MEDICION DE NANOPARTICULAS CON TECNOLOGIA "CPC" APLICADA A INSPECCION DE VEHICULOS

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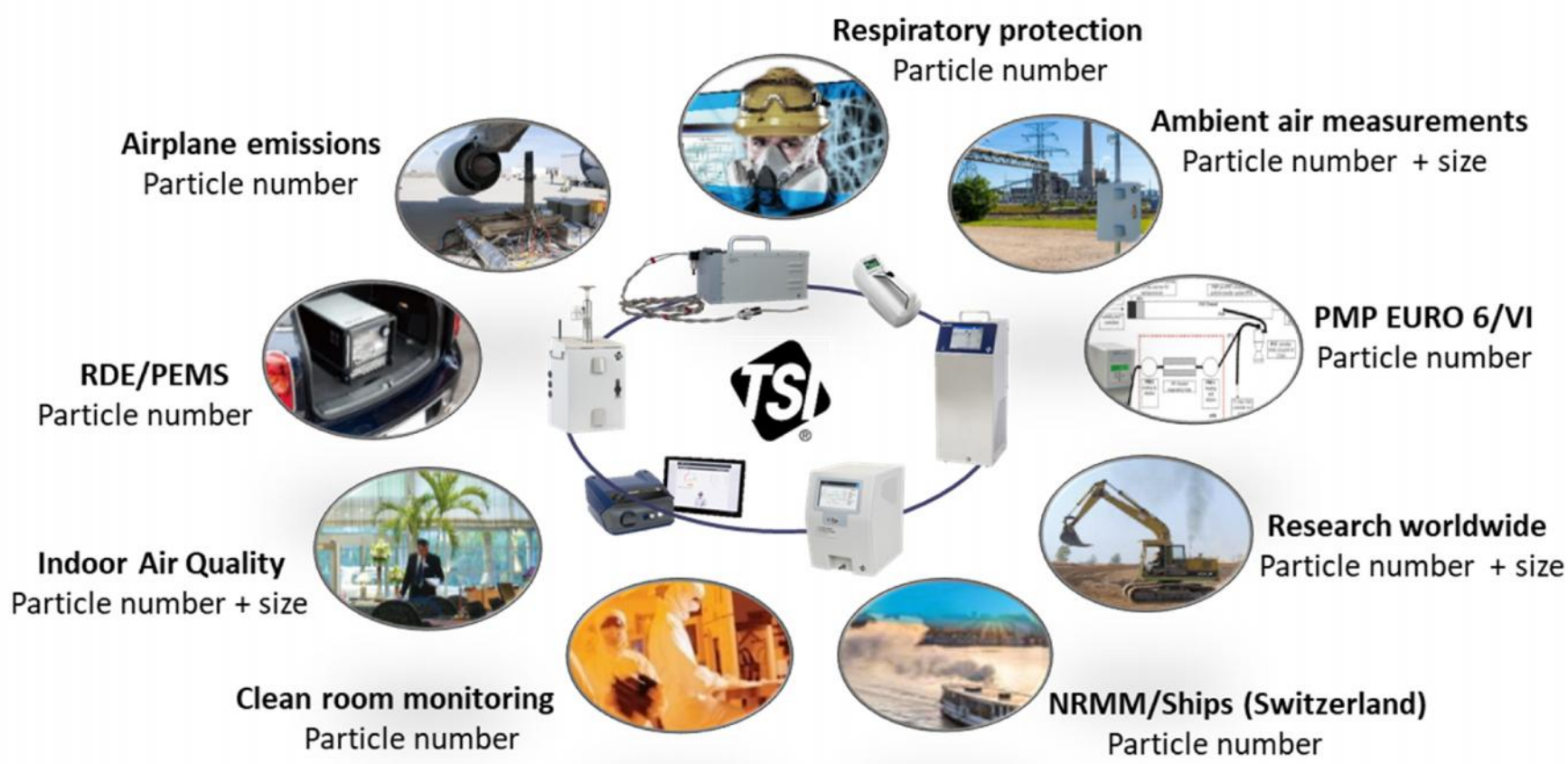
UNDERSTANDING, ACCELERATED

TSI, líder en Medición de Aerosoles

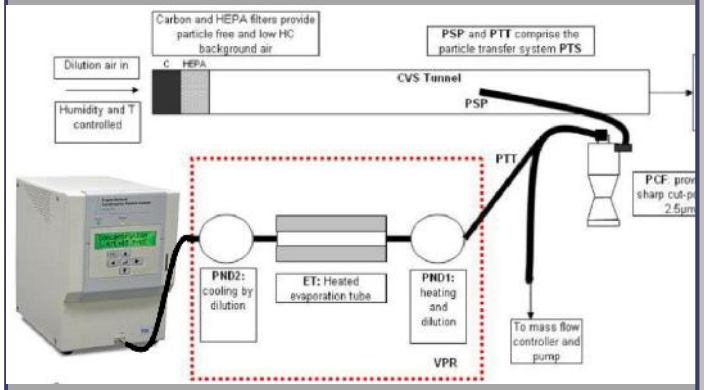


- Founded in 1961 by students of the University of Minnesota
- Since 1967 production of submicron particle sizers
- TSI has been building CPCs (3020 CPCs since 1979) and DCs (3070 EAD since 1974) for more than 40 years.
- Today, more than 100 people work on particle measuring instruments every day

Medición de Partículas en emisiones de escape de motores con CPCs

+ Used **>20 years** in engine emission testing

Type approval testing
EURO 5b/6 – Reg. 83/49



PMP Methodology

Real Driving Emissions
PN-PEMS

PEMs 4Nano

Source: www.horiba.com

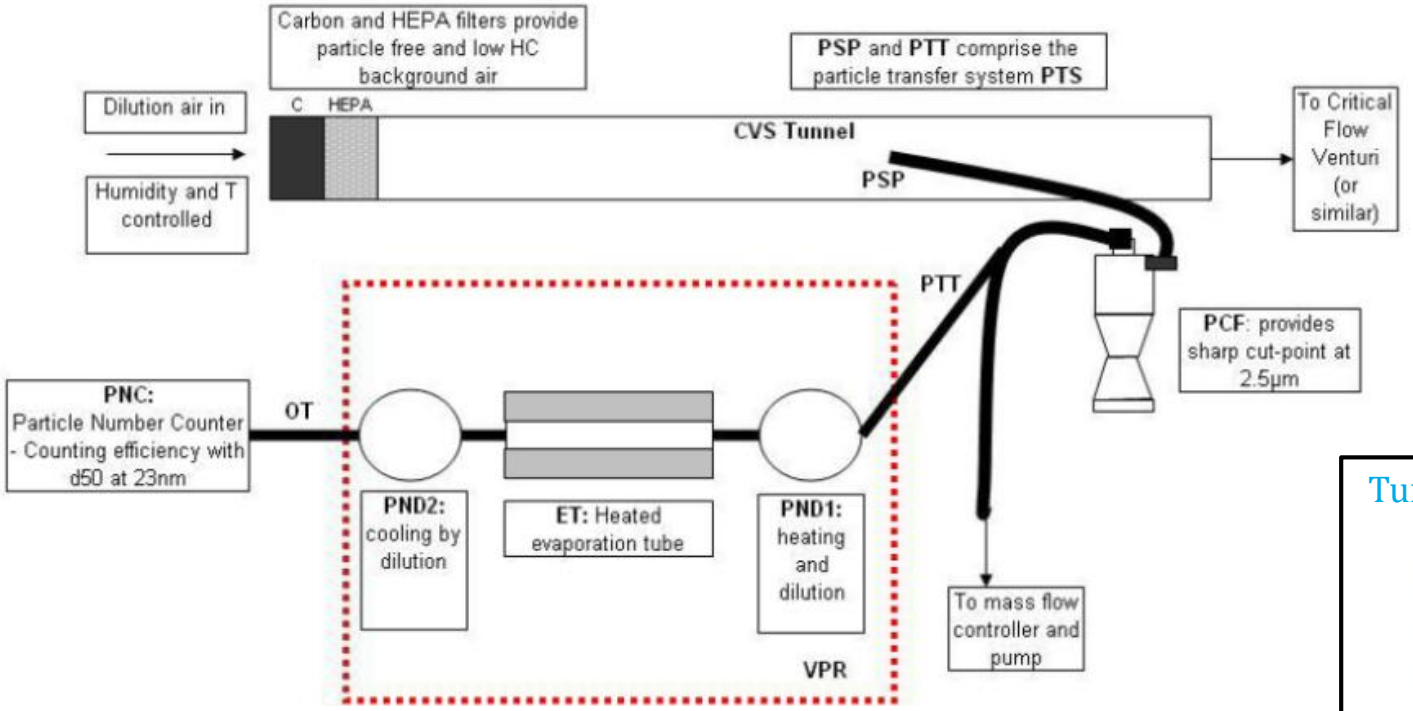
NRMM - SR 941.242/
Swiss ships SR 747.201.3

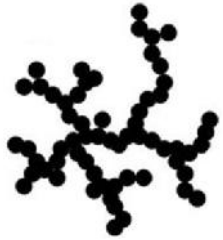
Aircraft emissions SAE E-31

Solid PN >10nm

+ Suitable for Diesel, gasoline, HD engine and aircraft turbine emissions
+ Reliable, accurate and traceable results

Homologación de Tipo de Vehículos Método PMP para PN (partículas sólidas); Regulaciones 49 y 83





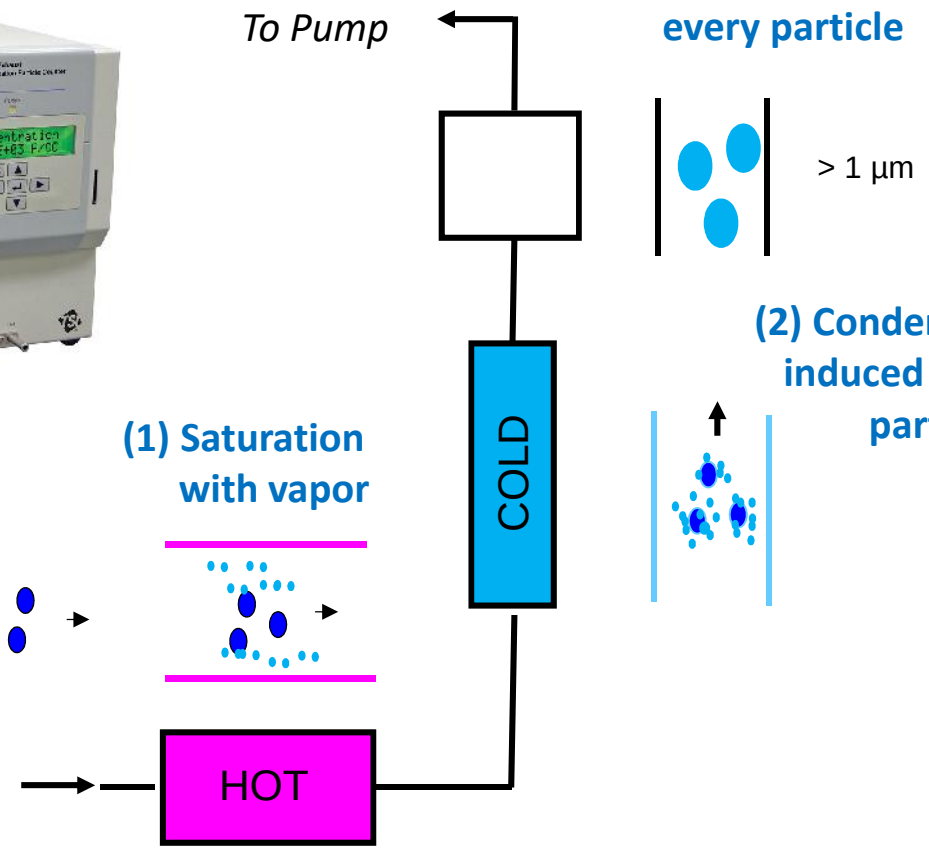
Turn-key PMP

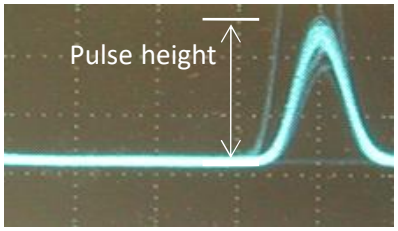
Horiba MEXA-2000SPCS

Particle number (PN) legislation implemented by EU based on → Particulate Measurement Programme (PMP) method for solid PN[1]

[1] Giechaskiel et al., AS&T, 2008

Principio de Detección en un CPC
(Contador de Partículas via Condensación)





Each particle generates a voltage pulse

Porqué usar CPCs?

+ **Direct counting** of particles
  (just like Euro 5/ Euro 6/ upcoming Euro 7)
  - No assumptions (no dependence on size distribution)
  - Flow rate can be measured accurately
  - Pulse height detector for reliable measurements
  - Experience with excluding volatiles efficiently
+ **Sensitive** and **linear response** over full size range relevant for this test
+ **Traceable Calibration** is covered by ISO 27891:2015
  "*Aerosol particle number concentration — Calibration of condensation particle counters*"

Legislación PN para Pruebas de Campo en Maquinaria

+ Swiss Ordinance of Air Pollution Control in 2015 is first to limit PN emissions for off-road vehicles
  - Regulation **SR 941.242** mandates in-use compliance testing of construction machinery DPFs

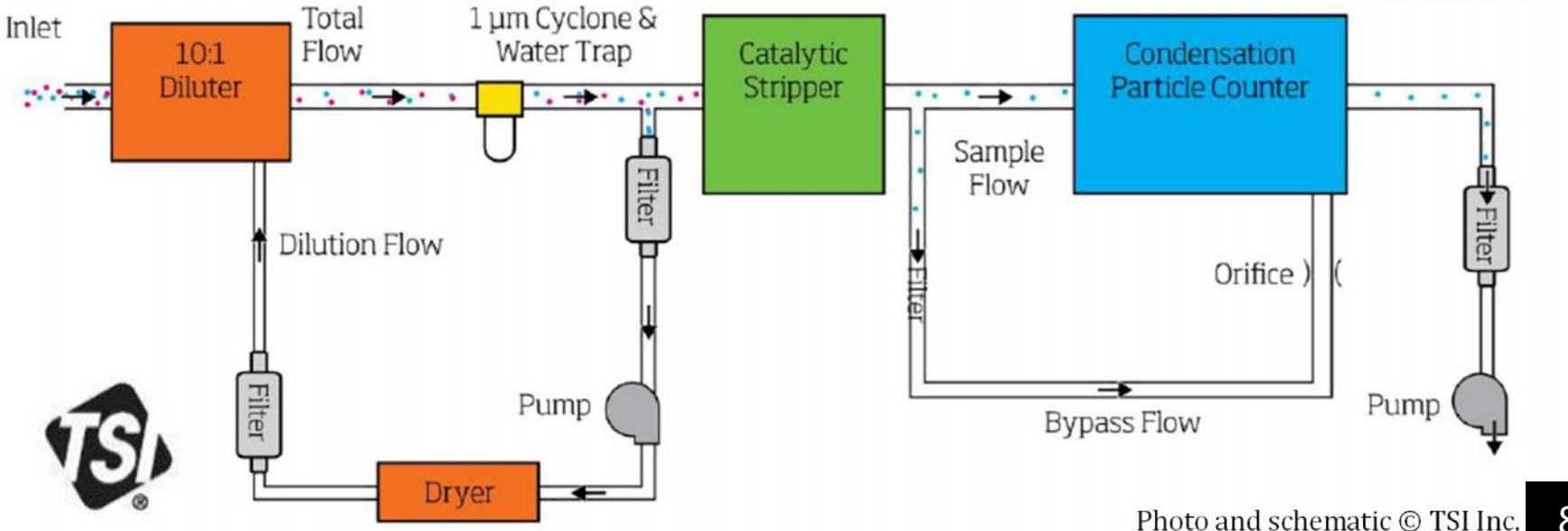
    → PN measurement in the field

  - Followed by **SR 747.201.3** for ships on Swiss lakes and rivers, mandatory from January 2019

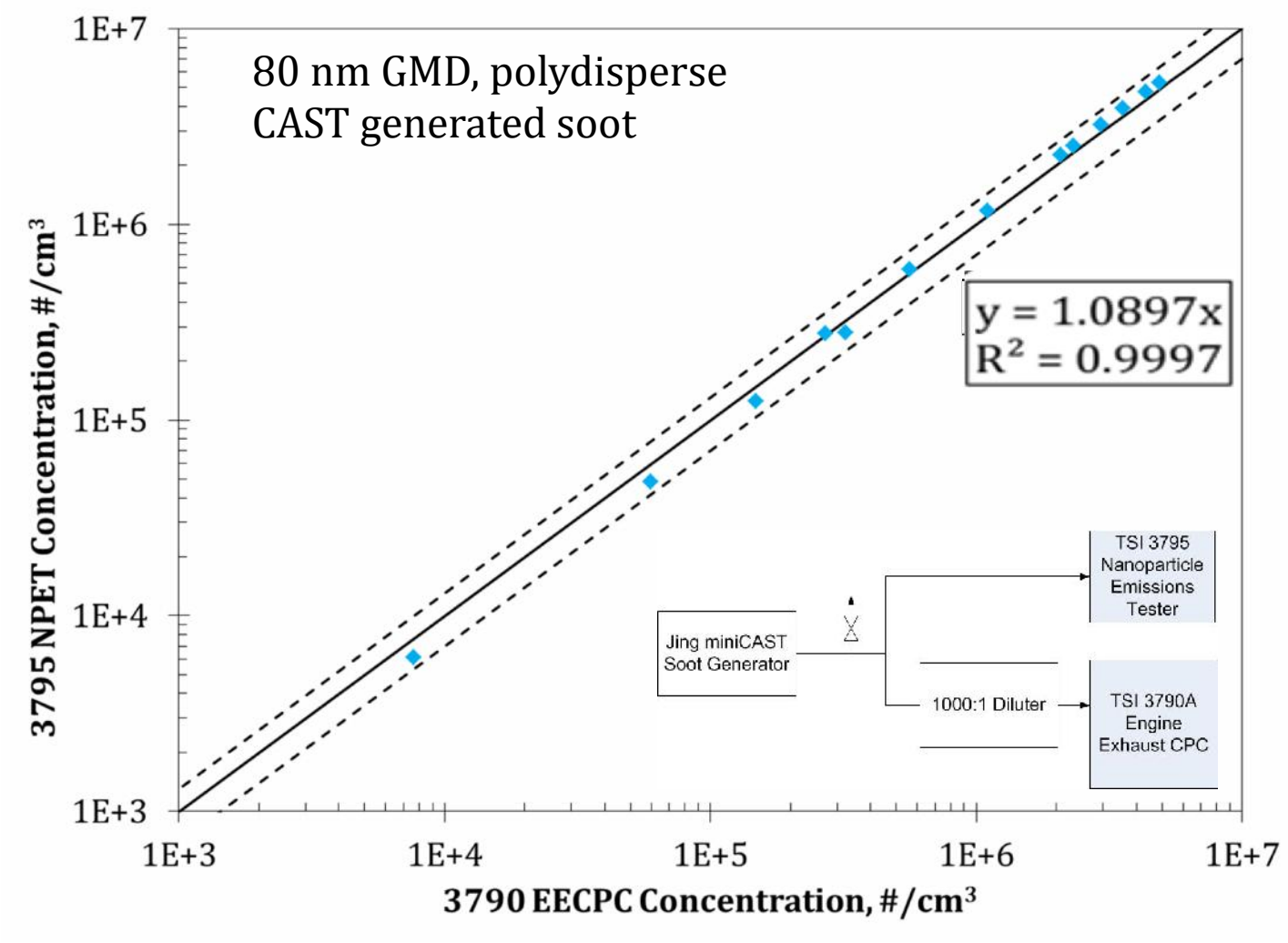
Solución en Uso: NPET

Nanoparticle Emission Tester (TSI 3795)

- + Probe for tailpipe measurement (up to 300°C)
- + 1 µm cyclone with water trap
- + Integrated, dried 10:1 probe-dilution
- + Catalytic stripper
- + Isopropanol-based condensation particle counter (CPC)
- + Research/general & official Swiss test mode



Linearidad en Concentración (log scale)
3795 NPET and 3790A EECPC

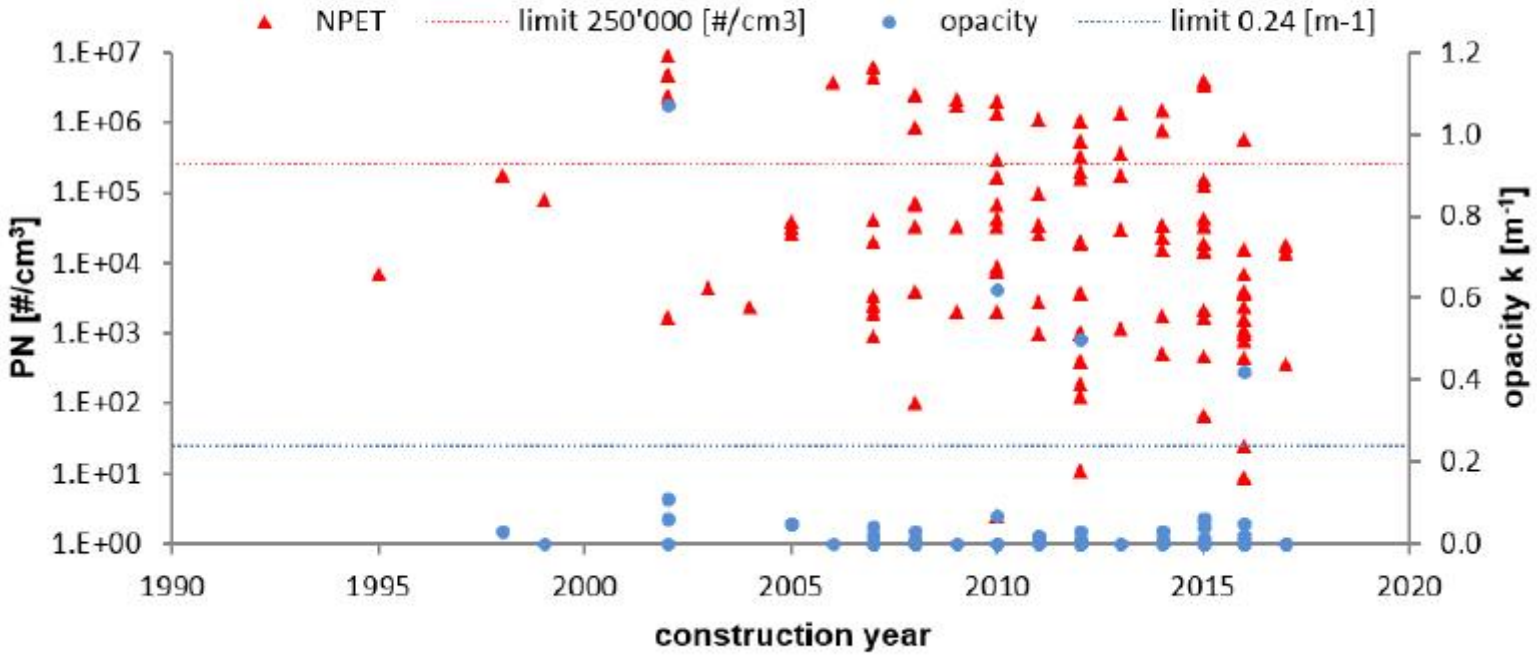


PN-PTI para Maquinaria de Construcción

Comparison PN (NPET) – Opacity
Sorted by: Construction Year

n = 87 machines

CPCs are more sensitive than Opacimeters!



Presented by S. Krähenbühl (FOEN) at VERT-Forum 2018

Source: AFHB 2017

Modo de Operación SR 941.242

Modell:	3795	**Hersteller:**	TSI Inc.
Serien-Nr.:	3795150507	**Letzte Kalibrierung:**	2015-01-29
Firmware-Version:	1.1	**Anwendungsversion:**	1.1.0.0
Anwendungsschlüssel:	6932-07BE-21E8-CA6D-B6A0-0F07-1F15-A089		

DELTATECH AG
Bahnhofstrasse 1
5502 Hunzenschwil
Hanspeter Frey

OFFIZIELLE MESSUNG

Datum/Uhrzeit:	2015-03-30, 14:51:52	**Mittelwert Nr. 1 (1/cm³):**	1,85E4
Dauer:	00:00:40	**Mittelwert Nr. 2 (1/cm³):**	1,90E4
Bediener:	-	**Mittelwert Nr. 3 (1/cm³):**	1,78E4
Maschinen-Fabrikat:	dyvapac	**Gesamtmittelwert (1/cm³):**	1,85E4
Maschinen-Modell:	1712	**Grenzwert (1/cm³):**	2,5E5
Maschinen-ID:	-	**Ergebnis:**	**ERFOLGREICH**
Motor-Kennzeichen:	-		

Umgebungsbedingungen: *15,2 °C, 96,1 kPa, 58 %r. F.*

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		

TSI
500 Cardigan Road
Shoreview, MN 55126, USA
TSI

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):**	5.05E4
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:

Pruebas en buses con DPF en Santiago, Chile

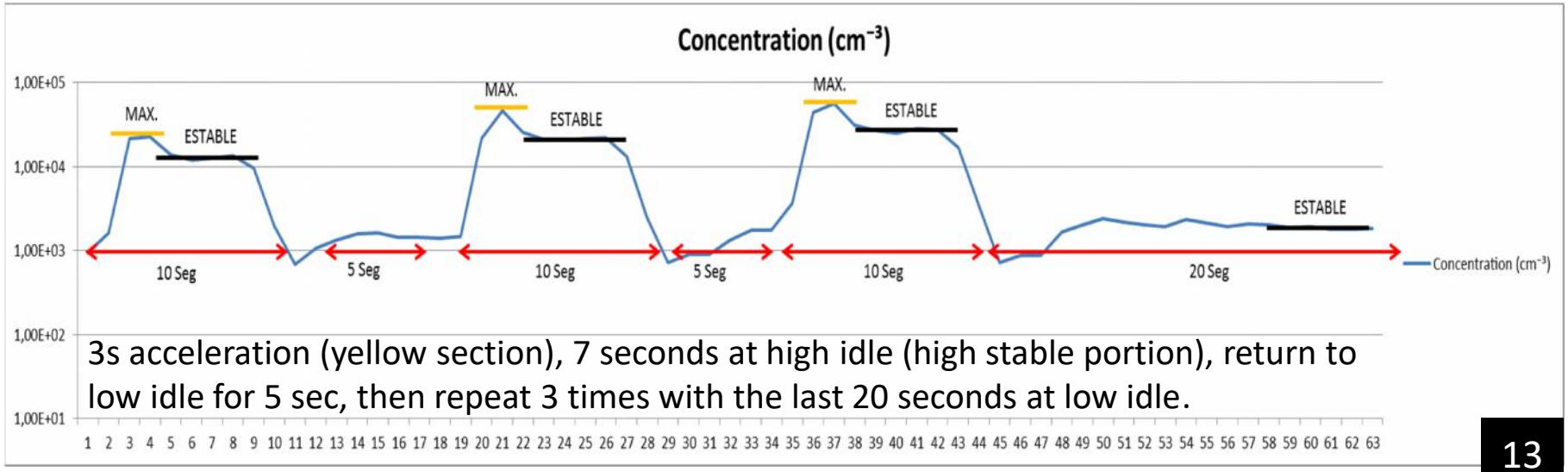
2014 DPF project in Chile (initiated by VERT). Fleet update of new buses with DFP and a retrofit program. NPET measurements were made at 10 in-use buses in the official Swiss Mode either as on-route testing or at the terminal.

	NPET Official measurement (at idle)					Opacimeter official measurement (free acceleration)		
Bus ID number	NPET measurement 1	NPET measurement 2	NPET measurement 3	NPET total measurement	Pass/Fail Limit=2.5E5 cm^{-3}	Opacimeter measurement 1	Opacimeter measurement 2	Pass/Fail Limit=0.24 m^{-1}
On route								
BDXR54	1.62E+04	1.75E+04	1.81E+04	1.72E+04	PASS	0.01	0.02	PASS
BJFB38	7.70E+03	7.49E+03	7.78E+03	7.66E+03	PASS	0.01	0.02	PASS
FLXD50	1.67E+06	1.71E+06	1.70E+06	1.69E+06	FAIL	0.07	0.07	PASS
BJFY74	3.99E+04	4.20E+04	4.26E+04	4.15E+04	PASS	0.01	0.02	PASS
BJFH22	4.75E+05	5.01E+05	5.04E+05	4.93E+05	FAIL	0.02	0.03	PASS
In SUBUS terminal								
CJRL33	7.21E+02	6.71E+02	5.83E+02	1.00E+03	PASS	N/A	N/A	N/A
CJRL49	4.00E+01	5.10E+01	6.50E+01	1.00E+03	PASS	N/A	N/A	N/A
CJRP81	2.95E+03	2.79E+03	2.87E+03	2.87E+03	PASS	N/A	N/A	N/A
CJRR35	9.13E+01	5.58E+01	5.08E+01	1.00E+03	PASS	N/A	N/A	N/A
CJRR38	4.66E+06	4.72E+06	4.57E+06	4.65E+06	FAIL	N/A	N/A	N/A

Pruebas de DPF en Santiago, Chile – Step 2: 400 buses

„The NPET has opened the eyes of the people involved in inspection and maintenance."

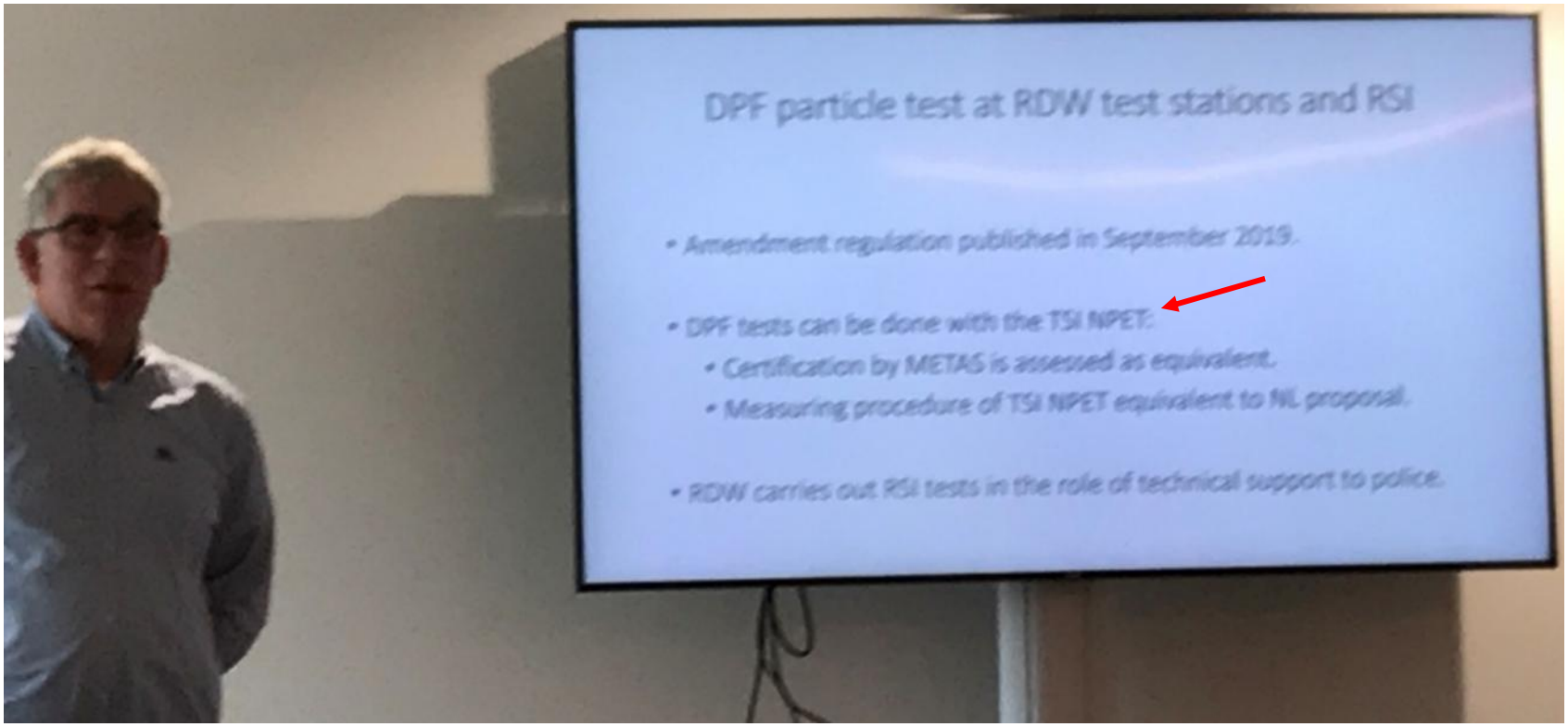
- Many buses with excellent results < 5.000 P/cc whereas ambient air showed 50.000 P/cc
- Small filter failures are visible
- Opacity measurement does not correlate well to PN



3s acceleration (yellow section), 7 seconds at high idle (high stable portion), return to low idle for 5 sec, then repeat 3 times with the last 20 seconds at low idle.

Nueva Iniciativa*: PN-PTI en Alemania, Bélgica y Holanda

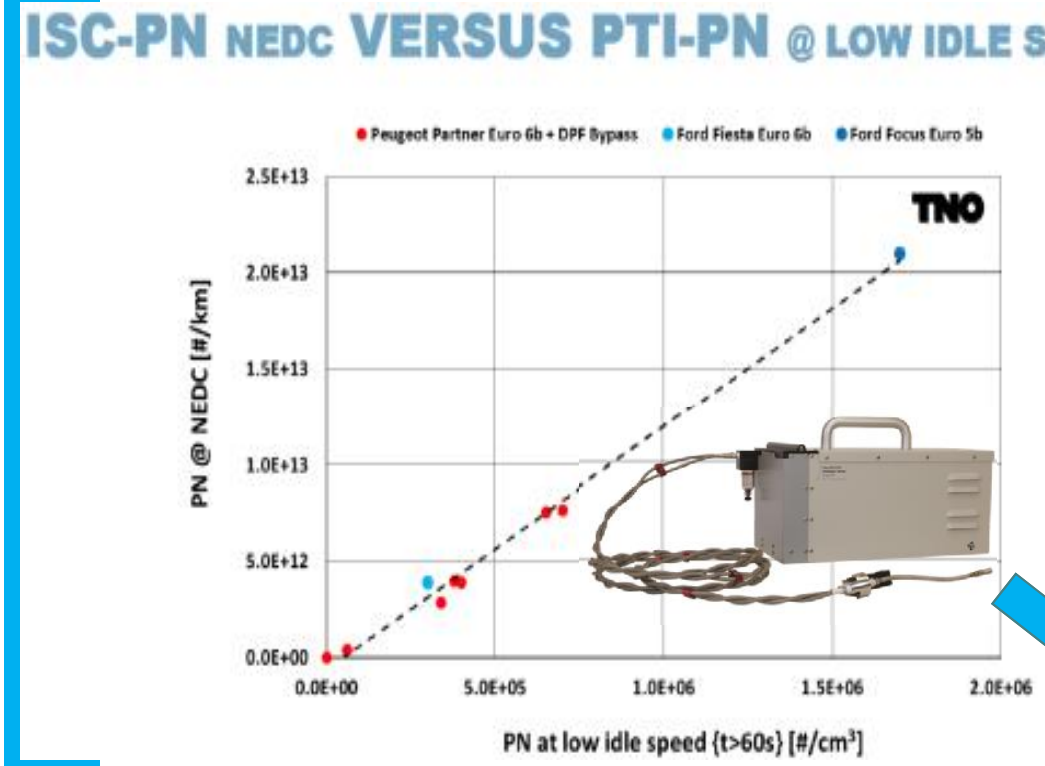
+ NPET is already the reference in The Netherlands

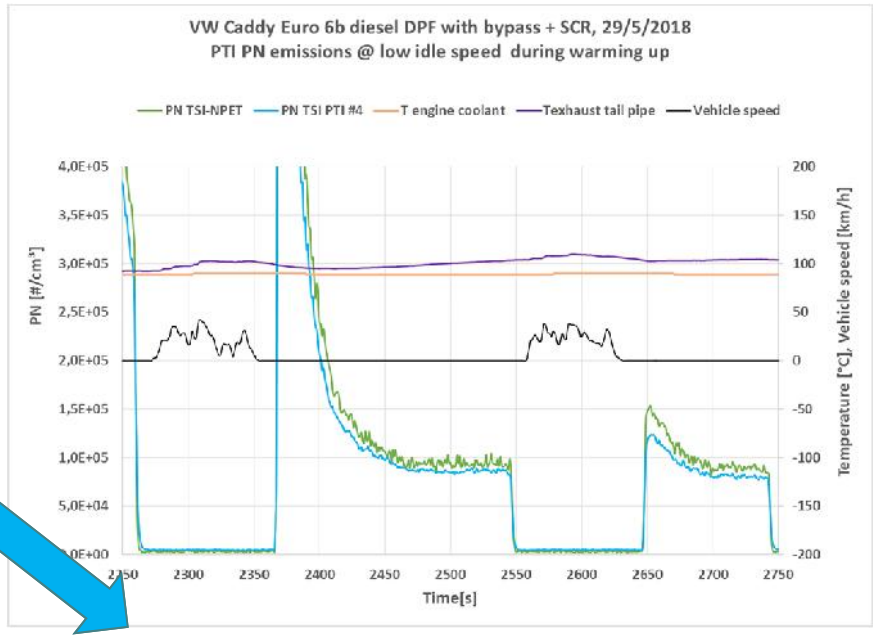


Presented by Louis Zuidgeest (Netherlands Ministry of Infrastructure and Water management) on several ocassions in 2019

* Initiated by VERT

Mediciones en TNO (Holanda)





Source: Presentation at VERT-Forum 2018 by Gerrit Kadijk

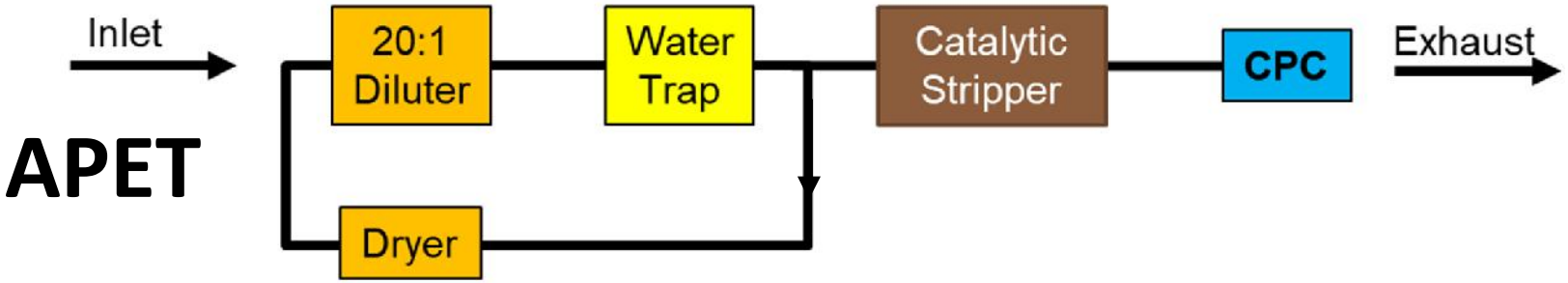
NEW

TSI APET (Automotive Particle Emission Tester)

+ Full system

+ Lower price

CPC es un componente del Sistema de medición de PN



+ Tailpipe exhaust contains solid particles & **volatile** components
  - Need for removing volatiles to avoid nucleation
+ Tailpipe exhaust contains high **humidity**
  - Need for drying to avoid condensation – water
+ Tailpipe exhaust can contain a high number of particles
  - Need for dilution

Nuevo instrumento para estaciones de servicio – TSI APET

Automotive Particle Emission Tester:

- Complete measurement system: Sampling + aerosol conditioning + particle counting
- Lightweight (< 5kg)
- Small (hand held)
- Robust (no free liquid)
- Low maintenance (yearly)

Docking Station:

- Charging the battery (daily)
- Liquid reservoir (1 L, ~1 year)

Conclusiones
CPCs para mediciones de escape

+ Tecnología Probada

Proven technology and in-use for over 20 years (PMP, RDE)

+ Medición directa y homologada

Direct measurement & certified single particle counting

- Comparable & reputable results from station to station
- Traceable calibration according to ISO 27891

+ CPCs son fáciles de mantener

CPCs are maintenance-free (≥1 Year)

- Robust & suitable for workshops. Measurement not affected by vibrations, electric fields, ambient conditions
- Liquid (isopropyl alcohol) refill about once a year

+ CPCs están listos para el futuro

CPCs are fit for the future

- Ready to measure gasoline vehicles
- Detection limit can be easily updated from 23 nm to 10 nm (Thousands of TSI's 10nm CPCs are in use worldwide)

Gracias por su Atención