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Hydraulic fluid power – Monitoring the level of particulate contamination – Comparison membrane technique

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Contents

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Foreword

Publishing information

This British Standard is published by BSI and came into effect on 31 October 2010. It was prepared by Technical Committee MCE/18, *Fluid power systems and components*. A list of organizations represented on this committee can be obtained on request to its secretary.

Use of this document

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its methods are expressed as a set of instructions, a description, or in sentences in which the principal auxiliary verb is "shall".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

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0 Introduction

In hydraulic fluid power systems, power is transmitted and controlled through a liquid under pressure within an enclosed circuit. The liquid is both a lubricant and power-transmitting medium. The presence of solid particulate contamination in the liquid interferes with its ability to lubricate and causes wear to the components. The extent of contamination in the liquid has a direct bearing on the performance and reliability of the system and has to be controlled to a level appropriate for the system concerned. The level of particulate contamination is usually determined by extracting a liquid sample from the hydraulic system and analyzing it for the number of particles at various sizes, often in a laboratory.

Particle count analysis requires precision to both obtain a representative sample of the liquid and to analyse the sample. ISO standards have been developed to limit the errors in the various processes. The result of particle count analysis is usually converted into broad contamination classes, such as the BS ISO 4406 system, to simplify the communication and reporting of this data. The interval between individual codes is usually a doubling or a halving of the numbers of particles. The user can then compare this broad level with that which is either usual for the system or is specified (required cleanliness level or RCL). The user of the data has an immediate and simple view of how clean or dirty the sample is and whether any corrective actions are necessary if it is dirtier than the RCL. Thus, for samples that are much dirtier or cleaner than the RCL, quantitative evaluation of the contaminant might not be required. For such samples an assessment of the general level of contamination might suffice, and this can offer significant savings in the period between taking the sample and obtaining the result.

1 Scope

This British Standard specifies methods to assess the level of particulate contamination in hydraulic liquids using an optical microscope. It includes assessment by two manual methods using either transmitted- or incident-lighting systems. It also includes procedures for evaluating and controlling the accuracy of the technique that ensure reproducible results.

This method is applicable to nearly all hydraulic liquids at a wide range of contamination levels, provided the samples can be filtered. However, the procedure requires modification for samples that are either heavily contaminated (e.g. > ISO -/20/17 according to BS ISO 4406) or lightly contaminated (< ISO -/12/10 according to BS ISO 4406), by decreasing or increasing the volume of sample filtered.

This procedure is not applicable to samples that have high concentrations of small (< 3 µm) particles (so called “silt”), gels or where overlapping particles are present on the membrane filter.

The method detailed is a qualitative assessment only, not a quantitative evaluation, and it is applicable to all samples where the data has to be expressed in terms of contaminant codes.

This procedure does not cover procedures for the extraction of fluid samples from systems or bulk containers.

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2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 5540-3*, Evaluating particulate contamination of hydraulic fluids – Part 3: Method of bottling fluid samples*

BS EN ISO 4788, *Laboratory glassware – Graduated measuring cylinders*

BS ISO 4406, *Hydraulic fluid power – Fluids – Method for coding the level of contamination by solid particles*

BS ISO 4407, *Hydraulic fluid power – Fluid contamination – Determination of particulate contamination by the counting method using an optical microscope*

BS ISO 5598, *Fluid power systems and components – Vocabulary*

BS ISO 11500, *Hydraulic fluid power – Determination of the particulate contamination level of a liquid sample by automatic particle counting using the light-extinction principle*

3 Terms and definitions

For the purposes of this British Standard, the terms and definitions given in BS ISO 5598 and the following apply.

3.1 blank analysis
determination of the extent of contamination introduced during the analysis stage from other sources, such as reagents, incomplete cleaning of glassware and preparation of the membrane filter

NOTE For this determination, a membrane filter is prepared using filtered solvent and is either counted in accordance with BS ISO 4407, or assessed using this standard.

3.2 effective filtration area (EFA)
circular area of the membrane filter that is open to flow during filtration of liquid

NOTE BS ISO 4407 describes a procedure for determining the effective filtration area.

3.3 fixative liquid
liquid that, as a result of a heat curing process, causes a membrane filter to adhere to the base glass slide, resulting in an opaque membrane filter. (See BS ISO 4407).

NOTE This is only used if a permanent slide is required.

3.4 field monitor
membrane filter pre-packed into a protective case for insertion into sampling equipment used to take samples from pressurized lines

3.5 gel
shapeless material that lacks definition and interferes with the measuring process by coating or by masking particles

NOTE A gel is usually formed by chemical reaction with the hydraulic or other liquids.

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3.6 gridded membrane filter
membrane filter with overprinted squares on its surface to assist with focusing in the incident light method

3.7 mountant liquid
liquid that, as a result of the heat curing process, causes a membrane filter to become transparent and to adhere to the glass cover slip

NOTE See BS ISO 4407.

3.8 required cleanliness level (RCL)
cleanliness level that is either specified or required for a specific hydraulic system

3.9 reference membrane filter
membrane filter specially prepared to represent different cleanliness levels

NOTE 1 This can be a permanent membrane filter in glass slides, digital images or photographs.

*NOTE 2 Clause **7** and BS ISO 4407 describe the preparation of reference membrane filters.*

3.10 silt
very small particles (< 3 µm) present in the fluid, often below the minimum detection size of the technique used, which can interfere with its effectiveness by either obscuring particles or by causing coincidence effects

NOTE These can be small wear particles or products of hydraulic liquid degradation.

3.11 solvent
liquid that is physically and chemically compatible with and miscible in the sample liquid

NOTE A solvent is used for diluting the sample liquid and can be used for cleaning and rinsing the equipment.

4 Principle

Solid particles are separated from a liquid sample by vacuum filtration and are deposited onto a membrane filter. The level of contamination is evaluated by comparing the density of particles with a series of reference membrane filters using an optical microscope. The cleanliness level of the reference membrane filter that has a particle concentration that is equal to or immediately greater than the sample membrane filter is taken as the cleanliness level for that sample.

WARNING. This British Standard calls for the use of substances and/or procedures that can be injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage.

5 Equipment

5.1 *Reference membrane filters*, covering the range of contamination expected. The cleanliness level of the reference membrane filters shall be certified using BS ISO 4407 and have both the cleanliness code and microscope magnification marked on it.

*NOTE Higher or lower levels of particulate contamination than those covered by the reference membrane filters can be examined by adjusting the volume of sample filtered. For instance, if the sample is cleaner than the cleanest reference, then additional volume should be filtered, and vice versa (**8.3.7** or **8.3.8**).*

5.2 *Microscope glass base slides and microscope glass cover slips*, for analysis using the transmitted-light method only, with dimensions greater than the diameter of the membrane filter. The thickness of the cover slip shall be selected to ensure that the particles on the membrane filter are in focus at the magnification used.

5.3 *Membrane filter holder, plastic, glass or equivalent with lid*, for retaining the membrane filter (incident-light method only), e.g. Petri slide.

5.4 *Membrane filters*, for separating the particles from the sample liquid. They shall have the following characteristics:

a) be compatible with the sample liquid and any solvents or chemicals used in the processes;

b) be of a colour to provide maximum contrast with the particles, for instance, white if most of the particles are dark in colour, or black if most of the particulates are translucent, transparent or white in colour;

NOTE 1 This might only be known after the membrane filter has been prepared and viewed and might necessitate repreparation.

c) have a pore size and colour that are identical to those of the reference membrane filter.

NOTE 2 The membrane filters are usually of 47 mm diameter and have a pore size of between 1 µm and 1.5 µm. However, if a membrane filter of a different diameter is used, the volume of sample filtered should be adjusted to give the same volumetric density as used for the reference membrane filter.

NOTE 3 Gridded membrane filters assist focusing. These usually have each grid squares with sides of 3.08 mm and a thickness of 0.05 mm and an area equal to 1/100th of the effective filtration area of a 47 mm membrane filter.

5.5 *Vacuum apparatus*, comprising:

a) a vacuum flask, suitable for the membrane filter support and of a sufficient capacity to filter the entire volume of sample liquid;

b) a funnel, of either 300 mL capacity with suitable calibrated volumetric graduations [e.g. (25 ±2) mL] for 47 mm diameter membrane filters or of 150 mL capacity with suitable calibrated volumetric graduations [e.g. (10 ±1) mL] for 25 mm diameter membrane filters;

c) a suitable cover for the funnel (e.g. a Petri dish);

d) a clamping device;

e) a suitable base to support the membrane filter; and

f) a means of dissipating any static electricity generated during the filtering process.

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5.6 *Graduated cylinders or bottles*, for measuring out the volume of test liquid. The graduation shall be ±2% for a 250 mL graduated cylinder or bottle.

NOTE Measuring cylinders to BS EN ISO 4788, Class A, conform to this accuracy requirement.

5.7 *Sample bottles*, between 150 mL and 500 mL nominal volume, flat-bottomed and wide-mouthed with a screw cap containing a suitable internal polymeric seal. These shall not be used for measuring the sample (see **5.6**).

5.8 *Pressurized solvent dispenser*, which discharges solvent through an in-line membrane filter with a pore size not greater than 1 µm.

5.9 *Sampling agitating device*, suitable for redispersing the particles in the liquid sample but which shall not alter their basic size distribution. A laboratory multi-axis shaker, three-axis paint shaker or ultrasonic bath (rated at 3 000 W/m^2 to 10 000 W/m^2 of base area) are suitable.

5.10 *Vacuum device*, capable of establishing a vacuum of 86.6 kPa (–0.87 bar, 650 mm Hg).

5.11 *Tweezers*, stainless steel, flat-bladed, non-serrated, with blunt tips.

5.12 *Microscope*, with a range of objective lenses that, in combination with the ocular lens, can resolve particles of ≥ 5 µm. The microscope shall be equipped with:

a) focus control;

b) through-the-lens lighting for the incident-light method and/or a bottom lighting source for the transmitted-light method;

c) a mechanical stage moveable in the x and y direction so that the effective filtration area of the membrane filter can be viewed;

NOTE A sliding stage which allows the sample and reference slides to be viewed consecutively has been found to be suitable (see Figure 1);

d) provision on the mechanical stage for securely holding the membrane filter holder or glass slide;

e) lens cleaning tissue, suitable for cleaning the microscope objective and eyepiece lens.

5.13 *External lamp*, of variable intensity, where oblique illumination of the specimen stage is required.

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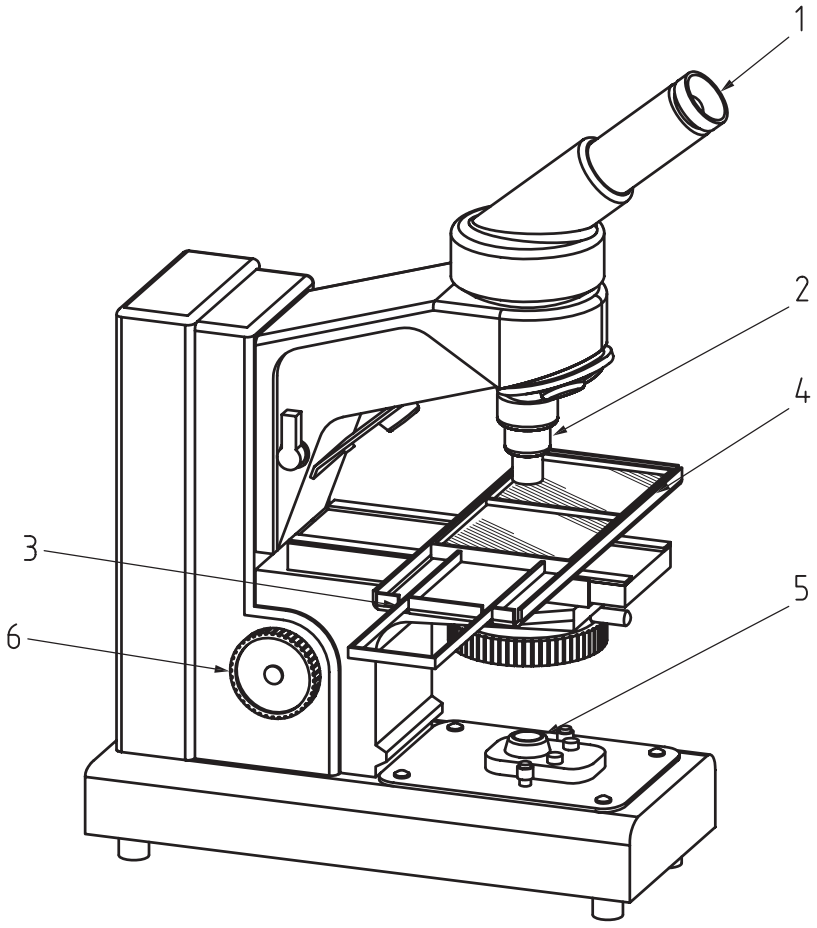
Figure 1 **Typical comparison microscope**



Key

1 Eyepiece
2 Objective
3 Lateral slide control
4 Transverse slide control
5 Transmitted-light source
6 Focus control

6 Chemicals

6.1 Rinsing and cleaning chemicals

6.1.1 *Liquid detergent*, without solid residue.

6.1.2 *Distilled or demineralized water*, general purpose reagent (GPR) grade.

6.1.3 *Propan-2-ol (iso-propyl-alcohol, IPA)*, GPR grade.

6.1.4 *Solvent*, for rinsing equipment and diluting samples. Petroleum spirit (boiling point 100 °C to 120 °C) or a hydrocarbon of similar solvency is suitable if the sample liquid is a mineral or synthetic oil, or distilled or demineralized water if the sample liquid is water based.

The solvent shall be physically and chemically compatible with the sample liquid and the equipment used.

WARNING. Take care when using solvents with low flash points as there is an explosion risk. Take appropriate precautions to avoid inhalation of fumes from these solvents. Always use suitable protective equipment.

6.2 Liquids for preparing the membrane filter for analysis using transmitted light

6.2.1 *Fixative liquid*, see **3.3**.

6.2.2 *Mountant liquid*, see **3.7**, with a refractive index similar to that of the glass cover slip.

7 Preparation of reference membrane filters

7.1 General

A series of reference membrane filters (**5.1**) shall be prepared in accordance with BS ISO 4407 and shall cover the range of cleanliness levels envisaged. The cleanliness code, the range of particle counts covered by the code and magnification shall be clearly marked on the microscope slide (**5.2**), the membrane filter holder (**5.3**) or the image.

7.2 Care of reference membrane filters in microscope slides

7.2.1 Reference membrane filters (**5.4**) are usually supplied as ready-made glass slides in a storage case; those reference slides not being used shall be placed horizontally in the case and stored in a clean area.

7.2.2 If it is necessary to clean the reference slides to remove finger marks or other matter which would obscure viewing, the glass slide shall be wiped with a dampened clean lens tissue. If this procedure is unsuccessful, the lens tissue shall be dampened with petroleum spirit and the glass wiped lightly.

8 Procedures

8.1 Blank analysis

8.1.1 Perform a blank analysis (**3.1**) before each sample analysis unless it can be demonstrated that acceptable blanks can be consistently obtained throughout the analysis period or day, whichever is the longer. If consistency has been demonstrated, perform a blank analysis before starting a counting programme and at least once during it.

8.1.2 Clean glassware in accordance with BS 5540-3 and rinse the filtration funnel with solvent from the solvent dispenser (**6.12**).

8.1.3 Assemble the vacuum apparatus (**5.5**) with the selected membrane filter (**5.4**) and prepare a blank membrane filter and measure out and use a graduated cylinder or bottle to dispense (**5.3**) a 100 mL volume of filtered solvent into the clean vacuum funnel. Vacuum to dryness.

8.1.4 Test the cleanliness by either counting the membrane filter in accordance with BS ISO 4407 or comparing it against the appropriate reference membrane filter using the procedure in this standard.

8.1.5 If the count or concentration exceeds 250 particles sized ≥ 5 µm in 100 mL of the vessel volume, clean the apparatus again and repeat steps **8.1.2** and **8.1.4**.

For an assessment of the blank levels using the method defined in this British Standard, a level of at least three BS ISO 4406 codes (or equivalent) cleaner than the expected ISO code of the sample should be achieved.

8.1.6 If high blanks still occur after cleaning, investigate all processes, i.e. cleaning procedure, filtration of solvent, membrane filter preparation procedure and the levels of airborne particulate contamination.

8.1.7 Record the result on a work sheet (an example is given in Annex A).

8.2 Test membrane filter preparation

8.2.1 Record all sample identification details and remove any tied-on or loosely attached labels. Thoroughly clean the outside of the sample bottle (**5.7**), particularly around the cap, by rinsing with filtered solvent dispensed from the pressurized dispenser (**5.8**). Do not force contaminant from the outside of the bottle into the cap area. Immediately re-label the sample container so that sample identity is retained.

8.2.2 Select a membrane of the same diameter and pore size as the reference membrane and filter a volume equal to that used for the reference membrane through it.

NOTE Membrane filters whose final assessment uses transmitted light are first viewed by incident light; this enables their suitability for assessment to be confirmed prior to creating a permanent slide.

8.2.3 Use the following procedure for samples contained in sample bottles. If the sample is a field monitor go to **8.2.4**.

a) Redistribute the particles in the sample bottle (**5.7**) by either hand-shaking the sample vigorously for at least 1 min or using an agitating device (**5.9**). If an ultrasonic bath is used, stand the sample container so that the level of the liquid in the bath is either just below the fluid level in the sample bottle, or 3/4 up the side of the container, whichever is least. The period of immersion in the ultrasonic bath should not exceed 1 min as this may promote settlement.

b) De-gas the sample by either placing it in a vacuum device (**5.10**) and applying vacuum until no surfacing air bubbles are observed, or placing the sample bottle in an energized ultrasonic bath for 30 s or until no surfacing air bubbles are observed. At the end, take the sample bottle out of the ultrasonic bath and remove the water from the outside of the bottle using a lint-free wiper.

c) Re-suspend the particles prior to filtration by gently turning the sample bottle on its axis for 10 s.

d) Prepare the membrane filter by filtering the sample in accordance with BS ISO 4407 and aspirate to dryness. When dry, place the membrane filter in a holder (**5.3**), replace the lid and mark the holder with a suitable identification.

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8.2.4 Extract the membrane filter from the field monitor in the following manner:

a) open the monitor using the reverse end of the tweezers (**5.11**) and separate the monitor halves;

b) carefully grasp the edge of the membrane filter using the gripping end of the tweezers, and remove it from the monitor, with the contamination-bearing surface uppermost;

c) immediately place the membrane filter on the support of the vacuum apparatus (**5.5**), apply vacuum and aspirate to dryness. If necessary, carefully de-oil the membrane by gently wetting the outside of the membrane filter with filtered solvent from the dispenser and aspirate to dryness. Avoid dislodging particles;

d) carefully transfer the membrane filter to the membrane filter holder (**5.3**) and replace the lid.

8.3 Assessment of cleanliness level

8.3.1 Remove the lid of the membrane filter holder and place the holder on the microscope stage [**5.12**d)]. Select a magnification of either ×40 or ×50 and adjust the microscope focus and illumination so that the surface of the membrane filter is evenly lit. Use additional lighting as required (**5.13**). View the general distribution of particles on the surface of the membrane filter by moving the microscope stage transversely and laterally to scan the complete surface of the membrane. Do not attempt to count the number of particles.

8.3.2 Assess the distribution of particles on the membrane filter and disqualify the membrane filter from assessment if it has:

a) an uneven distribution of particles; prepare another membrane filter using the same volume;

b) large numbers of silt (< 3 µm) particles that obscure the surface of the membrane filter; prepare another membrane filter using either a reduced sample volume or a coarser membrane filter, e.g. 3 µm;

c) overlapping particles; prepare another membrane filter using reduced sample volume;

d) the presence of gels that obscure particles sized > 5 µm; obtain another sample. If another sample cannot be obtained and it is essential that data is obtained, prepare another membrane and attempt to dissolve the gels by heating the fluid sample to between 40 °C and 50 °C and filtering when hot.

NOTE See also Annex B for more guidance on potential problems.

8.3.3 If the distribution of particles is acceptable, proceed to **8.3.4** for the incident-light method, otherwise prepare the membrane filter for viewing by transmitted light in accordance with BS ISO 4407 and then proceed to **8.3.4**.

8.3.4 Adjust the microscope to the same magnification used in the preparation of the reference membrane filter and make adjustments to the focus and illumination so that the membrane filter is evenly lit and in focus. View the membrane filter by moving the stage, survey the particles and retain a mental impression of the numerical density of particles. Do not attempt to size or count the particles.

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8.3.5 Compare the density of particles on the membrane filter to that of the reference membrane filter(s) selected and decide if the sample membrane filter is definitely cleaner or dirtier than the reference membrane filter. Eliminate the obviously cleaner and dirtier reference membrane filters first, reaching either a single or pair of reference membrane filters closest in cleanliness level to the sample under inspection.

8.3.6 Repeat the process in at least four different fields of view on the membrane and determine the code of the reference membrane filter that is closest in concentration to the sample membrane filter. Report the code of that membrane filter as the cleanliness of the sample.

NOTE Where an RCL is stated and the assessment is close to that value, it is recommended that confirmation of the assessment be performed using an ISO counting technique, either BS ISO 4407 (microscope method) or BS ISO 11500 (automatic particle counting).

8.3.7 If the sample is dirtier than the most concentrated reference membrane filter, then either report "greater than XX", where "XX" is the most concentrated reference membrane filter code or repeat **8.2** and **8.3** using smaller sample volumes to reduce the density of particles on the membrane filter.

NOTE For coding systems with an interval of two times, filtering 50 mL or 25 mL of sample liquid through a 47 mm membrane filter reduces the concentration by one or two codes respectively. The assessed code should be increased by one or two codes as appropriate to obtain the reportable code.

8.3.8 If the sample membrane filter is cleaner than the least concentrated reference membrane filter, then either report "cleaner than YY" where "YY" is the least concentrated reference membrane filter code or repeat **8.2** and **8.3** using a larger sample volume to increase the density of particles on the membrane filter.

NOTE For coding systems with an interval of two times, filtering 200 mL or 400 mL of sample liquid through a 47 mm membrane filter increases the concentration by one or two codes respectively. The assessed code should be reduced by one or two codes as appropriate to obtain the reportable code.

8.3.9 Where an assessment cannot be made, report that the analysis could not be performed and state the reason why.

8.4 Assessment consistency-checking procedure

8.4.1 Regular checks on the competence of the analyst shall be made to ensure consistent of application of this method by using the steps in **8.4.2** to **8.4.4**.

8.4.2 A checking membrane filter shall be prepared and a particle count analysis performed according to BS ISO 4407. A unique identification shall be given to it and the particle counts and the cleanliness code shall be recorded on a suitable worksheet (see Annex A for an example).

NOTE If a particle count cannot be performed, the prepared membrane filter should be assessed by the most experienced analyst.

8.4.3 Each analyst shall assess the checking membrane filter using steps **8.2** and **8.3** in this British Standard, record and compare the results of the assessment on a suitable data sheet.

8.4.4 The results of each analyst shall be compared with the level obtained in **8.4.2** and it shall be determined whether the results from each analyst are within ±1 of the cleanliness code as represented by the checking membrane filter. If results are above this limit, the membrane filter shall be examined to see whether the distribution of particles at other sizes (e.g. < 5 µm) could have any influence on the results, in which case this shall be stated on the results sheets. If the distribution of particles has not affected the results, the analyst shall be retrained and revalidated.

9 Test report

All measurements and test details shall be recorded on a worksheet (see Figure A.1).

As a minimum, the following shall be reported:

a) the sample designation;

b) the cleanliness coding obtained;

c) the effective filtration area of the membrane filter;

d) the volume analysed (mL);

e) the type of lighting used (incident or transmitted);

f) the number of this British Standard;

g) the laboratory or organization, and analyst, performing the test; and

h) other comments pertaining to the test.

Annex A (informative) Typical worksheet

Figure A.1 shows a typical worksheet.

Figure A.1 **Typical worksheet**

BS 8465:2010							Organization/analyst:		
Sample identification:			Microscope serial no.:				Magnification:		
Effective filtration diameter of membrane filter (mm):			Effective filtration area of membrane filter A (mm^2):				Membrane filter pore size (µm):		
Length of membrane grid square L (mm)			Sample volume, V (mL):				Lighting method: (transmitted/incident)		
Particle size (µm)									Fibres[A]
Blank Counts	No. of particles counted, n								
	No. of unit areas counted, f								
	Width of unit area, W (µm)								
	Particle count, N[B]								
Assessments	Blank reference membrane filter used								
	Blank achieved	Pass	Fail						
Sample	No. of particles counted, n								
	No. of unit areas counted, f								
	Width of unit area, W (µm)								
	Particle count per 100 mL, N[B]								
Reference	Particle count per 100 mL								
	Cleanliness code								
Date of analysis:							Signature:		

[A] Fibres are defined as particles > 100 µm in size with an aspect ratio greater than 10.

[B] Particle count is calculated from the formula: $N = \frac{nA \times 10^5}{fLWV}$ per 100 mL. This formula assumes that the membrane grid is formed of uniform squares whose length L = 3.08 mm.

Annex B (informative) Potential problems associated with preparing membrane filters

B.1 Large numbers of small particles

Large numbers of small particles, i.e. predominantly < 3µm ("silt") can occur in relatively high proportions and many will be removed by the membrane filter used in the analysis. Their high numbers means that they are likely to "coat" the surface of the membrane filter and obscure the 5 µm particles on which the comparison method relies. Thus it is difficult to make an accurate assessment.

These particles can be in three forms:

a) Wear metals

These are a result of the wear processes of the hydraulic system and the limitations in the performance of the filter in controlling these particles. Put simply, if the filter performance at the smaller sizes is low then the numbers of particles at this size will increase at a greater rate than will the larger ones. Furthermore some systems like geared systems produce unique characteristic debris referred to as "fatigue platelets" which are small and almost two-dimensional in shape. Thus they can more readily pass through filters.

b) Chemical reaction products

These are generally caused mainly by the reaction of the oil with another liquid, which can be generated in a number of ways:

- water contamination with mineral or synthetic oil. Oils with zinc based additive can produce a fine grey covering on the membrane filter indicating that the zinc has precipitated;
- contamination of mineral oils with some synthetic oils and vice versa.

c) Thermal degradation products

These are caused by subjecting the oil to excessive heat in either the environment (e.g. gas turbines) or "dieseling" where a vapour cavity implodes so violently that the localized temperature rises to over 1 000 °C and the oil/air mixture temporarily ignites.

B.2 Prepared membrane filters with circular patches of lighter colour

These are a result of either air bubbles or water droplets. Air bubbles can form during the specimen mounting operation necessary to view with transmitted light. Viewed through the microscope these appear as transparent discs near spheres but are defined by a thin black outline, which may give them an appearance rather similar to an "O-ring". These bubbles should be ignored when making the examination.

Water droplets on the membrane filter indicate the presence of water in the system from which the sample was taken. The droplets appear as translucent spheres somewhat smaller than air bubbles but with no definite outline.

Bibliography

Further reading

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DEF STAN 05-42, *Particulate contamination classes for fluids in hydraulic systems*

ISO 4021-1992, *Hydraulic Fluid Power – Particle contamination analysis – Extraction of fluid samples from lines of an operating system*

ISO 11218:1993, *Aerospace – Cleanliness classification for Hydraulic fluids*

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