Including MOT/08/19/01
Issued October 2001
1st Revision: April 2002
2nd Revision May 2003
3rd Revision January 2007

SPECIFICATION FOR DIESEL SMOKE METERS

CONTENTS PAGE

1. INTRODUCTION

This specification covers smoke meters to be used for statutory testing in the HGV, PSV, MOT and SVA schemes, including those to be used for Reduced Pollution Certification, Roadside Enforcement and by Vehicle & Operator Services Agency Testing Division.

Two categories of meter are covered, these relating to the types of vehicle to be tested.

All meter types to be used for statutory testing shall conform and be shown to continue to conform to these requirements.

All meters shall meet the requirements found in: Annexes 1 - 6

Additional optional requirements are:

Annex 7 - Vehicle & Operator Services Agency Vehicle Testing Division Requirements, and

Annex 8 - Roadside Enforcement Requirements

All meter types to be used for statutory testing must be calibrated according to the requirements found in Annex 9.

Individual annexes may be subject to change. You should check before applying this document that no changes have been made to any part of it.

2. CATEGORIES OF METER

Meters can be assessed and approved for testing one or both of two categories:-

Category A — Cars and light commercial vehicles (including MOT Class IV, VII and Single Vehicle Approval Scheme vehicles).

Category B — Public Service Vehicles and private buses (including MOT Class V and VI vehicles) and Heavy Goods Vehicles

3. MEASUREMENT ABILITY

Meters shall:

3.1 measure accurately the Free Acceleration Smoke (FAS) output over the whole speed range of an engine (no load from idle up to cut-off speed), where the engine is accelerated against its own inertia;

3.2 record, display and retain the peak value of the smoke output measured during each FAS test;

3.3 maintain a fixed effective optical path length irrespective of exhaust tailpipe size or shape;

3.4 correlate with the reference smoke meter whilst measuring FAS from the range of vehicles likely to be tested. For details of how this is assessed, see Section 8.4 FAS Correlation;

3.5 maintain correct sampling and purge air pressures at all times to ensure consistent measurement chamber filling with no variation in effective optical path length;

3.6 provide adequate safeguards against the possibility of condensation influencing the measurement with all sample pipe size and extension variants supplied with the meter;

3.7 produce accurate results without the need for precise or specific alignment of the sampling chamber or probe with the exhaust tailpipe;

3.8 maintain accuracy to meet all specific requirements under the rated operating conditions in Section 7.2 and Pattern Approval Procedures in Section 8;

3.9 for FAS correlation purposes, perform an uninterrupted sequence of 10 FAS and display each value, regardless of smoke level;

3.10 operate reliably in all conditions likely to be encountered within the vehicle testing environment and meet with all appropriate environmental performance standards as detailed in Section 8.5, Environmental Testing.

4. TECHNICAL REQUIREMENTS

4.1 General

Meters shall:

4.1.1 include a real time clock and a four year calendar which operates even when the mains is disconnected. The time may be adjustable by the operator. Seasonal time adjustment may be automatic. However, adjustment of the day and date shall only be accessible to UKAS approved operators.
NOTE: Where the meter may be used with a hand-held device or other similar accessory there shall be no adjustment of the meter day nor date possible via any such device.

4.1.2 Have a light source which shall be an incandescent lamp with a colour temperature in the range of 2,800K to 3,250K (conforming to CIE S 001) or a green light emitting diode (LED) with a spectral peak 560nm ±10nm.

4.1.3 Have a receiver that shall be a photocell or a photo diode (with filter if necessary) which in the case when the light source is an incandescent lamp shall have a spectral response similar to the photopic curve of the human eye (maximum response) in the range 560nm ±10nm, to less than 4% of that maximum response below 430nm and above 680nm.

4.2 Engine Temperature Measurement (Category A meters)

Meters shall:

4.2.1 incorporate a device for measuring Class IV, VII and SVA diesel engined vehicles engine temperature;

4.2.2 display the recommended and measured engine test temperature (according to the requirements at section 5.5);

4.2.3 state the measured engine temperature, at the point when the test proceeds (see also 5.3), on the printout and in outputs.

Temperature measuring devices shall:

4.2.4. be capable of measuring engine temperature with an accuracy of ±5% relative and equivalent to an indicated oil temperature of up to at least 90°C;

4.2.5. be suitable for all MOT Class IV, VII and SVA diesel engined vehicles.

A device which senses oil temperature shall:

4.2.6 be capable of being inserted via the dipstick tube of all MOT Class IV and VII diesel engined vehicles;

4.2.7 be adjustable in length to match the length of the dipstick for all MOT Class IV and VII diesel engined vehicles.

NOTE: It is accepted that this device may not cater for a minority of vehicles/engines which can be identified as not intended for the GB marketplace.

5. OPERATIONAL REQUIREMENTS

5.1 General

Meters shall:

5.1.1 automatically prevent measurement of smoke and prompt the user when the meter is due for **any** calibration;

5.1.2 perform a zero check automatically immediately before each series of FAS tests and reset zero as necessary. This should take no longer than 10 seconds;

5.1.3 remind the operator before the start of the FAS cycles to fully depress the accelerator in under one second, quickly and continuously, but not violently;

5.1.4 enable the operator to anticipate the prompt to depress the accelerator by a countdown or similar visual aid, for example by using red, amber and green indicators;

5.1.5 schedule a sequence of up to 6 accelerations (including fast pass), leaving a gap of at least 10 seconds between the release of the accelerator pedal and the prompt to carry out the next acceleration;
NOTE: the engine, and any turbocharger fitted, should be at idle before the start of each FAS cycle; this may mean leaving a gap in excess of 10 seconds between the release of the accelerator pedal and the prompt to carry out the next acceleration. The operator may be invited to confirm that the engine has returned to idle 10 seconds after the prompt to release the accelerator.

5.1.6 recognise that a FAS test is in progress. This may be done by monitoring any effective combination of the following: engine speed, exhaust gas temperature, exhaust gas pressure rise, smoke level. Proposals for other systems will be considered on their merits;

5.1.7 ensure that the smoke meter sees the complete pulse produced as a result of accelerating the engine. Calculate after each acceleration, and automatically, the arithmetic mean of the latest 3 readings. If any of the 3 readings is less than 75% of the mean smoke level then that individual reading shall be rejected (for the purpose of this average only) and no mean value shall be displayed.

NOTE: The total number of accelerations never exceeds 6. Also if one or more of the last 3 readings is rejected, then the meter shall take the mean of the valid readings contained in the last 3 (see Annex 2 for worked examples). Where no valid mean has been achieved a ‘void’ result will be returned;

5.1.8 provide a prompt to the operator based on FAS being in progress to “release the accelerator pedal as soon as the engine reaches cut-off speed”.

5.1.9 check, simply and quickly, for any zero drift which may have occurred during a complete test of up to 6 accelerations.

a) Zero drift shall not be more than $\pm 0.1 m^{-1}$ or $\pm 5\%$ of the arithmetic mean result, whichever is the greater. For values in excess of these the meter shall show an error message and not display or produce a result.

b) If the drift is either $0.1 m^{-1}$ or $\pm 5\%$ of the arithmetic mean, or less and positive, subtract it from the mean of the last valid readings if a complete sequence of 6 accelerations has been carried out;

5.1.10 clear the meter peak-hold and reset for the next acceleration in a single operation which is either automatic or such that it can be carried out by a tester sat in the driving seat of the vehicle under test;

5.1.11 when required in the specification, calculate with the smoke output measured in light absorption coefficient units ('K' values). Calculations are not to be rounded beyond that which is practical for device functionality;

5.1.12 display output results to 2dp (eg n.nn);

5.1.13 have standard pass/fail values built into the equipment. These must be easily changed. Where data is available via the test equipment interface as a routine part of each test process the standard values shall be checked and, if necessary, amended according to the data provided.

NOTE: Where no such data is available, for example when not linked to a read/write device, there will be an alternative means to amend the pass/fail values via a method or route acceptable to Vehicle & Operator Services Agency.

5.1.14 recognise when data is available via the test equipment interface and prompt the tester to enter the Vehicle Registration Mark (VRM) or the Test Number before starting the test. The meter shall compare the information entered with both the VRM and the Test Number. If either is matched the meter will allow the test to proceed, if no match is obtained the tester should be offered the option of re-entering the data or abandoning the test.

Sample probes shall:

5.1.15 Attach securely to, and sample from, exhaust pipes of various shapes, sizes, outlet angles and positions, positioning the sample probe effectively central to the flow of exhaust gas in straight tailpipes and those with bends close to the tailpipe outlet. Category B Meters must also make provision for reaching vertical stack or central exit exhausts and adapt prompts and timings to suit sample pipe lengths.

5.2 Test limits and procedures

Meters shall meet all the procedural requirements and limits found at Annex 1.

Additionally meters shall:

5.2.1 Automatically stop the test sequence if the measured value of the first acceleration is <=the Fast Pass smoke limit and produce a pass result to print and test equipment interface appropriate for Test Type - Fast Pass. For any other value continue with the test sequence of up to 6 FAS cycles;
NOTE: This facility shall be automatically disabled when any Reduced Pollution Certification option is selected by the operator.

5.2.2 Recognise when data is available via the test equipment interface and prompt the tester to carry out the Test Type as at Annex 5, 5.2.2. The tester shall be given
the opportunity to alter the Test Type before the test is started and if this is done procedures and limits appropriate to the Test Type selected by the tester shall be applied;
NOTE: The option of pre-selecting the Test Type of Fast Pass will not be available; this is an automatic function within the meter.

5.2.3 Allow the tester to select the Test Type where no such data is available via the equipment interfaces device.

5.3 Temperature sensing

Meters to be used for testing vehicles in Category A (Class IV, VII and SVA) shall:

5.3.1 Allow the operator to proceed with the test at any time when the minimum oil temperature of 60^{o}C (or equivalent) has been reached. This process will not inhibit the operator's ability to warm the engine further before proceeding. The operator will not be able to proceed to the smoke test procedure until the engine temperature has reached the minimum requirement. The temperature at which the test proceeded shall be output and shown on the results print (it will not default to show 60^{o}C);

5.3.2 if an oil temperature probe is used, prompt the operator to remove the oil temperature probe before raising the engine speed for any purpose and confirm by the press of a button that the probe has been removed;

5.3.3 where an alternative temperature sensing device is used, prompt the operator to work with care and be aware of hot and rotating components in the engine bay;

5.3.4 allow the operator to by-pass engine temperature and impose a time penalty of 40 seconds (showing the operator a clear count down) if the operator does choose to by-pass engine temperature measurement. 'No engine temperature taken' shall be clearly shown on any results print;

5.3.5 allow a pass result at any temperature >= 60^{o}C oil (or equivalent), to be issued for any test option or process;

5.3.6 in the event of a fail result from a first full set of 6 FAS at any temperature greater than 60^{o}C but less than 80^{o}C oil (or equivalent) the meter will not offer to produce a fail result from a single series of 6 FAS cycles. The operator will

be informed that the engine temperature should be raised to at least 80°C oil (or equivalent) or as close to this as may be considered normal for that engine and a second test cycle offered;

5.3.7 in the event of a fail from a first full set of 6 FAS at any temperature greater than 80°C oil (or equivalent) the meter must offer to produce and output a fail result;

5.3.8 in the event of a fail following two full sets of 6 FAS at any temperature which is not in excess of 80°C oil (or equivalent) the meter must produce and output a fail result and include advice that the test was conducted at under 80°C oil temperature (or equivalent).

5.4 Reduced Pollution Certificate

Meters to be used within Category B shall also offer Reduced Pollution Certificate (RPC) testing. A meter in Category B shall meet all of the general requirements in 5.1 and 5.2 above and in addition shall:

5.4.1 Allow the operator to select the RPC process. The selection of this process will invalidate the option for a fast pass to be offered as in 5.2.1;

5.4.2 Provide the operator with a choice of RPC values for application in the test process (or apply the limit provided via the test equipment interface and prompt the operator to confirm use) from:

Type 1 where the limit is Smoke Limit - RPC1
Type 2 where the limit is Smoke Limit - RPC2
Type 3 where the limit is Smoke Limit - RPC3
Type 4 where the limit is Smoke Limit - RPC4

5.4.3 Calculate, display and produce results in respect of both the RPC and 'standard' smoke limits;

5.4.4 Automatically offer a second test cycle following an initial RPC fail result, Prompting the operator to confirm the RPC limit selected for test;

5.4.5 Provide results outputs which include a Pass/Fail for the standard test limits for the vehicle under test, and the RPC Pass/Fail.
NOTE: It is acceptable that results may show a Pass at the standard turbo or non-turbo limits and an RPC Fail at the same time.

5.5 Display

5.5.1 All displays will be digital with figures at least 12mm high (unless the display is Hand held, in which case figures 4mm high will be acceptable);

5.5.2 The display shall be easily readable both in poor light conditions and bright sunlight;

5.5.3 The display shall be clearly visible to a tester sat in the driving seat of the vehicle under test;

5.5.4 The minimum scale range is K = $0m^{-1}$ to at least $9.99m^{-1}$;

5.5.5 The least significant figure of the display shall provide a resolution equal to or better than $0.10m^{-1}$.

5.6 Results outputs / Printout

5.6.1 Results shall be output via test equipment interface according to the requirements at Annex 5

5.6.2 The instrument shall also be equipped with a data printer;

5.6.3 The data transmission from the instrument to the printer shall be designed so that the results cannot be falsified;

5.6.4 The printout shall clearly show a minimum of the following:

a) Vehicle Testing Station (VTS) name and address
b) VTS number
c) date and time of test
d) engine temperature, or the words 'No engine temperature taken'
e) the words 'Tested at below 80°C oil temperature (or an acceptable equivalent)' where appropriate
f) test limit applied eg. $2.5m^{-1}$ or $3.0m^{-1}$
g) RPC value applied (where selected by operator) as n.nn
h) fast pass Smoke Limit applied (where appropriate value achieved on test)
i) result of each acceleration as n.nn
j) drift at the end of the test as n.nn
k) mean of the final valid accelerations undertaken as n.nn
l) the test type applied followed by the words 'Test result' followed by 'Fail','Pass', 'Void' or 'Aborted' as appropriate

Examples: Test types currently include non-turbo engine, turbo engine, fast pass and reduced pollution certification.
A void result may occur when no valid mean has been achieved.
An aborted result may occur when the tester aborts a test once in progress..

Note: It is acceptable for printouts not to show (a) and (b) above at the time of installation. These can be added when the meter receives its first full on-site calibration. In this case a space for the Vehicle Testing Station to stamp or emboss the printout must be provided.

5.6.5 No malfunction of the printer shall affect the measuring ability of the meter;

5.6.6 The smoke meter will always give the tester (by prompt) at least one printout at the end of each completed test sequence;

5.6.7 The meter must always offer to produce a second or further printout.

5.7 Calibration

5.7.1 The meter shall be supplied with a stable neutral density filter in the region 1.6 to 2.0m^{-1}. This value shall be programmed into the smoke meter. Only UKAS approved operators shall have access to re-program this value;

5.7.2 Meters shall prompt a verification check at least once every seven and a half days, using the filter specified in Section 5.7.1. No further testing shall be permitted unless the meter reads the value of that filter to within $\pm$0.1m^{-1}. This check shall be simple and quick to perform and within the capability of a vehicle tester;

5.7.3 Only UKAS approved operators shall have access to correct for non-linearity;

5.7.4. Provision shall be made for a more comprehensive check at 3 points in the range as specified in Annex 9. This check will be carried out by a UKAS approved operator at a frequency as specified in Annex 9.
Note: Methods of calibrating using other than optical filters will be considered on their merits.

5.8 User Manual(s)

Each meter shall be supplied with comprehensive user manual(s) in English including, in simple step-by-step terms:-

a) using the meter to carry out FAS testing according to the relevant Inspection Manual(s)
b) the use of the engine temperature device (including the appropriate temperature values required when not using an oil temperature probe)
c) an explanation of the types of vehicles for which the meter is 'Approved'
d) how to carry out a calibration verification check
e) routine maintenance
f) contact address (in the UK) for service and spare parts (including the neutral density filters referred to in 5.7.1).

A sample of each manual shall be provided to the Vehicle & Operator Services Agency.

Any subsequent manual updates shall also be provided to Vehicle & Operator Services Agency at the time of their issue.

In addition, a quick reference card, preferably laminated or plasticised, shall be attached to each meter and shall include the information necessary for daily use.

5.9 Markings

The meter shall be fitted with a permanent and easily read label giving its make, model and the category of vehicles for which it is approved (all as shown on the certificate of acceptance) and serial number.

These marking shall be clearly visible on at least one of the photographs

submitted to Vehicle & Operator Services Agency under the requirements of 8.2.

5.10 Calibration Manual

A calibration manual shall be provided with each meter supplied for type approval testing and its adequacy and completeness shall be checked by the laboratory carrying out the Environmental testing.

The manual shall contain all the information necessary to carry out a full annual calibration as specified by the Vehicle & Operator Services Agency. Before the Vehicle & Operator Services Agency issues a Certificate of Acceptance for a meter, the meter manufacturer (or UK importer) shall provide a written declaration.

The declaration shall state whether or not one copyright copy of this manual, and any additional software required for calibration purposes, will be made available to any third parties, at a reasonable price, requiring the information to gain UKAS accreditation.

Vehicle & Operator Services Agency will make it clear what manufacturers (or UK importers) have declared for each meter when it publishes lists of acceptable smoke meters.

6. TEST EQUIPMENT INTERFACE

6.1 General

Meters shall be able to communicate with 'MOT Computerisation Technical Infrastructure' (MOT System), receiving vehicle specific information on test methods and standards from, and transmitting test result to, the MOT System using the Test Equipment Interface Specifications found in Annex 5.

Before any equipment is put into service using the interface for MOT testing purposes, proof of compliance with the equipment interface specification will be provided by a system of 'Type Approval' of the interface and arrangements to ensure that equipment supplied to the market conforms to the type approved master.

6.2 Data Formats and Structures

Data structures for application will be found in Annex 5.

6.3 Data transfer and storage

Meters shall:

6.3.1 receive vehicle specific information on test methods and standards from, and transmit test results to the MOT System;

6.3.2 meet with all appropriate command and data performance requirements at Annex 5.

7. ENVIRONMENTAL REQUIREMENTS

7.1 Reference Conditions

7.1.1 For Correlation Tests

Stable ambient conditions.

7.1.2 For Environmental Testing

a) temperature	20°C ±4°C
b) relative humidity	60% ±10%
c) atmospheric pressure	stable ambient
d) mains voltage	nominal voltage ±2% nominal frequency ±1%

7.2 Rated Operating Conditions

a) temperature:	2°C to 40°C (any part of the instrument which is taken to the vehicle must be suitable for intermittent use down to 2°C)
b) relative humidity	up to 90%
c) atmospheric pressure variation:	ambient ±2,500 Pa
d) mains voltage variation	-15% to +10% of the nominal voltage and ±2% of the nominal frequency

See section 8.5 for details of tests to these requirements.

The power source need not be mains. In the case of a meter which runs on more than one power source, then either:-
a) type approval testing is carried out with the machine running on each power source, or
b) a large clear durable notice shall be permanently displayed on the unit saying, for example, '**For statutory testing, use mains power only'** or similar as appropriate.

7.3 Special Requirements for Category B Meters

The power supply to any part of the meter which will be handled by the vehicle tester during a test must not be greater than 24v. Additionally, those parts of the meter which would normally be used when testing a vehicle outside must effectively be sealed against the ingress of rain (see Section 8.5.8.)
Alternatives to using 24v power which can be demonstrated to be as safe will be considered.

7.4 Disturbances

The meter shall maintain accuracy to within $\pm 0.05 m^{-1}$, or shall indicate a fault or not register a result, when subject to the following disturbances:

a) mechanical shock (see Section 8.5.9)
b) short time power reduction (see Section 8.5.10)
c) bursts from the mains (transients) (see Section 8.5.11)
d) electrostatic discharges (see Section 8.5.12)
e) radiated, radio frequency, electromagnetic fields (see Section 8.5.13)

8. PATTERN APPROVAL PROCEDURES

8.1 General

Correlation testing shall be carried out on 2 units and environmental testing shall be carried out on at least one unit, all of which, in the opinion of the testing bodies, represent the definitive pattern.

Test houses will normally expect meters to be provided complete with:
a) a description of the general principle of measurement
b) a list of essential components with their characteristics
c) a description of the essential components with drawings and diagrams that are necessary for testing and maintenance
d) general information on the software required for a microprocessor equipped measuring meter
e) the operating instructions that shall be provided to the user
f) details of how calculations are performed
g) a fully documented calibration procedure and a set of calibration filters.

The pattern tests fall into 2 parts:

Part 1: Verify correlation with the reference meter, and takes the form of back-to-back FAS testing over a range of vehicles representative of those likely to be tested. This is to be conducted by an organisation having a proven ability in FAS testing to Type Approval standards using the reference meter and which can demonstrate independence from any smoke meter manufacturer.

The suitability of a particular test house should be confirmed with the Vehicle & Operator Services Agency before testing begins.

The organisation conducting this aspect of the approval process is also responsible for verifying that the operational requirements of this specification (Section 5) are met.

Part 2: Environmental testing using a neutral density filter to simulate smoke measurement. This can be done only by a test house having a UKAS accreditation which specifically covers the relevant tests on smoke meters.

Reports from other European Accreditation Multi Lateral Agreement (MLA),

or other International Laboratory Accreditation (ILAC) test houses will be considered on their merits.

8.1.1 Badge engineering

Where a meter is to be released by the original certification holder for the issue of a second or further certificate for marketing or other purposes these original reports will continue to be acceptable.

8.2 Submitting an application

NOTE: All documents shall be presented in English or accompanied by a full technical translation to English.

When both sets of tests have successfully been completed, application for inclusion on the List of Acceptable Equipment should be made to:

Garage Equipment Association
2/3 Church Walk
DAVENTRY
Northants
NN11 4BL

8.2.1 Applications for new meters should include the following as necessary:

 a copy of the test reports showing that all the required criteria have been satisfied

a copy of the user manual(s) to meet the requirements made under paragraph 5.8

 photographs of the meter

 clear identification of the power source during the test process eg. battery or mains

 any declaration made under paragraph 5.10

 a declaration of the categories of vehicle to be tested

 a declaration that any changes, as listed in the pattern approval report, which were required to obtain approval will be made to all production models

 a declaration that any future design modifications will be notified to the original test house

 a declaration that no changes have been made to meter software which will affect the equipment function for the purposes of MOT Testing

8.2.2 Applications for badge engineered meters should include the following as necessary:

a copy of the user manual(s) to meet the requirements made under paragraph 5.8

 photographs of the meter clearly showing new identifying features – colour, badging, etc.

 any declaration made under paragraph 5.10

 a declaration that any changes, as listed in the pattern approval report, which were required to obtain approval will continue to be made to all production models

 a declaration that any future design modifications will be notified to the original test house

 a declaration from the original certification holder to advise that the meter has been released to be sold an alternative trim format

 a request for the issue of alternative certification giving details from original certification and new identifying information

 a declaration that no changes have been made to meter software which will affect the equipment function for the purposes of MOT Testing

8.3 Conformity of production

The meter will be subject to annual conformity of production testing according to the requirements set out in Annex 6.

8.4 FAS Correlation

8.4.1 Range of vehicles/engines

Correlation with the reference meter, is to be carried out on a range of vehicles representative of those on which the meter will be used in-service as shown below.

8.4.2 Category A Meters

a) Naturally aspirated up to 1.8 litres;
b) Turbocharged, 1.4 to 2.0 litres;
c) Turbocharged, 2.1 to 3.0 litres;

8.4.2.1 The engines shall be set-up so that their FAS emission is in the region 0.1 to 3.0m^{-1},

8.4.2.2 At least one engine shall emit smoke in the region 2.5 to 3.0m^{-1}, one other in the region 1.0 to 1.5m^{-1} and one in the region 0.1 to 0.5m^{-1}.

8.4.2.3 One engine shall have electronically triggered injectors.

8.4.3 Category B Meters

d) Turbocharged, 2.1 to 3.0 litres
e) Turbocharged, 4.0 to 8.0 litres;
f) Turbocharged >8.0 litres.

8.4.3.1 The engines shall be set-up so that their FAS emission is in the region 0.1 to 3.0m^{-1},

8.4.3.2 One engine shall emit smoke in the region 2.5 to 3.0m^{-1}, one other in the region 1.0 to 1.5m^{-1}, and at least one vehicle shall be equipped with a regenerative particulate trap and emit smoke below 0.5m^{-1}.

8.4.3.3 At least one engine shall have electronically triggered injectors.

8.4.3.4 At least one engine shall be intercooled.

8.4.4. Correlation Test Procedure

The correlation tests shall be performed using complete vehicles. Test engines shall be at normal operating temperature as specified by the vehicle manufacturer.
The reference meter shall be properly calibrated using a neutral density filter, the value of which is known to better than 0.025m^{-1} and is traceable to National or International Standards according to UKAS requirements.

The reference meter shall indicate this value to within $\pm$0.05m^{-1}.

The following series of tests, each consisting of 10 FAS, will be performed on each vehicle with the meter indicated:

Test 1 Reference meter installed on its own and in accordance with Directive 72/306/EEC and as agreed with the Vehicle & Operator Services Agency.

Test 2 Subject meter installed on its own in the vehicle tailpipe and calibrated According to manufacturer's instructions using a neutral density filter the value of which is known to better than $0.025m^{-1}$ and is traceable to National or International Standards according to UKAS requirements.

Test 3 As Test 2

Test 4 As Test 1

Having performed Tests 1 to 4 on all engines, this will then be repeated on one engine selected at random from the appropriate category as a further check on the subject meter's repeatability.

8.4.5 Analysis of Results

Based on the mean of Free Accelerations 7, 8, 9 and 10 in each test:

1 A test sequence is valid only if Test 4 does not vary from Test 1 by more than $\pm 0.05m^{-1}$ or $\pm 5\%$ of the arithmetic mean result, whichever is the greater.

2 On 2 vehicles, the mean of Tests 2 and 3 must lie within $\pm 0.05m^{-1}$ or $\pm 5\%$ of the arithmetic mean result, whichever is the greater, of Tests 1 and 4. On the remaining vehicle, the mean of Tests 2 and 3 must lie within $\pm 0.1m^{-1}$ or $\pm 10\%$ of the arithmetic mean result, whichever is the greater, of Tests 1 and 4

3 The results of tests 2 and 3 must lie within $\pm 0.1m^{-1}$ or $\pm 10\%$ of the arithmetic mean, whichever is the greater, mean of the 2 tests.

4 For each of the 4 tests, the scatter of results of the last 4 FAS (ie 7, 8, 9 and 10) expressed in units of m^{-1} shall not exceed 15% coefficient of variation, where the coefficient of variation is defined as

$$\frac{\text{Standard Deviation} \times 100}{\text{Mean}} \ \%$$

8.5 Environmental Testing

The tests in this section are to be performed applying a randomly selected filter from one of two stable neutral density optical filters in the region of 0.7 to $1.5m^{-1}$ and 2.5 to $3.0m^{-1}$ to simulate a measurement situation. These filters are to be supplied by the meter manufacturer

and may or may not be part of the set of calibration filters. Their values need not be traceable to National standards. Once selected the same filter may be used for each of the environmental checks conducted.

Tests should normally be carried out on a complete unit, including the printer.
If the size or configuration of the meter is such that this is not practicable or if only a particular component or device of the meter is concerned, a test may be carried out on the component or device separately, but a simulated measurement set-up must be achieved.

It is not intended that meters be dismantled for testing.

Before each test, the unit shall be calibrated according to Section 5.7

The neutral density filters are to be kept with the meter during the climatic tests to prevent problems such as condensation or poor fit due to differential heating.

Not all tests are applicable to all meter power supply configurations. A schedule of tests relevant to each configuration is given at Annex 4.

8.5.1 Safety Checks

Part 1 Earth Continuity

The resistance from the earth pin of the mains supply plug to the meter chassis should be less than 0.5Ω. The point of measurement on the chassis should normally be that which is physically the farthest accessible point from the mains cable entry position of the meter enclosure.

Part 2 Dielectric Strength and Insulation Resistance

The test voltage of 2.1kV dc is applied between the live and neutral terminals (strapped together) and mains earth for at least one minute, followed by a measurement of the insulation resistance at 500V dc (applied across the same points). This resistance shall not be less than 20MΩ. Note that during this test, the equipment should not be powered up, but the mains switch should be in the 'on' position.

8.5.2. Repeatability

Carry out the manufacturers calibration procedure (para 5.7.4) and verify that it effectively and properly calibrates the meter. Repeat the calibration procedure 4 more times and confirm that calibration is repeatable to within $\pm 0.05 m^{-1}$.

8.5.3. Drift Stability

This test shall be conducted for a period of 4 hours following the warm up time. Measurements shall be performed every half hour.

The meter shall maintain accuracy to within $\pm 0.05 m^{-1}$ (or not indicate a result if the meter is battery powered and the battery has become discharged). For meters which are intended to run on batteries for only a short period (such as for the duration of a FAS test), this test shall be done twice, once without the unit being returned to the charger, and one with the unit alternating between being 'on charge' for 15 minutes and 'in use' for 15 minutes.

In the former test, where a permanent low voltage supply via the smoke meter is utilized the requirements at Annex 5, 2.2 shall be observed. Battery life shall be noted if this is less than 4 hours.

8.5.4 Dry Heat

The test consists of exposure of the meter to a temperature of $40^{o}C$ under 'free air' condition for 2 hours. The time duration specified beginning after the meter has reached temperature stability. During the test, the change in temperature shall not exceed $1^{o}C$/min during heating up and cooling down, and the relative humidity in the testing atmosphere shall not exceed 50%.

Reference: IEC 60068-2-2, 4 ed., 1974. 'Basic environmental testing procedures', Part 2: Tests, Test Bd: 'Dry heat, for heat dissipating EUT with gradual change in temperature'.

8.5.5. Cold

Part 1 This test consists of exposure of the meter to a temperature of $2^{o}C$ under 'free air' condition for 2 hours. The time duration specified beginning after the meter has reached temperature stability. During the heating up and cooling down of the meter, the change in temperature shall not exceed $1^{o}C$/min.

Reference: IEC 60068-2-1, 4 ed., 1974, 'Basic environmental testing procedures', Part 2: Tests, test AD 'Cold for heat dissipating EUT with gradual change of temperature'.

Part 2 Immediately after Part 1, any part of the meter which would normally be attached to a vehicle's exhaust pipe shall be placed in an ambient temperature of below $-2^{o}C$. It is accepted that cabinet doors may have to be left ajar during this test to allow for interconnecting cables, and the main body of the meter need not be kept critically at $2^{o}C$.

8.5.6. Damp Heat, Steady State

This test consists of exposure of the meter to a constant temperature of $40^{o}C$ and a constant relative humidity of 90% for 4 days. The exposure shall be such that water does not condense on the meter. The temperature is deemed to be steady when the difference between the extreme temperatures does not exceed $5^{o}C$, and the rate of change does not exceed $5^{o}C$ per hour.

Reference: IEC 60068-2-3, 3 ed., 1969, 'Basic environmental testing procedures', Part 2: Tests, test Ca: 'Damp heat, steady state'.

8.5.7 Power Supply Variation

Part 1 For meters which are directly connected to the mains while measurements are taken.

This test consists of exposing the meter to extreme values from the nominal power supply voltage, V_{nom}, and the nominal frequency, $f_{nom,}$ for a period long enough to perform the required measurement. A measurement shall be taken while the meter is exposed separately to each of the following conditions:

Mains voltage V (v)	upper limit lower limit	V_{nom} + 10% V_{nom} - 15%
Mains frequency f (Hz)	upper limit lower limit	f_{nom} + 2% f_{nom} - 2%

Part 2 For meters with a battery power supply

This test consists of exposing the meter to extreme values from the nominal power supply voltage, for a period long enough to perform a measurement. A DC power supply is to be used to simulate a battery, and a measurement shall be taken with the meter exposed to V_{nom} +10% and Vnom –25%. This latter figure may be reduced to coincide with voltage at which a 'battery low' or similar warning device operates.
Ingress Protection – Category B Meters only

8.5.8 This test applies to those parts of the meter which would normally be used outside when testing a vehicle outside. It consists of placing each unit under test equipment to prove protection against drops of water.

The test equipment is shown in BS 5490:1977; Figure 3 page 26. The rate of discharge shall be reasonably uniform over the area of the apparatus, with a rainfall of approximately between 3mm and 5mm of water per minute. The base of the dripping equipment shall be larger than the equipment under test. The component shall be tested in 4 fixed positions of tilt. These positions are 15°either side of the vertical in 2 mutually perpendicular planes. The total test duration will be 10 minutes with the equipment tested for 2.5 minutes in each position of tilt. On components which attach to exhaust pipes, the test will be carried out twice; once with the exhaust probe pointing vertically down and once with the exhaust probe horizontal. In each case, the exhaust probe will be effectively sealed against the ingress of water prior to the test.

The meter shall be switched on during the test, and a measurement shall be taken before and after. At the end of the test the components shall be examined to confirm that there has been no ingress of water.

Reference BS 5490 : 1977 'Specification for Classification of degrees of protection provided by enclosures', Test 8.2 'Test for second numeral 2' (IPX2)

8.5.9 Mechanical Shock

Part 1 For mechanical shock testing, the meter shall be placed in its normal position of use on a rigid surface. It shall be tilted on one bottom edge and then shall be allowed to fall freely onto the test surface. The following conditions shall be applied

Height of fall…….. 50 mm
Number of falls……..2 on each bottom edge

A measurement shall be taken before and after the test.

Reference IEC 60068-2-31, 1 ed., 1969 + Amendment 1 (1982), 'Basic environmental testing procedures', Part 2: Tests, test Ec: 'Drop and topple (procedure Dropping on to a face)'.

Part 2 This part applies only to those parts of the meter which contain electrical or electronic components and which are carried by the vehicle tester during normal use, for example any part which attaches to the vehicle exhaust or a remote control unit etc.

The test consists of subjecting the relevant component to two falls from a height of 0.5m onto a smooth hard rigid surface of either concrete or steel. A measurement shall be performed after the test and the component shall be examined to confirm that structural integrity has been maintained.

Reference IEC 60068-2-32: 'Basic environmental testing procedures', Part 2: Tests, Test Ed 'Free fall (procedure 1)'.

8.5.10 Short Time Power Reduction

A test generator shall be used to reduce the amplitude of the AC mains voltage as specified in the table below. It shall be adjusted before being connected to the meter. The mains voltage interruptions and reductions shall be repeated 10 times with an interval of at least 10 seconds between successive disturbances.
The following conditions shall be applied:

Reduction	100%	50%
Duration	10 ms	20 ms

8.5.11 Bursts from the mains (transients)

The test consists of exposure of the meter to bursts of 1.0 kV voltage spikes and having a double exponential waveform. Each spike shall have a rise time of 5ns and a half amplitude duration of 50ns. The burst length shall be 15 ms, the burst period (repetition time interval) shall be 300ms.

Repetition frequency of the impulses and peak values of the output voltage on 50Ω load: 5.0kHz ±20%.
The transient generator shall have an output impedance of 50Ω and shall be adjusted before connecting to the meter. At least 10 positive and 10 negative bursts randomly phased shall be applied. Insertion of blocking filters in the cables to the meter may be necessary to prevent the burst energy being dissipated in the mains.

Reference: IEC Publication 61000-4-4.

8.5.12 Electrostatic discharges

A capacitor of 150pF shall be charged by a suitable DC voltage source of 6kV in contact mode and 8kV in air mode. Then it shall be discharged through the meter by connecting one terminal to the meter's ground chassis and the other through a 330Ω resistance to the meter's surfaces that are normally accessible to the user.
At least 10 successive discharges shall be applied with a time interval between discharges of at least 10s. A meter not equipped with a grounding terminal shall be placed on a grounded plane surface that projects beyond the meter by at least 0.1m on all sides. The associated grounded connection to the capacitor shall be as short as possible. In the contact discharge mode, to be carried out on conductive surfaces, the electrode shall be in contact with the meter and the discharge shall be actuated by the discharge switch of the generator. In the air discharge mode, on insulating surfaces, the electrode is approached to the meter and the discharge occurs by spark.

Reference: IEC Publication 61000-4-2

8.5.13 Radiated, radio frequency, electromagnetic fields

The meter shall be exposed to an electromagnetic field strength as follows:

Frequency Range	26 – 1000MHz
Field Strength	3 V/m
Modulation	80% AM, 1kHz sine wave

The field strength may be generated in the following ways:

a) a strip line for low frequencies for small meters from DC to 150MHz
b) a TEM cell (Transverse Electromagnetic Mode cell) for higher frequencies,up to 1GHz
c) a biconical antenna (26MHz – 300MHz)
d) a log periodic antenna (100MHz – 1,000MHz)

The specified field strength shall be established prior to the actual testing (without the meter in the field).

When the test is carried out in a shielded enclosure to comply with international laws prohibiting interference to radio communications, care needs to be taken to handle reflections from walls. Anechoic shielding may be necessary.

Reference: IEC Publication 61000-4-3

8.6 Engine Temperature Measurement Approval
(required for category A meters used in Class IV, VII and SVA testing)

Verify that the meter meets the operational and accuracy requirements for measuring engine temperature as specified in Sections 4.2 and 5.3
Disconnect the probe from the meter and check that no reading is displayed and that the words 'No engine temperature taken' are recorded on the print out and the output to the read/write device is given as 'By-passed'.

ANNEX 1

STATUTORY TEST PROCEDURES

Full details of the Diesel Exhaust Emission Test procedures can be found in the current Vehicle & Operator Services Agency Inspection Manual for:

a) Car & Light Commercial Vehicle Testing (Class III, IV & VII)
b) Private Bus Testing (Class V)
c) Public Service Vehicle (Class VI)
d) Heavy Goods Vehicle
e) Single Vehicle Approval

NOTE: A meter must test according to the current Inspection Manuals at the time of sale.

ANNEX 2

EXAMPLE CALCULATIONS FOR SECTION 5.1.6

Example 1

Acceleration 1	3.0
Acceleration 2	2.0
Acceleration 3	1.5
Acceleration 4	1.5

The mean after the first 3 accelerations is $\frac{3.0 + 2.0 + 1.5}{3} = \frac{6.5}{3} = 2.167$

For this result to be valid, no reading may be lower than 75% of this value

75% of the mean is (0.75 x 2.167) = 1.625

The reading from acceleration 3 is below this value, so the result is not valid and another acceleration is necessary.

After 4 accelerations the mean of the last three is 1.67, and no reading is less than 75% of this value so the result is valid.

Example 2

Acceleration 1	4.2
Acceleration 2	4.1
Acceleration 3	4.2
Acceleration 4	4.0
Acceleration 5	1.6
Acceleration 6	4.2

We need consider only the last 3 accelerations

The mean is: $\frac{4.0 + 1.6 + 4.2}{3} = \frac{9.8}{3} = 3.267$

25% of the mean is: 0.25 x 3.267 = 0.817

So, for the mean to be valid, no reading can be less than

$$3.267 - 0.817 = 2.45$$

The reading from Acceleration 5 is clearly below this value and is not valid. The result of this test is the mean of accelerations 4 and 6, i.e.

$$\frac{4.0 + 4.2}{2} = 4.1$$

ANNEX 3

REFERENCE METER

The reference meter for correlation testing purposes will be a dedicated system consisting of:

i) the Bosch RTM 430 smoke tube,
ii) probe of internal diameter 10mm and length 1m for exhaust diameters to less than 70mm
iii) probe of internal diameter 16mm and length 1m for exhaust diameters from 70mm
iv) dedicated correlation software for use with this device.

Damping

The damping filter to be used with the reference smoke tube consists of two parts. An initial, physical response correction filter is applied to correct smoke output of the reference device to that of a smoke meter with a 400ms response time (EC 72/306 maximum allowable response time). A second, one second electrical filter is then applied.

NOTE 1: This two-stage filtering is recommended in ISO 11614, and also provides compliance with EC 72/306.

NOTE 2: Response time is largely dependent upon exhaust gas velocity. Exhaust gas velocity is not measured during FAS tests, therefore the physical response correction to 400ms is based around a specific point. The point chosen for the physical correction filter relates to an exhaust gas velocity of 20m/s with a corresponding response time of the reference meter of 150ms. Both the correction and the main electrical filters are based around a simple first order recursive filter.

These filters are applied in sequence to the raw output of the reference smoke tube.

Correction Filter

$Y_n = (0.9304 * Y_{n-1}) + (0.0696 * X_n)$

Electrical filter

$Y_n = (0.9772 * Y_{n-1}) + (0.0228 * X_n)$

Where;

Y_n new calculated (filtered) value

Y_{n-1} previous calculated (filtered) smoke value

X_n input raw (prior to filter) smoke value

All filtering is conducted on opacity values, with conversion to light absorption coefficient (k) occurring after the filters. Finally a temperature correction is applied.

Correlation software

Correlation software to enable manufacturers to conduct tests and trials prior to seeking correlation testing for acceptance certification will be available from December 2001.

ANNEX 4

SCHEDULE OF TESTS

The following table gives guidance on which tests to carry out on meters with various power supplies.

Power Test	Mains only	Mains/short life[1] Battery	Long Life[2] Battery	Dual power option
8.5.1	Yes	Yes	On charger	Yes
8.5.2	Yes	Yes	Yes	Battery
8.5.3	Yes	Yes, Twice	Yes	Battery
8.5.4	Yes	Yes	Yes	Either
8.5.5	Yes	Yes	Yes	Either
8.5.6	Yes	Yes	Yes	Either
8.5.7 (1)	Yes	No	No	Yes
8.5.7 (2)	No	Yes	Yes	Yes
8.5.8	N/A	Yes	Yes	Yes
8.5.9	Yes	Yes	Yes	Yes
8.5.10	Yes	No	No	Mains
8.5.11	Yes	No	No	Mains
8.5.12	Yes	Yes	Yes	Both[3]
8.5.13	Yes	Yes	Yes	Both[3]

NOTES:

1. 'Short life battery' means meters where the measuring unit is normally recharged between tests.
2. 'Long life battery' means meters which would be expected to run all day without recharging.
3. These tests must be repeated on each configuration due to different earthing arrangements etc.
4. Allowance should be made for the inclusion of the read/write device where the 12v supply for this is sourced from the meter.

ANNEX 5

TEST EQUIPMENT INTERFACES

1. Overview

The interface device comprises of a smart card Read/Writer and custom firmware running on a micro-controller to provide a simple interface. The data produced as part of the test can be stored onto the smart card for further processing by the MOT system. The interface device shall be mounted externally. The external device is physically identical to the EGA interface device.

2. Physical Interface

The physical interface consists of a number of elements that define how the device can be physically incorporated into the item of test equipment.
The interface device will be supplied to mount externally.

2.1 External Unit Serial Connection

The external serial interface connection will be presented as a 9-way female D-type connector, wired as a DCE interface. The signals shall be at RS232 levels.

The physical connector, as viewed from the rear of the interface device, is shown by Figure 1.

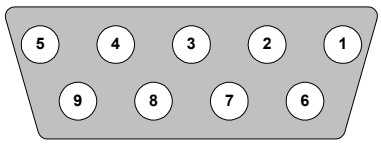

Figure 1 - External Serial Connector

The usage of the connections on the external serial interface is defined in Table 1.

NOTE: This shall not be used for any other purpose or functionality.

Pin	Name	Direction	Usage
1	DCD	Out	Not currently used. Reserved.
2	RXD	Out	Serial data from interface device.
3	TXD	In	Serial data to interface device.
4	DTR	In	Not currently used. Reserved.
5	GND	-	Signal Ground.
6	DSR	Out	Interface device ready. Raised on power up.
7	RTS	In	Handshake control.
8	CTS	Out	Handshake control.
9	RI	Out	Not currently used. Reserved.

Table 1 –Serial connector pin assignment

2.2 External Unit Power Requirements

The unit will require suitable power supply. The power connection will be via an external mains adapter.
Consideration will be given where an alternative 12v (9 – 13.8v range) power supply from the smoke meter via a standard DC power plug is proposed. Note: DC plug with a 2.1mm positive centre pin and negative outer shield. A right-angled type is recommended to reduce the incidence of accidental removal..

Where a permanent low voltage supply via the smoke meter is provided on meters which operate on a battery or mains/battery combination during vehicle test function the requirements of 8.5.3 shall be fulfilled to include power supply requirements for the functionality of the external read/write unit. Power supply electrical limits are as shown in Tables 2 and 3.

Parameter	Minimum	Typical	Maximum	Condition
DC input voltage	10.5v	12v	13.8v	RF power active, RS232 serial port active

Table 2 - DC input voltage

DC input current	Peak	500mA
	Average	100mA
	Standby	50mA

Table 3 - DC input current

3. Logical Interface

The Logical interface defines the high level commands used to communicate across the interface. The interface device operates in a slave mode. The test equipment must instigate all communication in a command/response manner.

3.1 Command Format

The requests to the interface device take the following format:

<cmd> <len> <data...>

where:

<cmd> is one of the commands described below.
<len> is the amount of data to follow (0 <= len <= 254).
<data...> is the optional data for the command.

The interface device will respond with the format:

<status> <len> <data...>

where:

<status> is the command status tabulated below.
<len> is the amount of data to follow (0 <= len <= 254).
<data...> is the optional data for the response.

3.2 Command Set

The interface device responds to a limited command set. These commands can be sent to the interface device in any order. On return the status byte should be checked for any errors (see 3.3).

NOTE: These commands are ASCII upper case characters as shown in Table 4.

<cmd>	Action
Q	Checks if device is active and a smart card is present
P	Returns test parameters for this device (if present)
W	Writes test data for this test device to the smart card
D	Disconnect power from smart card
Z	Enter low power mode (also see Note below)

Table 4 - Interface Device Command Set

Query Device Status (Q) - Returns the current status value. It should be used to check that a valid smart card is present before performing any other commands. The <len> value should be set to 0 in the command. On return, the <len> value will be set to 0 and no data is returned.

Read Test Parameters (P) – Returns the Vehicle Details or Test Parameters for the specified vehicle and test equipment type. The data structure for this command is described in 5.1, Table 8 or 9. On return, the <len> value will show the amount of data returned. If there is no Test Parameter data for this vehicle or test equipment type, the <len> value will be set to 0. The structure of the returned data is defined in 5.2, Tables 11 or 12.

Write Test Data (W) – Requests the passed data for the specified vehicle and test equipment type is written to the Smart card. The data structure for this command is described in 5.1, Table 10. On return, the <len> value will be set to 0 and no data is returned.

Disconnect Power from Smart card (D) – Instructs the device to remove power from the Smart card so that it can be safely removed. The <len> value should be set to 0 in the command. On return, the <len> value will be set to 0 and no data is returned.

Enter Low Power Mode (Z) – Instructs the device to enter low power mode. The <len> value should be set to 0 in the command. On return, the <len> value will be set to 0 and no data is returned.

NOTE: Smoke meters which are to be combined with an Exhaust Gas Analyser which meets the requirements of the 5th Revision of the 1996 EGA specification shall not apply the Z command. The Z command is intended for use with devices enabled for two-way communication only and will inhibit the 1996 specification exhaust gas analyser protocol.

3.3 Status Description

A successful response to a command can be assumed if bit 0 is set to 1 (smart card present) in the Status byte, and all other bits are set to 0.

If any of the other bits are set to 1, then an error has occurred. The prioritisation of these status checks is handled within the read/write device, and only one error flag will be present.

Errors shall reported back to the operator via the test equipment using the meanings taken from Table 5 followed by a clear instruction of the next appropriate action for the operator to take, based on the examples given in italics below.

The status byte is defined here:

Meaning	7	6	5	4	3	2	1	0
Reserved	0							
Read or Write Failure		1						
Invalid Command			1					
Invalid Data Length				1				
Invalid Vehicle					1			
Invalid Test Equipment ID						1		
Invalid Smart Card							1	
Smart Card Present								1

Table 5 - Status Byte Value

These status flags will be retained until a suitable action clears them. The status flags have the following meanings:

Reserved – This bit is reserved for future use. It will be set to 0.

Read or Write Failure – The smart card could not be read/written to. This may be due to a defective Smart card. Cleared on removal of the Smart card or after a subsequent command has been processed.

Error message: Smart card error. Report failure to helpdesk.

Invalid Command – The received command was not one of the known set. Cleared on removal of the Smart card or after a known command has been received.

Error message: Software error. Report failure to meter manufacturer/engineer.

Invalid Data Length – The test data to be written to the Smart card was incorrect. Cleared on removal of the Smart card or after a subsequent command has been processed.

Error message: Software error. Report failure to meter manufacturer/engineer.

Invalid Vehicle – The vehicle specified in the command has not been registered on the Smart card. Cleared on removal of the Smart card or after a subsequent command has been processed.

Error message: Check vehicle details, and that you are logged on correctly.

Invalid Test Equipment Type – The test equipment type specified in the command has not been registered on the Smart card. Cleared on removal of the Smart card or after a subsequent command has been processed.

Error message: Check vehicle details, and that you are logged on correctly.

Invalid Smart card – The Smart card inserted into the interface device is not a valid card. Cleared on removal of the Smart card.

Error message: Smart card error. Report failure to helpdesk.

Smart card Present – A valid Smart card is present in the Interface Device. All commands except the status request will be ignored if a valid card is not present.

This process will be fully exercised during the functionality check prior to acceptance for use.

3.4 Command Usage

The diagram in Figure 2 depicts the possible responses to the commands that the Interface Device may handle.

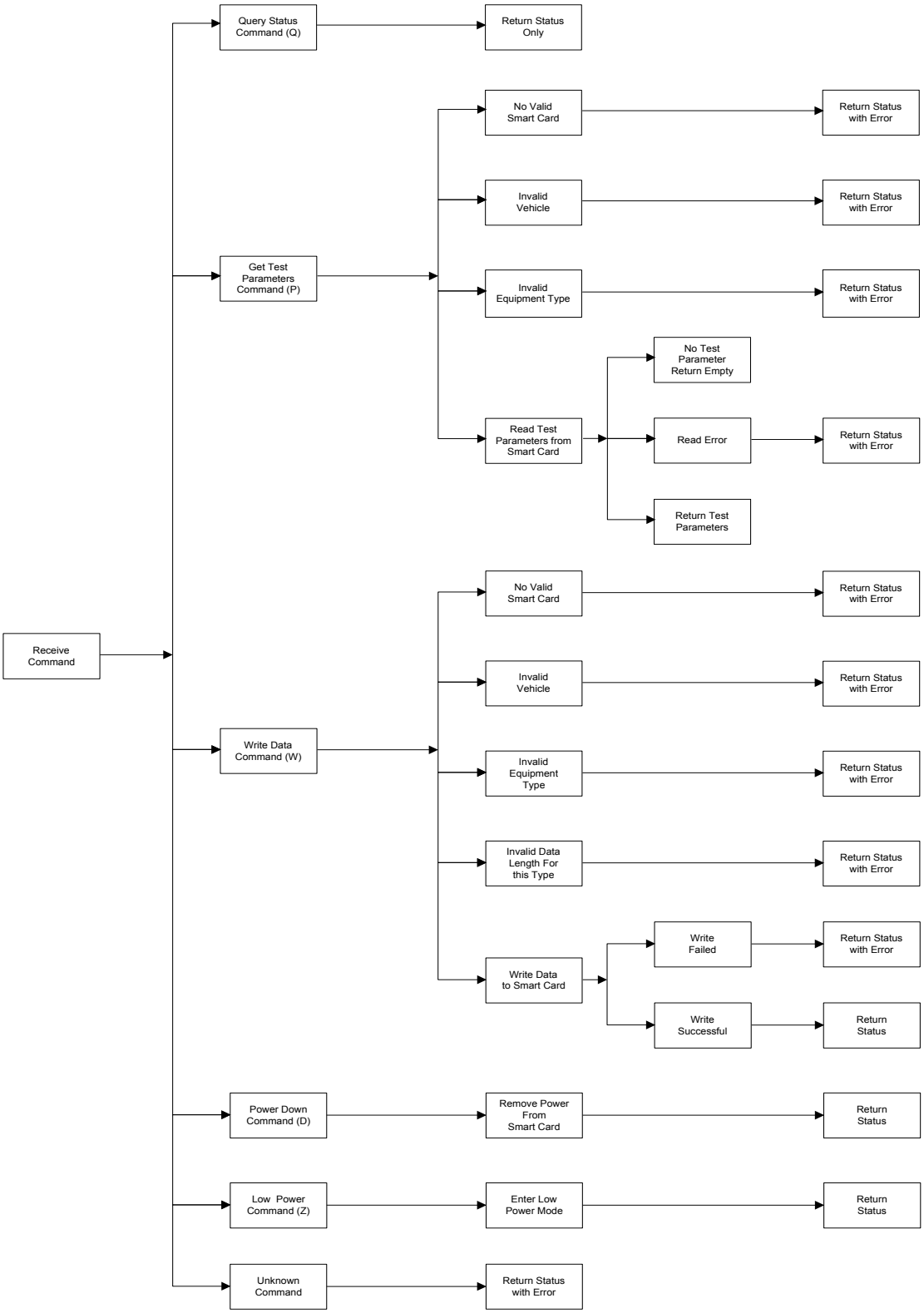

Figure 2 - Interface Device Response Tree

4. Data Transfer Protocols

The Data Transfer Protocol encapsulates the commands and responses and provides a reliable transport mechanism. This is used to detect transmission errors and if required, attempt a retransfer of the command.

4.1 Packet Structure

The data exchanged between the Test equipment and the Interface device is formatted into the following packet structure as shown by Table 6

PROLOG		Information Field	EPILOG		
DLE	STX	Command/Response	CSUM	DLE	ETX
1 Byte	1 Byte	N Bytes	1 Byte	1 Byte	1 Byte

Table 6 - General Packet Structure

The DLE character is used to introduce special characters required by the protocol. The DLE STX combination indicates the start of a packet. The DLE ETX combination indicates the end of a packet.

The DLE must be 'escaped' whenever it occurs in the data section. This is achieved by doubling the character in the form DLE DLE. The second DLE character is not included in the checksum calculation.

The Checksum is built from all the characters in the Data section of the packet in the form of an XOR calculation. If the checksum calculates out to be the DLE character, then it must be escaped by doubling the character in the form DLE DLE.

The Interface device will check the received packet against the checksum value. If these fail to match, a NAK packet will be sent back to the Test equipment. This will also occur if a parity error occurs or the character wait timeout expires. The format of a NAK packet is shown by Table 7;

DLE	NAK
1 Byte	1 Byte

Table 7 - NAK Packet Structure

The Test equipment must not send the NAK packet if it detects an error. Instead, it must re-send the original command packet.

4.2 Protocol Timeouts

The protocol will use two timeouts to manage errors in transmission.

Packet Wait Timeout – This is the maximum time that can elapse after sending a request before a response is obtained. When this time has expired, and a valid response has not been received, an error should be assumed. The Test equipment should respond by re-sending the command. The timeout is set to 10 Secs.

Character Wait Timeout – This is the maximum time that can elapse between receiving characters once the start of a packet has been detected. When this time expires, and the end of the packet has not been reached, an error should be assumed. The Interface device will respond by sending the NAK packet. The Test equipment should respond by re-sending the packet. The timeout is set to 50 mSecs.

The Character Wait Timeout is also used when a Parity error is detected. The receiver must wait until this timeout expires (i.e. all remaining characters in the packet have been received and discarded) before responding.

4.3 Protocol Examples

The diagrams shown in Figure 3 to Figure 5 depict the methods of handling low level protocol errors.

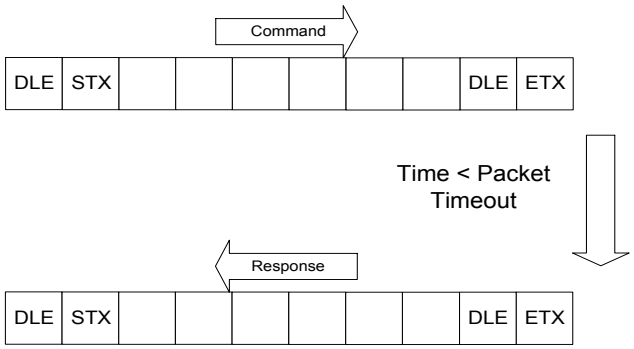

Figure 3 - Normal Command / Response

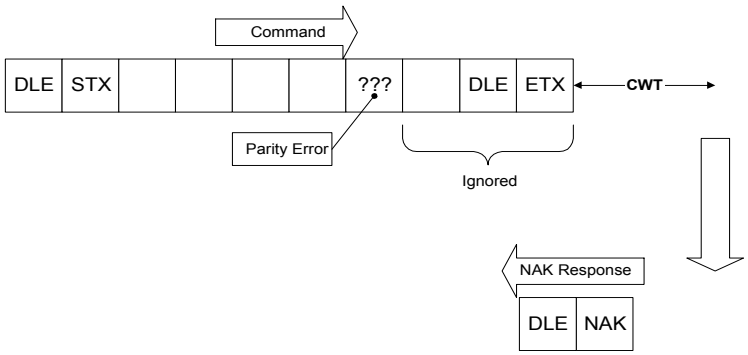

Figure 4 - Handling of Parity Errors with the Character Wait Timeout

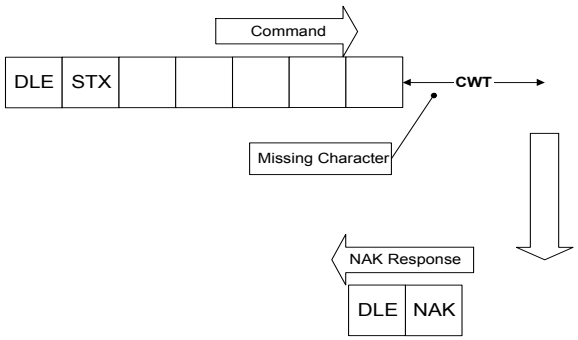

Figure 5 - Handling Missing Characters with the Character Wait Timeout

4.4 Communication Parameters

The protocol uses an asynchronous communication mode. The parameters for this are as follows:

Signal levels:	RS232
Baud Rate:	9600
Data Bits:	8
Stop Bits:	1
Parity:	EVEN

4.5 Flow Control

The Interface device will use Hardware handshaking to control the flow of data with the Test Equipment. This uses the RTS/CTS control lines.

4.5.1 Test Equipment to Interface Device flow control

The Interface device will use the CTS control line to halt the flow of data from the Test Equipment. It is however expected that the Interface device will be able to process the entire packet of data from the Test Equipment without the need for flow control. The Test Equipment should ensure that it does not send another packet of data before the Packet Wait Timeout has expired, if it has not received a valid response. Any data received while the Interface device is processing a command will be discarded.

4.5.2 Interface Device to Test Equipment flow control.

The Interface will check its incoming RTS line before sending each character of a response packet. If the RTS line is low, the transmission will be suspended. If however the RTS line remains low for a period of time greater that the RTS timeout of 2 seconds, then the transmission will be aborted and the response will be discarded.

5. Data Format and Structures

The data format and structures fall into two categories. The first type is the Command Data structure. The second type is the Application Data structure, see 3.2 for details of the Command Types.

5.1 Command Data Structures

To read the Vehicle Details, the format of the Read Test Parameters (P) command is shown in Table 8.

Details	Bytes	Notes
Test Equipment Type = 1	1	
Vehicle Identity (VRM or MOT test number)	12	(1)

Table 8 - Read vehicle details

To read the DSM Test Parameters Data, the format of the Read Test Parameters (P) command is shown in Table 9.

Details	Bytes	Notes
Test Equipment Type = 3	1	
Vehicle Identity (VRM or MOT test number)	12	(1)

Table 9 - Read Test Parameters command format

To write the DSM Results Data, the format of the Write Test Data (W) command is shown in Table 10.

Details	Bytes	Notes
Test Equipment Type = 3	1	
Vehicle Identity (VRM or MOT test number)	12	(1)
Test Data Length	1	(2)
Test Data (see Tables 14 and 15)	n	

Table 10 - Write Test Data command format

(1) – Either the VRM or MOT test number may be used to identify the vehicle under test. The value should be stripped of all spaces and then right space filled.

(2) – The Maximum data size must not exceed 127 bytes.

5.2 Data structures for application.

5.2.1 Vehicle Details

The Vehicle Details record is available to all items of test equipment and contains information about the test that may be useful to be displayed to the operator.

The record consists of variable length fields organised as Tag, Length, Value (TLV) data blocks.

Each item of data is identified by its tag, followed by the length of the data, followed by the data itself.

The tag and length values are stored as single bytes having a range of 0 to 255. The data is a sequence of ASCII characters.

The following table shows the tags that have been assigned to the different data types.

Parameter	Tag
MOT Test Number	0
VRM	1
Tester Identifier	2
VIN	3
Vehicle Make	4
Vehicle Model	5
Engine Size (cc)	6

Table 11 – Vehicle Detail Tags

This data can be read from the smart card device with the **Read Test Parameter Command (P),** supplying the Test Equipment Type of '1' with either the MOT test number or the VRM.

5.2.2 DSM Test Parameters Data

Byte	Type	Parameter	Comment
1	Byte	Test Type	Parameter - see Table Test Types
2	Byte	Temperature Limit	Minimum recommended test temperature - normally 60^{o}C
3 - 4	Word	Smoke Limit – Standard non-turbo	In 100ths
5 - 6	Word	Smoke Limit – Standard turbo	In 100ths
7 – 8	Word	Smoke Limit – Fast Pass	In 100ths
9 - 10	Word	Smoke Limit – RPC1	In 100ths
11 – 12	Word	Smoke Limit – RPC2	In 100ths
13 – 14	Word	Smoke Limit – RPC3	In 100ths
15 – 16	Word	Smoke Limit – RPC4	In 100ths

Table 12 – DSM Test Parameters Data

Word = 2 Bytes with LSB stored first.

This data can be read from the smart card device with the **Read Test Parameter Command (P),** supplying the Test Equipment Type of '3' with either the MOT test number or the VRM.

5.2.2.1 Test Type Table

For smoke meters the following current test types apply:

Test Type	Value
Non-turbo	30
Turbo	31
Fast Pass	32
RPC 1	33
RPC 2	34
RPC 3	35
RPC 4	36

Table 13 – Test Type Table

5.2.3 DSM Results Data

The DSM Results Data consists of two parts, a Common Data area that is present on all items of test equipment followed by the Equipment Specific Data.

5.2.3.1 Common Data

Byte	Type	Parameter		Comment
1	Byte	Data Version Number		This is version number 1
2	Byte	Global Test Results		See Global Results Table
3	Byte	Test Type Returned		See Test Types Table
4 - 11	ASCII	Identifier/Serial Number		To be assigned by VI
12	Byte	Calibration Date Due:	Day	1 – 31
13	Byte		Month	1 – 12
14	Byte		Year	01 – 99
15 - 24	ASCII	VTS Identifier		Based on VTS number (10 characters)
25 - 29	ASCII	Software Version		In the format AA999
30	Byte	Date Started:	Day	1 – 31
31	Byte		Month	1 – 12
32	Byte		Year	01 – 99
33	Byte	Time Started:	Hours	00 – 23
34	Byte		Minutes	00 – 59
35	Byte		Seconds	00 – 59
36	Byte	Test Duration:	Minutes	00 – 59

Table 14 –Common Results Data

5.2.3.2 Equipment Specific Data

Byte	Type	Parameter	Comment
37	Byte	Temperature Valid	0 = By-passed, 1 - Not By-passed
38	Byte	Temperature (°C)	Oil temperature - equivalent of up to 90°C
39 - 40	Word	FAS Result 1	In 100ths
41 - 42	Word	FAS Result 2	In 100ths. Unused entry must be set to FFFF hex.
43 - 44	Word	FAS Result 3	In 100ths. Unused entry must be set to FFFF hex.
45 - 46	Word	FAS Result 4	In 100ths. Unused entry must be set to FFFF hex.
47 - 48	Word	FAS Result 5	In 100ths. Unused entry must be set to FFFF hex.
49 - 50	Word	FAS Result 6	In 100ths. Unused entry must be set to FFFF hex.
51- 52	Word	Valid Mean Value	In 100ths. Unused entry must be set to FFFF hex.
53 - 54	Word	Drift at End	In 100ths
55	Byte	Total number of FAS	In the range 1 - 255 (1 - 6 is the most likely)
56	Byte	Repeat Cycle Applied	0 = No, 1 = Yes
57 - 58	Word	Test Result - RPC	In 100ths. Unused entry must be set to FFFF hex.

Table 15 – Equipment Specific Data

Total Record Size 58 Bytes

Word = 2 Bytes with LSB stored first.

This data can be written to the smart card device with the Write Test Data Command (W), supplying the Test Equipment Type of '3' with either the MOT test number or the VRM.

Where no data has been generated as a result of the test carried out egs. FAS Results have not been populated, no valid mean value achieved the surplus values shall all be given the value FFFF(hex). For engine temperature not measured this shall be FF(hex).

Where a WORD (2 bytes) is required in 100ths, this will give a possible range of values from 0.00 to 655.35, though the valid range in practice will be 0.00 to 9.99.

5.2.3.3 Global Results

Fail	0
Pass	1
Void	2
Aborted	3

Table 16 – Global Results Data

A void result may occur when no valid mean has been achieved.

An aborted result may occur when the tester aborts a test once in progress.

ANNEX 6

ANNUAL CONFORMITY OF PRODUCTION CHECKS

1. The conformity of production checks will be performed by a test house which is either a member of the European Accreditation Multi Lateral Agreement (MLA) or other International Laboratory Accreditation (ILAC), or in certain cases (see paragraph 6) by an accredited ISO 9000 certification body.

   The manufacturer/importer will nominate the test house or the ISO 9000 certification body, at the time of approval, which will be carrying out the conformity of production checks and will notify the GEA of the contact name and address.

   This body may be changed at any time during the meter life by notifying GEA of the new conformity of production contact details.

Conformity of Production by Test House

2. The test house will nominate a suitably qualified auditor who will visit the manufacturer/importer at any point between their manufacturing premises and point of sale.

   Starting from one calendar year after the date when the meter was accepted by GEA as meeting the requirements of the Specification For Diesel Smoke Meters the auditor will visit the manufacturer/importer and provide GEA with appropriate reports annually.

   In exceptional circumstances the test house and manufacturer may apply to the GEA to make alternative arrangements.

3. The manufacturer/importer will be required to provide a minimum of 2 sets of the following at the time of approval (see 8.1 Pattern Approval Procedures).

   i) Quality colour photographs (10” x 8”) showing the following

	Number of photographs
Meter	External - at least 2 (taken from opposite corners such that all sides of the meter, including identification markings are clearly visible) Internal - at least 1 (showing all circuit boards)
Probes	1

   ii) Documents as listed in Section 8.1 at items a) - g) of this specification (MOT/05/05/01) must bear unique references, information about the issue status, and a validation stamp from the test house.

The above sets will be distributed as follows after approval:

a. GEA
b. test house or ISO 9000 certification body (whichever applicable)
c. importer or distributor (where this is not the body seeking approval)

4. The manufacturer/importer will also be required to maintain a file of any modifications to the meter since it was first approved. The onus lies with the manufacturer/importer to decide in consultation with their nominated test house or certification body whether each modification requires re-approval.
Where a modification has not been re-approved, the file shall include a statement explaining why the modification does not affect the original approval.
A copy of this document must be made available to the test house at the time of the conformity of production check. A copy must also be made available to the GEA on request.

GEA reserve the right to request supporting information, or documentation to any modification related file statement.

5. At the annual inspection, the test house auditor will compare the original set of photographs, technical drawings and specifications to the meter currently being manufactured or offered for sale. Should there by any discrepancies, the test house auditor should advise appropriate action.
The GEA will require evidence from the test house of satisfactory audit reports, along with copies of any associated supporting information or documentation where requested.

NOTE: If any discrepancies arise which cannot be resolved between the test house auditor and the manufacturer/importer, they should be referred to the GEA. A decision will be made and the meter may then need to be submitted for full or partial approval testing to check whether it still meets the requirements of the specification.

If the auditor finds that the meter no longer meets the requirements of the specification, or where the GEA have not received appropriate periodic evidence of conformity of production checks, the certificate of acceptance holder will be notified and shall provide clear evidence that the meter continues to meet the requirements of the specification, for consideration by the GEA.
Warning will be given prior to the removal of the meter from the List of Acceptable Equipment. The meter will not be reinstated until it can be shown the required modifications have been made to both current production of the meter and to all identical models already being used for MOT purposes to the satisfaction of the test house auditor and GEA.

ISO 9000 Conformity of Production

6. Where the meter manufacturer holds certification from a UKAS accredited Certifying Body (or certification from any other accreditation body which is a member of the European Accreditation MLA or other International Laboratory Accreditation ILAC) to BS EN ISO 9000 covering the products concerned, then the annual test house conformity of production check can be replaced by providing the following to GEA:
   An annual written declaration, based on items 4 and 5 of this Appendix, from the manufacturer, endorsed by the Certification Body auditor to further the assurance, that no unauthorised changes have been made to the approved product.

   Declarations shall be retained by the manufacturer's representative in the UK.

Annual Conformity of Production Reports

7. Copies of Conformity of Production reports or declarations must be submitted to the GEA on an annual basis.

ANNEX 7

VEHICLE & OPERATOR SERVICES AGENCY VEHICLE TESTING DIVISION REQUIREMENTS

The equipment shall be capable of functioning or meeting the following:

1.1 The meter must appear as a Category B meter on the current List of Acceptable Equipment for statutory testing purposes;

1.2 Operational Life
The minimum operational life of the equipment, without need of major overhaul, shall be 5 years;

1.3 Environment
The test environment in which goods vehicle inspections are normally conducted is particularly hostile, for health and safety reasons most smoke testing is done outdoors and to meet this requirement smoke meters have to be capable of operating outdoors at all times, therefore the environmental conditions are those ambient conditions existing throughout the UK all year round;

1.4 Be suitable for testing all vehicle types, for example by the lengths of cables, probe and pipework , temperature probe design, etc;

1.5 Be designed such that 100% of all diesel powered vehicles can be tested having a multitude of possible exhaust outlets, varying from low mounted under vehicle to vertical stacks up to 4.9 meters high;

1.6 Be provided with detailed maintenance/operating instructions and calibration certificate;

1.7 Be capable of subsequent integration with Management Information Systems. The minimum information to be transferred will be: Vehicle identity, test results, date of test, time of test and overall assessment result. Manufacturers shall be required to supply full detail of data transfer capabilities;

1.8 Take a minimum of time to become operational after initial switching on from cold; information regarding typical time to be provided related to an ambient temperature of -10^{o}C;

1.9 Be ‘CE’ approved and marked accordingly;

1.10 Have an automatic self test function, irrespective however there should be a user operable calibration feature;

1.11 Operate correctly in an ambient temperature range of -15 to +30^{o}C, atmosphere of relative humidity of 90% (non condensing) and any other conditions identified elsewhere in the specifications;

1.12 Comply with all relevant British and International Standards and Health & Safety Regulations being in force at the time of commissioning. This shall include the Health & Safety at Work Act 1974, Supply of Machinery (Safety) Regulations 1992, Electrical Equipment (Safety) Regulations 1994, and other relevant supporting Regulation identified at the time of commissioning;
NOTE: Equipment in service will be maintained according to the requirements found within PUWER for all Vehicle & Operator Services Agency use;

1.13 If supplied with a trolley this shall be of robust design and suitable for high frequency use within the intended environment. The wheels of any such trolley will be:

i) lockable, or include wheel or other type of brakes to prevent unintended movement
ii) not less than 75 mm diameter
iii) of a design to minimise problems caused by small stones and surface imperfections
iv) be constructed to reduce vibration;

1.14 Although there are no installation risks anticipated manufacturers must supply details of any unusual risks associated with the normal usage/storage of the equipment.

ANNEX 8

ROADSIDE ENFORCEMENT REQUIREMENTS

The meter must appear on the current List of Acceptable Equipment for statutory testing purposes.

The meter will be 'CE' approved and marked accordingly.

The meter will be portable and ideally weigh less than 10kg. Heavier units may be considered acceptable if supported by a trolley. The wheels of any such trolley will be lockable and of a design to minimise problems caused by small stones and surface imperfections.

The existence of trailing cables for power and/or printer operation will be minimised.

Any display will be capable of being read in daylight.

The equipment should be capable of being powered by a single low voltage power supply.

The measuring probe will be of a design to offer the potential of gaining access to the greatest possible positional range of exhaust outlets.

The equipment will be supplied in a robust carrying case **containing all parts and accessories** (excluding the trolley if applicable).

Vehicle & Operator Services Agency

ANNEX 9

DIESEL SMOKE METER CALIBRATION REQUIREMENTS (MOT/08/19/1)

1. INTRODUCTION

The requirements detailed in this document relate to all smoke meter calibrations, which are carried out on meters to be used for statutory purposes after they are commissioned.

At the time of the first 'in-service' calibration, the opportunity should be taken to enter printout details such as VTS name and number etc.

2. INITIAL PERIOD OF CALIBRATION

A smoke meter may be calibrated before it is supplied as part of the in-house quality system at manufacture by a BSi/ISO registered company. Such meters will be issued with a dated Certificate of Conformity which carries the BSi and/or ISO logos at the time of the calibration.

This calibration will remain valid for 6 months from the date of issue.

3. FREQUENCY

Smoke meters are to be calibrated every 12 months.

Calibration certificates are normally valid for 12 months from the date of issue. However, if the certificate is issued no more than one month before the expiry of an existing certificate then the expiry date may be twelve months from the expiry of the old certificate.

Only UKAS approved operators can carry out annual smoke meter calibrations.

Meters must also be calibrated whenever they have been subject to a major repair, which is normally defined as a repair which the user would not normally be expected to carry out in the course of normal use.

4. CALIBRATION FILTERS

1. Calibration shall be carried out using 3 neutral density filters.
The value of these must lie in the ranges 0.5 to 1.0m^{-1}, 1.6 to 2m^{-1} and 3.0 to 3.5m^{-1}, and be known to better than $\pm$0.05m^{-1}.
2. Filters shall be calibrated using a light source of wavelength 565nm $\pm$5nm.
Calibration shall be traceable to National or International standards according to UKAS requirements.

5. ACCURACY REQUIREMENTS

1. Smoke meters shall indicate the value of the 3 calibration filters to at least $\pm 0.1 m^{-1}$.

2. Check oil temperature sensing device accuracy manually by correlation to a traceable calibrated device to at least one point in the range 50-90^{0}C.

The device shall indicate the temperature to an accuracy of at least $\pm 5^0$C.

3. Any temperature measuring device sensing an equivalent to an indicated oil temperature shall indicate the equivalent temperature to an accuracy of at least $\pm 5^0$C.

6. ANALYSIS OF RESULTS

Calibration results must be made available, on request, to the Vehicle & Operator Services Agency to verify the adequacy of the calibration periods.

Details of the form of the data to be given to the Vehicle & Operator Services Agency will be agreed with individual accredited laboratories.

7. CALIBRATION PROCEDURE

The items detailed below must, where relevant, be included in the periodic calibration checks of smoke meters used for statutory testing. The order in which they are performed may vary according to the equipment type.

1. Measure and record ambient temperature.

2. When the meter has completed any warm-up phase, insert the calibration filters and record the results.

3. Check that:
   a) the exhaust probe can be inserted into an exhaust pipe, and will clamp securely to it
   b) the hole(s) at the end of the probe are clear
   c) any sample hose, including any extension hose and pipework, is not chafed to the extent that failure is imminent
   d) any sample hose, including any extension hose and pipework, is not collapsed or kinked
   e) internal pipes are secure and not damaged or deteriorated to the extent that collapse or leakage is imminent
   f) the pump is operating correctly
   g) the heating system for the optical chamber is functional
   h) any sample period adjustments for extension hoses and pipework are correct
   i) internal voltages are within tolerance
   j) the purge air system is working correctly
   k) engine temperature devices are functional and within tolerance
   l) visual displays are readable and function correctly
   m) the casing is complete and there is electrical continuity between the earth on the input socket and all parts of the case
   n) all seals are complete and undamaged

o) the printer is working correctly and the printout details are correct

4. Calibrate the meter to within the limits given in Sections 4 and 5 using the neutral density filters.

5. Program the meter with the value of the weekly check filter.

6. Complete and affix calibration seals.

7. Wherever possible, carry out a Statutory smoke test to confirm that the meter is working properly.
NOTE: Following installation of the MOT Computerisation Technical Infrastructure this will include a check of communication via the Technical Interface of test values and results output.

8. Complete and issue a calibration certificate of a type approved for the purpose by UKAS and the Vehicle & Operator Services Agency.