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

Part 4:
Use of the light extinction technique

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

Partie 4: Technique d'absorption de lumière

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

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

This second edition cancels and replaces the first edition (ISO 21018-4:2016), which has been technically revised. The main changes compared to the previous edition are as follows:

- simplification of calibration procedure in Clause 7;
- moving the equipment for the calibration and validation procedure from Clause 5 to Clause 7 after the Operating Procedures.

A list of all parts in the ISO 21018 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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 a 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 online (i.e. directly connected to a system) in an attempt to reduce measurement errors that are inherent with bottle samples. Particle contamination monitors (PCM) have been developed for this purpose and are extensively used.

Instruments using this technique have become widely used in the industry and an international standard is required in order to standardize operating procedures. This document defines procedures for the use of light extinction 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.

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

Part 4:
Use of the light extinction technique

1 Scope

This document specifies a method for the determination of the particulate contamination level using the light extinction technique (also known as light blockage or light obscuration) either online or offline 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 document are suitable for monitoring:

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

The use of this method is applicable to single-phase liquid systems only.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 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 11171:2016, *Hydraulic fluid power — Calibration of automatic particle counters for liquids*

ISO 11500:2008, *Hydraulic fluid power — Determination of the particulate contamination level of a liquid sample by automatic particle counting using the light-extinction principles*

ISO 11943:2018, *Hydraulic fluid power — On-line automatic particle-counting systems for liquids — Methods of calibration and validation*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
light extinction

reduction in intensity of a light beam passing through the sensing volume caused by the interaction of the light with single particles

Note 1 to entry: See ISO 11500:2008, 3.3.

3.2
extraneous contamination

contamination that is not an integral part of the fluid from which a sample was taken, but was introduced into the sample from another source

Note 1 to entry: Extraneous contamination increases the measured level of contamination such that the sample appears to be more contaminated than it really is.

Note 2 to entry: See ISO 21018-4:2016, 3.2.

3.3
particle contamination monitor

PCM

instrument that automatically measures the concentrations of particles suspended in a fluid at certain sizes and cannot be calibrated in accordance with ISO 11171 whose output may be as a particle size distribution at limited sizes or as a contamination code

3.4
µm(c)

particle size as defined in accordance with ISO 11171

4 Health and safety

Operate the instrument in accordance with the manufacturer's instructions.

WARNING — The use of this document can involve hazardous materials, operations and equipment. This document does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this document to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

5 Equipment

5.1 General

If the analysis is performed using sample bottles or containers (see 6.5), a special sampling adaptor (sampler) may be required (see 6.2.1). Such an apparatus shall avoid introducing contamination if the inlet pipe is inserted into the sample bottle. For the process of calibration and verification of correct operation, see Clause 7.

6 Operating procedures

6.1 General

Select the mode of operation from the following:

- from a pressurized line (see 6.2);
- by suction from a system reservoir (see 6.3);
- by suction from a bulk container (see 6.4);

— from a sample bottle (see 6.5).

Operating online 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.

6.2 Operating from a pressurized line

6.2.1 General

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

Select the sampling valve or apparatus 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. Any pressure connection used as a sampling valve shall comply with the requirements of ISO 4021. Such a tapping point can require sustained flushing.

6.2.2 Procedure

6.2.2.1 Ensure that the system is at its normal operating conditions. Ensure that the instrument operates properly at both the minimum and maximum pressure observed when connected to the hydraulic system.

6.2.2.2 Establish whether there is any liquid residual from a previous analysis in the instrument and whether the residual liquid is miscible with the current test liquid. If there is any doubt, flush the previous fluid out of the unit in accordance with the instrument manufacturer’s recommendations.

6.2.2.3 Clean the outside of the sampling valve with a suitable pre-cleaned solvent and a lint-free cloth then connect the instrument to the sampling valve.

6.2.2.4 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. If the instrument was previously used to analyse a different but miscible liquid, flush with at least 10 complete volumes (instrument and connecting pipes) of system liquid and direct to waste.

6.2.2.5 Initiate the PCM analysis in accordance with the manufacturer’s instructions. Perform at least two analyses and compare the results. Verify that the procedure was followed correctly and repeat the analysis if either:

a) the difference between two successive cleanliness codes for instruments whose output is in cleanliness codes is greater than 1 code, or

b) the difference in particle counts is greater than 20 % under steady state conditions at the smallest particle size being monitored.

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

6.2.2.7 Record the data in accordance with Clause 9.

6.3 Operating from a system reservoir

6.3.1 General

Select the reservoir device (sampler) so that it complies with the requirements of ISO 4021. This device should allow unobstructed entry to the point of sampling within the reservoir and be easily cleaned of extraneous contamination. Its purpose is to facilitate sampling without the need to dip the inlet pipe into the fluid.

6.3.2 Procedure

6.3.2.1 Establish whether there is any liquid residual from a previous analysis in the instrument and whether the residual liquid is miscible with the current test liquid. If it is not miscible or there is any doubt, flush the previous fluid out of the unit in accordance with the instrument manufacturer's recommendations.

6.3.2.2 Clean the reservoir entry area where the sampling line is inserted and secure any screws, fittings etcetera. Clean the sampling valve or apparatus with a suitable solvent and lint-free, non-shedding cloth or wipe.

6.3.2.3 Ensure that the system is 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, it is possible that the sample analysed will not be representative of the whole.

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

6.3.2.5 If the instrument does not have an automatic self-flushing sequence, run the instrument to ensure that the sampling line and instrument are flushed. Do not exceed the minimum sensor pressure or the maximum viscosity value stated by the manufacturer. If the instrument has been used to analyse a different but miscible liquid flush with at least 10 complete volumes (instrument and connecting pipes) of system liquid and direct to waste.

6.3.2.6 Position the outlet line 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.

6.3.2.7 Initiate the PCM analysis in accordance with the manufacturer's instructions. Perform at least two analyses and compare the results. Verify that the procedure was followed correctly and repeat the analysis if either:

a) the difference between two successive contamination codes for instruments whose output is in cleanliness codes is greater than 1 code, or

b) the difference in particle counts is greater than 20 % at the smallest particle size being monitored.

6.3.2.8 Record the data in accordance with Clause 9.

6.4 Operating from a bulk container

6.4.1 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. This procedure can be subject to error and variability in measurement and can require additional stages. Such sources of error include:

- an inactive liquid source: It can be impracticable to agitate the container to re-distribute the particles and the extracted sample might not be representative of the whole. A secondary circulating pump can be necessary;
- 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.

6.4.2 Procedure

6.4.2.1 Agitate the container to redistribute the particles. If this is impractical, provide a secondary circulating pump to distribute the particles. If the contents cannot be agitated do not proceed as lack of proper agitation can lead to non-representative results; note the inability to agitate the sample in the report.

6.4.2.2 Establish whether there is any liquid residual from a previous analysis in the instrument and whether the residual liquid is miscible with the current test liquid. If it is not miscible or there is any doubt, flush the previous fluid out of the unit in accordance with the instrument manufacturer's recommendations.

6.4.2.3 Clean the entry area with a suitable solvent and lint-free, non-shedding cloth or wipe both the location where the sampler is inserted and the outside of the sampling line.

6.4.2.4 Position the sampler 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 sampler away from both the suction and return hoses and in an area of circulation.

6.4.2.5 If the instrument does not have an automatic self-flushing sequence, run the instrument to ensure that the sampling line and the instrument are flushed. Do not exceed the minimum sensor pressure or the maximum viscosity value stated by the manufacturer. If the instrument has been used to analyse a different but miscible liquid, flush with at least 10 complete volumes (instrument and connecting pipes) of system liquid and direct to waste.

6.4.2.6 Position the return hose either in the bulk container so that re-entrainment of the sample into the instrument suction line does not occur or direct the outlet to another container or waste as required.

6.4.2.7 Initiate the PCM analysis in accordance with the manufacturer's instructions. Perform at least two analyses and compare the results. Verify that the procedure was followed correctly and repeat the analysis if either:

a) the difference between two successive contamination codes for instruments whose output is in cleanliness codes is greater than 1 code, or

b) the difference in particle counts is greater than 20 % at the smallest particle size being monitored.

6.4.2.8 Record the data in accordance with Clause 9.

6.5 Operating from a sample bottle

6.5.1 General

This is the least favoured option as analysis from sample bottles can result in substantial errors from the introduction of extraneous contamination; the cleaner the system, the greater the error. These errors can be reduced by the use of a bottle sampling apparatus combined with appropriate procedures (see ISO 11500). 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.

6.5.2 Procedure

6.5.2.1 Any residual liquid from a previous analysis shall be flushed from both the instrument and any connecting hoses in accordance with the instrument manufacturer's recommendations.

6.5.2.2 If necessary, validate the cleanliness level of the apparatus in accordance with the manufacturer's instructions. Flush the instrument with clean solvent and verify the cleanliness is less than 10 % of the expected cleanliness level.

6.5.2.3 Re-suspend the contaminant in the sample bottle by vigorously shaking the sample bottle by hand for 60 s (see ISO 11500). Remove the air using a vacuum source to de-aerate the test liquid samples after shaking. An ultrasonic bath can be used as an alternative method. Do not allow more than 2 min to elapse before starting the analysis.

NOTE 1 De-aeration might not be required if the instrument utilizes a constant pressure source.

NOTE 2 The effectiveness of ultrasonic in removing air is reduced as the viscosity of the test liquid increases.

NOTE 3 For liquids with viscosity >50 mm^2/s at the test temperature, a longer agitation time can be necessary.

NOTE 4 The viscosity can be reduced by the addition of clean solvent before shaking.

6.5.2.4 Flush the external surfaces of the sampling tube with filtered solvent then immerse the tube 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.

6.5.2.5 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.

6.5.2.6 If the difference between successive analyses is greater than 1 contamination code or the difference in particle counts is greater than 20 % at the smallest particle size being monitored, this indicates that the contents of the sample bottle might not be sufficiently homogeneously distributed. Repeat 6.5.2.2 to 6.5.2.6 as appropriate.

6.5.2.7 Record the data in accordance with Clause 9.

7 Calibration and verification procedure

7.1 General principles

Particle size calibration or verification of correct operation of PCM shall preferably be carried out as per ISO 11943 utilizing a test rig that conforms to ISO 11943. A calibration shall be conducted on new instruments or after major service, and at periodic intervals not to exceed one year. Calibration and verification of correct operation can also be carried out by using prepared suspensions of test dust in the test liquid whose particle size distribution has been certified using a reference particle counter whose calibration is traceable to ISO 11171 or ISO 11943.

7.2 Required equipment for calibration and validation as per ISO 11943

7.2.1 Test rig that conforms to ISO 11943.

7.2.2 Reference particle counter or PCM calibrated in accordance with ISO 11171 or ISO 11943.

7.3 Required equipment for calibration and validation using prepared bottle samples

7.3.1 Primary calibration samples purchased through NIST or secondary calibration samples produced following the procedures outlined in ISO 11171:2016, Annex F follow the manufacturer's recommendation for transferring the calibration or verification fluid to the instrument.

7.3.2 Reference particle counter or PCM calibrated in accordance with ISO 11171 or ISO 11943.

7.4 Calibration and verification data presentation

Record the data in accordance with Clause 8.

8 Reporting of results of calibration and verification procedure

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

Table 1 — Test information

	Calibration	Yes/No	Calibration verification	Yes/No
Analysis mode:	Online	Yes/No	Bottle	Yes/No

Parameter	Information
Organisation	
Technician	
Comments	
Calibration or verification sample identification	
Date of calibration or verification	
Instrument designation	
Reference instrument	
Analysis mode	
Test contaminant or bottle sample lot number	

Table 2 — Calibration results

Parameter	Number concentration or contamination code[a]		
	≥4 µm (c)	≥6 µm(c)	≥14 µm(c)
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 Yes/No

Table 3 — Calibration verification

Parameter	Number concentration or contamination code[a]		
	≥4 µm(c)	≥6 µm(c)	≥14 µm(c)
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.

9 Test reports

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

- sample designation;
- system being sampled;
- organisation;
- person performing analysis;
- date of analysis;
- instrument designation;
- mode of analysis;
- analysis results as a contamination code at the relevant sizes;