SCR Retrofits: a potential for reducing NO_2 emissions in salt mines

MDEC 2005

Thierry Leprince – Extengine Transport Systems

Agenda

- Introduction
- Principles of urea-SCR systems
- SCR systems for mobile applications

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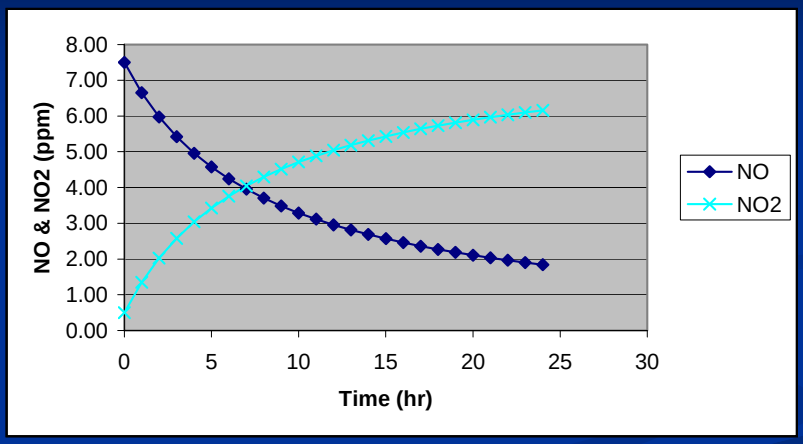
Introduction

- Salt mines may have an ambient NO2 problem because of:
  - Long residence time of ventilation air specific to salt mining architecture [large openings, front face is often located at the furthest point from the ventilation inlet]
  - Diesel engines emit NOx, which is 90% NO & 10% NO2. Long residence time leads to NO being oxidized into NO2; which contribute to higher ambient NO2 levels
  - Proportion of NO2 coming from the engine in ambient NO2 levels is not well known
- One potential method for reducing the amount of ambient NO2 is to reduce to reduce NOx emissions coming out of the tailpipe of diesel engines with SCR technology
- SCR is a mature technology that can reduce NOx emissions from diesel engines. It has been used in stationary applications for many years and can also be used on mobile non-road applications

NO-NO2 conversion

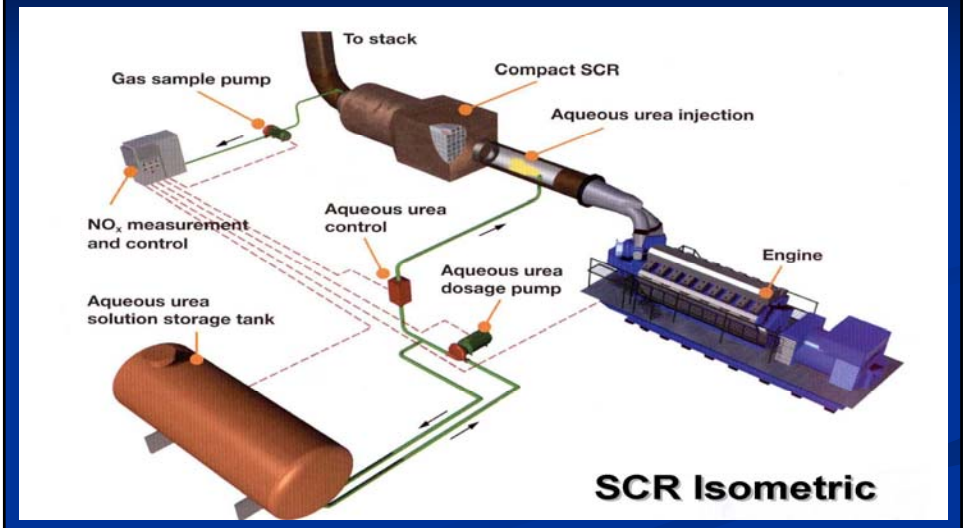


Theoretical example of NO conversion into NO2
Initial values: NOx = 8 ppm; NO = 7.5 ppm; NO2 = 0.5 ppm – O2 = 20.8%
Report Number: MRL 77-117(R)

Introduction

- SCR is a mature technology which has been used in stationary applications for many years

Principles of SCR catalysts



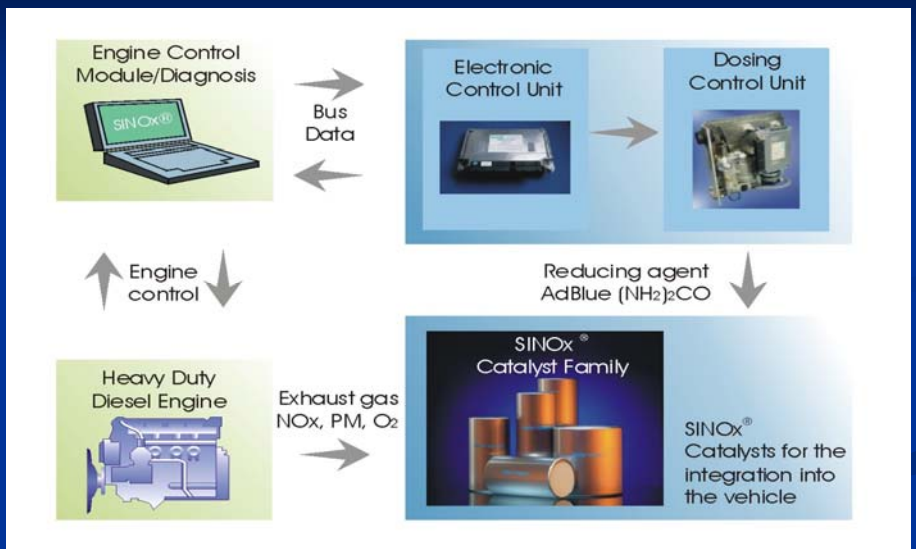
Tacoma Power

CAT 3516B Power Modules with *SINOx® SCR Systems*

Introduction

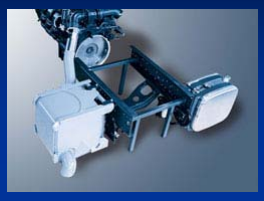
- SCR is a mature technology which has been used in stationary applications for many years
- SCR is now being used in Europe for mobile applications

SCR in Europe



www.argillon.com

SCR in Europe



http://www.purem.de

http://www.adbloom.co.uk/

http://www2.mercedes-benz.co.uk

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Introduction

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- SCR is now being used in Europe for mobile applications
- SCR is verified as a retrofit device for non-road applications by CARB

First SCR verified in Jan 05

Introduction

- SCR is a mature technology which has been used in stationary applications for many years
- SCR is now being used in Europe for mobile applications
- SCR is verified as a retrofit device by CARB
- SCR may be used in the US towards 2010

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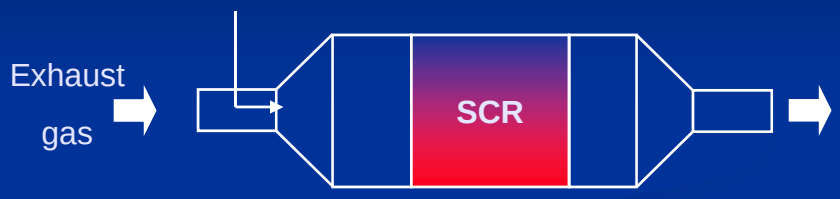
Principles of urea-SCR catalysts

Urea $(NH_2)_2CO$ or NH_3



$4NH_3 + 4NO + O_2 \rightarrow 4N_2 + 6H_2O$

$8NH_3 + 6NO_2 \rightarrow 7N_2 + 12H_2O$

$2NH_3 + NO + NO_2 \rightarrow 2N_2 + 3H_2O$

Principles of urea-SCR catalysts

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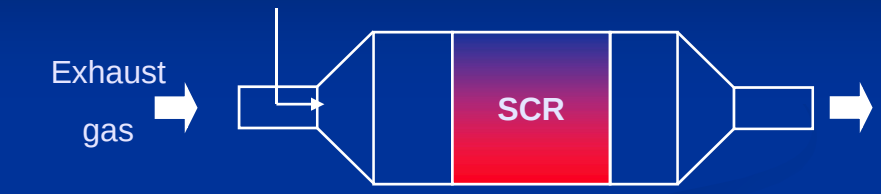

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Fastest reaction → $2NH_3 + NO + NO_2 \rightarrow 2N_2 + 3H_2O$

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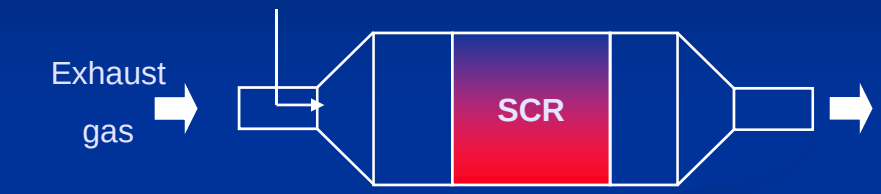

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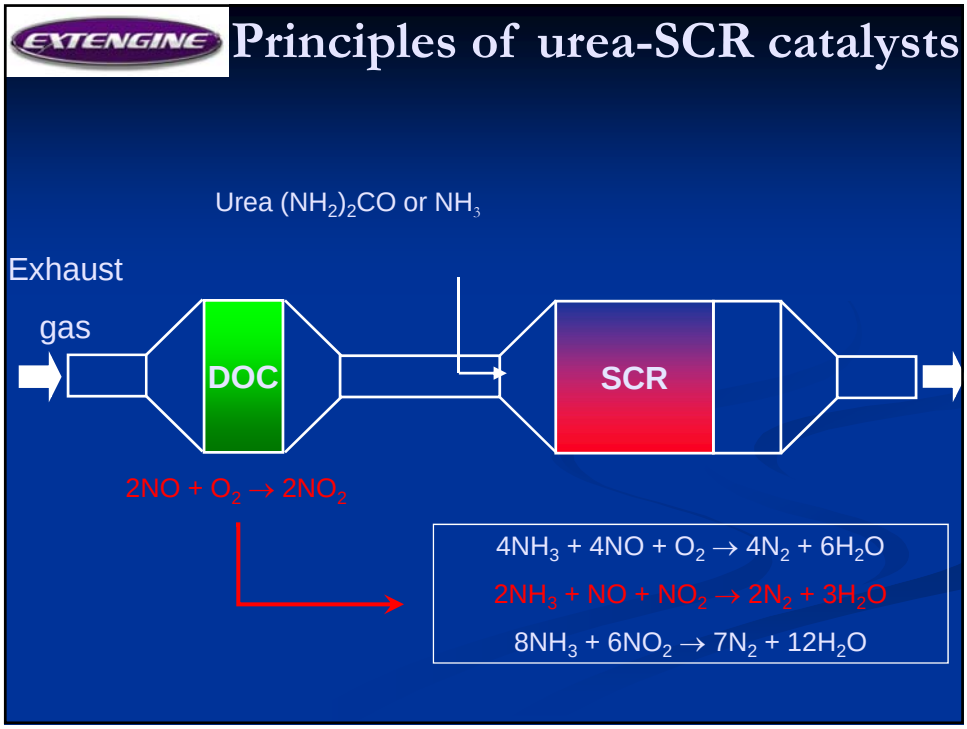
Optimum: $NO/NO_2 = 1$

Engine out: $NO/NO_2 \approx 10$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Urea $(NH_2)_2CO$ or NH_3
Exhaust gas
DOC
SCR
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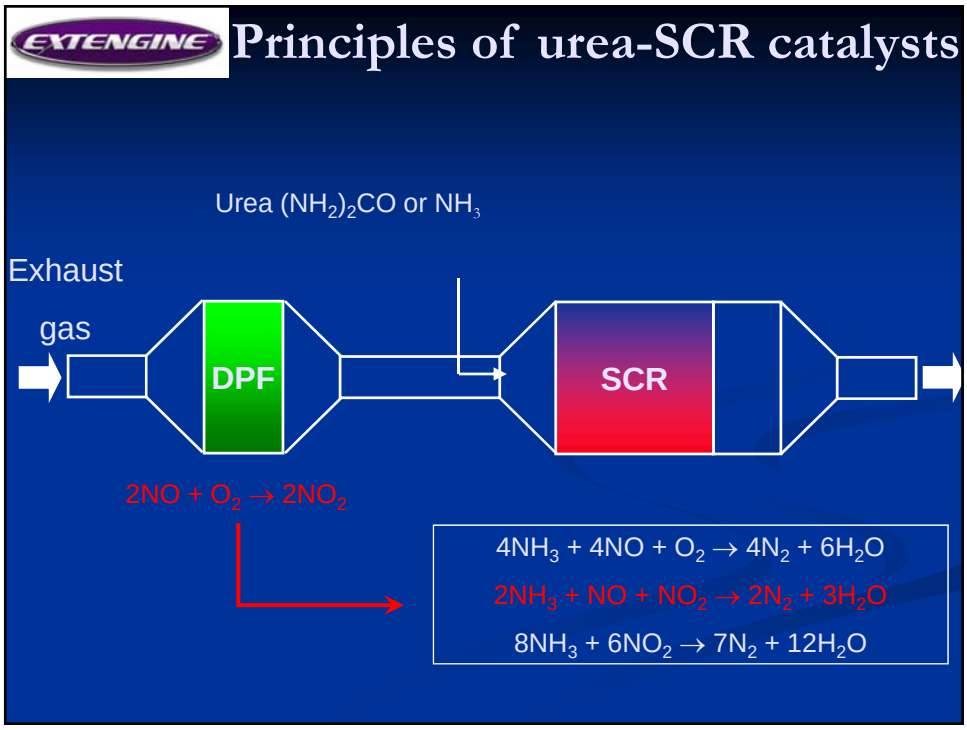
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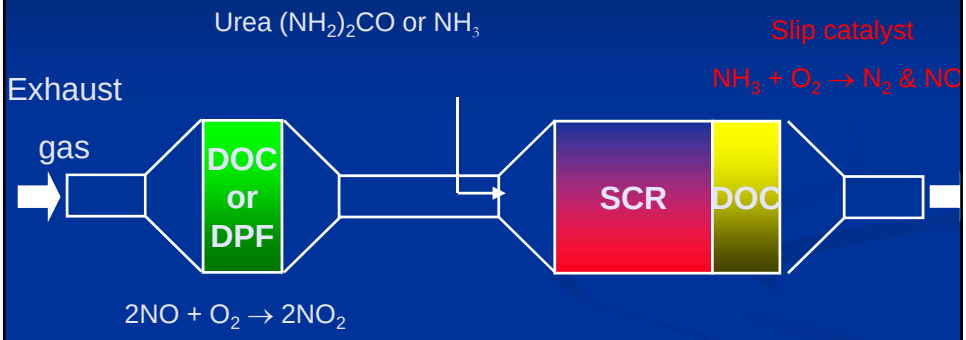

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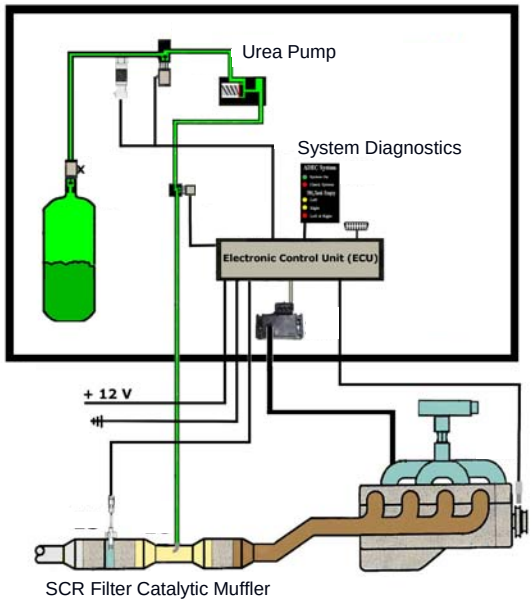
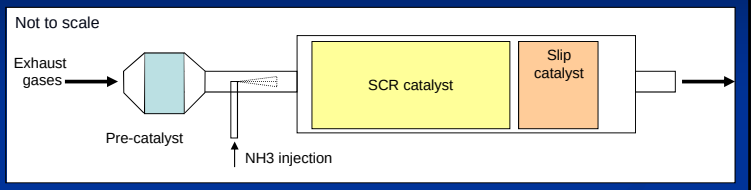
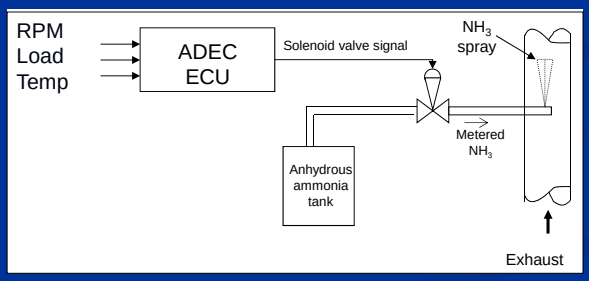


SCR system: ADEC Gen I

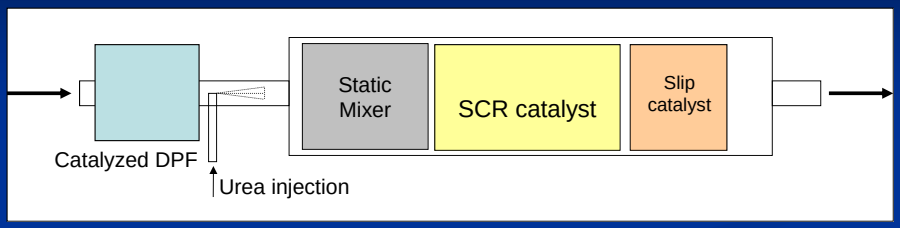
- Verified by CARB verification for non-road applications

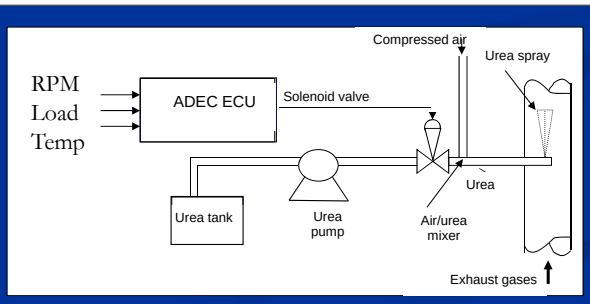




- Can also be used with urea

ADEC Generation II





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Objective

- Demonstrate the possibility of bringing a diesel engine to emission levels lower or similar to 2007 standards or CNG levels in terms of NOx+NHC and PM

Test engine

- 2003 Detroit Diesel 50 – 8.5 L displacement
- Direct injection
- Engine certified @ PM = 0.01 g/bhp.hr (equipped with catalyzed diesel particulate filter)
- Turbocharged, charge air cooling, water-cooled EGR
- Rated 275 HP @ 2100 RPM

Catalysts description

- Diesel particulate filter
  - Cordierite DPF catalyzed by Engelhard
  - Supplied by Detroit Diesel as certified system
- SCR catalyst
  - Metallic substrate catalyzed by Umicore
  - Vanadia based SCR catalyst
  - Diam 11.25" x 10"
- Slip catalyst
  - Metallic substrate catalyzed by Umicore
  - Diam 11.25" x 3"
- SCR & slip catalysts have been aged by 1000 hours
- Complete systems has run 25 hours prior to emission measurements

Results: baseline

Engine Certification Data (engine family)						
Emissions (g/bhp.hr)	**NMHC+NOx**	**PM**	**CO**	**NOx**	**NO2**	**CO2**
Diesel (3DDXH08.5FJB)	2.13	0.012	0.35	-----	-----	-----
CNG (3DDXH08.5FJG)	0.94	0.008	0.03	-----	-----	-----

Baseline Emission Tests (Engine is equipped with DPF)						
Emissions (g/bhp.hr)	**NMHC+NOx**	**PM**	**CO**	**NOx**	**NO2**	**CO2**
Hot start 1	2.95	0.01	0.26	2.95	0.69	755
Hot start 2	3.01	0.01	0.15	2.97	0.79	765
Hot start 3	2.81	0.01	0.17	2.77	0.73	743
Average Hot	2.92	0.01	0.19	2.90	0.74	754
Cold start	3.56	0.01	0.27	3.56	0.90	795
Composite Baseline	3.01	0.01	0.20	2.99	0.76	760

Engine data is higher than certification data

Results: NH_3 SCR

DPF with Anhydrous Ammonia SCR						
Emissions (g/bhp.hr)	**NMHC+NOx**	**PM**	**CO**	**NOx**	**NO2**	**CO2**
Hot start 1	0.77	0.005	0.25	0.75	0.15	741
Hot start 2	0.83	0.001	0.14	0.81	0.24	738
Hot start 3	0.90	0.002	0.24	0.90	0.23	735
Average Hot	0.83	0.003	0.21	0.82	0.21	738
Cold start	1.60	0.007	0.35	1.58	0.34	787
Composite Baseline	0.94	0.003	0.23	0.93	0.23	745
Conversion	69%	NC	-12%	69%	70%	2%

Results: urea-SCR

DPF with Urea SCR						
Emissions (g/bhp.hr)	**NMHC+NOx**	**PM**	**CO**	**NOx**	**NO2**	**CO2**
Hot start 1	1.06	0.01	0.43	1.06	0.25	746
Hot start 2	0.96	0.01	0.24	0.95	0.16	738
Hot start 3	0.99	0.01	0.27	0.99	0.24	740
Average Hot	1.00	0.01	0.31	1.00	0.22	741
Cold start	1.96	0.01	0.17	1.96	0.34	799
Composite Baseline	1.14	0.01	0.29	1.14	0.24	749
Conversion	62%	NC	-43%	62%	69%	1%

Results: summary

Results summary						
Emissions (g/bhp.hr)	**NMHC+NOx**	**PM**	**CO**	**NOx**	**NO2**	**CO2**
Certification data diesel	2.13	0.012	0.35	-----	-----	-----
Certification data CNG	0.94	0.008	0.03	-----	-----	-----
Baseline emissions	3.01	0.01	0.20	2.99	0.76	760
Retrofit NH3 SCR	0.94	0.00	0.23	0.93	0.23	745
Retrofit urea SCR	1.14	0.01	0.29	1.14	0.24	749

- NMHC + NOX engine emissions are higher than 2004 heavy-duty diesel standard
- Engine equipped with anhydrous NH_3-SCR shows similar NMHC+NOx and PM emissions when compared to CNG
- Engine equipped with urea-SCR is at 2007 NOx levels. It shows slightly higher emissions in terms of NOx+NMHC when compared to CNG engine. Emissions could be improved with larger catalyst

Summary

- Diesel engines can meet same levels as CNG engines in terms of NO+NMHC and PM emissions when retrofitted with SCR & DPF system
- Additional benefit with diesel is lower THC emissions when compared to CNG
- Overall reduction in greenhouse gases

Conclusion

- SCR could be used in salt mines for reducing NOx emissions form diesel engines
- It should reduce ambient NO2 levels.
- Magnitude of reduction on ambient NO2 levels is not known. It could be estimated with some modeling of air quality
- Extengine is interested in participating in a demonstration in a salt mine
- Active DPF could also be integrated into package in order to reduce PM emissions

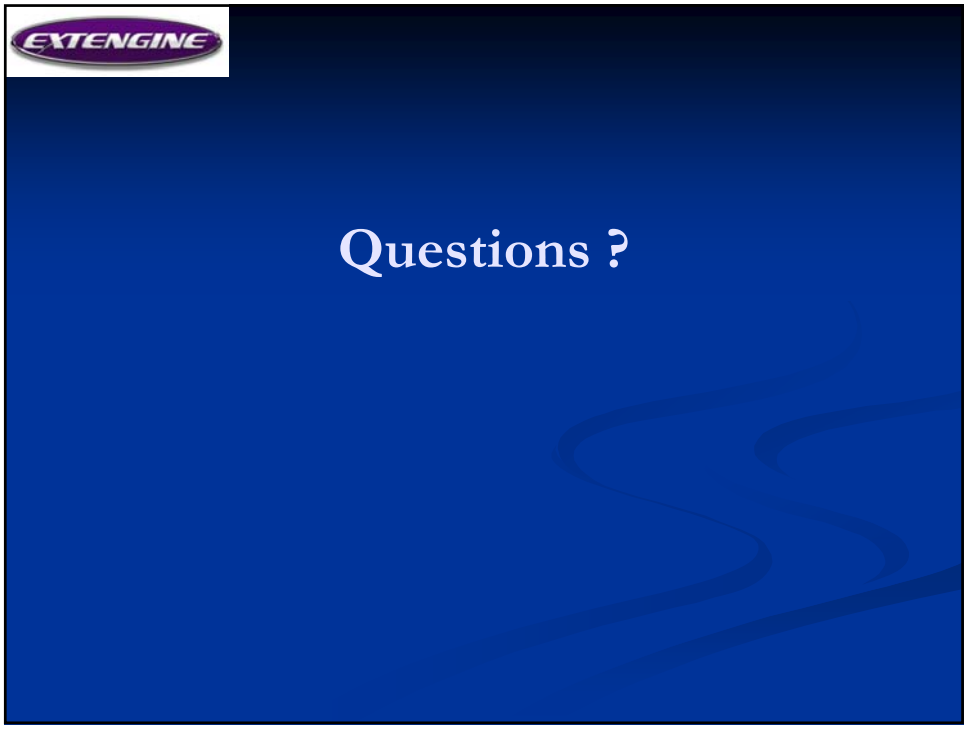
MaxTRAP™ Active Diesel Particulate Filter

Mercedes-Benz Sprinter Active DPF

Dimension and weight of ExoClean™ design for Mercedes-Benz Sprinter application.

Temperature (°C)	Time %	Pressure (mbar)	Time %
< 200	97.25	< 100	95.76
200 - 250	1,64	100 - 148	3.56
250 - 340	0.90	148 - 300	0.68
340 – 400	0.17	300 - 400	0.00
400 - 450	0.04	400 - 500	0.00
> 450	0.01	> 500	0.00

Data from ExoClean™ field application on Mercedes-Benz Sprinter with commercial standard fuel (350ppm of Sulfur) for 1900 to 2000 hour field operation (fleet) with average speed 9.2 km/h.


EXTENGINE
Questions ?