INTERNATIONAL STANDARD

ISO 4548-4

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Methods of test for full-flow lubricating oil filters for internal combustion engines —

Part 4:

Initial particle retention efficiency, life and cumulative efficiency (gravimetric method)

Méthodes d'essai des filtres à huile de lubrification à passage intégral pour moteurs à combustion interne —

Partie 4: Efficacité initiale, capacité de rétention et efficacité cumulée (méthode gravimétrique)

Reference number
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Contents

Annexes

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 4548-4 was prepared by Technical Committee ISO/TC 70, *International combustion* engines, subcommittee SC 7, *Tests for lubricating oil filters.*

ISO 4548 will consists of the following parts, under the general title *Method of test for full-flow lubricating oil filters for internal combustion engines*:

- *Part 1: Differential pressure/flow characteristics*
- *Part 2: Elements by-pass component characteristics*
- *Part 3: Resistance to high differential pressure and to elevated temperature*
- *Part 4: Initial particle retention efficiency, life and cumulative efficiency (gravimetric method)*
- *Part 5: Cold start simulation and hydraulic pulse durability test*
- *Part 6: Static burst pressure test*
- *Part 7: Vibration fatigue test*
- *Part 9: Inlet and outlet anti-drain valve tests*
- *Part 10: Life and cumulative efficiency in the presence of water in oil*
- *Part 11: Self-cleaning filters*
- *Part 12: Particle retention ability and contaminant holding capacity using particle counting*

Annexes A, B, C, D and E form an integral part of this part of ISO 4548. Annex F is for information only.

Introduction

ISO 4548 establishes standard test procedures for measuring the performance of full-flow lubricating oil filters for internal combustion engines. It has been prepared in separate parts, each part relating to a particular performance characteristic.

Together the tests provide the information necessary to assess the characteristics of a filter, but if agreed between the purchaser and the manufacturer, the tests may be conducted separately.

Methods of test for full-flow lubricating oil filters for internal combustion engines —

Part 4:

Initial particle retention efficiency, life and cumulative efficiency (gravimetric method)

Section 1: General

1.1 Scope

This part of ISO 4548 specifies tests for determining the performance of full-flow lubricating oil filters for internal combustion engines as follows.

Section 2: Initial particle retention efficiency. This gives the test procedures and parameters for the determination of the initial particle retention efficiency of lubricating oil filter elements under defined test conditions. By reporting the results in accordance with subclause 2.6, the probable retention efficiency for any particle size may be derived. The retention efficiency is determined by the gravimetric method.

Section 3: Life and cumulative efficiency. This gives the test procedures and parameters for the determination of element life and cumulative efficiency of lubricating oil filters. The cumulative efficiency is determined by the gravimetric method.

NOTE — By agreement between filter manufacturer and purchaser, tests on large filters can be conducted on the basis of tests carried out on filters scaled-down in length. The relationship of the filter flow and test dust addition rate to the effective length of the filter medium should be the same in the scaled-down tests as in the full size filter. For the purposes of this part of ISO 4548, a filter having a test flow rate exceeding 100 l/min is considered large.

1.2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 4548. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 4548 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1219-1:1991, *Fluid power systems and components — Graphic symbols and circuit diagrams — Part 1: Graphic symbols.*

ISO 4548-1:—[1], *Methods of test for full-flow lubricating oil filters for internal combustion engines — Part 1: Differential pressure/flow characteristics.*

ISO 11841-1:—[2], *Road vehicles and internal combustion engines — Filter vocabulary — Part 1: Definitions of filters and filter components.*

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[1] To be published. (Revision of ISO 4548-1:1982)

[2] To be published.

ISO 11841-2:— [2], *Road vehicles and internal combustion engines — Filter vocabulary — Part 2: Definitions of characteristics of filters and their components.*

ISO 12103-1:— [2], *Road vehicles — Test dust for filter evaluation — Part 1: Arizona test dust.*

ISO 12103-2:— [2], *Road vehicles — Test dust for filter evaluation — Part 2: Aluminium oxide test dust.*

1.3 Definitions

For the purposes of this part of ISO 4548, the definitions given in ISO 11841-1 and ISO 11841-2 apply.

1.4 Graphical symbols

The graphical symbols used in this part of ISO 4548 are in accordance with ISO 1219-1[1].

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[2] To be published.

Section 2: Initial particle retention efficiency

2.1 Operational characteristics to be assessed

The main function of the oil filter in engine lubricating oil systems is to prevent the damaging abrasive particles from reaching the bearings and other internal rubbing surfaces. It is generally accepted that particles between 5 µm and 40 µm cause the greatest amount of wear and it is therefore important to engine users and manufacturers that any proposed filter is adequate in removing particles within this defined range of sizes on an instantaneous, single-pass basis. This requirement is particularly relevant to filters fitted to new engines which may contain significant quantities of metallic and other abrasive contaminants accumulated during engine production processes.

This test procedure assesses the ability of an oil filter to retain abrasive contaminant, within a defined range of particle sizes, using a gravimetric method of analysis.

2.2 Test rig

2.2.1 The test rig, shown diagrammatically in figures 1 and 2, shall include the components indicated together with the necessary tubing connections and supports.

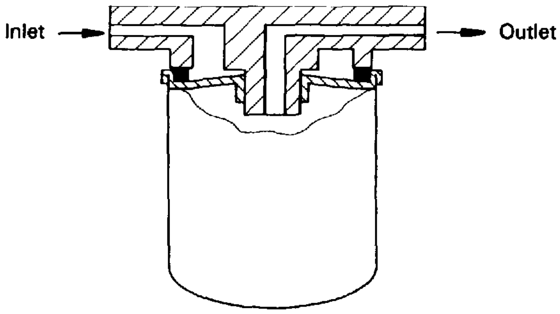

Figure 1 — Filter and mounting block in test position

2.2.2 The sump shall be capable of holding a quantity of oil as given in annex A and shall be equipped with a thermostatically controlled heater capable of maintaining the test temperature. The heater shall be arranged so that local overheating of the oil is avoided. The by-pass return to the sump and the main filter outlet pipe shall terminate below the surface of the oil in the sump when the oil is in circulation. The temperature shall be adjusted so that the stipulated test oil viscosity is maintained within a limit of ± 3 mm^2/s [3].

2.2.3 The pump shall be the pulse-free type.

2.2.4 The two valves **3** and **8** (see figure 2) shall be used for the purpose of pressure and flow control. Needle valves or diaphragm valves are recommended.

2.2.5 The flow-meter **4** shall be suitable for use with oil of 24 mm^2/s kinematic viscosity and shall register the flow in the pipeline leading to the test filter with an accuracy of ± 2 %.

2.2.6 The pressure tapping **14** shall be made at five internal pipe diameters upstream of the filter inlet port. The filter inlet and outlet pipes shall be straight and free from obstruction for eight internal pipe diameters upstream and 13 internal pipe diameters downstream of the filter inlet and outlet ports.

2.2.7 The filter shall be mounted vertically in the test rig (see figure 1) in accordance with the requirements of ISO 4548-1 to ensure consistency of tests to enable meaningful comparisons to be made.

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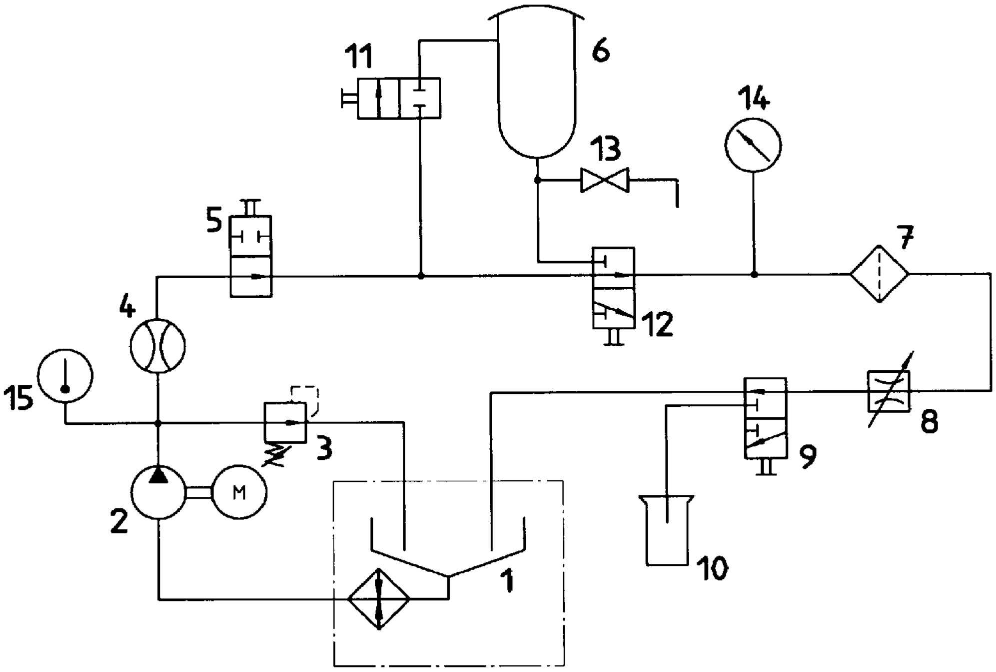
3) 1 mm^2/s = 1 cSt

2.3 Test liquids

2.3.1 The test liquid for these tests shall be a straight mineral oil of ISO VG 100 (SAE 30) grade or ISO VG 150 (SAE 40) grade (see [2] and [3]).

2.3.2 The oil shall be used at a kinematic viscosity of 24 mm^2/s ± 3 mm^2/s, at approximately 74 °C with ISO VG 100 (SAE 30) or at approximately 83 °C with ISO VG 150 (SAE 40).

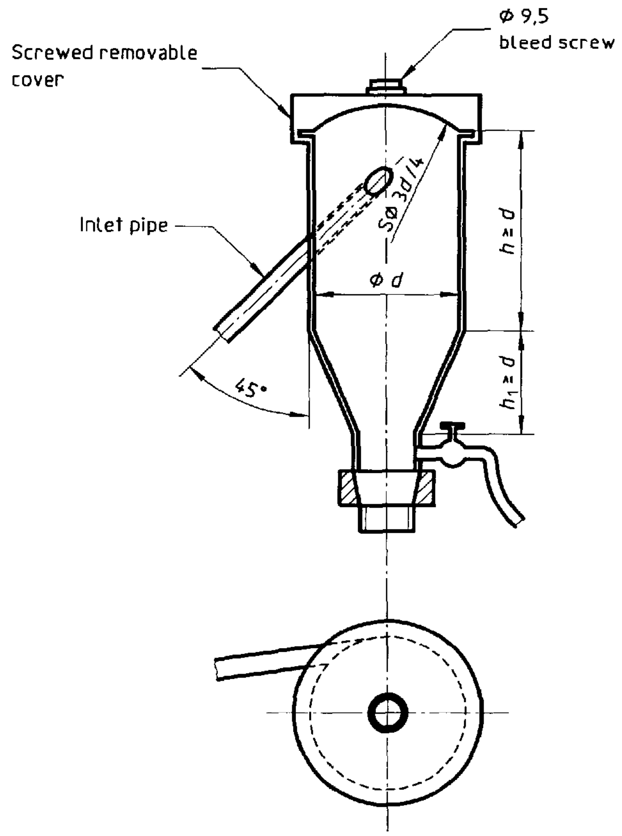


Key

1	Insulated sump with thermostatically controlled heater, conical bottom and smooth internal surfaces
2	Motor-driven pump
3	Pressure-regulating valve
4	Flow meter
5	ON-OFF valve
6	Slurry addition reservoir with a capacity equivalent to half the volume of the test filter ± 25 % with bleed screw in removable cover (see figure 3)
7	Test filter
8	Flow-regulating valve
9	Three-way valve
10	Filtrate receptacle with a capacity of four times the volume of the test filter
11	ON-OFF valve
12	Three-way valve
13	Drain cock
14	Inlet pressure gauge
15	Indicating temperature controller

Figure 2 — Diagrammatic arrangement of test rig for initial particle retention efficiency test

Dimensions in millimetres



NOTE — See **6** in figure 2 for the volume.

Figure 3 — Details of slurry addition vessel

2.4 Test contaminant

2.4.1 Contaminant grades

The grades of aluminium oxide dust[4] given in table 1 shall be used.

The particle size distribution of the grades of test dust in table 1 is given in ISO 12103-2.

Table 1 — Test dust grades

Grade	50 % mean particle size µm
ISO 12103-M2	6,9 ± 0,5
ISO 12103-M3	13,6 ± 0,9
ISO 12103-M4	30,1 ± 2,3
ISO 12103-M5	54 ± 3

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[4] Suitable fused aluminium oxide test dusts can be obtained from the Motor Industry Research Association, Lindley, Nuneaton, Warwickshire, UK. This information is given for the convenience of users of this part of ISO 4548 and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

2.4.2 Contaminant preparation

2.4.2.1 The dusts are normally supplied in a selection of different size jars. The dust, in storage, will tend to precipitate and quantities removed from the top of the jars will not be representative of the original particle distribution as defined in 2.4.1. To ensure that the dust used meets these requirements, the whole quantity from each jar shall be thoroughly mixed before individual increments are removed for weighing.

2.4.2.2 A sufficient quantity of the particular grade of test dust to be used shall be dried in an oven at a temperature of 105 °C ± 5 °C for at least 1 h. The dried dust shall then be stored for use in a desiccator.

2.4.2.3 When required for use in the test rig a quantity of the particular grade of dust as given in annex A 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 reservoir (see figure 2, **6**).

2.4.2.4 The contents of the beaker shall then be thoroughly mixed by means of a high speed stirrer (see annex E).

2.4.2.5 Mixing shall proceed for at least 1 h immediately prior to placing in the slurry addition reservoir and commencing the test.

2.5 Test procedure

2.5.1 General

This test procedure specifies the method of determining the retention efficiency of a filter element where a test dust of a particular mean particle size, suspended in a small quantity of oil, is injected into the main flow of oil being passed through the test filter under controlled conditions of temperature, pressure and flow rate. The period of injection will vary according to the size of the test filter and the test flow rate but for practical purposes the evaluation may be regarded as a measure of the instantaneous or single-pass retention efficiency of the test filter at the mean particle size of the test dust being used.

NOTE — The retention efficiency is a function of time, so the instantaneous or single-pass retention efficiency during the life of the filter element may differ from the initial value.

2.5.2 Test rig preparation

Before commencing particle retention efficiency tests, it is essential that the test rig be cleaned such that the results obtained are not influenced by residual contaminant in the test rig circuit. The total contaminant content of the test fluid shall not exceed 60 mg/l.

2.5.2.1 In order to achieve this degree of cleanliness, the following procedure is suggested.

Fit a new clean-up filter in place of the test filter and drain all fluids from the test rig.

Pour a sufficient quantity of suitable flushing fluid into the test rig sump such that the pump does not cavitate when running.

Circulate the flushing fluid through the complete test rig system, including the slurry addition by intermittent change-over of the appropriate valves, for at least 30 min at a flow rate which allows the clean-up filter to function at maximum efficiency in removing residual contaminant.

WARNING — Do not switch on the heater when using highly volatile or inflammable liquids.

Drain the test rig and refill with a sufficient quantity of the specified test oil so that the pump does not cavitate when running.

With the heater switched on, circulate the oil until the temperature stabilizes at the required figure and run the test rig for at least 20 min.

Drain the test rig and remove the clean-up filter.

2.5.2.2 The cleanliness of the rig shall be determined by the following procedure.

a) Fit a new clean-up filter and fill the test rig with the required quantity of oil as given in annex A. Record the relative density of the oil used.

b) With the heater switched on, circulate the oil until the temperature stabilizes at the required figure and run the test rig for at least 20 min.

c) Take a 50 ml sump oil sample and analyse for percentage contaminant content as described in B.6. The result of this analysis and calculation shall be referred to as the rig blank, and these rig blank tests shall be carried out prior to each retention test on any test filter. Where the total contaminant content of the test liquid exceeds 60 mg/l the rig cleaning operation shall be repeated until the rig blank contamination level is below the maximum mass allowed. The final rig blank test result shall be used for correction of particle retention values in 2.6.

d) Remove the clean-up filter and replace its oil content with an equal quantity of clean test oil added to the sump.

2.5.3 Particle retention test

2.5.3.1 Prepare the test rig as described in 2.5.2 and necessary dust increments as in 2.4.1 and 2.4.2.

2.5.3.2 The filter for test shall be installed vertically in the test rig as shown in figure 2 and the element by-pass component shall remain operative. Care shall be taken to ensure that the test filter housing and any additional pipework are clean before installation.

NOTE — The filter for test may be tested for fabrication integrity in accordance with ISO 2942 [2] prior to installation unless it is impractical to disassemble the filter assembly.

2.5.3.3 The test oil shall be circulated through the test rig system via the by-pass pipe only. Valve **5** is closed. No liquid shall pass through the test filter at this stage. The heater is switched on and the thermostat adjusted to a test temperature which provides the specified oil viscosity shown in annex A. Allow temperature to stabilize. The viscosity of the test oil shall be maintained within the defined limits for the duration of the test.

2.5.3.4 When the temperature has stabilized, the test oil shall be allowed to flow through the test filter while bypassing the slurry addition reservoir.

2.5.3.5 The flow through the test filter shall be adjusted to the required figure with the inlet pressure at a minimum of 40 kPa[5].

2.5.3.6 Slurry, containing one of the test dusts, shall be added to the slurry addition reservoir. The test dusts are specified in 2.4.1 and the quantity of test dust and preparation of the slurry shall be in accordance with 2.4.2.

2.5.3.7 By the simultaneous operation of valves **11**, **12** and **9**, flow shall be directed through the slurry addition reservoir and the effluent collected in the pre-cleaned receptacle **10**. The volume of effluent collected shall be approximately four times the volume of the test filter.

2.5.3.8 Reset valves **9** and **12** and close valve **11**, allowing the test liquid to flow directly through the filter into the sump. The test liquid flow shall then be stopped by closing valve **5** and opening valve **3**.

2.5.3.9 Collect the dust not offered to the test filter as follows: place the beaker used for mixing the slurry beneath the drain cock **13** of the reservoir **6** and drain the reservoir by opening the cock and the top cover bleed screw.

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5) 100 kPa = 1 bar

2.5.3.10 Rinse all internal surfaces of the reservoir with 100 ml of petroleum spirit, collecting the rinsings in the beaker referred to in 2.5.3.9.

2.5.3.11 The test dust content of the filter effluent shall be determined in accordance with annex B and the amount of test dust in drainings and rinsings from 2.5.3.9 and 2.5.3.10 shall be determined in the same manner, except that all the rinsings shall be used and finally washed through the membrane with 100 ml of petroleum spirit.

2.5.3.12 The filter bowl and test element shall be removed and the element discarded. In the case of sealed unit type filters, the filter shall be discarded.

2.5.3.13 The retention efficiency of the test filter relative to the particular grade of test dust used shall be calculated as defined in clause 2.6.

2.5.3.14 The test rig shall be prepared as in 2.5.2 before repeating the test as in 2.5.3.1 to 2.5.3.13 using the remaining grades of test dust. A clean element shall be used for each separate test.

2.5.4 Test rig validation

A test to check the efficiency of the slurry addition apparatus shall be made when the test rig is first assembled, when any major alteration is made to the rig, and at intervals based on approximately 250 rig running hours. This efficiency shall be determined by carrying out the test procedure in accordance with 2.5.3.1 to 2.5.3.13 except that a piece of smooth connecting pipe shall be inserted in the place of the test filter and the slurry containing test dust of grade ISO 12103-M5 (see table 1) shall be used.[6] The content of the effluent shall be determined as described in annex B and the mass of the test dust recovered in the test shall be not less than 95 % of the mass of dust added to the slurry addition reservoir.

If the recovery is less than the stipulated figure, or more than 100 %, the cause shall be investigated and rectified.

2.6 Test results and calculations

The results obtained from analysis of oil samples in accordance with annex B shall be used to calculate the percentage of dust retained by the filter and shall be expressed as a percentage for each grade of dust used.

The retention efficiency, E_r, as a percentage retained is given by the equation:

$$E_r = 100\left(1 - \frac{m_1}{m_2}\right)$$

where

m_1 is the mass of test dust transmitted after correction, in grams:

$$m_1 = m - m_0$$

in which

m is the uncorrected total mass of contaminant transmitted (see B.4.9 to B.4.17),

m_0 is the mass of contaminant in the effluent from the rig blank sample analysis [see B.6 and 2.5.2.2 c)];

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[6] For spin-on filters with a screwed adaptor block, a screw-on cap of minimum volume connecting the inlet with outlet may be used.

m_2 is the mass of test dust offered after correction, in grams:

$$m_2 = m_3 - m_4$$

in which

m_3 is the mass of test dust in slurry added to slurry addition reservoir (see 2.4.2.3),

m_4 is the mass of the dust in drainings and rinsings (see clause B.5, 2.5.3.9 and 2.5.3.10).

The retention efficiency values obtained from the above calculations for the different grades of test dust shall be plotted on graph paper, relative to the 50 % mean particle size, as shown in figure 4.

2.7 Report of test results for initial particle retention efficiency

The test report shall indicate as a minimum the data listed below.

a) reference to this part of ISO 4548;

b) test establishment;

c) filter details (manufacturer, model No., batch No., description as appropriate);

d) date of tests;

e) test liquid temperature, in degrees Celsius, at which the viscosity = 24 mm^2/s;

f) temperature of test liquid, in degrees Celsius;

g) test flow rate, in litres per minute;

h) volume of test liquid, in litres;

i) slurry reservoir capacity, in litres;

j) test filter volume, in litres;

k) test dust details, shown in the table below;

l) Retention Efficiency graph reference (see figure 4 for typical example).

Grade	**Supplier**	**50 % mean particle size**	**Batch No.**	**Filter retention efficiency**
Mass added for each test: .... g				

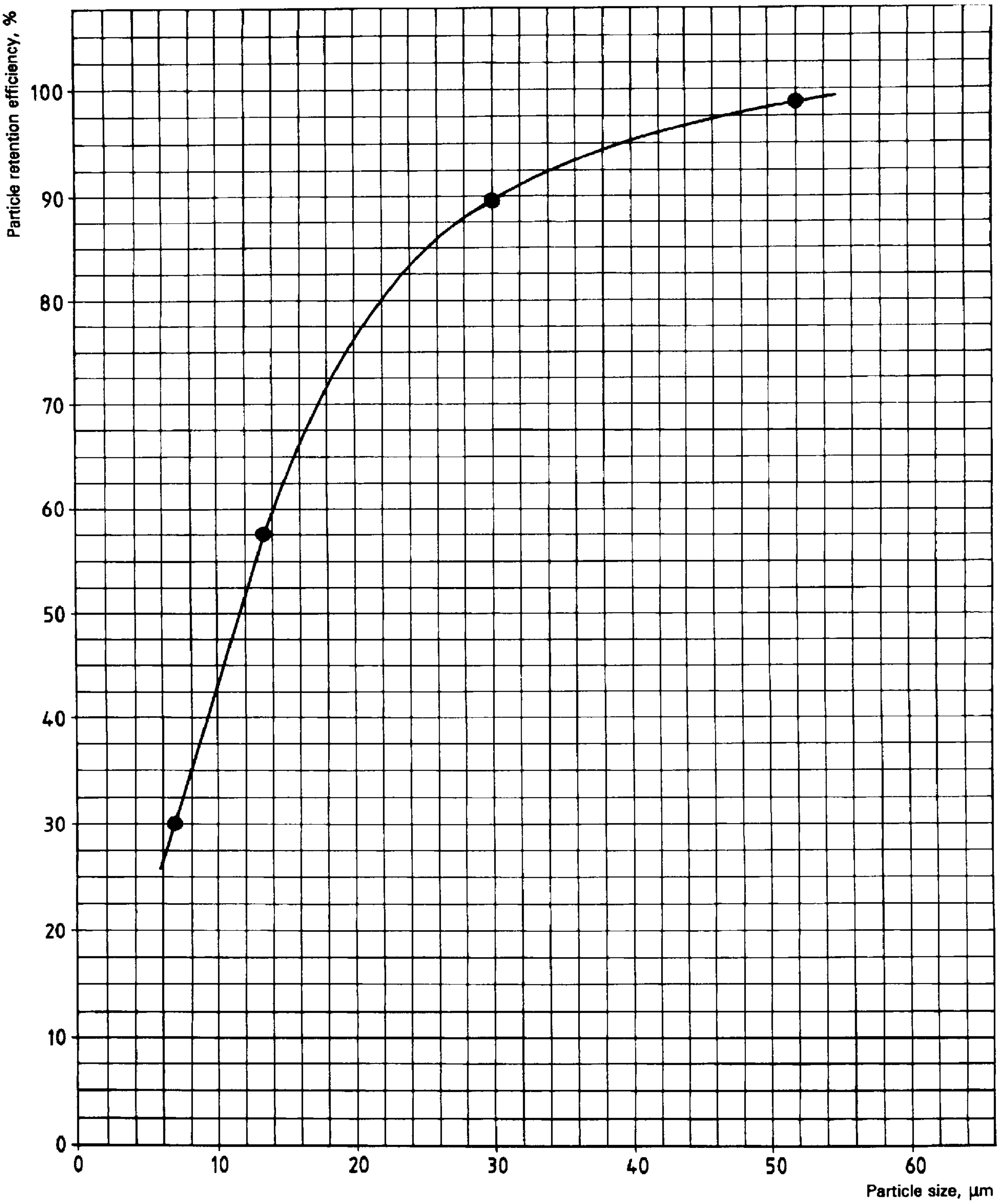

Figure 4 — Typical initial particle retention efficiency curve

Section 3: Life and cumulative efficiency

3.1 Operational characteristics to be assessed

This test assesses the ability of a filter to remove the potentially damaging particles normally present in an engine lubricating oil system.

During service the filter becomes progressively choked with a contaminant mixture varying from sub-micronic carbon particles to visible large metallic particles. Since the main function of the filter is to prevent the damaging particles of 5 µm and over from reaching the engine rubbing surfaces, this test procedure has been formulated with this function in mind. The test assesses the life and cumulative efficiency of a filter under a comparison to be made between different filters.

Whilst rig testing of filters is a suitable means of comparison between filters, the performance of those filters when fitted to engines may vary, due to operational characteristics, more widely than is evident during rig testing, and engine tests are essential to validate the suitability of the filter for that application.

3.2 Test rig

3.2.1 The test rig, shown diagrammatically in figure 9, shall include the components indicated, together with the necessary tubing, connections and supports.

3.2.2 The sump shall be capable of holding a quantity of oil as specified in annex C and shall be equipped with a thermostatically controlled heater (and cooler if required) capable of maintaining the test temperature. The heater shall be arranged so that local overheating of the oil is avoided. The by-pass return to the sump and the filter outlet pipe shall terminate below the surface of the oil in the sump when the oil is in circulation. The temperature shall be adjusted so that the stipulated test oil viscosity is maintained within a limit of ± 3 mm^2/s 7).

3.2.3 The pump shall be of a type that will not cause any alteration in the particle size distribution of the contaminant.

NOTE — In view of the abrasive characteristics of the contaminant, it is essential that the pump used be able to cope with such abrasive matter without undue wear.

3.2.4 The two valves (**3** and **10** in figure 5) shall be used for the purpose of pressure and flow control in conjunction with the variable speed control for the motor-driven pump. Needle valves or diaphragm type valves are recommended.

3.2.5 The flow meter **5** shall be suitable for use with oil of 24 mm^2/s kinematic viscosity and shall register the flow in the pipeline leading to the filter with an accuracy of ± 2 %.

NOTE — To be suitable for use with the tests specified in other parts of ISO 4548, the flow meter should also be capable of use with oil of 500 mm^2/s kinematic viscosity, and cope with the abrasive material used in this test without undue wear.

3.2.6 The filter shall be mounted vertically in the test rig in accordance with the requirements of ISO 4548-1 to ensure consistency of tests to enable meaningful comparisons to be made.

3.2.7 Tappings for the measurement of differential pressure across the complete filter shall be made at five internal pipe diameters upstream of the filter inlet port and 10 internal pipe diameters downstream from the filter outlet port. The inlet and outlet pipes shall be straight and free from obstruction for eight internal pipe diameters upstream and 13 internal pipe diameters downstream of the filter inlet and outlet ports.

3.2.8 Pressure differences shall be measured to an accuracy of ± 5 % and be recorded in kilopascals.

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7) 1 mm^2/s = 1 cSt

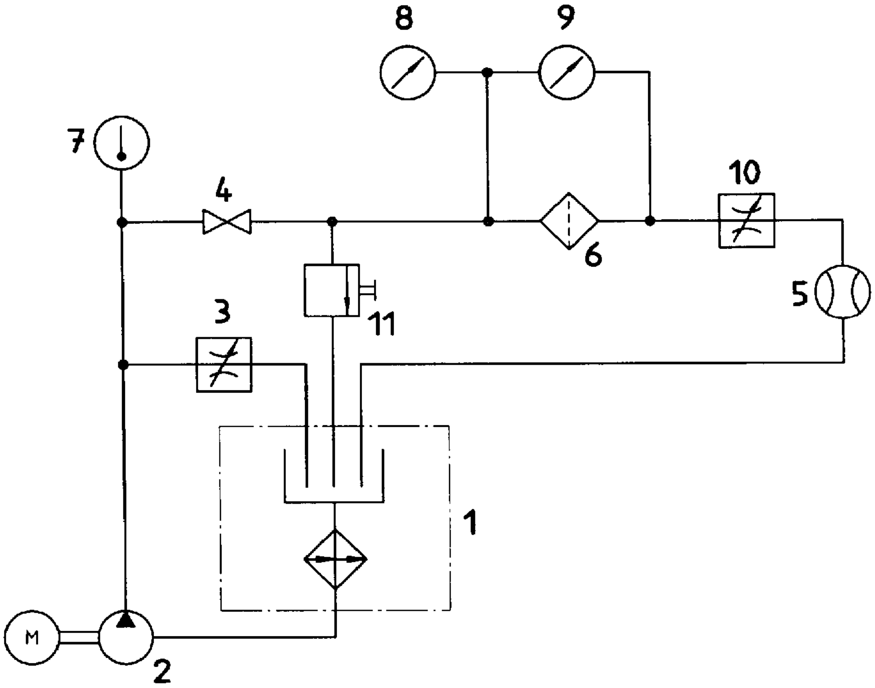
3.3 Periodic checks on equipment

The test rig shall be validated periodically to ensure the homogeneous distribution of the contaminant in the test rig system (see 3.6.3).

3.4 Test liquids

3.4.1 The test liquid for these tests shall be a straight mineral oil of ISO VG 100 (SAE 30) grade or ISO VG 150 (SAE 40) grade with addition of anti-static additive (see annex C)

3.4.2 The oil shall be used at a kinematic viscosity of 24 $\mathrm{mm^2/s}$ ± 3 $\mathrm{mm^2/s}$, at approximately 74 °C with ISO VG 100 (SAE 30) or at approximately 83 °C with ISO VG 150 (SAE 40).



Key

1 Sump (preferably insulated) incorporating a thermostatically controlled heater, and cooler if required
2 Motor-driven pump with variable speed control
3 Pressure-regulating by-pass valve
4 ON-OFF valve
5 Flow meter
6 Filter under test
7 Thermocouple connected to a temperature indicator
8 Pressure gauge
9 Differential pressure gauge, to measure the pressure drop across the filter[1]
10 Flow-regulating valve
11 Sampling cock

[1] For cases where mercury manometer(s) is (are) used in place of item **9**, it will be necessary to fit isolating valve(s) in the high-pressure leg(s) of the manometer pipework.

Figure 5 — Diagrammatic arrangement of test rig for life and cumulative efficiency test

3.5 Test contaminant

3.5.1 Contaminant grade

The contaminant shall be a test dust with the particle size distribution and chemical composition specified for ISO 12103-A2 (ISO Fine) [8].

3.5.2 Contaminant preparation

3.5.2.1 A sufficient quantity of ISO 12103-A2 dust to complete the test shall be dried in an oven at a temperature of 105 °C ± 5 °C for at least 1 h. The dried dust shall then be stored ready for use in a desiccator.

3.5.2.2 When required for use in the test rig a quantity of ISO 12103-A2 test dust shall be weighed into a clean beaker and to it shall be added a volume of test liquid to make a total volume of one litre. The mass of dust shall be within ± 10 mg of the calculated quantity given in annex C.

The contents of the beaker shall then be thoroughly mixed by means of a high speed stirrer and ultrasonic probe (see annex E for equipment details).

Mixing shall be carried out by first placing the stirrer blades close to the bottom of the beaker and stirring at a speed of approximately 2 000 r/min. The ultrasonic probe shall then be immersed into the liquid to a depth of 30 mm from the tip end and the power adjusted to produce an amplitude of 6 µm, peak to peak.

The combined mechanical stirring and ultrasonic dispersion of the dust shall proceed for one hour immediately prior to adding to the sump.

NOTES

1 Test dust is normally supplied in different size jars. This dust, in storage, will tend to precipitate and quantities removed from the top of the jar will not be representative of the original particulate distribution. To ensure that the test dust used meets the requirements of 3.5.1, the test dust must be thoroughly mixed before individual increments are removed for weighing.

2 It is essential that the test be completed without interruption.

3.6 Test procedure

3.6.1 General

This procedure specifies the method of determining the life of a filter where a particular contaminant is introduced into a quantity of oil which is being circulated through the filter under controlled conditions of temperature, pressure and flow rate. Samples of sump oil are taken at specified intervals for the determination of cumulative efficiency. Full-flow filter life is assessed in terms of the total quantity of contaminant added to the system when the pressure differential across the filter has increased by 50 kPa.

3.6.2 Test rig preparation

Before commencing particle retention efficiency tests, it is essential that the test rig be cleaned such that the results obtained are not influenced by residual contaminant in the test rig circuit. The total contaminant content of the test fluid shall not exceed 60 mg/l.

3.6.2.1 In order to achieve this degree of cleanliness, the following procedure is suggested.

Fit a new clean-up filter in place of the test filter and drain all fluids from the test rig.

Pour sufficient quantity of suitable flushing fluid into the test rig sump such that the pump does not cavitate when running.

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8) See ISO 12103-1.

Circulate the flushing fluid through the complete test rig system, including the slurry addition reservoir by intermittent changeover of the appropriate valves, for at least 30 min at a flow rate which allows the clean-up filter to function at maximum efficiency in removing residual contaminant.

WARNING — Do not switch on the heater when using highly volatile or inflammable liquids.

Drain the test rig and refill with a sufficient quantity of the specified test oil so that the pump does not cavitate when running.

With the heater switched on, circulate the oil until the temperature stabilizes at the required figure and run the test rig for at least 20 min.

Drain the test rig and remove the clean-up filter.

3.6.2.2 The cleanliness of the rig shall be determined by the following procedure.

a) Fit a new clean-up filter and fill the test rig with the required quantity of oil as given in annex C. Record the relative density of the oil used.

b) With the heater switched on, circulate the oil until the temperature stabilizes at the required figure and run the test rig for at least 20 min.

c) Take a sump oil sample and analyse for contaminant content. This figure shall be less than 0,007 % by mass (approximately 60 mg/l) before proceeding further. If necessary, repeat cleaning operations using clean-up filter until the contaminant level is below the maximum specified.

d) Remove the clean-up filter and replace its oil content with an equal quantity of clean test oil added to the sump.

3.6.3 Test rig validation

3.6.3.1 This procedure is necessary to confirm the ability of the test rig to maintain adequate suspension of the contaminant in the circulating oil during life tests.

3.6.3.2 Prepare the test rig as given in 3.6.2 and necessary test dust increments as in 3.5.2.

3.6.3.3 Fit a smooth straight pipe in place of the test filter.[9]

3.6.3.4 With the by-pass valve (**3** in figure 5) fully closed, adjust the flow through the smooth straight pipe to 125 % test flow rate (annex C) by varying the pump speed. Outlet pressure shall be set at 15 kPa min. Allow the temperature to stabilize at the required level before opening by-pass valve **3** slowly until the flow through the smooth straight pipe is at the specified test flow rate (annex C). This flow rate shall be maintained constant throughout the test by adjusting valve **3**.

3.6.3.5 Set the oil sample line to flow at approximately 0,5 l/min by adjusting valve **11** and, when stabilized readjust pump speed to correct the flow rate (annex C) through the smooth straight pipe.

3.6.3.6 Take a 50 ml sample from the sample line and replace with 50 ml clean test oil added to the sump.

3.6.3.7 Transfer the previously prepared slurry which is contained in the beaker (see 3.5.2.2) to the sump via a peristaltic pump. Precalibrate the transfer rate to give the required rate of contaminant addition (see annex C). Continuously stir the slurry during the transfer period, using the stirrer at a speed of approximately 1 000 r/min.

3.6.3.8 Take 50 ml samples every 20 min for a period of 2 hours. At each sample interval adjust the volume of oil in the sump to its original value, as specified in annex C.

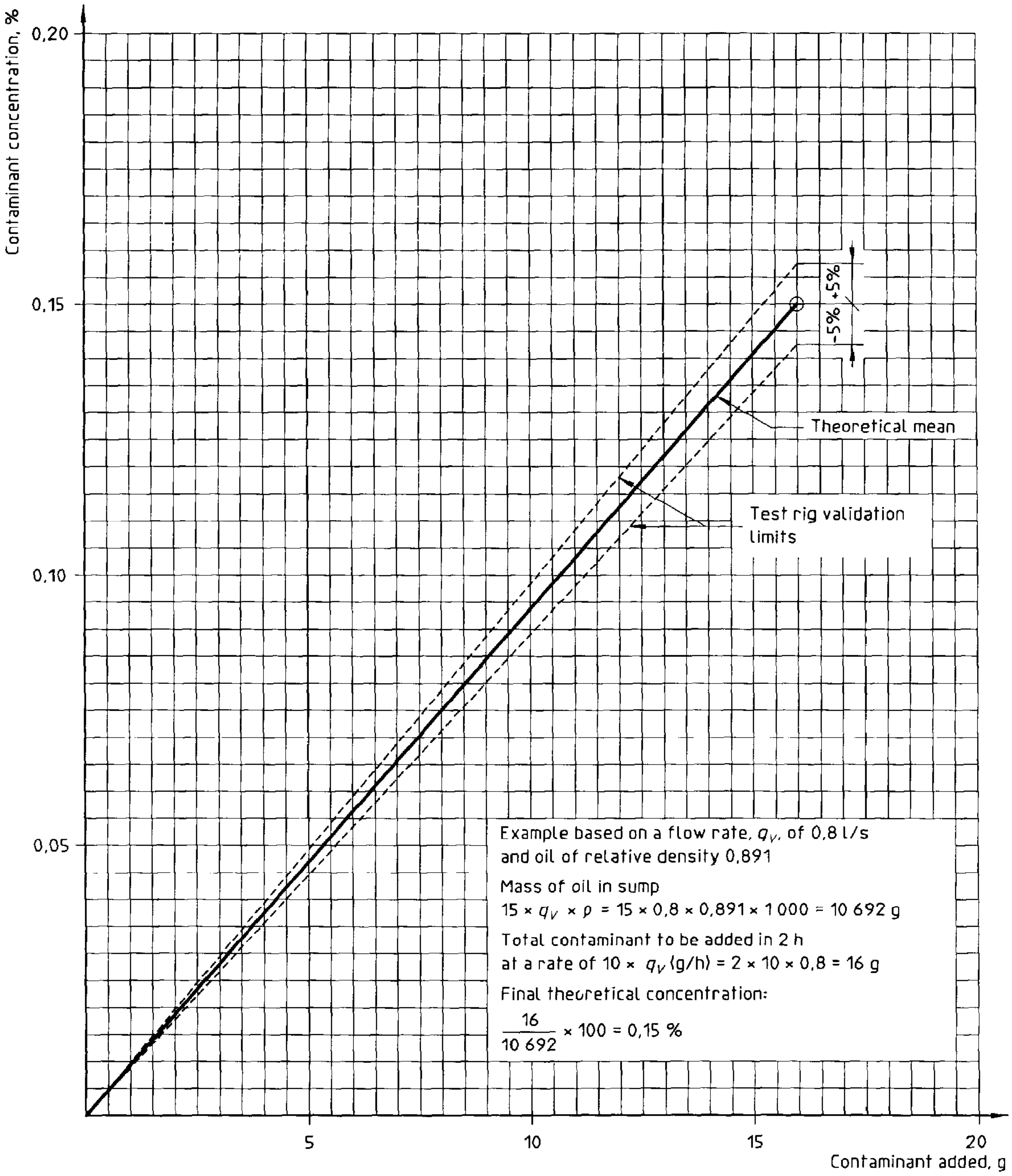
3.6.3.9 Analyse oil samples as in annex D.

---

[9] For spin-on filters with a screwed adaptor block, a screw-on cap of minimum volume connecting the inlet with outlet may be used.

3.6.3.10 Plot percentage contaminant in samples against contaminant added, in grams. This curve should be linear.

3.6.3.11 The graph drawn should not deviate more than ± 5 % from theoretical concentration, based on total mass of oil and contaminant added to the sump, at any point on the graph. A typical calibration graph is shown in figure 6. Where results are outside the specified limits, it will be necessary to modify the test rig system until the requirements are satisfied.



Example based on a flow rate, q_V, of 0,8 l/s and oil of relative density 0,891

Mass of oil in sump

$15 \times q_V \times \rho = 15 \times 0{,}8 \times 0{,}891 \times 1\,000 = 10\,692$ g

Total contaminant to be added in 2 h at a rate of $10 \times q_V$ (g/h) $= 2 \times 10 \times 0{,}8 = 16$ g

Final theoretical concentration:

$$\frac{16}{10\,692} \times 100 = 0{,}15\ \%$$

Figure 6 — Typical test rig validation graph

3.6.4 Life test procedure

3.6.4.1 Before commencing life tests, it is essential to ensure that the test rig used satisfies the validation requirements of 3.6.3 at a flow rate within 0,5 l/min of the test flow rate specified for the life test being conducted. It should be noted that the previous calibrations will be invalidated by test rig circuit modifications or significant pump wear. It is advisable, therefore, to calibrate the test rig at reasonably regular intervals (approximately 250 rig running hours) to ensure correct suspension of contaminant in the circulating oil during the test.

3.6.4.2 Prepare the test rig as detailed in 3.6.2 and install the test filter.

The filter for test shall be installed vertically in the test rig as shown in figure 5 and the element by-pass component shall remain operative. Care shall be taken to ensure that the test filter housing and any additional pipework are clean before installation.

NOTE — The filter for test may be tested for fabrication integrity in accordance with ISO 2942 prior to installation, unless it is impractical to disassemble the filter assembly.

3.6.4.3 Prepare sufficient test dust as detailed in 3.5.2.1 and sufficient clean oil sample containers (100 ml capacity) to cover the test requirements.

3.6.4.4 Open by-pass valve **3** (see figure 5), close on-off valve **4**, set the heater control to the required temperature and run the pump at low speed.

3.6.4.5 When the required oil temperature has been attained, open valve **4**, close by-pass valve **3** and adjust the flow rate through the test filter to 50 % of the test flow rate (annex C) by increasing the pump speed.

3.6.4.6 Allow the temperature to stabilize and adjust the pump speed to obtain 125 % of the test flow rate (annex C) through the test filter.

3.6.4.7 Gradually open by-pass valve **3**, until the flow through the test filter is set to the test flow rate (annex C).

3.6.4.8 Set the oil sample line flow to approximately 0,5 l/min by adjusting valve **11** and, when stabilized, re-adjust pump speed to correct the flow through the test filter to the test flow rate (annex C). This flow rate shall be maintained constant throughout the test by further adjustments to by-pass valve **3**.

3.6.4.9 Take a 50 ml sample from the sample line and replace with 50 ml of clean test oil, added to the sump.

3.6.4.10 Transfer the previously prepared slurry which is contained in the beaker (see 3.5.2.2) to the sump via a peristaltic pump. Precalibrate the transfer rate to give the required rate of contaminant addition (see annex C). Continuously stir the slurry during the transfer period, using the stirrer at a speed of approximately 1 000 r/min. Continuously add the slurry until the test terminating pressure across the filter attains the value specified in annex C.

3.6.4.11 Take 50 ml samples from the sample line every 20 min thereafter and at the test end point. At each sample interval adjust the volume of oil in the sump to its original value, as specified in annex C.

3.6.4.12 Record the temperature, and the pressure differential across the test filter, immediately prior to each 50 ml sample.

3.6.4.13 Take a final 50 ml sample at test end point (see annex C).

3.6.4.14 Record the total mass of dust added to the sump before analysing the oil samples as detailed in annex D.

3.7 Test results and calculation

3.7.1 Determination of filter life

Filter life shall be expressed in terms of grams of contaminant added to reach a pressure differential increase as specified in annex C. A graph as shown in figure 7 may be drawn, plotting the pressure differential against grams of contaminant added.

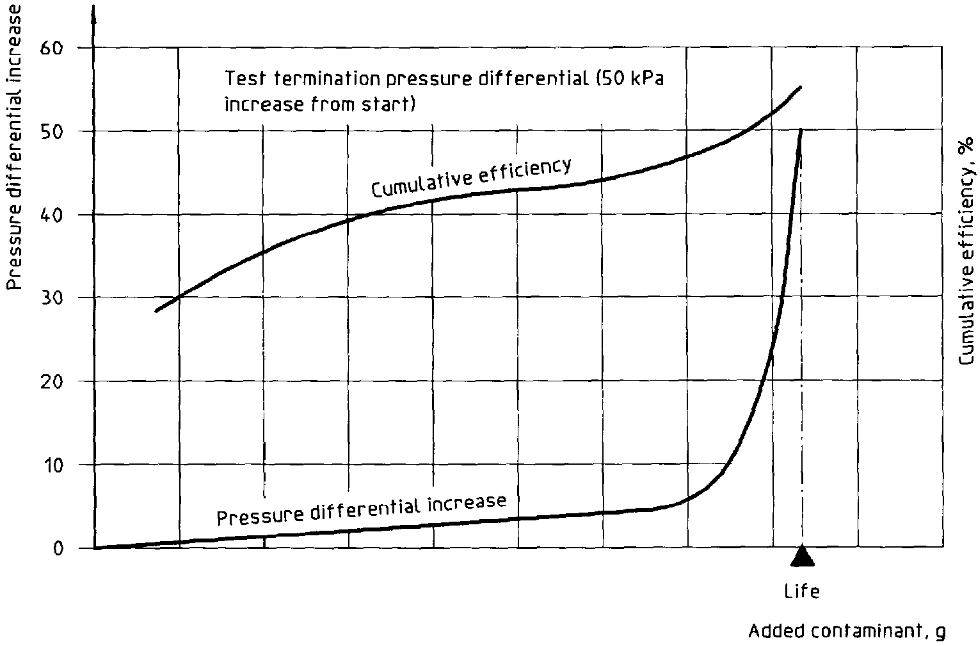


Figure 7 — Graph of cumulative efficiency against grams of contaminant added

3.7.2 Determination of cumulative efficiency

The results obtained from the analysis of oil samples as determined according to annex D shall be used to calculate the insolubles in the sump and the cumulative efficiency, E_c, during life, expressed as a percentage and found as follows:

$$E_c = \frac{m_i - m_o}{m_i} \times 100$$

where

m_o is the mass of insolubles in the oil sample times the mass of oil in the sump, m_s, divided by the mass of oil sample;

m_i is the initial mass of insolubles in the sump plus the mass of cumulative solids added;

m_s is the volume of oil in the sump times the volumic mass of the oil.

A graph as shown in figure 7 may be drawn, plotting cumulative efficiency against grams of contaminant added.

3.8 Report of test results for life and cumulative efficiency

The test report shall include as a minimum the data listed below. The cumulative efficiency and the pressure differential may be shown graphically as illustrated in figure 7.

a) reference to this part of ISO 4548;

b) test establishment;

c) filter type (manufacturer, model No., batch No., description as appropriate);

d) date of tests;

e) test liquid temperature, in degrees Celsius, at which the kinematic viscosity = 24 mm^2/s;

f) temperature of test liquid, in degrees Celsius;

g) test flow rate, in litres per minute;

h) contaminant details (supplier, batch No. and rate of addition, in grams per hour);

i) cumulative efficiency (see 3.7.2):

Sampling stage (grams added)	**Pressure drop across filter** kPa	**Cumulative Efficiency** (see 3.7.2) %

j) life (mass of contaminant added at test conclusion), in grams;

k) test rig validation graph (see figure 6 for typical example).

Annex A

(normative)

Test parameters for initial particle retention efficiency test

Test liquid: Straight mineral oil of ISO VG 100 (SAE 30) grade or ISO VG 150 (SAE 40) grade.

Test oil operating kinematic viscosity: 24 mm^2/s ± 3 mm^2/s, at approximately 74 °C with ISO VG 100 (SAE 30), or approximately 83 °C with ISO VG 150 (SAE 40).

The test flow rate (through the filter), q_V, in litres per second, shall be as specified by the customer or the manufacturer of the filter. In the absence of such a specification, the test flow rate shall be 1,5 l/s per square metre of filter media area.

NOTE — In the following the volume of test oil (litres) and the mass of test dust (grammes) are proportional to the test flow rate (q_V), and they are numerically equal to the product of a factor and the flow rate.

Volume of test oil: $15 \times q_V$, in litres. The minimum volume shall be 6 l.

Test dust: Grades M2, M3, M4 and M5 (see 2.4.1).

Mass of dust to be injected: $(8 \times q_V) \pm 0{,}002$ g.

Annex B

(normative)

Method for determining insolubles in test liquid samples for initial particle retention efficiency

B.1 Introduction

This annex describes the method used for determining the mass-to-mass concentration of insolubles in test liquid samples for the initial particle retention efficiency test. The petroleum distillate insolubles are separated from the oil by vacuum filtration. Two membranes[10] are used for each sample analysed: one is used for filtering the sample and the other as a control so that a correction can be made for any change in mass of the sample filtering membrane that may result from changes in humidity, temperature, etc.

B.2 Equipment

The following equipment is typical of that for filtering the sample (see figure B.1). Any suitable apparatus which can accommodate the particular membranes specified by **b** in figure B.1 may be used.

B.3 Ancillary equipment

The following equipment will be needed:

a) Laboratory oven, capable of maintaining a temperature of 105 °C ± 5 °C.

b) Vacuum pump, capable of producing a vacuum in the flask of at least 70 kPa.

c) Desiccator.

d) Petri dishes, complete with covers.

e) Force-feed wash-bottle, of at least 500 ml capacity.

f) Laboratory balance, accurate to 0,1 mg.

g) 500 ml per sample of analytical-grade petroleum distillate filtered through a 0,45 µm pore size membrane.

B.4 Determination of petroleum distillate insolubles in effluent sample

B.4.1 Wash the filter holder, and sufficient Petri dishes to cover the test requirements[11] in warm water to which a little detergent has been added. Remove the filter holder and the Petri dishes from the bath and assemble the filter holder components, but do not tighten.

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[10] Suitable membrane discs can be obtained from Millipore Corp., Bedford, Massachussets 01730, USA, and from Sartorius Membranfilter GmbH, Göttingen, Germany. This information is given for the convenience of users of this part of ISO 4548 and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

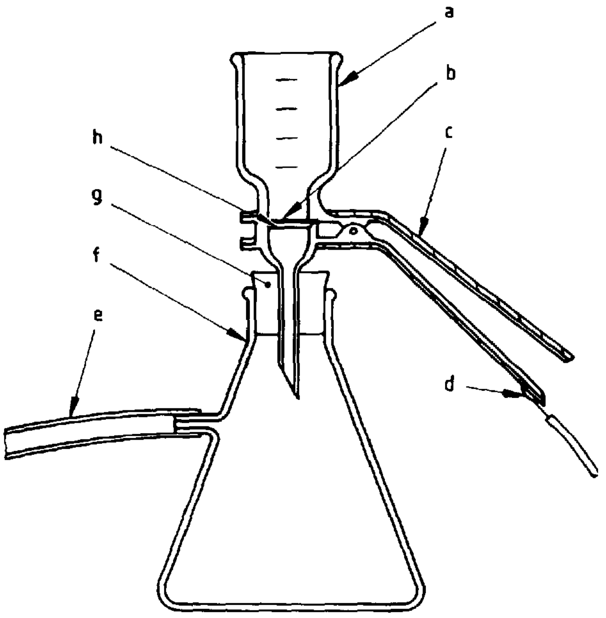
[11] Each oil sample to be analysed requires the use of two membranes: one for filtering the sample, the other to be placed beneath the filtering membrane as a control membrane, to enable corrections to be made for humidity, temperature, etc., when weighing.

B.4.2 Hold the filter holder and the Petri dishes with clean tongs and rinse thoroughly with acetone delivered from a force-feed bottle. The holder and the Petri dishes should be handled with tongs for the remainder of the determination.

B.4.3 Place the filter holder and the Petri dishes in an oven at a temperature of 105 °C ± 5 °C for at least 1 h.

B.4.4 Remove the filter holder from the oven and place it in a desiccator to cool for a minimum period of 1 h.

B.4.5 Remove the Petri dishes from the oven and place them in a desiccator to cool for a minimum period of 1 h.



Key

a	Filter holder
b	Two cellulose acetate, nitrate or ester membranes, pore size 0,8 µm; 47 mm or 60 mm diameter according to equipment available
c	Spring-loaded clamp
d	Earth terminal for connecting a wire to discharge static charges to earth
e	PVC tubing for connection to the vacuum pump
f	Vacuum flask, of suitable capacity
g	Stopper
h	Mesh or perforated support plate

Figure B.1 — Typical fixation apparatus — Membrane filter holder assembled on vacuum flask

B.4.6 Remove the Petri dishes from the desiccator, place the filter membranes as indicated by **b** in figure B.1 in each Petri dish, and replace them in the oven for at least 1 h.

B.4.7 Remove the Petri dishes with membranes from the oven, and place in a desiccator to cool for at least 1 h. Remove from the desiccator and stand in atmosphere for at least 1 h, then remove each membrane in turn and weigh it to the nearest 0,1 mg. Record the mass and replace in a Petri dish until required. Label and mark each Petri dish as appropriate.

NOTE — The Petri dishes and membranes may be weighed together directly from the desiccator, provided the balance pan is enclosed and the weighing chamber contains a desiccant.

B.4.8 Remove the filter holder from the desiccator, place the appropriate pre-weighed control membrane, and sample filtering membrane, with the control membrane beneath filtering membrane, and assemble the filter holder. Install on suitable vacuum flask, ensure that a filter holder is suitably earthed, and apply a vacuum of 65 kPa.

B.4.9 Weigh the receptacle containing the effluent and determine the mass of the test liquid to the nearest 0,1 g by subtracting the initial clean receptacle mass.

B.4.10 Take approximately 10 % of the effluent sample, after thorough mixing to ensure that it is representative, and determine its mass to the nearest 0,1 g in a clean pre-weighed measuring cylinder. Mix, by shaking, with an equal volume of petroleum distillate. Pour slowly on to the clamped membranes and wash through with a similar volume of petroleum distillate as before, assisted by a vacuum of not more than 65 kPa.

B.4.11 During filtration, wash the inside of the filter holder with petroleum distillate until clean and free from oil, allowing the washings to pass on to the membranes.

B.4.12 When the liquid has passed through the membranes, continue the washing process until a further 200 ml has been used.

B.4.13 Dismantle the filter holder and remove the membranes with care, keeping them horizontal so that no insolubles are lost, and return the membranes to their appropriate Perti dishes and replace them in an oven set at 105 °C ± 5 °C for at least 1 h.

B.4.14 Remove the Petri dishes and membranes from the oven and place them in a desiccator to cool for at least 1 h.

B.4.15 Remove the Petri dishes and membranes from the desiccator and stand in atmosphere for at least 1 h. Remove each membrane in turn, weigh to the nearest 0,1 mg, and record its mass.

NOTE — The Petri dishes and membranes may be weighed together directly from the desiccator, provided the balance pan is enclosed and the weighing chamber contains a desiccant.

B.4.16 The mass of insolubles present in the weighed oil sample shall then be determined as indicated in B.4.16.1 and B.4.16.2.

B.4.16.1 Correct the clean filtering membrane mass by applying the difference in mass occurring on the control membrane after filtering (i.e. add the difference if an increase occurs or subtract the difference if a decrease occurs).

B.4.16.2 Deduct the corrected mass of clean filtering membrane from the mass of used filtering membrane to obtain the corrected increase in membrane mass due to solids from the oil sample.

B.4.17 Express results as total mass of insolubles present in the complete effluent sample by using the multiplication factor obtained from the masses recorded in B.4.9 and B.4.10.

B.5 Determination of petroleum distillate insolubles in drainings, etc.

The amount of test dust in the drainings and rinsings from the mixing beaker and slurry addition reservoir (2.5.3.9 and 2.5.3.10) shall be determined as described in B.4.1 to B.4.16 except that all the rinsings shall be used and finally washed through the membrane with 100 ml of petroleum distillate. The final result shall be used for correction in the calculations detailed in subclause 2.6.

B.6 Determination of petroleum distillate insolubles in rig blank

The amount of petroleum distillate insolubles in the initial clean test liquid [see 2.5.2.2 c)] shall be determined as described in B.4.1 to B.4.16 except that the complete sample shall be filtered. The resulting percentage content of the sample is then applied to the total mass of test liquid in the effluent sample to obtain the correction m_0 to be applied in the calculation in subclause 2.6.

Annex C

(normative)

Test parameters for life and cumulative efficiency test

Test liquid: Straight mineral oil of ISO VG 100 (SAE 30) grade or ISO VG 150 (SAE 40) grade with the addition of anti-static additive[12] in the concentration of 0,25 ml per 10 litres.

Test oil operating kinematic viscosity: 24 mm^2/s ± 3 mm^2/s at approximately 74 °C with ISO VG 100 (SAE 30), or at approximately 83 °C with ISO VG 150 (SAE 40).

Test flow rate (through the filter), q_V, in litres per second, shall be as specified by the customer or the manufacturer of the filter. In the absence of such a specification, the test flow rate should be 1,5 l/s per square metre of filter media area.

Volume of test oil: 15 × q_V, in litres (minimum 6 l).

Test rig by-pass flow: approximately 25 % times q_V, in litres per second.

Contaminant: ISO 12103-A2 (ISO Fine — see 3.5.1).

Contaminant add rate: 10 × q_V, in grams per hour.

Test end point: 50 kPa increase above initial pressure drop.

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[12] A suitable anti-static additive is STADIS 450, available from Du Pont Petroleum Additives, Wilmington, DE 19898, USA. This information is given for the convenience of users of this part of ISO 4548 and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

Annex D

(normative)

Method for determining insolubles in test liquid samples for cumulative efficiency

D.1 Introduction

This annex describes the method used for determining the mass-to-mass concentration of insolubles in test liquid samples for the cumulative efficiency test. The petroleum distillate insolubles are separated from the oil by vacuum filtration. Two membranes are used for each sample analysed: one is used for filtering the sample and the other as a control so that a correction can be made for any change in mass of the sample filtering membrane that may result from changes in humidity, temperature, etc.

D.2 Equipment

The equipment shall be as given in B.2

D.3 Ancillary equipment

The ancillary equipment shall be as given in B.3.

D.4 Determination of oil sample petroleum distillate insolubles

D.4.1 Wash the filter holder, and sufficient sample containers (100 ml) and Petri dishes to cover the test requirements[13] in warm water to which a detergent has been added. Remove the filter holder, sample containers and Petri dishes from the bath and assemble the filter holder components, but do not tighten.

D.4.2 Hold the filter holder, sample containers and Petri dishes with clean tongs and rinse thoroughly with acetone delivered from a force-feed bottle. The holder, sample containers and Petri dishes should be handled with tongs for the remainder of the determination.

D.4.3 Place the filter holder, sample containers and Petri dishes in an oven at a temperature of 105 °C ± 5 °C for at least 1 h.

D.4.4 Remove the filter holder from the oven and place it in a desiccator to cool until required for further use.

D.4.5 Remove the sample containers from the oven and place them in a suitable covered glass beaker to cool to room temperature.

D.4.6 When cooled, label and weigh the sample containers to the nearest 0,1 mg, record the mass and replace them in a beaker. (These sample containers will then be used for sampling purposes.)

D.4.7 Remove the Petri dishes from the oven, and place them in a desiccator to cool for a minimum period of 1 h.

D.4.8 Remove the Petri dishes from the desiccator, place a filter membrane as indicated by **b** in figure B.1 in each Petri dish, and replace in the oven for at least 1 h.

---

[13] Each oil sample to be analysed requires the use of two membranes: one for filtering the sample, the other to be placed beneath the filtering membrane as a control membrane, to enable corrections to be made for humidity, temperature, etc., when weighing.

D.4.9 Remove the Petri dishes with membranes from the oven, and place in a desiccator to cool for at least 1 h. Remove from the desiccator and stand in atmosphere for at least 1 h, then remove each membrane in turn and weigh it to the nearest 0,1 mg. Record its mass, and replace it in the Petri dish until required. Label and mark each Petri dish as appropriate.

NOTE — The Petri dishes and membranes may be weighed together directly from the desiccator, provided the balance pan is enclosed and the weighing chamber contains a desiccant.

D.4.10 Remove a pre-weighed sample container and collect approximately 50 ml of the oil to be analysed, taken from the test rig sample point. Weigh it to the nearest 0,1 mg and record its mass.

D.4.11 Subtract the mass of the sample container from the total mass, to obtain the mass of the oil sample.

D.4.12 Remove the filter holder from the desiccator, place the appropriate pre-weighed control membrane, and sample filtering membrane, into the filter holder, with control membrane beneath the filtering membrane, and assemble the filter holder. Install on a suitable vacuum flask, ensure that filter holder is suitably earthed, and apply a vacuum of approximately 65 kPa.

D.4.13 Pour the oil sample (i.e. 50 ml) on to the membrane14) and simultaneously wash through with 250 ml petroleum distillate delivered from a force-feed wash-bottle. Continue to wash the oil sample container until clean and free from traces of oil, allowing oil washings to pass through the membranes.

NOTE — It is important that the minimum amount of petroleum distillate be used

D.4.14 Continue washing oil through the membrane until a total of 500 ml petroleum distillate has been used. There should be no traces of oil after this operation.

D.4.15 The filter holder shall then be dismantled, and the filtering membrane and control membrane returned to their appropriate Petri dishes and replaced in an oven set at 105 °C ± 5 °C for at least 1 h.

D.4.16 Repeat the procedure from D.4.10 to D.4.15 for each oil sample to be analysed in conjunction with the remaining pre-weighed membranes, prepared filter holder, etc.

D.4.17 Remove the Petri dishes containing membranes from the oven and place them in a desiccator to cool for a minimum period of 1 h.

D.4.18 Remove the Petri dishes containing membranes from the desiccator and stand in atmosphere for at least 1 h, then remove each membrane in turn and weigh to the nearest 0,1 mg and record its mass.

NOTE — The Petri dishes and membranes may be weighed together directly from the desiccator, provided the balance pan is enclosed and the weighing chamber contains a desiccant.

D.4.19 The mass of insolubles present in the weighed oil samples shall then be determined as indicated in D.4.19.1 and D.4.19.2.

D.4.19.1 Correct the clean filtering membrane mass by applying the difference in mass occurring on the control membrane after filtering (i.e. add the difference if an increase occurs, or subtract the difference if a decrease occurs).

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14) Filtering the sample is usually enhanced by adding approximately 50 ml petroleum distillate to the sample container and mixing by hand before pouring the sample on to the membrane.

D.4.19.2 Deduct the corrected mass of clean filtering membrane from the mass of used filtering membrane to obtain the corrected increase in membrane mass due to solids from the oil sample.

D.4.20 Express results as total mass of insolubles present in the sump oil prevailing at the time of removing the sample for substitution in formula for calculating cumulative efficiency (see 3.7.2).

Annex E

(normative)

Details of equipment used in the mixing of test dust and liquid slurry

E.1 Ultrasonic equipment

The ultrasonic equipment shall be in accordance with the following specifications.

Make: Kerry[15]

Model: ZS 150 AG

Power output: 850 W

The probe dimensions shall conform to figure E.1

E.2 Stirrer equipment

The stirrer equipment shall be in accordance with the following specifications:

Make: Citenco[16]

Type: LC9

Power: 150 W

Speed: 0 to 6 000 r/min

The stirrer paddle dimensions shall conform to figure E.2.

---

15) Kerry Ultrasonics Ltd, Hunting Gate, Wilbury Way, Hitchin, Hertfordshire, SG14 0TQ, U.K..

16) Park Products Ltd, Ordnance Street, Blackburn, Lancashire, BB1 3BN, U.K.

This information is given for the convenience of users of this part of ISO 4548 and does not constitute an endorsement by ISO of the companies named. Equivalent products may be used if they can be shown to lead to the same results.

Dimensions in millimetres

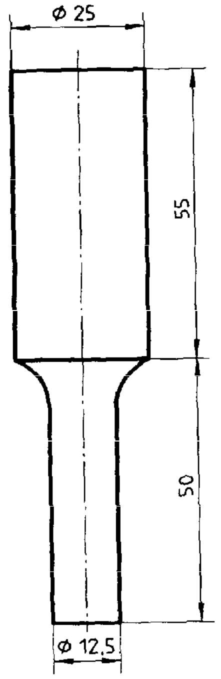
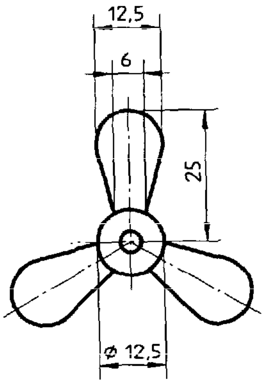


Figure E.1 — Ultrasonic probe dimensions

Dimensions in millimetres



Blade angle 20°

Figure E.2 — Stirrer paddle dimensions

Annex F

(informative)

Bibliography

[1] ISO 2942:1994, *Hydraulic fluid power — Filter elements — Verification of fabrication integrity and determination of the first bubble point.*

[2] ISO 3448:1992, *Industrial liquid lubricants — ISO viscosity classification.*

[3] ANSI/SAE J300-MAR93, *Engine oil viscosity classification.*

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