Cleaning Up Existing Diesel Engines

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California Air Resources Board

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Health Impacts of Diesels in California

• Annual health impacts
  – 2,900 premature deaths
  – 3,600 hospital admissions
  – 240,000 asthma attacks/respiratory symptoms
  – 600,000 lost days of work

• By comparison
  – 3,700 deaths from car accidents
  – 2,000 homicides
Diesel PM Emissions 2000

- Tractor: 66%
- Truck: 27%
- Other: 7%
Diesel Risk Reduction Plan

• Established a goal
  – 75% reduction in diesel PM by 2010
  – 85% reduction in diesel PM by 2020

• Multiple strategies
  – On- and off-road vehicles and equipment
  – New engine standards - 98+% reduction
  – Cleaner diesel fuel - 15 ppm S
  – Retrofit of existing engines with filters
  – Ensure in-use compliance
PM Emissions and Risk
Reduced 75+% w/ Plan

80% of reduction from retrofits
Status of Implementation
Diesel Risk Reduction Plan

- Reduce emissions from new engines
  - Trucks - ADOPTED
  - Off-road - STANDARDS PROPOSED

- Provide ultra-low sulfur fuel (<15ppm)
  - Available now, + ADOPTED (2006.5)

- Ensure in-use emission performance
  - Recall testing - AGREEMENT REACHED
  - OBD - PROPOSAL: APRIL, 2004

- Require retrofit of existing engines
  - Transit - ADOPTED
  - Trash trucks - ADOPTED
  - 7 Others - PLANNED 2003 - 2005
Mandatory Retrofit Programs Adopted

- Based on use of BACT
  - Repower, Retire, Replace, Retrofit
- Transit buses (8,000)
  - Retrofits begin 2003, complete 2009
- Trash trucks (13,000)
  - Retrofits begin 2004, complete 2011
Schedule for Adopting Additional Retrofit Regulations

- 2003 (remainder of)
  - Stationary engines
  - Transportation refrigeration units
  - Chip re-flash
Schedule for Adopting Additional Retrofit Regulations

• 2004
  – Fuel delivery trucks
  – Public fleets
• 2005+
  – Private on-road fleets
  – Private off-road fleets
Anatomy of the Trash Truck Rule

• Use best available retrofit technology
• Long phase-in: 2004-2010
  – Start with 1988-2002 engines - retrofits available (filters; catalysts)
  – Old engines next - re-engine or replacement
  – Newer engines last - filters
• Compliance flexibility
• Early compliance credit
### Possible Implementation Scenario - Trash Trucks*

<table>
<thead>
<tr>
<th>Eng MY</th>
<th>Level 1-catalysts</th>
<th>Level 2-fuels</th>
<th>Level 3-DPFs</th>
<th>Repower</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960-1987</td>
<td>n.v.</td>
<td>n.v.</td>
<td>n.v.</td>
<td>100%</td>
</tr>
<tr>
<td>1988-1990</td>
<td>n.v.</td>
<td>n.v.</td>
<td>n.v.</td>
<td>100%</td>
</tr>
<tr>
<td>1991-1993</td>
<td>95%</td>
<td>n.v.</td>
<td>n.v.</td>
<td>5%</td>
</tr>
<tr>
<td>1994-2002</td>
<td>66%</td>
<td>n.v.</td>
<td>29%</td>
<td>5%</td>
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<tr>
<td>2003-2006</td>
<td>70%</td>
<td>n.v.</td>
<td>30%</td>
<td>0</td>
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</tbody>
</table>

N.V. = not verified  
* Based on currently verified equipment only
PM Emission Reductions: 
Trash Truck Rule

![Graph showing PM emissions over years.]
NOx Emission Reductions: Trash Truck Rule

[Graph showing NOx emissions over years from 1998 to 2022 with lines for Baseline Inventory and Currently Verified.]
Cost and Cost Effectiveness
(based on trash truck rule)

• Cost
  – PM filters -- $5,500
  – PM + NOx reduction -- $14,000
  – Oxidation catalysts -- $3,100
  – Re-engine -- $50,000
  – Replace vehicle - $150,000-$250,000

• Cost effectiveness
  – PM: $32/lb; $900,000/death avoided
  – NOx+HC: $1.80/lb
Worldwide Experience with PM Filters

• Retrofit Programs in Sweden, Germany, Switzerland, Hong Kong, Taiwan, London, Paris, Mexico City, Tokyo, and California -
  – Over 100,000 as of 2003
  – Transit Buses, Sanitation Trucks, Delivery Trucks, Construction Equipment, etc.
Experience with PM Filters

- BP-Arco Demo
  - Grocery Trucks, Fuel Tanker Trucks, Buses, Delivery Trucks
  - Over 3 million miles driven since 2000
  - Fuel Delivery Truck
    - >500,000 miles w/ filter*
  - Grocery Truck
    - >350,000 miles w/ filter*

* As of late 2003
Experience with PM Filters

• Sanitation Trucks
  – City of Los Angeles
  – >350 Refuse Trucks Retrofitted

• School Buses
  – >500 Retrofits

• Conclusions
  – Transparent to End User
  – Reliable
  – Durable
  – No Fuel Penalty
Retrofit Verification Requirements

- Required PM Reduction - 25% Minimum
- Optional NOx Reduction - 15% Minimum
- Emission Testing
- Durability Demonstration
- Emission Control Group/Applicability
- Warranty
- In-Use Compliance Testing
  - Consistent with U.S. EPA Requirements
Fuel Based Strategies

• Require Multimedia Assessment
• Fuel Additives
  – Must be used with diesel particulate filter unless proven safe to use alone
  – Additional tests at high dose
  – Require review of environmental and health-related data every two years
  – On-board monitor of fuel additive level
Harmonization of CARB and EPA Verification Procedures

• Harmonized Items
  – Test Cycles
  – Test Fuels
  – Durability Demonstration
  – In-Use Compliance Testing
  – Use of Existing Data to Support Extension

• Items Not Yet Harmonized
  – Third Party Testing
  – Engine Testing/Chassis Testing
  – Multimedia Assessment
  – Warranty Requirements
  – NO2 Limit

• On-going joint efforts to further harmonize and streamline
Current Verification Status

- **Level 1:** 25% or greater PM reduction
  - DOC’s
- **Level 2:** 50% or greater PM reduction
  - No Systems Verified Yet
- **Level 3:** 85% or greater PM reduction
  - Active and passive DPF’s
- **On-going application process**
  - 102 applications received to date
  - 38 applications currently in active review process
Status of Technology Verification

• PM Filter (85+% PM reduction)
  – 94 + on-road/NOx Reduction
  – 94 + on-road dual-fuel
  – 94-2002 Cummins/Navistar on-road + NOx
  – 96 stationary emergency generators

• Oxidation catalyst (25+% PM reduction)
  – 91+  on-road 4 strokes
  – 93 + Cummins on-road + NOx
  – 96 + off-road port equipment

• Fuel reformulation - None

• New replacement engine - Many available
Status of Retrofit Technology - Summary

• On-road
  – 94-2003
    • Filters, OxyCats
  – 91-2003
    • OxyCats
  – Pre-91 - none yet

• Off-road
  – 96-2003
    • OxyCats
    • Filters for SS emergency generators
  – Pre-96 - None yet
Current Verifications
By Company/Level

• **Level 3:**
  - Johnson Matthey CRT DPF
  - Engelhard DPX DPF
  - Cleaire Flash and Catch CRT (25% NOx Reduction)
  - Cleaire Flash and Catch DPX (25% NOx Reduction)
  - Cleaire Longview DPF + Lean NOx (25% NOx Reduction)
  - Clean Air Partners DPF
  - CleanAIR Systems DPF

• **Level 1:**
  - Cleaire Flash and Match (25% NOx Reduction)
  - Donaldson DOC Spiracle
  - Donaldson DOC + Spiracle
  - Donaldson DOC Spiracle + USLD
Other Technologies Undergoing Verification

- Fuel Water Emulsion
- Alternative Diesel Fuel
- Fuel Borne Catalysts
- Additives
- Water Injection Systems
- Active Regeneration Systems
- Off-Board Regeneration System
- Flow Through Filters
- SCR
Summary

• Passive filter application 1994+, not all applications
• Catalysts 1991+
• Older vehicles: re-engine or replace
  – Achieves PM and NOx reduction
• Mandatory fleet retrofit rules evolving from filter based to modernization w/ filters for newer engines
• Reductions cost effective