TSI® NANOPARTICLE EMISSION TESTER (NPET) MODEL 3795 IN-USE APPLICATION EXAMPLES

APPLICATION NOTE NPET-001 (US)

Introduction

The TSI Nanoparticle Emission Tester (NPET) model 3795 is a powerful tool developed to measure the concentration (by number) of solid particles in engine exhaust. Designed for in-use after-treatment certification, inspection and maintenance, as well as emissions research, the NPET quickly determines the condition of diesel particulate filters (DPF) by measuring the raw exhaust directly from the tailpipe downstream of the DPF. The NPET's built-in diluter, catalytic stripper, and condensation particle counter (CPC) allow for easy measurement of the solid particle number concentration (SPN) from a variety of combustion sources such as non-road mobile machinery (NRMM), stationary generators, and both light-duty and heavy-duty on-road vehicles. This application note briefly describes the operating principle of the NPET and highlights a few in-use application examples.

Operating Principle

As shown in Figure 1, the NPET's sample probe dilutes a sample of exhaust. The diluted sample is drawn through a catalytic stripper to remove semi-volatile particles through evaporation and oxidation. The concentration of the remaining solid particles is then measured using a CPC. The use of CPC technology (the same measurement principle used in PMP testing) allows for accurate, repeatable measurements.

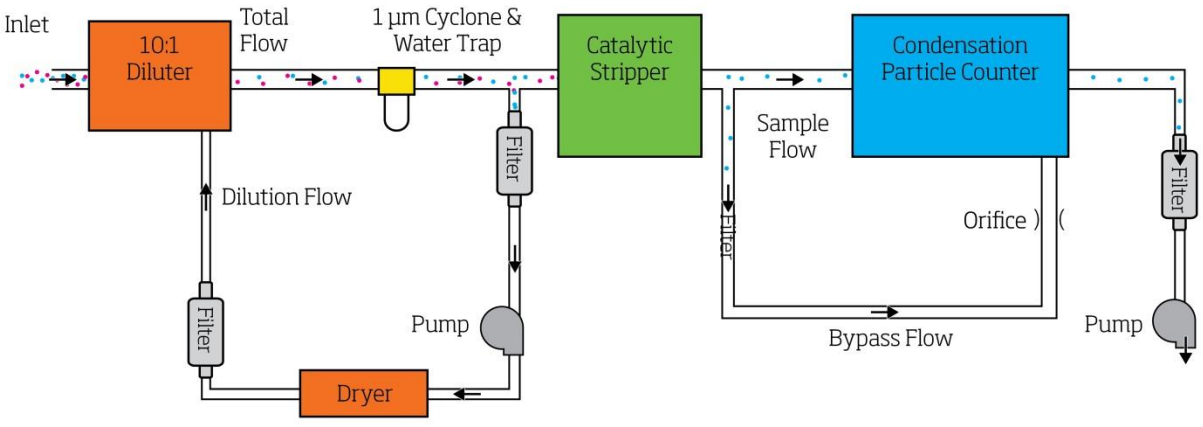

Figure 1: Model 3795 Instrument Schematic

Example Applications

Non-road Mobile Machinery

The NPET is certified by the Swiss institute of metrology (METAS) to test to Swiss Regulation 941.242, which mandates the bi-annual testing of all non-road mobile machinery (NRMM) to ensure that the DPFs are continuing to function throughout the life of the equipment. Figure 2 shows the NPET being used to measure the SPN of a Bobcat loader with diesel oxidation catalyst (DOC) and DPF, and an example of an official SR 941.242 report. At idle, the loader passed the SR 941.242 limit of 2.5×10^5 cm^{-3} with an SPN of 5.06×10^4 cm^{-3}.

Model:	3795	**Manufacturer:**	TSI Inc.
Serial:	379501234	**Last Calibration:**	2015-02-16
Firmware Version:	1.02	**Application Version:**	1.1.0.0
Application Key:	94DC-02B0-9588-C3B3-0D8C-BF52-5E7B-B5C5		

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OFFICIAL MEASUREMENT

Date/Time:	2015-03-18, 16:25:16	**Mean #1 (1/cm³):**	5.05E4
Duration:	00:00:40	**Mean #2 (1/cm³):**	5.06E4
Operator:	TSI	**Mean #3 (1/cm³):**	5.06E4
Machine Make:	Bobcat	**Overall Mean (1/cm³):**	5.06E4
Machine Model:	A770	**Limit (1/cm³):**	2.5E5
Machine Id:	TSIMID1	**Result:**	**PASS**
Engine Id:	TSIEID1		

Ambient Conditions: *14.0 °C, 100.0 kPa, 37 %RH*

SIGNATURE:

Figure 2: NPET measuring exhaust of a Tier 4 Bobcat A770 at idle and corresponding official test report

Stationary Generators

Two configurations of DPFs for stationary generators were tested with NPET to determine the concentration of solid particles passing through the DPF system. Both systems were Level 3 Verified by the California Air Resources Board (ARB), indicating that the DPF designs remove greater than 85% of the particulate mass emitted by the engine. Figure 3 shows NPET measuring downstream of one of the DPFs mounted to a 6.8L John Deere™ PowerTech™ diesel stationary generator. Before testing, the filters were loaded and then regenerated. The tests were performed at engine idle, immediately after regeneration. With no soot layer present immediately after regeneration, this condition was representative of a worst-case particle emission condition for an intact filter. Even in this condition, the systems emitted 3.00×10^3 cm^{-3} and 4.30×10^3 cm^{-3} respectively.

Figure 3: NPET measuring DPF condition of a John Deere 6068TF275 diesel engine stationary generator

Bus Fleets

Since 2010, all new buses in Santiago, Chile have been required to be equipped with DPF. Plans are in place for the entire Transantiago bus fleet to be equipped with DPFs by the end of 2018. Figure 4 shows the NPET being used by the Transport Minister to evaluate the condition of the DPF of a bus at a stop during its regular route during an initial NPET evaluation in April 2015.

Figure 4: The emissions of solid particles from a bus in Santiago, Chile are measured to determine the condition of the DPF

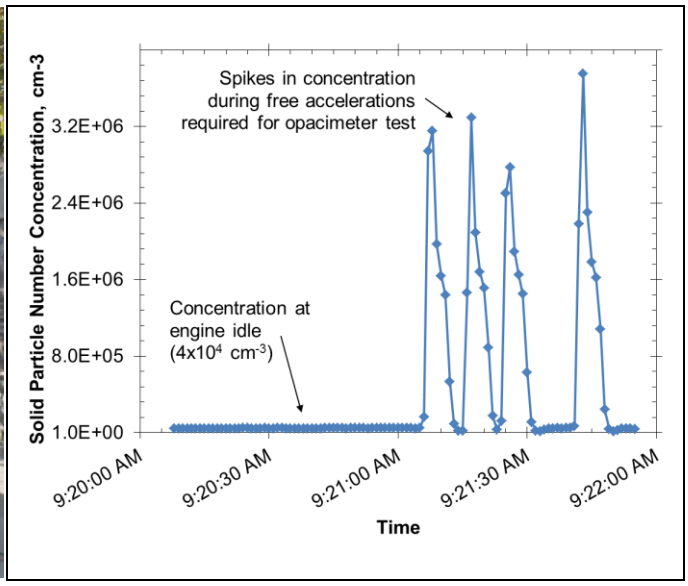

Figure 5: Measurements of solid particle numbers emitted by bus BJFY4 at idle and during free accelerations

During this campaign, five buses were measured on route. Each bus was stopped, and the 40-second official SR 941.242 test was run with the NPET. Following this test, the in-place opacimeter test was run with several free accelerations. During this time, the NPET measured the solid particle number concentration in parallel with the opacimeter. Figure 5 shows the corresponding NPET data collected for bus BJFY74 (shown in Figure 4) during the parallel free acceleration measurement.

From the initial NPET demonstration campaign in Santiago, Chile, all five of the tested buses passed the existing opacity standard of 0.24 m^{-1}, while only three of the five passed the Swiss standard of 2.5 x 10^5 cm^{-3} (see Table 1). Furthermore, bus #5 failed the NPET test but passed the opacity test with nearly identical opacity readings to the buses that passed the NPET test. This shows the higher sensitivity of the NPET when compared to an opacimeter. This sensitivity stands to lower emissions, and improve air quality, where the NPET is employed.

Table 1: Results from initial NPET demonstration campaign in Santiago, Chile

	NPET Measurement		Opacimeter Measurement		
Bus	Idle SPN [#/cm^3]	Certification status (<2.5E5 [#/cm^3])	Opacity [m^{-1}] 1st free acceleration	Opacity [m^{-1}] 2nd free acceleration	Certification status (<0.24 [m^{-1}])
1	1.72E+04	PASS	0.01	0.02	PASS
2	7.66E+03	PASS	0.01	0.02	PASS
3	1.69E+06	FAIL	0.07	0.07	PASS
4	4.15E+04	PASS	0.01	0.02	PASS
5	4.93E+05	FAIL	0.02	0.03	PASS

Conclusion

The NPET is being used to measure the concentration of solid particles in exhaust of engines in a variety of applications ranging from inspection and maintenance to fleet profiling and emissions research. Using an internationally recognized measurement principle, the NPET allows for the measurement of emission levels lower than are detectable by existing field measurement technology.

For more information about the TSI Model 3795 Nanoparticle Emission Tester visit:
www.tsi.com/NPET

TSI Incorporated – Visit our website **www.tsi.com** for more information.

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