

SCHEDULE 3

Regulation 2(3) and 9(1)(a)

(Annex III to Directive 97/68/EC)

TEST PROCEDURE

1. INTRODUCTION

1.1. This Annex describes the method of determining emissions of gaseous and particulate pollutants from the engines to be tested.

1.2. The test shall be carried out with the engine mounted on a test bench and connected to a dynamometer.

2. TEST CONDITIONS

General Requirements

2.1. All volumes and volumetric flow rates shall be related to 273 K (0°C) and 101.3 kPa.

2.2. Engine test conditions

2.2.1. The absolute temperature T_a of the engine intake air expressed in Kelvin, and the dry atmospheric pressure p_s , expressed in kPa, shall be measured, and the parameter f_a shall be determined according to the following provisions:

Naturally aspirated and mechanically supercharged engines:

$$f_a = \left(\frac{99}{p_s} \right) \left(\frac{T}{298} \right)^{0.7}$$

Turbocharged engine with or without cooling of the intake air:

$$f_a = \left(\frac{99}{p_s} \right)^{0.7} \times \left(\frac{T}{298} \right)^{1.5}$$

Test validity

2.2.2. For a test to be recognised as valid, the parameter f_a shall be such that:

$$0.98 \leq f_a \leq 1.02$$

Engines with charge air cooling

2.2.3. The temperature of the cooling medium and the temperature of the charge air have to be recorded.

Engine air inlet system

2.3 The test engine shall be equipped with an air inlet system presenting an air inlet restriction at the upper limit specified by the manufacturer for a clean air cleaner at the engine operating conditions as specified by the manufacturer which result in maximum air flow.

A test shop system may be used, provided it duplicates actual engine operating conditions.

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Engine exhaust system

2.4 The test engine shall be equipped with an exhaust system presenting an exhaust back pressure at the upper limit specified by the manufacturer for the engine operating conditions which result in maximum declared power.

Cooling system

2.5 An engine cooling system with sufficient capacity to maintain the engine at normal operating temperatures prescribed by the manufacturer.

Lubricating oil

2.6 Specifications of the lubricating oil used for the test shall be recorded and presented with the results of the test.

Test fuel

2.7 The fuel shall be the reference fuel specified in Annex IV.

The cetane number and the sulphur content of the reference fuel used for test shall be recorded at sections 1.1.1 and 1.1.2 respectively of Annex VI, Appendix 1.

The fuel temperature at the injection pump inlet shall be 306-316 K (33-43°C).

Determination of dynamometer settings

2.8 The settings of inlet restriction and exhaust pipe backpressure shall be adjusted to the manufacturer's upper limits, in accordance with sections 2.3 and 2.4.

The maximum torque values at the specified test speeds shall be determined by experimentation in order to calculate the torque values for the specified test modes. For engines which are not designed to operate over a speed range on a full load torque curve, the maximum torque at the test speeds shall be declared by the manufacturer.

The engine setting for each test mode shall be calculated using the formula:

$$S = \left((P_M + P_{AE}) \times \frac{L}{100} \right) - P_{AE}$$

If the ratio,

$$\frac{P_{AE}}{P_M} \geq 0.03$$

the value of P_{AE} may be verified by the technical authority granting type approval.

3. TEST RUN

Preparation of the sampling filters

3.1 At least one hour before the test, each filter (pair) shall be placed in a closed, but unsealed petri dish and placed in a weighing chamber for stabilization. At the end of the stabilization period, each filter (pair) shall be weighed and the tare weight shall be recorded. The filter (pair) shall then be stored in a closed petri dish or filter holder until needed for testing. If the filter (pair) is not used within eight hours of its removal from the weighing chamber, it must be reweighed before use.

Installation of the measuring equipment

3.2 The instrumentation and sample probes shall be installed as required. When using a full flow dilution system for exhaust gas dilution, the tailpipe shall be connected to the system.

Starting the dilution system and engine

3.3 The dilution system and the engine shall be started and warmed up until all temperatures and pressures have stabilized at full load and rated speed (section 3.6.2).

Adjustment of the dilution ratio

3.4 The particulate sampling system shall be started and running on bypass for the single filter method (optional for the multiple filter method). The particulate background level of the dilution air may be determined by passing dilution air through the particulate filters. If filtered dilution air is used, one measurement may be done at any time prior to, during, or after the test. If the dilution air is not filtered, measurements at a minimum of three points, after the starting, before the stopping, and at a point near the middle of the cycle, are required, and the values averaged.

The dilution air shall be set to obtain a maximum filter face temperature of 325 K (52°C) or less at each mode. The total dilution ratio shall not be less than four.

For the single filter method, the sample mass flow rate through the filter shall be maintained at a constant proportion of the dilute exhaust mass flow rate for full flow systems for all modes. This mass ratio shall be within $\pm 5\%$, except for the first 10 seconds of each mode for systems without bypass capability. For partial flow dilution systems with single filter method, the mass flow rate through the filter shall be constant within $\pm 5\%$ during each mode, except for the first 10 seconds of each mode for systems without bypass capability.

For CO₂ or NO_x concentration controlled systems, the CO₂ or NO_x content of the dilution air must be measured at the beginning and at the end of each test. The pre and post test background CO₂ or NO_x concentration measurements of the dilution air must be within 100 ppm or 5 ppm of each other, respectively.

When using a dilute exhaust gas analysis system, the relevant background concentrations shall be determined by sampling dilution air into a sampling bag over the complete test sequence.

Continuous (non bag) background concentration may be taken at the minimum of three points, at the beginning, at the end, and a point near the middle of the cycle and averaged. At the manufacturer's request background measurements may be omitted.

Checking the analysers

3.5. The emission analysers shall be set at zero and spanned.

3.6. Test cycle

3.6.1. Specification A of machinery according to Section I of Annex 1:

3.6.1.1. The following 8-mode cycle(1) shall be followed in dynamometer operation on the test engine:

| Mode Number | Engine Speed | Load (%) | Weighting Factor |
|-------------|--------------|----------|------------------|
| 1 | Rated | 100 | 0.15 |
| 2 | Rated | 75 | 0.15 |

(1) Identical with C1 cycle of the draft ISO 8178-4 standard.

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| Mode Number | Engine Speed | Load (%) | Weighting Factor |
|-------------|--------------|----------|------------------|
| 3 | Rated | 50 | 0.15 |
| 4 | Rated | 10 | 0.1 |
| 5 | Intermediate | 100 | 0.1 |
| 6 | Intermediate | 75 | 0.1 |
| 7 | Intermediate | 50 | 0.1 |
| 8 | Idle | — | 0.15 |

Conditioning of the Engine

3.6.2. Warming up of the engine and the system shall be at maximum speed and torque in order to stabilize the engine parameters according to the recommendations of the manufacturer.

Note: The conditioning period should also prevent the influence of deposits from a former test in the exhaust system. There is also a required period of stabilization between test points which has been included to minimise point to point influences.

Test sequence

3.6.3 The test sequence shall be started. The test shall be performed in the order of the mode numbers as set out above for the test cycle.

During each mode of the test cycle after the initial transition period, the specified speed shall be held to within $\pm 1\%$ of rated speed or $\pm 3 \text{ min}^{-1}$ whichever is greater except for low idle which shall be within the tolerances declared by the manufacturer. The specified torque shall be held so that the average over the period during which the measurements are being taken is within $\pm 2\%$ of the maximum torque at the test speed.

For each measuring point a minimum time of 10 minutes is necessary. If for the testing of an engine, longer sampling times are required for reasons of obtaining sufficient particulate mass on the measuring filter the test mode period can be extended as necessary.

The mode length shall be recorded and reported.

The gaseous exhaust emission concentration values shall be measured and recorded during the last three minutes of the mode.

The particulate sampling and the gaseous emission measurement should not commence before engine stabilization, as defined by the manufacturer, has been achieved and their completion must be coincident.

The fuel temperature shall be measured at the inlet to the fuel injection pump or as specified by the manufacturer, and the location of measurement recorded.

Analyser response

3.6.4. The output of the analysers shall be recorded on a strip chart recorder or measured with an equivalent data acquisition system with the exhaust gas flowing through the analysers at least during the last three minutes of each mode. If bag sampling is applied for the diluted CO and CO₂ measurement (see Appendix 1, section 1.4.4), a sample shall be bagged during the last three minutes of each mode, and the bag sample analysed and recorded.

Particulate sampling

3.6.5. The particulate sampling can be done either with the single filter method or with the multiple filter method (Appendix 1, section 1.5). Since the results of the methods may differ slightly, the method used must be declared with the results.

For the single filter method the modal weighting factors specified in the test cycle procedure shall be taken into account during sampling by adjusting flow rate and/or sampling time, accordingly.

Sampling must be conducted as late as possible within each mode. The sampling time per mode must be at least 20 seconds for the single filter method and at least 60 seconds for the multi-filter method. For systems without bypass capability, the sampling time per mode must be at least 60 seconds for single and multiple filter methods.

Engine conditions

3.6.6. The engine speed and load, intake air temperature, fuel flow and air or exhaust gas flow shall be measured for each mode once the engine has been stabilized.

If the measurement of the exhaust gas flow or the measurement of combustion air and fuel consumption is not possible, it can be calculated using the carbon and oxygen balance method (see Appendix 1, section 1.2.3).

Any additional data required for calculation shall be recorded (see Appendix 3, sections 1.1 and 1.2).

Re-checking the analysers

3.7. After the emission test a zero gas and the same span gas will be used for re-checking. The test will be considered acceptable if the difference between the two measuring results is less than 2%.

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Appendix 1

MEASUREMENT AND SAMPLING PROCEDURES

1. Gaseous and particulate components emitted by the engine submitted for testing shall be measured by the methods described in Annex V. The methods of Annex V describe the recommended analytical systems for the gaseous emissions (section 1.1) and the recommended particulate dilution and sampling systems (section 1.2).

Dynamometer specification

1.1 An engine dynamometer with adequate characteristics to perform the test cycle described in Annex III, section 3.6.1 shall be used. The instrumentation for torque and speed measurement shall allow the measurement of the shaft power within the given limits. Additional calculations may be necessary.

The accuracy of the measuring equipment must be such that the maximum tolerances of the figures given in section 1.3 are not exceeded.

Exhaust gas flow

1.2 The exhaust gas flow shall be determined by one of the methods mentioned in sections 1.2.1 to 1.2.4.

Direct measurement method

1.2.1 Direct measurement of the exhaust flow by flow nozzle or equivalent metering system (for detail see ISO 5167).

Note: Direct gaseous flow measurement is a difficult task. Precautions must be taken to avoid measurement errors which will impact emission value errors.

Air and fuel measurement method

1.2.2 Measurement of the air flow and the fuel flow.

Air flow-meters and fuel flow-meters with an accuracy defined in section 1.3 shall be used.

The calculation of the exhaust gas flow is as follows:

$$G_{EXHW} = G_{AIRW} + G_{FUEL} \text{ (for wet exhaust mass)}$$

or

$$V_{EXHD} = V_{AIRD} - 0.766 \times G_{FUEL} \text{ (for dry exhaust volume)}$$

or

$$V_{EXHW} = V_{AIRW} + 0.746 \times G_{FUEL} \text{ (for wet exhaust volume)}$$

Carbon balance method

1.2.3 Exhaust mass calculation from fuel consumption and exhaust gas concentrations using the carbon balance method (see Annex III, Appendix 3).

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Total dilute exhaust gas flow

1.2.4 When using a full flow dilution system, the total flow of the dilute exhaust (G_{TOTW} , V_{TOTW}) shall be measured with a PDP or CFV—Annex V, section 1.2.1.2. The accuracy shall conform to the provisions of Annex III, Appendix 2, section 2.2.

Accuracy

1.3 The calibration of all measurement instruments shall be traceable to national (international) standards and comply with the following requirements:

| <i>Number</i> | <i>Item</i> | <i>Permissible deviation (±values based on engines maximum values)</i> | <i>Permissible deviation (±values according to ISO 3046)</i> | <i>Calibration intervals (months)</i> |
|---------------|---|--|--|---|
| 1 | Engine speed | 2% | 2% | 3 |
| 2 | Torque | 2% | 2% | 3 |
| 3 | Power | 2% ⁽¹⁾ | 3% | not applicable |
| 4 | Fuel consumption | 2% ⁽¹⁾ | 3% | 6 |
| 5 | Specific fuel consumption | not applicable | 3% | not applicable |
| 6 | Air consumption | 2% ⁽¹⁾ | 5% | 6 |
| 7 | Exhaust gas flow | 4% ⁽¹⁾ | not applicable | 6 |
| 8 | Coolant temperature | 2K | 2K | 3 |
| 9 | Lubricant temperature | 2K | 2K | 3 |
| 10 | Exhaust gas pressure | 5% of maximum | 5% | 3 |
| 11 | Inlet manifold depressions | 5% of maximum | 5% | 3 |
| 12 | Exhaust gas temperature | 15K | 15K | 3 |
| 13 | Air inlet temperature (Combustion Air) | 2K | 2K | 3 |
| 14 | Atmospheric pressure | 0.5% of reading | 0.5% | 3 |

(1) The calculations of the exhaust emissions as described in this Directive are, in some cases, based on different measurement and/or calculation methods. Because of limited total tolerances for the exhaust emission calculation, the allowable values for some items, used in the appropriate equations, must be smaller than the allowed tolerances given in ISO 3046-3.

(2) Full flow systems—the CVS positive displacement pump or critical flow Venturi shall be calibrated following initial installation, major maintenance or as necessary when indicated by the CVS system verification described in Annex V.

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|---------------|--------------------------------|--|--|--|
| 15 | Intake air humidity (relative) | 3% | not applicable | 1 |
| 16 | Fuel temperature | 2K | 5K | 3 |
| 17 | Dilution tunnel temperatures | 1.5K | not applicable | 3 |
| 18 | Dilution air humidity | 3% | not applicable | 1 |
| 19 | Diluted exhaust gas flow | 2% of reading | not applicable | 24 (partial flow) (full flow) ⁽²⁾ |

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1.4 Determination of the gaseous components

General analyser specifications

1.4.1 The analysers shall have a measuring range appropriate for the accuracy required to measure the concentrations of the exhaust gas components (section 1.4.1.1). It is recommended that the analysers be operated such that the measured concentration falls between 15% and 100% of full scale.

If the full scale value is 155 ppm (or ppm C) or less or if read-out systems (computers, data loggers) that provide sufficient accuracy and resolution below 15% of full scale are used concentrations below 15% of full scale are also acceptable. In this case, additional calibrations are to be made to ensure the accuracy of the calibration curves—Annex III, Appendix 2, section 1.5.5.2.

The electromagnetic compatibility (EMC) of the equipment shall be on a level as to minimise additional errors.

Measurement error

1.4.1.1 The total measurement error, including the cross sensitivity to other gases—see Annex III, Appendix 2, section 1.9 shall not exceed $\pm 5\%$ of the reading or 3.5% of full scale, whichever is smaller. For concentrations of less than 100 ppm the measurement error shall not exceed $\pm 4\text{ppm}$.

Repeatability

1.4.1.2. The repeatability, defined as 2.5 times the standard deviation of 10 repetitive responses to a given calibration or span gas, must be no greater than $\pm 1\%$ of full scale concentration for each range used above 155 ppm (or ppm C) or $\pm 2\%$ of each range used below 155 ppm (or ppm C).

Noise

1.4.1.3. The analyser peak-to-peak response to zero and calibration or span gases over any 10-second period shall not exceed 2% of full scale on all ranges used.

Zero drift

1.4.1.4. The zero drift during a one-hour period shall be less than 2% of full scale on the lowest range used. The zero response is defined as the mean response, including noise, to a zero gas during a 30-seconds time interval.

Span drift

1.4.1.5. The span drift during a one hour period shall be less than 2% of full scale on the lowest range used. Span is defined as the difference between the span response and the zero response. The span response is defined as the mean response, including noise, to a span gas during a 30-seconds time interval.

Gas drying

1.4.2. The optional gas drying device must have a minimum effect on the concentration of the measured gases. Chemical dryers are not an acceptable method of removing water from the sample.

Analysers

1.4.3. Sections 1.4.3.1 to 1.4.3.5 of this Appendix describe the measurement principles to be used. A detailed description of the measurement systems is given in Annex V.

The gases to be measured shall be analysed with the following instruments. For non-linear analysers, the use of linearizing circuits is permitted.

Carbon monoxide (CO) analysis

1.4.3.1. The carbon monoxide analyser shall be of the non-dispersive infra-red (NDIR) absorption type.

Carbon dioxide (CO₂) analysis

1.4.3.2. The carbon dioxide analyser shall be of the non-dispersive infra-red (NDIR) absorption type.

Hydrocarbon (HC) analysis

1.4.3.3. The hydrocarbon analyser shall be of the heated flame ionization detector (HFID) type with detector, valves, pipework, etc, heated so as to maintain a gas temperature of 463 K (190°C) ± 10 K.

Oxides of nitrogen (NO_x) analysis

1.4.3.4. The oxides of nitrogen analyser shall be of the chemiluminescent detector (CLD) or heated chemiluminescent detector (HCLD) type with a NO₂/NO converter, if measured on a dry basis. If measured on a wet basis, a HCLD with a converter maintained above 333 K (60°C) shall be used, provided the water quench check (Annex III, Appendix 2, section 1.9.2.2) is satisfied.

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Sampling for gaseous emissions

1.4.4. The gaseous emissions sampling probes must be fitted at least 0.5m or three times the diameter of the exhaust pipe—whichever is the larger—upstream of the exit of the exhaust gas system as far as applicable and sufficiently close to the engine as to ensure an exhaust gas temperature of at least 343 K (70°C) at the probe.

In the case of a multicylinder engine with a branched exhaust manifold, the inlet of the probe shall be located sufficiently far downstream so as to ensure that the sample is representative of the average exhaust emissions from all cylinders. In multicylinder engines having distinct groups of manifolds, such as in a ‘V’-engine configuration, it is permissible to acquire a sample from each group individually and calculate an average exhaust emission. Other methods which have been shown to correlate with the above methods may be used. For exhaust emissions calculation the total exhaust mass flow of the engine must be used.

If the composition of the exhaust gas is influenced by any exhaust after-treatment system, the exhaust sample must be taken upstream of this device in the tests of stage I and downstream of the device in the tests of stage II. When a full flow dilution system is used for the determination of the particulates, the gaseous emissions may also be determined in the diluted exhaust gas. The sampling probes shall be close to the particulate sampling probe in the dilution tunnel (Annex V, section 1.2.1.2, DT and section 1.2.2, PSP). CO and CO₂ may optionally be determined by sampling into a bag and subsequent measurement of the concentration in the sampling bag.

Determination of the particulates

1.5. The determination of the particulates requires a dilution system. Dilution may be accomplished by a partial flow dilution system or a full flow dilution system. The flow capacity of the dilution system shall be large enough to completely eliminate water condensation in the dilution and sampling systems, and maintain the temperature of the diluted exhaust gas at or below 325 K (52°C) immediately upstream of the filter holders. De-humidifying the dilution air before entering the dilution system is permitted, if the air humidity is high. Dilution air pre-heating above the temperature limit of 303 K (30°C) is recommended, if the ambient temperature is below 293 K (20°C). However, the diluted air temperature must not exceed 325 K (52°C) prior to the introduction of the exhaust in the dilution tunnel.

For a partial flow dilution system, the particulate sampling probe must be fitted close to and upstream of the gaseous probe as defined in section 4.4 and in accordance with Annex V, section 1.2.1.1, figures 4-12 EP and SP.

The partial flow dilution system has to be designed to split the exhaust stream into two fractions, the smaller one being diluted with air and subsequently used for particulate measurement. From that it is essential that the dilution ratio be determined very accurately. Different splitting methods can be applied, whereby the type of splitting used dictates to a significant degree the sampling hardware and procedures to be used (Annex V, section 1.2.1.1).

To determine the mass of the particulates, a particulate sampling system, particulate sampling filters, a microgram balance and a temperature and humidity controlled weighing chamber are required.

For particulate sampling, two methods may be applied:

- *the single filter method* uses one pair of filters (see section 1.5.1.3 of this Appendix) for all modes of the test cycle. Considerable attention must be paid to sampling times and flows during the sampling phase of the test. However, only one pair of filters will be required for the test cycle.

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- *the multiple filter method* dictates that one pair of filters (see section 1.5.1.3 of this Appendix) is used for each of the individual modes of the test cycle. This method allows more lenient sample procedures but uses more filters.

1.5.1. Particulate sampling filters

Filter specification

1.5.1.1. Fluorocarbon coated glass fibre filters or fluorocarbon based membrane filters are required for certification tests. For special applications different filter materials may be used. All filter types shall have a 0.3µm DOP (di-octylphthalate) collection efficiency of at least 95% at a gas face velocity between 35 and 80 cm/s. When performing correlation tests between laboratories or between a manufacturer and an approval authority, filters of identical quality must be used.

Filter size

1.5.1.2. Particulate filters must have a minimum diameter of 47 mm (37 mm stain diameter). Larger diameter filters are acceptable (section 1.5.1.5).

Primary and back-up filters

1.5.1.3. The diluted exhaust shall be sampled by a pair of filters placed in series (one primary and one back-up filter) during the test sequence. The back-up filter shall be located no more than 100 mm downstream of, and shall not be in contact with the primary filter. The filters may be weighed separately or as a pair with the filters placed stain side to stain side.

Filter face velocity

1.5.1.4. A gas filter velocity through the filter of 35 to 80 cm/s shall be achieved. The pressure drop increase between the beginning and the end of the test shall be no more than 25 kPa.

Filter loading

1.5.1.5. The recommended minimum filter loading shall be 0.5 mg/1 075 mm² stain area for the single filter method. For the most common filter size the values are as follows:

| Filter diameter (mm) | Recommended stain diameter (mm) | Recommended minimum loading (mg) |
|-------------------------|------------------------------------|--|
| 47 | 37 | 0.5 |
| 70 | 60 | 1.3 |
| 90 | 80 | 2.3 |
| 110 | 100 | 3.6 |

For the multiple filter method, the recommended minimum filter loading for the sum of all filters shall be the product of the appropriate value above and the square root of the total number of modes.

1.5.2. Weighing chamber and analytical balance specifications

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Weighing chamber conditions

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

Reference filter weighing

1.5.2.2. The chamber (or room) environment shall be free of any ambient contaminants (such as dust) that would settle on the particulate filters during their stabilisation. Disturbances to weighing room specifications as outlined in section 1.5.2.1 will be allowed if the duration of the disturbances does not exceed 30 minutes. The weighing room should meet the required specifications prior to personnel entrance into the weighing room. At least two unused reference filters or reference filter pairs shall be weighed within four hours of, but preferably at the same time as the sample filter (pair) weighing. They shall be the same size and material as the sample filters.

If the average weight of the reference filters (reference filter pairs) changes between sample filter weighing by more than \pm 5% (\pm 7.5% for the filter pair) of the recommended minimum filter loading (section 1.5.1.5), then all sample filters shall be discarded and the emissions test repeated.

If the weighing room stability criteria outlined in section 1.5.2.1 is not met, but the reference filter (pair) weighing meet the above criteria, the engine manufacturer has the option of accepting the sample filter weights or voiding the tests, fixing the weighing room control system and re-running the test.

Analytical balance

1.5.2.3. The analytical balance used to determine the weights of all filters shall have a precision (standard deviation) of 20 μ g and a resolution of 10 μ g (1 digit = 10 μ g). For filters less than 70 mm diameter, the precision and resolution shall be 2 μ g and 1 μ g respectively.

Elimination of static electricity effects

1.5.2.4. To eliminate the effects of static electricity, the filters shall be neutralized prior to weighing, for example, by a Polonium neutralizer or a device of similar effect.

Additional specifications for particulate measurement

1.5.3. All parts of the dilution system and the sampling system from the exhaust pipe up to the filter holder, which are in contact with raw and diluted exhaust gas, must be designed to minimise deposition or alteration of the particulates. All parts must be made of electrically conductive materials that do not react with exhaust gas components, and must be electrically grounded to prevent electrostatic effects.

Appendix 2

1. CALIBRATION OF THE ANALYTICAL INSTRUMENTS

Introduction

1.1. Each analyser shall be calibrated as often as necessary to fulfil the accuracy requirements of this standard. The calibration method that shall be used is described in this paragraph for the analysers indicated in Appendix 1, section 1.4.3.

Calibration gases

1.2. The shelf life of all calibration gases must be respected.

The expiry date of the calibration gases stated by the manufacturer shall be recorded.

Pure gases

1.2.1. The required purity of the gases is defined by the contamination limits given below. The following gases must be available for operation:

- purified nitrogen
(contamination ≤ 1 ppm C, ≤ 1 ppm CO, ≤ 400 ppm CO₂, ≤ 0.1 ppm NO)
- purified oxygen
(purity $> 99.5\%$ vol O₂)
- hydrogen-helium mixture
($40 \pm 2\%$ hydrogen, balance helium)
(contamination ≤ 1 ppm C, ≤ 400 ppm CO)
- purified synthetic air
(contamination ≤ 1 ppm C, ≤ 1 ppm CO, ≤ 400 ppm CO₂,
 ≤ 0.1 ppm NO)
(oxygen content between 18-21% vol)

Calibration and span gases

1.2.2. Mixture of gases having the following chemical compositions shall be available:

- C₃H₈ and purified synthetic air (see section 1.2.1)
- CO and purified nitrogen
- NO and purified nitrogen (the amount of NO₂ contained in this calibration gas must not exceed 5% of the NO content)
- O₂ and purified nitrogen
- CO₂ and purified nitrogen
- CH₄ and purified synthetic air
- C₂H₆ and purified synthetic air

Note: other gas combinations are allowed provided the gases do not react with one another.

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The true concentration of a calibration and span gas must be within $\pm 2\%$ of the nominal value. All concentrations of calibration gas shall be given on a volume basis (volume percent or volume ppm).

The gases used for calibration and span may also be obtained by means of a gas divider, diluting with purified N₂ or with purified synthetic air. The accuracy of the mixing device must be such that the concentration of the diluted calibration gases may be determined to within $\pm 2\%$.

Operating procedure for analysers and sampling system

1.3. The operating procedure for analysers shall follow the start-up and operating instructions of the instrument manufacturer. The minimum requirements given in sections 1.4 to 1.9 shall be included.

Leakage test

1.4. A system leakage test shall be performed. The probe shall be disconnected from the exhaust system and the end plugged. The analyser pump shall be switched on. After an initial stabilisation period all flow meters should read zero. If not, the sampling lines shall be checked and the fault corrected. The maximum allowable leakage rate on the vacuum side shall be 0.5% of the in-use flow rate for the portion of the system being checked. The analyser flows and bypass flows may be used to estimate the in-use flow rates.

Another method is the introduction of a concentration step change at the beginning of the sampling line by switching from zero to span gas.

If after an adequate period of time the reading shows a lower concentration compared to the introduced concentration, this points to calibration or leakage problems.

1.5. Calibration procedure

Instrument assembly

1.5.1. The instrument assembly shall be calibrated and calibration curves checked against standard gases. The same gas flow rates shall be used as when sampling exhaust.

Warming-up time

1.5.2. The warming-up time should be according to the recommendations of the manufacturer. If not specified, a minimum of two hours is recommended for warming-up the analysers.

NDIR and HFID analyser

1.5.3. The NDIR analyser shall be tuned, as necessary, and the combustion flame of the HFID analyser shall be optimized (section 1.8.1).

Calibration

1.5.4. Each normally used operating range shall be calibrated.

Using purified synthetic air (or nitrogen), the CO, CO₂, NO_x, HC and O₂ analysers shall be set at zero.

The appropriate calibration gases shall be introduced to the analysers, the values recorded, and the calibration curve established according to section 1.5.6.

The zero setting shall be re-checked and the calibration procedure repeated, if necessary.

1.5.5. Establishment of the calibration curve

General guidelines

1.5.5.1. The analyser calibration curve is established by at least five calibration points (excluding zero) spaced as uniformly as possible. The highest nominal concentration must be equal to or higher than 90% of full scale.

The calibration curve is calculated by the method of least squares. If the resulting polynomial degree is greater than three, the number of calibration points (zero included) must be at least equal to this polynomial degree plus two.

The calibration curve must not differ by more than $\pm 2\%$ from the nominal value of each calibration point and by more than $\pm 1\%$ of full scale at zero

From the calibration curve and the calibration points, it is possible to verify that the calibration has been carried out correctly. The different characteristic parameters of the analyser must be indicated, particularly:

- the measuring range,
- the sensitivity,
- the date of carrying out the calibration.

Calibration below 15% of full scale

1.5.5.2. The analyser calibration curve is established by at least ten calibration points (excluding zero) spaced so that 50% of the calibration points are below 10% of full scale.

The calibration curve is calculated by the method of least squares.

The calibration curve must not differ by more than $\pm 4\%$ from the nominal value of each calibration point and by more than $\pm 1\%$ of full scale at zero.

Alternative methods

1.5.5.3. If it can be shown that alternative technology (eg computer, electronically controlled range switch, etc) can give equivalent accuracy, then these alternatives may be used.

Verification of the calibration

1.6 Each normally used operating range shall be checked prior to each analysis in accordance with the following procedure.

The calibration is checked by using a zero gas and a span gas whose nominal value is more than 80% of full scale of the measuring range.

If, for the two points considered, the value found does not differ by more than $\pm 4\%$ of full scale from the declared reference value, the adjustment parameters may be modified. Should this not be the case, a new calibration curve shall be established in accordance with section 1.5.4.

Efficiency test of the NO_x converter

1.7. The efficiency of the converter used for the conversion of NO₂ into NO is tested as given in sections 1.7.1 to 1.7.8 (Figure 1).

Test set-up

1.7.1. Using the test set-up as shown in Figure 1 (see also Appendix 1, section 1.4.3.5) and the procedure below, the efficiency of converters can be tested by means of an ozonator.

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Schematic of NO₂ converter efficiency device

Figure 1 Schematic of NO₂ converter efficiency device

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3.2.4.1. Make(s):
.....

3.2.4.2. Type(s):
.....

3.2.4.3. Speed at which cut-off starts under full load⁽¹⁾:
.....rpm

3.2.4.4. Maximum no-load speed⁽¹⁾:
.....rpm

3.2.4.5. Idling speed⁽¹⁾:
.....rpm

3.3. Cold Start System

3.3.1. Make(s):
.....

3.3.2. Type(s):
.....

3.3.3. Description:
.....

4. VALVE TIMING

4.1. Maximum lift and angles of opening and closing in relation to dead centres or equivalent data:
.....

4.2. Reference and/or setting ranges:⁽²⁾

⁽¹⁾ Specify the tolerance.
⁽²⁾ Strike out what does not apply.

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Calibration

1.7.2. The CLD and the HCLD shall be calibrated in the most common operating range following the manufacturer's specifications using zero and span gas (the NO content of which must amount to about 80% of the operating range and the NO₂ concentration of the gas mixture to less than 5% of the NO concentration). The NO_x analyser must be in the NO mode so that the span gas does not pass through the converter. The indicated concentration has to be recorded.

Calculation

1.7.3. The efficiency of the NO_x converter is calculated as follows:

$$\text{Efficiency (\%)} = \left\{ 1 + \frac{a-b}{c-d} \right\} \times 100$$

- (a) NO_x concentration according to section 1.7.6;
- (b) NO_x concentration according to section 1.7.7;
- (c) NO concentration according to section 1.7.4;
- (d) NO concentration according to section 1.7.5.

Adding of oxygen

1.7.4. Via a T-fitting, oxygen or zero air is added continuously to the gas flow until the concentration indicated is about 20% less than the indicated calibration concentration given in section 1.7.2. (The analyser is in the NO mode).

The indicated concentration (c) shall be recorded. The ozonator is kept de-activated throughout the process.

Activation of the ozonator

1.7.5. The ozonator is now activated to generate enough ozone to bring the NO concentration down to about 20% (minimum 10%) of the calibration concentration given in section 1.7.2. The indicated concentration (d) shall be recorded. (The analyser is in the NO mode.)

NO_x mode

1.7.6. The NO analyser is then switched to NO_x mode so that the gas mixture (consisting of NO, NO₂, O₂ and N₂) now passes through the converter. The indicated concentration (a) shall be recorded. (The analyser is in the NO_x mode.)

De-activation of the ozonator

1.7.7. The ozonator is now de-activated. The mixture of gases described in section 1.7.6 passes through the converter into the detector. The indicated concentration (b) shall be recorded. (The analyser is the NO_x mode.)

NO mode

1.7.8. Switched to NO mode with the ozonator de-activated, the flow of oxygen or synthetic air is also shut off. The NO_x reading of the analyser shall not deviate by more than ± 5% from the value measured according to section 1.7.2. (The analyser is in the NO mode.)

Test interval

1.7.9. The efficiency of the converter must be tested prior to each calibration of the NO_x analyser.

Efficiency requirement

1.7.10. The efficiency of the converter shall not be less than 90%, but a higher efficiency of 95% is strongly recommended.

Note: If, with the analyser in the most common range, the ozonator cannot give a reduction from 80% to 20% according to section 1.7.5, then the highest range which will give the reduction shall be used.

1.8. Adjustment of the FID

Optimization of the detector response

1.8.1. The HFID must be adjusted as specified by the instrument manufacturer. A propane in air span gas should be used to optimize the response on the most common operating range.

With the fuel and air flow rates set at the manufacturer's recommendations, a 350 ± 75 ppm C span gas shall be introduced to the analyser. The response at a given fuel flow shall be determined from the difference between the span gas response and the zero gas response. The fuel flow shall be incrementally adjusted above and below the manufacturer's specification. The span and zero response at these fuel flows shall be recorded. The difference between the span and zero response shall be plotted and the fuel flow adjusted to the rich side of the curve.

Hydrocarbon response factors

1.8.2. The analyser shall be calibrated using propane in air and purified synthetic air, according to section 1.5.

Response factors shall be determined when introducing an analyser into service and after major service intervals. The response factor (R_f) for a particular hydrocarbon species is the ratio of the FID C1 reading to the gas concentration in the cylinder expressed by ppm C1.

The concentration of the test gas must be at a level to give a response of approximately 80% of full scale. The concentration must be known to an accuracy of $\pm 2\%$ in reference to a gravimetric standard expressed in volume. In addition, the gas cylinder must be pre-conditioned for 24 hours at a temperature of $298 \text{ K } (25^\circ\text{C}) \pm 5 \text{ K}$.

The test gases to be used and the recommended relative response factor ranges are as follows:

| | |
|---|---------------------------|
| — methane and purified synthetic air: | $1.00 \leq R_f \leq 1.15$ |
| — propylene and purified synthetic air: | $0.90 \leq R_f \leq 1.1$ |
| — toluene and purified synthetic air: | $0.90 \leq R_f \leq 1.10$ |

These values are relative to the response factor (R_f) of 1.00 for propane and purified synthetic air.

Oxygen interference check

1.8.3. The oxygen interference check shall be determined when introducing an analyser into service and after major service intervals.

The response factor is defined and shall be determined as described in section 1.8.2. The test gas to be used and the recommended relative response factor range are as follows:

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—propane and nitrogen: $0.95 \leq R_f \leq 1.05$

This value is relative to the response factor (R_f) of 1.00 for propane and purified synthetic air. The FID burner air oxygen concentration must be within ± 1 mole % of the oxygen concentration of the burner air used in the latest oxygen interference check. If the difference is greater, the oxygen interference must be checked and the analyser adjusted, if necessary.

Interference effects with NDIR and CLD analysers

1.9. Gases present in the exhaust other than the one being analysed can interfere with the reading in several ways. Positive interference occurs in NDIR instruments where the interfering gas gives the same effect as the gas being measured, but to a lesser degree. Negative interference occurs in NDIR instruments by the interfering gas broadening the absorption band of the measured gas, and in CLD instruments by the interfering gas quenching the radiation. The interference checks in sections 1.9.1 and 1.9.2 shall be performed prior to an analyser's initial use and after major service intervals.

CO analyser interference check

1.9.1. Water and CO₂ can interfere with the CO analyser performance. Therefore a CO₂ span gas having a concentration of 80 to 100% of full scale of the maximum operating range used during testing shall be bubbled through water at room temperature and the analyser response recorded. The analyser response must not be more than 1% of full scale for ranges equal to or above 300 ppm or more than 3 ppm for ranges below 300 ppm.

NO_x analyser quench checks

1.9.2. The two gases of concern for CLD (and HCLD) analysers are CO₂ and water vapour. Quench responses of these gases are proportional to their concentrations, and therefore require test techniques to determine the quench at the highest expected concentrations experienced during testing.

CO₂ quench check

1.9.2.1. A CO₂ span gas having a concentration of 80 to 100% of full scale of the maximum operating range shall be passed through the NDIR analyser and the CO₂ value recorded as A. It shall then be diluted approximately 50% with NO span gas and passed through the NDIR and (H)CLD with the CO₂ and NO values recorded as B and C, respectively. The CO₂ shall be shut off and only the NO span gas be passed through the (H)CLD and the NO value recorded as D.

The quench shall be calculated as follows:

$$\% \text{ CO}_2 \text{ quench} = \left[1 - \left(\frac{(C \times A)}{(D \times A) - (D \times B)} \right) \right] \times 100$$

and must not be greater than 3% of full scale,

where:

A: undiluted CO₂ concentration measured with NDIR%

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| | |
|----|---|
| B: | diluted CO ₂ concentration measured with NDIR% |
| C: | diluted NO concentration measured with CLD ppm |
| D: | undiluted NO concentration measured with CLD ppm |

Water quench check

1.9.2.2. This check applies to wet gas concentration measurements only. Calculation of water quench must consider dilution of the NO span gas with water vapour and scaling of water vapour concentration of the mixture to that expected during testing. A NO span gas having a concentration of 80 to 100% of full scale to the normal operating range shall be passed through the (H)CLD and the NO value recorded as D. The NO gas shall be bubbled through water at room temperature and passed through the (H)CLD and the NO value recorded as C. The analyser's absolute operating pressure and the water temperature shall be determined and recorded as E and F, respectively. The mixture's saturation vapour pressure that corresponds to the bubbler water temperature (F) shall be determined and recorded as G. The water vapour concentration (in %) of the mixture shall be calculated as follows:

$$H = 100 \times \left(\frac{G}{E} \right)$$

and recorded as H. The expected diluted NO span gas (in water vapour) concentration shall be calculated as follows:

$$De = D \times \left(1 - \frac{H}{100} \right)$$

and recorded as De. For diesel exhaust, the maximum exhaust water vapour concentration (in %) expected during testing shall be estimated, under the assumption of a fuel atom H/C ratio of 1.8 to 1, from the undiluted CO₂ span gas concentration (A, as measured in section 1.9.2.1) as follows:

$$Hm = 0.9 \times A$$

and recorded as Hm.

The water quench shall be calculated as follows:

$$\% \text{ H}_2\text{O Quench} = 100 \times \left(\frac{De - C}{De} \right) \times \left(\frac{Hm}{H} \right)$$

and must not be greater than 3% of full scale

| | |
|-----|---|
| De: | expected diluted NO concentration (ppm) |
| C: | diluted NO concentration (ppm) |
| Hm: | maximum water vapour concentration (%) |
| H: | actual water vapour concentration (%) |

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Note: It is important that the NO span gas contains minimal NO₂ concentration for this check, since absorption of NO₂ in water has not been accounted for in the quench calculations.

Calibration intervals

1.10. The analysers shall be calibrated according to section 1.5 at least every three months or whenever a system repair or change is made that could influence calibration.

2. CALIBRATION OF THE PARTICULATE MEASURING SYSTEM

Introduction

2.1. Each component shall be calibrated as often as necessary to fulfil the accuracy requirements of this standard. The calibration method to be used is described in this section for the components indicated in Annex III, Appendix 1, section 1.5 and Annex V.

Flow measurement

2.2. The calibration of gas flow-meters or flow measurement instrumentation shall be traceable to national and/or international standards.

The maximum error of the measured value shall be within $\pm 2\%$ of reading.

If the gas flow is determined by differential measurement, the maximum error of the difference shall be such that the accuracy of GEDFis within $\pm 4\%$ (see also Annex V, section 1.2.1.1. EGA). It can be calculated by taking the root-mean-square of the errors of each instrument.

Checking the dilution ratio

2.3. When using particulate sampling systems without EGA (Annex V, section 1.2.1.1.), the dilution ratio shall be checked for each new engine installation with the engine running and the use of either the CO₂ or NO_x concentration measurements in the raw and dilute exhaust.

The measured dilution ratio shall be within $\pm 10\%$ of the calculated dilution ratio from CO₂ or NO_x concentration measurement.

Checking the partial flow conditions

2.4. The range of the exhaust gas velocity and the pressure oscillations shall be checked and adjusted according to the requirements of Annex V, section 1.2.1.1, EP, if applicable.

Calibration intervals

2.5. The flow measurement instrumentation shall be calibrated at least every three months, or whenever a system change is made that could influence calibration.

Appendix 3

1. DATA EVALUATION AND CALCULATIONS

Gaseous emissions data evaluation

1.1. For the evaluation of the gaseous emissions, the chart reading of the last 60 seconds of each mode shall be averaged, and the average concentrations (conc) of HC, CO, NO_x and CO₂ if the carbon balance method is used, during each mode shall be determined from the average chart readings and the corresponding calibration data. A different type of recording can be used if it ensures an equivalent data acquisition.

The average background concentrations (conc_d) may be determined from the bag readings of the dilution air or from the continuous (non-bag) background reading and the corresponding calibration data.

Particulate emissions

1.2. For the evaluation of the particulates, the total sample masses (M_{SAM,i}) or volumes (V_{SAM,i}) through the filters shall be recorded for each mode.

The filters shall be returned to the weighing chamber and conditioned for at least one hour, but not more than 80 hours, and then weighed. The gross weight of the filters shall be recorded and the tare weight (see section 3.1, Annex III) subtracted. The particulate mass (M_f for the single filter method; M_{f,i} for the multiple filter method) is the sum of the particulate masses collected on the primary and back-up filters.

If background correction is to be applied, the dilution air mass (M_{DIL}) or volume (V_{DIL}) through the filters and the particulate mass (M_d) shall be recorded. If more than one measurement was made, the quotient M_d/M_{DIL} or M_d/V_{DIL} must be calculated for each single measurement and the values averaged.

Calculation of the gaseous emissions

1.3. The finally reported test results shall be derived through the following steps:

Determination of the exhaust gas flow

1.3.1. The exhaust gas flow rate (G_{EXHW}, V_{EXHW}, or V_{EXHD}) shall be determined for each mode according to Annex III, Appendix 1, sections 1.2.1 to 1.2.3.

When using a full flow dilution system, the total dilute exhaust gas flow rate (G_{TOTW}, V_{TOTW}) shall be determined for each mode according to Annex III, Appendix 1, section 1.2.4.

Dry/wet correction

1.3.2. When applying G_{EXHW}, V_{EXHW}, G_{TOTW}, V_{TOTW}, the measured concentration shall be converted to a wet basis according to the following formulae, if not already measured on a wet basis:

$$\text{conc (wet)} = k_w \times \text{conc (dry)}$$

For the raw exhaust gas:

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$$k_{w,r,1} = \left(1 - F_{FH} \times \frac{G_{FUEL}}{G_{AIRD}} \right) - k_{w2}$$

or:

$$K_{w,r,2} = \left(\frac{1}{1 + 1.88 \times 0.005 \times (\% \text{ CO [dry]} + \% \text{ CO}_2 \text{ [dry]})} \right) - k_{w2}$$

For the diluted exhaust gas:

$$K_{w,e,1} = \left(1 - \frac{1.88 \times \text{CO}_2\% \text{ (wet)}}{200} \right) - k_{w1}$$

or:

$$K_{w,e,2} = \left(\frac{1 - K_{w1}}{1 + \frac{1.88 \times \text{CO}_2\% \text{ (dry)}}{200}} \right) - K_{w1}$$

F_{FH} may be calculated by:

$$F_{FH} = \frac{1.969}{1 + \frac{G_{FUEL}}{G_{AIRW}}}$$

For the dilution air:

$$K_{w,d} = 1 - k_{w1}$$

$$K_{w,01} = \frac{1.608 \times [H_d \times (1 - 1/DF) + H_a \times (1/DF)]}{1000 + 1.608 \times [H_d \times (1 - 1/DF) + H_a \times (1/DF)]}$$

$$H_d = \frac{6.22 \times R_d \times p_d}{P_B - P_d \times R_d \times 10^{-2}}$$

For the intake air (if different from the dilution air):

$$k_{w,a} = 1 - K_{w2}$$

$$k_{w2} = \frac{1.608 \times H_a}{1000 + (1.608 \times H_a)}$$

$$H_a = \frac{6.22 \times R_a \times p_a}{p_B - p_a \times R_a \times 10^{-2}}$$

where:

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| | |
|---------|---|
| H_a : | absolute humidity of the intake air, g water per kg dry air |
| H_d : | absolute humidity of the dilution air, g water per kg dry air |
| R_d : | relative humidity of the dilution air, % |
| R_a : | relative humidity of the intake air, % |
| p_d : | saturation vapour pressure of the dilution air, kPa |
| p_a : | saturation vapour pressure of the intake air, kPa |
| p_B : | total barometric pressure, kPa |

Humidity correction for NO_x

1.3.3. As the NO_x emission depends on ambient air conditions, the NO_x concentration shall be corrected for ambient air temperature and humidity by the factor K_H given in the following formula:

$$K_H = \frac{1}{1 + A \times (H_a - 10.71) + B \times (T_a - 298)}$$

where:

| | |
|---------|--|
| A: | $0.309 G_{FUEL}/G_{AIRD} - 0.0266$ |
| B: | $-0.209 G_{FUEL}/G_{AIRD} + 0.00954$ |
| T: | temperatures of the air in K $\frac{G_{FUEL}}{G_{AIRD}} = \text{Fuel air ratio (dry air basis)}$ |
| H_a : | humidity of the intake air, g water per kg dry air; $H_a = \frac{6.220 \times R_a \times p_a}{p_B - p_a \times R_a \times 10^{-2}}$ |
| R_a : | relative humidity of the intake air, % |
| p_a : | saturation vapour pressure of the intake air, kPa |
| p_b : | total barometric pressure, kPa |

Calculation of emission mass flow rates

1.3.4. The emission mass flow rates for each mode shall be calculated as follows:

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(a) For the raw exhaust gas(2)

$$Gas_{mass} = u \times conc \times G_{EXHW}$$

or:

$$Gas_{mass} = v \times conc \times V_{EXHD}$$

or:

$$Gas_{mass} = w \times conc \times V_{EXHD}$$

(b) For the dilute exhaust gas(2)

$$Gas_{mass} = u \times conc_c \times G_{TOTW}$$

or:

$$Gas_{mass} = w \times conc_c \times V_{TOTW}$$

where:

conc_c = is the background corrected concentration

$$conc_c = conc - conc_d \times (1 - (1/DF))$$

$$DF = 13.4 / (conc_{CO_2} + (conc_{CO} + conc_{HC}) \times 10^{-4})$$

or:

$$DF = 13.4 / conc_{CO_2}$$

The coefficients u – wet, v – dry, w – wet shall be used according to the following table:

| Gas | u | v | w | conc |
|-----------------|----------|----------|----------|---------|
| NO _x | 0.001587 | 0.002053 | 0.002053 | ppm |
| CO | 0.000966 | 0.00125 | 0.00125 | ppm |
| HC | 0.000479 | — | 0.000619 | ppm |
| CO ₂ | 15.19 | 19.64 | 19.64 | percent |

The density of HC is based upon an average carbon to hydrogen ratio of 1:1.85.

Calculation of the specific emissions

1.3.5. The specific emission (g/kWh) shall be calculated for all individual components in the following way:

$$\text{Individual gas} = \frac{\sum_{i=1}^n Gas_{mass_i} \times WF_i}{\sum_{i=1}^n P_i \times WF_i}$$

where P_i = P_{m,i} + P_{AE,i}.

The weighting factors and the number of modes (n) used in the above calculation are according to Annex III, section 3.6.1.

- (2) In the case of NO_x, the NO_x concentration (NO_xconc or NO_xconc_c) has to be multiplied by K_{HNOX}(humidity correction factor for NO_x quoted in the previous section 1.3.3) as follows:
K_{HNOX}^x conc or K_{HNOX}^x conc_c.
- (2) In the case of NO_x, the NO_x concentration (NO_xconc or NO_xconc_c) has to be multiplied by K_{HNOX}(humidity correction factor for NO_x quoted in the previous section 1.3.3) as follows:
K_{HNOX}^x conc or K_{HNOX}^x conc_c.

Calculation of the particulate emission

1.4 The particulate emission shall be calculated in the following way:

Humidity correction factor for particulates

1.4.1. As the particulate emission of diesel engines depends on ambient air conditions, the particulate mass flow rate shall be corrected for ambient air humidity with the factor K_p given in the following formula:

$$K_p = 1/(1 + 0.0133 \times (H_a - 10.71))$$

H_a : humidity of the intake air, grammes of water per kg dry air;

$$H_a = \frac{6.22 \times R_a \times p_a}{p_b - p_a \times R_a \times 10^{-2}}$$

R_a : relative humidity of the intake air, %;

p_a : saturation vapour pressure of the intake air, kPa;

p_b : total barometric pressure, kPa.

Partial flow dilution system

1.4.2. The final reported test of the particulate emission shall be derived through the following steps. Since various types of dilution rate control may be used, different calculation methods for equivalent diluted exhaust gas flow rate GEDF or equivalent diluted exhaust gas volume flow rate VEDF apply. All calculations shall be based upon the average values of the individual modes (i) during the sampling period.

1.4.2.1. Isokinetic systems

$$GEDFW_i = GEXHW_j \times q_i$$

or:

$$VEDFW_i = VEXHW_j \times q_i$$

$$q_i = \frac{GDILW_j + (GEXHW_j \times r)}{(GEXHW_j \times r)}$$

or:

$$q_i = \frac{VDILW_j + (VEXHW_j \times r)}{(VEXHW_j \times r)}$$

Where r corresponds to the ratio of the cross sectional areas of the isokinetic probe A_p and exhaust pipe A_T :

$$r = \frac{A_p}{A_T}$$

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1.4.2.2. Systems with measurement of CO₂ or NO_x concentration

$$G_{EDFW,j} = G_{EXHW,j} \times q_i$$

or

$$V_{EDFW,j} = V_{EXHW,j} \times q_i$$

$$q_i = \frac{Conc_{E,i} - Conc_{A,i}}{Conc_{D,i} - Conc_{A,i}}$$

where:

Conc_E = wet concentration of the tracer gas in raw exhaust

Conc_D = wet concentration of the tracer gas in the diluted exhaust

Conc_a = wet concentration of the tracer gas in the dilution air

Concentrations measured on a dry basis shall be converted to a wet basis according to section 1.3.2. of this Appendix.

1.4.2.3. Systems with CO₂ measurement and carbon balance method

$$G_{EDFW,j} = \frac{206.6 \times G_{FUEL,i}}{CO_{2D,i} - CO_{2A,i}}$$

where:

CO_{2D} = CO₂ concentration of the diluted exhaust

CO_{2a} = CO₂ concentration of the dilution air

(concentrations in volume % on wet basis)

This equation is based upon the carbon balance assumption (carbon atoms supplied to the engine are emitted as CO₂) and derived through the following steps:

$$G_{EDFW,j} = G_{EXHW,j} \times q_i$$

and:

$$q_i = \frac{206.6 \times G_{FUEL,i}}{G_{EXHW,j} \times (CO_{2D,i} - CO_{2A,i})}$$

1.4.2.4. Systems with flow measurement

$$G_{EDFW,j} = G_{EXHW,j} \times q_i$$

$$q_i = \frac{G_{TOTW,j}}{(G_{TOTW,j} - G_{DILW,j})}$$

Full flow dilution system

1.4.3. The final reported test results of the particulate emission shall be derived through the following steps.

All calculations shall be based upon the average values of the individual modes (i) during the sampling period.

$$\boxed{GEDFW_i = GTOTW_i}$$

or:

$$\boxed{VEDFW_i = VTOTW_i}$$

Calculation of the particulate mass flow rate

1.4.4. The particulate mass flow rate shall be calculated as follows:

For the single filter method:

$$PT_{mass} = \frac{M_f}{M_{SAM}} \times \frac{(GEDFW)_{aver}}{1\ 000}$$

or:

$$PT_{mass} = \frac{M_f}{V_{SAM}} \times \frac{(VEDFW)_{aver}}{1\ 000}$$

where:

$(GEDFW)_{aver}$, $(VEDFW)_{aver}$, $(M_{SAM})_{aver}$, $(V_{SAM})_{aver}$ over the test cycle shall be determined by summation of the average values of the individual modes during the sampling period:

$$(GEDFW)_{aver} = \sum_{i=1}^n GEDFW_i \times WF_i$$

$$(VEDFW)_{aver} = \sum_{i=1}^n VEDFW_i \times WF_i$$

$$M_{SAM} = \sum_{i=1}^n M_{SAM,i}$$

$$V_{SAM} = \sum_{i=1}^n V_{SAM,i}$$

where $i=1, \dots, n$

For the multiple filter method:

$$PT_{mass,i} = \frac{M_{f,i}}{M_{SAM,i}} \times \frac{(GEDFW_i)}{1\ 000}$$

or:

$$PT_{mass} = \frac{M_{f,i}}{M_{SAM,i}} \times \frac{(VEDFW_i)}{1\ 000}$$

where $i=1, \dots, n$

The particulate mass flow rate may be background corrected as follows:

For single filter method:

$$PT_{mass} = \left[\frac{M_f}{M_{SAM}} - \left(\frac{M_d}{M_{DIL}} \times \left(1 - \frac{1}{DF} \right) \right) \right] \times \left[\frac{(GEDFW)_{aver}}{1\ 000} \right]$$

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or:

$$PT_{mass} = \left[\frac{M_f}{V_{SAM}} - \left(\frac{M_d}{V_{DIL}} \times \left(1 - \frac{1}{DF} \right) \right) \right] \times \left[\frac{(VEDFW)_{aver}}{1000} \right]$$

If more than one measurement is made, (M_d/M_{DIL}) or (M_d/V_{DIL}) shall be replaced with $(M_d/M_{DIL})_{aver}$ or $(M_d/V_{DIL})_{aver}$, respectively.

$$DF = \frac{13.4}{conCO_2 + (concCO + concHC) \times 10^{-4}}$$

$DF = 13.4/concCO_2$

For multiple filter method:

$$PT_{mass, i} = \left[\frac{M_{f, i}}{M_{SAM, i}} - \left(\frac{M_d}{M_{DIL}} \times \left(1 - \frac{1}{DF} \right) \right) \right] \times \left[\frac{GEDFW, i}{1000} \right]$$

or:

$$PT_{mass, i} = \left[\frac{M_{f, i}}{V_{SAM, i}} - \left(\frac{M_d}{V_{DIL}} \times \left(1 - \frac{1}{DF} \right) \right) \right] \times \left[\frac{VEDFW, i}{1000} \right]$$

If more than one measurement is made, (M_d/M_{DIL}) or (M_d/V_{DIL}) shall be replaced with $(M_d/M_{DIL})_{aver}$ or $(M_d/V_{DIL})_{aver}$, respectively.

$$DF = \frac{13.4}{conCO_2 + (concCO + concHC) \times 10^{-4}}$$

or;

$DF = 13.4/concCO_2$

Calculation of the specific emissions

1.4.5. The specific emission of particulates PT (g/kWh) shall be calculated in the following way(3)

For the single filter method:

$$PT = \frac{PT_{mass}}{\sum_{i=1}^n P_i \times WF_i}$$

For the multiple filter method:

$$PT = \frac{\sum_{i=1}^n PT_{mass, i} \times WF_i}{\sum_{i=1}^n P_i \times WF_i}$$

(3) The particulate mass flow rate PT_{mass} has to be multiplied by K_p (humidity correction factor for particulates quoted in section 1.4.1).

Status: This is the original version (as it was originally made). This item of legislation is currently only available in its original format.

$$P_i = P_{m,i} + P_{AE,i}$$

Effective weighting factor

1.4.6. For the single filter method, the effective weighting factor $WF_{E,i}$ for each mode shall be calculated in the following way:

$$WF_{E,i} = \frac{MSAM_{,i} \times (GEDFW)_{aver}}{MSAM \times (GEDFW_{,i})}$$

or:

$$WF_{E,i} = \frac{VSAM_{,i} \times (VEDFW)_{aver}}{VSAM \times (VEDFW_{,i})}$$

where $i=1, \dots n$.

The value of the effective weighting factors shall be within ± 0.005 (absolute value) of the weighting factors listed in Annex III, section 3.6.1.