

Hydraulic fluid power — Monitoring the level of particulate contamination of the fluid

Part 3: Use of the filter blockage technique

ICS 23.100.60

National foreword

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**Hydraulic fluid power — Monitoring the
level of particulate contamination of the
fluid —**

Part 3:
Use of the filter blockage technique

*Transmissions hydrauliques — Surveillance du niveau de pollution
particulaire des fluides —*

Partie 3: Technique de colmatage de filtre



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Contents

Page

Foreword.....	iv
Introduction	v
1 Scope	1
2 Normative references	1
3 Terms and definitions.....	2
4 Health and safety	2
4.1 General.....	2
4.2 Electrical power	2
4.3 Mechanical fluid power	2
4.4 Process liquids	2
5 Principle of filter blockage technique.....	3
6 Equipment	3
6.1 General.....	3
6.2 Equipment for on-line and off-line calibration and verification	3
7 Operating procedures	5
7.1 General.....	5
7.2 Operating from a pressurized line	5
7.3 Procedure for operating from a system reservoir.....	6
7.4 Operating from a bulk container	6
7.5 Operating from a sample bottle.....	7
8 Calibration and verification procedure.....	8
8.1 General principles.....	8
8.2 Equipment required	8
8.3 Preliminary procedures.....	8
8.4 Preparation of dust sample	9
8.5 On-line calibration/verification procedure	9
8.6 Verification of correct operation	10
9 Calibration and/or verification.....	11
10 Test report	12
11 Identification statement.....	12
Annex A (informative) Examples of use and applicability of the filter blockage technique.....	13

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 21018-3 was prepared by Technical Committee ISO/TC 131, *Fluid power systems*, Subcommittee SC 6, *Contamination control*.

ISO 21018 consists of the following parts, under the general title *Hydraulic fluid power — Monitoring the level of particulate contamination of the fluid*:

- *Part 1: General principles*
- *Part 3: Use of the filter blockage technique*

A Part 2, dealing with the calibration and verification procedure for field contamination monitoring, and a Part 4, dealing with the use of the light extinction technique, are under development.

Introduction

In hydraulic fluid power systems, power is transmitted through a liquid under pressure within a closed circuit. The liquid is both a lubricant and power-transmitting medium. The presence of solid contaminant particles in the liquid interferes with the ability of the hydraulic liquid to lubricate and causes wear. The extent of contamination in the liquid has a direct bearing on the performance and reliability of the system and should be controlled to an appropriate level.

Quantitative determination of particulate contamination requires precision both in obtaining a representative sample of the liquid and the measurement of the contamination. The awareness of the benefits of cleanliness monitoring has led to the development of instruments that operate on-line (i.e. directly connected to a system) in an attempt to reduce measurement errors that are inherent with bottle samples. Automatic particle counters (APC) and monitors have been developed and are extensively used. Unfortunately, the hydraulic liquids in many systems might not be suitable for this method of measurement as the optical interfaces created by two-phase liquids (emulsions), immiscible liquids (water in oil and vice versa) and air in all liquids, interfere with the operation of the APC and give incorrect data.

Instruments using the filter blockage principle were developed specifically to provide an alternative on-line instrument in applications where light extinction or scattering techniques are not suitable. The principle used is that the rate of filter blockage is related to the number of captured particles whose size is larger than the pore size of the filters. The filter blockage technique does not directly measure the size of individual particles and so the principle of direct traceability does not apply.

Instruments using this technique are becoming widely used in industry and an International Standard is required in order to standardize operating procedures. This part of this ISO 21018 defines procedures for the use of filter blockage instruments in evaluating the cleanliness level of a hydraulic liquid. It also includes procedures for calibrating and verifying that the instruments are operating correctly to ensure consistent results and also closer correlation with on-line or in-line instruments using the light extinction principle.

Hydraulic fluid power — Monitoring the level of particulate contamination of the fluid —

Part 3: Use of the filter blockage technique

1 Scope

This part of ISO 21018 specifies a method for the semi-quantitative determination of the particulate contamination level using the filter blockage technique (also known as the mesh-obscuration method or the pore-blockage technique) either on-line or off-line in containers. It also defines procedures for calibrating the instruments and verifying their correct operation both in the laboratory and in service.

In general, the techniques described in this part of ISO 21018 are suitable for monitoring

- a) the general cleanliness level in hydraulic systems,
- b) the progress in flushing operations,
- c) support equipment and test rigs.

The use of this method is applicable to all single- or multi-phase liquid systems.

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.

ISO 3722, *Hydraulic fluid power — Fluid sample containers — Qualifying and controlling cleaning methods*

ISO 4021, *Hydraulic fluid power — Particulate contamination analysis — Extraction of fluid samples from lines of an operating system*

ISO 5598, *Fluid power systems and components — Vocabulary*

ISO 11171, *Hydraulic fluid power — Calibration of automatic particle counters for liquids*

ISO 11943:1999, *Hydraulic fluid power — On-line automatic particle-counting systems for liquids — Methods of calibration and validation*

ISO 12103-1:1997, *Road vehicles — Test dust for filter evaluation — Part 1: Arizona test dust*

ISO 21018-1, *Hydraulic fluid power — Monitoring the level of particulate contamination of the fluid — Part 1: General principles*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5598 and ISO 21018-1 and the following apply.

3.1

blockage

restriction to flow through a filter caused by the capture of particles

3.2

extraneous contamination

contamination that is not an integral part of the sample being analysed and is from another source

NOTE It unrepresentatively increases the level of contamination.

4 Health and safety

4.1 General

Operate the instrument in accordance with the manufacturer's instructions and follow local health and safety procedures at all times.

4.2 Electrical power

Take care when connecting the instrument to an electrical power source and follow the manufacturer's instructions. Ensure that the correct safety fuse is fitted.

4.3 Mechanical fluid power

Instruments shall be connected to pressurized lines in accordance with the instrument manufacturer's instruction and in such a manner that the connection is secure and leak-free. Any connectors used shall be suitable for the pressure at the point of sampling.

Internal pressure shall be dissipated before removing any fittings or closures.

NOTE See 7.2 for guidance regarding sampling from pressurized lines.

4.4 Process liquids

4.4.1 Volatile liquids

Flammable liquids shall be used

- a) in accordance with the relevant material safety data sheet (MSDS),
- b) at a temperature below the stated flash point,
- c) away from potential sources of ignition.

4.4.2 Solvents

Solvents shall be used in well-ventilated areas and the generation of aerosol mists shall be avoided.

4.4.3 Electrical earthing/grounding

Equipment used for filtering or dispensing solvents or any volatile flammable liquid shall be electrically earthed/grounded so as to avoid the risk of static discharge near the jet.

4.4.4 Environmental

All liquids and substances shall be disposed of in accordance with local environmental procedures.

Spillage shall be cleaned-up as detailed in the relevant MSDS.

4.4.5 Chemical compatibility

Ensure that all chemicals and fluids used in the various processes are chemically compatible with each other and with any equipment used.

5 Principle of filter blockage technique

The filter blockage technique shall be based on either of the following principles:

- a) constant differential pressure across the filter: The change in flow through a filter is measured as it gradually becomes blocked by particles in a known volume of liquid. A change in flow relates to the quantity of particles that are removed from the liquid by the filter; or,
- b) constant flow through the filter: The differential pressure across the filter is measured as it gradually becomes blocked by particles in a known volume of liquid. The change in differential pressure relates to the quantity of particles removed from the liquid by the filter.

Particles that are retained on the surface of the filter are removed by back-flushing prior to performing the next analysis.

NOTE 1 Individual particles are not detected and any reported numerical data is only an assessment of the number of particles from the detection process.

NOTE 2 If the liquid being analysed contains contaminants other than particulate (e.g. gels or non-soluble additives), these can be removed by the instrument filters and affect the output data.

6 Equipment

6.1 General

If the analysis is performed using sample bottles or containers (see 7.5), sampling apparatus (6.2.1) may be required. Such equipment avoids adding contamination when the inlet hose is inserted into the sample bottle.

For the process of calibration and verification of correct operation, use the equipment detailed in 6.2.

6.2 Equipment for on-line and off-line calibration and verification

6.2.1 Bottle sampling apparatus, for transferring the calibration/verification sample to the instrument.

If a pressure chamber is used to force the liquid through the device at constant pressure, a suitable source of filtered and regulated air is required.

6.2.2 Calibration/verification dust, test dust, designated ISO 12103-A3, used for calibration and/or verification shall meet the requirements ISO 12103-1:1997, Clause 3, and have a size distribution measured using an automatic particle counter (APC) calibrated in accordance with ISO 11171 or ISO 11943.

6.2.3 Flushing liquid, separate liquid for flushing the instrument prior to verification.

This liquid shall have a required cleanliness level (RCL) of less than 10 particles sized $\geq 6 \mu\text{m(c)}$ /ml.

NOTE $\mu\text{m(c)}$ refers to the sizes of an APC calibrated in accordance with ISO 11171 or ISO 11943.

6.2.4 Oven, non-circulating, capable of providing a controlled temperature between 100 °C and 150 °C for drying the test dust.

6.2.5 Reference instrument, for example, a filter blockage unit or an APC, with a calibration status verified using an APC calibrated in accordance with ISO 11171 or ISO 11943.

6.2.6 Sample agitating device, suitable for re-dispersing the test dust within the contents of the sample bottle, such as an ultrasonic bath rated at 3 000 W/m² to 10 000 W/m² of base area, or a three-axis shaker.

The agitating device shall not alter the basic size distribution of the test dust.

6.2.7 Sample bottles, cleaned and validated in accordance with ISO 3722.

Use the following RCLs:

- a) less than 100 particles $\geq 6 \mu\text{m(c)}$ /ml of sample bottle volume for sample bottles used for mixing the test dust;
- b) less than 5 particles $\geq 6 \mu\text{m(c)}$ /ml of sample bottle volume for sample bottles used for both verifying system cleanliness and preparing the calibration verification samples.

6.2.8 Solvent, compatible with the instrument and equipment used and miscible with the test liquid.

Any solvent used shall be filtered to 0,8 μm or better to achieve an RCL of less than 2 particles $\geq 6 \mu\text{m}$ /per ml.

6.2.9 Solvent dispenser, pressurized, fitted with a 0,8 μm in-line membrane filter at the outlet.

6.2.10 Test rig, validated in accordance with ISO 11943.

6.2.11 Test liquid, conforming to the requirements used for on-line calibration (ISO 11943:1999, 7.2.7).

The test liquid is used for both cleaning and validating the test instrument and shall be kept in suitable sample bottles.

6.2.12 Vacuum source, to de-aerate the test liquid samples after shaking, and may be incorporated in the bottle sampling apparatus.

An ultrasonic bath can be used as an alternative method (see 6.2.6).

NOTE De-aeration might not be required if the instrument utilizes a constant pressure source.

6.2.13 Verification samples, samples bottles containing a suspension of ISO 12103-A3 in oil (see ISO 12103-1:1997, Clause 3) that is compatible with the instrument concerned and at a concentration specified by the instrument manufacturer.

The particle size distribution shall be determined using an APC calibrated in accordance with ISO 11171 or ISO 11943.

6.2.14 Weighing balance, with a resolution of 0,1 mg or better.

7 Operating procedures

7.1 General

Select the mode of operation from the following:

- a) from a pressurized line (see 7.2);
- b) by suction from a system reservoir (see 7.3);
- c) by suction from a bulk container (see 7.4);
- d) from a sample bottle (see 7.5).

NOTE Operating on-line from a pressurized source is preferred as it eliminates contamination from the environment.

Select the sampling position and sampling valves in accordance with ISO 4021.

If periodic or continuous trend monitoring is being carried out on a machine or process, take repeat samples from the same place, in the same manner and under similar operating conditions.

7.2 Operating from a pressurized line

7.2.1 General

WARNING — Ensure that all equipment and procedures used are safe and compatible with the maximum system pressure.

Select the sampling valve so that it complies with ISO 4021.

Position the sampling valve in a flow line that carries a significant flow and at a point of turbulence, such as after an elbow.

A pressure tapping point should not be considered a suitable sampling valve unless it complies with the requirements of ISO 4021. Such a tapping point can require sustained flushing prior to sampling.

7.2.2 Procedure

7.2.2.1 Stabilize the system at its normal operating conditions. Ensure that the minimum system pressure is sufficient for correct operation of the instrument.

7.2.2.2 Establish whether there is any liquid residual from a previous analysis in the instrument and whether it is miscible with the current test liquid. If it is not or there is any doubt, use the procedure detailed in A.3 to flush the previous liquid out of the unit. If it is miscible, proceed to 7.2.2.3.

7.2.2.3 Clean the outside of the sampling valve and then connect the instrument to the sampling valve.

7.2.2.4 Operate the instrument in accordance with the manufacturer's instructions. If the instrument does not have an automatic self-flushing sequence, run the instrument to ensure that the sampling line and instrument are adequately flushed (seek advice from the manufacturer where necessary). If the instrument was previously used to analyse a different but miscible liquid, flush with at least ten complete volumes (instrument and connecting pipes) of system liquid and direct to waste.

7.2.2.5 Analyse the sample in accordance with the manufacturer's instructions. Perform at least two analyses and compare the results. If the difference between successive analyses is greater than one contamination code, this indicates that the flushing was inadequate or that the system was not stabilized. Repeat the analysis as appropriate.

7.2.2.6 After analysis, close the sample valve and ensure that any residual pressure has been exhausted from the sampling line before disconnecting the instrument.

7.2.2.7 Record the data.

7.3 Procedure for operating from a system reservoir

7.3.1 Stabilize the system at its normal operating conditions and check that there is sufficient liquid movement in the reservoir to promote adequate dispersion of the particles in the area where the sample is taken.

NOTE If there is insufficient movement, the sample analysed might not be representative of the whole.

7.3.2 Establish whether there is any liquid residual from a previous analysis in the instrument and whether it is miscible with the current test liquid. If it is not or there is any doubt, use the procedure detailed in Clause A.3 to flush the previous liquid out of the unit. If it is miscible, proceed to 7.3.3.

7.3.3 Clean the reservoir entry area where the sampling line is inserted and secure any screws, fittings, etc. Clean the outside of the sampling line.

7.3.4 Insert the inlet hose into the reservoir so that it draws from a representative portion of the liquid (normally mid-depth).

7.3.5 If the instrument does not have an automatic self-flushing sequence, run the instrument to ensure that the sampling line and instrument are adequately flushed (seek advice from the manufacturer when necessary). If the instrument was previously used to analyse a different but miscible liquid, flush with at least ten complete volumes (instrument and connecting pipes) of system liquid and direct to waste.

7.3.6 Either position the return hose in the reservoir so that re-entrainment of the sample into the monitor suction line does not occur or direct it to another container or waste.

7.3.7 Analyse the sample in accordance with the manufacturer's instructions. Perform at least two analyses and compare the results. If the difference between successive analyses is greater than one contamination code, this indicates that cleaning was inadequate or that the system was not stabilized. Repeat the analysis as appropriate.

7.3.8 Record the data.

7.4 Operating from a bulk container

7.4.1 General

This procedure requires the sample to be sucked (or sipped) from the bulk container by a pump, either integral with the instrument or specially provided. It can, potentially, be subject to error and variability in measurement and can require additional stages. Such sources of error are

- a) an inactive liquid source: It can be impracticable to agitate the container to redistribute the particles and the extracted sample might not be representative of the whole. A secondary circulating pump can be necessary;
- b) high viscosity: The liquid can be at ambient temperatures and have a high viscosity. A vacuum can be generated when the pump sucks the liquid and this can release air or starve the inlet to the instrument. This can reduce the flow rate or cause erratic operation of the instrument.

7.4.2 Procedure

7.4.2.1 Agitate the container to redistribute the particles. If this is impractical, provide a secondary circulating pump to distribute the particles. If this cannot be done, note the inability to agitate the sample in the report.

7.4.2.2 Establish whether there is any liquid residual from a previous analysis in the instrument and whether it is miscible with the current test liquid. If it is not or there is any doubt, use the procedure detailed in Clause A.3 to flush the unit of previous liquid. If it is miscible, proceed to 7.4.2.3.

- 7.4.2.3** Clean the entry area where the sampling line is inserted and the outside of the sampling line.
- 7.4.2.4** Position the inlet hose in the bulk container so that the inlet hose draws from below the surface of the liquid. If a secondary pump is used, position the inlet pipe away from both the suction and return hoses and in an area of circulation.
- 7.4.2.5** If the instrument does not have an automatic self-flushing sequence, run the instrument to ensure that the sampling line and the instrument are adequately flushed (seek advice from the manufacturer when necessary). If the instrument was previously used to analyse a different but miscible liquid, flush it with at least ten complete volumes (instrument and connecting pipes) of system liquid and direct to waste. If the liquids are not miscible, the procedure detailed in Clause A.3 shall be used.
- 7.4.2.6** Position the return hose either in the reservoir so that re-entrainment of the sample into the monitor suction line does not occur or direct the outlet to another container or waste as required.
- 7.4.2.7** Analyse the sample in accordance with the manufacturer's instructions. Perform at least two analyses and compare the results. If the difference between successive analyses is greater than one contamination code, this indicates that cleaning was inadequate or that the system was not stabilized. Repeat the analysis as appropriate.
- 7.4.2.8** Record the data.

7.5 Operating from a sample bottle

7.5.1 General

This is the least favoured option as the potential for the addition of extraneous contamination to the sample is increased when a bottle sampler is not available.

If a bottle sampler is not available, it is recommended that a sampling probe be made to facilitate taking the sample from the bottle or container and so avoid having to immerse the inlet hose into the sample bottle. In addition, such a probe can be easily cleaned.

Once the sample liquid has passed through the instrument, it shall be directed to waste. The liquid shall not be returned to the sample bottle or container.

7.5.2 Procedure

7.5.2.1 Any residual liquid from a previous analysis shall be flushed from both the instrument and any connecting hoses. An appropriate solvent(s) shall be used if the sample liquid is not compatible with the previous liquid tested (see Clause A.3).

7.5.2.2 If necessary, validate the cleanliness level of the apparatus in accordance with the manufacturer's instructions. Clean the instrument such that the background analysis is less than 10 % of the subsequent analysis.

7.5.2.3 Re-suspend the contaminant in the sample bottle by agitating it by either shaking the sample bottle by hand for 30 s or using a suitable sample-agitating device (6.2.6). Remove the air using a suitable device or by allowing most of the air bubbles to rise to the free surface.

Do not allow more than 2 min to elapse before starting the analysis.

7.5.2.4 Flush the external surface(s) of the sampling tube with filtered solvent and immerse it in the sample bottle to approximately 5 mm above the base. Do not allow the end of the pipe to touch the bottom of the bottle.

7.5.2.5 Operate the instrument (and the bottle sampling apparatus if used) in accordance with the manufacturers' instructions. Initially flush the instrument with the sample liquid or perform a first analysis and discard the results. Make at least two further analyses and compare the results.

7.5.2.6 If the difference between successive analyses is greater than one contamination code, this indicates that the contents of the container might not be sufficiently homogeneously distributed. Repeat 7.5.2.2 to 7.5.2.5 as appropriate.

7.5.2.7 Record the results.

8 Calibration and verification procedure

8.1 General principles

Calibration and/or verification of the correct operation of filter blockage instruments shall be carried out using ISO 12103-A3 test dust (see ISO 12103-1:1997, Clause 3) in the test liquid and performed using a specially designed test rig. The test unit shall be matched to a reference instrument (6.2.5).

Adjustments to the calibration of filter blockage instruments are made by making changes to its operating system software. As this requires specialist knowledge, it is best performed by the instrument manufacturer. Verification of the correct operation can be performed either on-line or off-line using liquid samples containing ISO 12103-A3 test dust whose particle size distribution has been verified using an APC calibrated in accordance with ISO 11171 or ISO 11943.

For this procedure, the instruments used in the process are set to record the particle number concentration (whether calculated or measured) to increase resolution of the test results.

Verification of correct operation is carried out either using the test rig described above or using prepared suspensions of ISO 12103-A3 test dust in the test liquid whose size distribution has been certified using an APC whose calibration is traceable to ISO 11171 or ISO 11943.

8.2 Equipment required

Some or all of the equipment listed in 6.2 is required.

8.3 Preliminary procedures

8.3.1 Clean and validate all glass and laboratory ware in accordance with ISO 3722 and 6.2.7 prior to performing the test.

8.3.2 Inspect the instrument for any condition that can affect the effectiveness of the calibration and/or verification process.

8.3.3 Thoroughly flush the instrument using a solvent to remove any previous liquids. It can be necessary to use a succession of solvents if the previous liquid is not miscible with the liquid to be tested (see Clause A.3). The manufacturer of the instrument should be consulted for advice.

8.3.4 Flush out the instrument for the on-line method as follows.

- a) Pre-clean the test rig until an RCL of either less than 10 particles $\geq 6 \mu\text{m(c)}/\text{ml}$ or better than 1 % of the expected calibration/verification concentration is obtained.
- b) Connect the instrument to the test rig and operate in accordance with the manufacturer's instructions to flush out any previous liquid. Direct the outlet to waste. Operate for a minimum period corresponding to the passage of a volume of at least 20 times the internal volume of the instrument and connection pipes.
- c) Verify the cleanliness of the apparatus by analysing the test liquid over at least three cycles of operation, and record the data in accordance with Clause 9.

8.3.5 Flush out the instrument for the method using a bottle sampler method as follows.

- a) Flush out any residual liquid from the sampler using either a suitable solvent or a flushing liquid (6.2.3), so that at least 20 volumes of the instrument and bottle sampler piping volume is passed;
- b) Flush out the sampler using the filtered test liquid in accordance with the analysis procedure to purge the flushing liquid (if different to the test liquid). Connect the instrument to the sampler and analyze the complete volume (200 ml) to flush out the instrument.
- c) Verify the cleanliness of the apparatus and record the data in accordance with Clause 9.

8.3.6 Flush out the instrument for operation directly from the bottle as follows.

- a) Flush any bottle adapters, such as sampling pipes or down pipes, using filtered solvent from a solvent dispenser.
- b) Connect the instrument to a bottle of filtered test liquid or solvent and operate in accordance with the manufacturer's instructions, so that a minimum volume equivalent to 20 times the internal volume of the instrument and connectors is passed.
- c) Verify the cleanliness of the apparatus by analyzing the later samples and record the data in accordance with Clause 9.

8.4 Preparation of dust sample

Prepare a test dust sample in the following manner.

- a) Dry the bulk test dust sample in a non-circulating oven (6.2.4) at between 100 °C and 150 °C for at least 1 h. Mix the test dust sample by rotating its container around at least two axes.

It is recommended that a small quantity of dust (20 g) is set aside and used only for calibration/verification purposes. The particle size distribution should be verified using an APC calibrated in accordance with ISO 11171 or ISO 11943.

- b) Extract a quantity of dust to give the desired concentration, such as 1 mg/l, either in the test rig or in the verification sample bottle and deposit it into a pre-cleaned sample bottle.
- c) Half fill the sample bottle with filtered test liquid and mix the contents either by vigorously hand shaking for 15 s or by using a suitable device (6.2.6) for 15 min. Then, sonicate the sample for 15 min and use the sample immediately afterwards.

8.5 On-line calibration/verification procedure

8.5.1 Clean the test liquid in the rig by circulating it through the clean-up filter until the RCL is obtained.

The initial cleanliness level shall not significantly contribute to the overall contamination level and should be < 1 % of the final concentration.

8.5.2 When temperature conditions have stabilized, remove the system clean-up filter and measure the cleanliness level using both the reference and test instruments. Record the data in accordance with Clause 9.

8.5.3 If required, by-pass the test section and gradually add the contaminated sample to the reservoir. Flush out any test liquid remaining in the bottle using filtered test liquid either from the reservoir or from a sampling valve and add to the test reservoir.

8.5.4 Continuously monitor the contamination level and circulate the contents of the rig for 15 min or until consistent data are recorded.

8.5.5 If the flow has been by-passed, divert the flow to the test-rig test section and allow the concentration of test dust to equalize in both the test and the by-pass sections. Analyse three consecutive samples using the reference and test instruments.

8.5.6 Calculate the average of the data from both instruments and review each data set individually. Check that the average data values are within 10 % of the mean at the relevant size and reject initial data if they fall outside these limits, as this indicates that mixing was not complete. Analyse additional samples and recalculate the mean.

8.5.7 If the stability of the suspension is acceptable, divide the average number of particles given by the reference instrument by the concentration used in order to give the number of particles per mg/l. The allowed variation, V_{al} , is calculated using Equation (1):

$$V_{al} = \pm 0,74(N_s)^{0,85} \quad (1)$$

where N_s is the certified concentration of particles of size s .

NOTE This variation is twice that allowed for automatic particle counters as defined in ISO 11943:1999, 9.15, for a similar test process.

8.5.8 If the data from the reference instrument fall outside the limits given, repeat 8.5.1 to 8.5.7.

8.5.9 Divide the average particle concentration given by the test instrument by the concentration of test dust used, to give the particle concentration per mg/ml and compare the mean with that for the reference instrument. Accept the calibration/verification if it is within the limits defined by the instrument manufacturer.

8.5.10 If the mean falls outside the values calculated in 8.5.7, adjust the test instrument operating system software as required,

8.5.11 If changes to the instrument software are made, verify the calibration status by performing at least three consecutive analyses using the test rig and record the data in accordance with Clause 9. The results shall fall within the limits calculated in 8.5.7.

8.6 Verification of correct operation

8.6.1 General

This procedure is normally performed in service to establish whether the unit is functioning correctly and the previous calibration is valid. The verification is performed using prepared samples of ISO 12103-A3 test dust whose size distribution has been determined using an APC with calibration traceable to ISO 11171 or ISO 11943.

NOTE The instrument manufacturer usually prepares these samples.

Verification frequency depends on usage and the user shall consult the instruction manual of the instrument manufacturer for details.

Unless other instructions are available, verification shall be performed at least annually. Verification can be performed by using the procedure detailed in 8.6.2 or using the test rig detailed in 8.5.

8.6.2 Procedure

8.6.2.1 Clean the apparatus in accordance with 8.3 using the appropriate procedure. Record the equipment cleanliness in accordance with Clause 9.

8.6.2.2 Re-suspend the contaminant in the sample bottle or container by agitation either by hand shaking the sample bottle for 30 s or using a suitable sample-agitating device (6.2.6). Remove the air using either a vacuum, an ultrasonic bath or by allowing the air bubbles to rise to the free surface. Do not allow the sample to stand for more than 2 min before analysis.

NOTE De-gassing equipment might not be necessary if the filter blockage instrument being verified is of the constant-differential-pressure type.

8.6.2.3 Analyse the samples in accordance with the manufacturer's instructions at least twice and record the averaged results in accordance with Clause 9.

8.6.2.4 Calculate the average of the data at the sizes monitored and compare the data of each run with the average. Compare the average with the number concentration listed on the verification sample certificate. The calibration status is acceptable if it is within the limits given on the certificate.

8.6.2.5 If the values are outside the limits, consult the manufacturer in order to establish whether any further action is required.

9 Calibration and/or verification

Report the following information on suitable forms as given in Tables 1 to 3.

Calibration Calibration verification

Analysis mode: On-line Bottle

Table 1 — Test information

Parameter	Information
Calibration/verification sample identification	
Date of calibration/verification	
Instrument designation	
Reference instrument	
Analysis mode	
Concentration of ISO 12103-A3 used	
ISO 12103-A3 batch number	

Table 2 — Results

Parameter	Paraticle concentration or contamination code ^a		
	> 6 µm	> 10 µm	> 14 µm
Test instrument cleanliness			
Reference instrument cleanliness			
Average test instrument results			
Average Reference instrument results			
Test limit: maximum			
Test limit: minimum			
	Test unit	Reference unit	
Volume analysed			
Analysis duration			

^a Delete where not applicable.

Adjustment required

Table 3 — Verification

Parameter	Particle concentration or contamination code ^a		
	> 6 µm	> 10 µm	> 14 µm
Test instrument cleanliness			
Test instrument results			
Reference instrument results			
Test limit: maximum			
Test limit: minimum			
	Test unit	Reference unit	
Volume analysed			
Analysis duration			
^a Delete where not applicable.			

10 Test report

The report of the results of a sample analysis shall include at least the following information:

- a) sample designation;
- b) date of analysis;
- c) instrument designation;
- d) mode of analysis;
- e) analysis results as a contamination code at the relevant sizes;
- f) any comments relating to the sample or results.

11 Identification statement

It is strongly recommended to manufacturers who have chosen to conform to this part of ISO 21018 that the following statement be used in test reports, catalogues and sales literature:

Determination of solid particulate contamination by the filter blockage technique performed in accordance with ISO 21018-3:2008, *Hydraulic fluid power — Monitoring the level of particulate contamination of the fluid — Part 3: Use of the filter blockage technique.*

Annex A (informative)

Examples of use and applicability of the filter blockage technique

A.1 Types of filter blockage instrument

A.1.1 General

There are two basic requirements for any instrument using the filter blockage technique:

- a) ability to determine the proportion of filter pores which are blocked;
- b) ability to determine the volume of liquid which has passed through the filter.

Each filter used in the filter blockage technique is considered a filter medium consisting of many single pores of known, relatively uniform pore size. The presented area of each filter typically contains thousands of pores the uniformity of which is dependent on the filter structure. The instrument manufacturer determines both the pore size of the filter and the number of pores. The concentration of particles that is trapped is then converted to a contamination code. Some instrument models calculate and present the data as a number concentration.

A.1.2 Measuring the change in liquid parameters

The number of pores that becomes blocked during a test period can be determined from an examination of the change in the measured parameters as the liquid passes through the filter. The operational processes for assessing the change in these flow characteristics are:

- a) keeping a constant flow rate through the filter and measuring the change in differential pressure;
- b) keeping a constant pressure upstream of the filter and measuring the change in flow rate;

The two types in current use are illustrated in Figures A.1 and A.2. It is necessary that the measurement period be only long enough to determine accurately the change in characteristics; for example, in Figure A.1 the test can be terminated after the filter becomes 15 % blocked. It is essential not to exceed the manufacturer's stated maximum pressure drop associated with the particular filter fitted.

Provided that the operating conditions are determined at the beginning and at the end of a period in which a certain quantity of liquid has passed, then consideration of the degree of filter blockage is an estimate of the particle concentration of the sample. This relationship is obtained by calibration (see 8.5).

A.1.3 Measuring the liquid volume analysed

The volume analysed can be calculated or measured by, for example, a flow metering device (which can involve time), a volume measure or an integrating sensor.

A.1.4 Continuous or sequential use

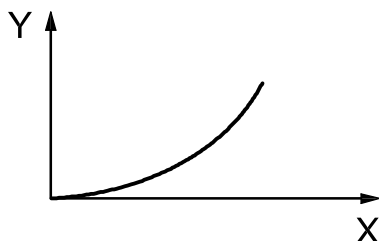
Continuous or sequential use is achieved by reversing the flow after each test period to remove captured particles by back-flushing.

The reverse flow can either commence a new measurement cycle (and at the same time back-flush the filter) or be used to only back-flush the filter with the same liquid or with a separate pre-cleaning liquid.

A.1.5 Current types of filter blockage

A.1.5.1 Constant flow

The flow is held constant and the pressure drop generally increases exponentially as the filter blocks (see Figure A.1).



Key

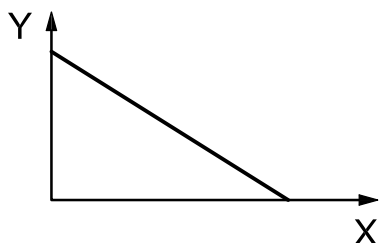
X time

Y differential pressure

Figure A.1 — Constant flow

A.1.5.2 Constant differential pressure

The upstream pressure is held constant and the flow decreases linearly as the filter blocks (see Figure A.2).



Key

X time

Y flow

Figure A.2 — Constant pressure

A.2 Applicability of the filter blockage technique

A.2.1 General

The filter blockage technique has features that make it an advantageous choice for use in some circumstances and not in others. It is important that potential users of the method be aware of the advantages and disadvantages of the filter blockage technique so that the most appropriate choice of instrument can be made for an application.

A.2.2 Factors not affecting filter blockage data

The filter blockage technique is not affected by the following:

- a) changes in test liquid optical characteristics:

Test liquids can be opaque, dark, coloured, mixed phase and can have any refractive index. Variation of any of these properties during a test have no effect on the results.

- b) changes in test liquid density:

In principle, changes in test liquid density have no effect on the test results provided that any change is homogeneous. The effect of an increase in liquid density is to increase the differential pressure across the filter and generally is not significant unless the increase is accompanied by higher viscosity. The instrument manufacturer can define such operating conditions.

- c) aeration:

A.2.3 Factors affecting filter blockage data

Entrained air, including bubbles of a size range equal to, or less than that of the particles being studied, does not affect filter blockage monitors provided that the amount remains reasonably consistent throughout the analysis cycle. Very large quantities of air in a system, causing large discrete bubbles that fill the sampling hoses, can cause variation in readings depending on the construction of the instrument's liquid system and software. Some (generally small) variation in readings, equal to the proportion of liquid flow that has been displaced by air resulting in errors in the liquid volume measured, can be expected.

The filter blockage technique can be affected by the following:

- a) changes in test liquid viscosity:

Changes in viscosity affect the differential pressure across the filter and can potentially affect the results. However, in the constant-flow method, the viscosity is measured and this is used to correct for changes in viscosity over the analysis cycle.

The constant-differential-pressure method is unaffected by viscosity, provided that there is sufficient pressure at the point of application to force the liquid through the filter.

- b) presence of gels, soaps and sludges in the test liquid:

These materials can cause errors in data if they are captured by the instruments filters. However, as they are deformable, they can be forced through the mesh and not be registered. Filter blockage monitors are designed to back-flush their filters. Occasionally, some system contaminants (e.g. soft, sticky or deformable contaminants) can bind more permanently to the filters than others, resulting in a degree of permanent blockage. The presence of such materials is likely to indicate the existence of other problems in the hydraulic or lubrication systems.

- c) chemical compatibility:

Test liquids and solvents used should be chemically compatible with each other and with the wetted parts of the instrument. The operator should be aware of the operational limits of using the instrument under these conditions.

A.3 Use of different and immiscible liquids

The pores can be blocked by any precipitates that are generated when immiscible liquids come into contact with the instrument filters. Any such blockage interferes with the operation of the instrument. If it is impossible to back-flush successfully the filter to clear the residue, it will be necessary to either clean or replace the filters.

As it is not possible to cover the wide range of liquids that can be used with these instruments, only broad guidelines are given. If there is any doubt, the instrument manufacturer should be contacted for guidance.

When changing from one test liquid to another, it is recommended that

- a) a liquid be chosen that is miscible with the previous and new liquids. As a range of liquids can be necessary, the manufacturer of the test liquid should be contacted for advice;
- b) all surplus test liquid be drained from the instrument;
- c) if possible, the instrument be operated on the first change liquid so that flow by-passes the instrument filters and is directed into the waste outlet. Continue to operate the instrument until the exiting liquid becomes clear. Then, operate the instrument in its normal analysis mode as long as the exit liquid is clear;
- d) step A.3 c) be repeated with the other liquids as required;
- e) at least three complete tests be run with the flow directed to the outlet to waste before performing any analysis cycles.

NOTE Dispose of any waste liquid in accordance with local procedures. Do not allow alien liquids to enter the hydraulic system or any other liquid containers.

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