

CORE TECHNOLOGY WHITEPAPER

Solid Particle Number System

Two-stage dilution system
coupled with SwRI patented
high efficiency catalytic
stripper technology

By Imad Khalek, Southwest Research Institute &
Russell Graze, Engineering Consultant to Sierra-CP

August 21, 2018

sierra-cp.com/spns

GLOBAL EMAIL: INFO@SIERRA-CP.COM

NORTH AMERICA

16475 Ingersoll Road, Lansing, MI 49106 / USA
ph 517.323.8909

EUROPE

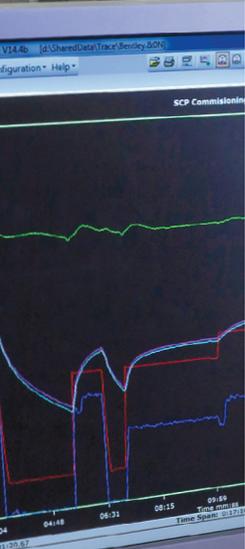
Sandy's Road, Malvern, Worcestershire WR14 1JJ
United Kingdom
ph +44(0) 1684 584850

INDIA

401, Vasudha Equinox, S/No. 5/12, CTS No. 2504
Bopodi, Pune 411003 / India
ph +91 86 0014 8055

ASIA - PACIFIC

Second Floor Building 5 / Senpu Industrial Park
25 Hangdu Road Hangtoun Town / Pu Dong New District
Shanghai, P.R. China Post Code 201316
ph +86 21 5879 8521/22



Increasingly, regulatory activity surrounding solid Particle Number (PN) has become one of the more difficult challenges for engine and vehicle manufacturers today. Manufacturers of, and researchers in, automobiles, diesel engines, turbines, exhaust after treatment systems, motorcycles and mopeds are affected.

Real time PN measurement enables increased regulatory focus on the employment of best available technology diesel particulate filter (DPF) and gasoline particulate filter (GPF) to minimize human exposure to exhaust particles. While previous regulatory activity has focused on solid particles greater than 23nm, research activity is now focused on the viability and value of PN regulation down to 10nm.

Partnering with Southwest Research Institute (SwRI), Sierra will manufacture a fully commercial UN-ECE R49 and R83 compliant Solid Particle Number System (SPNS) utilizing SwRI patented high-efficiency Catalytic Stripper Technology.¹ The system is brand named Sierra SPNS Elite and is the only patented (US 6,796,165) R49-compliant PN certification-grade system available.

The system is specifically engineered to enable testing with either partial or full flow systems to yield simultaneously sampled PM and PN results that are fully compliant with all current and anticipated PM and PN regulations. The system measures particulate concentration down to 23 nm with future versions to 10 nm. Sierra has licensed the SPNS technology from SwRI; the initial versions of the system are projected to be commercially available starting in September 2018. This document introduces the SPNS and highlights some of its more salient technical features.



The SPNS was developed by SwRI in compliance with the United Nations Economic Commission for Europe (UN-ECE) regulations R49 and R83 for automotive emissions applications, and ICAO/SAE Air 6241 for aircraft emissions applications. SPNS technology has been used extensively by SwRI for over a decade in their own labs for engine emissions certifications and R&D purposes.

SPNS TECHNOLOGY

The SPNS includes a two-stage dilution system coupled with SwRI patented high efficiency Catalytic Stripper Technology (CST). The SPNS is used in combination with a partial flow sampling system (PFSS) or a full-flow (CVS) flow sampling system for engine emissions certification and R&D. When properly fitted, SPNS can also be used to sample directly from engine exhaust upstream or downstream from aftertreatment systems. Furthermore, the SPNS can be used to sample directly from the blow-by stream to quantify blow-by solid particle number emissions independently if needed.

The primary and secondary dilution systems of the SPNS use radial inflow porous tube technology designed for low particle loss, enabling compliance with aircraft emissions applications down to 15 nm in diameter. The two stages of dilution allow for a nominal particle correction reduction factor between 100 and 2000 which is suitable for most applications when combined with a PFSS or CVS. For engine out or direct exhaust measurement applications, the SPNS may be equipped with an additional dilution stage for a total particle correction reduction factor of 6000 combined with a PFSS or a CVS dilution. The SPNS incorporates a butanol-based condensation particle counter (CPC) with a CST for butanol oxidation to reduce butanol inhalation and contamination in the laboratory. SPNS can also accommodate a second CPC for R&D purposes.

SPNS Overview

- Used exclusively by SwRI for over a decade; Sierra to commercialize with first units September 2018
- Measures particulate concentration down to 23 nm, future versions to 10 nm
- Each unit calibrated independently by SwRI in their ISO-17025 lab
- Incorporates a fully compliant butanol-based condensation particle counter (CPC)
- Takes a sample from a CVS unit or partial flow diluter
- Simultaneous sampled PM and PN results are compliant with regulations
- Ideal for autos, diesels, pre/post after treatment, jet engines, and more

CATALYTIC STRIPPER TECHNOLOGY (CST)

The selection of CST technology for the volatile particle remover allows the SPNS the flexibility to be used on different technology engines for solid particle measurement. When compared with standard volatile particle remover evaporation tube technology, the CST technology used in SPNS has demonstrated superior performance in removing tetracontane particles up to 100 nm in diameter. Further, the use of CST enables improved quantification of sub-23 nm particles due to significant reduction in the formation of organic artifacts.

The highly efficient removal of organic materials by the CST (as evidenced by the previously mentioned test results on very large tetracontane particles) maintains the sampling system free of any adsorbed organic carbon species that may result in contamination or measurement artifacts. The SPNS has been used by SwRI on two-stroke engines with high levels of organic materials and four-stroke diesel, gasoline (port fuel and direct injection) and natural gas engines, with no evidence of artifact particle formation down to a very small particle size of 3 nm in diameter.

CST Overview:

- Volatile particle remover for flexibility on different technology engines
- Removes nearly 100% of organics and toxic gases
- Assures butanol oxidation to reduce butanol lab inhalation and contamination
- Improves quantification of sub-23 nm particles from reduced organic artifacts

INSTALLATION

The SPNS is available with long (15 ft) or short (3ft) heated sample lines to meet various applications in engine laboratory, where space is a limitation. Such flexibility allows it to be situated near an engine test cell if needed or away from an engine test cell or a dilution tunnel, while meeting the full requirement of the regulations.

¹ Khalek I., T. Bougher, "Development of a Solid Exhaust Particle Number Measurement System Using a Catalytic Stripper Technology, *SAE Paper 2011-01-0636*, *SAE Int. J. Engines*, June 2011 4: 650-666; doi: 10.4271