HOW TO DETERMINE DPF EFFICIENCY IN THE FIELD

APPLICATION NOTE NPET-003 (US)

Can DPF Efficiency be Measured Accurately in the Field?

The High Concentration Nanoparticle Emission Tester is a robust tool, designed for field measurements of solid particle number concentration in emissions directly from the tailpipe, pre- and post-particle filters.

Capable of measuring up to 10^8 #/cm^3, it is suitable for making upstream measurements. This capability, combined with its field-friendly design, means that it can be used for calculating DPF efficiencies in the field, under real-use conditions.

Accuracy of HC-NPET: Comparing to PMP-Compliant Techniques

While HC-NPET is not a PMP-compliant instrument, it has the same 50% counting efficiency at 23 nm, and counts only solid particles.

Figure 1 shows the agreement between the HC-NPET and the PMP-compliant system (TSI's 379020A-30 Rotating Disk Diluter with Thermal Conditioner plus TSI's 3790A Engine Exhaust CPC) when measuring DPF efficiency on a light duty diesel engine (GM 2.0L) under three different conditions: low idle, high idle, and medium speed/load.

The overall agreement across all three engine conditions is very good (slope = 1.00, R^2 = 0.945). This strong agreement between the HC-NPET and a PMP-compliant technique suggests strongly that the HC-NPET is a powerful tool for making DPF efficiency measurements in the field.

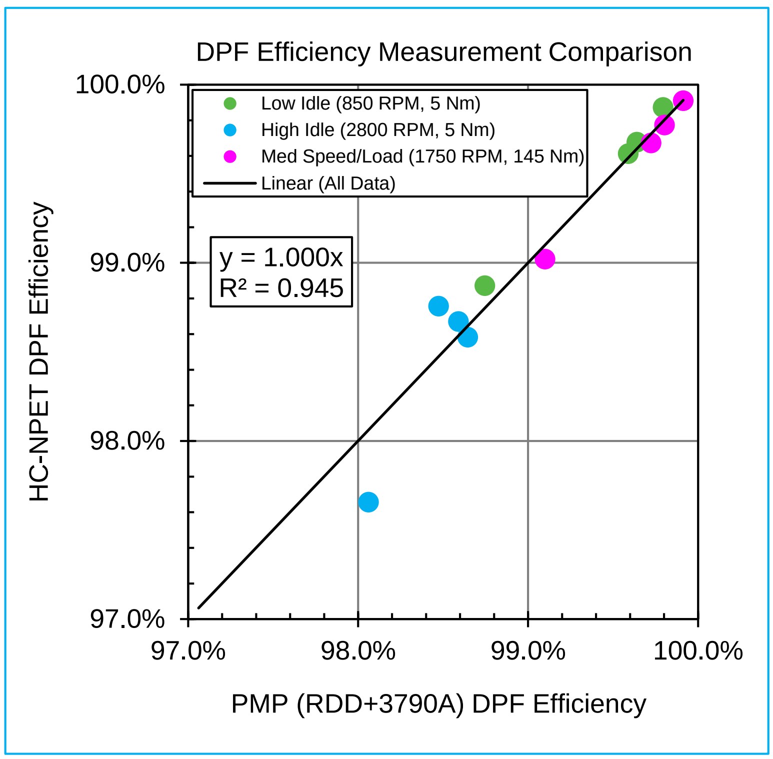

Figure 1: DPF efficiency comparison between HC-NPET and a PMP-compliant system.

How do I Sample at Overpressure, Upstream of the DPF?

The largest technical challenge when measuring DPF efficiency is sampling upstream, at overpressure conditions. The instructions below will guide you on how to construct a sampling port that will enable the HC-NPET to measure in an overpressure environment.

Instructions

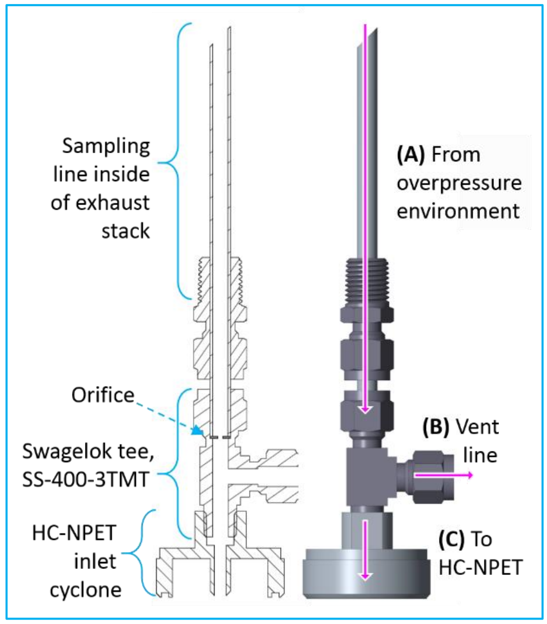

Figure 2: Sampling design to allow the HC-NPET to sample safely from an overpressure environment.

1. **Choose and install** one of two plumbing designs for controlling excess flow:

   a. Install a bung on the exhaust stack, and install a bored-through Swagelok® fitting into the bung. Use a Swagelok® nut to install a sampling line (ex. ¼” stainless steel) into the bored-through fitting, keeping the sampling line length as short as possible. At the end of the sampling line, install a Swagelok® run NPT tee (SS-400-3TMT).

   b. Weld a sampling line (ex. ¼” stainless steel tubing) to a hole created in the exhaust stack; keep sampling line length to a minimum. At the end of the sampling line, install a Swagelok® run NPT tee (SS-400-3TMT).

   Regardless of whether you select (a) or (b) above:

   – The straight-through leg of the tee will have 1/8” NPT threading; this will go to the NPET; see Figure 2. Instructions on how to attach the NPET are covered in a later section, “How do I Collect and Analyze my Data?”

   – The 90 degree leg of the tee will have ¼” Swagelok® threading, and will serve as the vent; see Figure 2. Instructions on how to plumb the vent are covered in steps 3–4.

2. **Choose the right orifice** for your application. An orifice is necessary to control the excess flow out of the tee, and should be installed in the overpressure leg of your sampling tee (in Figure 2, A). When choosing an orifice it is important to know the maximum overpressure you expect to encounter, and the temperature of the overpressure environment. Table 1 provides guidance on how to select an orifice. For further guidance in this regard, contact TSI.

3. **Plumb the excess (vent) line**. Starting at the 90 degree leg of the tee (in Figure 2, B), plumb the following components in order. Components may be omitted at your discretion.

   – *A cooling line*, slanting downward from the tee, which allows the sample to cool. Avoid low spots where condensation could collect. Stainless steel is recommended;

   – *A condensate trap*, which will cool the sample and collect condensate;

   – *Filter*, to trap particles, and

   – *Check valve*, which will prevent momentary drops in exhaust stack pressure (due to drive cycle details) from inducing flow into the sampling tee. The selected check valve should have a cracking pressure < 4 kPa.

4. **Decide where the excess flow should go**. Plumb the check valve outlet to either:

   a. Downstream of the after-treatment device, or

   b. A house ventilation system (or allow the check valve to vent to the workspace).

Table 1: Orifice selection guidance. Use the expected minimum pressure of your overpressure environment, as well as temperature, to select an orifice. A smaller orifice reduce the excess venting of exhaust gas, but requires a higher minimum exhaust gas pressure to maintain the NPET sampling flow. Refer to Figure 2.

Orifice size	**Inches**	**0.020**		**0.026**		**0.040**	
Temperature at (A)	°C	25	350	25	350	25	350
Flow rate at (B), assuming: • 0.7 SLPM at (C), and • 301.3 kPa (abs.) at (A)	SLPM	5.7	3.7	10.2	6.8	25	17.1
Minimum pressure at (A) required to maintain positive overflow at (B)	kPa (abs.)	103.9	106.7	102.3	103.5	101.5	101.7

How do I Collect and Analyze my Data?

1. **Get ready.** Warm up the HC-NPET instrument and establish communication between the instrument and the HC-NPET software. Further details are available in the HC-NPET Quick Start Guide.

2. **Connect your HC-NPET to your equipment**.
   a. Upstream: the straight-through leg of the sampling tee (in Figure 2, C) can screw directly into the 1/8” NPT female thread in the HC-NPET’s inlet cyclone using Teflon® tape. The inlet cyclone is located between the flexible hose and the sampling probe. To access the inlet cyclone, simply unscrew the sampling probe.

   b. Downstream: this step is quite simple—just sample from the tailpipe! Use the sampling probe that is normally used with the NPET, stick it into the tailpipe, and hold it in place with the black clamp. If you will make sequential measurements with only one HC-NPET instrument, keep the upstream sampling port capped when making downstream measurements.

3. **Define your test cycle**. Using a defined test cycle can provide consistency from test to test, and thus instills confidence in the quality of the data gathered. Figure 3a is a screenshot of the software showing the test cycle parameters that are specified during test cycle configuration.

4. **Make measurements**. After the test cycle is defined, click the forward arrow button. During the measurement, the mean concentrations for each of the measurement periods are displayed as soon as they are available; see Figure 3b.

5. **Calculate DPF efficiency**. The efficiency of a DPF can be easily calculated by dividing the ‘after’ mean value by the ‘before’ mean value, and subtracting that from 1. In Figure 3c-d, the downstream and upstream values are circled in pink and cyan, respectively. So in this example, the calculation looks like this:

$$DPF\ efficiency = 1 - \frac{downstream}{upstream} = 1 - \frac{11{,}166}{502{,}467} = 0.9778 = 98\%$$

Want More Detailed Data?

Calculating DPF efficiency can be easily done using the “Test Cycle” mode, as described above. To observe the dynamics within your data and conduct a more detailed analysis, use the “Measure” mode. When collecting data in this mode, all collected data are plotted, and the full dataset can be exported. Further instructions in this regard are found in the HC-NPET manual.

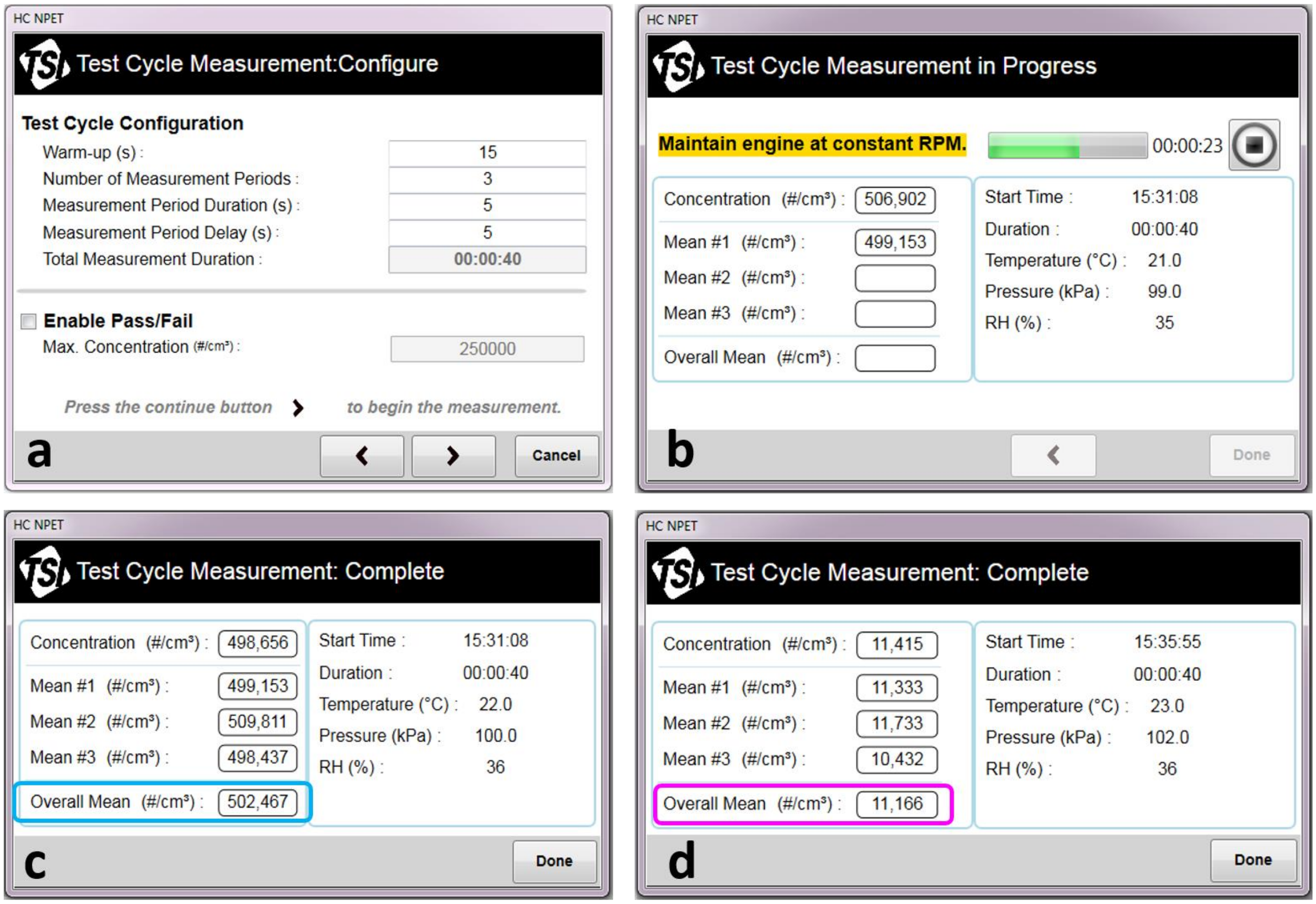

Figure 3: Screenshots of HC-NPET software during a test cycle measurement. The test cycle is defined (a), run (b), and results are shown for typical upstream and downstream conditions (c and d, respectively).

References

1. HC-NPET manual (P/N 6012021).
2. Calibration of TSI's High-Concentration Nanoparticle Emissions Tester (NPET-002).
3. TSI Nanoparticle Emission Tester (NPET) Model 3795 In-Use Application Examples (NPET-001).

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