
Retrofit Technology and Programs: Recent Developments and Experience

WRAP Member Offroad Retrofit Program Workshop

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Introduction

- Emission Reduction Strategies
 - Retrofit technology types, experience, and applications are growing
 - Experience with, and application of, fuel-based strategies are growing
 - Operational Strategies (e.g., reduced idling) are being applied
- Retrofit Program Implementation
 - Retrofit Programs are being implemented worldwide
 - Program experience in the U.S. is growing
 - Available funding will be critical to the future growth of retrofit programs in the U.S.

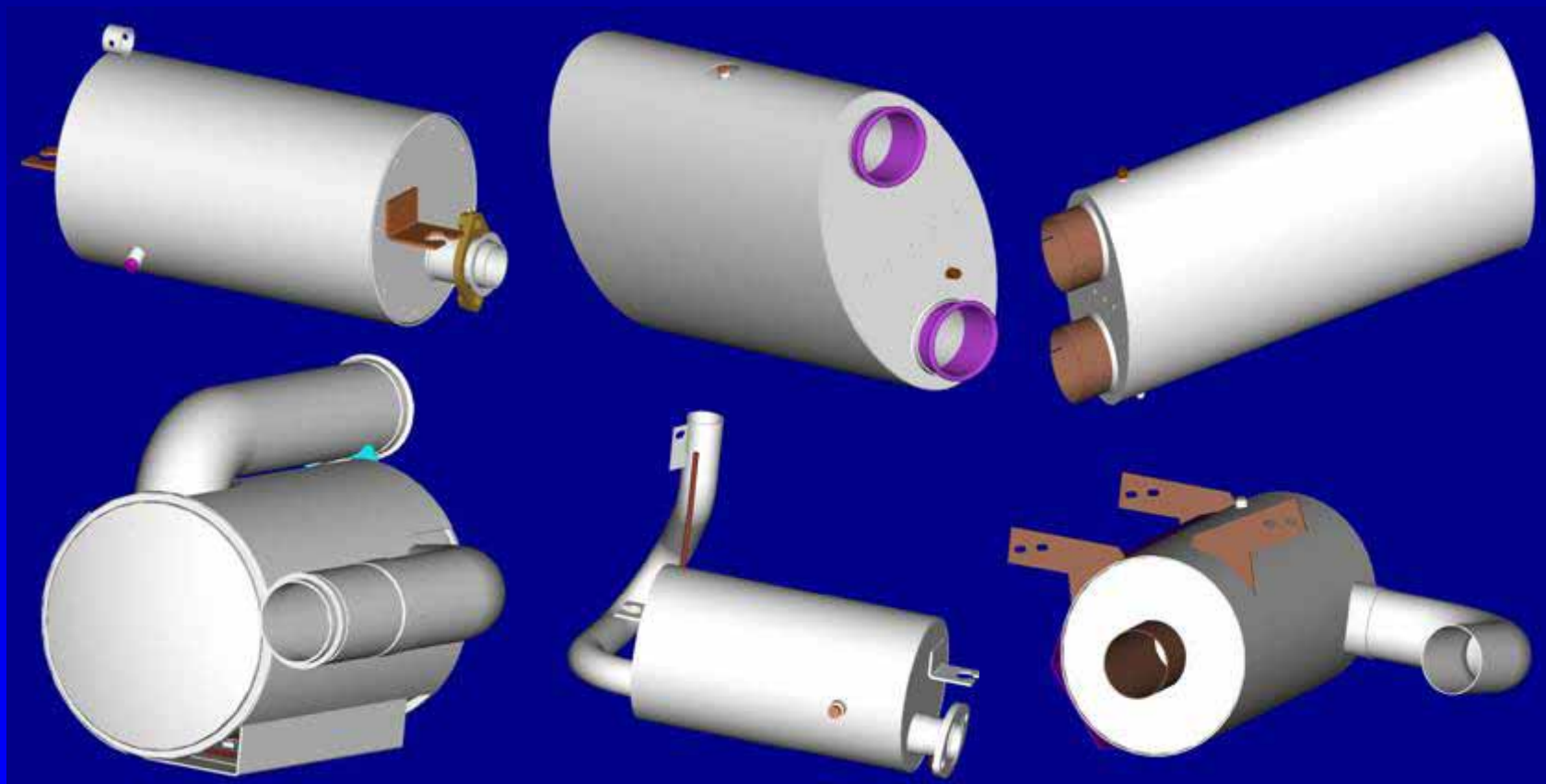
Available Retrofit Technologies

- Retrofit Technologies
 - Diesel Oxidation Catalysts (DOCs)
 - Diesel Particulate Filters (DPFs)
 - Crankcase Emission Control
 - Selective Catalytic Reduction (SCR)
 - Lean NO_x Catalyst (LNC)/DPF
 - Low Pressure Exhaust Gas Recirculation (EGR)/DPF

Diesel Oxidation Catalysts Are Efficient and Have Excellent Operating Experience

- Oxidation Catalyst Control Capabilities
 - PM – 20-50% Reduction
 - CO and HC – up to 90% Reduction
 - Toxic HCs – up to 70% Reduction
- Oxidation Catalyst Operating Experience
 - >250,000 Off-Road Engines
 - >400,000 Heavy Trucks and Buses
 - >2,500,000 Class 1 & 2 Vehicles (Pick-Ups)
 - >50,000,000 LDD vehicles in Europe
- Application Experience
 - Near universal application and simple to install
 - Virtually no operational issues
- Costs -- <\$1000 to \$2000+

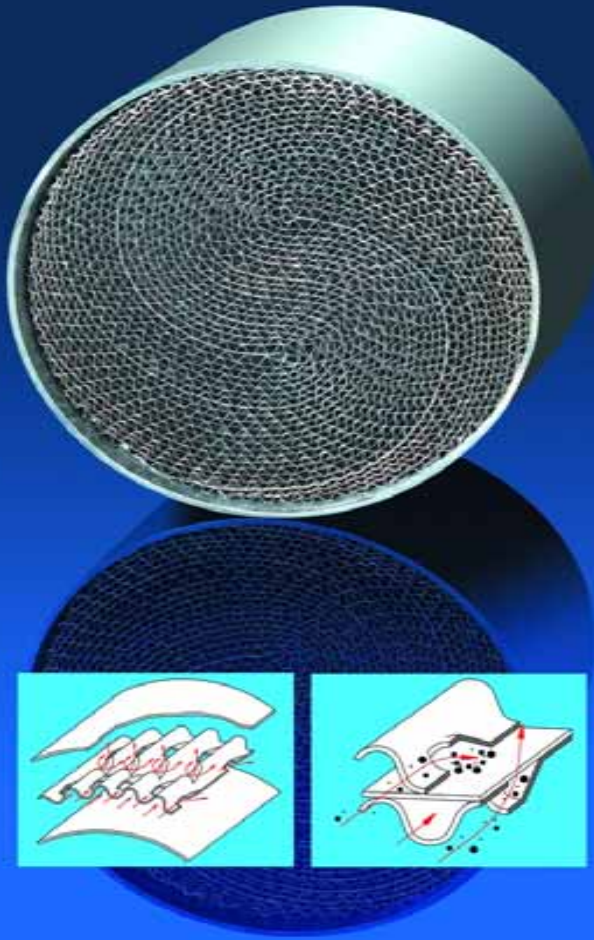
DOC Technology Is Flexible! Adaptable to Essentially All Diesel Engines



Diesel Particulate Filters Are Efficient and Are Developing an Impressive Track Record

- Filter Control Capabilities
 - PM reductions with ultra-low sulfur fuel
 - PM mass - >85%; fine PM - >99%
 - CO and HC - up to 90% reduction
 - Toxic HCs - up to 90% reduction
- Filter Operating Experience
 - 750,000 passenger cars in Europe
 - >150,000 trucks and buses
 - > 20,000 off-road engines
- Application Experience
 - Engine/Vehicle/Operation specific
 - More complex technology to maintain
- Costs -- \$5000 to \$10,000

“Flow-Thru” or “Partial” Filter Technologies Emerging

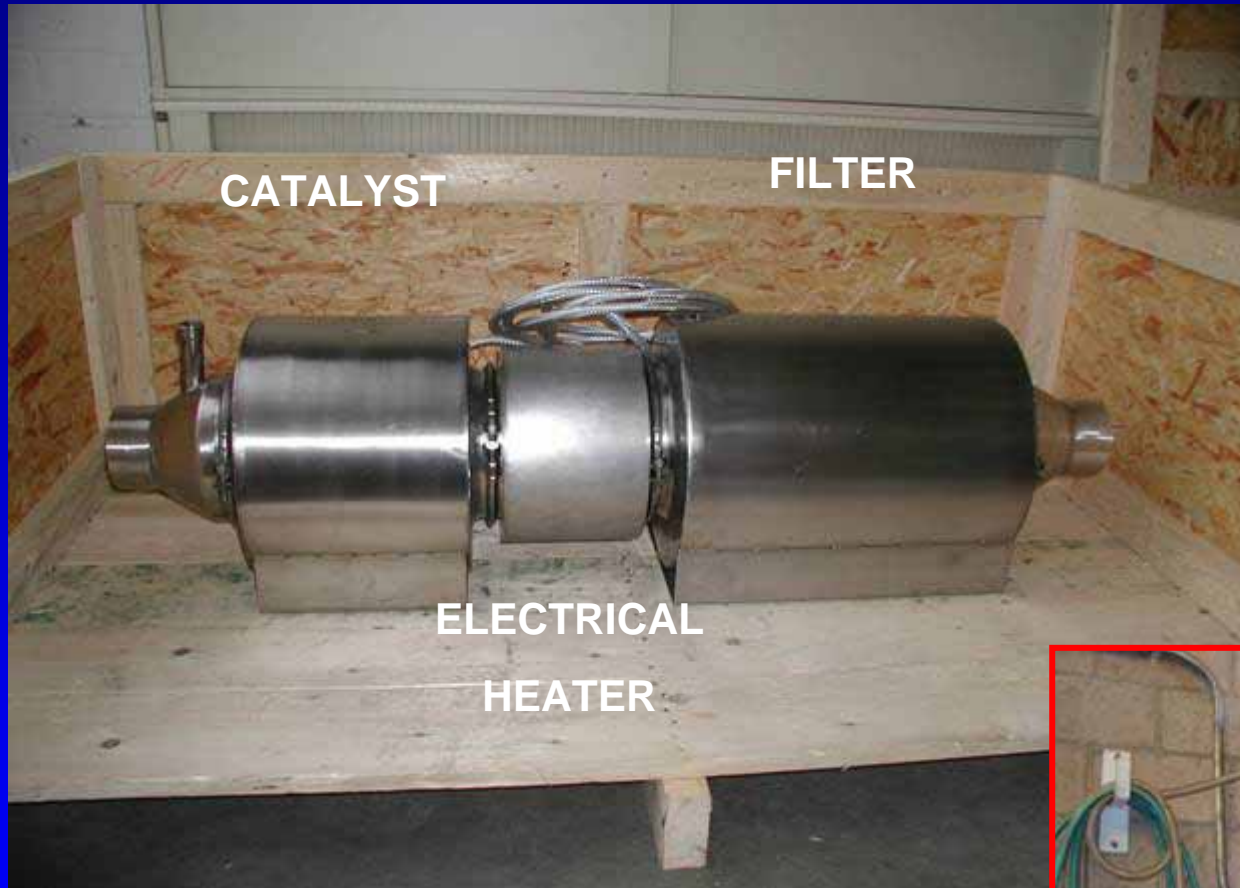


- Potential for 50-70% PM reduction (ARB Level 2)
- Can be catalyzed or used with a DOC
- May have applicability on older engines
- Filtering achieved with sintered metal sheets or wire meshes
- More resistant to plugging
- Exhaust temperature a factor

To Expand DFP Application Active DPF Are Emerging

- Passive DPFs with Electric Assist
 - Uses on-board heaters intermittently in combination with catalyst-based filters or fuel additives
 - Exhaust temperature of 240°C needed for catalyst-based filter regeneration
- Electrically-heated Active DPFs
 - Regenerated on-board at stand-still or off-board / exchange
- Fuel Burner / Thermal Regeneration

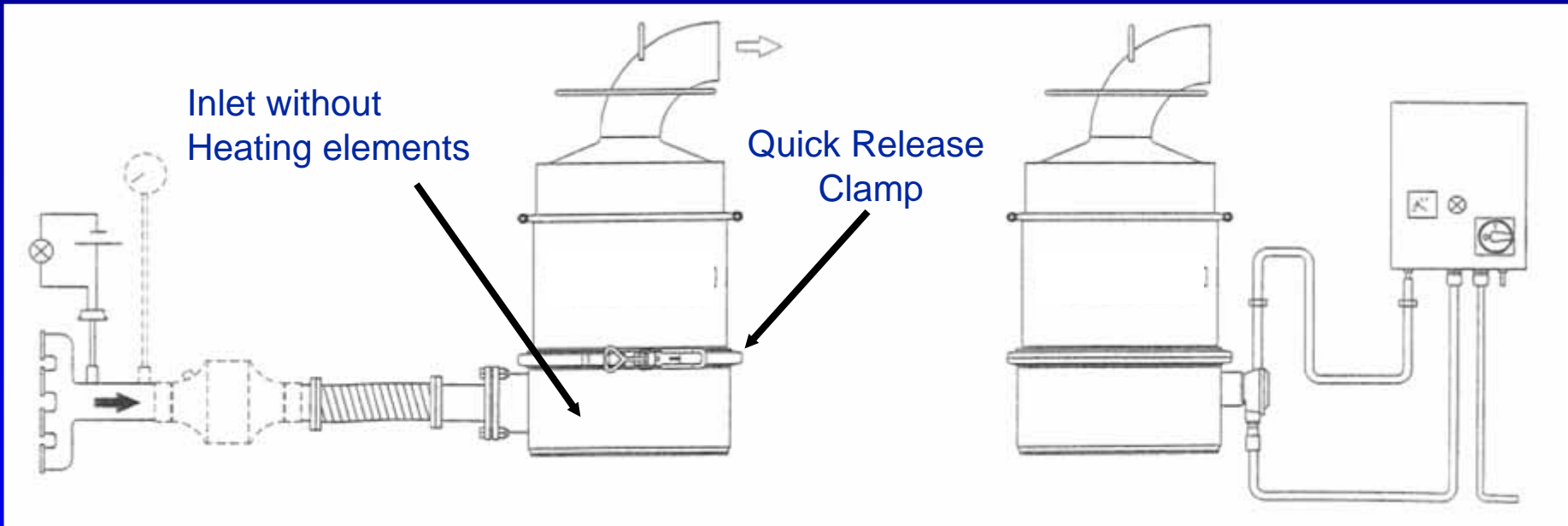
Passive DPF with Active Assist System



Active DPF System - CA Refuse Truck



Exchange System: Off-Board Regeneration

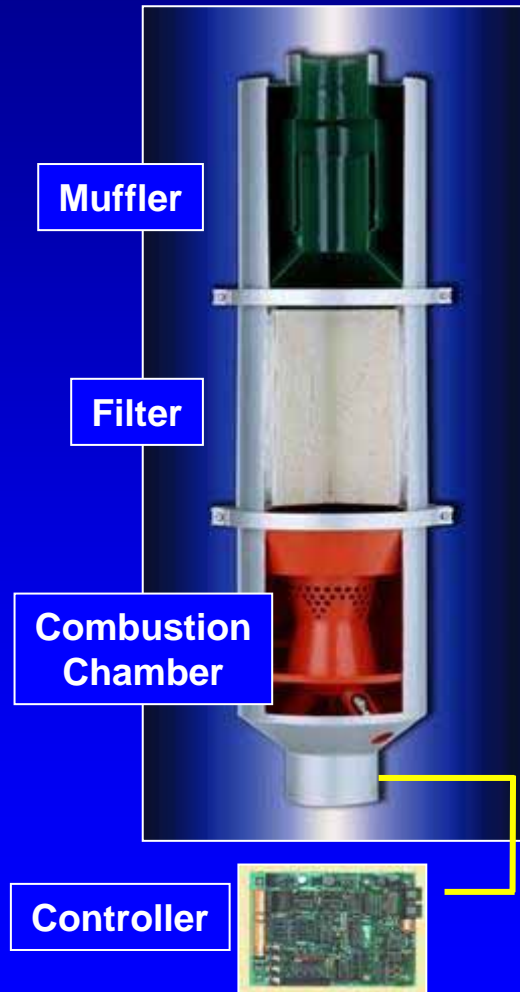
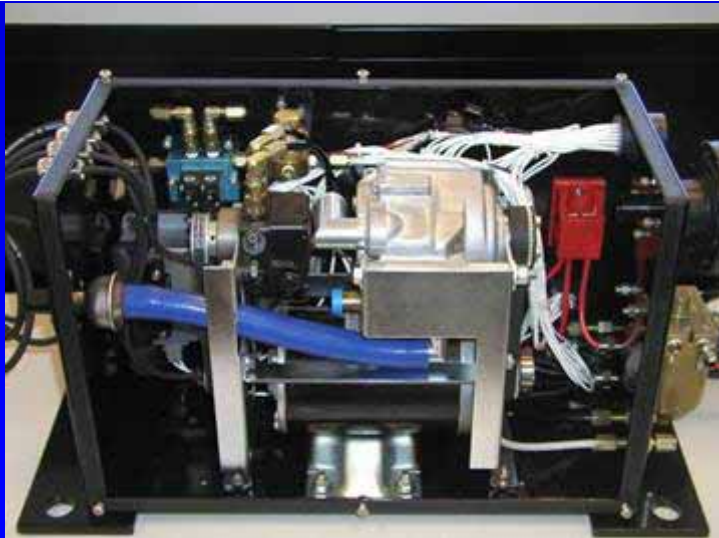


- Filter is exchanged as required (usually once per shift)
- Filter exchange takes about two minutes
- Very common with lift trucks operating multiple shifts

Active DPF System - Road Sweeper



Active Thermal Regenerator



Thermal Regenerator Installed on a Truck



DPF Off-Vehicle Cleaning Station



- Provide safe & healthy way to clean DPF products
- Effective way to remove ash and improve DPF durability
- Offers improved flexibility and reduced cost



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Active DPFs in Materials Handling and Construction Equipment

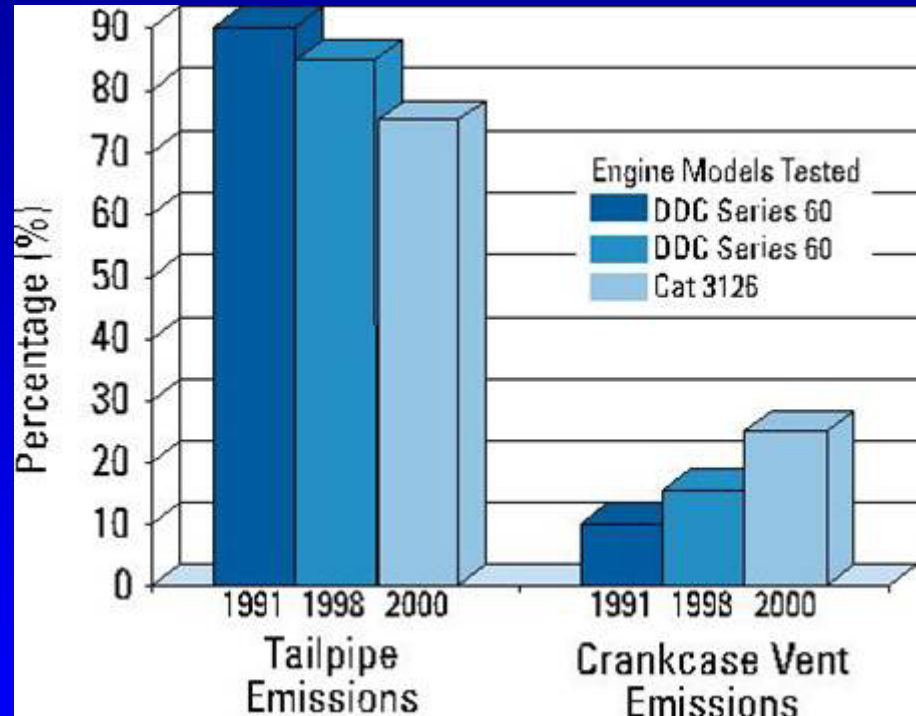


Active DPFs - Service Locomotives

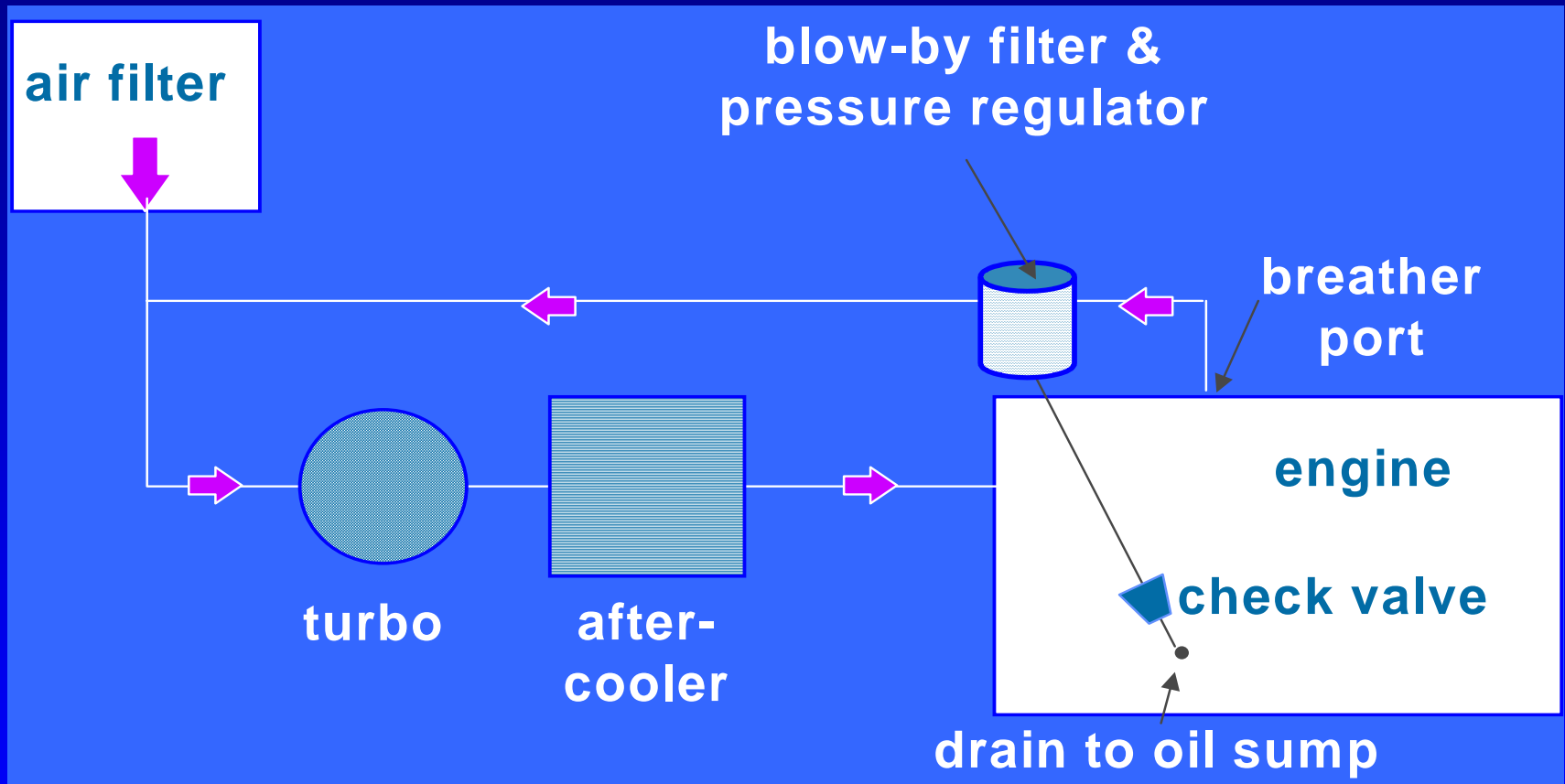


Crankcase Emissions and Control Strategies

- Created during combustion process
- Emissions contain hydrocarbon vapor and aerosol, diesel soot (PM) and various engine oil contaminants
- Crankcase emissions are a significant portion of total emissions when calculating total emission reductions
- In 2007, crankcase emissions are included in the total emissions count. They have never been included before
- Crankcase filter controls PM (10-25), HC (30-40), CO (30-35)
- >1000 retrofits installed and number growing rapidly
- Cost -- \$500-\$600
- Replace filter (every 25,000 miles/Annually) Cost <\$50



Crankcase VOC PM Emissions Can Be Controlled



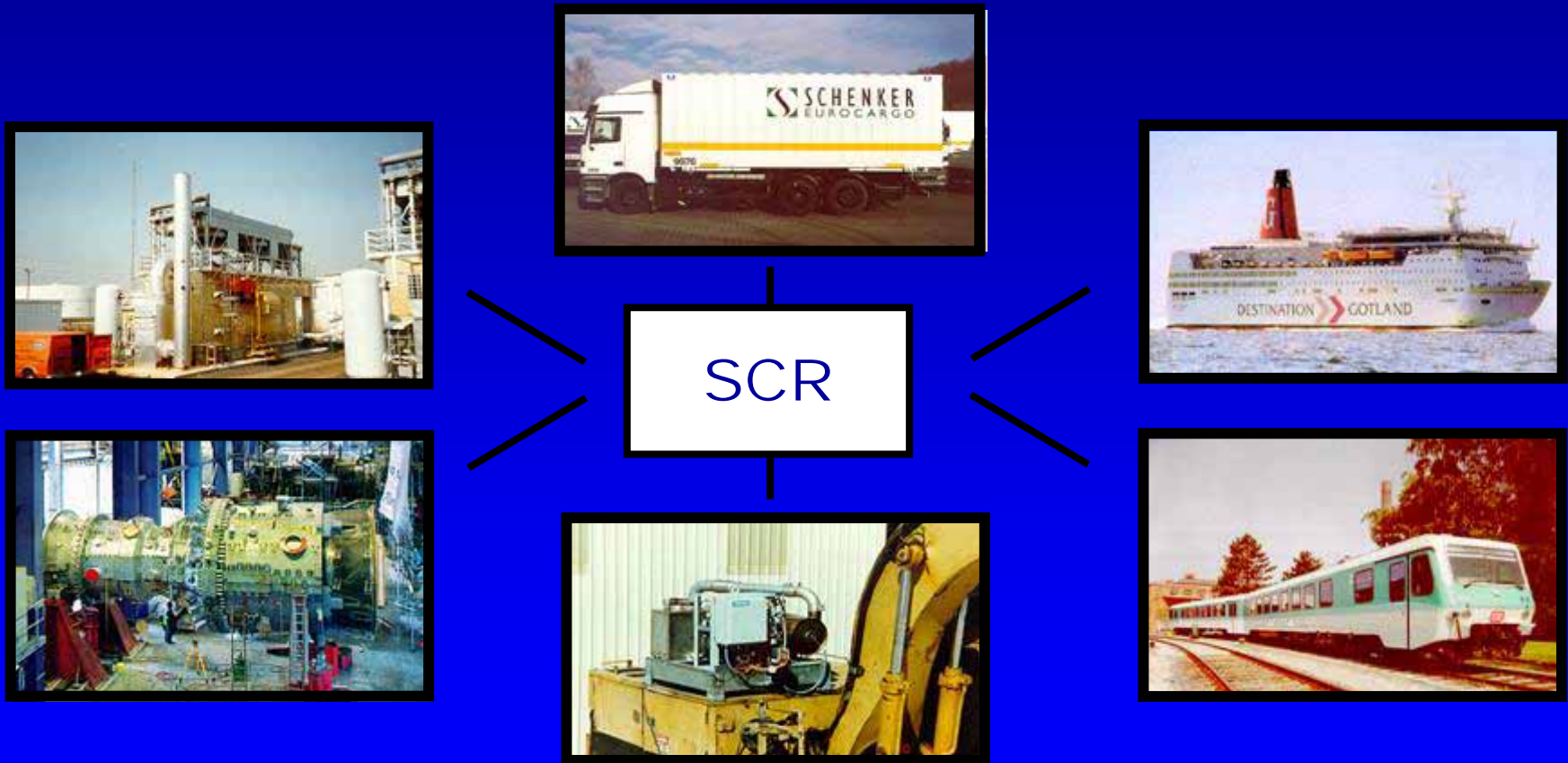
Returns Crankcase PM Emissions to the Oil Sump

Eliminates a Significant Source of PM

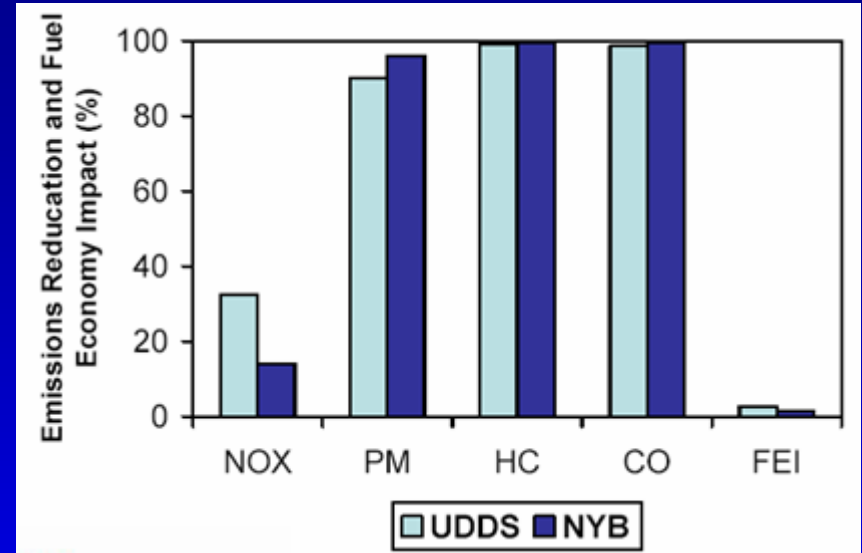
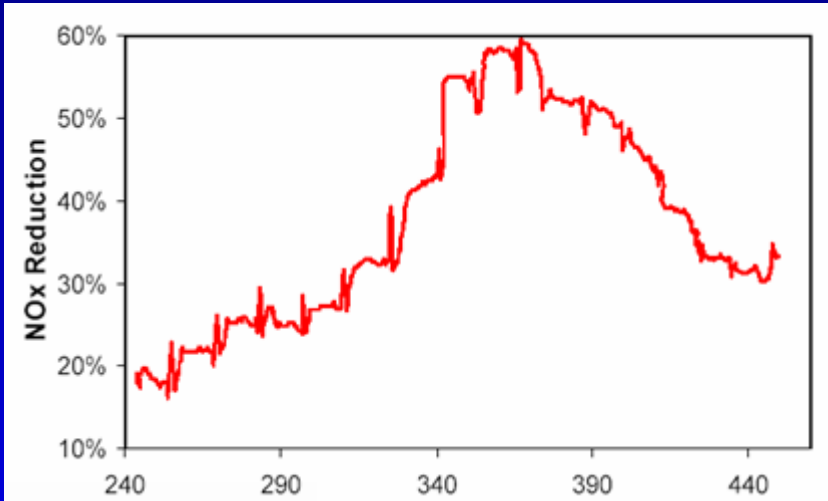
SCR Is Very Successful Worldwide on Stationary Sources and Is Now Applied to On-Road Engines

- SCR Control Performance (with Integral Oxidation Function)
 - PM - 20-50% reduction of organic PM
 - CO and HC - up to 90%
 - Toxic HCs - up to 70%
 - NO_x - 50 to 90%
- SCR Operating Experience
 - HD truck demonstration in Europe since 1995 with mileage exceeding 400,000 miles
 - Expected to be used to meet the HDE Euro 4 standards in 2005
 - Some use on locomotives and marine vessels
- Application Experience
 - Engine Specific Application
- Costs -- \$15,000

SCR Applications



LNC+DPF Systems Are Available for Retrofit

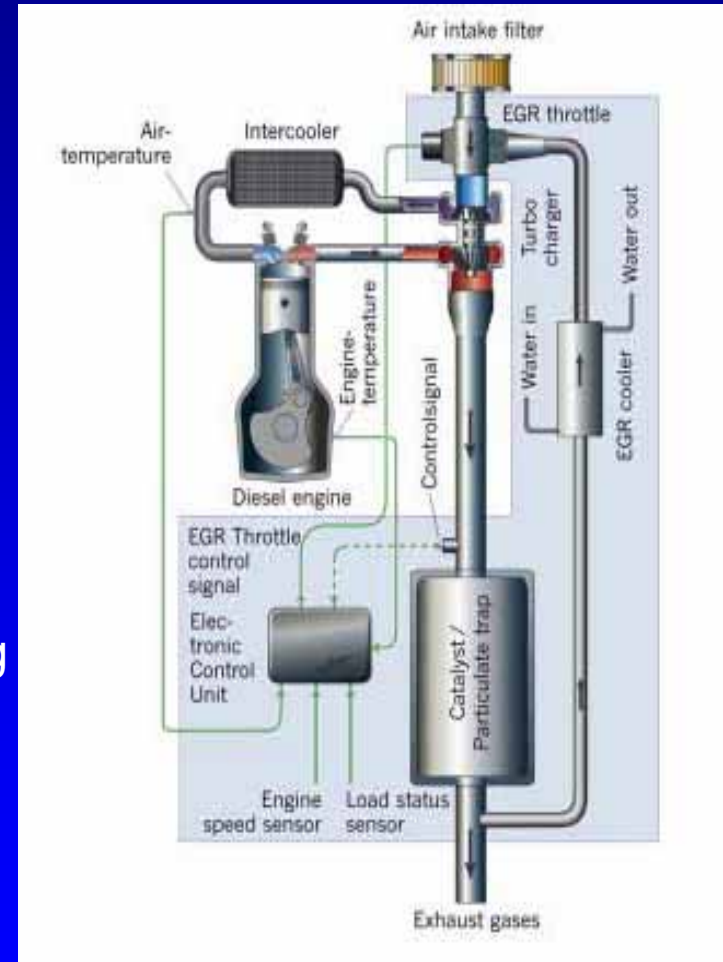


The upstream NOx catalysts (HC-SCR) do not contain precious metals, but above 300 C they act like oxidation catalysts. In addition to significant NOx reductions, this heats the filter and soot layer.

- Field test and early demonstrations
 - Used in transit, refuse, line haul, vocational, and nonroad applications.
- 25% NOx and >85% PM reduction
- Engine specific application
- Cost -- \$15,000+

Low Pressure EGR/DPF System

- Replaces inlet air with clean exhaust gas by recirculation through a CB-DPF
- Decreases the combustion temperature, thus lowering the NOx production
- Calibrated for minimum affect on power and fuel consumption
- For trucks, buses, and on-highway vehicles
- > 40% NOx efficiency with > 90% PM efficiency
- >1500 systems operating worldwide including several U.S. programs
- Engine specific applications
- Costs -- \$15,000+



Retrofit Programs Experience

Retrofit Programs are Being Implemented Worldwide

- Hong Kong
- Tokyo
- Sweden
- Switzerland/Germany/Austria
- United Kingdom
- Korea
- Mexico
- Chile
- China (planned)
- India (planned)
- Brazil (planned)

Effectively Designed Programs Produce Impressive Results

- Swiss 1998 Ordinance on Air Pollution Control
 - Mandates the curtailment of diesel particulate emissions at construction sites
 - 6000+ nonroad vehicles retrofitted
- Failure (both mechanical and thermal) rates:
 - Year 1998 – 10%
 - Year 2000 – 6%
 - Year 2003 – 2%
 - Goal is <1% and likely will be attained
- Most failures occurred soon after installation
- Failures after prolonged operation are rare

Retrofit Program Experience in the U.S.

- Voluntary Programs

- Nearly 200 programs nationwide (not counting the >200 individual school districts participating in the Washington State School Bus Program)
- Some start-up challenges and issues with technology, but overall programs have been successful
- U.S. EPA's Voluntary Retrofit Program has had a major impact in generating interest in retrofits
- State and local governments, community and environmental groups and the private sector have also played an important role
- Funding is critical to the future of voluntary retrofit projects
 - SEPs and EPA funding have enabled many programs
 - Tight budget restraints make future Congressional funding a challenge
 - Several States have provided significant funding

Retrofit Program Experience in the U.S.

- Examples of Mandatory Programs
 - ARB Diesel Risk Reduction Program
 - New York City Construction Equipment Program
 - New Jersey Retrofit Program (pending in the State Legislature)
 - Connecticut DOT I-95 Construction Retrofit Project

Conclusions

- Retrofit Technologies Continue to Evolve and While Problems and Application Limitations Still Occur, the Overall Experience is Improving
- Careful Planning, Active Involvement, and Attention to Detail Are Critical to the Success of the Program
- Voluntary Programs
 - Building support
 - Providing the necessary incentives
 - Funding is critical