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UN-GRPE PMP Phase 3 Inter-laboratory Correlation Exercise: Updated Framework and Laboratory Guide for Heavy Duty (HD) Engine Testing

A Document For The UK Department for Transport

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PMP PHASE 3 INTER-LABORATORY CORRELATION EXERCISE (ILCE-HD): HEAVY DUTY ENGINES: VALIDATION EXERCISE (VE_HD) and ROUND ROBIN (RR_HD)

1. INTRODUCTION

This document has been prepared in response to a request from UK DfT as part of the Particle Measurement Programme (PMP).

The document's purpose is to specify the testing guidelines and protocol for an inter-laboratory correlation exercise. This exercise is specifically designed to evaluate the revised particulate mass and particle number measurement techniques proposed by PMP Phase 2. The document also introduces particle number and particulate mass measurements from partial flow dilution systems as integral parts of the PMP Phase 3 work.

In Section 9, the document contains specific and detailed guidelines on how the testing should be conducted at each laboratory.

2. SCOPE

This document defines test procedures for the inter-laboratory validation exercise and round-robin exercises to evaluate methods for particulate (all materials collected by the conventional filter method) and particle (exhaust aerosol; solid particles as defined by the measurement system) exhaust emissions measurement from heavy duty engines under transient conditions on a bench dynamometer. It is derived from the light duty inter-laboratory correlation exercise document (Ricardo RD04/04/80801.4), the existing HD type approval procedure and from draft procedures for future HD legislation (Regulation 49, ISO 16183 and US 2007).

Regulated gaseous emissions will be measured at the same time as particulate and particle emissions, using established regulatory measurement techniques.

This document is concerned with two exhaust dilution systems, namely: a full flow primary dilution tunnel with constant volume sampler (CVS) and secondary dilution system and a partial flow dilution system.

This document acts as the guide for testing in the validation exercise (VE_HD) and the round robin (RR_HD).

3. REFERENCES

This specification is based upon or draws from the following documents:

UN documents:

- R83 - ECE/TRANS/WP.29/GRPE/2007/8/Rev.1

- R49 - GRPE-PMP-13-3

- WHDC - GTR 4

Code of Federal Regulations Title 40 Part 86 Subpart N – Emission Regulations for New Otto-Cycle and Diesel Heavy-Duty Engines; Gaseous and Particulate Exhaust Test Procedures (Revised July 1 2001). “US2007”

ISO16183 Heavy-Duty Engines – Measurement of gaseous emissions from raw exhaust gas and of particulate emissions using partial flow dilution systems under transient test conditions. To be used in its final form and referred to as “16183”.

Euro Directives 2005/55/EC, 2005/78/EC and 2006/51/EC

Aerosol Measurement: Principles, Techniques and Applications. Ed: Paul A Baron and Klaus Willeke, 2nd edition 2005.John Wiley & Sons Inc.

ASTM (1999). American Society for Testing and Materials ASTM E691–99: Standard Practice for Conducting an Inter-laboratory Study to Determine the Precision of a Test Method, West Conshohocken, PA

4. TEST SPECIFICATIONS

4.1 Testing Environment

The participating laboratories shall provide facilities and resources required to perform heavy duty engine emissions tests according to the Regulation 49, plus additional capability as required for particulate and particle measurements as defined in this document. They will also be required to install the test engine, supply measurement systems, and to liaise with the programme managing agent (PMA) and “golden engineer” (GE).

4.2 Engine Specifications

Two engines will be employed in the PMP programme. The first (VE-E1), a Euro III compliant Iveco Cursor 8 equipped with a catalyst based uncoated DPF, will be employed in the Validation Exercise (VE_HD). The second engine (RR-E2), a Euro III compliant Mercedes OM501 equipped with a catalyst based uncoated DPF, will be employed in the round-robin programme (RR_HD).

Laboratories may test an additional engine. This could be:

- A Euro IV compliant conventional Diesel (without DPF). This is likely to employ high pressure injection (via CR or EUI) and selective catalytic reduction (SCR) to reach Euro IV NOx and PM levels simultaneously

- Diesel-fuelled Euro IV compliant engine equipped with an OEM system Diesel particulate filter (DPF). Ideally this engine will also be equipped with either common rail (CR) or electronic unit injection (EUI) systems

- A Euro III or IV compliant engine equipped with a partial (open) filter

- US 2007/2010 or Euro V, Euro VI development engines

Laboratories may test further engines as above, but also other possibilities:

- A Euro IV compliant CNG engine

4.3 Lubricating Oil

A single lubrication oil shall be employed for VE-E1. This has been supplied by Concawe (BP) and is : BP Vanellus E8 ULTRA 5W-30.

Typical Characteristics

	Test Methods	Units	Grade : SAE
			SAE 5W-30
Density at 15 °C	ISO3675/ASTM D1298	kg/m³	860
Kinematic Viscosity at 100 °C	ISO3104/ASTM D445	mm²/s	12.03
Viscosity Index	ISO2909/ASTM D2270	-	163
CCS Viscosity at -30 °C	ASTM D2602	mPa.s	5260
Pour Point	ISO3016/ASTM D97	°C	-54
Flash Point (COC)	ISO2592/ASTM D92	°C	220
Total Base Number	ISO 3771/ASTM D2896	mgKOH/g	15.9
Sulphated Ash	ISO3687/ASTM D874	%m	1.9

A large single batch of lubricant will be shipped to the test laboratories in advance of the arrival of the test engine. The total volume that has been acquired for the whole of VE_HD is sufficient for a rigorous flush and fill procedure for VE-E1 at each laboratory across the entire inter-laboratory correlation exercise.

Lubricating oil requirements for RR-E2 will be defined and provided by OICA. It is not intended that lubricant be changed at each RR_HD laboratory, but filling with new lubricant may be necessary where RR-E2 is transported to a laboratory by air freight.

4.3.1 Lubricant Flush and Fill

The flush and fill procedure employed at JRC will be implemented upon arrival of VE-E1 at each test laboratory. An example flush and fill procedure is shown in Appendix 1.

If required, a lubricating oil change procedure for RR-E2 will be defined and provided by OICA.

4.4 Test Fuel

The Diesel fuel to be employed during this programme will be RF06, which also complies with Annexes 3 and 4 of Directive 2003/17/EC describing fuel specifications to be employed after 1st January 2009*. This fuel specification was also employed in the ILCE_LD. A specification is given in Appendix 2.

A single batch of fuel for VE_HD has been arranged by Concawe (Total), VE_HD laboratories must purchase fuel from this batch directly from jean.thiebaut@total.com.

With contingency, each laboratory will require 2,000 litres of Diesel fuel.

RR-E2 will also be tested on RF-06 Diesel, but this should be sourced by RR_HD laboratories and will not be from the VE_HD single batch.

5. TEST PROTOCOL

5.1 Delivery and Preparation of Test Engines

The test engines shall be inspected for damage on arrival at the laboratory. Any problems shall be reported to the GE and PMA (VE-E1) or to Mr. Stein of OICA (RR-E2).

Contact details as follows:

- GE: Jon.Andersson@Ricardo.com
- PMA: Giorgio.Martini@JRC.IT
- RR: hj.stein@daimler.com

All engines shall be stored in an appropriate manner prior to installation.

5.1.1 Components and Information

The following components and information shall be provided with the test engine.

- Engine with test bed compatible ECU and control system
- Diesel Particulate Filter (DPF)
- Other exhaust components: catalysts etc
- Diagnostic system
- Engine mounts and brackets
- Aftercooler and air-side pipe work (pre-set for correct pressure drop across aftercooler)
- Exhaust pipe flange to adapt to test bed system
- Complete dimensions of test cell exhaust system
- Wiring harness and throttle pedal
- Wiring diagram
- Engine operating parameters (eg back pressure, coolant and fuel temp, aftercooler outlet temperature map etc)
- Full load power curve data
- Instrumentation for critical engine and aftertreatment operating parameters: temperatures, pressures, fuel system etc with suitable quick-fit connectors
- Baseline particulate mass and gaseous emissions data

* If a CNG engine is tested, a fuel specification will be required. Approximately fuel requirements would be 2500-3000kg.

5.2 Installation

Care shall be taken to closely replicate the manufactured test cell exhaust system dimensions between laboratories. For example, the distance between exhaust manifold and aftertreatment components shall, as far as possible, be matched between all test laboratories. The critical dimensions of the exhaust system, gas residence times between manifold and catalyst inlet and exhaust system contribution to backpressure will be supplied with the engine following installation at the first laboratory.

5.3 Pass-off Tests

To confirm correct engine operation, 3 ETC cycles will be run on receipt of the engine and the results compared with data from the previous test laboratory.

5.4 Test Cycles

The engine shall be tested over 8 repeats of the cold start World Heavy Duty Transient Cycle (WHTC) along with 8 repeats of a hot-start WHTC following a 10 minute soak. In addition, 8 further tests on each of the World Heavy Duty Steady State Cycle (WHSC), the European Transient Cycle (ETC) and the European Steady State Cycle (ESC) will be undertaken.

5.5 Criteria for Repeat Tests

8 tests of each cycle shall be performed on the engine. Supplementary tests shall be carried out if one or more of the tests does not comply with current type-approval test practices (for example if the cycle does not validate, cold start failure, any malfunction during the tests). Statistical methods based on ASTM (1999) will be employed to identify outliers from the complete VE_HD and RR_HD datasets following completion of each programme.

5.5.1 Supplementary tests

No more than 2 additional tests will be required for any single cycle.

5.6 Testing Approach

The test work shall be carried out according to a pre-defined schedule for engine, exhaust & sampling system conditioning, measurement system checks and test cycles.

5.7 Test Order and System Preconditioning

Test order shall consider the possibility of contamination of test results by a previously tested engine, or from an engine in an adjacent facility which shares the dilution system. Prior to performing any emissions tests, a preconditioning phase shall be completed in order to purge the engine's exhaust system and to stabilise the dilution system with respect to the chemistry of the engine's exhaust.

In order to enable close control of both test procedures and test timing, a continuity protocol (Section 5.7.4) is included in the test matrix. The continuity protocol controls the time and engine operation between tests specifically, so that testing can be exactly reproduced between laboratories.

A shared dilution system, in which one or more other engines are tested during the PMP test period, may not be employed in the VE_HD. In RR_HD, where, for facility scheduling reasons, testing of other engines in a shared dilution system during the PMP test period is unavoidable, the fact that other engines have been tested must be reported. In addition RR_HD labs should make every effort to limit other engine testing to wall-flow DPF equipped engines only.

5.7.1 Catalyst System Fill-state Consistency

5.7.1.1 Catalyst System Fill-state Consistency: RR-HD

Prior to the first testing in each laboratory, the DPF will be fully regenerated by sustained operation (2h) at ESC Mode 10. This will be the last test activity performed by each test laboratory prior to shipping of the test engine.

5.7.1.2 Catalyst System Fill-state Consistency: VE-HD

Prior to the first testing in each laboratory, the DPF will be fully regenerated by sustained operation at ESC Mode 10. This will be conducted as part of the oil change and conditioning procedure.

5.7.2 Sampling, Measurement and Catalyst Systems Preconditioning – Evening before each Test Day

- Preconditioning will include a 15 minutes passive regeneration phase (ESC Mode 10) and a 30 minutes DPF loading phase (ESC mode 7)
- For the 15 minutes duration of the ESC Mode 10 operation and the ESC Mode 7 phase, exhaust will be diverted through the CVS and secondary dilution system.
- The partial flow sampling system shall be operated in bypass during the 15 minutes of the ESC Mode 10 conditioning period and the ESC Mode 7 phase, with operating parameters adjusted to give tunnel temperature of ~70°C

5.7.3 Preconditioning - Shared Dilution System

For RR_HD laboratories, in a shared dilution system, where a non wall-flow DPF equipped engine's exhaust is passed into a dilution tunnel which is shared between 2 or more cells, the preconditioning detailed in Section 5.7.2 must be performed the previous evening. A dilution system shared between two DPF equipped Diesel engines is acceptable without additional tunnel pre-conditioning.

5.7.4 Continuity Protocol (CP)

Between each transient cycle, the continuity protocol shall be applied.

The continuity protocol is employed to ensure identical temperature profiles in the engine and exhaust following each test. This will enable the test work to be closely replicated from facility to facility. The protocol will be similar to that described below:

- Drop to idle for 5 minutes (if the engine was not turned off)
- 5 minutes operation at ESC mode 7
- Drop to idle for 3 min and commence test sequence (Firstly a zero and span of the analysers and then commencement of the automated part of the emissions cycle)
- If a specific period of engine operation is mandated as preconditioning for a particular drive cycle, this operation may replace one or more stages of the CP for that cycle only.

6. MEASUREMENT AND SAMPLING SYSTEMS FOR GASEOUS EMISSIONS

6.1 Full flow Dilution System

The mass of gaseous emissions shall be measured from the dilute exhaust during all tests in accordance with the current R49 / WHDC regulation.

6.2 Raw Exhaust Sampling

The mass of gaseous emissions shall be measured from the raw tailpipe exhaust in accordance with R49 / WHDC regulation for steady-state cycles, and ISO 16183 for transient cycles. If possible, engine out raw emissions shall also be measured on a continuous basis throughout the test.

7. MEASUREMENT & SAMPLING SYSTEMS FOR PARTICULATES: FULL FLOW

7.1 Introduction

The mass of particulate material emitted by the test engine and for each test will be measured using the system defined in Sections 7.2. to 7.5.5 and Section 9. Two possible examples of compliant particulate measurement system configurations are shown in Figure 1 and Figure 2.

Figure 1: Example of Particulate Measurement System (1)

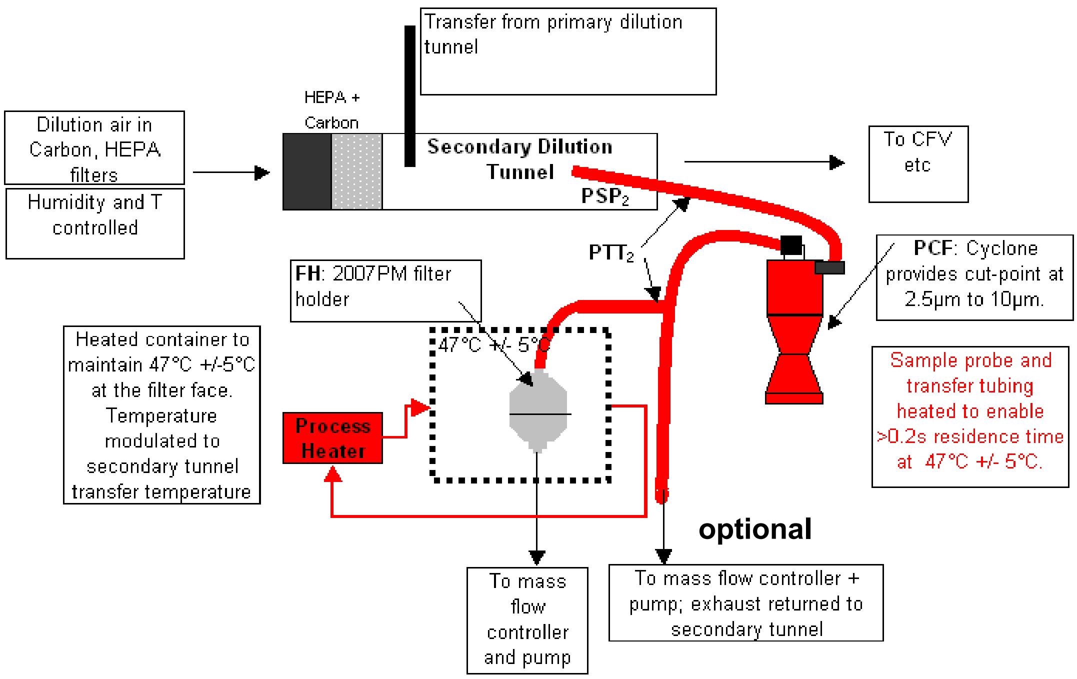
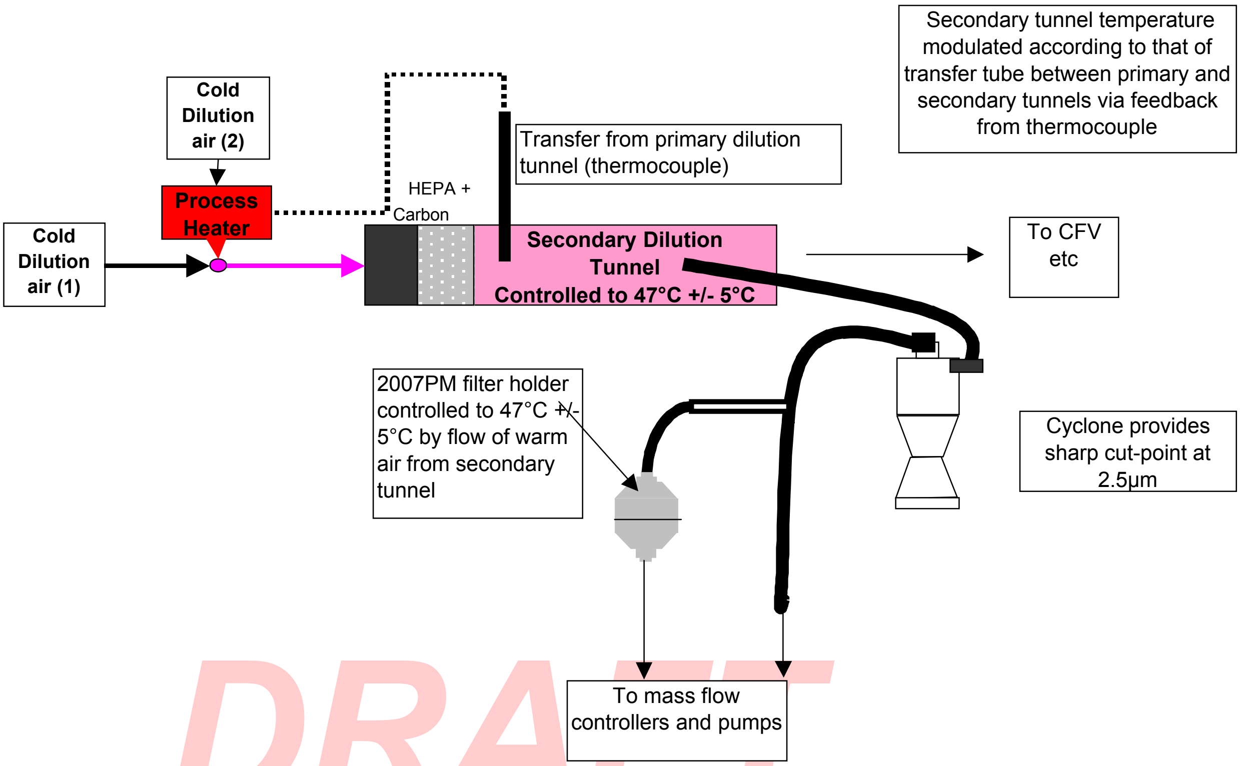


Figure 2: Example of Particulate Measurement System (2)



7.2 Dilution Systems

A full flow double dilution system shall be used for particulate mass measurements.

7.2.1 Primary Tunnel

A full flow CVS exhaust dilution tunnel system meeting the requirements of Regulation 49 shall be used. The CVS flow rate at each lab (Q_i) will be selected such as to ensure similar residence times in the primary dilution tunnel (±25%), according to the equation:

$Q_i = Q \times L / Li \times D^2/Di^2$

where

$Q=80\ m^3/min$, D=0.47cm, L=4.7m and Li and D_i are the lengh and inner diameter of the test lab CVS

The dilution air used for the primary dilution of the exhaust in the CVS tunnel shall be first charcoal scrubbed and then passed through a secondary filter. The secondary filter should be capable of reducing particles in the most penetrating particle size of the filter material by at least 99.95%, or through a filter of at least class H13 of EN 1822; this represents the specification of High Efficiency Particulate Air (HEPA) filters.

7.2.2 Secondary Dilution System

A secondary dilution system meeting the requirements of Regulation 49 shall be used. The dilution ratio in the secondary dilution system shall be fixed such that tunnel temperature is <52°C and ideally 47°C +/- 5°C. Where possible, the dilution should be one part dilution air to one part sample aerosol.

The dilution air for the secondary dilution system shall be subject to HEPA and charcoal filtration.

7.3 Particulate Sampling: Primary Tunnel

A sample probe shall conduct materials to the secondary dilution tunnel. It shall be installed near the tunnel centre-line, 10 - 20 tunnel diameters downstream of the gas inlet and have an internal diameter of at least 12 mm. The sample probe will be sharp-edged and open ended, facing directly into the direction of flow in the primary dilution tunnel.

7.3.1 Particulate Sampling: Secondary Tunnel

Where the system permits, a sample probe will be installed in the secondary dilution tunnel. It shall be sharp-edged and open ended, facing directly into the direction of flow. For systems which draw the entire secondary tunnel flow through the PM filter this is not necessary.

A cyclone or impactor based pre-classifier shall be employed at VE_HD laboratories. At RR_HD laboratories use of a cyclone or impactor pre-classifier shall be optional.

A pump will draw a sample of dilute exhaust gas proportional to the total tunnel flow through the sample pre-classifier and filter holder.

The distance from the entrance to the secondary tunnel to the filter mount shall be at least five probe diameters, but shall not exceed 1,500 mm.

7.4 Sample Pre-classifier

At VE_HD laboratories, and optionally at RR_HD laboratories, in accordance with the recommendations of the draft Regulation 49 document (GRPE-PMP-13-3), a cyclone or impactor pre-classifier shall be located upstream of the filter holder assembly. The pre-classifier 50% cut point particle diameter shall be between 2.5 µm and 10 µm at the volumetric flow rate selected for sampling particulate mass emissions. The pre-classifier shall allow at least 99% of the mass concentration of 1µm particles entering the pre-classifier to pass through the exit of the pre-classifier at the volumetric flow rate selected for sampling particulate mass emissions. Evidence of compliant performance to this specification shall be presented (e.g. manufacturer's calibration certificate).

7.5 Filter Sampling

7.5.1 Filter face temperature

A temperature of <52°C, and ideally 47±5°C shall be maintained within 20 cm of the filter face.

This shall be achieved by either direct heating means: the filter holder shall be heated by a mantle or similar, or be mounted inside a temperature-controlled enclosure with the transfer lines to the filter holder heated to enable a residence time of at least 0.2s at the above temperature to be achieved.

Or

The temperature of the aerosol within the secondary dilution tunnel shall be controlled to the required temperature by heating of the dilution air. In this case, the temperature of the dilution air shall be modulated in response to the temperature of the transfer gases between the primary and secondary dilution tunnels. Residence time at ~47°C in the secondary tunnel and at the filter face shall be at least 0.2s.

7.5.2 Filter holder assembly

The filter holder assembly shall be of a design that provides for a single filter only. The shape of the holder shall be such that an even flow distribution of sample across the filter stain area is achieved.

7.5.3 Filter medium

Pallflex TX40 Fluorocarbon coated glass fibre filters shall be employed. All filters will be drawn from a single batch procured by the project-managing laboratory for the VE_HD. Laboratories participating in the RR_HD may use alternative media if that media meets the perfromance specifications of the TX40 filters.

7.5.4 Filter size and Stain Area

For VE_HD laboratories the filter diameter shall be 47mm and the stain area shall be at least 1075 mm^2.

7.5.5 Filter face velocity/ volumetric sample flow rate

Filter face velocity shall be in the range 55cm/s to 90cm/s, which corresponds to a flow rate range of 30l/min to 50l/minwith 47mm filters. Filter face velocity should be calculated at 47°C or temperature corrected mass-flow controllers used.

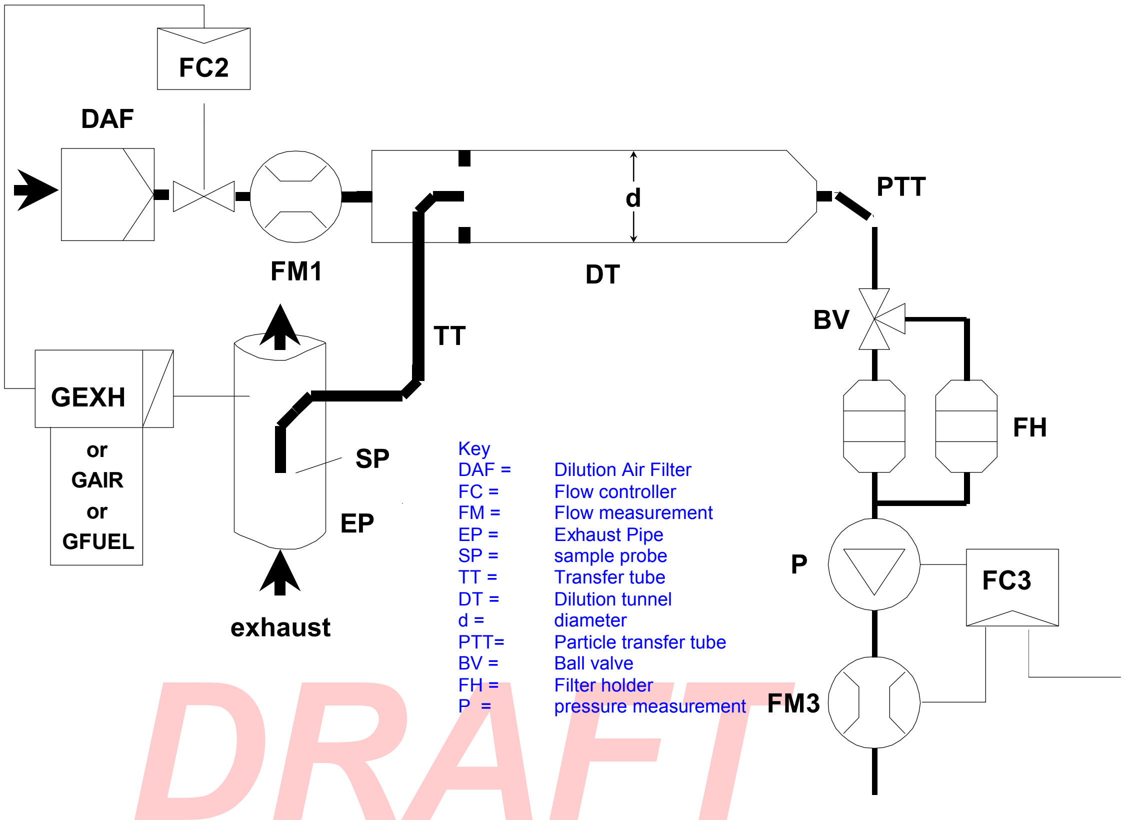
8. MEASUREMENT & SAMPLING SYSTEMS FOR PARTICULATES: PARTIAL FLOW

8.1 Introduction

The mass of particulate material emitted by the test engine and for each test will be measured using the system defined in Sections 8.2. to 8.6.4 and Section 9. An example of a compliant particulate measurement system configuration is shown in Figure 3.

Sampling and measurements will be undertaken according to ISO 16183 except where parameters are explicitly specified in this document.

Figure 3: Example of Partial Flow Measurement System



8.2 Dilution System

A partial flow, single dilution system meeting the requirements of ISO 16183 shall be used for particulate mass measurements in tandem with the full flow system. Exhaust gas mass flow shall be determined using one of the methods outlined in ISO 16183, and the resulting data shall be used for controlling the sample rate from the raw exhaust into the partial flow dilution tunnel.

For transient tests, attention should be given to the dynamic performance of the various measurement and control systems, and good engineering practise should be employed as required to ensure that the sample drawn from the raw exhaust is proportional to the exhaust flow rate at the sample point. The use of a pre-recorded exhaust flow trace for look-ahead control is not allowed.

The same flow measurement and control approach as used for transient cycles shall be used for steady state tests.

All dilution air supplies for the partial flow dilution system shall be subject to HEPA and charcoal filtration.

The dilution system shall be capable of achieving the filter sampling conditions as outlined in Section 8.6 below.

8.3 Dilution System Parameters for Golden Engine

For the Golden Engine only, dilution system operating parameters such as split ratio, dilution factor and filter flow rate shall be as follows:

Split ratio	Total CVS flow rate	Filter flow rate
For 80m^3/min and 50lpm or 0.000626	For 80m^3/min or 6200kg/h	50 lpm or 3000nl/h or 1.08g/s

These provide maximum tunnel temperature of 52°C, maximised filter loading and filter face velocity in the permitted range (Section 8.6.5.1) for all test cycles.

These parameters will be reproduced during VE-E1 testing at each test laboratory. Testing in the RR_HD may employ these or a laboratory's own standard procedures.

When particle number and particulate mass samples are taken simultaneously from a partial flow system, the additional flow taken by the particle number measurement system must be either replaced – flow pumped back into the system under mass flow control downstream of the filter but upstream of the measurement element - or corrected in the partial flow systems' software.

8.4 Particulate Sampling Point

The sampling point for collection of particulate matter from the exhaust system of the test engines shall be determined according to the recommendations of the partial flow dilution system manufacturer and ISO 16183.

8.4.1 Particulate Sampling Point for VE-E1 only

The distance between the exit from the DPF and the sampling point has been determined following preliminary testing at JRC as 5m (d_{in}=15 cm), as far as possible the sampling point for particle measurements using the partial flow tunnel shall be reproduced in all subsequent laboratories. However, if different diameter exhaust tubing is employed, sampling after a similar exhaust volume is required. The exhaust volume at the sampling point should be 0.09 +/- 0.01 m^3 (80 to 100 litres).

8.4.2 Particulate Sampling Point for Additional Engine(s) and RR-E2

Sampling may use either the same point as the VE-E1 or an alternative point selected according to 8.4.

8.5 Sample Pre-classifier/Probe

The sample probe used for raw exhaust sampling shall be the original equipment provided by the partial flow system manufacturer.

In accordance with ISO 16183, it is recommended that a pre-classifier is installed immediately upstream of the filter holder.

8.6 Filter Sampling

8.6.1 Filter face temperature

A maximum filter face temperature of 52°C shall be recorded within 20cm of the filter face. This temperature will be controlled by selecting the appropriate split / dilution ratios within the partial flow system and according to the manufacturers recommendations and ISO 16183.

8.6.2 Filter holder assembly

The filter holder shall be the original equipment as provided by the partial flow system manufacturer. This may be of a design that provides for either a single filter, or sample and backup filters, but in the latter case only the sample filter should be used.

8.6.3 Filter medium

For the VE_HD 47mm Pallflex TX40 Fluorocarbon coated glass fibre filters shall be employed. All filters for VE-E1 will be drawn from a single batch procured by the project-managing laboratory.

For the RR_HD, either 47mm or 70mm filters of TX40 (or equivalent) may be employed.

8.6.4 Filter size and Stain Area

The filter diameter shall be 47mm or 70mm with a stain area of at least 1075 / 2825 mm^2 respectively.

8.6.5 Filter face velocity/ volumetric sample flow rate

8.6.5.1 VE-E1 Sampling

The filter face velocity conditions selected by the first laboratory testing the Golden Engine shall be reproduced by all other test laboratories. The filter face velocity shall be in the range 55cm/s to 90cm/s, which corresponds to a flow rate range of 72l/min to 130l/min with 70mm filters and 30l/min to 50l/min with 47mm filters. Filter face velocity shall be calculated at mean partial flow tunnel temperature. Ideally, temperature corrected mass-flow controllers shall be used.

The reccomended flowrate is 50lpm (similar to the full flow secondary tunnel). This corresponds to 3000nl/h (for PSS) and 1.08g/s for Smart sampler (47mm filters).

8.6.5.2 RR-E2 and Additonal Engine(s) sampling

For any additional engines, the test laboratory may use any appropriate sampling conditions according to the manufacturer's recommendations and ISO 16183. All conditions must be reported.

9. PARTICULATE MEASUREMENT EQUIPMENT AND ENVIRONMENT

The following parameters and equipment are common to both partial flow and full-flow particulate mass sampling.

9.1 Filter Preparation

The particulate sampling filters shall be conditioned (as regards temperature and humidity) in an open dish that has been protected against dust ingress for at least 8 and for not more than 80 hours before the test in an air-conditioned chamber. After this conditioning, the uncontaminated filters will be weighed and stored until they are used. If the filters are not used within one hour of their removal from the weighing chamber they shall be re-weighed.

The one-hour limit may be replaced by an eight-hour limit if one or both of the following conditions are met:

a stabilised filter (filters) is placed and kept in a sealed filter holder assembly with the ends plugged, or;

a stabilised filter (filters) is placed in a sealed filter holder assembly which is then immediately placed in a sample line through which there is no flow.

9.2 Microgram balance

The analytical balance used to determine filter weight must have a precision (standard deviation) of better than 2 µg for a clean filter; better than 1µg for a reference weight and a readability of 1µg or better. To eliminate the effects of static electricity: the balance should be grounded through placement upon an antistatic mat and particulate filters should be neutralised prior to weighing; this can be achieved by a Polonium neutraliser or a device of similar effect.

9.2.1 Balance Integrity

At the start of each weighing session a 50mg weight with a certified value (recertified annually) will be weighed 3 times. The mean of these three weighings shall be +/-5µg of the certified value.

If the mean value is outide this tolerance, the balance shall be recalibrated.

9.3 Weighing Chamber Parameters

The temperature of the chamber (or room) in which the particulate filters are conditioned and weighed must be maintained to within 295K ± 3 K (22°C ± 3°C) during all filter conditioning and weighing. The humidity must be maintained to a dew point of 282.5K ± 3 K (9.5°C ± 3°C) and a relative humidity of 45 % ± 8 %.

The weighing room parameters should be controlled as tightly as possible.

9.4 Calibration Requirements

9.4.1 Microbalance Calibration

The microbalance shall be calibrated according to the manufacturer's specification within 3 months prior to the commencement of the test programme.

9.4.2 Reference Filter Weighing

To determine the specific reference filter weights, at least two unused reference filters shall be weighed within 8 hours of, but preferably at the same time as, the sample filter weighings. Reference filters shall be the same size and material as the sample filter.

If the specific weight of any reference filter changes by more than ±5µg between sample filter weighings, then the sample filter and reference filters shall be reconditioned in the weighing room and then reweighed.

The comparison of reference filter weighings shall be made between the specific weights and the rolling average of that reference filter's specific weights.

The rolling average shall be calculated from the specific weights collected in the period since the reference filters were placed in the weighing room. The averaging period shall be at least 1 day but not exceed 30 days.

Multiple reconditionings and reweighings of the sample and reference filters are permitted until a period of 80 h has elapsed following the measurement of gases from the emissions test.

If, prior to or at the 80h point, more than half the number of reference filters meet the ±5µg criterion, then the sample filter weighing can be considered valid.

If, at the 80h point, two reference filters are employed and one filter fails the ±5µg criterion, the sample filter weighing can be considered valid under the following condition: the sum of the absolute differences between specific and rolling averages from the two reference filters must be less than or equal to 10µg.

In the case that less than half of the reference filters meet the ±5µg criterion the sample filter shall be discarded, and the emissions test repeated. All reference filters must be discarded and replaced within 48h.

In all other cases, reference filters must be replaced at least every 30 days and in such a manner that no sample filter is weighed without comparison with a reference filter that has been present in the weighing room for at least 1 day.

10. PARTICLE MEASUREMENT SYSTEM AND SAMPLING SYSTEMS

For the VE_HD, the number of particles emitted by each engine technology and for each test cycle shall be determined using two nominally identical ‘Golden Particle Measurement Systems’ (GPMS). These will be Horiba Solid Particle Counting Systems (SPCS). Particle numbers shall be determined by measurement from the primary dilution tunnel (full flow) and from the partial flow dilution system. The majority of GPMS components will be provided, though certain items indicated in the text shall be provided by the laboratory.

Throughout the duration of the VE_HD, each laboratory participating in the RR_HD will supply two particle measurement systems and must perform simultaneous measurements from the full flow dilution system and a partial flow system.

After completion of testing in the VE_HD, laboratories participating in the RR_HD may elect to measure particle numbers from full-flow alone, partial flow alone or both full-flow and partial-flow dilution systems and will supply sufficient particle number measurement systems.

All alternative particle number measurement systems [ALT_SYS] including all systems to be employed in the RR_HD must be fully certificated to the requirements of the following sections and/or to the relevant sections in the UK proposal to Amend R83:

- ECE/TRANS/WP.29/GRPE/2007/8/Rev.1

Calibration reports demonstrating compliance with the above requirements must be provided for all RR_HD measurement systems and all VE_HD alternative measurement systems.

10.1 Safety

The electrical components of the GPMS supplied as part of the PMP Programme, shall not be modified in any way by employees of the participating laboratories unless the express permission of the Inter-lab manager or Golden Engineer is given. All modifications, for example: of electrical connectors shall be recorded and the subsequent laboratory informed of changes so that safety checks can be performed prior to further testing.

10.2 Particle Sampling System

The particle sampling system shall be identical for the two GPMS systems with the exception of the sampling tubes. Two sampling tubes will be required: in the primary dilution tunnel for full flow sampling (PST_f) and partial flow dilution tunnel for partial flow sampling (PST_p). Further elements of the particle sampling system are: a particle pre-classifier (PCF) and the GPMS particle conditioning and measurement system comprising a volatile particle remover (VPR) upstream of the particle number counter (PNC_GOLD) unit. The particle sampling system is required to draw a sample from the primary or partial flow dilution systems, size classify it, transfer it to a diluter, condition the sample so that only solid particles are measured, and pass a suitable concentration of those particles to the particle counter.

10.2.1 Sample Probe: Full flow

The sampling probe tip (PSP) in the CVS and particle transfer tube (PTT) together comprise the particle transfer system (PTS). The PTS conducts the sample from the dilution tunnel to the entrance to the VPR. The PTS shall meet the following conditions:

- It shall be installed near the tunnel centre line, 10 to 20 tunnel diameters downstream of the gas inlet, facing upstream into the tunnel gas flow with its axis at the tip parallel to that of the dilution tunnel.
- It shall have an internal diameter of ≥ 8 mm

Sample gas drawn through the PTS shall meet the following conditions:

- It shall have a flow Reynolds number (Re) of <1700
- It shall have a residence time in the PTS of ≤ 3 seconds

Any other sampling configuration for the PTS for which equivalent particle penetration at 30 nm can be demonstrated will be considered acceptable.

10.2.2 Sample Probe: Partial Flow

A sample probe is recommended to be installed in the partial flow dilution tunnel or downstream sampling system but will be placed upstream of the PM sample filter holders. It shall be sharp-edged and open-ended and comprised of stainless steel.

10.2.3 Particle Pre-classifier: Full Flow

The upper limit of the particle size range to be measured shall be determined by the use of the cyclone particle size pre-classifier provided. The 50% cut-point of the particle pre-classifier shall lie at between 2.5µm and 10µm. The laboratory will provide a suitable pump to ensure that the upper size limit of particles sampled into the measurement system lies within this range.

10.2.4 Particle Pre-classifier: Partial Flow

Optionally, the upper limit of the particle size range to be measured will be determined by the use of an inertial particle size pre-classifier. The 50% cut-point of the particle pre-classifier shall lie at 2.5μm. The laboratory will provide a suitable pump to ensure an upper size limit of particles sampled into the measurement system of 2.5μm.

Any flow drawn from the partial flow tunnel must be replaced upstream of the measurement element or taken into account in the partial flow system software.

10.3 Volatile Particle Remover (VPR)

The VPR shall be used to define the nature of the particles to be measured.

10.3.1 Description

The VPR provides heated dilution, thermal conditioning of the sample aerosol, further dilution for selection of particle number concentration and cooling of the sample prior to entry into the particle number counter.

10.3.2 Elements of the VPR

The VPR shall comprise the following elements:

10.3.2.1 First Particle Number Diluter (PND_1)

The first particle number dilution device shall be specifically designed to dilute particle number concentration and operate at a (wall) temperature of 150°C - 400°C. The wall temperature setpoint should not exceed the wall temperature of the ET (paragraph 10.3.2.2.). The diluter should be supplied with HEPA filtered dilution air and be capable of a dilution factor of 10 to 200 times. For the Golden Engine, the dilution factor of this diluter; $PNDF_1$ will be provided by the Golden Engineer and replicated at subsequent sites. For additional engines, the dilution ratio will be determined by experimentation and agreed with the GE and PMA.

10.3.2.2 Evaporation Tube (ET)

The entire length of the ET shall be controlled to a wall temperature greater than or equal to that of the first particle number dilution device and the wall temperature held at a fixed value between 300 °C and 400 °C.

10.3.2.3 Second Particle Number Diluter (PND_2)

PND_2 shall be specifically designed to dilute particle number concentration. The diluter shall be supplied with HEPA filtered dilution air and be capable of maintaining a single dilution factor within a range of 10 to 30 times. The dilution factor of PND_2 shall be selected in the range between 10 and 15 such that particle number concentration downstream of the second diluter is less than the upper threshold of the single particle count mode of the PNC and the gas temperature prior to entry to the PNC is <35°C.

10.3.3 Performance

The VPR shall achieve >99.0 per cent vaporisation of 30nm tetracontane ($CH_3(CH_2)_{38}CH_3$) particles, with an inlet concentration of $\geq$10,000 cm^{-3}, by means of heating and reduction of partial pressures of the tetracontane. It shall also achieve a particle concentration reduction factor (f_r)† for particles of 30nm and 50nm electrical mobility diameters, that is no more than 30 per cent and 20 per cent respectively higher, and no more than 5 per cent lower than that for particles of 100nm electrical mobility diameter for the VPR as a whole.

10.3.4 Performance of Other Particle Sampling and Transport System Elements: GPMS

The outlet tube (OT) conducting the diluted sample from the VPR to the inlet of the PNC shall have the following properties

- It shall have an internal diameter of ≥ 4 mm
- Sample Gas flow through the POT shall have a residence time of ≤ 0.8 seconds

Any other sampling configuration for the OT for which equivalent particle penetration for particles of 30nm electrical mobility diameter can be demonstrated will be considered acceptable.

10.4 Particle Counter (Particle Number Measurement Unit, PNC)

The particle counter is used to determine the number concentration of solid particles in a diluted sample of engine exhaust aerosol continuously drawn from the CVS.

10.4.1 PNC Performance Characteristics

- Operate under full flow operating conditions.
- Have a counting accuracy of +/- 10 per cent across the range 1 cm^{-3} to the upper threshold of the single particle count mode of the PNC against a traceable standard. At concentrations below 100cm^{-3} measurements averaged over extended sampling periods may be required to demonstrate the accuracy of the PNC with a high degree of statistical confidence.
- Have a readability of at least 0.1 particles cm^{-3} at concentrations below 100cm^{-3}.
- Have a linear response to particle concentrations over the full measurement range in single particle count mode.
- Have a data reporting frequency equal to or greater than 0.5 Hz.
- Have a T90 response time over the measured concentration range of less than 5s.
- Incorporate a coincidence correction function up to a maximum 10 per cent correction, and may make use of an internal calibration factor as determined in paragraph 2.1.3, but shall not make use of any other algorithm to correct for or define the counting efficiency. For the 3010Ds of the SPCSs the correction will be done externally
- Have counting efficiencies at particle sizes of 23nm (+/-1nm) and 41nm (+/-1nm) electrical mobility diameter of 50% (+/-12%) and >90% respectively. These counting efficiencies may be achieved by internal (for example; control of instrument design) or external (for example; size pre-classification) means.
- The PNC working liquid, shall be replaced at the frequency specified by the instrument manufacturer. At least 2.5 litres of the working fluid, per PNC, shall be provided for the test work.

† To be certificated by the manufacturer

- The sum of the residence time of the PTS, VPR and OT plus the T90 response time of the PNC shall be no greater than 20 s.

10.5 Sampling lines

It is recommended that all sampling lines be of stainless steel composition with conductive silicone tubing and TYGON (specifically R3603) are also acceptable. Sampling lines shall contain smooth internal surfaces and be of minimal length. Sharp bends and abrupt changes in section should be avoided in all sampling lines.

10.6 Calibration of Particle Number Measurement Systems

Calibration requirements for the PNC and VPR, including the calculation of the particle concentration reduction factor, can be found in the following documents, supplied with this guide:

- PNC: Particle Number Counter Calibration Procedure, Report to the Department for Transport; ED47382004/PNC, AEA Technology Issue 5, December 2007
- VPR: Volatile Particle Remover Calibration Procedure, Report to the Department for Transport; ED47382004/VPR, AEA Technology Issue 5, December 2007
- ECE/TRANS/WP.29/GRPE/2007/8/Rev.1

10.6.1 Golden Particle Number Measurement Systems

Prior to commencement of the test programme, the GPMSs will be fully calibrated by the instrument suppliers to meet the required specifications.

10.6.2 Alternative Measurement Systems For Particles

For Alternative Systems (ALT-SYS) in the VE_HD and for all systems in the RR_HD, test laboratories shall propose their own specific particle number measurement systems for measurement from the CVS and partial flow systems. In the VE_HD, alternative systems installations will be subject to approval by the GE and/or PMA.

Alternative Systems shall comply with the sections of this document and provide appropriate certification to ensure performance and calibration of the systems meet the required specification: sections 10.2.1, 10.2.3, 10.3 (including all sub-sections), 10.4 (including all sub-sections), 10.5 (including all sub-sections).

11. TEST PROCEDURES

11.1 Test Matrix

Testing shall be undertaken strictly according to the requirements and order stated in the test matrix.

A test matrix addressing 8 cold start WHTC (C-WHTC), 8 hot start WHTC preceded by a 10 minute soak (H-WHTC_10), 8 ETC, 8 WHSC and 8 ESC cycles during two week's testing in a single laboratory is shown in Table 1 below.

Table 1: Example Test Matrix, Heavy Duty Testing

Previous lab	Day 0	Days 1-7	Day 8
	oil change	IFV	IFV
	2h ESC Mode 10	cold WHTC	cold WHTC
	3 x ETC	10 minute soak	10 minute soak
		hot WHTC	hot WHTC
		10 minutes at WHSC mode 9	10 minutes at WHSC mode 9
		WHSC	WHSC
		CP	CP
		ETC	ETC
		CP	CP
		ESC	ESC
*2 hours at ESC Mode 10	Precon	Precon	*2 hours at ESC Mode 10

ESC - European Steady State Cycle for emissions measurement [30 min]
ETC - European Transient Cycle for emissions measurement [30 min]
WHTC - World Harmonised Steady State Cycle for emissions measurement [30 min]
WHTC - World Harmonised Transient Cycle for emissions measurement [30 min]
IFV - Instrument Functional Verification
CP - Continuity Protocol
Precon - 15 miuntes ESC mode 10, 30 minutes ESC mode 7
* DPF regeneration only required if oil change and conditioning not performed

11.2 Preparation of the Engine

Engines shall be prepared in accordance with R49 and good engineering practice for emissions testing. The fuel and lube oil used shall be as specified in Section 4 of this document.

11.2.1 Instrumentation

The engine and exhaust system will be suitably instrumented for exhaust and catalyst temperatures, and DPF pressure drop and backpressure. These shall be recorded from each emissions cycle and during the Mode 10 conditioning.

11.3 Dynamometer Preparation

The engine shall be mapped across the speed range according to R49, and the ESC, WHSC[‡] / ETC / WHTC cycle reference speeds (n_{lo} , n_{hi} and n_{ref}) once per engine and cycle set-points shall be calculated.

The dynamometer control parameters shall be adjusted as necessary to meet the test cycle verification requirements of R49.

The results of the power map and cycle verification tests shall be reviewed by the Project Manager & Golden Engineer.

11.4 Test and Conditioning Protocols

Prior to any testing, the exhaust system, transfer tube and dilution systems shall be thermally purged. This shall be achieved by operating the engine at ESC mode 10 for 15 minutes the previous day. The flow settings on the partial flow system may be adjusted for this procedure, so that an elevated tunnel temperature is achieved (52-70°C) whilst remaining within safe operational limits.

[‡] Where applicable

Specific requirements for the preconditioning are specified in Section 5.7.2.

Throughout each day's testing, the engine shall be stabilised between tests through the continuity protocol (Section 5.7.4).

Warm-up and pre-conditioning procedures shall be carried out on the measurement and sampling systems as appropriate. System verification and calibration checks as required shall be performed daily.

11.5 Test Procedures – Gaseous Emissions

For the full flow dilution system, gaseous emissions shall be determined from diluted exhaust according to the procedures described in the R49.

Gaseous emissions shall also be determined directly from the raw exhaust according to R49 for steady-state cycles and ISO 16183 for transient cycles.

11.5.1 Preparation for the Test

Prior to the test the gaseous emissions analysers shall be calibrated using suitable reference gases, on the ranges that will be used during the test. The zero and span readings shall be recorded.

11.5.1.1 Partial Flow Dilution only

Prior to the test the response times of the gas analysers and exhaust flow measurement devices shall be determined in accordance with ISO 16183.

11.5.2 During the test

During each test the data from the gaseous emissions analysers shall be recorded with a logging rate of at least 0.5 Hz for the full flow (dilute) analysers, and 2 Hz for the raw emissions analysers.

11.5.2.1 Full flow Dilution only

At the start of the test, the bag-sampling unit shall be switched to start filling the sample and ambient bags.

11.5.3 Post-test : Full flow dilution

At the end of the test the bag sampling unit shall be stopped.

Following the test the zero and span readings of the gaseous emissions analysers shall be checked and recorded. The analysers shall then be calibrated using suitable reference gases, on the ranges that will be used for analysing bag samples. The emissions concentrations in the bag samples shall then be measured and recorded.

11.6 Test Procedures – Particulate Emissions: Full and Partial Flow

11.6.1 Preparation of the Partial Flow Dilution System

Prior to the test, the flow settings for the partial flow dilution system shall be determined, as required to meet the sampling requirements of Section 8. If necessary, a pre-test cycle shall be run and the exhaust flow data recorded by the partial flow sampling system.

11.6.2 Preparation for the Test (filter weighing, switch to bypass)

Prior to the test the test filters shall be conditioned in the weighing room. The initial filter masses shall be measured and recorded on a microbalance with 1µg or better resolution. Temperature and humidity during sample and reference filter weighings shall be recorded.

During the system stabilisation procedure, the particulate sampling systems shall be operated on bypass.

11.6.3 During the test (switch to sample)

At the start of the test, the particulate sampling systems shall be switched from the bypass to the sample filters.

11.6.4 Post-test (condition and weigh filters)

On completion of the test, the particulate sampling systems shall be stopped. The filter holders shall be removed and the filters returned to the weighing room or chamber for conditioning.

After conditioning the filters shall be weighed and the masses recorded. Temperature and humidity during sample and reference filter weighings shall be recorded.

It is recommended that the sample filters are not weighed until at least 4 hours have elapsed since they were placed in the weighing room or chamber.

11.7 Test Procedures – Particle Emissions

The following sections describe the procedures that shall be followed by each laboratory in receiving, installing and operating Particle Measurement Systems.

11.7.1 Equipment Arrival at Laboratory (GPMS Only)

On arrival at the laboratory, all equipment shall be unpacked and inspected for damage. If any components are missing or damaged the Golden Engineer and Project Manager shall be informed.

11.7.1.1 List Of Equipment/Components

The equipment accompanying the VE_HD Golden Engine that will be circulated between laboratories is summarised in Table 2.

Table 2: Components for Circulation Around Participating Laboratories

Engine		

Lubricant		
Filter for the lubricant change		
TX40 filters		
SPCS-19 with lap top		
SPCS-20 with lap top		
4m heated line with controller		
2 T connections for SPCSs (HEPA/sample)		
3790 CPC		
Cyclone		
Sampling tube (insulated)		
Pump with orifice for 90 lpm		

Labs should provide filtered pressurised air for SPCS (6 bar, 25 lpm each), LAN and RS232 cables (for each SPCS) of enough length to move the laptops outside the test cell, power for the SPCS units (380V 32 A supplies fed by 220V 16A transformers for each SPCS), feedback filtered and HC scrubbed air for the partial flow sampling systems (3.5 lpm) that cannot take into account the extracted flow for particle number measurement. Around 2 l of butanol for the CPCs.

11.7.1.2 Initial Checks and Assembly of GPMS [For each system]

The instrument Functional Verification at the beginning of the day includes:

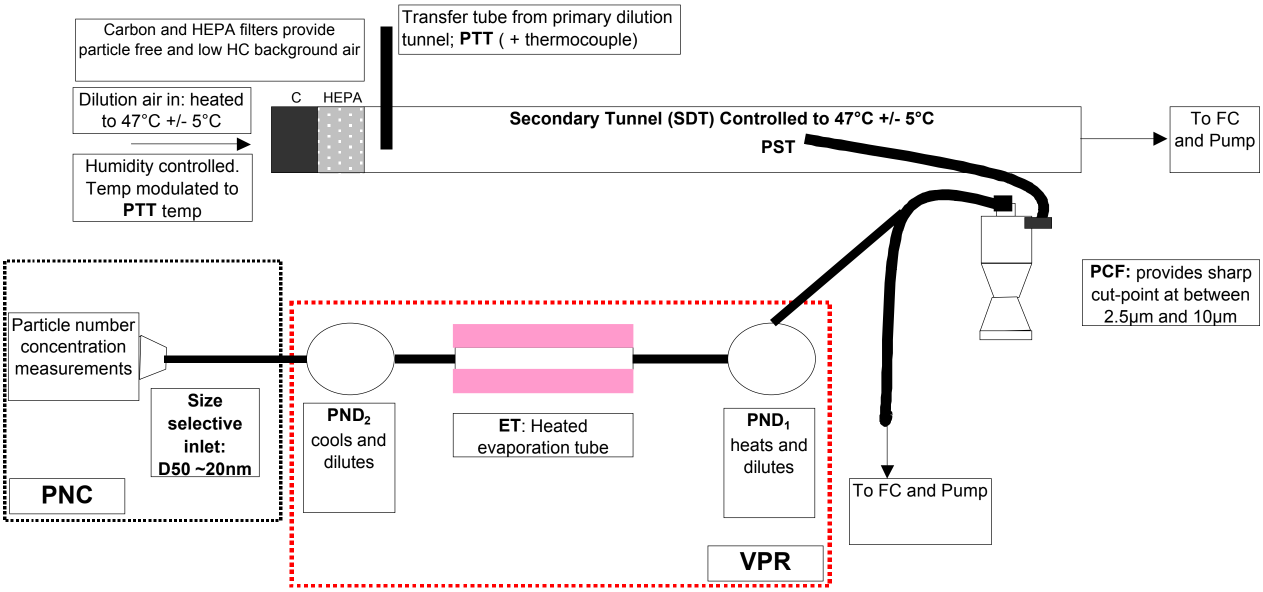
- Warm up of both SPCS 30 min
- Connect HEPA filter at the inlet
- Open laptops and software, CPC check
- File→ Sample
- Set correct values (dilution air and dilution factor)
- If everything ok, connect SPCS to dilution tunnel or partial flow sampling system

More details will be supplied in the "daily check" spreadsheet that will be provided by JRC.

Dilution factor settings for PND_1 and PND_2 have been determined in the first laboratory. These shall be employed for the first test on VE-E1 at each subsequent laboratory. The DFs for the first and second diluters are as fiollows (for both SPCS units):

- PNDF1 =10, dilution air=11 (11.5 for SPCS-20)
- PNDF2 = 15, dilution air=10.5
- Bypass=2

Figure 4: Schematic Layout for GPMS



11.7.2 Preparation for Daily Protocol: Instrument Warm-up and Daily Verification Exercises

The following will be undertaken for GPMS and ALT_SYS in both the VE_HD and RR_HD.

First thing each morning all the elements of the particle measurement systems will be activated, and left for at least 30 minutes to stabilise. This includes pumps, heaters, diluters and particle counters. The temperature of heated sections will be inspected to ensure compliance with the requirements of Section 8.2.2.

Instrument manufacturers of the various elements of the particle measurement systems will provide calibration certification for the diluter(s), evaporation tube and particle counter employed for PMP particle number measurements. These data will be appropriate to address those requirements for primary calibration of instrumentation defined in the draft R49 regulation. However, it should be noted that the regulations are drafted with the intention that instrument manufacturers will have time to develop entirely suitable equipment and at this time exact compliance of all instrumentation with the draft regulations may not be possible.

Therefore the main issues are that operation consistent with the baseline calibrations is ensured, and that repeatable and valid operation can be demonstrated and maintained. In order to ensure this, regular calibration checks shall be performed. These are summarised as follows:

11.7.2.1 Verification of Free Sample Flow and Flow rate – The particle measurement systems shall be checked for physical blockages and the CPC flow rate checked. The measured flow rate shall be within 5% of the instrument's nominal value.

11.7.2.2 Verification of Counter Zero – An initial concentration of around 10000/cm^3 (e.g. background number concentration) will be applied to any PNCs via a HEPA filter and using clean, particle free tubing. Testing shall commence if the measured particle count is less than 0.2/cm^3

11.7.2.3 Verification of System Contamination and Leak Integrity – After heating the evaporation tube a HEPA filter will be applied to the inlet of the diluter and particle number concentration through the whole system measured using PNC_GOLD. Testing can commence providing the measured particle count is less than 0.5/cm^3.

The particle measurement system shall then be fully reassembled. A sample line connected downstream of the particle pre-classifier shall then be connected to the inlet of the VPR. Sampling shall commence.

11.8 Troubleshooting

In the VE_HD any problems encountered during the daily verification exercise should be referred to the Golden Engineer or Project Manager who will make a decision on whether to proceed with the test programme.

In the RR_HD, the particle measurement system manufacturer shall be consulted.

11.9 During the test

During each emissions test, particle number concentrations from the PNC shall be measured continuously in the particle sampling system with a frequency of >=0.5 Hz. The average concentrations shall be determined by integrating the analyser signals over the entire period of the test cycle, with data recorded electronically. The system response time shall be ≤20 s, and shall be co-ordinated with primary tunnel (CVS) flow fluctuations and sampling time/test cycle offsets, if necessary.

11.10 Post-test (where specified in the Test Matrix)

The following instrument function verification tests will be performed according to the demands to the daily test protocol:

Verification of Free Sample Flow – The particle measurement system shall be checked for physical blockages. (Section 11.7.2.1). The PNC flow rate will be checked.

Verification of Counter Zero – An initial concentration of around 10000/cm^3 (e.g. background number concentration) will be applied to the PNC via a HEPA filter and using clean, particle free tubing. Testing shall commence if the measured particle count is less than 0.2/cm^3. (Section 11.7.2.2)

Data from each test will be inspected to determine whether instantaneous concentrations at the PNC have exceeded 10^4 particles/cm^3 during the emissions cycle. If this has occurred, the dilution ratios of PND1 and PND2 may need to be modified. In the PMP, these modifications shall be discussed with and approved by the project manager or golden engineer prior to the next test on that engine.

If necessary, the PND_1 and PND_2 diluters should be cleaned at this stage. It is not anticipated that this will be required with tests on a DPF equipped engine, but laboratories testing conventional diesels may encounter contamination issues.

11.10.1 Repeat Daily Verification Exercise

Following the first block of tests, correct VPR functional temperatures will be established and the checks described in Sections 11.7.2.1 to 11.7.2.3 inclusive conducted.

11.11 VE_HD only: On Completion Of The Test Matrix

On completion of all testing, the GPMS and engines will be prepared for despatch to the next laboratory for testing.

However, prior to testing at the first laboratory and subsequent to testing at some additional laboratories, the VPR will be returned to JRC for a performance check. This check will determine key performance parameters of the VPR.

These performance evaluations will be undertaken during the shipping process for the Golden Engine and shall not delay the test programme. The decision as to when the VPR will be returned to the calibration facility will depend on the number of participating laboratories and will be at the discretion of the project manager and Golden Engineer.

12. DATA CAPTURE AND PRESENTATION IN CORRECT FORMAT

All data will be presented in a format compatible with Microsoft Excel. A standard spreadsheet for these data will be provided, prior to the commencement of testing, by the Project manager.

12.1 Regulated Emissions

Summary regulated gaseous emissions, carbon dioxide and fuel consumption data shall be quoted as g/kWh according to current European regulations. Data will be presented from complete ETC, WHTC cycles as well as WHSC, ESC and steady states where appropriate.

12.2 Particulate Mass

Summary particulate mass data shall be quoted as g/kWh according to current European regulations. Data will be presented from the complete emissions cycles.

12.3 Particle Number

Summary particle number data shall be quoted as number/kWh and number/s. Data will be presented from individual urban, rural and motorway phases and from the combined, ETC and WHTC cycles.

Data from the ESC and WHSC cycle shall be presented per mode in particles/s and per kWh for the weighted cycle.

In addition, logged particle number data, time-aligned and synchronised with the regulated gaseous emissions shall be presented in a time-aligned format on a CD-R.

12.4 Diagnostic Data

Testbed data shall be logged continuously throughout each test at a rate of at least 1Hz in order to provide diagnostic capability if repeatability or reproducibility of engine tests is poor. These data shall be employed to interpret catalytic activity and engine management control. All logged data shall be presented in a time-aligned format on a CD-R. As a minimum these data shall include:

- engine speed and torque
- intake, exhaust and catalyst temperatures and pressures
- coolant and oil temperatures and pressures
- DPF backpressure
- dilute gaseous emissions and CVS flow rate
- raw gaseous emissions and exhaust / air / fuel flow rate
- partial flow dilution system sample flow rate and split ratio

Appendix 1a: Lubricant Change and Flush Protocol (VE_HD)

- Commence oil drain
- Allow drain to continue until flow stops
- Fill with 15 +/ - 1 litre of replacement oil
- Start engine and idle (ESC Mode 1) for 30 seconds
- Run the engine up to ESC mode 4
- Allow the engine speed and load to settle for ~15 seconds
- Return to idle and allow to settle ~15 seconds
- Repeat the ESC Mode 4 / Idle cycling 5 times
- Drain the oil down and remove the oil filter.
- Refill with 15 litres of new oil and new filter filled with oil

Lubricant preconditioning/ageing

- 3 times: 10 min at mode 10 (ESC) plus 10 min at low load (800 rpm / 200 Nm)
- 4 times: 15 min at mode 10 (ESC) plus 5 min at idle.

Appendix 1b: Lubricant Change and Flush Protocol (RR_HD)

To be added during the programme if required

Appendix 2: Specification of Reference Fuel (RF06)

TOTAL Additifs et Carburants Spéciaux

Place du Bassin - 69700 Givors
Tél: +33 4 72 49 84 10 - Fax: +33 4 72 49 84 20

APPELATION : gazole type CEC RF 06-03 PMP		Reference of analysis : 9460	
N° of samples : 0	N° of batch : B7277051	Date: 05/06/2007	
COMPLIANCE CERTIFICATE	☐	BULLETIN OF ANALYSIS	☒

DIESEL FUEL	RESULTS	UNITS	METHODS
PHYSICAL DATA			
Density 15 °C	834.9	kg/m3	EN ISO 3675-98
Viscosity 40°C	2.654	cSt	ASTM D 445
DISTILLATION			
IBP	171	°C	ASTM D 86
5 % Vol	196	°C	ASTM D 86
10 % Vol	204	°C	ASTM D 86
20 % Vol	224	°C	ASTM D 86
30 % Vol	242	°C	ASTM D 86
40 % Vol	262	°C	ASTM D 86
50 % Vol	277	°C	ASTM D 86
60 % Vol	291	°C	ASTM D 86
70 % Vol	304	°C	ASTM D 86
80 % Vol	318	°C	ASTM D 86
90 % Vol	334	°C	ASTM D 86
95 % Vol	346	°C	ASTM D 86
FBP	357	°C	ASTM D 86
E 250 °C	33.8	%Vol	ASTM D 86
E 350 °C	96.1	%Vol	ASTM D 86
CETANE NUMBER			
Cetane number	53.1	index	ISO 5165-98
Flashpoint	67	°C	EN 22719
COMPOSITION			
Poly-aromatics	5.1	%Mass	IP 391
COLD BEHAVIOUR			
Cold Filter Plugging Point (CFPP)	-17	°C	EN 116, NF M 07042
COMBUSTION			
Lower Calorific Value	46.4	MJ/kg	ASTM D 4868
%C, %H, %O	86.7/13.2:<0.2	%Mass	GC / Calculated
COMPLEMENTARY DATA			
Oxidation stability	2	g/m3	ISO 12205
Copper Strip Corrosion at 50 °C	1	merit	ISO 2160
Sulfur content	7	mg/kg	ISO 4260 / ISO 8754
Conradson Carbon Residue on 10% Dist.Residue	<0.2	%Pds/%mass	ISO 10370
Ash content	<0.001	%Pds/%mass	ISO 6245
Neutralisation Number	<0.02	mg KOH/g	ASTM D 974
Sediment content	6	mg/kg	ASTM D 2276
Fatty Acid Methyl Ester	<0.2	%Mass	
Water content	30	mg/kg	EN ISO 12937
HFRR 60°C	310	µm	ISO/DIS 12156