

# **Verification of Diesel Emissions Control Strategies in California**

**Heavy Duty In-Use Strategies Branch**

**May 10, 2007**

# Overview

- Today we have a singular purpose – to discuss, define, illustrate, and educate applicants as to what should be included in a preliminary and final verification application for a diesel emission control strategy
- We will provide information on the level and quality of the information required with the submission of your application

# ARB Verification Program AKA-The 'Procedure'

- PM driven program, must achieve at least a 25% reduction in diesel PM to be considered
- NOx reductions verified in 5% increments starting at 15%, only if PM reduction is at least 25%
- For hardware, fuels and combination systems for on-road, off-road and stationary applications
- Requires complete product description, emissions/durability test data, warranty information, in-use compliance testing, etc.

# Objectives of the Procedure

- Determine if Emissions Reductions are Real and Durable
- Quantify Emissions Reductions
- Ensure Continued Emissions Reductions Through In-Use Compliance Reporting and Testing

# ARB Does Not Verify The Following:

- Concepts
- NOx only systems
- Strategies that cannot achieve at least a 25% reduction in PM
- 'Black Boxes'
- Strategies that increase NMHC or NOX by more than 10% above baseline, or NO2 by more than 30% above baseline as of 2007 (lowers to 20% as of 2009)
- Strategies that increase CO emissions

# Verification Process

- Where to Start?
  - Read through the ‘Procedure’
  - A copy can be found on our web site at <http://www.arb.ca.gov/diesel/verdev/verdev.htm>
  - Provide ARB with a Preliminary Application
  - Follow the Outline Format Shown in Section 2702 (d) of the Procedure to develop the Preliminary Application

# Preliminary Application

## What's Included?

- Short answer - Everything
  - 1. Introduction
  - 2. DECS Information
  - 3. Alt Diesel Fuel Info (if applicable)
  - 4. DECS & Emission Control Group Compatibility
  - 5. Testing Information
  - 6. Durability Demonstration

# 1. Introduction

- 1.1 Identification of applicant, mfgr, product
- 1.2 Type of verification sought
  - 1.2.1 Describe emission control group
  - 1.2.2 Emission reduction claim

# 1.1 Identification of the applicant, manufacturer, and product

- **Clearly Identify: Applicant**
  - Who's applying for the Verification
  - If applying for others, provide us with a letter stating you have the authority to act on their behalf
  - Include all contact information
  - Only one point of contact

# 1.1 Identification of the applicant, manufacturer, and product (cont.)

- **Clearly Identify: Manufacturer**
  - Who actually makes the system or its components
  - Identify if you are presenting a previously verified product
    - If so, you may need to get written permission from the device manufacturer and/or entity holding the original verification

# 1.1 Identification of the applicant, manufacturer, and product (cont.)

- **System Definition**
  - A system is the entirety of the device being submitted for verification
  - Changes to the system during verification constitutes a new application and will increase review times

# 1.1 Identification of the applicant, manufacturer, and product (cont.)

- **What's a Component**

- Any part of the system presented for verification which is necessary for the proper functioning of the system, or notification of the end user as to system status

# 1.1 Identification of the applicant, manufacturer, and product (cont.)

- **Clearly Identify: Product**
  - What is the product
    - **Example: catalyzed wall-flow DPF**
  - What's it called. Please identify any acronyms or trade names
    - **Example: SDF III™ (Super Duper Filter, Mod 3)**

# 1.2 Identification of type of verification being sought:

- **Identify the type of Verification being sought (please include emission reduction claim)**
  - What level of PM reductions can the device achieve
  - If applicable, what level of NOx reductions can the device achieve
  - On-road, Off-road, Stationary
    - Example:
      - We propose to verify the SDF III™ as a level 3 device for off-road applications

# 1.2.1 Description of emission control group selected

- **Describe the Emission Control Group**
  - What engines/equipment/duty cycles/emissions levels are appropriate for your DECS? The group must be based on the parameters necessary for the successful operation of your DECS
- **Support your Claim**
  - If you describe ‘all on-road engines’ be prepared to support your claim with appropriate testing or existing data

# 1.2.1 Description of emission control group selected (cont.)

- ARB staff can advise applicants on the selection of their emission control group
- Remember: Broad groups will require additional testing/data to support your claim
- Emissions testing and durability demonstrations for verification are based on the selection of a 'worst-case' and/or representative engine or engines (or vehicles/engines)
- The selection of your emission control group is wholly dependant upon your DECS technology and should be based on YOUR in-field experience

# 1.2.1 Description of emission control group selected (cont.)

- **‘Worst-Case’ – What does this mean, how do we define it**
  - ‘Worst-case’ is defined as the engine, vehicle, or application that provides the greatest challenge to demonstrating the successful operation of your DECS
  - This will vary by strategy, it may be the engine with the highest PM emissions, the vehicle with the greatest vibration, the coldest duty cycle, or the engine family with the highest NO<sub>x</sub> emissions

# 1.2.1 Description of emission control group selected (cont.)

- ‘Representative’ – What does this mean
  - ‘Representative’ is defined as the engine, vehicle, or application which characterizes your emissions control group
  - Depending on your strategy and desired emission control group you may need to test on a “worst case” or “representative” engine and/or application

# 1.2.1 Description of emission control group selected (cont.)

- **Example:** An active DPF seeking Level 3 verification, applicant has field data on successful operation of the DECS on a 1991 Cummins 14 liter, turbocharged, non-EGR, route delivery truck, max backpressure of 92" H<sub>2</sub>O, average backpressure of 48" H<sub>2</sub>O, engine was certified to 0.25 g/bhp-hr PM standard and use of the DECS increased NO<sub>2</sub> emissions by roughly 10% above baseline

# 1.2.1 Description of emission control group selected (cont.)

- **Proposed Emission Control Group**
- 1991-2006 on-road engines certified to a PM standard of 0.25 g/bhp-hr or less
- Non-EGR only
- Turbocharged or NA
- No OEM catalyst or filter

# 1.2.2 Emission Reduction Claim

- **Specifically Identify your documented (anticipated) emission reduction claim**
  - What level of PM reductions can the device achieve
  - If applicable, what level of NO<sub>x</sub> reductions can the device achieve
  - Discuss NO<sub>2</sub> emissions
  - Identify/discuss any additional emissions

# 2.1 General Description of the DECS

- **General description of the DECS**
  - Provide general information on the DECS principles of operation
  - Must adequately describe all components - catalyst substrates, washcoats, manufacturers, sensors, etc.
  - Include sizing information
  - Include any backpressure and temperature sensors
  - More information is ALWAYS better

# 2.1.1 Discussion of Principles of Operation and System Design

## How Does it Work

- Detailed information on the DECS principles of operation
- Must adequately explain how the strategy achieves emission reductions and how it works
- Describe any engine maps or control strategies
- Again more information is ALWAYS better

# 2.1.1 Discussion of Principles of Operation and System Design (cont.)

- **Example: What it should look like**

- The SDF III™ is an un-catalyzed wall-flow silicon carbide diesel particulate filter. The filter uses thermal regeneration (oxidation by oxygen) to oxidize the particulate matter collected in the filter pores into gaseous products which can be described by one of the following reactions:



The rate of soot oxidation occurs in the temperature range of .....

# 2.1.1 Discussion of Principles of Operation and System Design (cont.)

- **Example: What it shouldn't look like**
  - The ZipDoDa pneumatic resonator is a secret blend of 11 herbs and spices and our patent attorney will not allow us to divulge its exact formulation. We can tell you that it synergistically causes each individual molecule in the diesel fuel to advance to a higher quantum state, thereby increasing its 'combustibility'. This has the effect of lowering all exhaust emissions, improving fuel economy by 75%, and increasing horsepower by 200%. By incorporating magnets in the effluent channel we can increase the effectiveness of .....

## 2.1.2 Schematics Depicting Operation

- Please provide a schematic(s) depicting operation
- Please make them specific to the application
- Show all Electro/mechanical interfaces
- Include the specific location of any sensors

# 2.2 Description of the Regeneration Method

- **Passive Systems**
- How does the DECS regenerate
- Completely describe the regeneration process, thermal or otherwise
- Include reaction equations
  
- **Active Systems**
- On-line, off-line, other
- Describe the process
- Include reaction equations

# 2.2.1 Operating Condition Requirements for Regeneration

- **Description of the conditions necessary to facilitate regeneration**
  - Passive/Active systems - what are the specific operating conditions and how does it work with respect to your strategy - on line, off line, automatic?
  - Specifically define the operating conditions that enable your DECS to regenerate- include any design information for clarity and discuss all temperature issues.

## 2.2.2 Thresholds and Control Logic to Activate Regeneration

- Thoroughly describe/identify control logic, set points, look-up table information used to control regeneration events
- Be prepared to quantify regeneration emissions
- Include information on the expected frequency of regeneration events
- Include information on average back pressure

## 2.2.3 Description of BP Monitor Including Thresholds and Control Logic

- **Backpressure Monitor**
  - Completely describe the BP monitoring system
  - Include information on the BP sensor and any temperature sensors
  - Include pictures/diagrams of any in-cab monitoring/warning devices
  - Provide information on BP warning levels/triggers
  - Completely describe any end-user interface and/or instructions

## 2.2.3 Description of BP Monitor Including Thresholds and Control Logic (cont.)

- **Backpressure Monitor**
  - Remember, all filter based strategies MUST include a backpressure monitor and are considered part of the ‘system’
  - A monitor without a readily apparent display for the operator will probably not be acceptable
  - All parts of the system must adhere to same warranty requirements found in Section 2707

## 2.3 Favorable Operating Conditions

- Completely describe the favorable operating conditions – duty cycle, temperature, lube oil requirements, fuel requirements, NO<sub>x</sub>/PM ratio, etc.
- Depending on your strategy, this may be a list of the conditions required for successful operation of the DECS.

## 2.4 Unfavorable Operating Conditions and Associated Reductions in Performance

- Completely describe the unfavorable operating conditions – these may include deviations from the favorable conditions, please provide a detailed discussion of each and the anticipated impact on the DECS operation.
- Be sure to include information in the discussion on the nature of the impact - is it likely to be permanent or can the DECS recover

# 2.5 Fuel Requirements and Misfueling Considerations

- Describe any fuel requirements for proper operation of the DECS
- Be prepared to support broad claims with test data
- If not previously done, describe any misfueling considerations associated with your DECS. Provide a detailed explanation of their effects and long-term impact on the strategy

## 2.6 Identification of Failure Modes and Associated Consequences

- Identify and discuss any possible failures of the strategy and the associated consequences
- What would happen if a component failed
- This information should include the applicant's own in-field experience

# 2.7 Complete Discussion of Potential Safety Issues

- Identify and discuss any potential safety issues
- Are there any components or systems used with the DECS that could lead to a safety issue
- Completely discuss issues such as uncontrolled regeneration, unfavorable operating conditions, lack of maintenance, etc., as they relate to safety

## 2.8 Installation Requirements

- Identify and discuss any specific installation requirements, please provide specific details
- Who will perform installation, your company or trained representatives. How complex is the installation procedure. How long will it take.
- If your DECS requires occasional cleaning please describe how the component will be removed and re-installed

## 2.9 Maintenance Requirements

- Identify and discuss any specific maintenance requirements and their anticipated frequency
- Will the applicant provide maintenance as a separate service. If not, how will it be accomplished.
- Are additional parts, tools, kits required for maintenance procedures. If so, please clearly identify these items

# 3. Alternative Diesel Fuel Information

- **Fuel Based Strategies**

- All fuel based strategies are required to prepare and submit a multimedia evaluation for review by the California Environmental Policy Council
- This is not at our discretion: it's required by the California Health and Safety Code, Section 43830.8
- Section 2710 of the Procedure contains information regarding the requirements and information for the development of a proposed test protocol.

# 3. Alternative Diesel Fuel Information (cont.)

- **Multimedia Evaluations:**
  - These are processed on a multi-agency level. The ARB's Stationary Source Division handles all requests for multimedia evaluations.
  - For additional information please contact:
    - Gary Yee, Manager
    - Industrial Section
    - (916) 327-5986
    - [gyee@arb.ca.gov](mailto:gyee@arb.ca.gov)

## 4.1.1 Discussion on Calibrations and Design Features That May Vary from Engine to Engine

- Will calibrations and/or design features that vary from engine to engine require changes to the strategy
- Example: Sizing Criteria – substrate volume verses engine displacement, may require a defined ratio

## 4.1.2 Effect on Overall Engine Performance

- Does the strategy have any effect on engine performance
- This could be a positive or a negative effect
- In some rare cases it could be both
- If your response is 'none' support your claim

## 4.1.3 Effect on Engine Backpressure

- Does the strategy have any effect on engine backpressure
- If so, please provide average & maximum backpressure information
- **Example:** Field testing shows that the SDF III™ has an average backpressure of 40" H<sub>2</sub>O and a maximum backpressure of 80" H<sub>2</sub>O, which also triggers the high backpressure alarm

## 4.1.4 Additional Load on the Engine

- Does the strategy create any additional load on the engine
- If so, please be prepared to quantify the additional load
- Example: Strategies that rely on inputs from engine accessories or significantly increase engine back pressure

## 4.1.5 Effect on Fuel Consumption

- Does the strategy have any impact on fuel consumption
- If so, please be prepared to quantify any fuel penalty/benefit and provide data to support your claim

# 4.1.6 Engine Oil Consumption Considerations

- Is the strategy sensitive to lube oil
- If so, please be prepared to provide information on what the strategy will tolerate and the anticipated effects of exposure
- Provide some general guidelines

# 4.1.6 Engine Oil Consumption Considerations (cont.)

- **Engine Oil Consumption Considerations**
  - Example: SDF III™ is an un-catalyzed wall-flow silicon carbide diesel particulate filter
  - Engines that consume lube oil at a rate greater than that specified by the mfgr can have a temporary impact on the filter but no permanent damage (poisoning) has been observed since the filter is un-catalyzed. Higher lube oil consumption will result in rapid increases in backpressure and require more frequent cleaning of ash deposits

## 4.2.1 Dependence on Calibration and other Design Features on Application Characteristics

- Will calibrations and/or design features of the strategy vary from application to application
- Example: Does the DECS have any specific temperature/duty cycle requirements that may vary from application to application

## 4.2.2 Presentation of Typical Exhaust Temperature Profiles and other Relevant Field-Collected Data

- May not be available for inclusion in preliminary application, but is recommended
- Must be included in final application
- Provide information on typical exhaust temperature profiles and/or other relevant information from applications within your ECG
- Compare your field collected data with above, it should be representative of typical applications from within your ECG

## 4.2.3 Comparison of Field-Collected Application Data with Operating Conditions for the DECS

- Example: the SDF III™ requires a duty cycle of 350 degrees Celsius at least 40% of time
- Generate a graphical data analysis from actual datalogger files showing average temperature vs time in operation from in-field durability demonstration
- Include data from several vehicles in your ECG that were datalogged prior to the start of the durability demonstration

# 5.1.1 Test Facility Information

- Identify the test facility selected for emissions testing
- Please note that we do not endorse or recommend any test facility
- Applicants are free to choose the test facility of their choice provided it can conduct testing per the Verification Procedure's requirements

# 5.1.2 Description of Test Vehicle and Engine

- Provide a description of the test vehicle/test engine
- Include: make, model, model year, displacement, horsepower rating, engine family name, and emissions certification levels (if applicable)
- Submit this information with your preliminary application

# 5.1.2 Description of Test Vehicle and Engine (cont.)

- **Test Vehicle/Engine Selection**

- The test vehicle/engine selected must be ‘worst case’ and/or representative of the application(s) included in your selected ECG
- Based on the size of your ECG, and the nature of your DECS, you may need to select more than one test vehicle/engine
- Initial verifications: staff suggests selecting a ‘narrow’ ECG to start with, then applying for extensions as necessary

# 5.1.2 Description of Test Vehicle and Engine (cont.)

- **Example: What it should look like**
  - Applicant has an un-catalyzed DPF and requests an ECG that includes non-EGR on-road HDD engines manufactured from 1998-2006 with a PM cert level of not more than 0.1 g/bhp-hr.
  - The applicant has submitted for approval the following test engines:
    - **Test Engine #1** – A 14.6 liter, 1998, Caterpillar 3406, 475 Hp, EFN~WCPXH0893ERK, PM emission standard of 0.1 g/bhp-hr, and a PM cert value of 0.08 g/bhp-hr
    - **Test Engine #2** – A 8.5 liter, 2000, Detroit Diesel Series 50, 300 Hp, EFN~YDDXH08.5EJL, PM emission standard of 0.1 g/bhp-hr, and a PM cert value of 0.09 g/bhp-hr

# 5.1.2 Description of Test Vehicle and Engine (cont.)

- **Example: What it shouldn't look like**
  - Applicant has a catalyzed DPF and requests an ECG that includes all on-road HDD engines manufactured from 1991-1993 with a PM cert level of not more than 0.25 g/bhp-hr
  - The applicant has submitted for E.O. approval the following test engine:
    - **Test Engine #1** – A 8.3 liter, 2000, Cummins 553E, 275 Hp, EFN~YCEXH0505CBI, PM emission standard of 0.1 g/bhp-hr, and a PM cert value of 0.02 g/bhp-hr

# 5.1.2 Description of Test Vehicle and Engine (cont.)

- The E.O. will only approve CA appropriate engines for emission reduction testing
- Unique, strange, or 'one-of-a-kind' engines are usually not representative of most ECG's
- Check your test engine(s): Engines that baseline test far different than their original Cert values may not be accepted

# 5.1.3 Test Procedure Description

- Provide detailed information on the test procedures: chassis or engine dyno testing, test cycle(s) selected, preconditioning requirements, etc.
- Provide a list of the instruments that will be used to quantify emissions: make, model, method
- Please refer to the sample application for detailed information

# 5.1.3 Test Procedure Description (cont.)

- Emission testing requirements can be found in Section 2703 of the Procedure
- The Procedure requires you to work with staff to develop an approved test plan prior to emission testing
- Any deviation from these requirements must be approved in advance
- Failure to do so may result in ARB rejecting your test data

# 5.1.4 Test Results and Comments

- Usually not included in the preliminary application: unless you have pre-existing data
- Must be included in the final application
- Include any and all data from failed or aborted testing

# 5.1.4 Test Results and Comments (cont.)

- This Section only requires a summary table(s) of the actual test data and results
- We also require you to submit raw (1 Hz) data as well, but this should be included in Appendix A
- We will discuss Appendix A later in the presentation

# 5.2.1 Test Facility Identification

- Durability testing (aging or service accumulation) is required for all applications
- Durability testing requirements can be found in Section 2704 of the Procedure
- The Procedure allows either field or lab-based demonstrations
  - Lab-based demonstrations must be robust and equivalent to in-field testing

# 5.2.1 Test Facility Identification (cont.)

- If lab-based, provide the name and location of the lab
- If not, provide the location of the field application
- If the same, list the name of the test facility selected for emission testing
- If different, provide all relevant information

# 5.2.2 Description of Field Application

- **Description of Field Application**
  - Completely describe the field application (i.e. the in-field durability demonstration): provide information on the location, company or individuals name, nature or type of the application, date of installation, type of duty cycle, miles/driven or hours/used per week, datalogged parameters, etc.
  - Provide information on the datalogger and sensors

# 5.2.3 Description of Test Vehicle and Engine

- Provide a description of the durability test vehicle/test engine
- Include: make, model, model year, displacement, horsepower rating, engine family name, and emissions certification levels (if applicable)
- Submit this information with your preliminary application

## 5.2.3 Description of Test Vehicle and Engine (cont.)

- The durability test vehicle/engine selected must be 'representative' or the 'worst case' relative to your ECG or application(s)
- Based on the size of your ECG, and the nature of your DECS, you may need to select more than one durability test vehicle/engine

# 5.2.4 Test Procedure Description

- Describe your durability demonstration – include information on test cycles used for aging, how hours will be accumulated, clearly define the actual procedure used to age the system
- For field demonstrations, some of this information may be found in 5.2.2 – use this Section to expand on it in greater detail

# 5.2 Durability Testing – Final Thoughts

- If you are requesting a lab-based demonstration, be prepared to show how what you are proposing will replicate what the DECS will likely experience in actual service based on the ‘worst case’ or ‘representative’ application
- **For Example:**
  - If you are trying to verify a DPF and your proposed ECG includes solid waste collection vehicles (trash trucks), we won’t approve a lab-based durability demonstration that recommends installing the DPF on a test engine and running replicate FTP test cycles for 1000 hours in the lab

# 5.2.5 Test Results and Comments

- Provide information on the durability testing, any comments, document any problems during the demonstration
- Provide a summary of the actual datalogger files
- We also require you to submit the actual raw data from the datalogger, this should be included in Appendix A

# 5.2.6 Summary of Evaluative Comments from Third-Party

- Use this Section to summarize any comments contained in your third-party letters
- We require you to submit originals of all third-party letters, these should be included in Appendix B
- Don't forget to include information on performance issues

# 5.3.1 Field Application Identification

- If you elected to perform an in-field durability demonstration, Section 5.3 is 'Not Applicable'
- If you performed a lab-based durability demonstration you must complete a field demonstration
- Please completely identify the field application: provide information on the location, company or individuals name, nature or type of the application, date of installation, type of duty cycle, miles/driven or hours/used per week, datalogged parameters, etc.

# 5.3.2 Description of Test Vehicle and Engine

- Provide a description of the field demonstration test vehicle/test engine
- Include: make, model, model year, displacement, horsepower rating, engine family name, and emissions certification levels (if applicable)
- Submit this information with your preliminary application

## 5.3.3 Engine Back Pressure and Exhaust Temperature Graphs with Comments

- Provide a graphical analysis of the engine backpressure and exhaust temperature using the data collected during the field demonstration
- We also require you to submit the actual raw data from the datalogger, this should be included in Appendix A

## 5.3.3 Common Problems to Avoid

- Testing before having the test plan approved by ARB
- Testing with unrepresentative engines
- Changing system components in the middle of the durability demonstration
- Forgetting to log exhaust temperature and backpressure

## 5.3.4 Summary of Evaluative Comments from Third-Party

- Use this Section to summarize any comments contained in your third-party letters from your field demonstration
- We require you to submit originals of all third-party letters, these should be included in Appendix B

# 6. References

- Use this Section to attach any references you may cite or quote in either your preliminary or final application
  - Examples: SAE articles or papers, research papers, ASTM standards for reference, etc.

# 7. Appendices

- Use the Appendices' to attach any raw test data, datalogger files, driving traces, all test QA/QC information, third-party letters, sample DECS labels, owner's manual, etc.
- Usually not used with a preliminary applications

# 7. Appendices (cont.)

- Appendix A
  - Actual lab test data
  - Actual BP & temp data
  - Driving Traces
  - All QA/QC data
    - What do we want – please see handout for minimum requirements

# 7. Appendices (cont.)

- Appendix B
  - Originals of all third-party letters
- Appendix C
  - Sample of the DECS label
- Appendix D
  - English language copy of the owner's manual

# 7. Appendices (cont.)

- Appendix E
  - Other supporting docs

# Contact Information

## Web Site

<http://www.arb.ca.gov/diesel/verde/verde.htm>

**Erik White, Chief**

(916) 322-1017

[ewhite@arb.ca.gov](mailto:ewhite@arb.ca.gov)

**Shawn Daley, Manager**

(626) 575-6972

[sdaley@arb.ca.gov](mailto:sdaley@arb.ca.gov)

# Questions?

