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Hydraulic fluid power — Cleanliness of components — Inspection document and principles related to contaminant extraction and analysis, and data reporting

Transmissions hydrauliques — Propreté des composants — Documents d'inspection et principes d'extraction et d'analyse des contaminants et d'expression des résultats

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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 meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword — Supplementary information.

The committee responsible for this document is ISO/TC 131, *Fluid power systems*, Subcommittee SC 6, *Contamination control.*

This second edition cancels and replaces the first edition (ISO 18413:2002), of which it constitutes a minor revision.

Introduction

In hydraulic fluid power systems, power is transmitted and controlled through a pressurized liquid within an enclosed circuit. Contaminants present in the circulating working liquid can degrade system performance. The presence of particles residual from the manufacturing and assembly processes can cause a substantial increase in the wear rates to the system during the initial run-up and early life and can even cause catastrophic failures. In order to achieve reliable performance of components and the system, control over the amount of particles introduced during the build phase is necessary. Accurate assessment of the effectiveness of part and component cleaning requires documentation of both the cleanliness requirement and the methods used for contaminant extraction and analysis and data reporting.

Hydraulic fluid power — Cleanliness of components — Inspection document and principles related to contaminant extraction and analysis, and data reporting

1 Scope

This International Standard specifies the content of an inspection document that specifies both the cleanliness requirement for the specified hydraulic fluid power component and the inspection method to be used for evaluating its cleanliness level. In addition, guidelines for relevant extraction methods and analysis methods are given.

Determination of what constitutes as an appropriate cleanliness level requirement for any particular component is beyond the scope of this International Standard. ISO 12669 provides a method of determining the required cleanliness of a hydraulic system. ISO TR 10686 provides a method of relating the required cleanliness of components to the required cleanliness of the hydraulic system.

For the purposes of this International Standard, approved functional liquids are considered to be components.

This International Standard is applicable to the particulate contamination on the wetted surfaces and volumes of any hydraulic fluid power system component. Appearance defects and liquid or gaseous contamination are not covered by this International Standard.

This International Standard does not address safety problems that might arise from hazardous materials, operations, and equipment associated with its use. The user of this International Standard is responsible for establishing appropriate safety and health practices and determining the applicability of regulatory limitations prior to use.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 4405, *Hydraulic fluid power — Fluid contamination — Determination of particulate contamination by the gravimetric method*

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

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

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

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

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

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

ISO 14644-1, *Cleanrooms and associated controlled environments — Part 1: Classification of air cleanliness*

ISO 21018 (all parts), *Hydraulic fluid power — Monitoring the level of particulate contamination in the fluid*

3 Terms and definitions

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

3.1
blank level
amount of contaminant introduced from sources other than the test component, such as reagents, glassware, preparation of test units, and the environment

3.2
blank test
analysis carried out in the same operating conditions as on the test component but without the test component

Note 1 to entry: The blank test enables quantification of the contamination introduced from sources other than the test component, such as reagents, glassware, preparation of test units, and the environment.

3.3
clean
state of cleanliness of a component or fluid that meets the specified cleanliness level

3.4
cleanliness
condition of a product, surface, device, liquid, etc., characterized by the absence of particulate contamination

3.5
component
general term to cover a part, a component, a sub-assembly, or a part assembly used in a hydraulic system

Note 1 to entry: This definition differs from that given for the same term in ISO 5598.

3.6
component contamination
amount or nature of contaminants extracted from the wetted or controlled surfaces of a component, as measured by an applicable analysis method

3.7
contaminant
undesirable solid substance that is in suspension in a fluid or in a component or on a controlled surface of a component

Note 1 to entry: For the purposes of this International Standard, contaminants include solid material suspended in liquids, but exclude liquids and gases. This definition differs from ISO 5598 in its exclusion of liquids and gases.

3.8
controlled surface
wetted surface of a component that is subject to a cleanliness requirement

3.9
controlled volume
wetted volume of a component that is subject to a cleanliness requirement

3.10
end-point sample
last in a series of repetitive samples, which produces a result that is ≤10 % of all the samples

3.11
external surface
surface of the component which is not wetted by the system fluid in normal operation

3.12
extraction
operation required to transfer as much contaminant as possible that is present within a controlled volume or on a controlled surface into a test liquid and its collection for subsequent analysis

3.13
extraction curve
progress curve of the cleanliness level of an extraction liquid applied to the test component as a function of the number of extractions

Note 1 to entry: This is related to the extraction time or to the volume of test liquid passed through or over the test component.

3.14
extraction liquid
test liquid loaded with contaminants extracted from the test component

3.15
fluid contamination monitor
FCM
instrument that quantitatively evaluates the particulate contamination level of a liquid in an on-line mode

3.16
inspection document
written description of the component cleanliness requirement and the agreed inspection method

3.17
inspection method
procedure for contaminant extraction, contaminant analysis, and data reporting which is used to evaluate component cleanliness as specified by the inspection document

3.18
representative sample
material extracted such that it is typical of the amount and nature of the contaminant contained in or on a component

3.19
test liquid
suitable liquid of known initial cleanliness used to remove, suspend, and extract contaminant from a component and which is compatible with the component being tested and the apparatus used

3.20
validation
process by which a test method evaluates the capability of the contaminant removal process

3.21
wetted surface area
A_C
surface area of the component that is exposed to system liquid

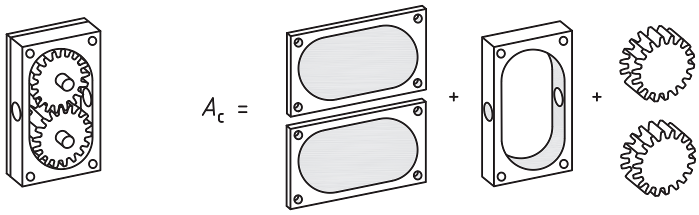

Figure 1 — Wetted surface area (A_c)

3.22
wetted volume
V_c
volume of the component that is exposed to system liquid

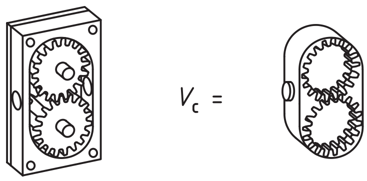

Figure 2 — Wetted volume (V_c)

4 Inspection document principles

4.1 Content

This International Standard specifies the content of the inspection document, not its format. The inspection document may exist as a single document or as a series of related documents. Regardless of format, the inspection document shall clearly identify the component cleanliness requirement and the agreed inspection method.

4.2 Component cleanliness requirement

The inspection document shall define the component cleanliness requirement when this is known. The cleanliness requirement shall be consistent with the known or anticipated function or application of the component. ISO TR 10686 and ISO 12669 give guidance and tools to establish such requirements. The component cleanliness requirement shall be established and agreed upon by the parties involved.

International Standards should be used in preference to other references sources (e.g. example historical data, existing company, industry, and national standards, functional performance, reliability, and durability requirements of the component, and data on similar components to determine the cleanliness requirement for a particular component).

4.3 Inspection method

4.3.1 The inspection document shall specify the inspection method to be used to evaluate component cleanliness. The inspection method shall be established and agreed upon by the parties involved. The inspection method shall be consistent with the design and the cleanliness requirement of the component.

4.3.2 The inspection document shall specify the appropriate parameters applicable to extracting contaminants, conducting analyses, and reporting results. Typical reference sources for consideration in determining the agreed inspection method include: International Standards, previously used methods of contaminant extraction, contaminant analysis, and data reporting; existing company, industry, and

national, standards; functional, reliability, and durability requirements of the component; and methods used on similar parts or components.

4.4 Effectivity

The inspection document shall become effective upon mutual agreement between the parties involved, both of which shall maintain a copy of the applicable inspection document.

4.5 Conformance

Unless otherwise stated in the inspection document,

a) all components for which a cleanliness level has been specified shall meet that requirement when evaluated in accordance with the agreed inspection method and

b) it is not necessary to inspect those components for which no cleanliness level has been specified (it is possible that some components are required to meet a specified cleanliness level and others are not).

4.6 Verification of conformance to specified component cleanliness requirements

4.6.1 Conformance to component cleanliness requirements can be verified either by the use of industry-accepted statistical sampling methods or by joint purchaser-supplier monitoring of the inspection processes.

4.6.2 Verification of test results requires special care because differences in method of contaminant extraction or analysis of the same component affect the results obtained. In addition, because the contaminant extraction process results in cleaning of the component used as a test item, that same test item shall not be reused for subsequent conformance verification.

4.7 Additional information

4.7.1 Unless otherwise agreed by purchaser and supplier, 4.7.2 to 4.7.5 shall apply.

4.7.2 The inspection document shall specify both the required cleanliness level for the component and the scope of its applicability. The points in the process at which the cleanliness requirement applies shall be stated in the inspection document. Because prolonged or improper storage of components can result in the introduction of new contaminants, such as oxidation products, the inspection document shall, when applicable, address these factors.

4.7.3 Temporary shipping covers are excluded from the inspection process; however, any contaminants contributed by such covers shall be included in the evaluation of component cleanliness.

4.7.4 Contaminants contributed by such defects as nicks, blemishes, and discoloration shall be included in the evaluation of component cleanliness.

4.7.5 Where applicable, a requirement for allowable residual magnetic density may be included as part of the inspection document.

NOTE Residual magnetism can cause retention of contaminant on component surfaces and the formation of agglomerates, both of which affect contaminant extraction or analysis or both.

5 Guidelines for selecting contamination extraction and analysis procedures

5.1 Overview

The following information is intended to be neither exhaustive nor restrictive. It is intended only to assist the user of this International Standard by indicating methods of sample extraction, sample analysis, and data reporting that are widely recognized as appropriate under selected conditions. The requirements applicable to a specific component shall be stated in the inspection document.

5.2 Contaminant extraction

Select the extraction method most suited to the component being inspected from Table 1. The method of contaminant extraction shall be agreed upon and stated in the inspection document.

NOTE Table 1 is a summary of guidelines for selection of contaminant extraction methods as they relate to categories of hydraulic components.

Table 1 — Guidelines for selection of contaminant extraction methods

Component	Contaminant extraction method			
	Agitation	Pressure rinse	Ultrasonic vibration	Functional test
Assemblies				
Pumps and motors	NR	NR	NA	R
Valves and cylinders	NR	NR	NA	R
Manifold and body assemblies	NR	A	A	R
Accumulators	A	NR	NA	R
Simple shapes and housings				
Gears, plates, and shafts	A	R	R	NA
Spools, rods, and pistons	A	R	R	NA
Hardware and seals	A	R	R	NA
Tanks and reservoirs	A	R	NA	NR
Hollow parts				
Manifolds and bodies	R	A	A	A
Hoses and tubes	R	A	A	R
Fittings	A	R	A	A
Filtration components				
Filter elements — cleanable	Method shall be agreed between the supplier and purchaser			
Filter elements — non-cleanable	Method shall be agreed between the supplier and purchaser			
Filter housings	R	A	A	R
R = Recommended A = Acceptable NR = Not recommended NA = Not applicable				

5.3 Contaminant analysis

Select the contaminant analysis method from Table 2. The method of contaminant analysis shall be agreed upon and stated in the inspection document.

Table 2 — Guidelines for selection of contaminant analysis methods

Contaminant extraction method	Contaminant analysis method					
	Gravimetric analysis	Particle size	Chemical composition	Particle size distribution		
				Microscopy	APC[a] (bottle)	APC or FCM[b] (on line)
Agitation	R	R	R	R	R	NA
Pressure rinse	R	R	R	R	R	A
Ultrasonic vibration	R	R	R	R	R	NA
Functional test	A	A	A	R	A	R

R = Recommended

A = Acceptable

NR = Not recommended

NA = Not applicable

[a] Determined using a light extinction APC used in accordance with ISO 11500.

[b] Determined using a fluid contamination monitor used in accordance with one of the parts of ISO 21018.

6 Contaminant extraction principles

6.1 General

The method of contaminant extraction shall be agreed upon and stated in the inspection document. The measured component cleanliness level depends upon the effectiveness of the extraction procedures chosen and upon whether those extraction methods have been validated (see 6.3). The effectiveness of the contaminant extraction process should be validated by using the end point concept (see 3.10). Testing personnel shall follow the contaminant extraction method(s) specified in the inspection document. Inspection facilities and environment shall be as clean as practicable so as not to significantly affect the measurement of component cleanliness, which is quantified by the blank test (see 6.4.).

6.2 Overview

Contaminant extraction consists of various techniques for removing contaminants from controlled surfaces of components by the hydraulic and chemical action of a suitable liquid, suspending contaminant in the test liquid, then collecting the extraction liquid and suspended contaminant for analysis. This International Standard describes four basic contaminant extraction techniques: agitation, pressure rinse, ultrasonic vibration, and functional test method. Other methods of contaminant extraction may also be used when agreed upon between supplier and purchaser. The contaminant extraction method shall be properly validated. The entire extraction fluid volume used shall be analysed and processed as such.

6.3 Extraction procedure setup and validation

6.3.1 Setup environment

6.3.1.1 The number of components to be analysed shall be chosen so as to measure a significant amount of contaminant that complies with the requirement for a blank.

6.3.1.2 If the break-in of the component is part of its manufacturing process, the extraction procedure shall be agreed between parties and included in the inspection document because break-in can alter its initial cleanliness level.

6.3.1.3 The contaminants included in the inspection process are particles that have been detached from controlled surfaces during transportation of the test component, particles from the packaging, and those

in the shipping liquid. They shall be extracted using an appropriate extraction method (e.g. low pressure rinsing). The extraction processes shall be included in the inspection document.

6.3.1.4 For active components, it might be necessary to operate them in order to pass the test liquid through during the extraction process. In this case, the initial contamination level can be altered. The extraction conditions should be agreed upon between parties and included in the inspection document.

6.3.1.5 Apply the appropriate extraction method on the component to be tested, and analyse the whole extraction liquid volume in accordance with Clause 7 and label the results obtained as S1.

6.3.1.6 Repeat 6.3.1.5 on the same component, using, when necessary, a different container for each extraction liquid sample, and label the results obtained as S2. The extractions shall be made one after the other.

6.3.1.7 If six extractions have been performed without achieving the end point in the required number of extractions, as specified in 6.3.2.2.1, this means that the extraction parameters are not suitable and shall be changed. Repeat operations 6.3.1.5 to 6.3.1.7 with new parameters on a new component.

6.3.1.8 If the criterion is not fulfilled, set up a new extraction protocol and validate it according to 6.3, or apply another extraction method.

6.3.2 Validation

6.3.2.1 Blank test

6.3.2.1.1 Whichever extraction method is used, a blank test is performed to verify that the operating conditions, equipment, and products used in the extraction procedure do not contribute a significant amount of contamination to the component analysed. A blank test should be performed, using identical test parameters, at intervals as established in the testing laboratory's quality control plan.

6.3.2.1.2 System blank values shall be determined under conditions identical to the ones applied during testing of the component, but with the component omitted.

The blank value shall be determined and shall comply with the requirements for each analysis method specified in the inspection document.

6.3.2.1.3 Proceed as specified in 6.3.1.5 to 6.3.1.7 with the same equipment and total volume of test liquid as required for the extraction process, but without the component.

6.3.2.1.4 Analyse the entire extraction liquid volume as specified in Clause 7.

6.3.2.1.5 The blank value depends on the presumed or specified cleanliness level of the component(s) and on the analysis method. If this is not stated in the inspection document, then the following blank values shall be applied:

a) gravimetric analysis: less than 10 % of the presumed or specified gravimetric cleanliness level of the component.

   When using a four-digit balance in uncontrolled environmental conditions (that is, uncontrolled humidity and temperature), the minimum measurable blank value is 0,3 mg; a five-digit balance with an accuracy of 0,1 mg should be used. Because of this, at least 3 mg should be extracted during the component test in order to meet the 10 % blank criterion.

b) particle counting and sizing:

   1) Particle counts: less than 10 % of the presumed or specified numbers, at the relevant sizes, each calculated number being rounded down. For example, if no more than 167 particles for

a particular particle size are presumed or specified, no more than 16 particles of that size are allowed in the blank. If zero particle is stated at a given size, the blank value is zero particle at the next smaller size range. The particle sizes for the blank test shall be those specified in the inspection document for the component contamination analysis.

2) If the component's presumed contamination level is not known or if the inspection document states no requirement, the blank shall contain the following:

   i) less than 4 000 particles ≥5 µm and less than 500 particles ≥15 µm per 100 mL of extraction liquid;

   ii) no particle ≥50 µm.

6.3.2.1.6 If the blank level exceeds 10 %, there are two possible reasons:

a) the equipment is not clean; in which case, clean all equipment and solvents again and repeat 6.3.2.1 and 6.3.2.1.4;

b) the components are too clean for the blank obtained; in which case, increase the number of test components analysed in order to extract more particles and, thus, fulfil the 10 % limit.

6.3.2.2 Validation of contamination extraction

6.3.2.2.1 Validate the contamination extraction procedure to ensure its efficacy as follows:

a) For each of the two analyses described in 6.3.1.4 and 6.3.1.5, establish the total cumulated mass of contaminants or the total cumulated number of particles larger than the particle sizes specified in the inspection document.

b) Divide the result of the last sample by the sum of all the values obtained in 6.3.2.2.1 a).

c) If the value obtained is less than or equal to 0,10 (10 %), the end-point is reached and the extraction is completed.

$$Sn \leq \frac{10}{100} \sum_{i=1}^{n} Si$$

d) If not, repeat 6.3.1.5 through 6.3.2.2.1 b) until the last sample *Sn* produces a result ≤10 % of the sum of all samples, as calculated in 6.3.2.2.1 c), or until six extractions have been performed without reaching the ≤10 % value (see 6.3.1.7), whichever occurs first.

NOTE 1 This procedure enables the extraction curve to be drawn and the end-point (≤10 %) to be demonstrated (see Figure 3). Alternatively, the data and calculation can be shown in tabular form.

NOTE 2 The cleanliness level of the component is the sum of contamination collected with all extractions.

In some cases (for example, a very low or a stable contamination level, difficulties in extracting particles, inappropriate blank level, etc.), the extraction curve might not be of the form seen in Figure 3. If this is the case, ensure that all extraction parameters have been properly investigated.