S.3 Engine
Business & Mini Technical Session

Aftertreatment Challenges Experience and Best Practices

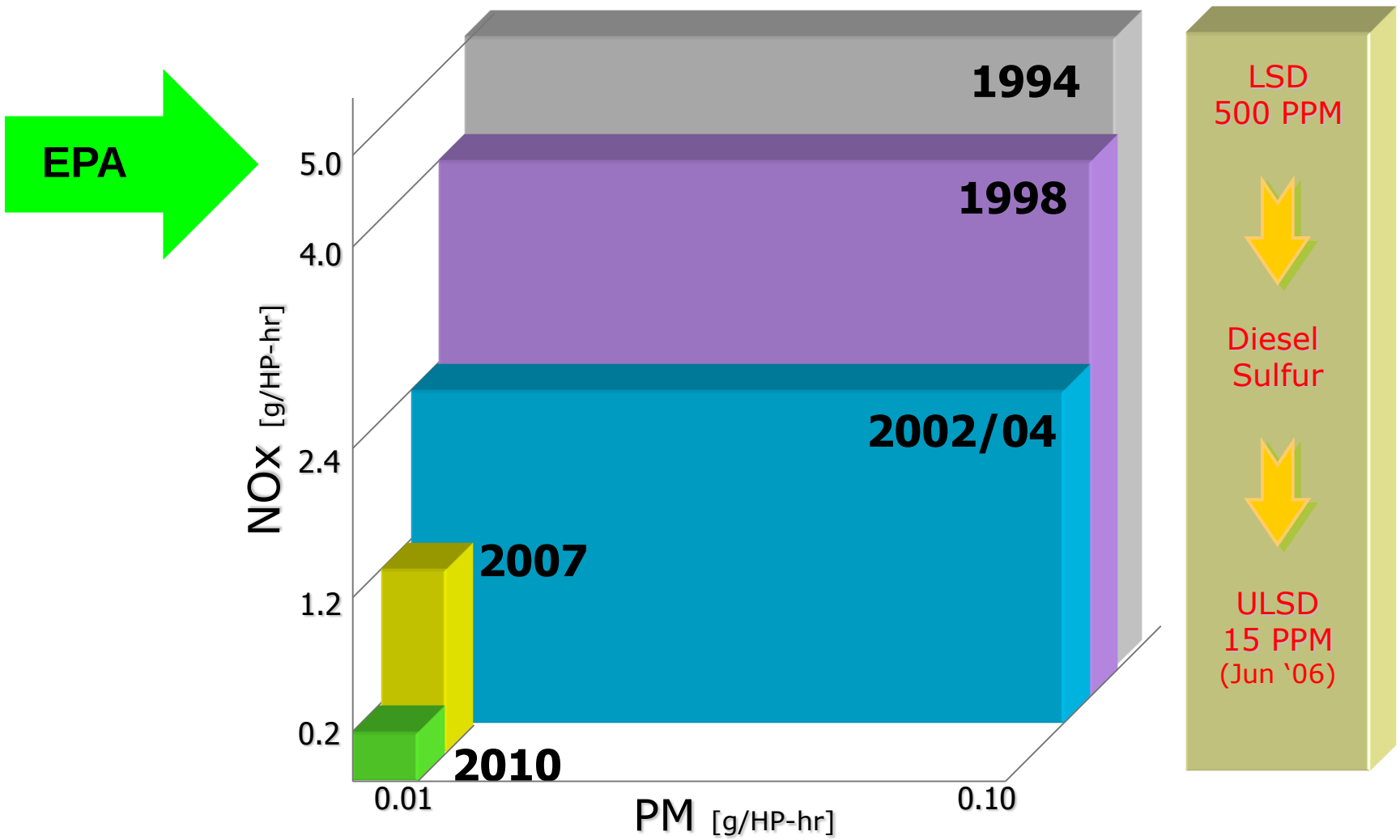
September 24, 2014

Constructive Comments Are Always Appreciated!

TMC welcomes your comments, but please make certain that they are constructive and appropriate before you turn in your evaluation sheet!

Thank You for Your Cooperation!

Progression of On-Highway Emissions Standards



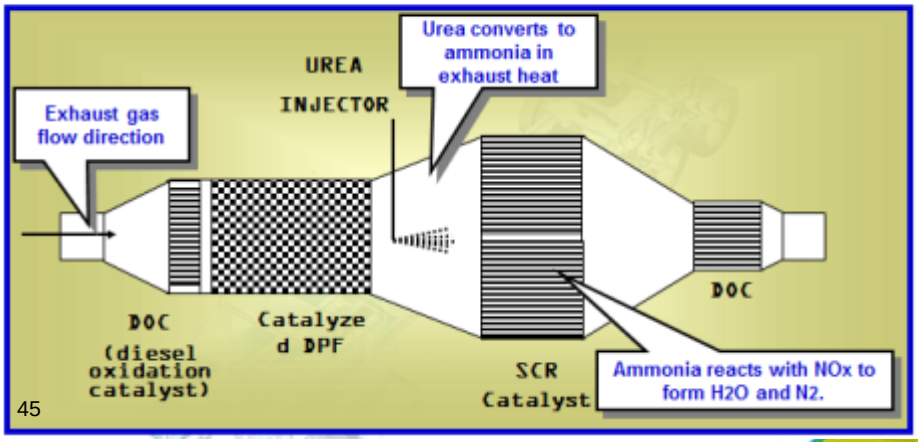
Related TMC S.3 Presentations . . .

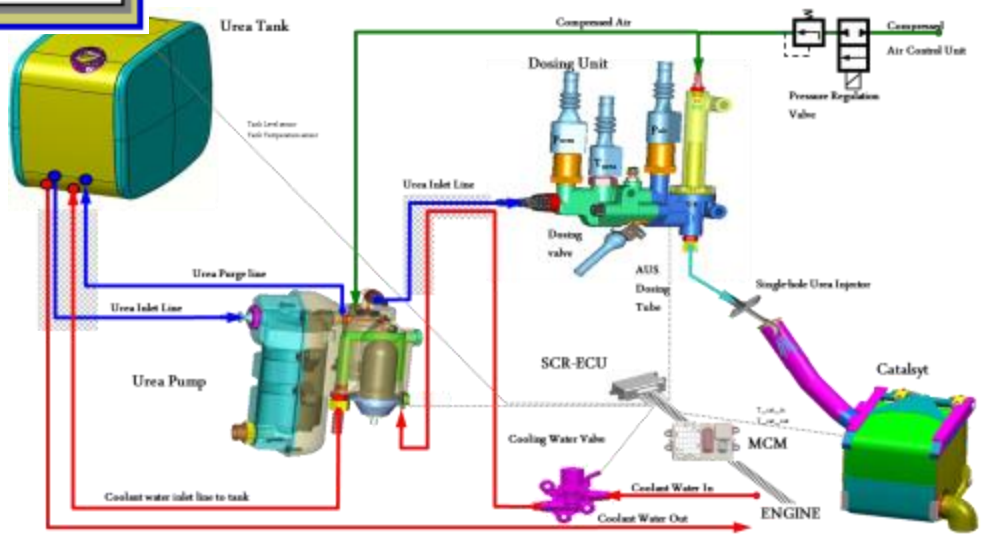
Quick History . . .

- Feb 07: **Advanced Glimpse at 2010 Heavy Truck Emissions Technology**
- Sep 08: **Update on 2010 Engine and Emission Technologies**
- Feb 10: **Fleet Experiences with EPA 2007 Compliant Diesel Engines**
- Sep 10: **Cleaning of Diesel Exhaust Particulate Filters**
- Feb 12: **EPA 2007/2010 Engine Report Card**
- Mar 13: **Engine Manufacturers' Update on 07 & 10 Experiences** *(& Fleet Survey)*

Feb 2007:
Advanced Glimpse at 2010 Heavy Truck Emissions Technology

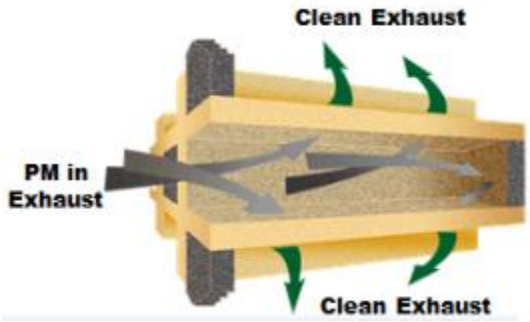
Urea Selective Catalytic Reduction





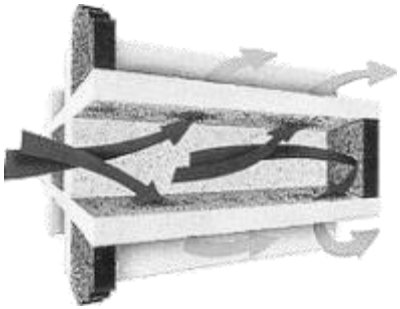
Sep 2010:
Cleaning of Diesel Exhaust Particulate Filters

How DPFs work . . .

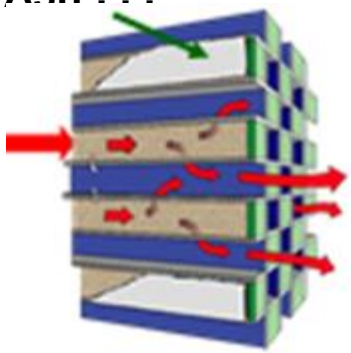


Regeneration . . .

PM



Ash . . .



Cleaning . . .

Report Card
Fleet Experiences with Aftertreatment Systems

Feb 2010:
2007 Emissions Compliant Engine Report Card

	Better	Same	Not as Good
Durability	8%	44%	48%
Fuel Economy	24%	33%	43%
Maintenance Intervals	11%	67%	22%
Maintenance Issues	7%	2	
Emissions Hardware	7%	3	
Driver Satisfaction	10%	4	
Out of Service Time	7%	2	
Replacement Parts Availability	6%	4	
Road Breakdowns	7%	3	

Feb 2012:
EPA'10 VS EPA'07 Compliant Engines
Subset of Survey Results - TMC Fall 2011 Fleet Survey

	Better	Same	Worse Than
After-Treatment Device Durability	43%	28%	29%
Driver Understanding of AT Sys.	29%	38%	33%
EGR Related Failures Rates	29%	48%	23%
Engine Maintenance Issues	32%	41%	27%
Fuel Economy	70%	25%	4%
Overall Maintenance Cost	36%	14%	50%
Replacement Parts Availability	23%	50%	27%
Road Breakdowns	32%	50%	28%
Serviceability, Ease of Diagnostics	29%	19%	52%
Vehicle Out of Service Time	40%	35%	25%

Summary

- Past presentations . . .
  - New technologies
  - Fleet experience from a high level
- Now – a different view . . .
  - Fleet Perspective
    - Aftertreatment Experiences
    - Best Practices
- 3-C Theme
  - Complaint
  - Cause
  - Correction
  - Ultimately – “Take-Aways”

Mike Dennis

Ryder
Group Director Maintenance Operations

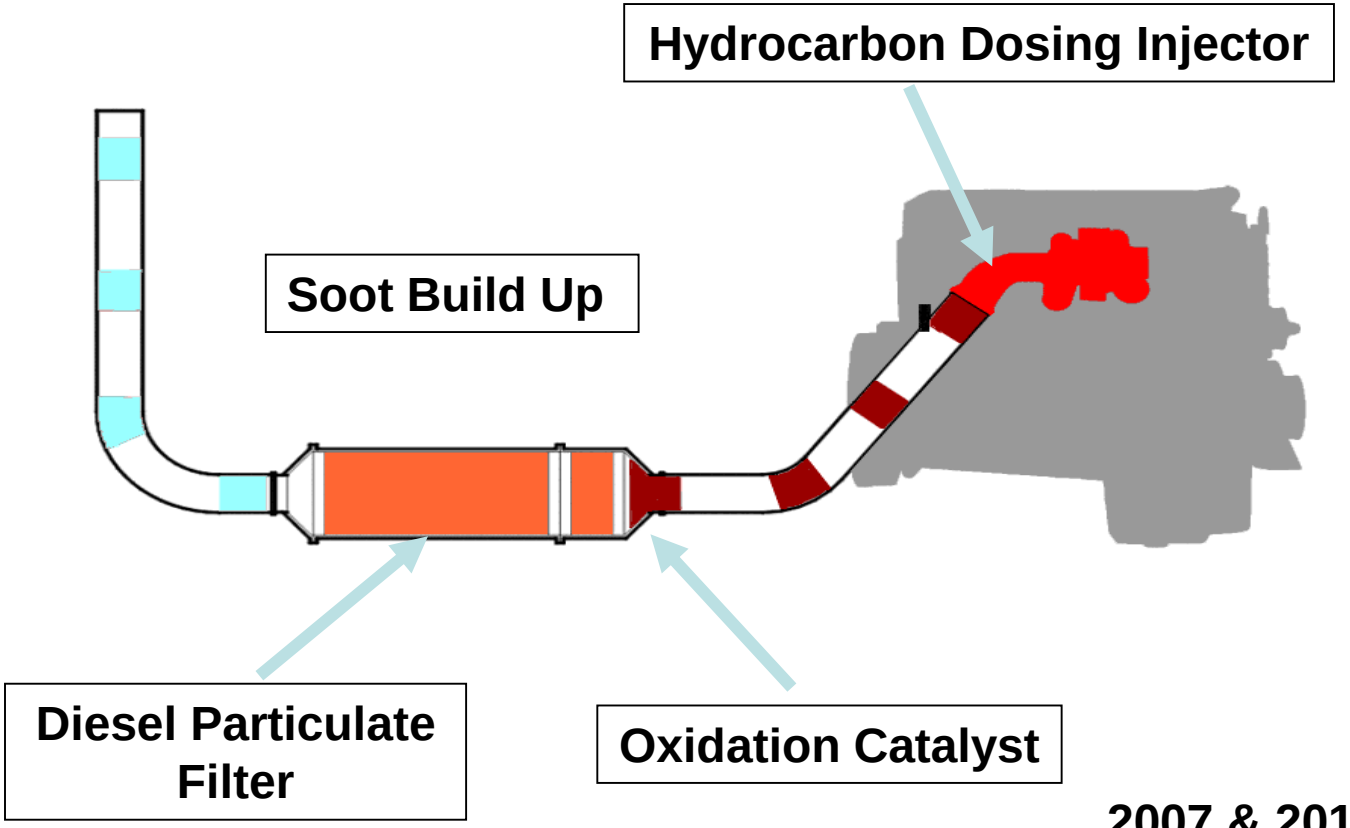
- 200,000 vehicles approximately 175,000 are power
- 830 Shop locations
- 5000 Technicians
- Operations in Canada, US, Mexico and UK

Aftertreatment Devices

- When properly used and maintained, the new technology helps reduce the harmful pollution from heavy-duty highway vehicles
- When not properly used, the technology can cause some serious pain points for our customers
  1. Decreased fuel economy
  2. Unscheduled downtime = missed deliveries
  3. Engine de-rating (loss of engine power)
- What can we do?
  1. Train the technicians
  2. Use of diagnostic tools
  3. Understand the OE fault codes
  4. Train the drivers and operators

ATD Regeneration Strategies

AFTERTREATMENT REGENERATION ANIMATION

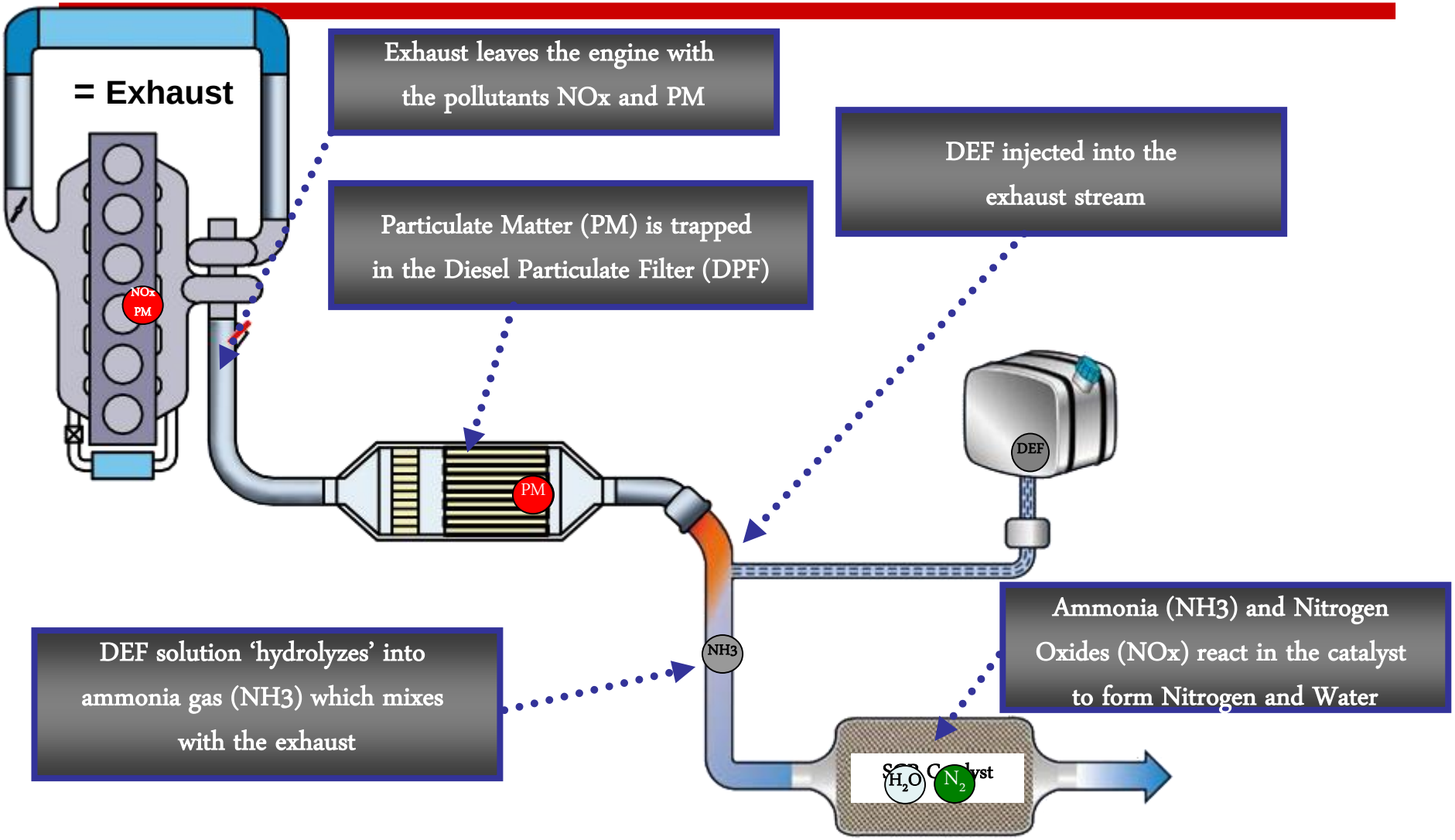


2007 & 2010 ENGINES

How SCR Works

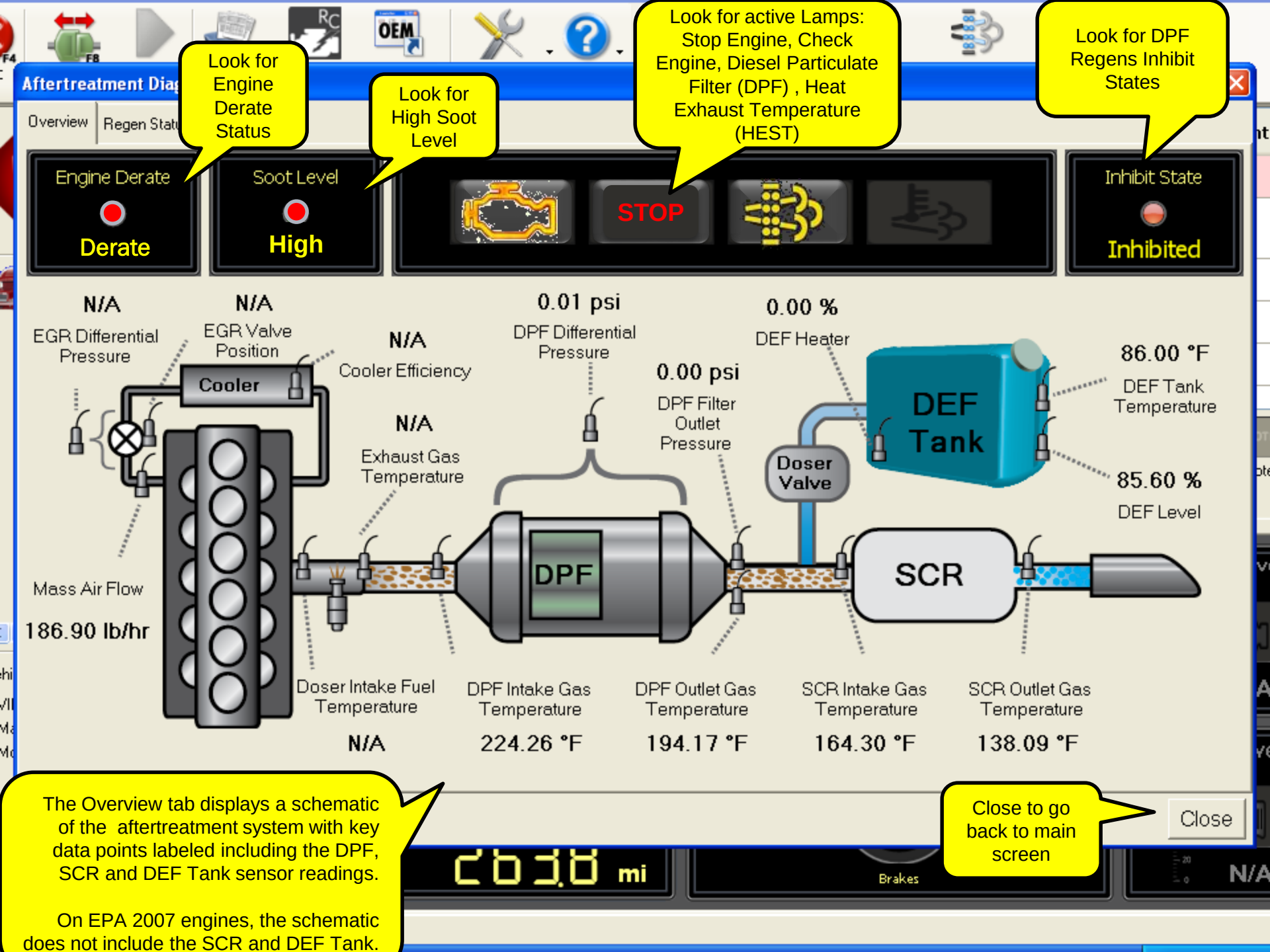
= Exhaust

= Diesel Exhaust Fluid (DEF)



Understanding the tools and the fault codes

- The following slides show one of the many diagnostic tools used to diagnose engine and emission fault codes. Additional screens show engine manufactures critical codes as related to emissions and exhaust system components.
- It is critical that maintenance operations establish solid trouble shooting procedures and train the technicians on the impact that upstream component failures have on all exhaust components.
- Educating the drivers/operators on the importance of understanding the warning lights and proper regeneration is more important now that it ever has been in the past. Ensure they understand the impact that long idle times has on the DPF.


Aftertreatment Diag
Overview
Regen Stat
Look for Engine Derate Status
Look for High Soot Level
Look for active Lamps: Stop Engine, Check Engine, Diesel Particulate Filter (DPF) , Heat Exhaust Temperature (HEST)
Look for DPF Regens Inhibit States
Engine Derate
Derate
Soot Level
High
STOP
Inhibit State
Inhibited
N/A
EGR Differential Pressure
N/A
EGR Valve Position
N/A
Cooler Efficiency
0.01 psi
DPF Differential Pressure
0.00 %
DEF Heater
86.00 °F
DEF Tank Temperature
0.00 psi
DPF Filter Outlet Pressure
N/A
Exhaust Gas Temperature
Cooler
DEF Tank
Doser Valve
85.60 %
DEF Level
DPF
SCR
Mass Air Flow
186.90 lb/hr
Doser Intake Fuel Temperature
N/A
DPF Intake Gas Temperature
224.26 °F
DPF Outlet Gas Temperature
194.17 °F
SCR Intake Gas Temperature
164.30 °F
SCR Outlet Gas Temperature
138.09 °F
Close
Close to go back to main screen
The Overview tab displays a schematic of the aftertreatment system with key data points labeled including the DPF, SCR and DEF Tank sensor readings.
On EPA 2007 engines, the schematic does not include the SCR and DEF Tank.
mi
Brakes
N/A

DPF Inspections

Codes that potentially lead to DPF cleaning or DPF replacement

SPN	FMI	Description	ACTION
3720	0	DPF Ash Cleaning Request	Volvo PTT2 Troubleshooting
3483	12	DPF Regeneration Efficiency too Low	Volvo PTT2 Troubleshooting
3936	0	Aftertreatment DPF differential pressure sensor value too high	Volvo PTT2 Troubleshooting
3251	0	Aftertreatment DPF Differential Pressure- Critically High Pressure	Volvo PTT2 Troubleshooting
3064	11	Aftertreatment DPF System Monitor- Critically high soot load	Volvo PTT2 Troubleshooting

Codes that require a Mobile or Parked Regenerations to remove Soot

3064	0	DPF Moderately High Soot Load	A parked regeneration might be sufficient to clear code.
3251	16	Aftertreatment DPF Differential Pressure- Moderately high pressure	A mobile or parked regeneration might be sufficient to clear code.

- All fault codes must be troubleshoot before cleaning or replacing a DPF.
- Follow engine manufacturers diagnostics trees to determine the recommended actions.

Where Do We Go From Here

- Awareness (shop, rental, sales, customers)
  - Sales presentation and FAQ available on sales and marketing portal
  - Quick reference guide and updated customer orientation materials to follow
- Training (technicians, drivers & dispatch)
- Continuous improvement deep dives on running cost
- Maintenance practices to include upstream component failure
- Investments into DPF cleaning machines
- OEM research partnership

Roger Straker

Superintendent
New York City Transit
(NYCT)

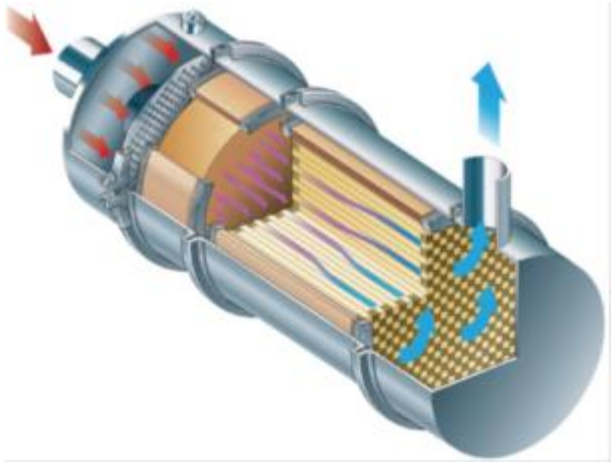
NYCT

- NYCT Department of Buses (DOB) operates approximately 5,500 buses

- 1,815 buses are EPA 2007 and EPA 2010 compliant

EPA 2007 Complaint Transit Bus

- EPA 2007 compliant engines are equipped the Diesel Particulate Filter (DPF)
- The DPF reduces particulate matter/soot from the bus exhaust system
- The DPF is a wall flow honeycomb filter that reduces soot to ash
- EPA 2007 compliant engines have an increased tailpipe out temperatures over 900 degrees Fahrenheit



DPF Equipped Transit Bus Best Practices

- DPF must be removed and cleaned on specific intervals that reflect OEM engine maintenance recommendations
- AT NYCT all DPF equipped buses have DPFs removed, cleaned and replaced with a reman'ed DPF between 12 and 18 months
- Since all operations for NYCT are within NYC metropolitan area. NYCT uses "severe duty" OEM guidelines for maintenance
- Typical DPF maintenance intervals range between 4500 and 6000 engine hours

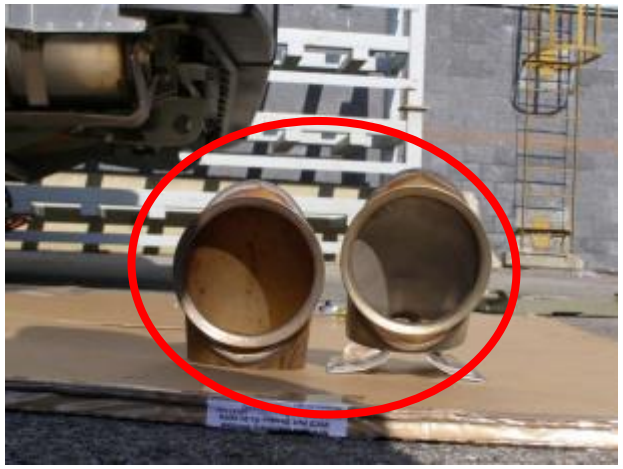
Ground Level EPA 2007 Compliant Exhaust System Best Practices

- Due to increased exhaust heat, in excess of 900ºF, ground level exhaust systems became a concern

- Heat level potential to burn or melt property or cause bodily injury within close proximity to exhaust outlet

Ground Level EPA 2007 Compliant Exhaust System Best Practices (cont'd)

- Use diffusers to reduce concentrated heat exiting from center of tailpipe
- Work with Bus OEM to include exhaust diverter to reduce concentrated heat at center of tailpipe
- Spread exhaust heat over a wider area



DPF Equipped Transit Bus Best Practices

- Exhaust temperature and backpressure modules directly mounted to DPF module
- Sensors and ports get damaged during (removal and replacement) R&R process
- The use of anti-seize compound on temperature and backpressure ports has reduced damage to sensors and transducers during the R&R process

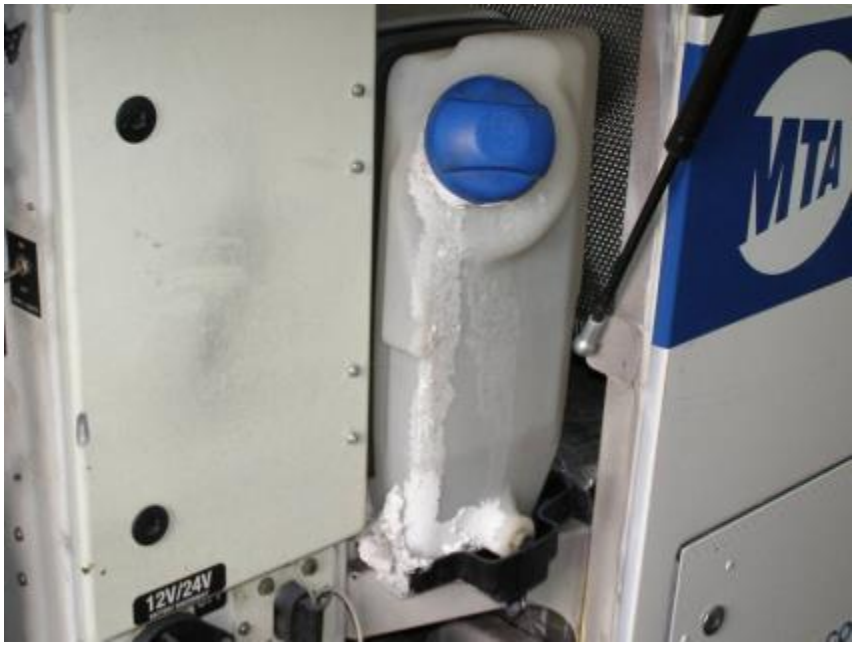
DPF Equipped Transit Bus Best Practices

- NYCT GPS-based DPF regeneration is based on Geo-Fencing.
  - 300 ft. for Local service
  - ½ mile for Express service
- Better control of exhaust regeneration events
- Elimination of dash-mounted regeneration inhibit switch

EPA 2010 Compliant Transit Bus

- EPA 2010 technology introduces Selective Catalytic Reduction (SCR)
- SCR removes NOx emissions from engine tailpipe exhaust
- Diesel Exhaust Fluid (DEF) is used to facilitate the conversion of NOx by the SCR
- DEF Tanks
  - Local buses: 10 gallon
  - Express buses: 15 gallon

DEF House Keeping Best Practices



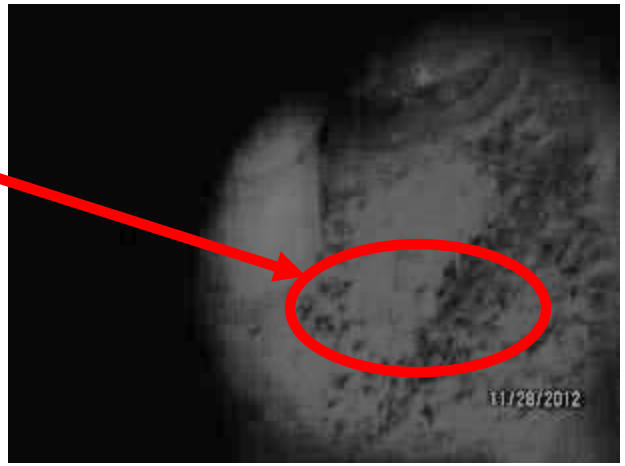
DEF House Keeping Best Practices

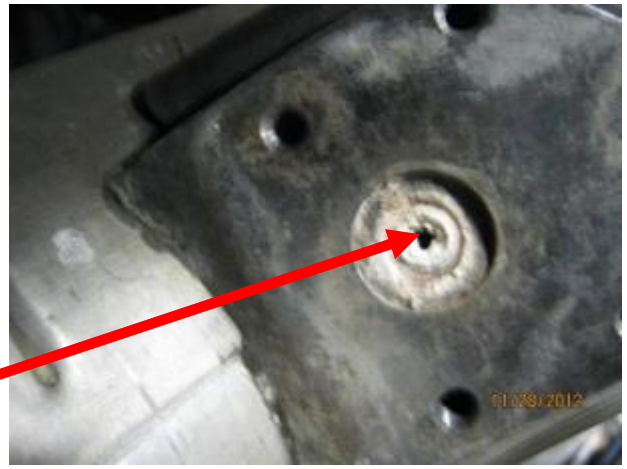
- DEF tank cap leaking and crystallized DEF
- Leaking cap
  - Moisture issues
  - Attracts dirt
  - Leads to DEF contamination
- Frequent exterior cleaning
  - Warm water
  - Tank & cap

DEF System Contamination Control

- Debris in DEF tank
- DEF pump and doser failures connected to tank debris
- Implementation of DEF tank inlet filter/screen (approx. 100 micron) in DEF tanks

Sediment in DEF Tank



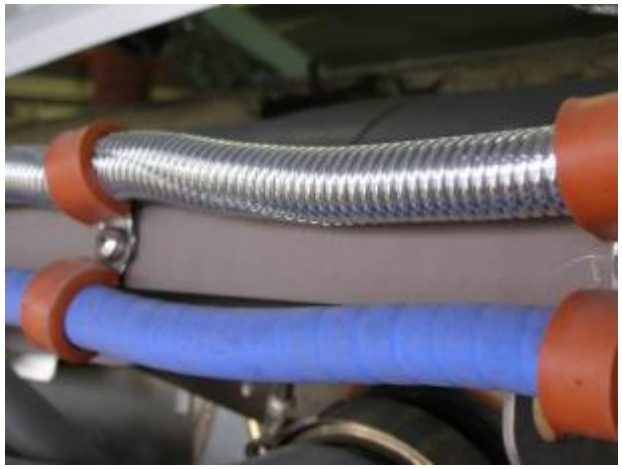


Build up of DEF crystallization

DEF System Contamination Control

DEF Cold Temperature Operability

- DEF doser clogging
- Poor or reduced coolant flow to doser
- Insulating DEF lines and repositioning/re-routing of coolant lines for improved temperature control at DEF doser



Take Aways

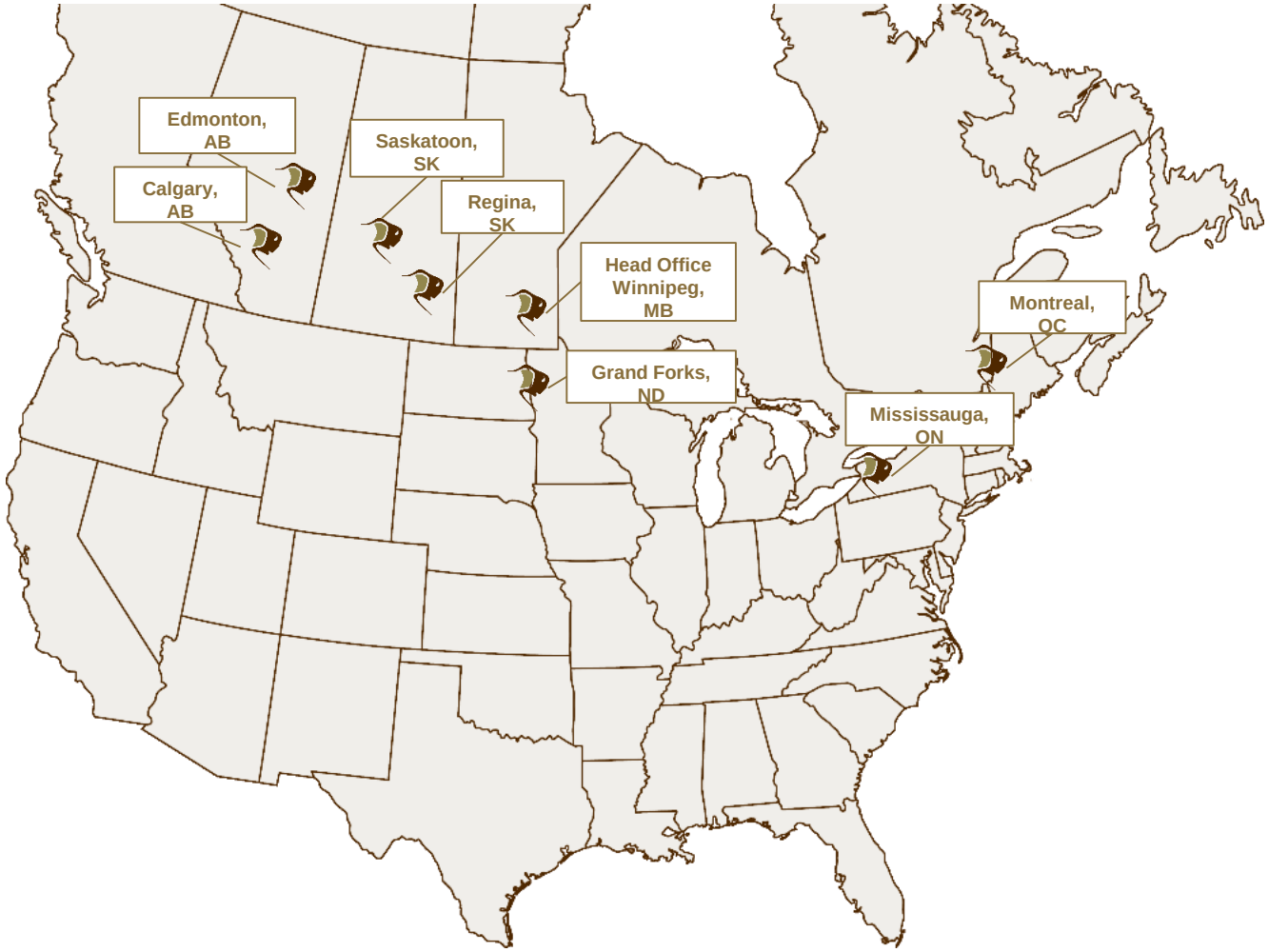
- Inspect and replace exhaust diverters to reduce risk to property and people
- Clean DOC and DPF to reduce nuisance face plugging faults
- Regularly Clean DEF cap and exterior of DEF tank near filler opening to reduce DEF contamination
- Implement DEF tank inlet screens to reduce contaminants entering tank
- Regularly inspect DEF supply and coolant lines to optimize DEF doser performance

Mark Irwin

Bison Transport

Director of Maintenance, Eastern Region

Our Facilities



Fleet Challenges

- Extreme temperature for a period of 4 to 6 weeks at -45ºF.
  - Record last year of -63ºF; Wind-chill not calculated
  - 11 foot frost line
- Temperature variance from -45ºF (Winnipeg) to +70ºF in TX during a 3 day transition period.
- Yearly flooding can isolate our routes traveling east / west.
- Fuel quality for this environment is a must.
- Driver hours of operation reduced, their tolerance for delays due to maintenance has also been shortened.

Extreme Temperature Impact

Experience

- Cracked DEF tank and internal bulkhead cracking
- Split DEF lines
- DEF quality is not consistent in all regions
- High moisture content in the air system compromises purging process
- Frozen batteries
- Fuel gelling

2007 Emission Performance

- Objectives were set by the EPA and met by the OEMs
- The OEM accomplishment was a testament to their ingenuity
- Fleet Performance operating with 2007 emissions experienced drivability symptoms ranging from:

Symptoms

- Low power
- Regen failure
- Constant regen attempts while driving
- Full park regen required
- Coolant consumption

2007 Emission Performance

Root Cause

- DPF failure due to thermal events or cracking
- 7th injector failure due to carbon build up
- Air regulator purge valve failure
- Reduce cycle time on the DPF cleaning process – 200,000 miles
- EGR cooler leaking
- Pre DPF exhaust system leakage

2010 Emission Performance

- The OEMs have made great improvements given the ability to field test their products.
- Fleet performance operating with 2010 emissions

Symptoms

- Derating of engine performance
- Frequently postponed regen will move truck into “Limp Mode”
- Repeat regen attempts - failure
- DEF & Coolant leakage
- Hard start

2010 Emission Performance

Root Cause

- Quality of DEF
- DOC & DPF pressure sensor failure, hard to diagnose sensor failure at high temperature.

- NOX sensor failure, sensor active only at operating temperature.

2010 Emission Performance

- DEF tank heater solenoid and connectors leaking / breaking
- Hydrocarbon doser valve or injector cups leaking
- Lower fuel rail pressure creating hard starting

- Urea injector leaking into the exhaust system causing crystallization and exhaust blockage

2010 Emission Performance

– Exhaust leaks lowering catalyst efficiency

– Plugged hydrocarbon doser limiting catalyst effectiveness

2010 Emission Performance

Benefits

- SCR NOx reduction permits engine timing to be advanced, increasing volumetric efficiency
- DPF service cycle has improved to 300,000 miles and testing to extend due to low ash content
- Less Soot
- Extended oil drain
- Improved fuel economy
- Reduced down time for drivers
- Healthier shop environment for technicians

Best Practices

1. Train the Drivers at orientation and when new vehicles are purchased
2. Train the Technicians to push past the initial failed component and look for the root cause
3. Invest in your shops to keep them current with today’s technologies

Bryan Lewis

ASE Master Truck Technician

Our Experience

- **Complaints / Symptoms**
  - **Fault light on**
  - **Low performance (power, MPG)**
  - **Engine shutdown**
- **Hardware Problems**
  - **Exhaust leaks**
  - **Coolant loss**
  - **Fuel leaks**
  - **Dirty air systems**
- **Training Hurdles**
  - **Technician (how the equipment operates)**
  - **Driver (how to operate the equipment)**
  - **New maintenance procedures**
  - **Learning the component acronyms**

Acronyms

DPF-	Diesel Particulate Filter
SCR-	Selective Catalyst Reduction
DEF-	Diesel Exhaust Fluid
DOC-	Diesel Oxidation Catalyst
ACM-	Aftertreatment Control Module
EGR-	Exhaust Gas Recirculation
MIL-	Malfunction Indicator Light
ECM-	Electronic Control Module
PM-	Particulate Matter
CEL-	Check Engine Light

Complaint:

Engine Low Power

- Check engine light on
- Fails to complete parked regen

Cause:

Stainless exhaust pipe

- Exhaust leak in flex pipe
- Lost exhaust heat and fuel doser vapor

Correction:

Replace Hardware

- Stainless exhaust pipe
- Related gaskets and clamps

Electronic Repair

- Perform park regen with laptop
- Clear fault codes
- Test system for proper operation

Complaint:

Engine Derate

- Check engine and MIL on

Cause:

EGR Valve

- EGR valve mechanical fault
- EGR valve failed calibration

- Stuck EGR valve
- Coolant contamination

Why?

Cause:

EGR Cooler

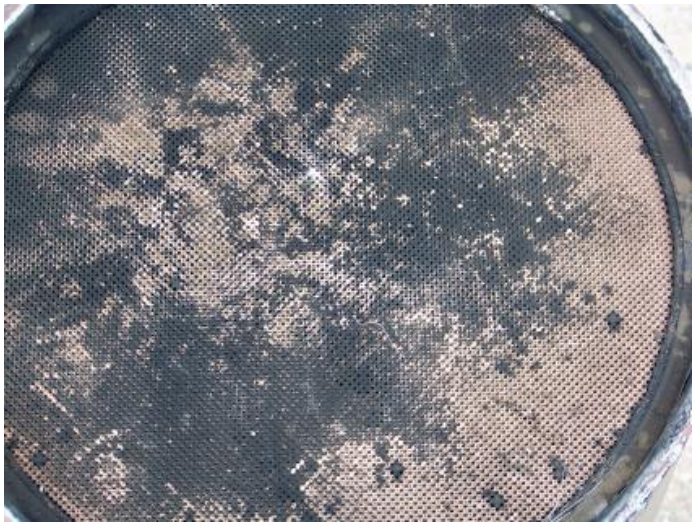
- Inspect for source of coolant contamination.

- Verified the source of coolant contamination
- EGR Cooler internal leak

What else?

DPF

- Check for other component damage
- DPF face plugging



- Check component for further damage
- DPF catalyst broken

Correction:

Replace Hardware

- EGR cooler
- EGR valve
- DPF
- Related gaskets and clamps

Electronic Repair

- Recalibrate ECM software
- Clear fault codes
- Test system for proper operation

Complaint:

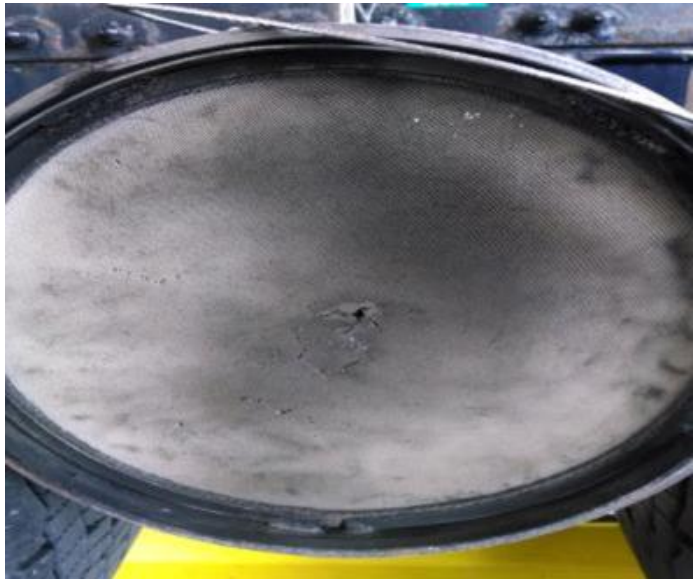
Engine Low Power/MPG

- Check engine light on and low MPG
- SCR catalyst conversion efficiency fault

Cause:

DOC

- Inspect Aftertreatment component
- Found a hole in DOC face
- Inspect and test system for other component problems
- Aftertreatment fuel shutoff valve leaking



Correction:

Replace Hardware

- Aftertreatment Fuel Shut-off Valve
- DOC
- Doser injector PM or replace
- Related caskets and clamps

Electronic Repair

- Recalibrate ECM software
- Clear fault codes
- Test system for proper operation

Complaint:

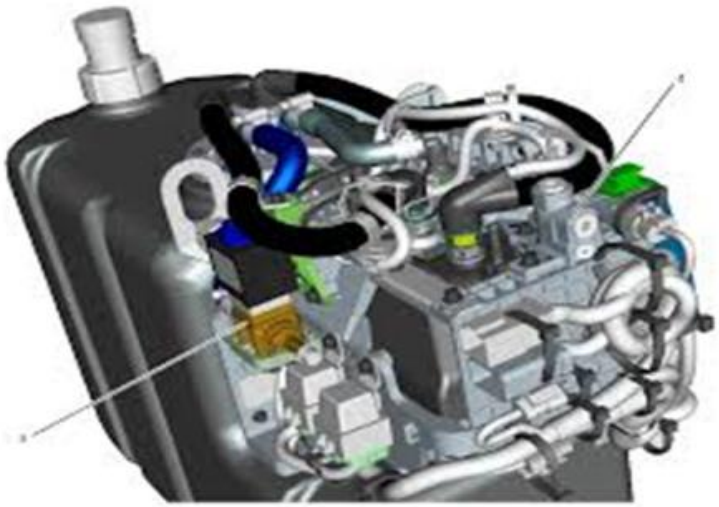
Intermittent Check Engine Light

- Intermittent CEL and MIL
- Inactive fault low DEF pressure
- System fails air/DEF pressure test

Cause:

DEF Pump Low Pressure

- Perform pressure tests
- Replaced failed component
- Rerun tests
- Road test

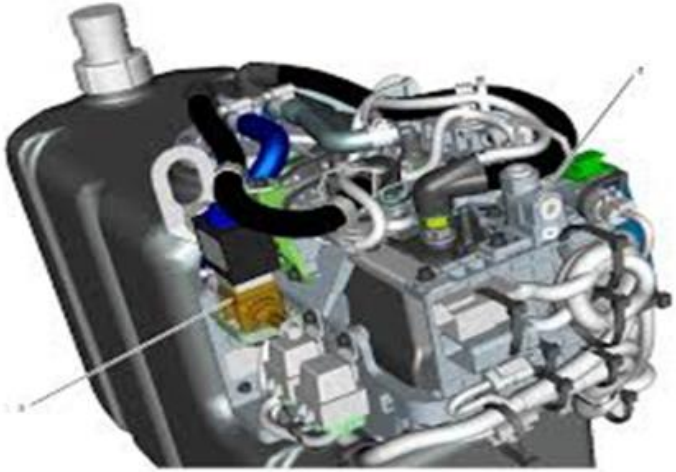


- CEL and MIL lights back on
- Contact customer support
- Send for ACM software updates

Further Investigation:

DEF Pump Pressure Low

- Intermittent CEL MIL lights
- Inspected / touched wiring harness
  - Different faults now active



Next: **ACM/DEF Pump Harness**

- Wiggle test!
- Wiggle wiring harness during inspection
- Different faults activate

Correction:

Replace Hardware

- ACM wiring harness assembly
- DEF pump wiring interface harness

Electronic Repair

- Perform system self and pressure test
- Clear fault codes
- Road-test and check systems for proper operation

Complaint:

Engine Derate 25 MPH MAX

- Check engine and MIL lights on
- Engine low power, derate EPA regulatory
- Active fault DEF air pressure low

Cause:

DEF Metering Unit

- Test components
- DEF metering unit air pressure low
- DEF metering unit air filter plugged
- Air supply contaminated

Why?

Further Investigation:

Air Dryer

- Test system, air dryer inoperative
- Leaking unloader circuit in air dryer or air compressor
- Perform leak test

Final Cause:

Air Compressor

- Failed unloader piston seals
- 100 % compressor duty cycle
- Extreme discharge air temp, STEAM!

Correction:

Replace Hardware

- Air compressor unloader valve
- Air dryer
- DEF air pressure regulator and metering unit

Electronic Repair

- Perform system self test
- Clear codes
- Monitor SCR efficiency

Take Aways

- Train Everyone
  - Train Technicians
    - Train Drivers

Take Away

- Integrity of system components

  - Functionality and interface of other system

Take Away:

Tools and Maintenance Procedures

- Laptop
- Internet access
- OE and aftermarket hardware/software

- Coolant vacuum kit
- GET the AIR OUT of the COOLANT!

- Air pressure gauge and flow manifold

Aftertreatment system experiences and best practices

Q & A