ArvinMeritor

Thermal Regeneration System Performance Inter-Laboratory Data Comparison

Mahe Gangal, Brent Rubeli & David Young (NRCan - CANMET)

Prasad Tumati & Nik Birkby (ArvinMeritor)

November 4 – 6, 2003

MDEC, Markham, Ontario

ArvinMeritor

Background

- Developed and introduced first in 1992
- Redesigned product in testing since Spring ‘02
- Installed on 3 different vehicles
- VERT verified
- CANMET-MMSL Testing during 6/03

ArvinMeritor

MDEC, Toronto
11/5/2003

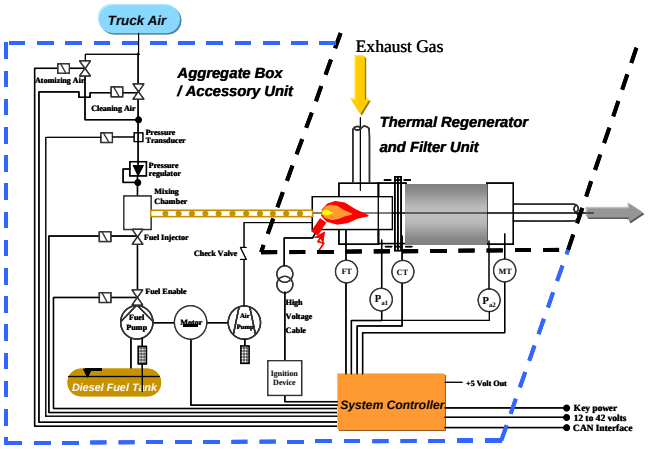
Thermal Regenerator System

3

ArvinMeritor

MDEC, Toronto
11/5/2003

TR Control Schematic



4

ArvinMeritor

MDEC, Toronto
11/5/2003

Overview of VERT Verification

- Consortium of occupational health authorities from Switzerland (SUVA), Austria (AUVA), and Germany (TBG) along with the Swiss clean air authority BUWAL.
- Phase I & III - Pre and Post Field Test Engine Dynamometer Tests
  - Functionality and reliability of regeneration system
  - Filtration efficiency of counts and mass at different soot loadings
  - Particle size analysis between 10 – 500 nm
  - Monitoring of gaseous emissions during regenerations
- Phase II – 2000 hours of durability tests

5

ArvinMeritor

MDEC, Toronto
11/5/2003

VERT Verification Program

- Phase I & III – Test Engine, Cycle, and Procedure
  - Test Engine – Liebherr D914T
    - 6.11 Liters, 4 cylinder-inline
    - 105KW (141 hp) @ 2000 rpm
    - Turbocharged without intercooling
    - In service since 1988
  - Test Cycle - ISO-cycle 8178 C/4 C1
    - All emissions measurements are based on 4 operating points from the cycle

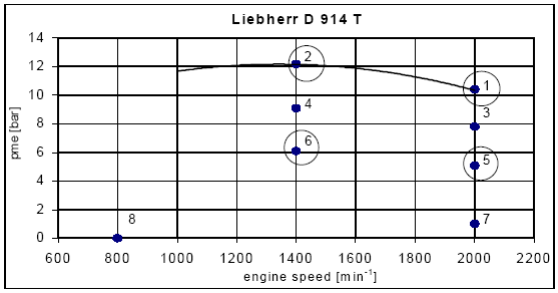
6

ArvinMeritor

MDEC, Toronto
11/5/2003

VERT Verification Program

- Phases I & III
  - Operating Point 1: Full load, rated RPM
  - Operating Point 2: Full load, mean RPM (maximum torque)
  - Operating Point 5: Rated RPM, 50% Load
  - Operating Point 6: Mean RPM, 50% Load



7

ArvinMeritor

MDEC, Toronto
11/5/2003

VERT Verification Program

- Emission Analyzers
  - Volatile Components
    - **Horiba Exhaust Gas Measurement Devices**
      - » **VIA-510 – CO_2, CO, HC_{IR}, O_2**
      - » **CLA-510 – NO and NO_X**
    - **Amluk Exhaust Gas Measurement Device**
      - » **FID 2010 – HC_{FID}**
  - Particulate Emissions
    - **ELPI – Electrical Low Pressure Impactor**
    - **NanoMet**
    - **SMPS – Scanning Mobility Particle Sizer**
    - **AVL Smart Sampler II**

8

ArvinMeritor

VERT Program Results and Conclusions

- DPF is efficient at filtration of nanoparticles (up to 99%)
- DPF sufficiently eliminates the opacimetric acceleration smoke
- Regeneration of the DPF with TRS works well
- During regeneration of DPF, there are emissions peaks for CO, HC, and nanoparticles
  - Except for CO, these emissions are below level of stationary engine operation with DPF and within VERT limits

9

ArvinMeritor

Liebherr Engine Testing @ CANMET-MMSL

10

ArvinMeritor

MDEC, Toronto
11/5/2003

Liebherr D914T Engine @ CANMET-MMSL

11

ArvinMeritor

MDEC, Toronto
11/5/2003

Engine Parameters - Comparison

Mode	Power, kW		Torque, Nm		BSFC, g/kWh	
	CANMET	BIEL	CANMET	BIEL	CANMET	BIEL
A (2)	88.0	88.3	600	602	211.5	214.1
B(6)	43.6	43.5	298	297	213.2	226.7
C(5)	53.3	52.8	254	252	249.2	256.4
D(1)	108.0	104.7	515	500	226.1	235.7
E(2)	87.7	85.9	598	586	209.4	217.0

12

ArvinMeritor

MDEC, Toronto
11/5/2003

Engine Parameters - Comparison

Mode	Intake air, kg/hr		Exh flow, kg/hr	
	CANMET	BIEL	CANMET	BIEL
A	396	421	415	440
B	315	327	324	337
C	514	546	527	559
D	663	709	687	734
E	399	411	418	430
CANMET Intake air is 4 to 6% lower				
Effect on emissions observed				

13

ArvinMeritor

MDEC, Toronto
11/5/2003

Engine Emissions- Comparison

Mode	CO, g/kWh		NOx, g/kWh		DPM, g/kWh	
	CANMET	BIEL	CANMET	BIEL	CANMET	BIEL
A	0.85	0.18	10.50	18.94	0.099	0.107
B	0.36	0.18	9.93	16.28	0.087	0.072
C	0.99	0.80	7.63	12.37	0.139	0.163
D	1.94	2.93	8.87	14.34	0.131	0.273
E	0.84	0.21	10.71	18.92	0.109	0.090
- CO CANMET is much higher						
- NOX CANMET lower						
- DPM varies for both engines						

14

ArvinMeritor

MDEC, Toronto
11/5/2003

Particulate Emissions in g/kwh

	DPF Regenerated		DPF Charged	
Mode	CANMET	BIEL**	CANMET	BIEL
A	0.020	0.051	0.004	nm
B	0.029	0.018	0.009	0.014
C	0.034	0.034	0.015	0.031
D	0.170	0.032	0.012	nm
E	0.009	0.016	0.004	nm
** New DPF results, Regenerated DPF not measured				

15

ArvinMeritor

MDEC, Toronto
11/5/2003

Filter Efficiency

CANMET DATA								
	PMAG [%]				PZAG [%]			
	2000 rpm 100% load	1400 rpm 100% load	2000 rpm 50% load	1400 rpm 50% load	2000 rpm 100% load	1400 rpm 100% load	2000 rpm 50% load	1400 rpm 50% load
DPFregenerated	87.1%	80.3%	75.9%	66.7%	99.82%	99.71%	99.86%	97.60%
DPF charged	91.1%	95.5%	88.9%	90.0%	99.90%	99.86%	99.91%	99.04%
average	89.1%	87.9%	82.4%	78.3%	99.86%	99.79%	99.89%	98.32%
Overall average		84.4%				99.46%		

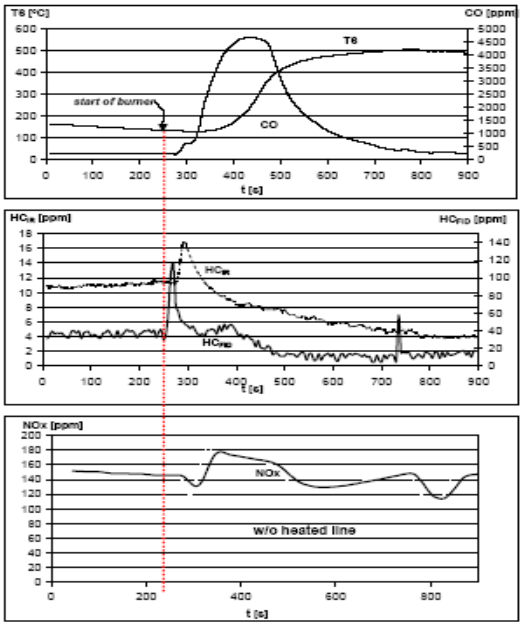
BIEL DATA								
	PMAG [%]				PZAG [%]			
	2000 rpm 100% load	1400 rpm 100% load	2000 rpm 50% load	1400 rpm 50% load	2000 rpm 100% load	1400 rpm 100% load	2000 rpm 50% load	1400 rpm 50% load
DPFregenerated	nm	nm	nm	nm	99.21%	98.78%	99.30%	99.24%
DPF charged	nm	nm	80.8%	81.0%	99.36%	99.11%	99.46%	99.42%
average			80.8%	81.0%	99.3%	98.9%	99.4%	99.3%
Overall average		80.9%				99.23%		

16

ArvinMeritor

MDEC, Toronto
11/5/2003

regeneration attempt "A"(engine at idle)
with particle filter Zeuna BS-30



VERT Results

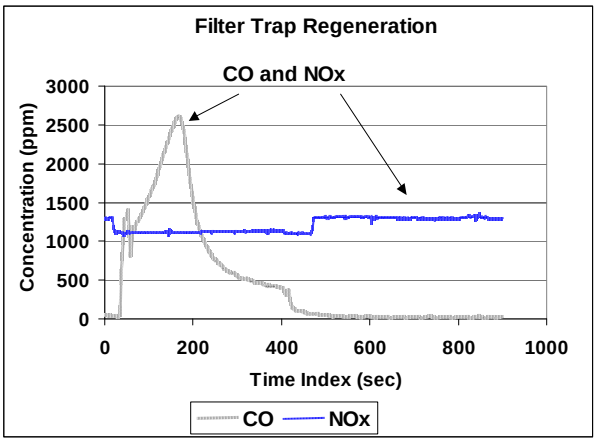
CO& NOx during Regeneration

17

ArvinMeritor

MDEC, Toronto
11/5/2003

CO and NOx Concentrations during filter Regeneration(CANMET-MMSL)

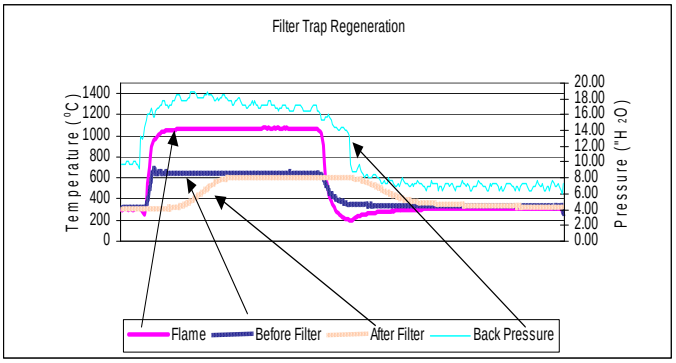


18

ArvinMeritor

MDEC, Toronto
11/5/2003

Temperature and Pressure during filter Regeneration(CANMET-MMSL)

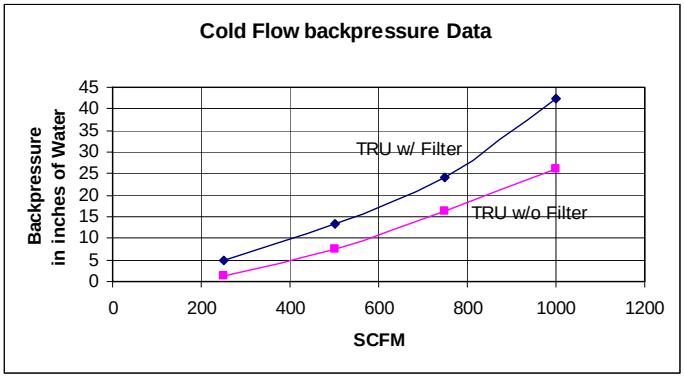


19

ArvinMeritor

MDEC, Toronto
11/5/2003

Backpressure Data



20

ArvinMeritor

System Components

ArvinMeritor

Summary and Conclusions

- Liebherr engine at CANMET-MMSL produced Higher CO and Lower NOx compared to VERT data.
- Filtration efficiencies are comparable on both mass basis and particle number counts.
- Thermal regenerator performed well on demand.
- RC-200 filtration efficiency was higher under loaded conditions.
- Regeneration process did not increase NOx Concentrations.
- However, CO Levels increased sharply during regeneration of a fully loaded filter for a duration of 3 minutes.
- CO peak can be reduced by increasing regeneration frequency and having less accumulated particulate matter on the trap.