IN-USE COMPLIANCE TESTING FOR OFF-ROAD RETROFIT

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ABSTRACT

- As part of regulations for CARB Verified DPFs in California, an in-use compliance test program must be executed.
- 4 DPFs were selected with operating hours more than 50% of the warranty period.
- On-site visual inspection and opacity test was conducted on the selected DPFs
- These DPF's were sent to lab for testing to determine PM reduction and NO_2 creation.
- All 4 tested DPFs met the requirements as laid out by CARB, and long term effectiveness data was collected.

DIESEL PARTICULATE FILTERS

- Removes > 85 PM by mass
- Removed > 99.9 PM by particle count
- Built out of 409 stainless steel for enhanced durability
- Packaged using a high-performance mat to provide long-term protection
- Certified/verified for retrofit with CARB, EPA and VERT
- Passive regeneration with pre-filter/DOC
- **Proven durability up to 9000 hours**

DCL's MINE-X SOOTFILTER

- Passive Regeneration system that uses the engine exhaust temperature to reduce PM by 85%
- Exhaust temperature at 300°C for 30% of operating time
- Keeps NO2 levels below 20%
- **Uses 3 components:**
  - Catalyzed Prefilter
  - Catalysed Wall Flow Diesel Particular Filter
  - Temperature and Backpressure Monitor

CARB DIESEL EMISSION CONTROL STRATEGY (DECS)

- Purpose of In-Use Compliance to evaluate effectiveness of DPF to meet specific PM emission reductions
- Technology is applied to older engines (Tier 1, 2 and 3)
- Program demonstrates that emission reductions are real and durable and that production units in the field are achieving reductions that are consistent with their verification

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KOMATSU PC600LC-8 EXCAVATOR

2-DLT 4 MINE-X SOOTFILTER®
Komatsu SAA6D140E-5
Engine - 429hp

HITACHI EX1200-5 EXCAVATOR

2-DLT 5.9 MINE-X SOOTFILTER®
Hitachi S6RY1TAA1 Engine – 671hp

CATERPILLAR D6N DOZER EXCAVATOR

DLT 6 MINE-X SOOTFILTER®
Caterpillar C6.6 - 150hp

DCL's IN-USE COMPLIANCE PLAN

- Must test the following on 4 DPFs:
  - Evaluation maintenance records of each engine
  - Field inspection of each DPF
  - Opacity Testing
  - Emissions Testing
- Selected DPFs must have operated at least 50% of warranty period (> 4000 hr)

DCL's IN-USE COMPLIANCE PLAN

Unit #	1	2	3	4
Vehicle Make/Model	Caterpillar 980H	Taylor THDC955	Taylor THDC975	Taylor THDC975
Vehicle Type	Wheel Loader	Top Pick	Top Pick	Top Pick
Engine Model	Caterpillar C15	Cummins QSM11C	Cummins QSM11	Cummins QSM11
Engine Family	5CPXL15.2ESK	6CEXL0661AAF	4CEXL0661AAC	2CEXL0661AAC
DPF Install Date	12/07/2009	02/13/2013	04/29/2013	4/26/2013
DPF Hours	7,115	5,337	9,114	7,886



ON-SITE INSPECTION

3-Test Opacity average (According to J1667) must be below 3%

Unit #	1	2	3	4
Opacity Results	0.7% 0.8% 0.9%	1.3% 1.4% 1.4%	0.0% 0.0% 0.0%	1.1% 0.7% 0.8%
3-Test Opacity Average	0.8%	1.4%	0.0%	0.9%

FTP vs. OPACITY FIT CURVES

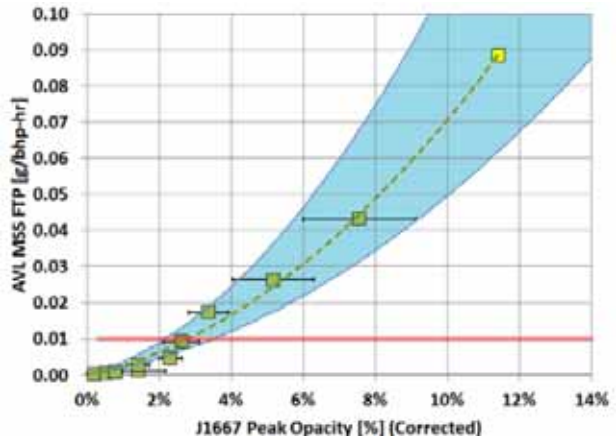

Figure 1. *FTP vs. Opacity Fit Curves (NREL, 2016).*

LAB TESTING

- The average of the three tests was compared to determine whether the unit passed emissions testing.
- In order to pass emissions testing unit:
  - Cannot increase NO2 levels by more than 22%
  - Must have a PM reduction efficiency better than 77%
  - Cannot spend more than 2% of the first NRTC cycle with a backpressure above 60”wc

IN-USE COMPLIANCE RESULTS

Unit #	1	2	3	4
Product Model	2-DLT4	DLT5.5	DLT5.9	DLT5.9
Part Number	951Q-C1-5S55-22	95KG-C1-5SG5-21	95LE-C1-5SL5-21	95LE-C1-5SL5-21
Vehicle Model	Caterpillar 980H Wheel Loader	Taylor THDC955 Container Handler	Taylor THDC975 Container Hander	Taylor THDC975 Container Handler
Engine Family	5CPXL15.2ESK	6CEXL0661AAF	4CEXL0661AAC	2CEXL0661AAC
Install Date	December 7, 2009	February 13, 2013	April 29, 2013	April 26, 2013
Operating Hours	7115	5337	9114	7886
Test Cycle	NRTC	NRTC	NRTC	NRTC
PM Efficiency	95.6%	96.4%	95.7%	97.4%
NO2 Increase	13.8%	10.2%	12.0%	12.7%
Agency Reference	CARB Letter ICE-2017-004	CARB Letter ICE-2017-004	CARB Letter ICE-2017-004	CARB Letter ICE-2017-004

CARB & VERT VERIFICATION TEST SUMMARY

Agency Reference	CARB letter RAS-08-15	CARB Executive Order DE-09-012	CARB Executive Order DE-09-012	CARB Executive Order DE-08-002-01	VERT report B230
Application	Caterpillar 950G Wheel Loader	Caterpillar 321C LCR Excavator	Liebherr HS895 Crane	Genset	Volvo L180E Wheel Loader
Application Engine	Caterpillar 3126B, 183 hp, Tier 2	Caterpillar 3306, 138 hp, Tier 2	Liebherr D2842LE103, 905 hp, Tier 2	John Deere 6125HF070, 443 hp, Tier 2	Volvo D12DLAE3, 286 hp, Stage IIIA
In-Field Period	1998 hours	1300 hours	1534 hours	1524 hours	2004 hours
Test Cycle	ISO8178 C1	ISO8178 C1	ISO8178 C1	ISO8178 D2	ISO8178 C/4 C1
PM Efficiency	88.8%	97%	92%	97%	99.62%
CO Efficiency	95.7%	98%	96%	100%	-
HC Efficiency	72.2%	86%	80%	95%	-
NO2 Increase	<20%	<20%	<20%	<20%	-
Report Date	April 10, 2007	January 5, 2009	March 5, 2009	April 23, 2008	August 2008

DPF APPROVALS

California Air Resources Board

United States EPA

Verminderung der Emissionen von Realmaschinen im Tunnelbau

Japan MLIT

REFERENCES

- *NREL, 2016. Aerodynamic Drag Reduction Technologies Testing of Heavy-Duty Vocational Vehicles and a Dry Van Trailer: Appendix C-Heavy-Duty On-Road Vehicle Opacity and Engine Repair Durability. National Renewable Energy Laboratory. October 2016. http://www.nrel.gov/docs/fy17osti/64610.pdf*


DCL
THANK YOU!