

SCR Opportunities & Challenges Vehicle Integration Perspective

Clean Diesel Implementation Workshop

Chicago

August 7, 2003

Timothy Blubaugh

Director

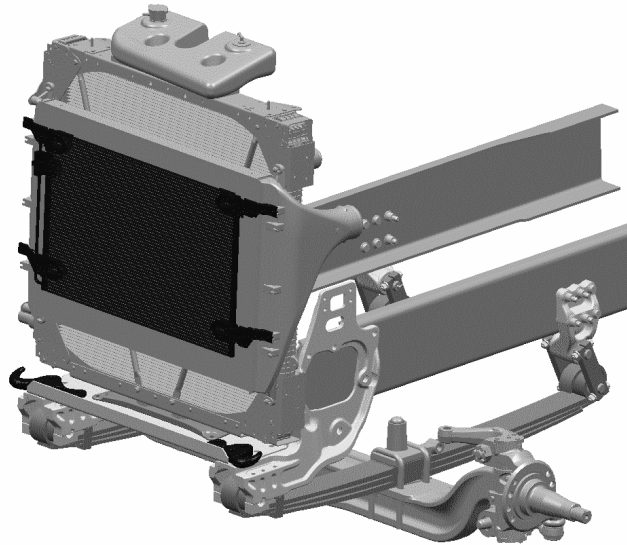
Government Technical Affairs

SCR Opportunities & Challenges

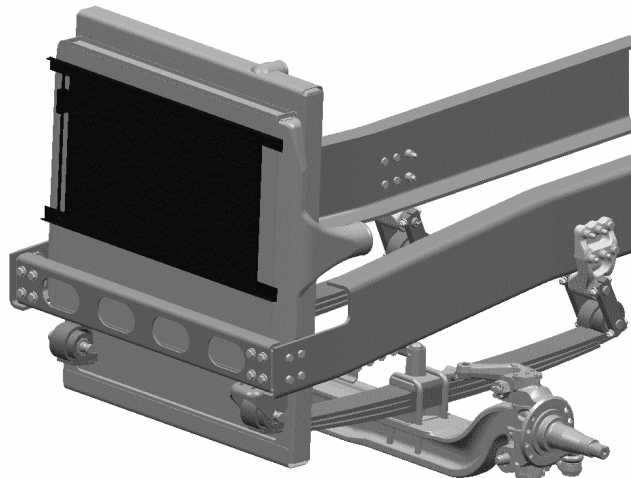


	High EGR	SCR	NOx Adsorber
Fuel Economy	-3%	+6% (3 - 6% Urea Usage)	-3%
Cooling Requirements	+55%	-20%	0%
Power Density	-5%	+6%	0%
Weight	+50 lbs.	-400 lbs.	+200 lbs.
Oil Exchange Intervals	1X	2X	1X
Urea Infrastructure	No	Yes	No
Driver's Responsibility	None	Urea Refill	None

2004 vs. 2007 Radiators



2002/2004 Design
Crossflow Radiator
1500 in²



2007 Design
Downflow Radiator
1850 in²
Splayed Frame
Interference w/ Axle Forward Springs

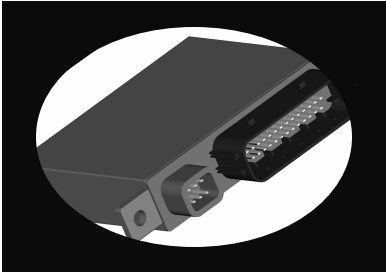
SCR Vehicle Integration



- **SCR System Elements**
- Urea Solution
 - Properties
 - Low Temperature Issues
 - Filling
- Urea Tank
 - Volume
 - Hardware
- SCR Catalyst
 - Location
 - Volume

SCR System Elements

Dosing Control Unit



Air Pressure Control Unit



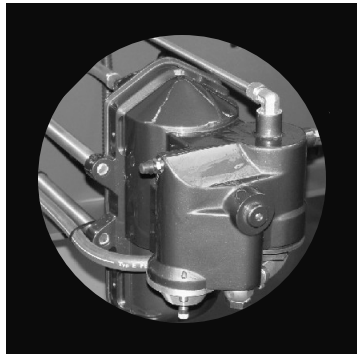
Urea Tank



Dosing Unit



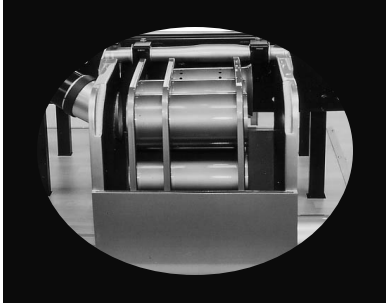
Urea Pump



Urea Injector



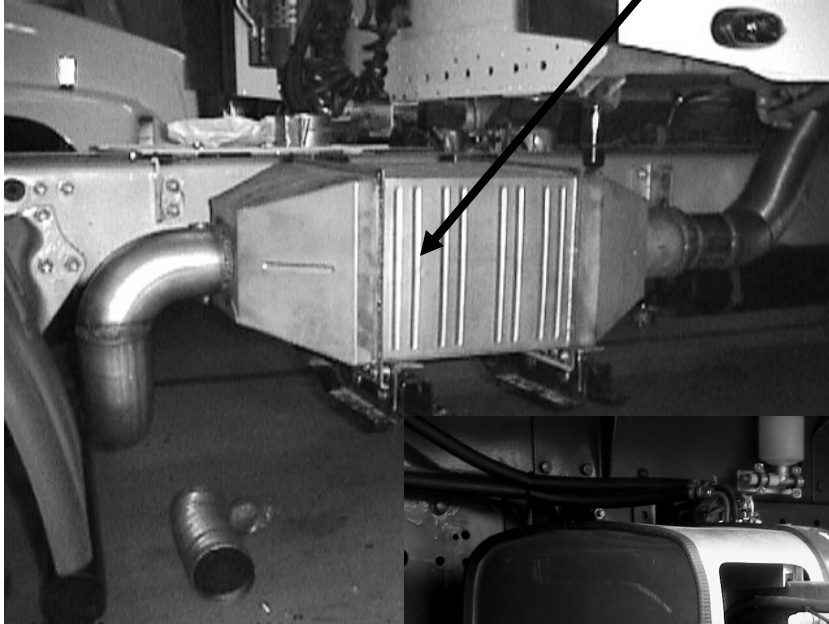
SCR Catalyst



SCR Demonstration: UC-Davis, Detroit Diesel, Freightliner



Catalyst



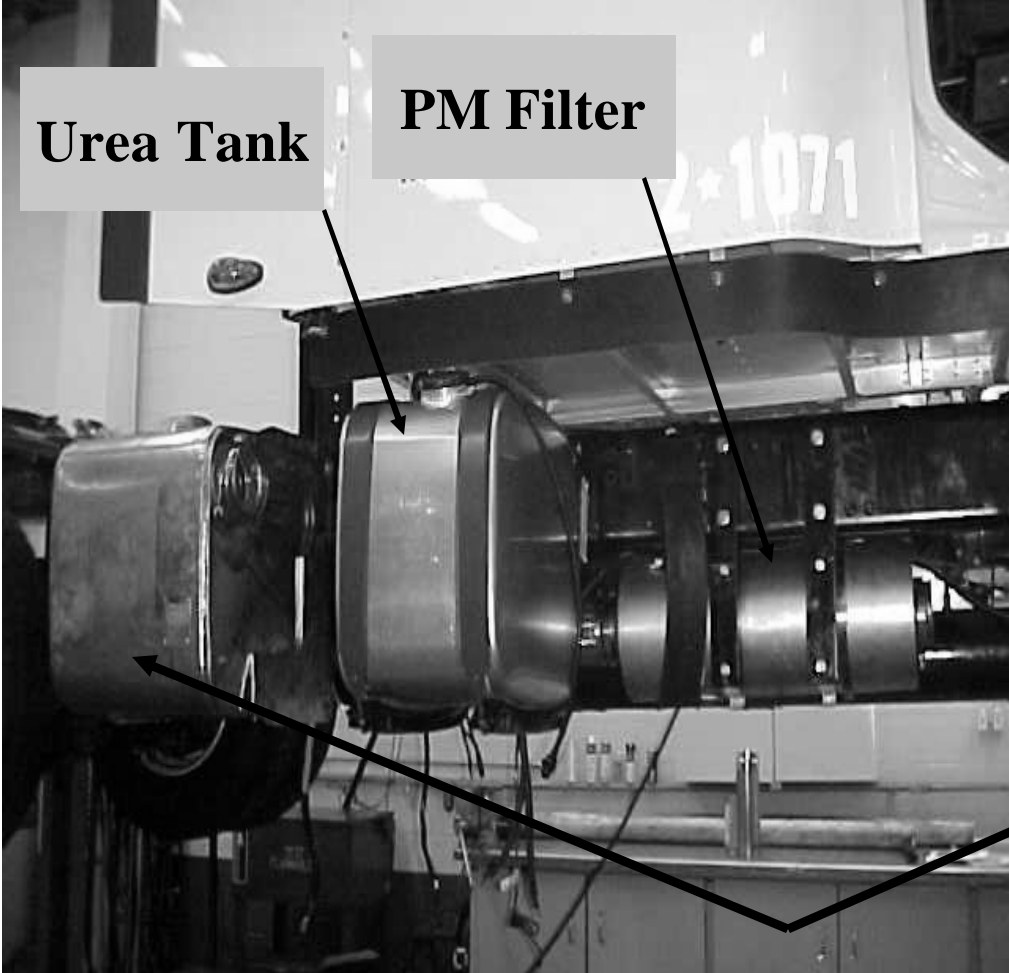
Combined
Urea Tank &
Dosing
System



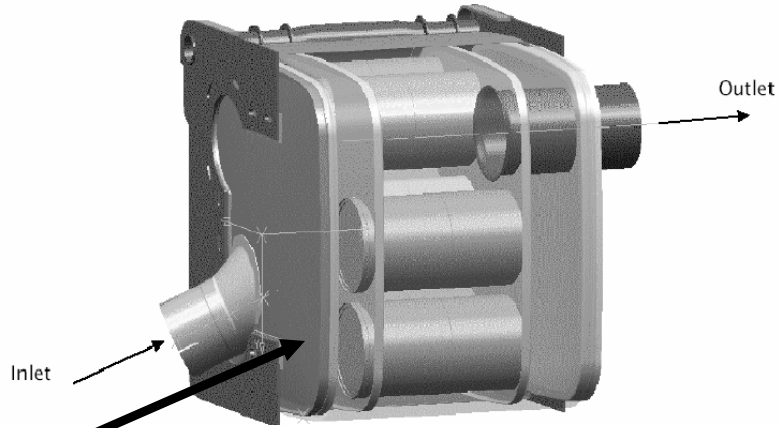
SCR Demonstration: Detroit Diesel, Freightliner & Private Carrier



SCR Demonstration: Detroit Diesel, Freightliner & Private Carrier



Cross Section of
SCR Catalyst

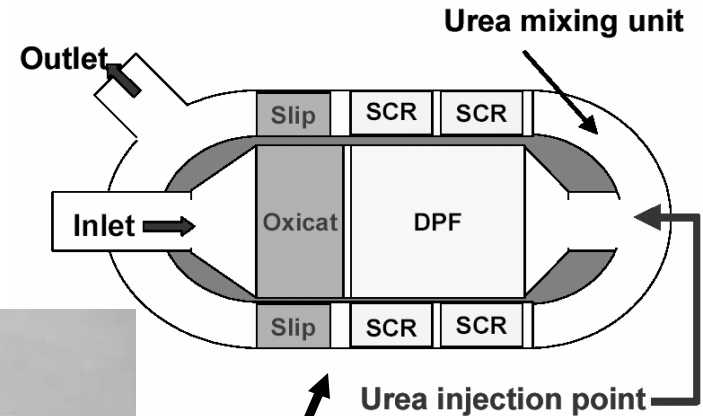


SCR Demonstration: Volvo, Johnson Matthey, Eminox, Bosch



SAE 2003-01-0778

Urea Tank



SCR Catalyst &
Diesel Particulate
Filter packaged
together

SCR Vehicle Integration

- SCR system Elements
- **Urea Solution**
 - **Properties**
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Chemical & Physical Properties:

- $\text{H}_2\text{N-CO-NH}_2 + \text{H}_2\text{O}$ (aqueous solution)
- 32.5% \pm 0.5% concentration in water
- Clear, No smell
- Acidity (pH-value) max. 10
- Freezing point: 12°F
- Non-toxic
- Weight: 9.2 lbs./gal.
- Currently many industrial uses:
 - Agriculture
 - Pharmaceutical
 - Chemical
 - Power generation
- Acceptable to drink in limited quantities

Urea Low Temperature Issues



- Urea Freezes at: 12°F
 - Minneapolis/St. Paul
 - Average January temperature
 - High = 20.6 °F
 - Low = 2.6 °F
 - Expansion similar to water (+10%)
- Urea Low Temperature Options:
 - Heat urea
 - Heat entire system
 - Heat portion of system and allow for expansion (~10%)
 - Introduce urea freeze-point depressants



Urea Low Temperature Issues



- Heat Urea System
 - Tank, lines, pump, injector, etc.
- Electrically
 - Viable option for lines & dosing (injector)
 - Tank requires significant energy to heat
- Engine Coolant
 - Circulate engine coolant around urea
 - Engine must be running
 - Urea in system may freeze
 - May require 30 minute engine heat up in extremely cold conditions

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- Urea Freeze-Point Depressants
 - Organic additives currently not feasible
 - Adversely affect NOx conversion efficiency
 - Can produce secondary emissions
 - Inorganic additives may poison catalyst
 - Chemical industry working to overcome challenges
 - Ford Recommendation (SAE 2003-01-0775)
 - “Let the urea freeze and develop engineering solutions to heat the aqueous urea in cold climates”

SCR Vehicle Integration



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- Urea Consumption 4%-5% of Diesel Fuel
- Urea Tank Volume Minimum
 - Primary + Reserve Volumes
 - Primary Volume = 4% of diesel fuel capacity
 - Reserve Volume = 1 gallon

Example: 150 Gallon Diesel Fuel Tank

$$\underbrace{150 \text{ gallon} \times 4\%}_{\text{Primary} = 6} + \underbrace{1 \text{ gallon}}_{\text{Reserve} = 1} = \underbrace{7 \text{ gallon urea tank}}_{\text{Total Urea Volume}}$$

Urea Tank Volume



Urea Capacity	Vehicle Range*
0.7 gal (90 oz)	100 miles
3.3 gal	500 miles
6.7 gal	1,000 miles
13.3 gal	2,000 miles
33.3 gal	5,000 miles
40.0 gal	6,000 miles

*Assumptions:

Urea Consumption = 4% Diesel Consumption

6.0 mpg Diesel Fuel Consumption

- **Urea Tank Level Sensor #1**
 - Indicates urea level at reserve level
 - 1 gal. urea = 25 gal. diesel → 150 mi. range*
 - Sensor similar to current oil pan level sensor
- **Urea Tank Level Sensor #2**
 - Indicates 8 oz. urea remaining in tank reservoir
 - 8 oz. urea = 1.5 gal. diesel → 9 mi. range*
 - Sensor similar to current oil pan level sensor
- **Urea Quality Sensor**
 - Indicates urea outside tolerance range
 - Sensor could measure specific gravity, density, or conductivity

Urea Filling Station

Urea filling station



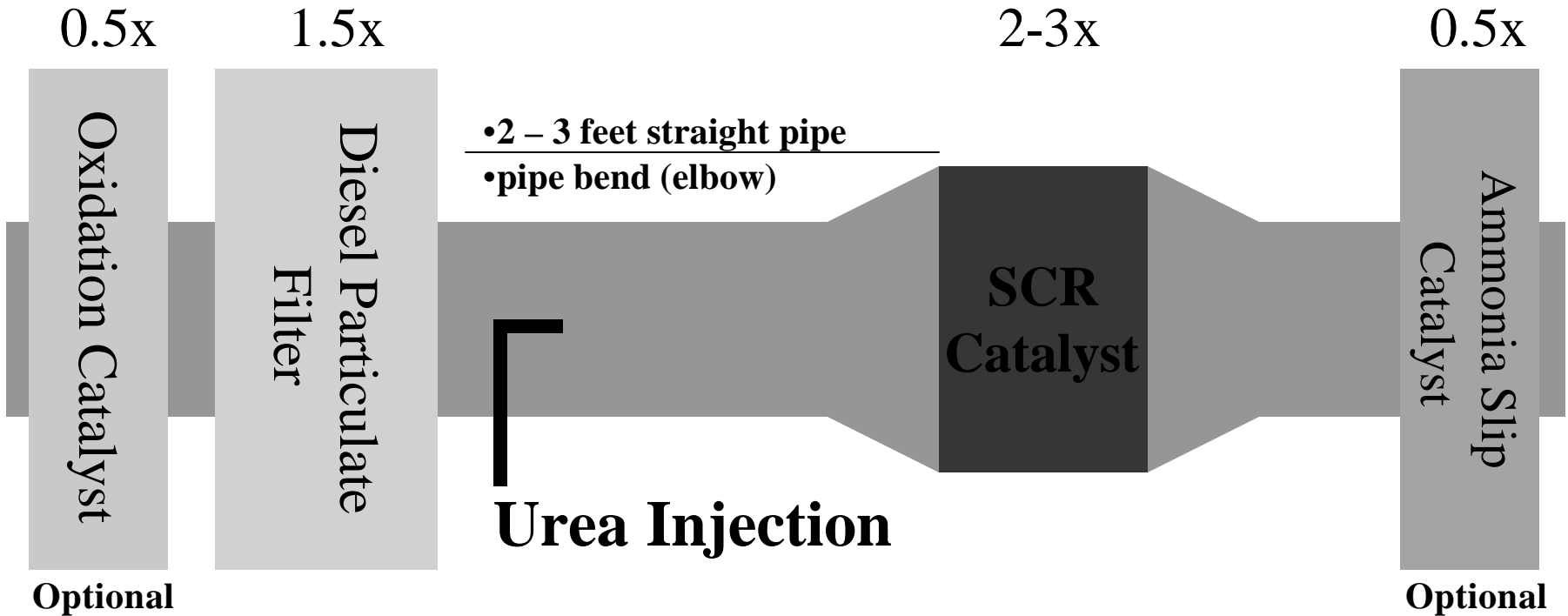
1000 L urea transportation container (264 gal.)

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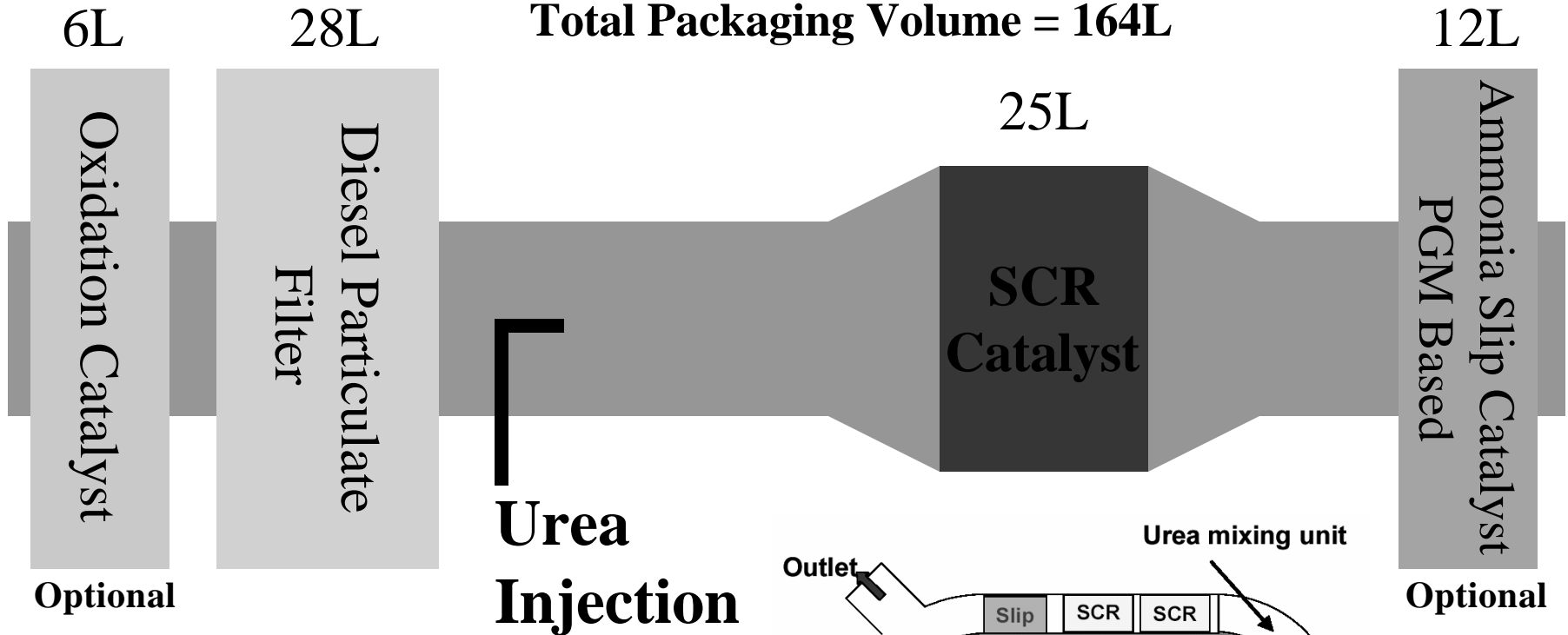
Size & Packaging of Catalyst

Catalyst Volume Roughly Approximated by Engine Displacement

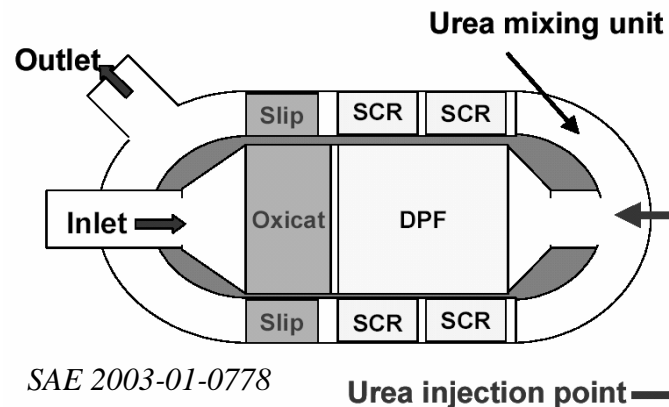


Size & Packaging of Catalyst

Engine Displacement = 12L
Total Catalyst Volume = 71L
Total Packaging Volume = 164L



Johnson Matthey
Compact SCR Design
2 feet x 2 feet x 2 feet



SAE 2003-01-0778

Size & Packaging of Catalyst



- SCR Catalyst (Non-Precious Metal)
 - Metal base or ceramic base
 - Volume 2-3x engine displacement
 - Example: 12 L engine
 - 34 liter SCR catalyst PUReM
 - 25 liter SCR catalyst Johnson Matthey
 - 200 to 350 cells per square inch (cpsi) available
- Total Volume of Example Systems
 - 175 liters (w/muffler) PUReM
 - 164 liters (w/DPF) Johnson Matthey
 - < 8 cubic feet for total packaging

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