Diesel Engines: Environmental Impact and Control—A Critical Review Introduction

Judith C. Chow

Diesel engines are widely used to power trucks, buses, passenger cars, locomotives, and ships. These engines power the heavy equipment that plants and harvests crops, tills soil, clears and reshapes land for roads and buildings, and hauls ores from mines to processing centers. Diesel engines generate electricity as portable power sources, peaking units, and emergency backups when line power is out. They are also employed to pump water and fuel at remote locations. Much of our national defense depends on the mobility, portability, and safety provided by diesel engines and fuels. Diesel fuel has a lower vapor pressure than gasoline and rarely ignites at ambient temperatures in the presence of an open flame.

Diesel engines are more attractive than gasoline engines because they deliver more power per unit of fuel consumed; have lower emissions of CO_2, CO, and hydrocarbons (HCs) for the same energy output; and last longer. Although their initial cost is higher than comparable gasoline engines, their lifetime operating costs are substantially lower. Diesel engines are widely used in passenger cars outside the United States due to differences in fuel pricing policies.

The common perception of diesel exhaust emissions is the belch of black smoke seen as a truck or bus accelerates from a complete stop. Indeed, particulate diesel exhaust emitted to the atmosphere is the most visible and well-documented effect of these engines on the environment. Diesel particles are emitted, albeit with varying chemical compositions, throughout the operating cycle. Most diesel emissions are invisible to the naked eye. Diesel exhaust is explicitly defined as a hazardous air pollutant, the only one that is not chemically specific. Diesel exhaust particles have the highest proportion of black carbon, or "soot", of any combustion emissions. This soot, a complex mixture of carbon, sulfur, nitrogen, hydrogen, and oxygen, adsorbs organic and sulfur gases containing irritants that cause short-term respiratory distress and long-term lung cancers. This soot absorbs visible light, contributing to urban and regional hazes and to changes in the Earth's radiation balance. Owing to its low volatility, diesel fuel persists longer than gasoline when spilled or leaked into waterways or land surfaces. Cleanup after these accidents has been technically challenging, time-consuming, and costly.

This year's 31st annual Critical Review, entitled "Diesel Engines: Environmental Impact and Control," by Alan Lloyd and Thomas Cackette of the California Air Resources Board (ARB), provides a comprehensive examination of diesel exhaust and its effects on the environment. The review describes how diesel engines work and why they are used for certain applications and not for others. It justifies concerns about the effect of diesel particles on occupational and public health, while recognizing its beneficial effect on ozone-forming HC precursors and ambient CO levels. The review discusses how advances in diesel engine design, fuel production, and after-engine exhaust treatments have reduced, and continue to reduce, pollutant emissions. Several emerging energy technologies are identified as replacements for or enhancements of the diesel system. A promising near-term modification is the diesel/fuel cell hybrid in which a small fuel cell would supply power during idling and other low-energy situations (e.g., some steady-state and downhill operations) that make up a relatively large proportion of engine use.

The authors conclude that the use of diesels is here to stay, and is likely to grow in the foreseeable future. There is no intent for regulatory agencies, such as the ARB, to ban their use or to phase them out. However, these reviewers also conclude that the advances made in diesel emissions and efficiency improvements would not have been as great had there been no regulation in the past. They believe that the recent federal and California regulations for fuel sulfur content and allowable particle emissions will spur engine manufacturers and refiners to innovate in order to achieve the required reductions. They recommend more comprehensive and realistic monitoring of emissions, beyond that of engine certification, to determine the diesel engine's contribution to the overall mix of $PM_{2.5}$ and PM_{10} in ambient air and to track progress toward achieving the desired emissions reductions under real-world conditions.

Dr. Alan Lloyd has been chairman of the ARB since 1999. He has 25 years of experience in air quality modeling and emissions estimation, 30 years of experience in atmospheric chemistry, and 12 years of experience in advanced technology development for mobile source emission controls. Dr. Lloyd has a B.S. in chemistry and a Ph.D. in gas kinetics from the University College of Wales. He was chief science advisor at the South Coast Air Quality Management District for 8 years, where he directed projects for mobile sources involving alternative fuels and advanced technologies.

Mr. Thomas Cackette is chief deputy executive officer of the ARB. He has more than 27 years of experience in emissions estimation and advanced technology development for mobile source emissions controls. Mr. Cackette has a B.S. in aeronautics and astronautics and an M.S. in engineering. Before joining the ARB, he worked at the U.S. Environmental Protection Agency's Motor Vehicle Emissions Laboratory for 8 years.

Although Dr. Lloyd and Mr. Cackette are the primary presenters of this review, they were supported by dozens of dedicated and knowledgeable staff at the ARB in assembling and analyzing a broad spectrum of information about diesel exhaust. ARB has been a pioneer in efforts to reduce emissions from mobile sources, and many of its initial efforts have been copied and enhanced at the federal level and throughout the world.

The A&WMA Critical Review Program welcomes your participation at the annual meeting in Orlando and encourages all in attendance to take part in the Critical Review session on Wednesday morning, June 27, 2001. In addition to Dr. Lloyd's and Mr. Cackette's oral presentation of this review, experts from the academic, regulatory, industrial, and consulting communities in different countries will provide additional information on diesel emissions, their effects on air, land, water, and health, and the technologies being implemented to minimize those impacts. These experts may agree or disagree with Dr. Lloyd's and Mr. Cackette's conclusions and recommendations and will highlight international policy implications. Those attending the session may respond from the floor, and those who cannot be present may respond in writing. Discussants' presentations, public responses, and the authors' final words will be published in the September issue of the *Journal*.

Critical Review Committee Chair
Judith C. Chow

Critical Review Committee Members
John G. Watson
Ronald L. Berglund
Pratim Biswas
Chang-Yu Wu

Come hear the Critical Review presentation

"Diesel Engines: Environmental Impact and Control"

Wednesday, June 27, 2001
Orange County Convention Center
Room CC-311 F, G, H
8:00–11:45 am