Field Measurement
Technical Aspects of the First Generation PN Field Instrument

TSI Nanoparticle Emission Tester Model 3795

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UNDERSTANDING, ACCELERATED

Overview

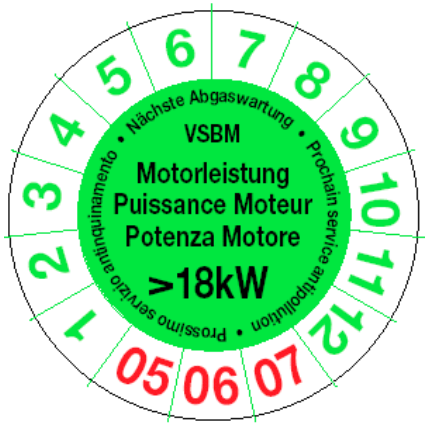
+ Purpose & background
+ TSI Model 3795 –technical overview
+ Prototype conformance tests at METAS
  - SR 941.242 requirements and NPET specifications
+ First field measurement results

Purpose & Background

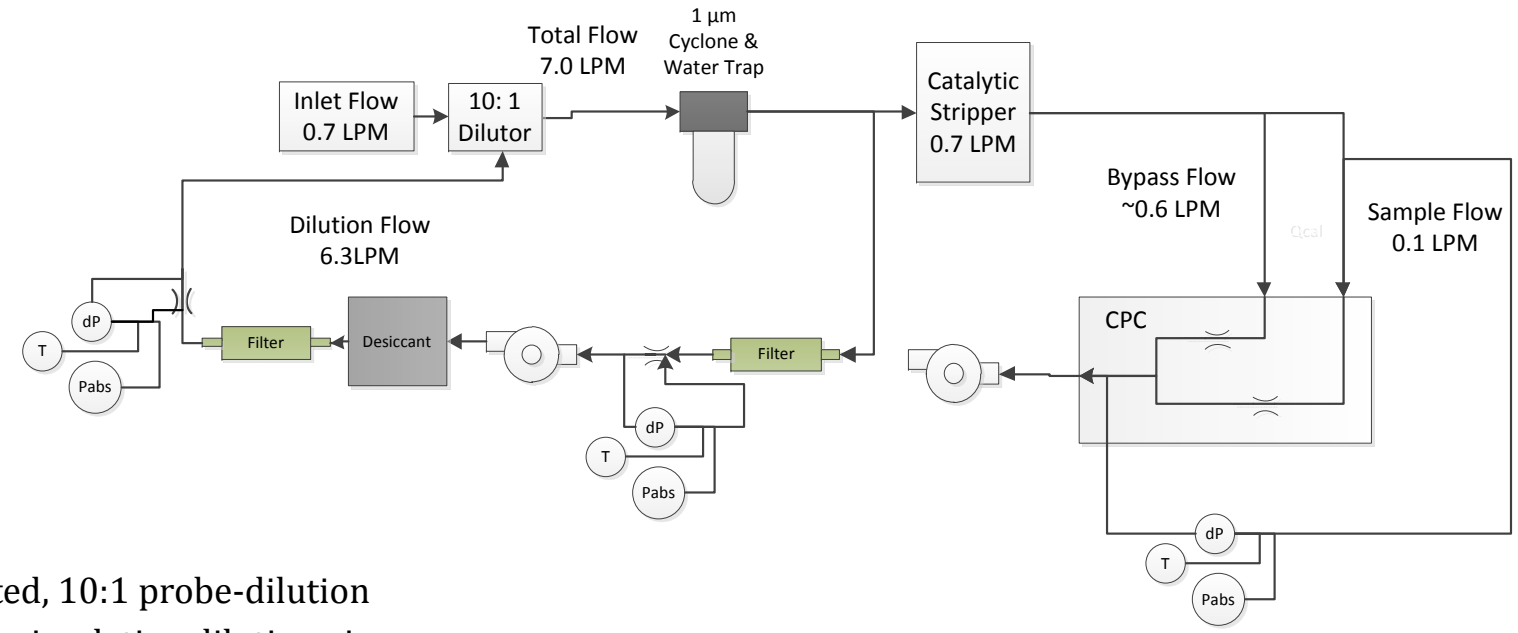
+ Swiss ordinance requires diesel particulate filter (DPF) for non-road mobile machinery (NRMM)
  - Test the efficacy of installing DPF
+ Bi-annual test to certify machinery for use
  - Determine if DPF is good or is damaged (e.g. cracked) and needs to be replaced

Swiss Regulation SR 941.242

+ Effective Jan. 1, 2013 (latest changes effective March 1, 2014), Switzerland amended the regulation requiring periodic PN emissions testing and compliance for diesel engines
  - Amended the *"Ordinance of the Federal Department of Justice and Police on Exhaust Gas Analyzers"*
+ Candidate instruments must be tested & approved by Federal Office of Metrology (METAS)
  - i.e. "Conformity of Compliance"
+ Measurement procedure refinement is underway, BAFU workshop in April 2014
+ Enforcement expected to start ~January 2015

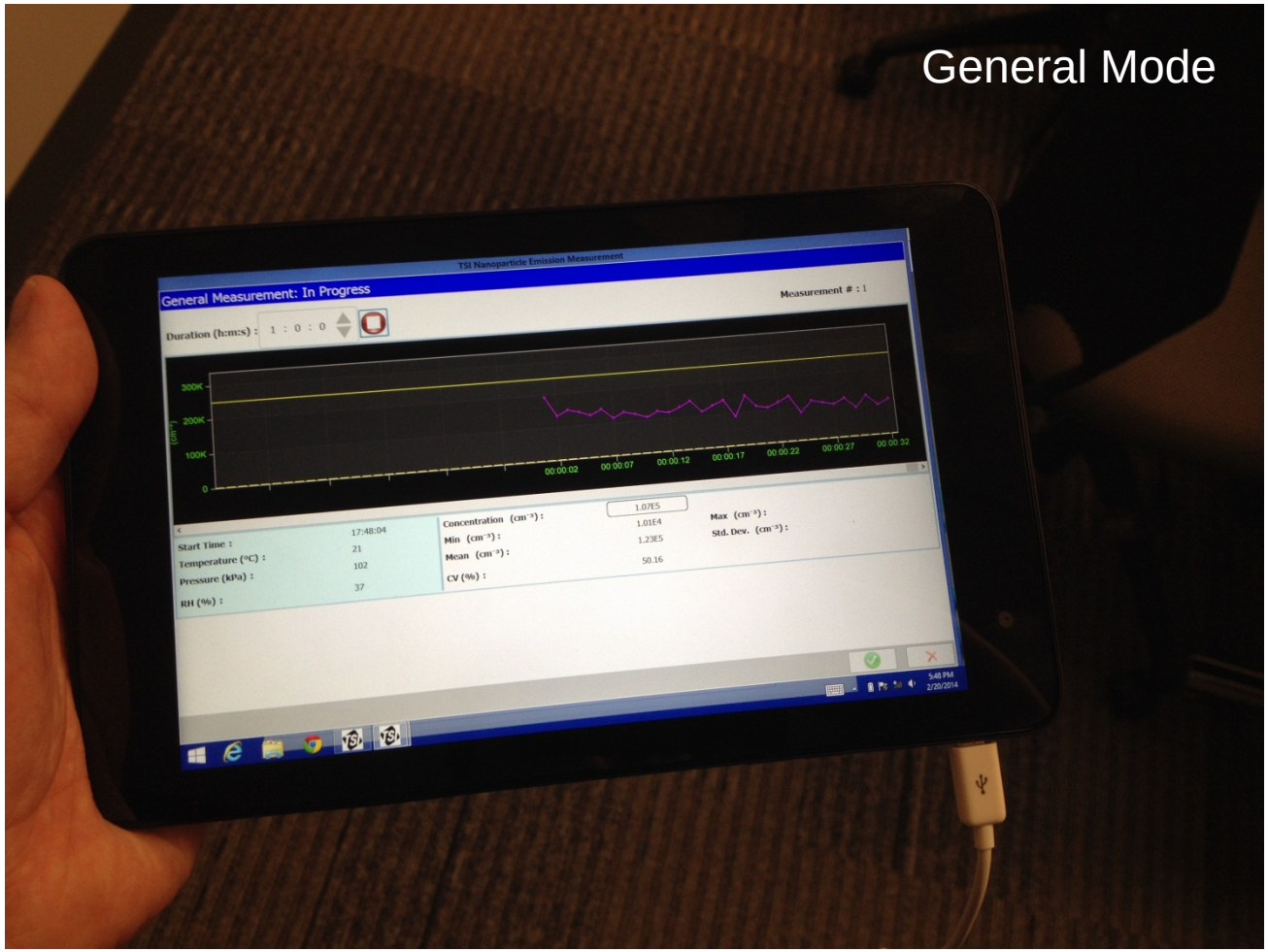


Block Diagram



- Integrated, 10:1 probe-dilution
- Dried, recirculating dilution air
- 1 micron cyclone with water trap
- Catalytic stripper
- Isopropyl-based condensation particle counter
- Powered e.g. by a Windows 8 Pro tablet and software application
- General purpose & official Swiss test mode

General & Official Operation Modes



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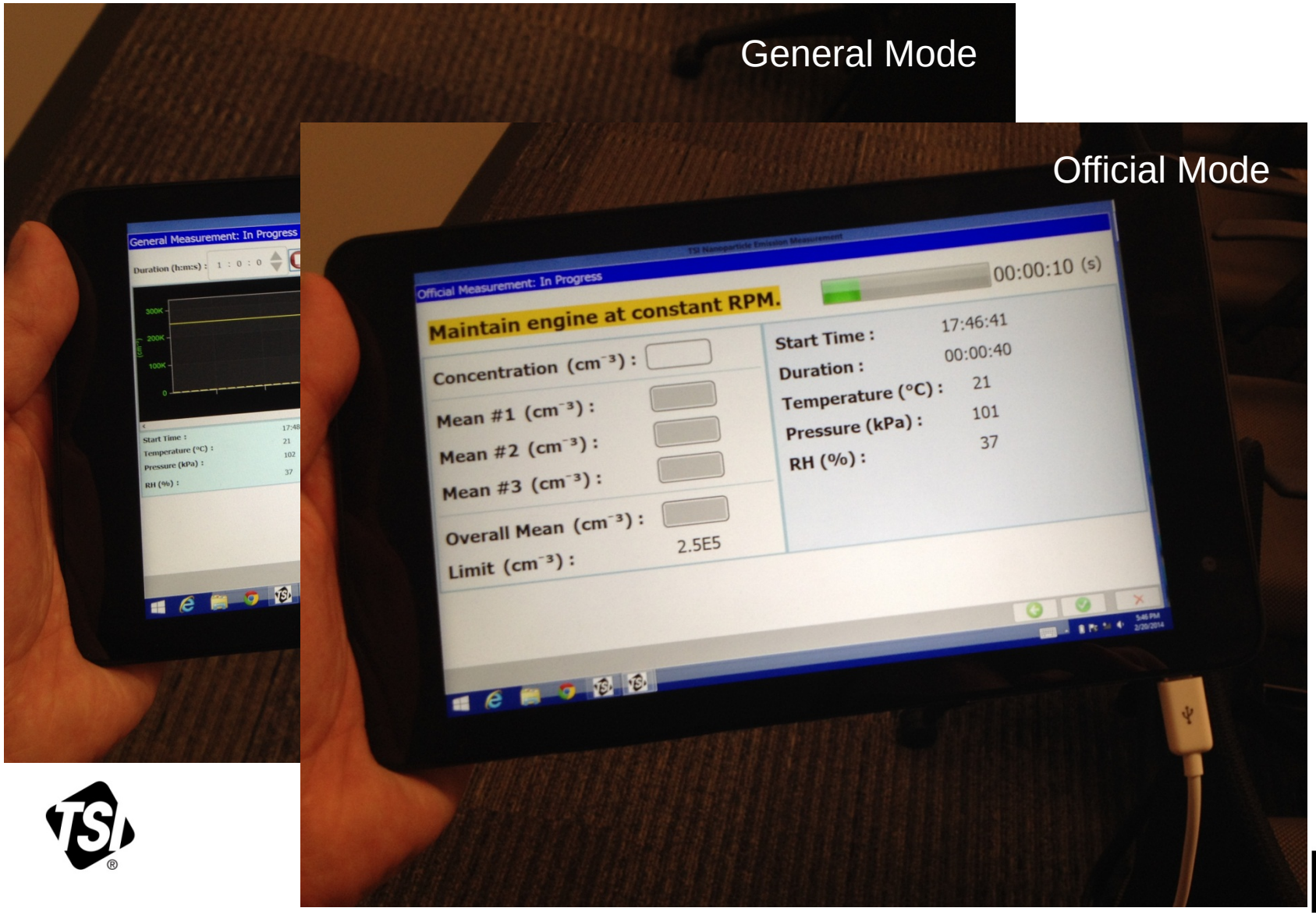
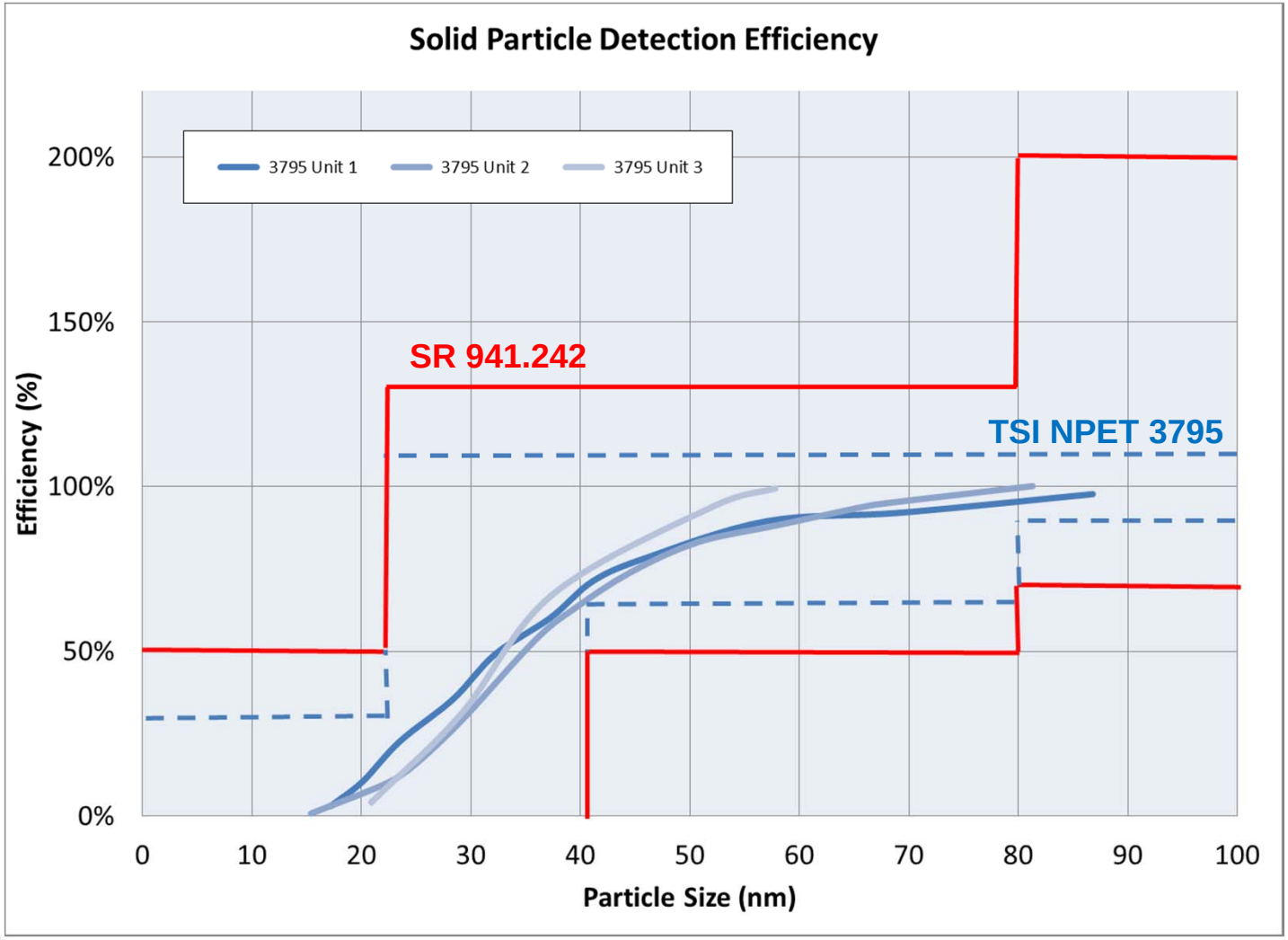
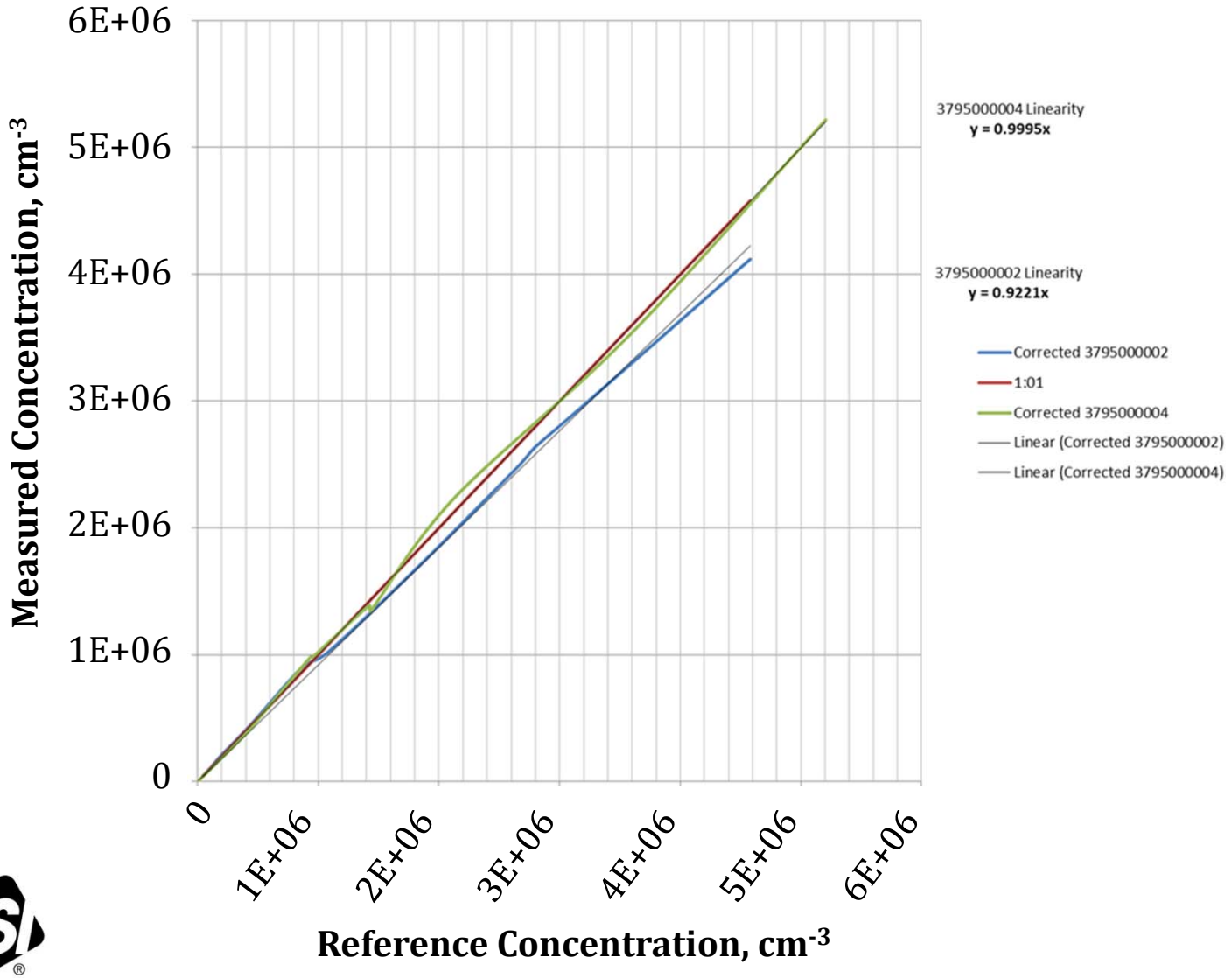


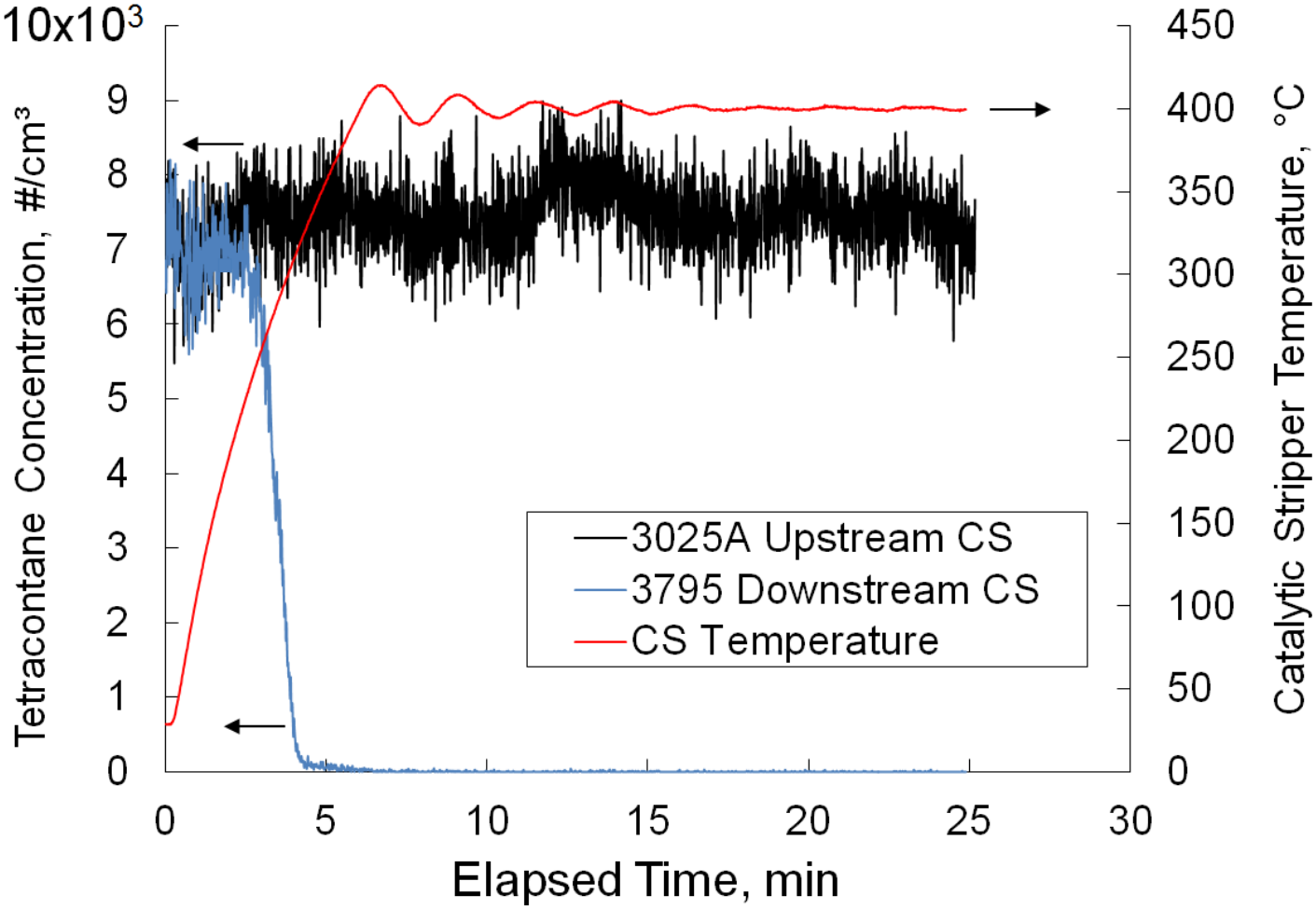
Solid Particle Detection Efficiency



Concentration Range and Linearity



Volatile Particle Removal



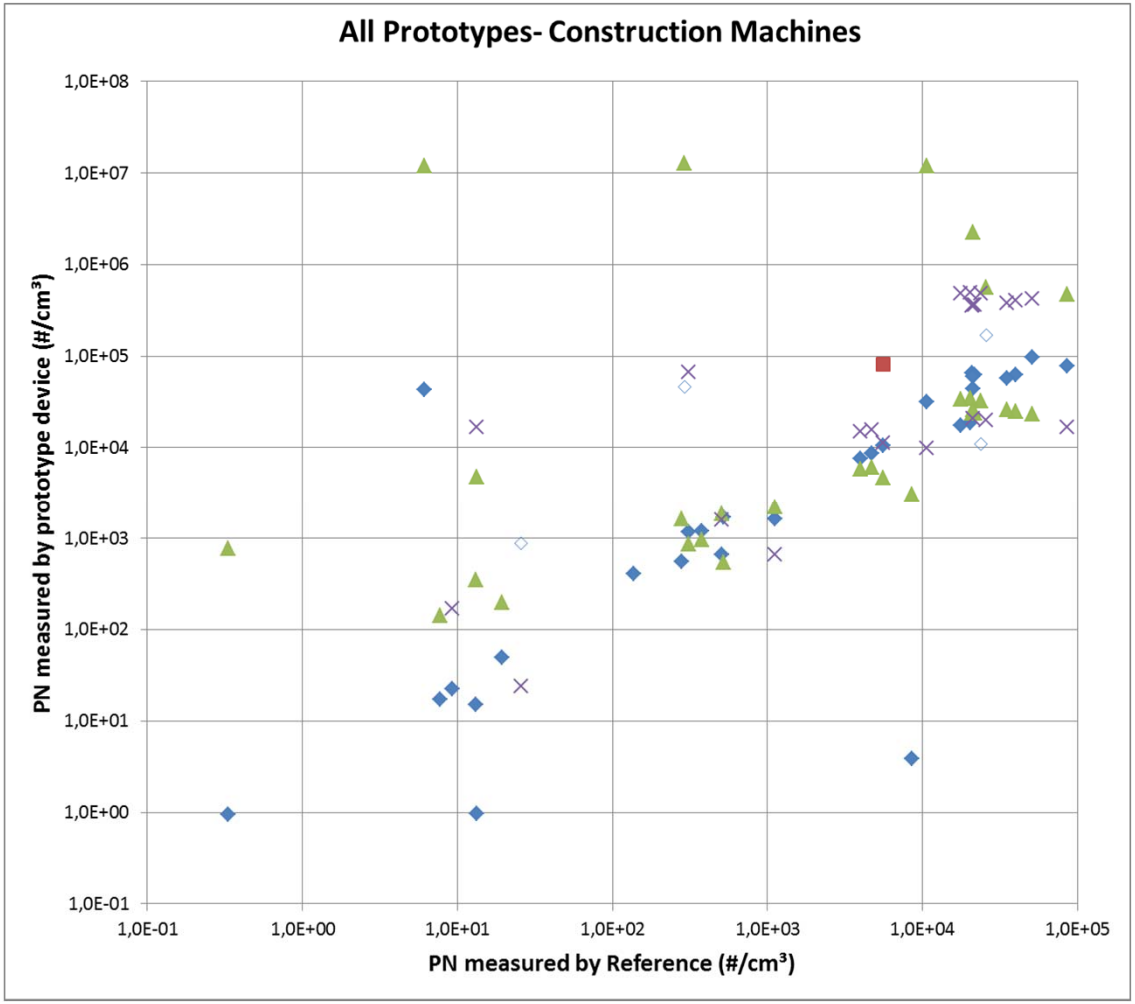
Prototype Conformity Tests at METAS

Test	Requirement	NPET Prototype
Efficiency 23 nm CAST 23 nm, GSD = 1.48	$[E = \frac{C_{Dut}}{C_{CPC}}] < 0.5$	E = 0.47
Efficiency 41 nm CAST 41 nm, GSD = 1.57	$0.5 < [E = \frac{C_{Dut}}{C_{CPC}}]$	E = 0.84
Efficiency 80 nm CAST 83 nm, GSD = 1.54	$0.7 < [E = \frac{C_{Dut}}{C_{CPC}}] < 1.3$	E = 1.13
Efficiency 200 nm CAST 192 nm, GSD = 1.56	$[E = \frac{C_{Dut}}{C_{CPC}}] < 2.0$	E = 1.23
Endurance 6 h; CAST 80 nm w/o VPR, C ≈ 5e6 cm^{-3}	$0.7 < [E = \frac{C_{Dut}(t)}{C_{CPC}(t)}] < 1.3$	t = 0 h: E = 1.05 t = 6 h: E = 0.99
Official measurement CAST 80 nm, C_1 ≈ 1e5 cm^{-3}, C_2 ≈ 5e5 cm^{-3}	$0.7 < [E = \frac{C_{Dut}}{C_{CPC}}] < 1.3$	C_1 = 1.27e5 cm^{-3}: E = 1.075 C_2 = 5.57e5 cm^{-3}: E = 1.055
Tetracontane removal 30 nm, C_{Tc} = 10^5 cm^{-3}	$[E = \frac{C_{Dut}}{C_{Tc}}] < 0.05$	$\frac{1.14}{7.2e5} = 0.0000016$

Prototype Conformity Tests at METAS
continued

Test	Requirement	NPET Prototype
Ambient pressure dependence $P \approx P_{atm} \pm 10$ kPa	$0.7 < [R = \frac{C_{Dut}(P)/C_{CPC}(P)}{C_{Dut}(P_{amb})/C_{CPC}(P_{amb})}] < 1.3$	P_1 = 86 kPa: R = 1.04 P_{amb}= 95 kPa: R = 1.00 P_2 = 104 kPa: R = 0.85
Amb. low temp. dependence $T_1=T_{amb}$, T_2=-8°C	$0.7 < [R = \frac{C_{Dut}(T)/C_{CPC}(T)}{C_{Dut}(T_{amb})/C_{CPC}(T_{amb})}] < 1.3$	T_{amb}= 24 °C: R = 1.00 T_2 = -8 °C: R = 0.84
Amb. high temp. dependence $T_1=T_{amb}$, T_2=38°C	$0.7 < [R = \frac{C_{Dut}(T)/C_{CPC}(T)}{C_{Dut}(T_{amb})/C_{CPC}(T_{amb})}] < 1.3$	T_{amb}= 24 °C: R = 1.00 T_2 = 38 °C: R = 0.73
Step response $T_{10\%-90\%}$	$T_{10\%-90\%} < 5$ s	$T_{10\%-90\%} < 4$ s
Time Lag $T_{0\%-70\%}$	$T_{0\%-70\%} < 10$ s	$T_{0\%-70\%} < 7$ s

Results of First Field Tests by BAFU
Construction Machines



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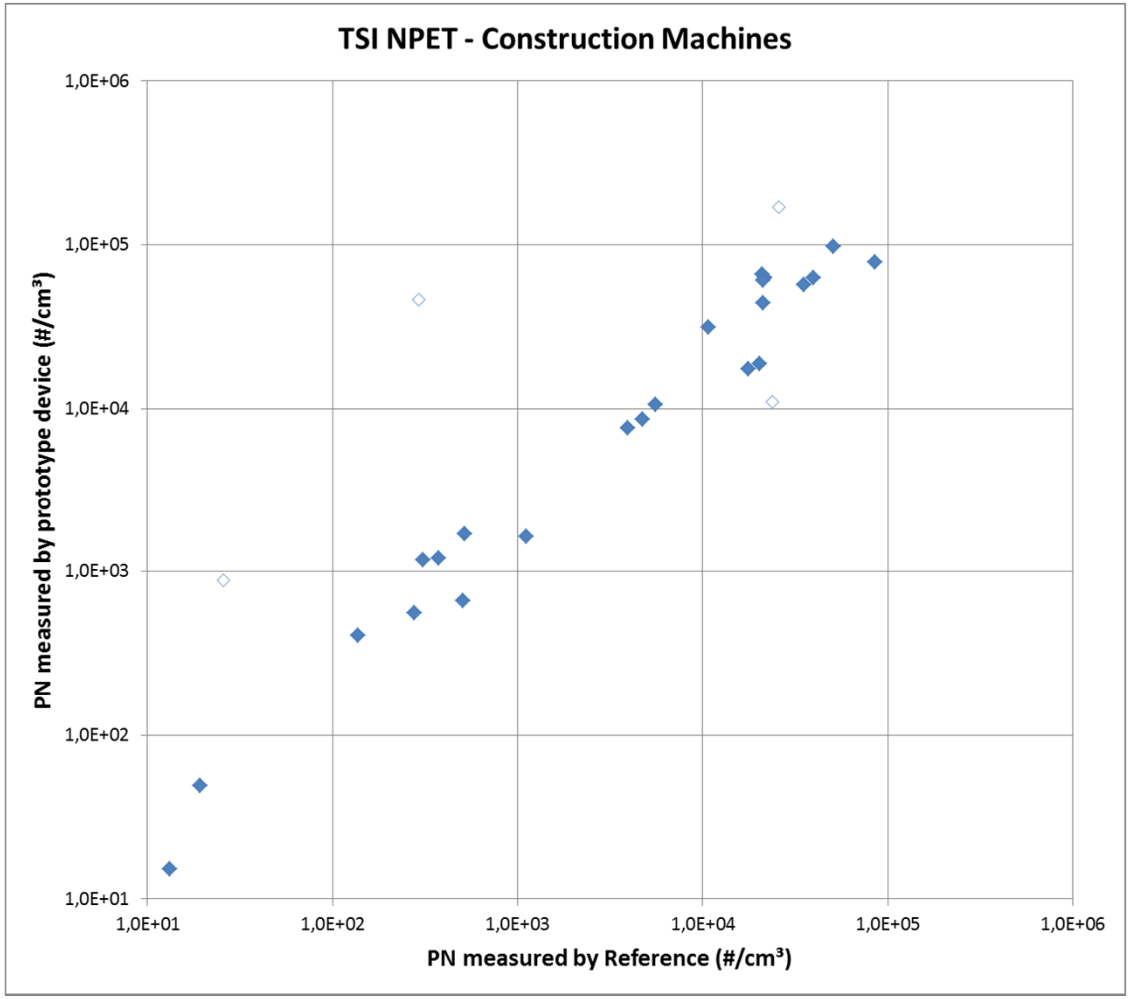

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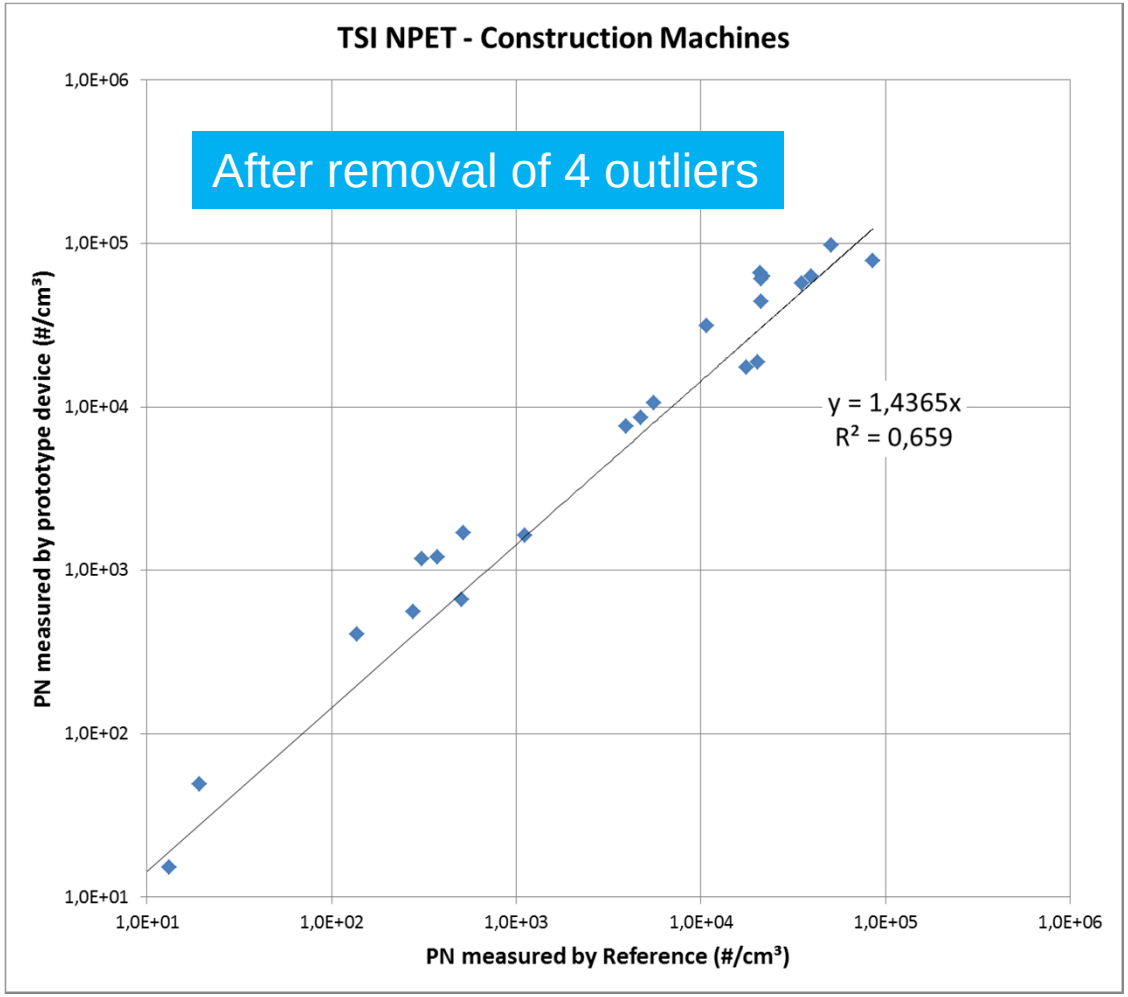
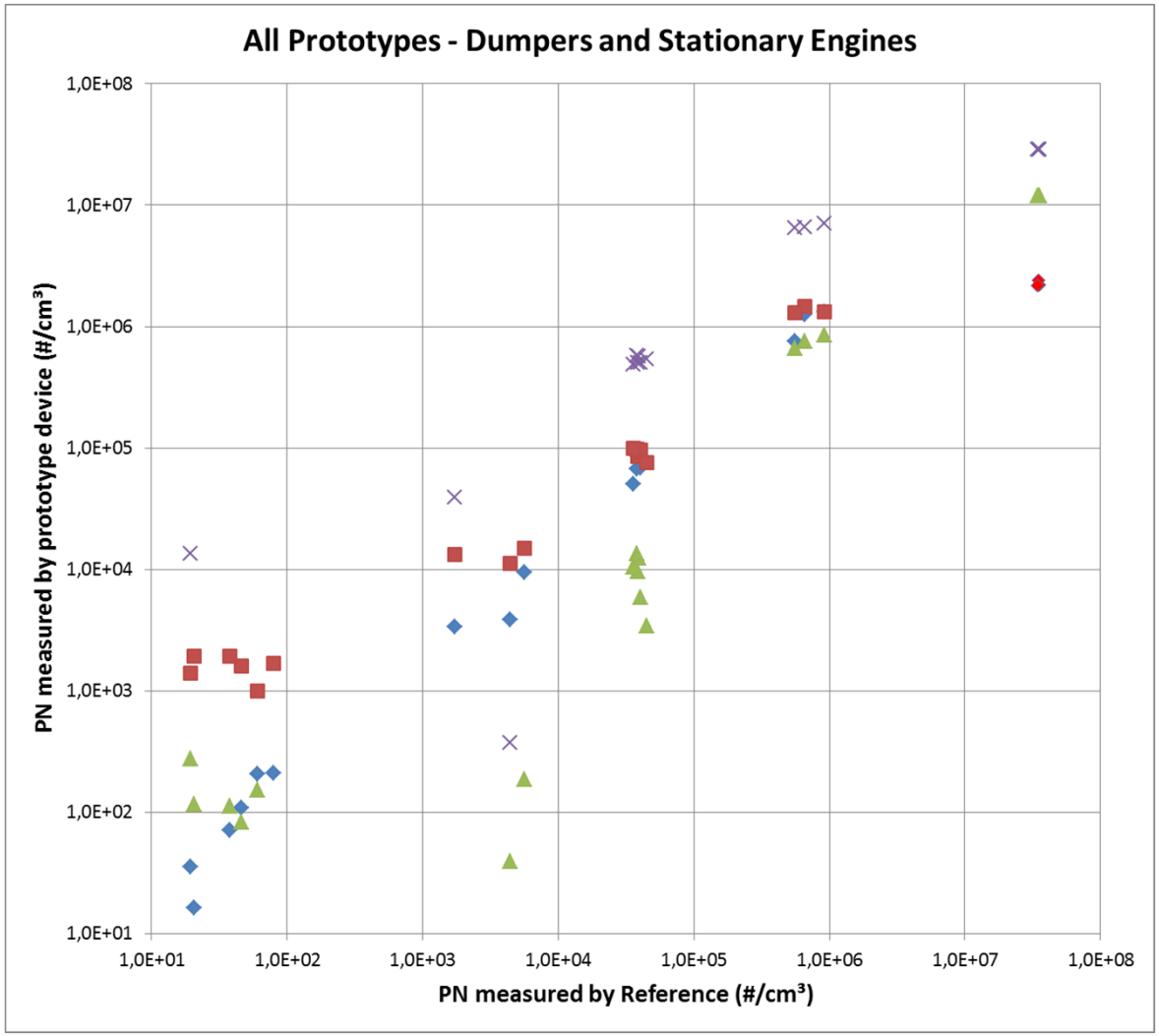


Results of First Field Tests by BAFU
Dumpers & Stationary Engines



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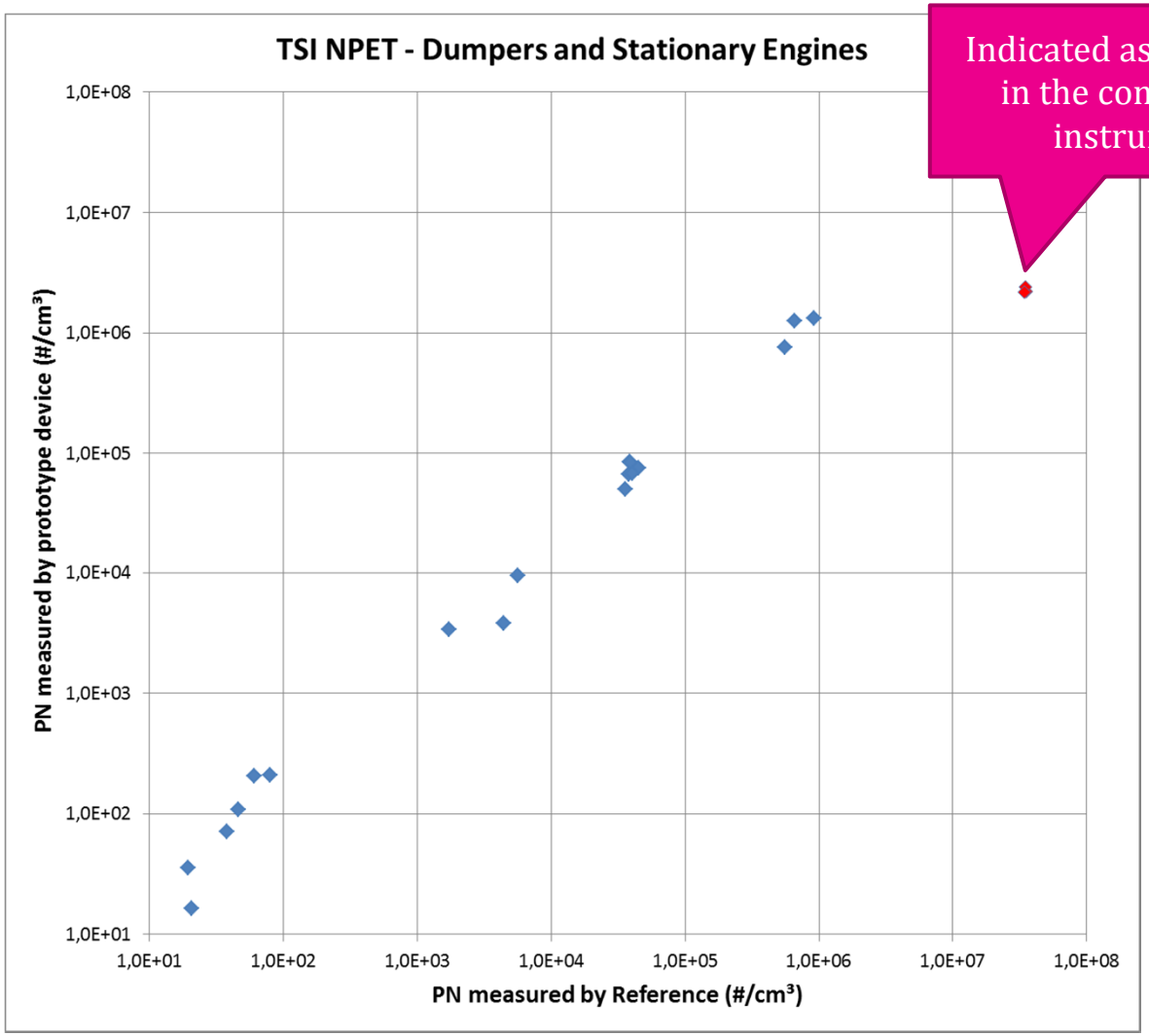

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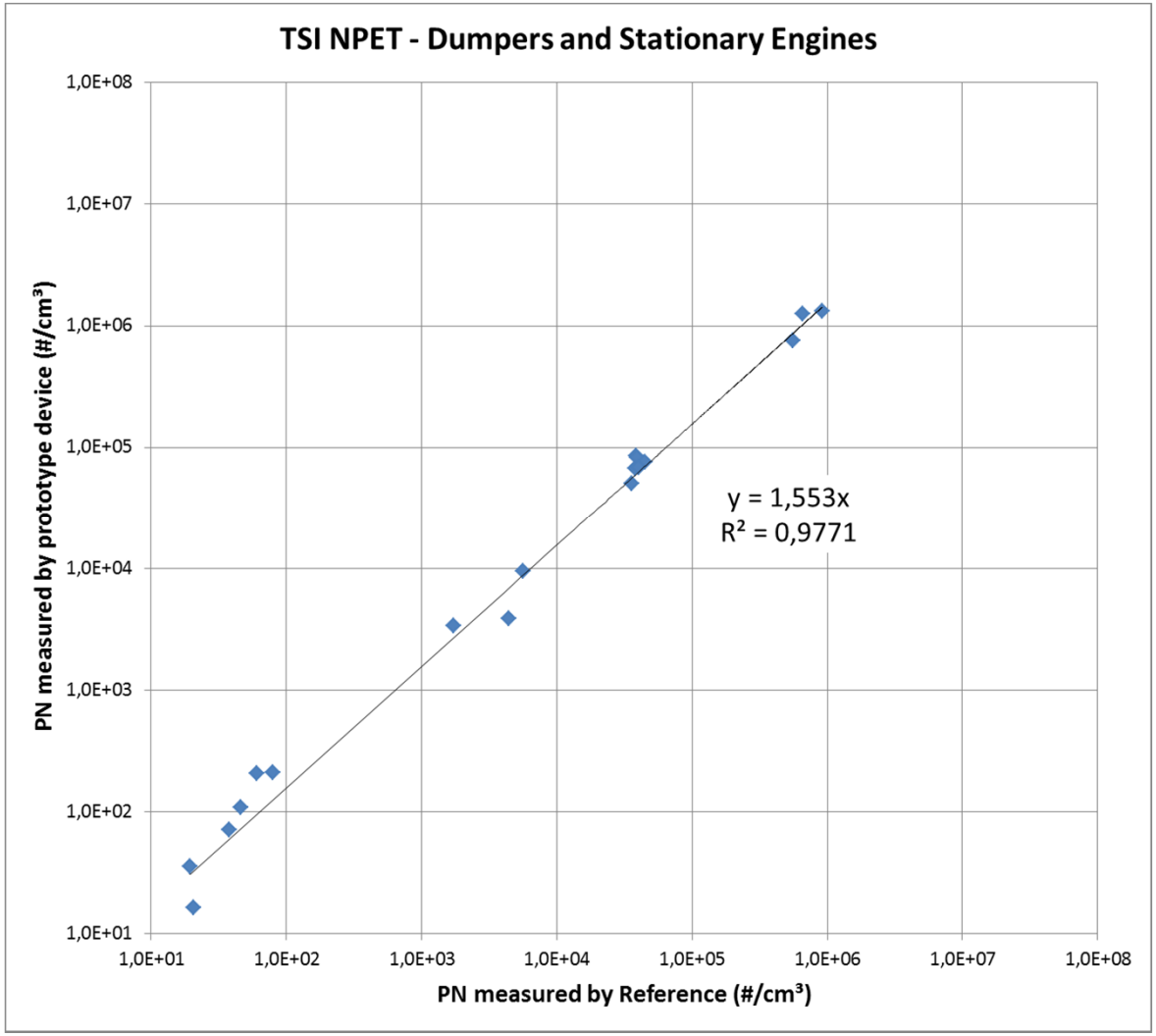
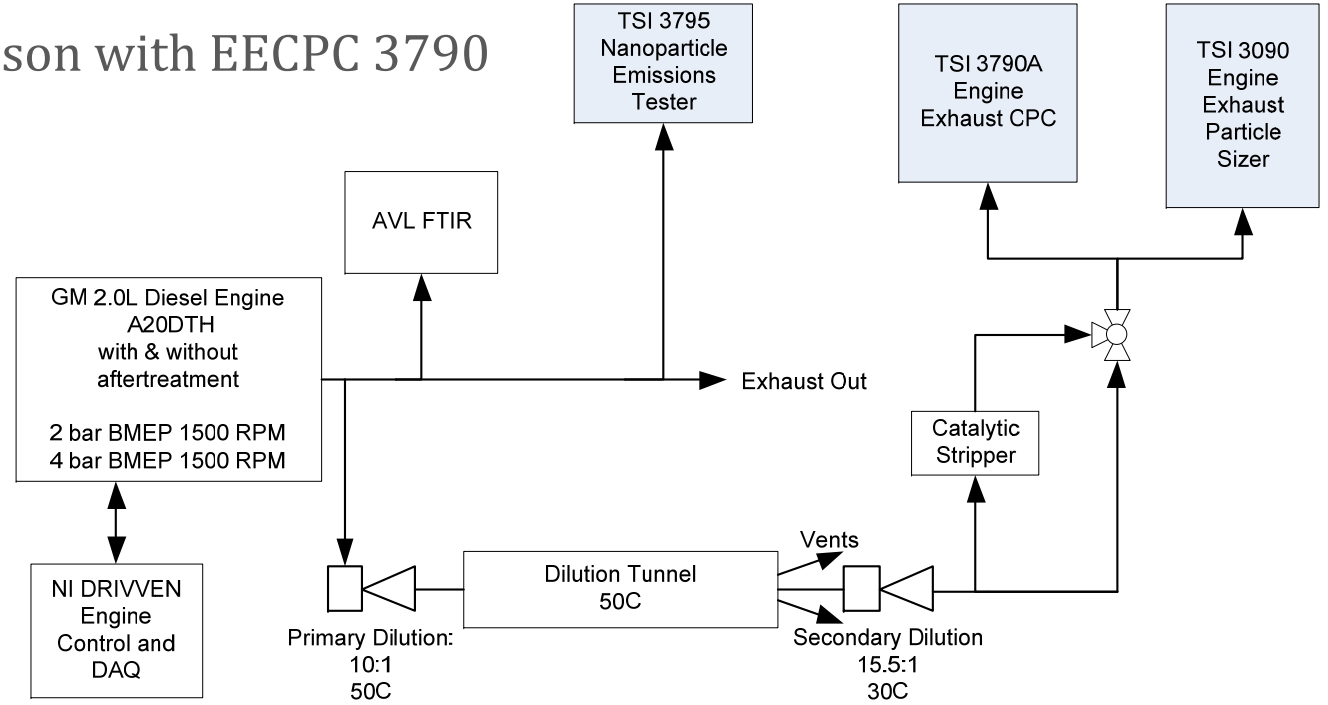


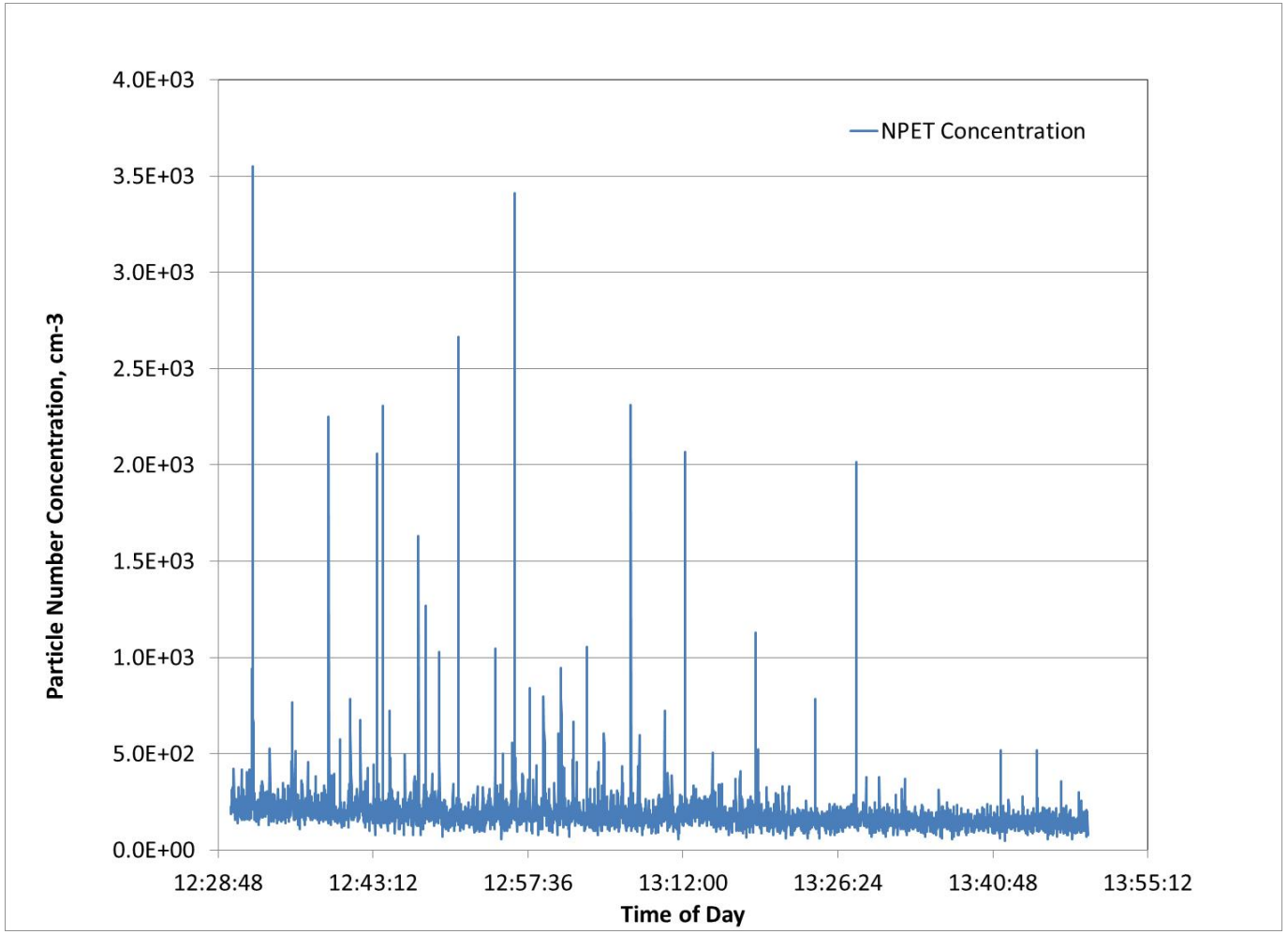
Measurement Examples

+ Data were taken at U of Minnesota (Dave Kittelson & Will Northrup)
  - Engine held at a simulated high idle
  - Regeneration event
  - Comparison with EEPS
  - Comparison with EECPC 3790

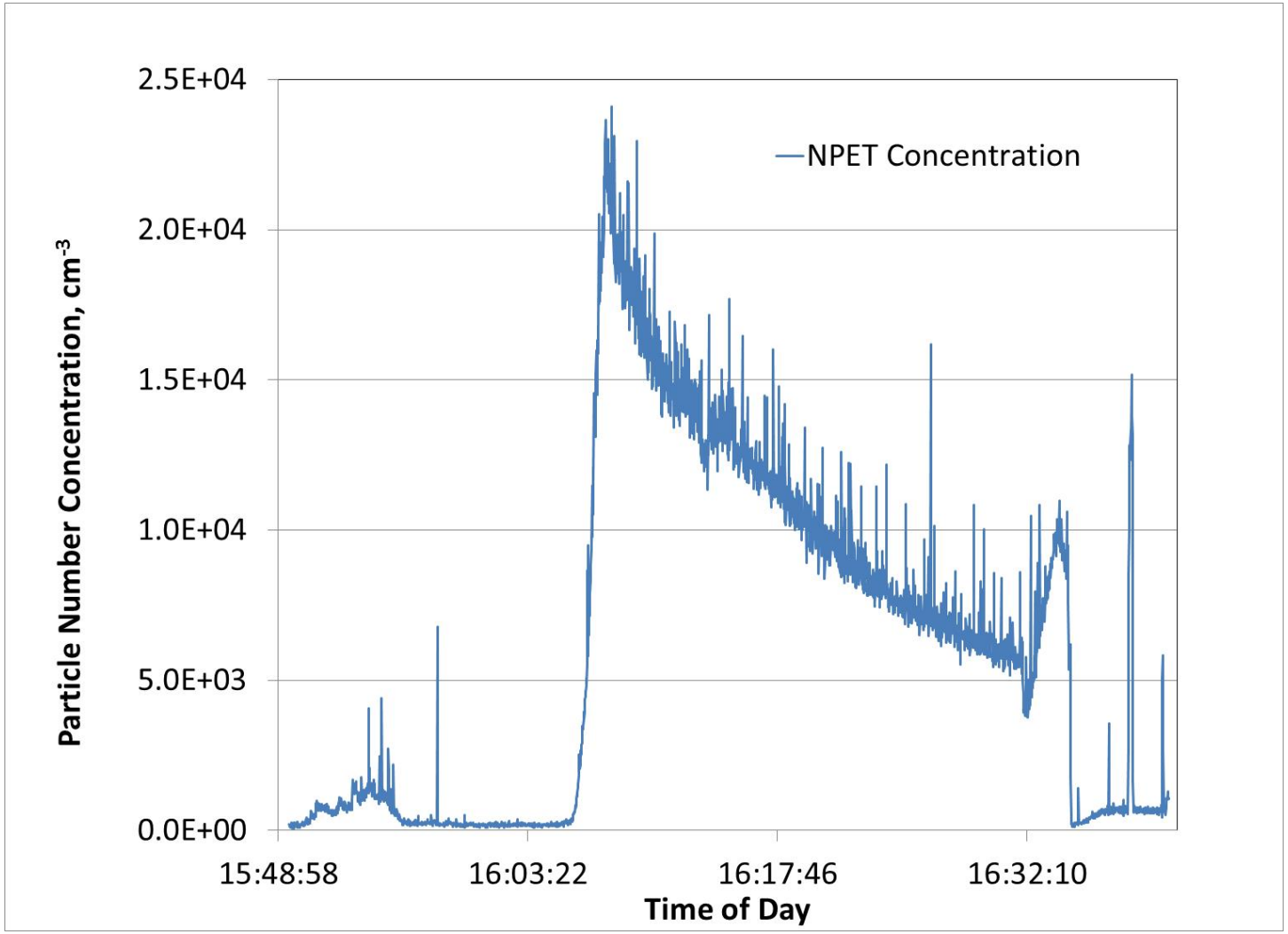


Simulated High Idle

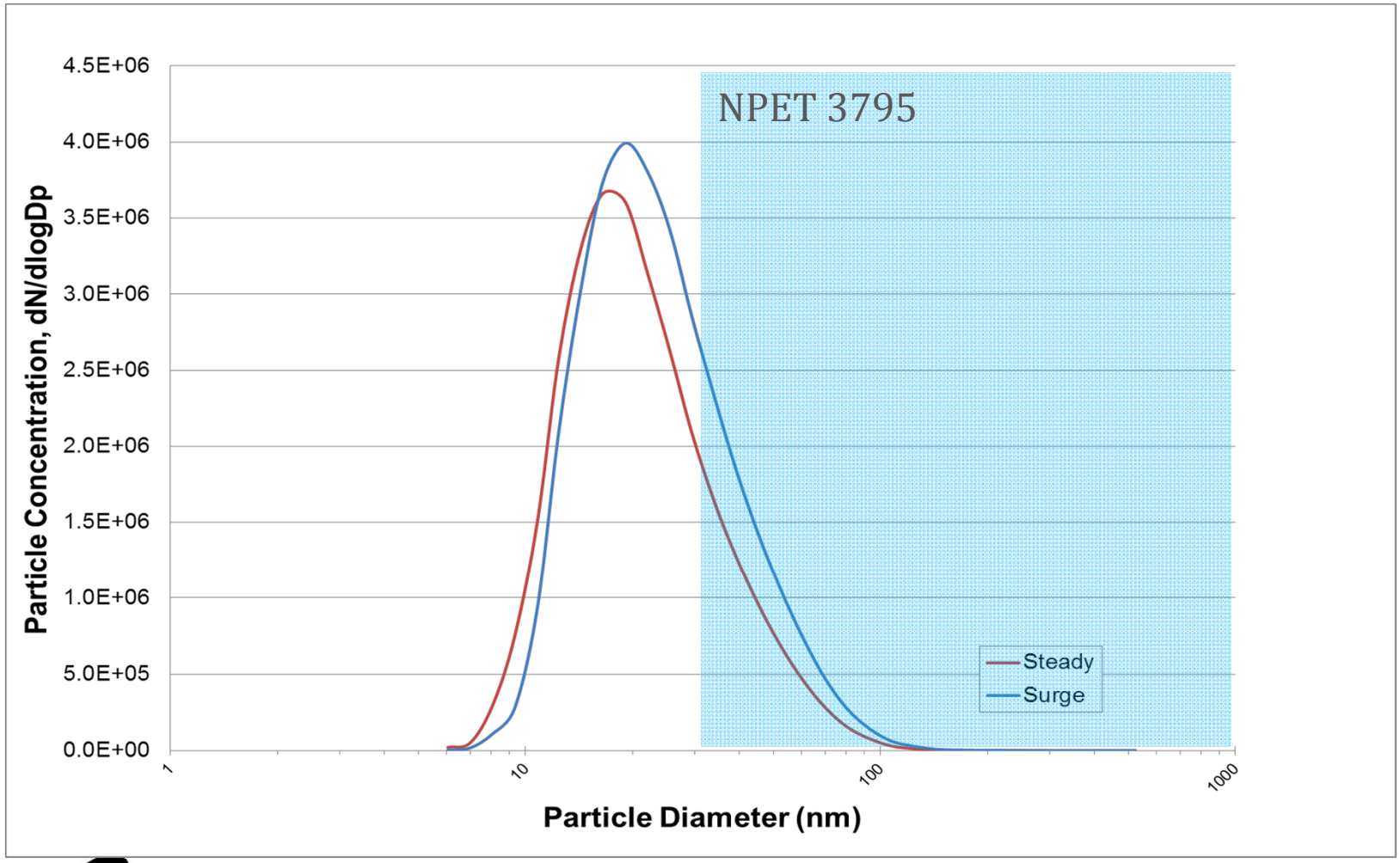
Mean Concentration = 193 cm^{-3}



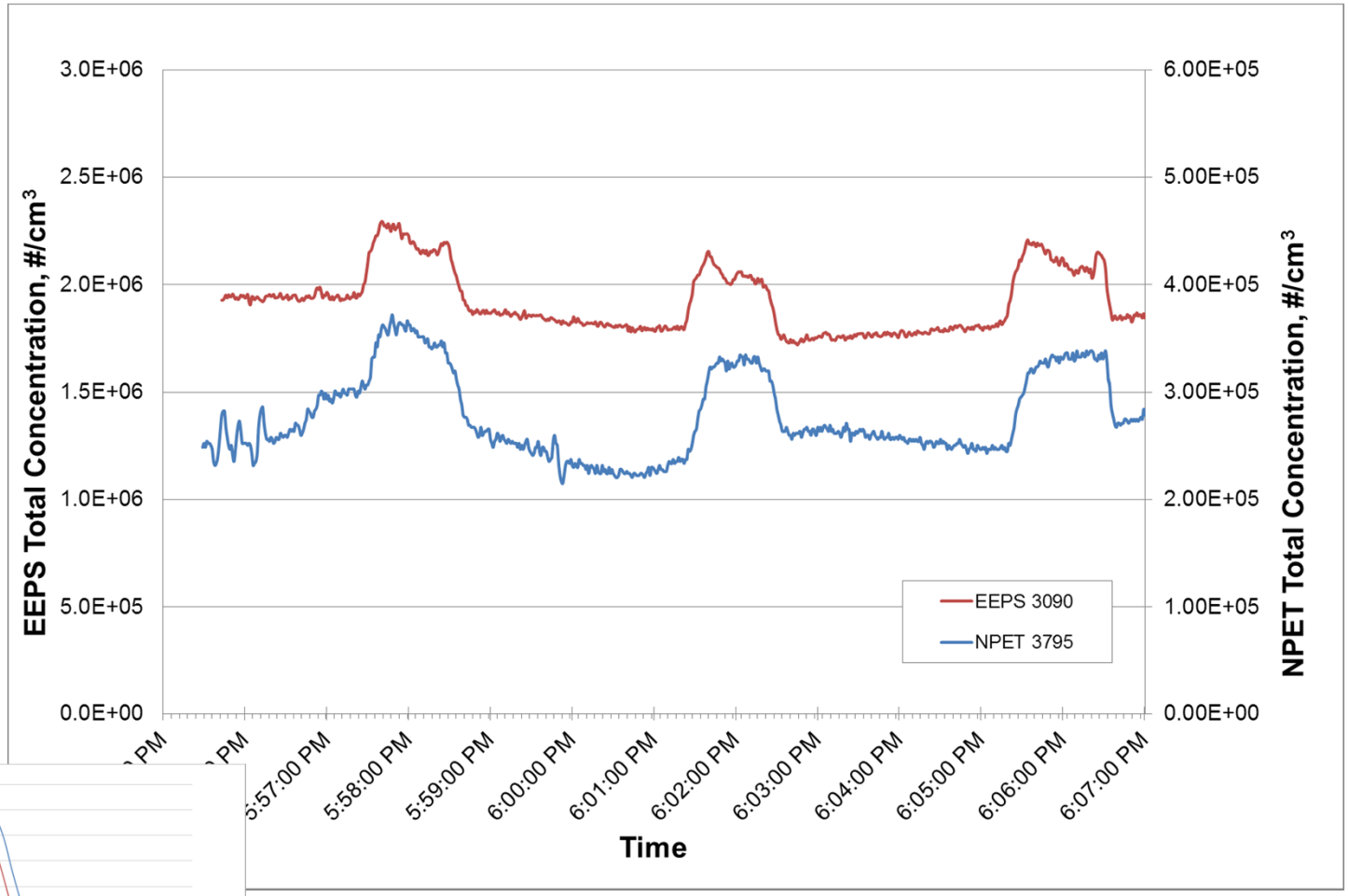
Regeneration Event

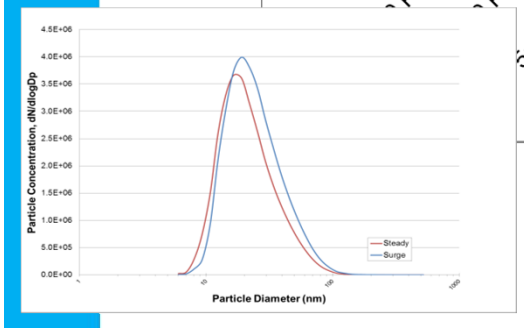


Comparison with EEPS

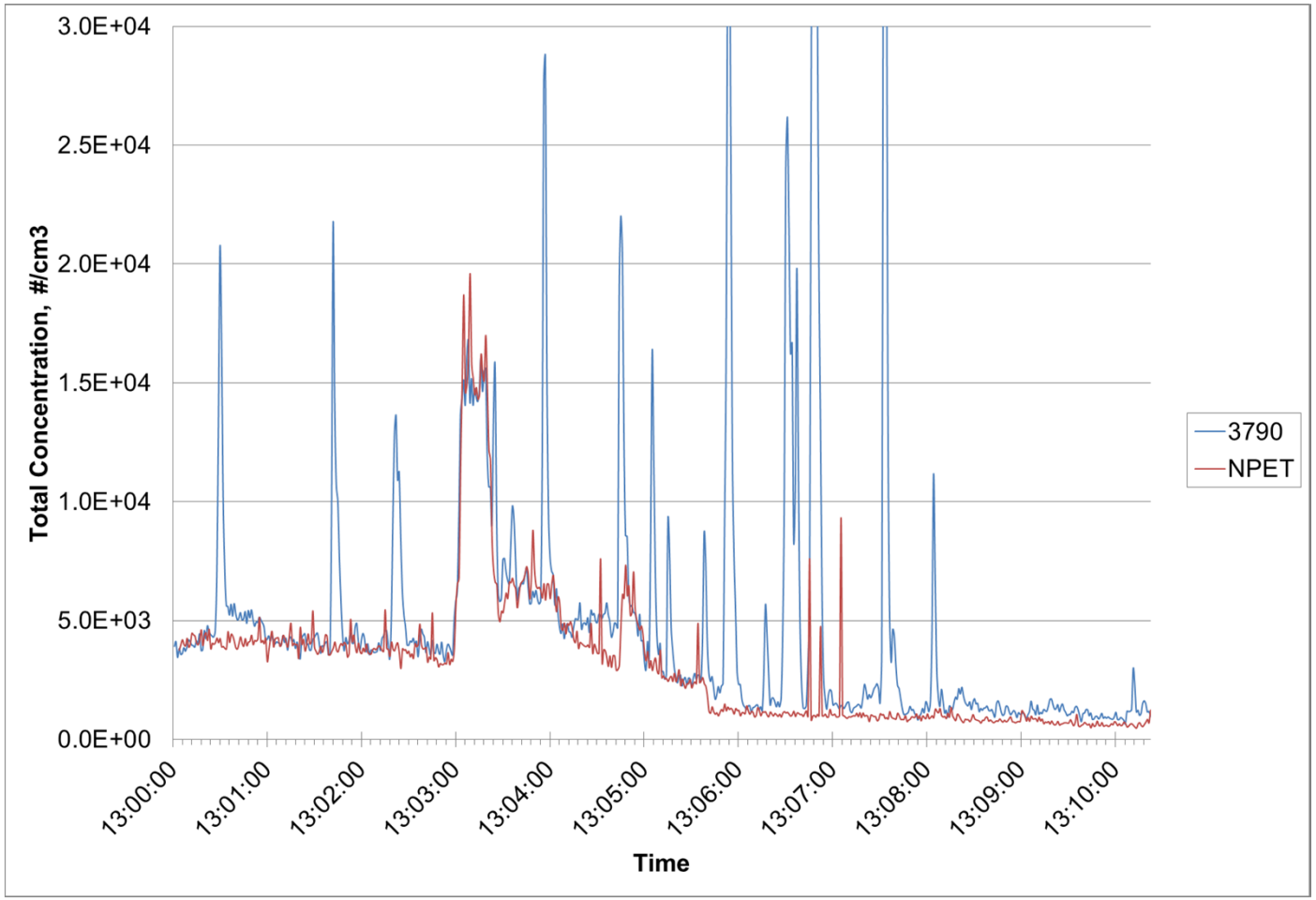


Comparison with EEPS





Engine Startup, DPF Out



Conclusions

+ Robust, portable instrument for field measurements
+ Conformity to Swiss SR 941.242
+ Good linearity of response between ~ 200 and 5e6 particles per cm^3 in official measurement mode
+ Distribution, customer service and support in Switzerland by Deltatech in Hunzenschwil
+ We are ready to accept your orders

Thank you very much!

Questions ?

For additional information:

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www.tsi.com

www.deltatech.ch

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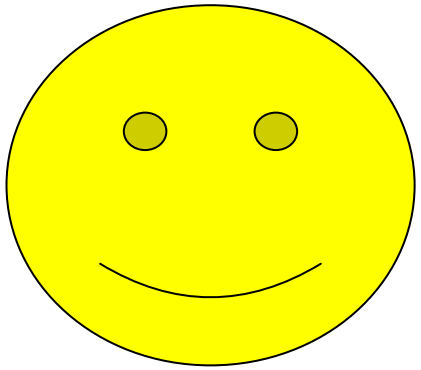

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