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Hydraulic fluid power — Online automatic particle-counting systems for liquids — Methods of calibration and validation

Transmissions hydrauliques — Systèmes de comptage automatique en ligne de particules en suspension dans les liquides — Méthodes d'étalonnage et de validation

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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 of 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 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 third edition cancels and replaces the second edition (ISO 11943:2018), which has been technically revised.

The main changes compared to the previous edition are as follows:

— addition of 7 µm and 14 µm to Table C.2.

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, and controlled, through a fluid under pressure within an enclosed circuit. The fluid is both a lubricant and a power-transmitting medium.

Reliable system performance requires control of the fluid medium. Qualitative and quantitative determination of particulate contaminant, in the fluid medium, requires precision in obtaining the sample and determining the size and distribution of contaminants.

Automatic particle counters (APC) are an accepted means for determining the size and size distribution of particulate contamination in fluids. Individual instrument accuracy is established through calibration performed with reference primary calibration suspensions or with secondary calibration suspensions.

APCs are being utilized online to eliminate the need for sample containers, to provide increased accuracy, and to provide for a more rapid access to particle count information. A major application of online particle counting is for evaluating filtration efficiency of hydraulic filter elements during a multi-pass test as defined in ISO 16889. Depending upon the type of filter tested and the capabilities of the APC used, it can be necessary to dilute the samples before flowing through the sensor.

This document establishes procedures for validation of equipment for preparation of secondary calibration suspensions and for online counting of particles with or without dilution circuits, and the online calibration of APCs. It defines a procedure to match two or more particle counters with the intention of improving the accuracy of particulate filtration efficiency as shown, for example, in ISO 16889.

Hydraulic fluid power — Online automatic particle-counting systems for liquids — Methods of calibration and validation

1 Scope

This document establishes methods for:

— validating equipment used to prepare secondary calibration suspensions for automatic particle counters;

— performing online secondary calibration of automatic particle counters;

— matching two or more online particle counters, i.e. to count the same number of particles at a given size by two APCs associated online;

— validating online particle counting systems with and without online dilution as used, for example, to measure the filtration efficiency of a hydraulic filter as described in the multi-pass filter test in ISO 16889.

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

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

ISO 16889, *Hydraulic fluid power — Filters — Multi-pass method for evaluating filtration performance of a filter element*

ISO 80000-1, *Quantities and units — Part 1: General*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5598 and ISO 11171 apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Units of measurements

The international system of units (SI) is used in accordance with ISO 80000-1.

Throughout this document, the use of µm(c) means that particle size measurements are carried out using an automatic particle counter that has been calibrated in accordance with either ISO 11171 or this document and particle size reported as defined in ISO 11171.

Previous editions of ISO 11171 allowed for calibration in µm or µm(b) notations. Conformance with ISO 11171:2020 and later requires µm(c) only.

5 Test equipment

5.1 Liquid automatic particle counters, requiring either calibration or verification, or a particle counter with two independent sensors.

5.2 A reference particle counter, which shall be calibrated with a reference material in accordance with ISO 11171.

5.3 ISO medium test dust (ISO MTD) concentrate, which shall be in accordance with ISO 12103-1, category A.3, dried at 110 °C to 150 °C for at least 1 h and for use in the test system, mixed in the test fluid, mechanically agitated, then dispersed ultrasonically with a power density of 3 000 W/m^2 to 10 000 W/m^2.

NOTE This standard test dust is used for filter test purposes in ISO 16889.

5.4 Test fluid, which shall be as specified in ISO 16889.

5.5 Hydraulic equipment, comprising:

a) a reservoir, pump, liquid temperature control system and instrumentation which are capable of meeting the validation requirements of Clause 8;

b) a clean-up filter capable of providing an initial fluid contamination level of less than 50 particles per millilitre at the smallest particle size that will be validated or less than 2 % of the expected number of counts;

c) a configuration which does not alter the contaminant distribution over the anticipated test duration (refer to ISO 16889);

d) fluid sampling sections which shall be in accordance with ISO 4021;

e) a configuration which supplies contaminated liquid to the particle counters under constant flow and temperature within the limits of Table 1.

NOTE 1 A multi-pass test rig (see ISO 16889) can be used provided it has been validated in accordance with Clause 8.

NOTE 2 An alternative typical configuration which has proven satisfactory is given in Annex A.

5.6 Hydraulic circuit, containing dilution equipment, if required, for online counter adaptation to a filter multi-pass test stand.

For typical hydraulic circuit configurations which have proven satisfactory, refer to Annex B.

6 Accuracy of measuring equipment and test conditions

6.1 Utilize measuring equipment with an accuracy within the limits in Table 1.

Table 1 — Accuracy of measuring equipment and test conditions

Test conditions	SI Unit	Instrument accuracy (± of reading)	Allowed test condition variations
Flow	l/min	0,5 %	2 %
Kinematic viscosity	mm^2/s	1 %	2 mm^2/s
Pressure	kPa	1 %	2 %
Temperature	°C	0,5 °C	1 °C
Time	s	0,05 s	0,1 s
Volume	l	1 %	
Mass	g	0,1 mg	2 %

WARNING — maintaining the accuracy of test conditions, within the limits of Table 1, does not imply that by doing so the validation limits are satisfied. It has been proven that the most useful way of attaining the validation requirements is by maintaining the accuracy of test conditions given in Table 1, along with using the proper particle counting procedures and correctly designed equipment.

7 Offline APC calibration procedure

7.1 Conduct a sizing calibration on a particle counter when new or after major service as suggested by the particle counter manufacturer in accordance with ISO 11171.

NOTE The calibration is a primary calibration if the calibration suspension is National Institute of Standards and Technology (NIST) SRM 2806x where "x" is the SRM 2806 batch identification letter of the primary calibration samples. The APC then is called a 'reference APC'.

7.2 Use the procedures specified in ISO 11171 to determine particle coincidence error limits of the particle counter and sensor, or use the manufacturer's stated levels, provided that they have been obtained in accordance with ISO 11171.

8 Validation of online hydraulic equipment

8.1 This procedure of validation demonstrates whether:

— particle size distribution of the suspension circulating within the equipment is stable within stated limits over time;

— the sampling or bottle filling ports gives representative samples. The complete and following procedure is given in Figure 1.

8.2 Connect a single particle counter with a valid calibration as defined in Clause 7 and set it to the cumulative mode with at least six different threshold settings over the particle size range of interest. In accordance with ISO 11943, sizes outside of this range cannot be reported.

NOTE Since this procedure only aims at verifying the stability of particle counts over time, the use of a reference APC with primary calibration is not necessary.

8.3 Adjust the total fluid volume, expressed in L, in the suspension preparation equipment to the maximum volume it is designed to prepare and measure it within ±1 %. Maintain fluid viscosity at (15 ± 2,0) mm^2/s.

8.4 Circulate the fluid at a flow rate through the clean-up filter until the fluid contamination level is < 5 particles > 5 µm(c)/mL.

8.5 Determine the mass of ISO MTD to be introduced in the system to achieve a concentration of (3 ± 0,3) mg/L. Record the ISO MTD lot number.

NOTE Any other concentration can be used provided it does not produce a particle count at the lowest size that is in excess of 75 % of the particle concentration limit of the instrument determined in 7.2.

8.6 Prepare the test dust concentrate in accordance with 5.3. Bypass the clean-up filter element and add the required quantity of ISO MTD into the reservoir and allow it to circulate for approximately 15 min.

8.7 Start the test by conducting online automatic particle counts on samples with a minimal volume of 10 mL) at least at 2-min intervals for 1 h, or at least 30 intervals spaced evenly throughout the longest period of time that the system is to be used.

8.8 Complete Table 2 by filling in the required data. For each particle-size setting, calculate the mean $\bar{x}$, also the standard deviation, σ of all the counts using Formula (1):

$$\sigma = \sqrt{\frac{n\sum_{i=1}^{n}(x_i^2)-(\sum_{i=1}^{n}x_i)^2}{n(n-1)}} \qquad (1)$$

where

σ is the standard deviation of all counts

x_i is the particles per mL for each threshold setting for sample i;

n is the total number of particle counts recorded

8.9 Calculate the acceptable standard deviation for each particle size by using Formula (2):

$$\sigma_a = \sqrt{\bar{x} + 0{,}0004 \cdot \bar{x}^2} \qquad (2)$$

where

σ_a is the acceptable standard deviation for each particle size

$\bar{x}$ is the mean of the measured particle size

NOTE This acceptable standard deviation is based upon the average standard deviation obtained in the inter-laboratory study discussed in Annex C.

8.10 Accept the validation if the standard deviation for each particle size is less than or equal to the acceptable standard deviation for that size.

8.11 If the standard deviation for a given particle size exceeds the acceptable standard deviation, then re-evaluate the hydraulic equipment and procedures, the flow rates through the APC sensor and dilution system, and particle count volumes for the online particle counting equipment.

Take appropriate action and repeat the procedure from 8.3 to 8.9. If these actions do not improve the standard deviation to an acceptable level, then the APC sensor may require a service.

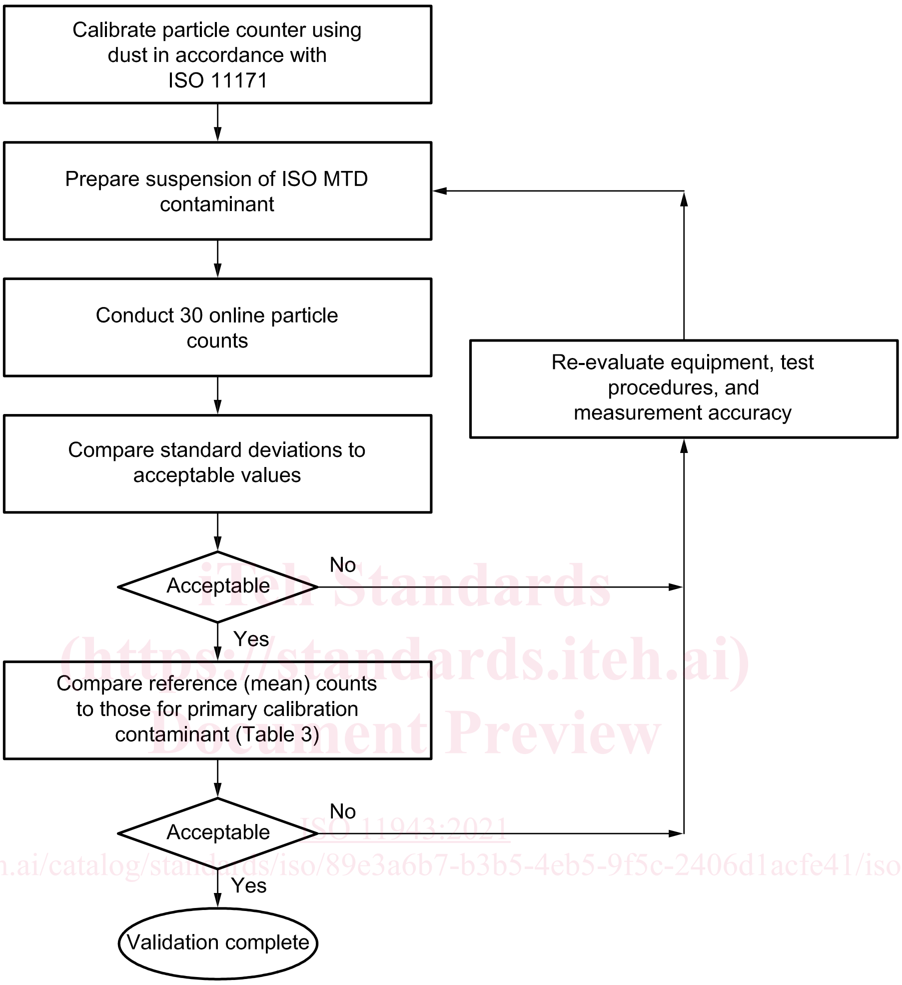

Figure 1 — Flowchart for the validation procedure of online hydraulic equipment