fuel consumption in grams of fuel per kilowatt-hour (g/kW-hr).

F_i = Fuel mass flow rate of the engine during mode i, [g/hr].

f_i = Weighting factors for each mode according to Part IV, section 10(a).

P_i = Average power measured during mode i, [kW], calculated according to the formula given in Part IV, section 23(b). Power for the idle mode shall always be zero for this calculation.

85. CVS Concept of Exhaust Gas Sampling System.

(a) A dilute exhaust sampling system is designed to directly measure the true mass of emissions in engine exhaust without the necessity of measuring either fuel flow or intake air flow. This is accomplished by diluting the exhaust produced by an engine under test with ambient background air and measuring the total diluted exhaust flow rate and the concentration of emissions within the dilute flow. Total mass flow of an emission is then easily calculated.

(b) A constant volume sampler (CVS) is typically used to control the total amount of dilute flow through the system. As the name implies, a CVS restricts flow to a known value dependent only on the dilute exhaust temperature and pressure.

(c) For the testing described in this Part, a CVS must consist of: A mixing tunnel into which the engine exhaust and dilutant (background) air are dumped; a dilute exhaust flow metering system; a dilute exhaust sample port; a background sample port; a dilute exhaust sampling system; and a background sampling system.

(1) Mixing tunnel. The mixing tunnel must be constructed such that complete mixing of the engine exhaust and background air is assured before the sampling probe.

(2) Exhaust flow metering system. A dilute exhaust flow metering system must be used to control the total flow rate of the dilute engine exhaust as described in Part IV, section 21.

(3) Exhaust sample port. A dilute exhaust sample port must be located in or downstream of the mixing tunnel at a point where complete mixing of the engine exhaust and background air is assured.

(4) Background sample port. A dilute background sample port must be located in the stream of background air before it is mixed with the engine exhaust. The background probe must draw a representative sample of the background air during each sampling mode.

(5) Exhaust sampling system. The dilute exhaust sampling system controls the flow of samples from the mixing tunnel to the analyzer system. This could be either a continuous sampling system or grab (bag) sampling system. If a critical flow venturi (CFV) is used on the dilute exhaust sample probe, this system must assure that the sample CFV is in choke flow during testing. If no CFV is used, this system must assure a constant volumetric flow rate through the dilute exhaust sample probe or must incorporate electronic flow compensation.

(6) Background sampling system. The background sampling system controls the flow of samples from the background air supply to the analyzer system. This

could be either a continuous sampling system or grab (bag) sampling system. This system must assure a constant volumetric flow rate through the background sample probe.

86. Dilute Gaseous Exhaust Sampling and Analytical System Description.

(a) General. The exhaust gas sampling system described in this section is designed to measure the true mass emissions of engine exhaust. This system utilizes the Constant volume Sampling (CVS) concept (described in Part IV, section 20) of measuring mass emissions of HC, NO_x, CO, and CO_2. Grab sampling for individual modes is an acceptable method of dilute testing for all constituents, HC, NO_x, CO, and CO_2. Continuous dilute sampling is not required for any of the exhaust constituents, but is allowable for all. Heated sampling is not required for any of the constituents, but is allowable for HC and NO_x. The mass of gaseous emissions is determined from the sample concentration and total flow over the test period. As an option, the measurement of total fuel mass consumed over a cycle may be substituted for the exhaust measurement of CO_2. General requirements are as follows:

(1) This sampling system requires the use of a Positive Displacement Pump-Constant Volume Sampler (PDP-CVS) system with a heat exchanger, or a Critical Flow Venturi-Constant Volume Sampler (CFV-CVS) system with CVS sample probes and/or a heat exchanger or electronic flow compensation. Figure 2 in Appendix A of this Part is a schematic drawing of the PDP-CVS system. Figure 3 in Appendix A of this Part is a schematic drawing of the CFV-CVS system.

(2) The HC analytical system requires:

~~(i)~~(A) Grab sampling (see Part IV, section 20, and Figure 2 or Figure 3 in Appendix A of this Part) and analytical capabilities (see Part IV, section 23, and Figure 4 in Appendix A of this Part), or

~~(ii)~~(B) Continuously integrated measurement of diluted HC meeting the minimum requirements and technical specifications contained in paragraph (b)(2) of this section.

~~(iii)~~(C) The dilute HC analytical system for spark-ignition marine engines does not require a heated flame ionization detector (HFID).

~~(iv)~~(D) If used, the HFID sample must be taken directly from the diluted exhaust stream through a heated probe and integrated continuously over the test cycle.

~~(v)~~(E) The heated probe must be located in the sampling system far enough downstream of the mixing area to ensure a uniform sample distribution across the CVS duct at the sampling zone.

(3) The CO and CO_2 analytical system requires:

~~(i)~~(A) Grab sampling (see Part IV, section 20, and Figure 2 or Figure 3 in Appendix A of this Part) and analytical capabilities (see Part IV, section 23, and Figure 4 in Appendix A of this Part), or

~~(ii)~~(B) Continuously integrated measurement of diluted CO and CO_2 meeting the minimum requirements and technical specifications contained in paragraph (b)(4) of this section.

(4) The NO_x analytical system requires:

~~(i)~~(A) Grab sampling (see Part IV, section 20, and Figure 2 or Figure 3 in Appendix A of this Part) and analytical capabilities (see Part IV, section 23, and Figure 4 in Appendix A of this Part), or

~~(ii)~~(B) A continuously integrated measurement of diluted NO_x meeting the minimum requirements and technical specifications contained in paragraph (b)(4) of this section.

(5) Since various configurations can produce equivalent results, exact conformance with these drawings is not required. Additional components such as instruments, valves, solenoids, pumps, and switches may be used to provide additional information and coordinate the functions of the component systems. Other components, such as snubbers, which are not needed to maintain accuracy on some systems, may be excluded if their exclusion is based upon good engineering judgment.

(6) Other sampling and/or analytical systems may be used if shown to yield equivalent results and if approved in advance by the Executive Officer.

(b) Component description. The components necessary for exhaust sampling must meet the following requirements:

(1) Exhaust dilution system. The PDP-CVS must conform to all of the requirements listed for the exhaust gas PDP-CVS in Part IV, section 20 of this chapter. The CFV-CVS must conform to all of the requirements listed for the exhaust gas CFV-CVS in Part IV, section 20. In addition, the CVS must conform to the following requirements:

~~(i)~~(A) The flow capacity of the CVS must be sufficient to maintain the diluted exhaust stream in the dilution system at a temperature of 190 degrees Celsius or less at the sampling zone for hydrocarbon measurement and as required to prevent condensation at any point in the dilution system. Gaseous emission samples may be taken directly from this sampling point.

~~(ii)~~(B) For the CFV-CVS, either a heat exchanger or electronic flow compensation is required (see Figure 3 in Appendix A of this Part).

~~(iii)~~(C) For the CFV-CVS when a heat exchanger is used, the gas mixture temperature, measured at a point immediately ahead of the critical flow venturi, must be within ± 11 degrees Celsius of the average operating temperature observed during the test with the simultaneous requirement that condensation does not occur. The temperature measuring system (sensors and readout) must have an accuracy and precision of ± 2 degrees Celsius. For systems utilizing a flow compensator to maintain proportional flow, the requirement for maintaining constant temperature is not necessary.

(2) Continuous HC measurement system.

~~(i)~~(A) The continuous HC sample system (as shown in Figure 2 or 3 in Appendix A of this Part) uses an "overflow" zero and span system. In this type of system, excess zero or span gas spills out of the probe when zero and span checks of the analyzer are made.

~~(ii)~~(B) No other analyzers may draw a sample from the continuous HC sample probe, line, or system, unless a common sample pump is used for all analyzers and the sample line system design reflects good engineering practice.

~~(iii)~~(C) The overflow gas flow rates into the sample line must be at least 105 percent of the sample system flow rate.

~~(iv)~~(D) The overflow gases must enter the sample line as close as practical to the outside surface of the CVS duct or dilution system.

~~(v)~~(E) The continuous HC sampling system consists of a probe (which for a HFID analyzer must raise the sample to the specified temperature) and, where used, a sample transfer system (which for a HFID must maintain the specified temperature). The HFID continuous hydrocarbon sampling system (exclusive of the probe) must:

> ~~(A)~~(i) Maintain a wall temperature of 190 degrees Celsius ± 11 degrees Celsius as measured at every separately controlled heated component (that is, filters, heated line sections), using permanent thermocouples located at each of the separate components.
>
> ~~(B)~~(ii) Have a wall temperature of 190 degrees Celsius ± 11 degrees Celsius over its entire length. The temperature of the system is demonstrated by profiling the thermal characteristics of the system where possible at initial installation and after any major maintenance performed on the system. The profiling is to be accomplished using the insertion thermocouple probing technique. The system temperature must be

monitored continuously during testing at the locations and temperature described in Part IV, section 21(b)(2).

~~(C)~~(iii) Maintain a gas temperature of 190 degrees Celsius ± 11 degrees Celsius immediately before the heated filter and HFID. Determine these gas temperatures by a temperature sensor located immediately upstream of each component.

~~(vi)~~(F) The continuous hydrocarbon sampling probe:

~~(A)~~(i) Is defined as the first 25.4 to 76.2 cm of the continuous hydrocarbon sampling system.

~~(B)~~(ii) Has a 0.483 cm minimum inside diameter.

~~(C)~~(iii) Is installed in the dilution system at a point where the dilution air and exhaust are well mixed and provide a homogenous mixture.

~~(D)~~(iv) Is sufficiently distant (radially) from other probes and the system wall so as to be free from the influence of any wakes or eddies.

~~(E)~~(v) For a continuous HFID sample probe, the probe must increase the gas stream temperature to 190 degrees Celsius ± 11 degrees Celsius at the exit of the probe. Demonstrate the ability of the probe to accomplish this using the insertion thermocouple technique at initial installation and after any major maintenance. Demonstrate compliance with the temperature specification by continuously recording during each test the temperature of either the gas stream or the wall of the sample probe at its terminus.

~~(vii)~~(G) The response time of the continuous measurement system must be taken into account when logging test data.

(3) Sample mixing.

~~(i)~~(A) Configure the dilution system to ensure a well mixed, homogeneous sample before the sampling probe(s).

~~(ii)~~(B) Make the temperature of the diluted exhaust stream inside the dilution system sufficient to prevent water condensation.

~~(iii)~~(C) Direct the engine exhaust downstream at the point where it is introduced into the dilution system.

(4) Continuously integrated NO_x, CO, and CO_2 measurement systems.

~~(i)~~(A) Sample probe requirements:

~~(A)~~(i) The sample probe for continuously integrated NO_x, CO, and CO_2 must be in the same plane as the continuous HC probe, but sufficiently distant (radially) from other probes and the tunnel wall so as to be free from the influences of any wakes or eddies.

~~(B)~~(ii) The sample probe for continuously integrated NO_x, CO, and CO_2 must be heated and insulated over the entire length, to prevent water condensation, to a minimum temperature of 55 degrees Celsius. Sample gas temperature immediately before the first filter in the system must be at least 55 degrees Celsius.

~~(ii)~~(B) Conform to the continuous NO_x, CO, or CO_2 sampling and analysis system to the specifications of Part III with the following exceptions and revisions:

~~(A)~~(i) Heat the system components requiring heating only to prevent water condensation, the minimum component temperature is 55 degrees Celsius.

~~(B)~~(ii) Coordinate analysis system response time with CVS flow fluctuations and sampling time/test cycle offsets, if necessary.

~~(C)~~(iii) Use only analytical gases conforming to the specifications of Part III, section 12 for calibration, zero and span checks.

~~(D)~~(iv) Use a calibration curve conforming to Part III, section 21 for CO and CO_2 and Part III, section 18 for NO_x for any range on a linear analyzer below 155 ppm.

~~(iii)~~(C) Convert the chart deflections or voltage output of analyzers with non-linear calibration curves to concentration values by the calibration curve(s) specified in Part III section 21 before flow correction (if used) and subsequent integration takes place.

87. **[Reserved].**

88. **Exhaust Gas Analytical System; CVS Grab Sample.**

(a) Schematic drawings. Figure 4 in Appendix A of this Part is a schematic drawing of the exhaust gas analytical system used for analyzing CVS grab "bag" samples from spark-ignition engines. Since various configurations can produce accurate results, exact conformance with the drawing is not required. Additional components such as instruments, valves, solenoids, pumps and switches may be used to provide additional

information and coordinate the functions of the component systems. Other components such as snubbers, which are not needed to maintain accuracy in some systems, may be excluded if their exclusion is based on good engineering judgment.

(b) Major component description. The analytical system, Figure 4 in Appendix A of this Part, consists of a flame ionization detector (FID) or a heated flame ionization detector (HFID) for the measurement of hydrocarbons, nondispersive infrared analyzers (NDIR) for the measurement of carbon monoxide and carbon dioxide, and a chemiluminescence detector (CLD) (or heated CLD (HCLD)) for the measurement of oxides of nitrogen. The exhaust gas analytical system shall conform to the following requirements:

(1) The CLD (or HCLD) requires that the nitrogen dioxide present in the sample be converted to nitric oxide before analysis. Other types of analyzers may be used if shown to yield equivalent results and if approved in advance by the Executive Officer.

(2) If CO instruments are used which are essentially free of CO_2 and water vapor interference, the use of the conditioning column may be deleted. (See Part III, sections 17 and 20.)

(3) A CO instrument will be considered to be essentially free of CO_2 and water vapor interference if its response to a mixture of three percent CO_2 in N_2, which has been bubbled through water at room temperature, produces an equivalent CO response, as measured on the most sensitive CO range, which is less than one percent of full scale CO concentration on ranges above 300 ppm full scale or less than 3 ppm on ranges below 300 ppm full scale. (See Part III, section 17.)

(c) Alternate analytical systems. Analysis systems meeting the specifications and requirements of this Part for dilute sampling may be used upon approval of the Executive Officer.

(d) Other analyzers and equipment. Other types of analyzers and equipment may be used if shown to yield equivalent results and if approved in advance by the Executive Officer.

89. Dilute Sampling Procedure – CVS Calibration.

(a) The CVS is calibrated using an accurate flowmeter and restrictor valve.

(1) The flowmeter calibration shall be traceable to the National Institute for Standards and Testing (NIST), and will serve as the reference value (NIST "true" value) for the CVS calibration. (Note: In no case should an upstream screen or other restriction which can affect the flow be used ahead of the flowmeter unless calibrated throughout the flow range with such a device.)

(2) The CVS calibration procedures are designed for use of a "metering venturi" type flowmeter. Large radius or American Society of Mechanical Engineers (ASME) flow nozzles are considered equivalent if traceable to NIST measurements. Other measurement systems may be used if shown to be equivalent under the test conditions in this section and traceable to NIST measurements.

(3) Measurements of the various flowmeter parameters are recorded and related to flow through the CVS.

(4) Procedures used by ARB for both PDP-CVS and CFV-CVS are outlined below. Other procedures yielding equivalent results may be used if approved in advance by the Executive Officer.

(b) After the calibration curve has been obtained, verification of the entire system may be performed by injecting a known mass of gas into the system and comparing the mass indicated by the system to the true mass injected. An indicated error does not necessarily mean that the calibration is wrong, since other factors can influence the accuracy of the system (e.g., analyzer calibration, leaks, or HC hangup). A verification procedure is found in paragraph (e) of this section.

(c) PDP-CVS calibration.

(1) The following calibration procedure outlines the equipment, the test configuration, and the various parameters which must be measured to establish the flow rate of the CVS pump.

~~(i)~~(A) All the parameters related to the pump are simultaneously measured with the parameters related to a flowmeter which is connected in series with the pump.

~~(ii)~~(B) The calculated flow rate, in cm^3/s, (at pump inlet absolute pressure and temperature) can then be plotted versus a correlation function which is the value of a specific combination of pump parameters.

~~(iii)~~(C) The linear equation which relates the pump flow and the correlation function is then determined.

~~(iv)~~(D) In the event that a CVS has a multiple speed drive, a calibration for each range used must be performed.

(2) This calibration procedure is based on the measurement of the absolute values of the pump and flowmeter parameters that relate the flow rate at each point. Two conditions must be maintained to assure the accuracy and integrity of the calibration curve:

~~(i)~~(A) The temperature stability must be maintained during calibration. (Flowmeters are sensitive to inlet temperature oscillations; this can cause the data points to be scattered. Gradual changes in temperature are acceptable as long as they occur over a period of several minutes.)

~~(ii)~~(B) All connections and ducting between the flowmeter and the CVS pump must be absolutely void of leakage.

(3)During an exhaust emission test the measurement of these same pump parameters enables the user to calculate the flow rate from the calibration equation.

(4) Connect a system as shown in Figure 5 in Appendix A of this Part. Although particular types of equipment are shown, other configurations that yield equivalent results may be used if approved in advance by the Executive Officer. For the system indicated, the following measurements and accuracies are required:

Parameter	Symbol	Units	Sensor-readout tolerances
Barometric pressure (corrected)	P_B	kPa	± 0.34 kPa
Ambient temperature	T_{EI}	℃	± 0.28 ℃
Air temperature into metering venturi	T_{EI}	℃	± 1.11 ℃
Pressure drop between inlet & throat of venturi	P_{ED}	kPa	± 0.012 kPa
Air flow	Q_S	M^3/min.	± 0.5 % of NIST value
Air temperature at CVS pump inlet	P_{TI}	℃	± 1.11 ℃
Pressure depression at CVS pump inlet	P_{PI}	kPa	± 0.055 kPa
Pressure head at CVS pump outlet	P_{PO}	kPa	± 0.055 kPa
Air temperature at CVS pump outlet (optional)	P_{YO}	℃	± 1.11 ℃
Pump revolutions during test period	N	Revs	± 1 Rev.
Elapsed time for test period	t	seconds	± 0.5 seconds

(5) After the system has been connected as shown in Figure 5 of Appendix A of this Part, set the variable restrictor in the wide open position and run the CVS pump for 20 minutes. Record the calibration data.

(6) Reset the restrictor valve to a more restricted condition in an increment of pump inlet depression that will yield a minimum of six data points for the total

calibration. Allow the system to stabilize for 3 minutes and repeat the data acquisition.

(7) Data analysis:

~~(i)~~(A) The air flow rate, Qs, at each test point is calculated in standard cubic feet per minute 20 degrees Celsius, 101.3 kilopascals from the flowmeter data using the manufacturer's prescribed method.

~~(ii)~~(B) The air flow rate is then converted to pump flow, V_O, in cubic meter per revolution at absolute pump inlet temperature and pressure:

$$V_O = \frac{Q_S}{n} x \frac{T_p}{293} x \frac{101.3kPa}{P_p}$$

Where:

V_O	=	Pump flow, m^3/rev at T_P, P_P.
Q_S	=	Meter air flow rate in standard cubic meters per minute, standard conditions are 20° Celsius, 101.3 kPa.
n	=	Pump speed in revolutions per minute.
T_P	=	Pump inlet temperature in Kelvin, = P_{TI}+273° K.
P_P	=	Absolute pump inlet pressure, kPa = Pp-P_{PI}.

Where:

P_P	=	barometric pressure, kPa.
P_{PI}	=	Pump inlet depression, kPa.

~~(iii)~~(C) The correlation function at each test point is then calculated from the calibration data:

$$X_O = \frac{1}{n}\sqrt{\left(\frac{\Delta P}{P_E}\right)}$$

Where:

X_O	=	correlation function.

ΔP = The pressure differential from pump inlet to pump outlet = P_E-P_P, kPa.

P_E = Absolute pump outlet pressure = P_B+P_{PO}, kPa.

Where:

P_{PO} = Pressure head at pump outlet, kPa, (inches fluid).

~~(iv)~~(D) A linear least squares fit is performed to generate the calibration equation which has the form:

$$V_O = D_O - M(X_O)$$

D_O and M are the intercept and slope constants, respectively, describing the regression line.

(8) A CVS system that has multiple speeds should be calibrated on each speed used. The calibration curves generated for the ranges will be approximately parallel and the intercept values, D_O, will increase as the pump flow range decreases.

(9) If the calibration has been performed carefully, the calculated values from the equation will be within ± 0.50 percent of the measured value of V_O. Values of M will vary from one pump to another, but values of D_O for pumps of the same make, model and range should agree within ± three percent of each other. Calibrations should be performed at pump start-up and after major maintenance to assure the stability of the pump slip rate. Analysis of mass injection data will also reflect pump slip stability.

(d) CFV-CVS calibration.

(1) Calibration of the CFV is based upon the flow equation for a critical venturi.

~~(i)~~(A) Gas flow is a function of inlet pressure and temperature:

$$Q_S = \frac{K_V P}{\sqrt{T_K}}$$

Where:

Q_S = flow rate [m^3/min].

K_V = calibration coefficient.

P = absolute pressure [kilopascals].

T_K = absolute temperature [degrees Kelvin].

~~(ii)~~(B) The calibration procedure described in paragraph (d)(3) of this section establishes the value of the calibration coefficient at measured values of pressure, temperature and air flow.

(2) The manufacturer's recommended procedure shall be followed for calibrating electronic portions of the CFV.

(3) Measurements necessary for flow calibration are as follows:

Parameter	Symbol	Units	Tolerances
Barometric pressure (corrected)	P_B	kPa	± 0.34 kPa
Air temperature into flowmeter	T_{EI}	℃	± 0.28 ℃
Pressure drop between inlet & outlet of venturi	P_{ED}	kPa	± 0.012 kPa
Air flow	Q_S	m^3/min.	± 0.5 percent of NIST value
CVS inlet depression	P_{PI}	kPa	± 0.055 kPa
Pressure head at CVS pump outlet	P_{PO}	kPa	± 0.055 kPa
Temperature at venturi inlet	T_V	℃	± 2.22 ℃

(4) Set up equipment as shown in Figure 6 of Appendix A of this Part and eliminate leaks. (Leaks between the flow measuring devices and the critical flow venturi will seriously affect the accuracy of the calibration.)

(5) Set the variable flow restrictor to the open position, start the blower, and allow the system to stabilize. Record data from all instruments.

(6) Vary the flow restrictor and make at least eight readings across the critical flow range of the venturi.

(7) Data analysis. The data recorded during the calibration are to be used in the following calculations:

~~(i)~~(A) The air flow rate (designated as Qs) at each test point is calculated in standard cubic feet per minute from the flow meter data using the manufacturer's prescribed method.

~~(ii)~~(B) Calculate values of the calibration coefficient for each test point:

$$K_V = \frac{Q_S \sqrt{T_V}}{P_V}$$

Q_S = Flow rate in standard cubic meter per minute, at the standard conditions of 20° C, 101.3 kPa.

T_V = Temperature at venturi inlet, degrees Kelvin.

P_V = Pressure at venturi inlet = $P_B - P_{PI}$, kPa

Where:

P_{PI} = Venturi inlet pressure depression, kPa.

~~(iii)~~(C) Plot K_V as a function of venturi inlet pressure. For choked flow, K_V will have a relatively constant value. As pressure decreases (vacuum increases), the venturi becomes unchoked and K_V decreases. (See Figure 7 in Appendix A of this Part.)

~~(iv)~~(D) For a minimum of eight points in the critical region calculate an average K_V and the standard deviation.

~~(v)~~(E) If the standard deviation exceeds 0.3 percent of the average K_V, take corrective action.

(e) CVS system verification. The following "gravimetric" technique can be used to verify that the CVS and analytical instruments can accurately measure a mass of gas that has been injected into the system. (Verification can also be accomplished by constant flow metering using critical flow orifice devices.)

(1) Obtain a small cylinder that has been charged with 99.5 percent or greater propane or carbon monoxide gas.

(2) Determine a reference cylinder weight to the nearest 0.01 grams.

(3) Operate the CVS in the normal manner and release a quantity of pure propane into the system during the sampling period (approximately five minutes).

(4) The calculations are performed in the normal way except in the case of propane. The density of propane (0.6109 kg/m^3) carbon atom is used in place of the density of exhaust hydrocarbons.

(5) The gravimetric mass is subtracted from the CVS measured mass and then divided by the gravimetric mass to determine the percent accuracy of the system.

(6) Good engineering practice requires that the cause for any discrepancy greater than ± two percent must be found and corrected.

90. CVS Calibration Frequency.

Calibrate the CVS positive displacement pump or critical flow venturi following initial installation, major maintenance or as necessary when indicated by the CVS system verification (described in Part IV, section 24(e)).

91. Dilute Emission Sampling Calculations.

(a) The final reported emission test results must be computed by use of the following formula:

$$A_{wm} = \frac{\sum (W_i \, x \, WF_i)}{\sum (P_i \, x \, WF_i)} \, x \, K_{Hi}$$

Where:

A_{wm} = Weighted mass emission level (HC, CO, CO_2, or NO_x) for a test [g/kW-hr].

W_i = Average mass flow rate of an emission from a test engine during mode i [g/hr].

WF_i = Weighting factor for each mode i as defined in Part IV, section 10(a).

P_i = Gross average power generated during mode i [kW] calculated from the following equation (power for the idle mode shall always be zero for this calculation):

$$P_i = \frac{2\pi}{60{,}000} \, x \, speed \, x \, torque$$

speed = average engine speed measured during mode i [rev./minute]

torque = average engine torque measured during mode i [N-m]

K_{Hi} = Humidity correction factor for mode i. This correction factor only affects calculations for NO_x and is equal to one for all other emissions. K_{Hi} is also equal to one for all two-stroke engines.

(b) The mass flow rate (Wi) of an emission for mode i is determined from the following equation:

$$W_i = Q_i \, x \, D \, x \left(C_{Di} - C_{Bi} \, x \left(1 - \frac{1}{DF_i} \right) \right)$$

Where:

Q_i	=	Volumetric flow rate of the dilute exhaust through the CVS at standard conditions [m^3/hr at STP].
D	=	Density of a specific emission (D_{HC}, D_{CO}, D_{CO2}, D_{NOx}) in the exhaust [g/m^3].
DF_i	=	Dilution factor of the dilute exhaust during mode i.
C_{Di}	=	Concentration of the emission (HC, CO, NO_x) in the dilute exhaust extracted from the CVS during mode i [ppm].
C_{Bi}	=	Concentration of the emission (HC, CO, NO_x) in the background sample during mode i [ppm].
STP	=	Standard temperature and pressure. All volumetric calculations made for the equations in this section are to be corrected to a standard temperature of 20 degrees Celsius and 101.3 kilopascals.

(c) Densities for emissions that are to be measured for this test procedure are:

D_{HC}	=	576.8 g/m^3
D_{NOx}	=	1912 g/m^3
D_{CO}	=	1164 g/m^3
D_{CO2}	=	1829 g/m^3

(1) The value of D_{HC} above is calculated based on the assumption that the fuel used has a carbon to hydrogen ratio of 1:1.85. For other fuels, D_{HC} can be calculated from the following formula:

$$D_{HC} = \frac{M_{HC}}{R_{STP}}$$

Where:

M_{HC} = Molecular weight of the hydrocarbon molecule divided by the number of carbon atoms in the molecule [g/mole].

R_{STP} = Ideal gas constant for a gas at STP = 0.024065 [m^3-mole].

(2) The idealized molecular weight of the exhaust hydrocarbons, i.e., the molecular weight of the hydrocarbon molecule divided by the number of carbon atoms in the molecule, M_{HC} can be calculated from the following formula:

$$M_{HC} = M_C + \alpha M_H + \beta M_O$$

Where:

M_C = Molecular weight of carbon = 12.01 [g/mole].

M_H = Molecular weight of hydrogen = 1.008 [g/mole].

α = Hydrogen to carbon ratio of the test fuel.

(3) The value of D_{NOx} above assumes that NO_x in entirely in the form of NO_2.

(d) The dilution factor (DF) is the ratio of the volumetric flow rate of the background air to that of the raw engine exhaust. The following formula is used to determine DF:

$$DF = \frac{13.4}{C_{D_{HC}} + C_{D_{CO}} + C_{D_{CO_2}}}$$

Where:

C_{DHC} = Concentration of HC in the dilute sample [ppm].

C_{DCO} = Concentration of CO in the dilute sample [ppm].

C_{DCO2} = Concentration of CO_2 in the dilute sample [ppm].

(e) The humidity correction factor K_H is an adjustment made to the measured NO_x. This corrects for the sensitivity that a spark-ignition engine has to the humidity of its combustion air. The following formula is used to determine K_H for NO_x calculations:

$$K_H = \frac{1}{1 - 0.0329(H - 10.71)}$$

Where:

H = Absolute humidity of the engine intake air [grams of water per kilogram of dry air].

(f) The absolute humidity of the engine intake air H is calculated using the following formula:

$$H = \frac{6.211\, P_{dew}}{P_B - \left(\frac{P_{dew}}{100}\right)}$$

Where:

P_{dew} = Saturated vapor pressure at the dew point temperature [kilopascals].

P_B = Barometric pressure [kilopascals].

(g) The fuel mass flow rate F_i can be either measured or calculated using the following formula:

$$F_i = \frac{M_f}{T}$$

Where:

M_f = Mass of fuel consumed by the engine during the mode [g].

T = Duration of the sampling period [hr].

(h) The mass of fuel consumed during the mode sampling period, M_{FUEL} can be calculated from the following equation:

$$M_f = \frac{G_s}{R_2\, x\, 273.15}$$

Where:

G_S = Mass of carbon measured during the mode sampling period [g].

R_2 = The fuel carbon weight fraction, which is the mass of carbon in fuel per mass of fuel [g/g].

(i) The grams of carbon measured during the mode G_S can be calculated from the following equation:

$$G_S = \frac{12.011\, x\, HC_{mass}}{12.011 + 1.008\alpha} + 0.429\, CO_{mass} + 0.273\, CO_{2\ mass}$$

Where:

HC_{mass} = mass of hydrocarbon emissions for the mode sampling period [g].

CO_{mass} = mass of carbon monoxide emissions for the mode sampling period [g].

CO_2 mass = mass of carbon dioxide emissions for the mode sampling period [g].

α = The atomic hydrogen to carbon ratio of the fuel.

92. Catalyst Thermal Stress Resistance Evaluation.

(a) (1) The purpose of the evaluation procedure specified in this section is to determine the effect of thermal stress on catalyst conversion efficiency. The thermal stress is imposed on the test catalyst by exposing it to quiescent heated air in an oven. The evaluation of the effect of such stress on catalyst performance is based on the resultant degradation of the efficiency with which the conversions of specific pollutants are promoted. The application of this evaluation procedure involves the several steps that are described in the following paragraphs.

(2) The engine manufacturer need not submit catalyst conversion efficiency data for pollutants that the catalyst being tested was not designed to reduce/oxidize. The engine manufacturer must specify the pollutants that the catalyst will be converting and submit catalyst conversion efficiency data on only those pollutants.

(b) Determination of initial conversion efficiency.

(1) A synthetic exhaust gas mixture having the composition specified in section 29 is heated to a temperature of 450 degrees Celsius ± 5 degrees Celsius and

passed through the new test catalyst or, optionally, a test catalyst that has been exposed to temperatures less than or equal to 500 degrees Celsius for less than or equal to two hours, under flow conditions that are representative of anticipated in-use conditions.

(2) The concentration of each pollutant of interest, that is, hydrocarbons, carbon monoxide, or oxides of nitrogen, in the effluent of the catalyst is determined by means of the instrumentation that is specified for exhaust gas analysis in Part III.

(3) The conversion efficiency for each pollutant is determined by:

~~(i)~~(A) Subtracting the effluent concentration from the initial concentration,

~~(ii)~~(B) Dividing this result by the initial concentration,

~~(iii)~~(C) Multiplying this result by 100 percent.

(c) Imposition of thermal stress.

(1) The catalyst is placed in an oven that has been pre-heated to 1000 degrees Celsius and the temperature of the air in the oven is maintained at 1000 degrees Celsius ± 10 degrees Celsius for six hours. Optionally, the catalyst may instead be placed in an oven having a 90% nitrogen/10% water vapor environment that has been pre-heated to at least 850 degrees Celsius and the temperature of the nitrogen/water vapor environment in the oven is maintained at 850 degrees Celsius ± 10 degrees Celsius for six hours.

(2) The catalyst is removed from the oven and allowed to cool to room temperature.

(d) Determination of final conversion efficiency. The steps listed in paragraph (b) of this section are repeated.

(e) Determination of conversion efficiency degradation.

(1) The final conversion efficiency determined in paragraph (c) of this section is subtracted from the initial conversion efficiency determined in paragraph (b) of this section.

(2) This result is divided by the initial conversion efficiency.

(3) This result is multiplied by 100 percent.

(f) Determination of compliance with degradation limit. The percent degradation determined in paragraph (e) of this section must not be greater than 20 percent.

Appendix A to Part IV – Figures.

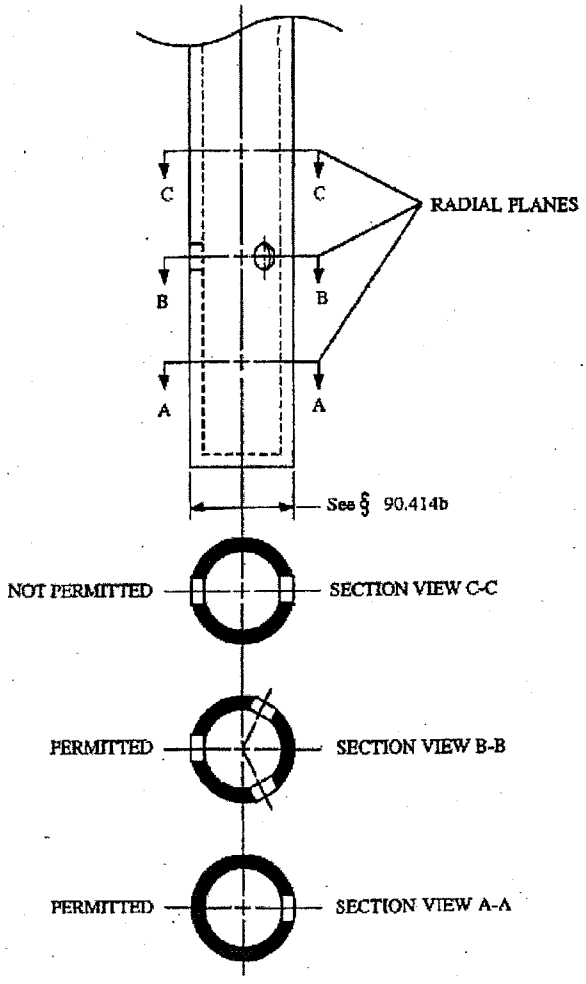

Figure 1.—Sample Probe and Typical Hole Spacings

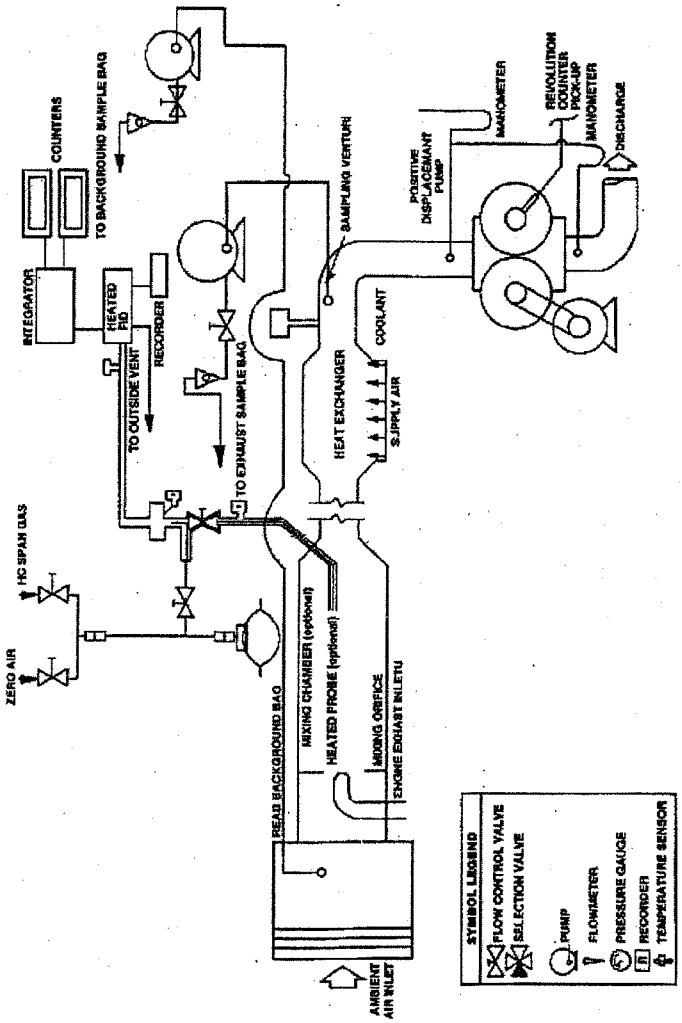

Figure 2 — Gaseous Emissions Sampling System (PDP-CVS)
Showing both grab bag sampling and continous sampling

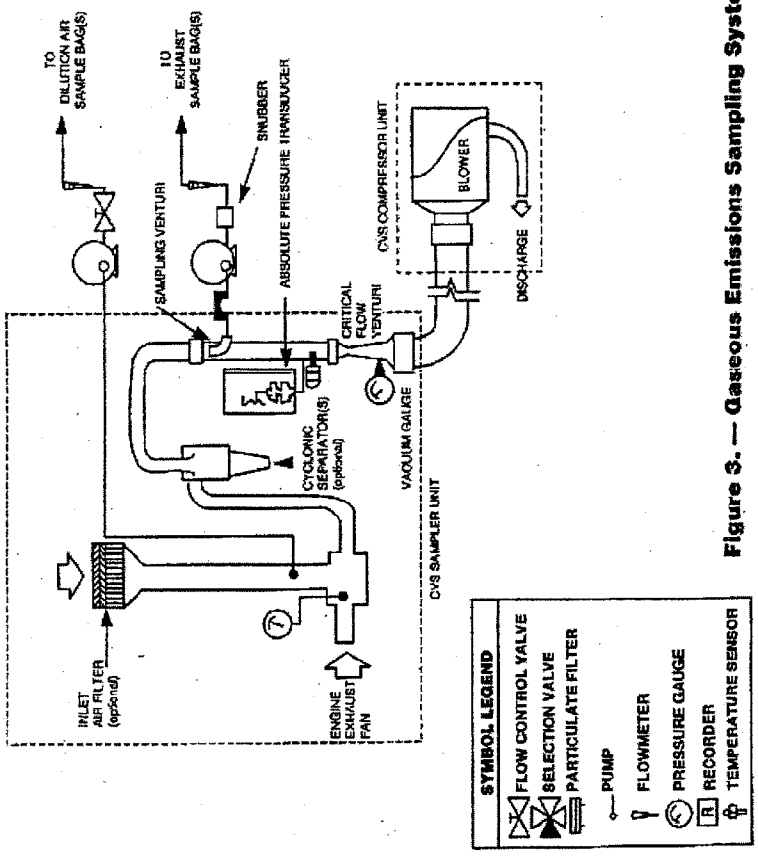

Figure 3. — Gaseous Emissions Sampling System (CVF-CVS)

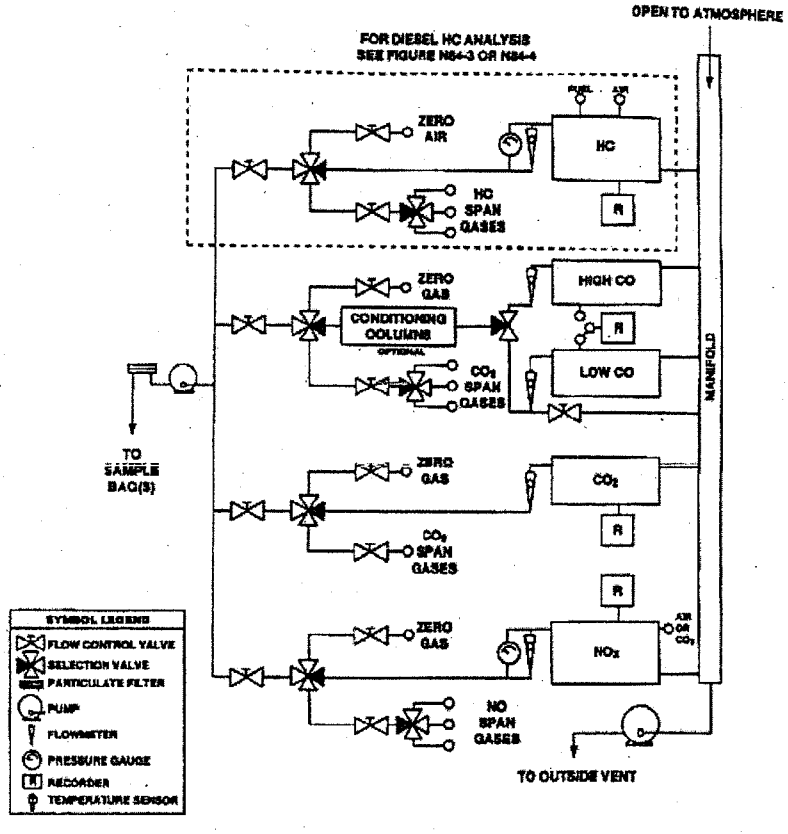

Figure 4. — Exhaust Gas Analytical System

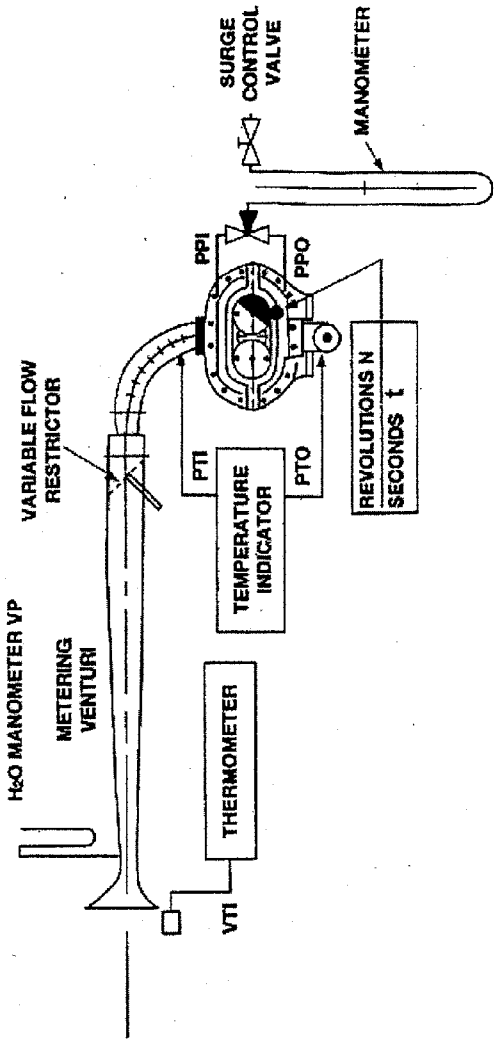

Figure 5. — PDP-CVS Calibration Configuration

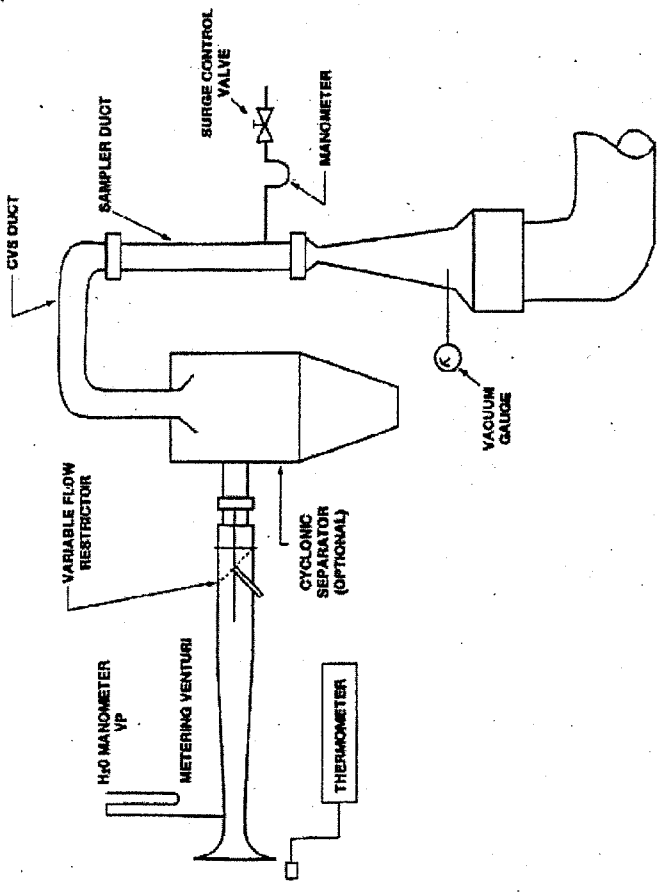

Figure 6. — CFV-CVS Calibration Configuration

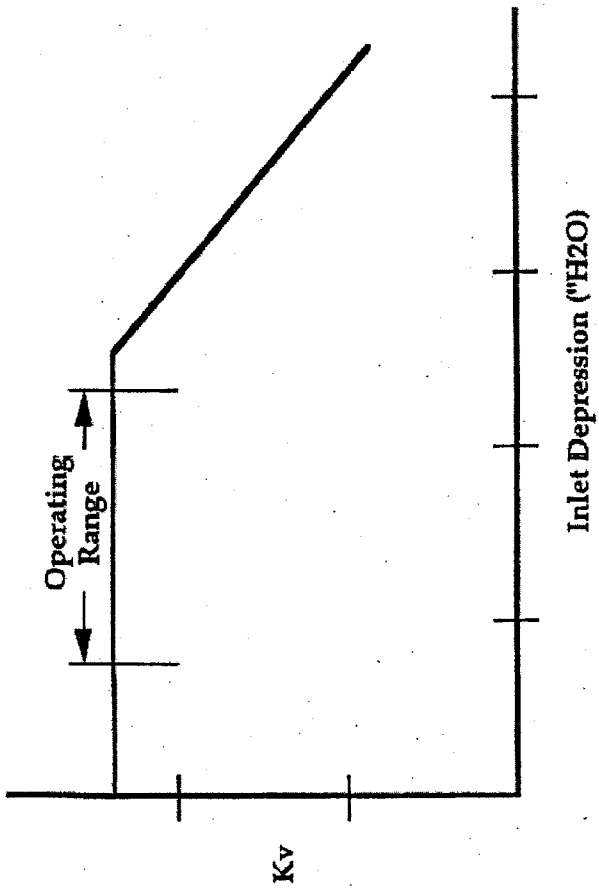

Figure 7.—Sonic Flow Choking

ATTACHMENT C

PROCEDURES FOR EXEMPTION OF ADD-ON AND MODIFIED PARTS FOR OFF-ROAD CATEGORIES

State of California

AIR RESOURCES BOARD

PROCEDURES FOR EXEMPTION OF ADD-ON AND MODIFIED PARTS FOR OFF-ROAD CATEGORIES

Adopted: July 14, 2000
Amended: <Insert Date Here>

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AIR RESOURCES BOARD

PROCEDURES FOR
EXEMPTION OF ADD-ON AND MODIFIED PARTS
FOR OFF-ROAD VEHICLES/ENGINES/EQUIPMENT

I. APPLICABILITY

These criteria apply to add-on or modified parts that are emission related, as defined in Sections 1900 (b), (1) and (10), Chapter 3, Title 13, California Code of Regulations (CCR). Examples of emission related parts for on-road vehicles are shown in Appendix B of these procedures. Such parts require an exemption from the prohibitions of Sections 27156 and 38391 of the California Vehicle Code (VC) or 13 CCR, Section 2472 in order to be legally advertised, offered for sale, sold, or installed in California. The Executive Officer shall grant an exemption from VC 27156 and VC 38391 or 13 CCR, Section 2472 for parts that satisfy the criteria specified in these procedures.

These procedures do not affect the provisions of Title 13, CCR Sections 2403(g), 2412(g), 2423(e), and 2433(e).

II. APPLICATION FOR EXEMPTION BY THE BOARD FROM THE PROHIBITIONS OF SECTIONS 27156 AND 38391 OF THE CALIFORNIA VEHICLE CODE OR 13 CCR, SECTION 2472.

The manufacturer of an add-on or modified part shall file an application for exemption for each generic category, as defined in Paragraph III.D of these procedures. The application shall be in writing, and must be signed by a person authorized to act on behalf of the manufacturer.

An applicant shall provide the information required in the application form in Appendix A of these procedures. In addition to the application, the Executive Officer shall require an applicant to submit other design or technical information, photographs, and a sample of the part, if the information submitted in the application does not permit a proper evaluation of the add-on or modified part. Upon request of an applicant, the Executive Officer shall return any sample part within 30 days after the exemption request is either granted, denied, or withdrawn.

III. EMISSION TESTING REQUIRED BY THE EXECUTIVE OFFICER

A. Vehicle/Engine/Equipment Selection

The Executive Officer shall require an applicant to conduct emission testing in accordance with Paragraphs IV.E.,V, and VI of these procedures unless the Executive Officer determines, based

upon a review of available information, that the part for which an exemption is sought meets the standards and requirements set forth in these procedures, and does not significantly affect emissions. Upon request by the applicant, the Executive Officer shall provide a list of test vehicles/engines/equipment, including alternates. When selecting test vehicles/engines/equipment, the Executive Officer shall consider the worst case and/or the most popular configurations, as defined in Paragraph III.E.2 of these procedures. The number of vehicles/engines/equipment to be tested is specified in Paragraph III.E of this section. Manufacturers are advised to consult with the Air Resources Board staff before conducting any testing in support of an exemption application.

B. Test Laboratory

The applicant shall have any required testing performed at a laboratory properly equipped to conduct such tests. The test vehicle(s)/engine(s)/equipment shall be under the control of the laboratory for the entire test period and shall not be returned until the completion of the test period.

C. Additional or Alternate Testing

If the Executive Officer finds that the emission testing specified in Paragraphs IV.E, V, and VI of these procedures is not adequate to characterize the emissions performance or durability of an add-on or modified part, the Executive Officer shall require alternate emission testing (including monitoring of toxic emissions or "off-cycle" testing) and/or functional and bench testing. If the Executive Officer requires such additional or alternate testing, the Executive Officer shall notify the applicant of the requirement prior to the start of any other required testing and shall provide the applicant with reasons or justification for imposing the alternate or additional requirements. The Air Resources Board may conduct confirmatory tests at the option of the Executive Officer. Confirmatory tests, if required, shall be performed by ARB within 30 days of the receipt of all data, materials, and vehicles necessary for conducting the tests. The results of ARB confirmatory tests shall be reported to the applicant within 20 days of completion of all ARB testing. The applicant shall be given the opportunity to observe the confirmatory tests. The confirmatory testing conducted by the Air Resources Board shall utilize the same procedure and test type as that used by the applicant.

D. Categorization of Parts - Generic Categories

Any add-on or modified part will be categorized according to its "Generic Category". For example, the term "intake manifold" shall define the entire generic category for this part. Generic categories shall include:

Turbochargers
Superchargers
Intercoolers

Carburetors
Fuel Injection Systems
Intake Manifolds
Ignition Systems (excluding Distributors)
Ignition Distributors
Electronic Control Units
Camshafts
Other Internal Engine Components
Evaporative Control System
Positive Crankcase Ventilation System
Exhaust Gas Recirculation System
Air Injection System
Fuel Filler Necks with Restrictions
Thermal Reactors
Exhaust Systems

For other components which in any way can affect emissions, applicants should check with the Executive Officer for a determination of the appropriate breadth of the generic category.

E. Number and Type of Test Vehicles/Engines/Equipment Required

1) When required by the Executive Officer, add-on or modified parts shall be emission tested using the test procedures specified in Paragraphs IV.E, V, and VI of these procedures, as applicable.

2) The required number and type of test vehicles/engines/equipment is the same for each test procedure specified in paragraphs IV.E, V, and VI of these procedures. The test vehicle/engine/equipment types will be the "worst case" and/or "most popular" as determined by the Executive Officer. Selection of a "most popular" test vehicle/engine/equipment shall be based on the configuration with the highest projected sales volume of the add-on or modified part. Selection of a "worst case" test vehicle/engine/equipment shall be based on the engine displacement and vehicle/engine/equipment test weight which produce the greatest stress on the emission related components. When the Executive Officer finds that a "worst case" vehicle/engine/equipment cannot be obtained with a reasonable effort or cost to the applicant, one with the same engine displacement but different test weight may be substituted. When the Executive Officer makes such a finding, the substitute vehicle/engine/equipment may be emission tested at the same test weight and road load horsepower as that of the "worst case" vehicle/engine/equipment. If the applicant elects to test the substitute vehicle/engine/equipment at a test weight less than that of the "worst case", the Executive Officer shall restrict the exemption for the add-on or modified part to vehicles/engines/equipment with the lower weight, unless the Executive Officer

determines that the lower weight adequately represents the heavier vehicle/engine/equipment substituted for in all ways related to emissions. The number of vehicles/engines/equipment the applicant will be required to emission test depends on the application and is provided herein.

a) Universal Vehicle/Engine/Equipment Application Type:

Refers to the generic categories in which the add-on or modified part exemption application applies to the product line of four or more vehicle/engine/equipment manufacturers. In such cases the applicant shall be required to emission test a maximum of four different model vehicles, engines, or equipment for each application category.

b) Less Than Universal Vehicle/Engine/Equipment Application Type:

Refers to the generic categories in which the add-on or modified part exemption application applies to the product line of two or three vehicle/engine/equipment manufacturers. In such cases the applicant shall be required to emission test a number of vehicles, engines, or equipment equal to or less than the number of applicable manufacturers for each application category.

c) Single Manufacturer Vehicle/Engine/Equipment Application Type:

Refers to the generic categories in which the add-on or modified part exemption application only applies to one vehicle/engine/equipment manufacturer. In such cases the applicant may be required to emission test no more than one vehicle/engine/equipment for each application category.

IV. EVALUATION CRITERIA

A. Basis of Emissions Evaluation

The Executive Officer shall review the applicant's emission test data and the Air Resources Board test results, if any, to determine if the add-on or modified part increases emissions. In the absence of certification emission test data, the Executive Officer shall use good engineering judgment and the results of any functional, emission test results from similar parts in making the determination regarding the effect of the add-on or modified part on emissions.

B. Resolution of Discrepancies

In the event of discrepancies between the Air Resources Board test results and the applicant's test results, the Executive Officer's evaluation may be based solely on the Air Resources Board test

results. The Executive Officer shall inform the applicant of any such discrepancies, and shall endeavor to resolve the conflict between the test results. If the conflict cannot be resolved, the Executive Officer shall inform the applicant that there are still discrepancies and that the Air Resources Board test results will be used.

C. Performance and Driveability

The Executive Officer shall use good engineering judgment to evaluate the effects of the add-on or modified part on the vehicle's/engine's/equipment's driveability or performance. If the Executive Officer determines that the add-on or modified part degrades a vehicle's/engine's/equipment's driveability or performance such that owners may be encouraged to adjust the engine settings or tamper with required emission control systems to improve driveability or performance, the Executive Officer may find that the add-on or modified part will increase emissions.

D. Durability

If the Executive Officer has reason to believe, on the basis of an engineering evaluation, that an add-on or modified part will adversely affect the durability of the vehicle/engine/equipment emission control system, or that in the past the part did not demonstrate durability equivalent to the part or system replaced or added to, the Executive Officer shall find that the modification will increase emissions. In such cases the applicant shall be required to submit data in order to show that the vehicle/engine/equipment emission control system is not adversely affected, and/or that the add-on or modified part has demonstrated adequate durability.

E. Specific Evaluation Criteria Parts Subject to Emission Testing

When the Executive Officer requires an add-on or modified parts manufacturer to perform emission testing, the applicant shall demonstrate compliance with the requirements of these test procedures using the procedures contained herein.

1) Determination of Baseline Emissions

The applicant shall submit a list of vehicles/engines/equipment for which the add-on or modified part may be applied to, before commencing testing. The ARB shall inform the applicant as to which vehicle/engine/equipment may need to be tested. An applicant may be required to test more than one vehicle/engine/equipment.

The applicant shall select a functional vehicle/engine/equipment. A functional vehicle/engine/equipment is one that complies with the original certification standard. The baseline emissions of the test vehicles/engines/equipment without the add-on or modified part (s) shall be determined using the appropriate test procedures specified in paragraphs V and VI of these procedures.

2) Emissions Testing

Emissions testing performed pursuant to these test procedures shall be conducted by an exhaust emissions test laboratory.

V. OFF-ROAD CATEGORIES

Applicants shall utilize the appropriate test procedure for their vehicle/engine/equipment category, as defined in this section.

The test vehicle/engine/equipment shall be operated for the appropriate break-in period, as specified in the applicable exhaust emissions test procedures before commencing testing. Break-in periods for each off-road category are specified in the test procedures referenced below. The baseline emissions without the add-on or modified part shall be determined prior to testing, but after stabilization of the vehicle/engine/equipment. Following the addition of the add-on or modified part, the test vehicle/engine/equipment shall be tested to ensure that the original certification standards are met. For the purposes of these procedures, off-road vehicles/engines/equipment are categorized as follows:

A. Small Off-Road Engines

Small Off-Road Engines include all engines that produce, or are designed to produce, less than 25 horsepower (hp), manufactured on or after January 1, 1995, and used in off-road mobile applications, with the exceptions of off-road motorcycles, all-terrain vehicles, marine vessels, snowmobiles, model airplanes, model cars, or model boats.

B. Off-Road Diesel Engines and Equipment

The heavy-duty off-road diesel cycle engine and equipment category consists of off-road diesel-cycle engines that are:

(1) greater than or equal to 50 hp and less than 100 hp manufactured on or after January 1, 1998, and certified to meet the federal emission standards and certification provisions;

(2) greater than or equal to 100 hp and less than 175 hp manufactured on or after January 1, 1997, and certified to meet the federal emission standards and certification provisions; and

(3) diesel cycle and alternative fueled diesel cycle engines equal to 175 hp and above for off-road engines produced on or after January 1, 1996, and certified to meet California's exhaust emission standards and test procedures. This last category includes

engines used in farm and construction equipment, as well as mining, forestry, and industrial equipment.

C. Off-Highway Recreational Vehicles and Engines

The off-highway recreational vehicle category includes new off-highway recreational vehicles and engines in such vehicles, produced on or after January 1, 1997. This category includes off-road motorcycles, all-terrain vehicles, and golf carts. New golf carts used in areas that do not meet the federal ozone standards will continue to have a zero-emission requirement.

D. Spark-Ignition Marine Engines

The spark-ignition marine engine category includes 2001 and subsequent model year outboard and personal watercraft engines used to propel marine watercraft~~, but not including~~ 2003 and subsequent model year sterndrive/~~or~~ inboard engines less than or equal to 373 kw, and 2009 and subsequent model year sterndrive/inboard engines greater than 373 kw.

E. Off-Road Large Spark-Ignition Engines

The off-road large spark-ignition engine category includes engines that produce, or are designed to produce 25 and greater horsepower, and that are produced on or after January 1, 2001. Such engines are typically used to power forklift trucks, sweepers, generators, industrial equipment and other miscellaneous applications.

VI. TEST PROCEDURES AND STANDARDS

A. Test Procedures

1) Test Procedures for Small Off-Road Engines

"California Exhaust Emission Standards and Test Procedures for 1995 and Later Small Off-Road Engines," adopted March 20, 1992 and last amended March 23, 1999, which is incorporated by reference herein. (These procedures are also incorporated by reference by Title 13, California Code of Regulations (CCR) Section 2403.)

2) Test Procedures for Off-Road Diesel Engines and Equipment

i) For 175 horsepower and greater:

"California Exhaust Emission Standards and Test Procedures for New 1996 and Later Heavy-Duty Off-Road Diesel Cycle Engines,"adopted May 12, 1993, which is incorporated by reference herein, and "California Smoke Test Procedures for

New 1996 and later Heavy-Duty Off-Road Diesel Cycle Engines," adopted May 12, 1993, which is incorporated by reference herein. (These procedures are also incorporated by reference by 13, CCR Section 2423).

ii) For greater than or equal to 50 horsepower and less than 175 horsepower:

The exhaust emission standards and test procedures specified in Appendix C of these procedures, which is incorporated by reference herein.

3) Test Procedures for Off-Highway Recreational Vehicles and Engines

i) For new off-road motorcycles, all-terrain vehicles, and golf carts:

"California Exhaust Emissions Standards and Test Procedures for 1997 and Later Off-Highway Recreational Vehicles and Engines," adopted November 23, 1994, and as last amended October 22, 1999, which is incorporated by reference herein. (These procedures are also incorporated by reference by Title 13, CCR Section 2412).

ii) For all-terrain vehicle engines

"California Exhaust Emission Standards and Tests Procedures for 1995 and Later Small Off-Road Engines," adopted March 20, 1992, and last amended March 23,1999,which is incorporated by reference herein. (These procedures are also incorporated by reference by Title 13, CCR Section 2412).

4) Test Procedures for Spark-Ignition Marine Engines

"California Exhaust Emission Standards and Test Procedures for 2001 and Later Spark- Ignition Marine Engines" adopted October 21, 1999, and last amended <Insert Date Here> which is incorporated by reference herein. (These procedures are also incorporated by reference by Title 13, CCR Section 2442).

5) Test Procedures for Off-Road Large Spark-Ignition (LSI) Engines

i) For new off-road LSI engines with engine displacement greater than 1.0 liter

"California Exhaust Emission Standards and Test Procedures for New 2001 and Later Off-Road Large Spark-ignition Engines," adopted September 1, 1999, which is incorporated by reference herein. (These procedures are also incorporated by reference by Title 13, CCR Section 2433).

ii) For new off-road LSI engines with engine displacement equal to or less than 1.0 liter

"California Exhaust Emission Standards and Test Procedures for 1995 and Later Small Off-Road Engines," as last amended March 23, 1999, which is incorporated by reference herein. (These procedures are also incorporated by reference by Title 13, CCR Section 2433).

6) Alternative Test Plan

An applicant may use an alternative test procedure subject to prior approval by the Executive Officer. An applicant requesting the use of an alternative test procedure must fully describe the proposed test procedure and submit information that demonstrates the proposed procedure will yield results equivalent to those generated by the applicable standard test procedures.

The Executive Officer may reject data generated under alternative test procedures which do not correlate with data generated under the specified procedures.

B. Vehicle/Engine/Equipment Exhaust Emission Standards

1) 2000 and later model-year small off-road engines

To demonstrate compliance with the applicable emission standards, each emission test result shall be adjusted by the application of the certification deterioration factor provided in the original engine manufacturer's certification application for the model and model year of the test engine. The deteriorated emission test results shall be in compliance with these procedures only if they are equal to or less than the California new engine exhaust emission standards. The applicant shall be permitted one retest if the initial emission test results fail to demonstrate compliance with these procedures. The results of the initial test and the retest will be averaged, and the averaged result must comply with the standards set for the single test in order to demonstrate compliance.

2) All other off-road categories:

The add-on or modified part manufacturer shall demonstrate compliance with these procedures by showing that the exhaust emissions from the test vehicle/engine/equipment with the add-on or modified part installed are in compliance with the applicable exhaust

emission standards for the class and model year of the test vehicle/engine/equipment.

3) Vehicles/Engines/Equipment certified under optional averaging banking, and trading provisions

For purposes of these procedures the applicable emission standards for vehicles/engines/equipment certified under optional averaging, banking, and trading provisions shall be the family emission limit (FEL) that the vehicle/engine/equipment is certified to.

VII. ACTION ON THE APPLICATION

A. Application Evaluation

The Air Resources Board staff will initially evaluate the application, the test data, and any other pertinent information concerning the add-on or modified part. On the basis of the information provided by the applicant and/or the Air Resources Board test results, the staff will make a recommendation to the Executive Officer. If the Executive Officer determines that an add-on or modified part will not reduce the effectiveness of the emission control system or result in emissions that exceed the applicable emission standards for each vehicle/engine/equipment, he or she shall issue an Executive Order exempting the add-on or modified part from the prohibitions of VC Sections 27156 and 38391 or 13 CCR, Section 2472. This Executive Order may restrict the installation of the add-on or modified parts certified by engineering evaluation to certain makes, model-years, or classes of vehicles/engines/equipment. As a condition of exemption the applicant shall not use the Executive Order as an endorsement or approval by the Air Resources Board.

The Executive Officer shall deny the applicant's exemption request if the add-on or modified part increases emissions more than allowed under the Evaluation Criteria of section VI of these procedures. If the Executive Officer denies the applicant's exemption request, the Executive Officer shall convey by letter notice of and the reasons for denial.

B. Labeling Requirements

The add-on or modified part manufacturer shall provide a product information label and complete instructions for its installation in a location readily visible to the average person with each part or kit of parts sold. The product information label shall contain, at a minimum, the product name as exempted, ARB executive order number using the format "CARB D-O-XXX," manufacturer's name, and the manufacturer's address. The product information label shall be designed for a minimum life of five years.

If the installation of an add-on or modified part requires the removal of any emission control component, re-routing of any vacuum hose, or changes to the vehicle manufacturer tune-up specifications, the add-on or modified part manufacturer must provide two identical product information labels. These product information labels shall, in addition to the information specified in the immediately preceding paragraph, provide a complete description of the required changes and the new tune-up specifications. One product information label will be installed either on or near the add-on or modified part, in a location readily visible to the average person. The other product information label will be installed adjacent to, but not covering, the vehicle/engine/equipment manufacturer's Vehicle Emission Control Information (tune-up) label or Important Engine Information Label.

The add-on or modified part manufacturer shall submit a facsimile or prototype of the product information label and the installation instructions with each application for exemption.

VIII. WARRANTY REQUIREMENTS

The manufacturer of an add-on or modified part will warrant to the ultimate purchaser and to each subsequent purchaser that the add-on or modified part is designed and manufactured to conform with the applicable requirements of these Procedures and is free from defects in materials and workmanship which may cause the add-on or modified part to fail to conform with the applicable requirements of these Procedures or cause damage to any other part on the modified vehicle/engine/equipment.

This warranty shall cover customer service, and shall cover the full repair and replacement costs including the costs of diagnosis, labor, and parts (including any part on the modified vehicle/engine/equipment that is damaged due to a defect in the add-on or modified part).