

Methods of test for

**Full flow lubricating oil
filters for internal
combustion engines
within the range 180 l/h
to 14 000 l/h (40 gal/h
to 3150 gal/h)**

Co-operating organizations

The Mechanical Engineering Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

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British Chemical Plant Manufacturers' Association	Institution of Gas Engineers
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	Telecommunications Engineering Manufacturing Association
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The Government department and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this British Standard:

Ministry of Aviation Supply	The University of Southampton, Institute of Sound and Vibration Research
Ministry of Defence (Navy Department)	Individual filter manufacturers
Motor Industry Research Association	
Society of British Aerospace Companies	
Technical Section of British Paper and Board Makers' Association	

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Foreword

This standard makes reference to the following British Standard:

BS 3406, *Methods for the determination of particle size of powders.*

BS 3406-2, *Liquid sedimentation methods.*

This British Standard has been prepared under the authority of the Mechanical Engineering Industry Standards Committee. Its purpose is to clarify test procedure in order to determine a standard of measurement of performance for lubricating oil filters.

The imperial equivalents of the metric figures are approximate.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 30, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 General

1.1 Scope

This British Standard specifies tests for determination of pressure differential/flow characteristics, initial retention of a specified dust, variation in particle retention, filter life and cumulative efficiency and filter element strength (resistance to distortion, leakage or fracture) for full-flow lubricating oil filters for internal combustion engines within the range of 180 l/h to 14 000 l/h (40 gal/h to 3 150 gal/h).

It is considered that this schedule of tests provides the minimum information necessary to assess the characteristics of a filter. However, if agreed between the purchaser and the manufacturer, a restricted series of tests may be conducted.

2 Determination of pressure differential/flow characteristics

2.1 Test rig

The recommended test rig is shown diagrammatically in Figure 1. It shall consist of an insulated sump capable of holding the required volume of oil, and accommodating a thermostatically controlled heater capable of maintaining the required temperature to $\pm 2.0\text{ }^{\circ}\text{C}$ ($\pm 4\text{ }^{\circ}\text{F}$). Local overheating of the oil shall be avoided.

A pipe shall connect the base of the sump with the inlet port of a motor driven pump. The outlet port of the pump shall connect by further pipework with the filter inlet.

The pump delivery is directed to a four-way connector, one limb of which accommodates an indicating thermostat¹⁾, another the bypass return line to the sump. The fourth limb is connected to a flowmeter, which shall be suitable for use with oils of 24 cSt and 490 cSt kinematic viscosity and shall register the flow to an accuracy of $\pm 2\%$, in the pipeline leading to the filter. As an alternative the flowmeter may be installed in the filter outlet pipe. The bypass return to the sump and the filter outlet pipe shall terminate below the surface of the oil when the oil is in circulation.

Two regulating valves²⁾ shall be provided for the purpose of flow control, one being situated in the filter bypass pipe (6) and the other in the filter outlet pipe (4) (see Figure 1). An ON – OFF valve (1) shall also be installed in the filter feed pipe. The pipes connecting the filter shall have a bore equivalent to that of the filter inlet and outlet ports or those incorporated in the engine block. A straight run of at least 12 pipe diameters shall be provided before the filter and 8 pipe diameters after the filter. Tappings for pressure measurement shall be made at 1 pipe diameter and 4 pipe diameters from the filter inlet and outlet ports respectively. Pressure tappings shall also be made into the test filter in communication with the upstream and downstream sides of the filter element. Wherever practicable, the pressure gauge tappings shall be positioned to measure pressure in quiescent locations within the filter.

Differential pressure gauges, preferably of the mercury manometer type, are recommended, in addition to an inlet pressure gauge, calibrated in kN/m^2 (lbf/in^2). The differential pressure gauges shall be accurate to 0.7 kN/m^2 (0.1 lbf/in^2).

The slurry addition vessel, quadrant and filtrate receptacle shown in Figure 1 are not necessary for the test in this section, but are required and referred to in subsequent sections.

2.2 Test liquids

Straight mineral oils³⁾ shall be used. The temperature of the oil shall be controlled to achieve kinematic viscosities of 24 cSt (approximately 100 Redwood No. 1 seconds) and 490 cSt (approximately 2 000 Redwood No. 1 seconds), but it shall not exceed $100\text{ }^{\circ}\text{C}$ ($212\text{ }^{\circ}\text{F}$).

For example, a viscosity of 24 cSt is achieved using an SAE 30 oil at approximately $74\text{ }^{\circ}\text{C}$ ($165\text{ }^{\circ}\text{F}$). A viscosity of 490 cSt is achieved using an SAE 140 oil at approximately $42\text{ }^{\circ}\text{C}$ ($108\text{ }^{\circ}\text{F}$). If specified, additional tests at other viscosities may be carried out.

2.3 Test liquid volume

The volume of test liquid shall be 1.25 litres per 100 litres per hour (1.25 gallons per 100 gallons per hour) test flow rate, as indicated in Table 1 and precautions shall be taken to avoid aeration and local overheating of the test liquid when the test is in operation.

¹⁾ An indicating thermostat is recommended but a separate thermometer and thermostat may be used provided insertion in the system is made at the same point.

²⁾ Needle valves or diaphragm type valves are recommended.

³⁾ An additive-free oil can be obtained on request from most petroleum companies.

2.4 Test procedure

2.4.1 The filter shall be unused and the test liquid and apparatus clean. The term “clean” in this section implies that when the test liquid is circulated through the test rig and the filter at the rated flow for 5 minutes no increase in pressure differential across the filter occurs.

2.4.2 The filter shall be installed for test as shown in Figure 1 using suitable connectors or adaptors in the case of flanged and headless filters.

2.4.3 The required quantity of clean test liquid shall be added to the sump and circulated through the test system via the bypass pipe only. No test liquid shall pass through the filter at this stage.

2.4.4 The heater shall be switched on and the thermostat shall be adjusted to the required temperature (see 2.2).

2.4.5 Upon stabilization of temperature the test liquid shall be allowed to flow through the filter at approximately 50 % rated flow, and the temperature allowed to restabilize.

2.4.6 Readings of flow rate against pressure differences across the filter and filter element shall then be obtained by adjustment to the bypass and outlet valves (6) and (4) shown in Figure 1. The adjustment of these shall be such that the inlet pressure exceeds the indicated pressure difference, in order to ensure a positive pressure at the filter outlet.

2.4.7 At least eight readings shall be obtained at approximately equal increments of flow rate between 10 % and 110 % of the test flow rate. The flow rate shall be held constant for a minimum period of 10 seconds before taking each pressure differential reading across the complete filter and filter element only.

2.4.8 Tests as in 2.4.3 to 2.4.7 shall be repeated for each viscosity.

2.5 Test results

These shall be shown graphically, for each viscosity, pressure differential with respect to flow rate of complete filter and filter element only. A typical graph is shown in Figure 4.

3 Determination of element bypass component characteristics

3.1 Test rig

The test rig shall be as specified in 2.1 and as shown in Figure 1.

3.2 Test liquids

The test liquids shall be as specified in 2.2.

3.3 Test liquid volume

The test liquid volume shall be as specified in 2.3.

3.4 Test procedure

3.4.1 The filter shall be unused and the test liquid and apparatus clean. The term “clean” in this section implies that when the test liquid is circulated through the test rig and the filter at the rated flow for 5 minutes no increase in pressure differential across the filter occurs.

3.4.2 The filter element shall be removed from the filter and in its place a non-permeable dummy element, of identical dimensions shall be installed. In respect of sealed unit oil filters, from which the element cannot readily be removed and replaced by a non-permeable dummy element, it is necessary to open the unit and remove the bypass component for testing in a separate housing, the design of which shall be agreed between the purchaser and the manufacturer.

3.4.3 The filter shall be installed for test as shown in Figure 1 using suitable connectors or adaptors in the case of flanged and headless filters.

3.4.4 The required quantity of clean test liquid shall be added to the sump and circulated through the test system via the bypass pipe only, with valve (1) closed and valve (6) open (see Figure 1). No test liquid shall pass through the filter at this stage.

3.4.5 The heater shall be switched on and the thermostat shall be adjusted to the required temperature (see 2.2).

3.4.6 Upon stabilization of temperature the test liquid shall be allowed to flow through the filter bypass component at approximately 50 % rated flow, and the temperature allowed to restabilize.

3.4.7 The flow rate through the filter bypass component shall be reduced to zero and the pressure difference shall be increased slowly, by adjusting the bypass valve (6) (see Figure 1). The pressure difference at which a continuous stream of oil starts to issue from the filter outlet shall be noted.

3.4.8 Readings of pressure difference against flow rate at eight approximately equal increments of flow rate up to 110 % of the filter's rated capacity shall be obtained. This is carried out by adjustment to the bypass (6) and outlet valves (4) (see Figure 1). The adjustment of these shall be such that the inlet pressure exceeds the indicated pressure difference. The flow rate shall be maintained constant for a minimum period of 10 seconds before taking each reading.

3.4.9 The flow rate shall then be decreased by the same increments as used in 3.4.8 and the pressure difference noted after each decrease.

3.4.10 The pressure difference shall be decreased to 75 % of the mean of the designed opening pressure range, and the rate of leakage, if any, shall be measured by means of a stopwatch and graduated measure. Valve (5), shown in Figure 1, is a convenient place where this leakage can be collected. The pressure at the inlet shall be further reduced until the continuous stream of oil from the filter is just discontinued, and the pressure difference shall be noted. If the flow from the filter ceases above 75 % of the designed opening pressure, the pressure difference at which this occurs shall be recorded.

3.4.11 Any noise emitted by the bypass component throughout the test shall be noted and the points of occurrence recorded.

3.4.12 Tests as in 3.4.4 to 3.4.11 shall be repeated for each viscosity.

3.5 Test results

The pressure difference with respect to both increasing and decreasing flow rates shall be shown graphically, as indicated in Figure 5, for each viscosity. Leakage rate at a pressure 75 % of the mean of the designed opening pressure range at a viscosity of 24 cSt shall be indicated. This leakage rate shall be the value recorded for a decreasing flow rate, and shall be quoted in l/h, (gal/h) and as a percentage of the rated flow, at a viscosity of 24 cSt. Flow rates at which noise is emitted shall also be marked along the contour of the curves. A typical graph is shown in Figure 5.

4 Determination of initial retention of inorganic particles of specified sizes, variation in particle retention, filter life and cumulative efficiency

4.1 Introduction

4.1.1 No laboratory test method can duplicate the performance of an engine installation. The following method of test provides a basic means of comparison of performance between filters. Filters of known field performance may be used as references.

4.1.2 The complete test comprises tests for initial retention of specified size grades of non-combustible test dust, variation in filter particle retention ascertained by determination of retention of one selected grade of non-combustible particles during the process of filter choking, followed by a cumulative efficiency and life test.

4.1.3 Three initial particle retention tests are recommended on separate elements using non-combustible particles (see 4.5.1) of different sizes, in order to select the grade of dust as specified in 4.5.1.1. When the filter element is of a permanent type, possibly with a built-in means of cleaning, the element shall be reserviced before each test.

4.1.4 The variation in particle retention test requires individual retention tests being carried out with the selected grade of non-combustible contaminant during the process of filter choking. Determination shall be made at specified pressure differential increments.

4.1.5 The basic principle of the life test is the introduction of a specified contaminant into a quantity of oil which is being circulated through the filter under controlled conditions of temperature, pressure and flow rate. Samples of the sump oil shall be taken at specified intervals for determination of cumulative efficiency. Full-flow filter life is assessed by the rig test hours achieved when the terminating pressure differential, i.e. a pressure differential 75 % of the mean of the designed opening pressure range of the element bypass component, is reached.

4.1.6 The tests have been devised and precautionary measures to be observed in the testing process have been designated in order to minimize variations and discrepancies in results. The degree of reproducibility and repeatability of these test methods are considered sufficiently reliable to assess life and efficiency on a comparative basis.

4.1.7 Throughout the tests in Section 4, it is permissible, by agreement between the manufacturer and the user, to carry out scaled-down tests on filters exceeding 4 550 l/h (1 000 gal/h) rating. The filters used for such scaled-down tests shall have a working capacity of between 3 640 l/h to 4 550 l/h (801 gal/h to 1 000 gal/h). The relationship of flow to filter medium area in the scaled-down tests shall be identical with that of the larger filter.

4.2 Test rig

4.2.1 The recommended test rig is shown diagrammatically in Figure 1.

4.2.2 The test shall consist of a heat insulated sump with inverted conical or pyramidal bottom, with an included angle of not more than 120°. The internal surface of the sump shall be smooth and free from protrusions, recesses and sharp corners. The sump shall have sufficient capacity to hold the required volume of oil (see Table 1). The system shall include a thermostatically controlled heater capable of maintaining the required temperature between $\pm 2^\circ\text{C}$ ($\pm 4^\circ\text{F}$). Local overheating of the oil shall be avoided.

4.2.3 The lowest point at the base of the sump shall be connected by a pipe to the inlet of a motor driven pump. In view of the abrasive matter in the oil, it is recommended that a pump should be used that can handle abrasive matter without undue wear⁴⁾.

4.2.4 It is also an advantage to run the pump at the lowest speed possible, by the use of either stepped pulleys or a variable speed drive. The outlet of the pump shall be connected, via various fittings, with the filter inlet.

4.2.5 A valve for sampling shall be fitted to the pipe leading from the pump to the cross-piece. The cross-piece accommodates the thermostat⁵⁾ which is arranged so that the circulating oil will wash its stem as soon as the oil pump is in operation. To avoid overheating it should be made impossible to switch on the heater unless the pump is in operation. Overheating of the oil may arise due to the heat input from the pump, and some provision for oil cooling may be required.

4.2.6 A bypass pipe shall be fitted with a valve for fine control of pressure and flow through the filter. A flowmeter, which shall be calibrated for an oil of 24 cSt viscosity, shall be fitted as indicated. Further fittings (see Figure 1) are an ON – OFF valve (1), followed by the slurry addition vessel and isolating valves (2) and (3), as shown in Figure 3a. The capacity of the slurry addition vessel shall be equivalent to half the capacity of the complete filter plus or minus 25 % of this volume. At the outlet of the filter a flow regulating valve⁶⁾ (4) shall be included, followed by a three way valve (5), as shown. This latter valve is used for sampling the filter effluent when carrying out the particle retention test. The return lines to the sump (bypass and filter outlet pipe) terminate below the oil level to avoid the entrainment of air.

4.2.7 All pipes to the filter and to the slurry addition vessel shall be smooth inside and shall have a bore with a cross-sectional area similar to that of the area of the filter inlet and outlet ports, or those incorporated in the engine block.

A differential pressure gauge, preferably of the mercury manometer type calibrated in kN/m^2 (lbf/in^2) and accurate to 0.7 kN/m^2 (0.1 lbf/in^2), shall be available for connection to tapings made into the test filter, in communication with the upstream and downstream sides of the filter element. In addition, an inlet pressure gauge shall connect to the upstream side of the filter element. Where practical the pressure gauge tapings shall be positioned to measure pressure in quiescent locations within the filter.

4.3 Organic contaminant feed mechanism

An organic contaminant feed mechanism shall be constructed to introduce contaminant into the test system at a constant rate (see Table 1).

A design is shown in Figure 2 and consists of an internally polished metal container, in quadrant form, free from internal protrusions and having a discharge rate of $200 \pm 5 \text{ ml/h}$ and a maximum capacity of 800 ml when filled to a horizontal plane corresponding to the lower edge of the outlet slot. The container walls shall extend approximately 25 mm (1 in) above the level of this plane in order to avoid spillage of the contaminant when it is agitated. When the rating of the filter under test exceeds 4 550 l/h (1 000 gal/h), the number of feed quadrants used shall be increased.

Agitation shall be achieved by an efficient rotating stirrer. The following arrangement is recommended:

A four bladed stirrer with the blades constructed from a 25 mm (1 in) diameter disc and with their planes at 45° to the plane of the disc, rotating at approximately 2 500 rev/min, the direction of rotation being such as to lift liquid from the base of the quadrant; the stirrer to be attached in such a position that its shaft is at right angles to the quadrant rim and the blade tips at a distance of 3.2 mm ($\frac{1}{8}$ in) from the base of the quadrant (see Figure 2). The quadrant shall be equipped with a clamping device, thus enabling resetting to a horizontal position.

The quadrant feed rate shall be checked periodically to ensure that the flow rate and solids delivery are constant to within $\pm 2\frac{1}{2}\%$ of the required values.

⁴⁾ A suitable pump is the Mono pump made by Mono Pumps Ltd., Sekforde Street, Clerkenwell Green, London E.C.1.

⁵⁾ An indicating thermostat is recommended but separate thermometer and thermostat may be used provided insertion in the system is made at the same point.

⁶⁾ Needle valves or diaphragm type valves are recommended.

4.4 Test liquids

The test liquid for all particle retention tests shall be a straight mineral oil⁷⁾. The type and grade of oil used shall be recorded. For the life test MIRA reference oil No. 1 shall be used⁸⁾. For these tests the viscosity of the oil at the filter shall be held constant at 24 cSt (approximately 100 Redwood No. 1 seconds).

4.5 Standard contaminants

4.5.1 Non-combustible contaminant for particle retention tests. Fused aluminium oxide dust⁹⁾ of the following grades shall be used:

MIRA Grade 2 (see Figure 8)

MIRA Grade 3 (see Figure 9)

MIRA Grade 4 (see Figure 10)

MIRA Grade 5 (see Figure 11)

The particle size distribution of the above test dusts falls within the limits illustrated by the curves in Figure 8, Figure 9, Figure 10 and Figure 11. The particle size analysis shall be by the Andreasen method given in BS 3406-2. An alumina or silica dust consisting of larger particles may be used in addition to that specified in Grade 5 if filter retention requires determination above that particle size.

4.5.1.1 For the determination of variation in particle retention during the filter choking test, that grade of dust (see 4.5.1) which gives an initial retention nearest to 50 % shall be used, provided that the retention lies between 75 % and 25 %.

If two adjacent, grades of test dust produce particle retention figures equally spaced about the 50 % level, then the finer grade of test dust shall be used.

4.5.1.2 The fused aluminium oxide slurry for the particle retention tests shall be prepared as follows:

- 1) Each grade of test dust shall be thoroughly mixed prior to use.
- 2) Sufficient quantity of each dust for a test series shall be dried in an oven at a temperature of $110 \pm 5^\circ\text{C}$ ($230 \pm 9^\circ\text{F}$) for 2 hours and placed in a desiccator to cool. The dusts shall be subsequently used from and stored in the desiccator for the remainder of the test series.

4.5.1.3 A quantity of test dust equivalent to 0.22 ± 0.002 g for each 100 l/h test flow rate (1 ± 0.01 g for each 100 gal/h test flow rate) shall be weighed into a clean beaker and to it shall be added a volume of test liquid equivalent to that of the slurry addition vessel (see Figure 3a and Figure 3b).

4.5.1.4 The contents of the beaker shall then be thoroughly mixed by means of a high speed stirrer.

4.5.1.5 Mixing shall proceed for at least 1 hour immediately prior to placing in the slurry addition vessel and commencing the test.

4.5.2 Organic contaminant concentrates.

Organic contaminant concentrates shall consist of the following:

- 12 % by weight carbon black¹⁰⁾, arithmetical mean diameter $0.056\text{ }\mu\text{m}$.
- 3 % by weight pulverized vinsol (natural pine) resin¹¹⁾.
- 85 % by weight test liquid (see 4.4).

4.5.2.1 Preparation of organic contaminant concentrate for testing variations in particle retention. 1 700 g of straight mineral oil (see 4.4) shall be added to a 4.5 litres (1 gallon) ball mill porcelain pot containing a 9.5 kg (21 lb) charge of steel balls¹²⁾. The charge of steel balls shall be as follows:

Diameter		Weight		Approximate number
mm	in	kg	lb	
13	$\frac{1}{2}$	2.7	6	324
19	$\frac{3}{4}$	3.4	$7\frac{1}{2}$	120
25	1	3.4	$7\frac{1}{2}$	52–53
Total		9.5	21	496–497

⁷⁾ An additive-free oil can be obtained on request from most petroleum companies.

⁸⁾ MIRA Reference Oil No. 1 is obtained from the Motor Industry Research Association, Lindley, Nuneaton, Warwickshire. It is an SAE 30 engine oil and contains complex multi-functional detergent dispersant and anti-oxidant additives; its specification will not be altered.

⁹⁾ Suitable fused aluminium oxide test dusts can be obtained from the Motor Industry Research Association, Lindley, Nuneaton, Warwickshire.

¹⁰⁾ A suitable product is known as Ebonex 237, obtainable from Philblack Ltd., Severn Road, Avonmouth, Bristol.

¹¹⁾ This material, also known as PV resin, is a natural resin product (not poly-vinyl) identified as Item 514, of the National Biochemical Co., 3106 W. Lake Street, Chicago 12, Illinois, U.S.A. It has the following particle size distribution:

100 % smaller than $850\text{ }\mu\text{m}$.

85 % smaller than $180\text{ }\mu\text{m}$.

50 % smaller than $75\text{ }\mu\text{m}$.

¹²⁾ Suitable steel balls are obtainable from the Pascall Engineering Co. Ltd., Gatwick Road, Crawley, Sussex.

To this shall be added 240 g of carbon black (Ebonex 237) and 60 g of PV resin. The ball mill pot shall be rolled at approximately 50 rev/min for 16 hours.

The mixed concentrate shall be drained into a wide mouthed container. Prior to withdrawing any quantity of organic contaminant concentrate, either for checking of solids content or for a test series, the contents of the container shall be agitated for at least 1 hour to ensure resuspension of solid matter.

Alternatively, the mixed concentrate shall be poured into a drum which is well closed and rolled continuously at approximately 50 rev/min to maintain the solids in suspension. This concentrate shall be ready immediately for sampling or blending as required.

Before using each batch of contaminant, a 10 g sample shall be removed and thoroughly mixed with clean test liquid to make a total 100 ml sample for determination of petroleum ether insolubles concentration by weight (see A.5 or B.6). The sample shall be representative of the bulk.

4.5.2.2 Preparation of organic contaminant concentrate for life test. The preparation shall be identical to the procedure described in 4.5.2.1 except that, instead of the straight mineral oil, MIRA reference oil No. 1 (see 4.4) shall be used.

4.6 Blending of organic contaminant for test

4.6.1 Blending of the organic contaminant refers to the intermixing of the contaminant concentrate and test oil by means of high speed stirring in preparation for its addition to the test system. The quadrant container and stirrer arrangement described in 4.3 shall be held in a horizontal position by means of a suitable stand. The quadrant is later used to feed contaminant to the test rig sump. Two quadrants are required thus enabling one to be used for contaminant blending whilst the other is in use for contaminant feeding.

In order to achieve the correct solids feed rate the quantity of contaminant concentrate to be blended with test liquid (see Table 1) shall be calculated from the solids concentration of contaminant concentrate determined in 4.5.2.1.

4.6.2 The calculated weight of contaminant concentrate for a single charge of the feed quadrant shall be transferred from the agitator in a suitable preweighed vessel.

4.6.3 The contents of the vessel shall be transferred to the inoperative feed quadrant.

4.6.4 The vessel shall be rinsed with clean test oil and inverted above the quadrant for at least 30 minutes to ensure that all traces of contaminant concentrate are transferred¹³⁾.

4.6.5 Clean test oil shall be added to the quadrant until the total content including the contaminant concentrate equals the volume required for half the test period (see 4.11.10), i.e. 200 ml for each hour of the test.

4.6.6 The stirrer shall then be set at a speed of 2 500 rev/min and the contaminant concentrate and clean test oil thoroughly mixed for 2 hours, with the quadrant outlet closed.

4.6.7 After mixing for the prescribed period, the quadrant shall be removed from the stand and attached to the drive shaft of the feed mechanism, as shown in Figure 2, and stirring of the contents shall be recommenced.

4.7 Test procedure, initial particle retention test of complete filter

The recommended test rig and slurry addition vessel are shown diagrammatically in Figure 1, Figure 3a and Figure 3b. First, a test shall be made to check the efficiency of the slurry feed apparatus (see 4.7.4), then a blank test to determine the non-combustibles in the prepared rig (see 4.7.2) and finally the retention test on the complete filter unit (see 4.7.3).

4.7.1 Preparation

4.7.1.1 The test shall be conducted using the appropriate filter casing, and the element bypass component shall remain operative. The test liquid and apparatus shall be clean.

4.7.1.2 The filter shall be installed for test as shown in Figure 1 and Figure 3a, with the element removed. If the filter to be tested is of the sealed-unit type, then a special case shall be made without an element insert.

4.7.1.3 The specified volume of clean test liquid (see Table 1) shall be added to the sump and recirculated through the test system via the bypass pipe only. No liquid shall pass through the filter at this stage.

4.7.1.4 The heater shall be switched on and the thermostat adjusted to achieve the specified viscosity (see 4.4); the temperature shall be noted and maintained to within $\pm 2^\circ\text{C}$ ($\pm 4^\circ\text{F}$) for the duration of the test.

¹³⁾ Providing a suitable balance is available, the required weight of contaminant concentrate can be transferred direct to a preweighed feed quadrant, eliminating the necessity for 4.6.2 and 4.6.3.