INTERNATIONAL
STANDARD

ISO
18413

First edition
2002-10-01

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

Transmissions hydrauliques — Propreté des pièces et composants — Documents de contrôle et principes d'extraction et d'analyse des polluants et d'expression des résultats

Reference number
ISO 18413:2002(E)

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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 International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 18413 was prepared by Technical Committee ISO/TC 131, *Fluid power systems*, Subcommittee SC 6, *Contamination control and hydraulic fluids*.

Annexes A to G of this International Standard are for information only.

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 may degrade system performance. One method of reducing the amount of these contaminants within the system is to clean parts and components prior to final assembly. Accurate assessment of the effectiveness of part and component cleanliness requires documentation of both the cleanliness requirement and the methods used for contaminant collection, analysis, and data reporting.

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

1 Scope

This International Standard specifies the content of an inspection document that includes both the cleanliness requirement for the specified part or component and the inspection method to be used for evaluating its cleanliness level. The cleanliness requirement and inspection method shall be established and agreed upon by the parties involved.

NOTE 1 Determination of what constitutes an appropriate cleanliness level requirement for any particular part or component is beyond the scope of this International Standard.

NOTE 2 For the purposes of this International Standard, approved functional liquids are considered to be components.

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

This International Standard does not address safety problems that may 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 normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

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 particulate contamination by automatic counting using the light extinction principle*

3 Terms and definitions

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

3.1
component cleanliness

amount or nature of contaminant collected from the wetted or controlled surfaces of a component, as measured by an applicable analysis method

3.2
contaminant

loose or detachable solid material present in a part or component or on a wetted or controlled surface of a part or component

NOTE 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.

3.3
controlled surface

wetted surface of a part or component that is subject to a cleanliness requirement

3.4
controlled volume

wetted volume of a part or component that is subject to a cleanliness requirement

3.5
end-point sample

last sample in a series of repetitive samples, which produces a result that is $\leqslant 10\ \%$ of the sum of the previous samples

3.6
inspection document

written description of the part or component cleanliness requirement and the agreed inspection method

3.7
inspection method

procedure for contaminant collection, analysis and data reporting that is used to evaluate part or component cleanliness as specified by the inspection document

3.8
part cleanliness

amount or nature of contaminant collected from the wetted or controlled surfaces of a part, as measured by an applicable analysis method

3.9
purchaser

party that stipulates the requirements of a machine, equipment, system, part or component and judges whether the product satisfies those requirements

3.10
representative sample

material collected such that it is typical of the amount and nature of the contaminant contained in or on a part or component

3.11
supplier

party that contracts to provide the product(s) to satisfy the purchaser's requirements

3.12
test liquid

suitable liquid of known initial cleanliness used to remove, suspend and collect contaminant from a part or component which shall be compatible with the part or component being tested and the apparatus used

3.13
validation
process by which a test method evaluates the efficiency of the contaminant removal process or confirms that a laboratory analysis instrument is operating properly

NOTE This definition differs from ISO 8402:1994 (withdrawn in 2000) because, in this case, validation addresses the test method or laboratory analysis instrument, whereas in ISO 8402:1994 validation addresses the final product.

3.14
wetted surface
surface area of the part or component that is exposed to system liquid

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 part or component cleanliness requirement and the agreed inspection method.

4.2 Part or component cleanliness requirement

The inspection document shall define the part or component cleanliness requirement. The cleanliness requirement should be consistent with the known and/or anticipated function or application of the part or component. Typical reference sources for consideration in determining the cleanliness requirement for a particular part or component include: historical data; existing company, industry, national, and international standards; functional performance, reliability, and durability requirements of the part or component; and data on similar parts or components.

The part or component cleanliness requirement shall be established and agreed upon by the parties involved.

NOTE Determination of what constitutes an appropriate cleanliness level requirement for any particular part or component is beyond the scope of this International Standard.

4.3 Inspection method

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

4.3.2 The inspection document shall define appropriate parameters applicable to collecting contaminant, conducting analyses, and reporting results. Typical reference sources for consideration in determining the agreed inspection method include: previously used methods of contaminant collection, analysis and data reporting; existing company, industry, national, and international standards; functional, reliability and durability requirements of the part or component; and methods used on similar parts or components. ISO standards should be used when these are available. If ISO standards are not available, national, industry and company standards may be used, in that order of preference.

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

4.5.1 Unless otherwise stated in the inspection document, 4.5.2 and 4.5.3 shall apply.

4.5.2 All parts or components shall meet the specified cleanliness requirement when evaluated by the agreed inspection method.

4.5.3 Inspection of all parts and components may not be required. It is possible that some parts or components are required to meet a specified cleanliness level and that other parts or components have no cleanliness requirements.

NOTE Development and incorporation of cost-effective cleaning methods are encouraged as part of the normal manufacturing process. An audit process is commonly used to monitor conformance to dimensional, cleanliness and functional requirements.

4.6 Conformance verification

4.6.1 Conformance to part or component cleanliness requirements may 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 methods of contaminant collection or analysis of the same part or component will affect the results obtained. In addition, because the contaminant collection process results in cleaning of the part or 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 part or 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 parts or components may result in the introduction of new contaminants, such as oxidation products, the inspection document should, 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 part and component cleanliness.

4.7.4 Contaminants contributed by such defects as nicks, blemishes and discoloration shall be included in the evaluation of part and 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 part or component surfaces and the formation of agglomerates, both of which affect contaminant collection and/or analysis.

5 Contaminant collection principles

5.1 General

The method of contaminant collection shall be agreed upon and stated in the inspection document. The measured part or component cleanliness depends greatly upon the procedures used to collect the contaminant for analysis. If the collected contaminant cannot be analysed directly, proper controls should be in place to ensure that a representative sample is collected. The effectiveness of the contaminant extraction or collection process should be confirmed using the concept of end point sampling. Testing personnel shall follow the contaminant collection method specified in the inspection document. Inspection facilities shall be as clean as practicable so as not to affect the measurement of part or component cleanliness.

5.2 Overview

Contaminant collection consists of various techniques for removing contaminants from controlled surfaces of parts and components, suspending contaminants in a suitable test liquid, then collecting the test liquid and suspended contaminants for analysis. This International Standard describes four basic contaminant collection techniques: agitation, pressure rinse, ultrasonic vibration and end use simulation. Other methods of contaminant collection may also be used when agreed upon between supplier and purchaser. The contaminant collection method shall be properly validated.

5.3 Agitation

5.3.1 Contaminant contained within simple enclosed surfaces shall be removed by partially filling the part or component under test with an appropriate test liquid, sealing the openings, and agitating the part or component to remove the contaminant from the controlled surface and to suspend the contaminant in the test liquid. Immediately after agitation, all test liquid used in the test shall be drained and collected for analysis. Annex A provides additional information.

5.3.2 Primary process variables to be controlled include: test liquid and its relevant properties, test liquid volume and temperature, type and duration of agitation, the number of samples collected up to and including the end-point sample, and the volume of test liquid collected for analysis.

5.3.3 Consideration should be given to the size and mass of the part or component, the need for slings or fixtures, and any auxiliary equipment necessary for proper contaminant collection.

5.4 Pressure rinse

5.4.1 Contaminant on exposed and accessible surfaces shall be removed by directing a stream of test liquid onto the controlled surface of the part or component, which is placed over appropriate liquid collection apparatus. Immediately after rinsing, all test liquid used in the test shall be collected for analysis. Annex B provides additional information.

5.4.2 Primary process variables to be controlled include: test liquid and its relevant properties, test liquid pressure and flow rate, test liquid volume and temperature, the sequence followed in rinsing the part or component, the number of samples collected up to and including the end-point sample, and the volume of test liquid collected for analysis.

5.4.3 Consideration should be given to the overall accessibility of controlled surfaces for rinsing, the size and mass of the part or component, the need for slings and fixtures, and auxiliary equipment necessary for proper contaminant collection.

5.5 Ultrasonic vibration

5.5.1 Contaminant on surfaces accessible to ultrasonic vibration shall be detached from the surface by immersing the part or component in test liquid and applying ultrasonic vibration. Upon removal of the part or component from the ultrasonic bath, all test liquid used in the test shall be collected for analysis. Annex C provides additional information.

5.5.2 Primary process variables to be controlled include: test liquid and its relevant properties, test liquid volume and temperature, equipment power settings, duration of exposure, the number of samples collected up to and including the end-point sample, the volume of test liquid collected for analysis, and the effectiveness of removing detached contaminant from the part or component surface and collecting the sample from the ultrasonic bath for analysis.

5.5.3 Consideration should be given to the size and mass of the part or component relative to the capacity of the ultrasonic tank and to the shape of the part or component, because both factors affect the effectiveness of the ultrasonic bath.

5.6 End use simulation

5.6.1 Contaminant on internal surfaces with limited accessibility shall be collected by installing the part or component on a test stand that simulates the end use application. The part or component is actuated while test liquid is circulated through the test stand. Upon completion of the simulation cycle, a representative sample of test liquid shall be collected for analysis. Annexes D and E provide additional information.

5.6.2 A production test stand may be used for end use simulation. When a production test stand is used for the final cleaning process (i.e., with a clean-up filter on-line) it may be agreed by purchaser and supplier that the part or component cleanliness is determined from the analysis of samples collected from a suitable point downstream from the part or component.

5.6.3 Primary process variables to be controlled include: test liquid and its relevant properties, test liquid volume and temperature, the simulation cycle used, circulation time, the size and number of samples collected, and the procedures for controlling any carryover effects from previous tests.

5.6.4 Care should be used in the selection of simulation cycles (for example, cycles that generate contamination associated with break-in of the part or component) and in addressing potential sources of cross-contamination from other parts or components in the hydraulic system, especially when components are fitted to the test stand. It is important to minimize the generation of contaminant, because generated contaminant will introduce additional variability in subsequent contaminant analysis results.

6 Contaminant analysis principles

6.1 General

The method of contaminant analysis shall be agreed upon and stated in the inspection document. The measured cleanliness level of a part or component depends upon the procedures used to analyse the contaminant. Because the sample collected will often contain small amounts of contaminant diluted significantly in test liquid, good laboratory techniques are necessary to avoid both loss of contaminant and cross-contamination from other sources during analysis. Testing personnel shall follow the analysis method specified in the inspection document.

NOTE The presence of residual materials (such as liquids, protective films, or grease) may cause problems during analysis if these materials are not miscible with the test liquid.

6.2 Overview

A variety of standard laboratory methods may be used to produce the required part or component cleanliness data. The data reporting format and contaminant analysis method are closely related. This standard describes four basic contaminant analysis methods: gravimetric, particle size, chemical composition, and particle size distribution. Other methods of analysis may also be used when agreed upon between supplier and purchaser.

6.3 Gravimetric analysis

Obtain the sample so as to contain all of the contaminants collected from controlled surfaces. Contaminant is generally separated from the test liquid by filtration through a membrane under controlled conditions. Contaminant concentration (mass per area, mass per volume, mass per part, or mass per component) is determined by weighing the amount of material deposited on a membrane filter after filtration (see ISO 4405).

6.4 Particle size

Obtain the sample so as to contain all of the contaminants collected from controlled surfaces. Contaminant is generally separated from the test liquid by filtration through a membrane under controlled conditions. Contaminant residue is examined to determine particle size by means of optical microscope or optical image analyser (see ISO 4407), scanning electron microscope, or other image producing instruments.

Size parameter (total area or longest linear dimension) should be specified when reporting data.

NOTE The sample from 6.3 may be used in 6.4.

6.5 Chemical composition

Obtain the sample so as to contain all of the contaminants collected from controlled surfaces. Contaminant is generally separated from the test liquid by filtration through a membrane under controlled conditions. Contaminant residue is examined to determine chemical composition by means of appropriate instrumentation, such as a scanning electron microscope equipped with X-ray fluorescence spectrometer.

NOTE The sample from 6.3 may be used in 6.5.

6.6 Particle size distribution

Obtain the sample so as to contain a representative portion of the contaminants. The number and size of particles is determined by means of an appropriate counting method, such as automatic optical particle counter using light extinction sensors (see ISO 11500) and optical microscope or optical image analyser (see ISO 4407).

NOTE 1 Use sample handling procedures that minimize sedimentation of larger particles; this is particularly important for samples containing particles larger than 50 µ in size.

NOTE 2 Some particle counting instruments cannot tolerate high contaminant concentrations or particles large enough to see with the naked eye. In such cases, sample dilution and/or pre-screening may be required.

7 Data reporting principles

7.1 General

The presentation of data shall be agreed upon and stated in the inspection document. The format selected generally indicates the contaminant properties of greatest interest. It may also serve to indicate the degree of importance attached to the cleanliness requirement specified for a given part or component.

7.2 Overview

Contaminants can be characterized in several ways, and no single data reporting format will apply to all applications. It is therefore important to determine the contaminant properties of greatest interest and to specify an appropriate data reporting format in the inspection document. This International Standard describes four contaminant properties that are often determined: contaminant mass, particle size, chemical composition, and particle size distribution.

When data are to be reported as a concentration or a normalized distribution, the area or volume of the part or component shall be clearly defined. When appropriate, the procedure described in annex G may be used.

7.3 Contaminant mass

Perform gravimetric analysis methods to obtain information about the mass of contaminant on part and component surfaces. Data on contaminant mass are often used to monitor in-process control of contaminants.

7.4 Particle size

Perform microscopic analysis methods to obtain information about the size of specific contaminant particles. Data on particle size are often used for critical parts and components known to be sensitive to contaminants of a specific size or to monitor in-process control of contaminants.

7.5 Chemical composition

Perform specialized laboratory analysis methods to obtain information about the chemical composition of contaminants. Data on contaminant chemical composition are often used for critical parts and components known to be sensitive to contaminants of a specific composition or to monitor in-process control of contaminants.

7.6 Particle size distribution

Perform particle counting analysis methods to obtain information on the size distribution of contaminants. Data on particle size distribution are often used as a final cleanliness check of assembled components and process fluids. Particle size distributions can also be used as requirements for surfaces of parts or components.

8 Selection guidelines

8.1 Overview

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

8.2 Contaminant collection

See Table 1 for a summary of guidelines for selection of contaminant collection methods as they relate to categories of hydraulic parts and components.

8.3 Contaminant analysis

See Table 2 for a summary of guidelines for selection of contaminant analysis methods as they relate to sample collection methods.

8.4 Data reporting

See Table 3 for a summary of guidelines for selection of data reporting methods as they relate to the contaminant property being evaluated and the applicable analysis method.

9 Criterion for acceptance

Accept the part or component if the reported cleanliness, as determined by the agreed inspection method, is equal to or better than part or component cleanliness specified in the inspection document.

10 Identification statement (reference of this International Standard)

Use the following statement in test reports, catalogues and sales literature when electing to comply with this International Standard:

“Inspection document for cleanliness of parts and components in accordance with ISO 18413:2002, *Hydraulic fluid power — Cleanliness of parts and components — Inspection document and principles related to contaminant collection, analysis and data reporting*”.

Table 1 — Guidelines for selection of contaminant collection methods

Part or component	Contaminant collection method			
	Agitation	Pressure rinse	Ultrasonic vibration	End use simulation
Assemblies				
Pumpes 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				
The method of contaminant collection shall be agreed upon and stated in the inspection document.				

Table 2 — Guidelines for selection of contaminant analysis methods

Contaminant collection method	Contaminant analysis method				
	Gravimetric analysis	Particle size	Chemical composition	Particle size distribution	
				Bottle	On-line
Agitation	R	R	R	R	NA
Pressure rinse	R	R	R	R	A
Ultrasonic vibration	R	R	R	R	R
End use simulation	A	A	A	A	R
R = Recommended A = Acceptable NR = Not recommended NA = Not applicable					
The method of contaminant analysis shall be agreed upon and stated in the inspection document.					

Table 3 — Guidelines for selection of data reporting methods

Contaminant analysis method		Property measured	Units for data reporting		Notes
			Recommended	Acceptable	
Gravimetric analysis		Mass	mg/m^2 of controlled surface	mg/component [a]	
			mg/L of controlled volume		
			mg/part	mg/kg	
Particle size		Maximum particle size	µm	mm	Longest dimension is preferred
		Number of particles larger than specified size	Number of particles larger than the specified size, in µm	Number of particles larger than the specified size, in mm	
Chemical composition		Chemical composition	Presence or absence of specified elements or compounds	mass fraction	Report chemical analysis method
				volume fraction	
Particle size distribution	Bottle	Particle size and number of particles	Number of particles larger than the specified sizes per cm^2 of controlled surface		Usually includes several particle sizes
			Number of particles larger than the specified sizes per mL of controlled volume		
			Number of particles larger than the specified sizes per part		
			Number of particles larger than the specified sizes per component		
	On-line	Particle size and number of particles	Number of particles larger than the specified sizes per cm^2 of controlled surface		
			Number of particles larger than the specified sizes per mL of controlled volume		
			Total number of particles larger than the specified sizes per part		
			Total number of particles larger than the specified sizes per component		

[a] This unit is not generally applicable for assembled components.

Annex A
(informative)

Contaminant collection principles — Agitation method

A.1 Scope

This annex presents contaminant collection principles for the agitation method. The cleanliness level of a part or component as determined by this method depends greatly upon the test parameters such as type of agitation, duration of agitation, choice of test liquid, etc. These parameters shall be stated in the inspection document and strictly followed by testing personnel.

A.2 Summary of method

A.2.1 Contaminant is collected by partially filling the test item with a known volume of test liquid, sealing the openings, and agitating the test item in order to remove the contaminant from the controlled surfaces and suspend it in the test liquid.

A.2.2 Multiple samples are required to achieve maximum contaminant removal.

A.2.3 If a means of mechanical agitation supplemental to the test liquid is used, the method of mechanical agitation should be carefully selected so as to limit any resultant cross-contamination.

A.2.4 Solid test items (such as gears, plates, shafts, etc.) need to be placed in a receptacle that contains test liquid for agitation and consequent removal of contaminants into the test liquid.

A.2.5 Immediately after agitation, drain and collect the test liquid used in each contaminant collection sequence. Agitation and contaminant collection should be performed with the highest practicable liquid turbulence.

A.2.6 Analyse the samples of test liquid in conformance to the inspection document.

A.3 Materials and equipment

A.3.1 Test liquid

WARNING — Exercise care when using test liquids with low flash points.

Supplier and purchaser should agree upon the test liquid to be used in the collection process, and its required initial cleanliness level, prior to the test. The test liquid should be compatible with all materials used in the part or component, as well as with the functional liquid of the final system. Test liquid should be compatible with all test apparatus, including seals and filters, and filtered to the agreed initial cleanliness level. A low viscosity test liquid is recommended. Viscosity of the test liquid should be $\leqslant 5\ \text{mm}^2/\text{s}$ at the test temperature.

Test liquid contamination level should be sufficiently low to minimize its contribution to the total measured part or component contamination.

A.3.2 Collection tray and/or vessels

Clean all collection apparatus to $\leqslant 5\ \%$ of the presumed or allowable contamination level of the part or component. Any collection apparatus should be covered after cleaning and prior to use in order to limit contamination from the environment.

NOTE It is possible for contaminant remaining on the apparatus to be transferred to the sample and included as part of the contaminant attributed to the part or component.

A.3.3 Clean sample containers

Sample containers shall be sufficiently clean so as not to affect the results of contaminant analysis. If the expected contamination level is unknown, a maximum contamination level of three particles larger than or equal to 6 µm(c), or equivalent, per millilitre of container volume is considered appropriate.

NOTE The term “µm(c)” refers to the size when counted by an automatic particle counter calibrated to ISO 11171. For particles counted using microscopic methods, 5 µm is equivalent to 6 µm(c).

A.4 Procedure

A.4.1 Determine the controlled volume and controlled surface area of the part or component to be analysed. Include the volumes and surface areas of all spaces that system liquid will occupy during normal operation. The volume and/or surface area of the part or component for which cleanliness is to be controlled shall be specified in the inspection document.

A.4.2 Clean external surfaces of the test item. External surfaces should be cleaned in a different physical location from where contamination samples will be collected from the controlled surfaces of the test item. Take care not to introduce contaminant to controlled surfaces. External surfaces are defined as those that will not be in contact with the system liquid during normal operation of the part or component.

A.4.3 Remove shipping plugs as necessary to add test liquid. If a part or component is shipped partially filled with test liquid, drain the liquid, measure its volume, and analyse the contaminant per A.4.6.

A.4.4 Transfer an amount of test liquid of between 30 % and 40 % the total part or component volume into a properly prepared measuring vessel, such as a graduated cylinder or beaker. Take care to measure the volume of test liquid as accurately as possible. A minimum accuracy of ± 2 % is recommended.

A.4.5 Carefully pour measured test liquid into the test item. Reseal with plugs that do not introduce contamination. Agitate the test item in accordance with the predetermined method. Drain test liquid from the test item into a clean collection vessel or the reservoir of an on-line particle counting system. Take care to avoid contact with non-wetted surfaces. Cover the collection vessel to avoid contamination by outside sources.

A.4.6 Analyse samples as specified in the inspection document. Refer to Annex E.

A.4.7 Repeat the procedure detailed in A.4.4 to A.4.6 two more times on the same test item, using a separate container for each sample collected.

A.4.8 Confirm the efficiency of contaminant removal by the following method:

a) For each of the three samples collected in A.4.4 to A.4.7, determine the total mass of contaminant or the total number of particles larger than the specified particle sizes.

b) Divide the result for the third sample by the sum of results for the first two samples.

c) If the calculated value is $\leqslant$ 0,10, contaminant collection is complete. For particle counting, this $\leqslant$ 0,10 criterion applies to the total number of particles larger than the particle size stated in the inspection document.

d) If the calculated value is $>$ 0,10, additional sampling is required. Repeat A.4.4 to A.4.6 until the last sample gives a result $\leqslant$ 0,10 of the total results of previous samples.

A.4.9 Report data as specified in the inspection document. Refer to Annex E.

Annex B
(informative)

Contaminant collection principles — Pressure rinse method

B.1 Scope

This annex presents contaminant collection principles for the pressure rinse method. The cleanliness level of a part or component as determined by this method depends greatly upon the test parameters (such as rinse pressure, liquid volume, type of spray nozzle, etc.). These parameters shall be stated in the inspection document and strictly followed by testing personnel.

B.2 Summary of method

B.2.1 A pressurized stream of test liquid is directed at all controlled surfaces of the test item. Mechanical agitation may also be used to detach contaminant particles from the controlled surfaces. Rinsing should be performed with the highest practicable liquid turbulence.

B.2.2 Multiple rinsings are required to achieve maximum contaminant removal.

B.2.3 Immediately after rinsing, collect the test liquid used in each sample collection sequence.

B.2.4 Analyse the samples of test liquid in conformance to the inspection document.

B.3 Materials and equipment

B.3.1 Test liquid

WARNING — Exercise care when using test liquids with low flash points. Care should be taken not to generate aerosol mists, as these may increase the risk of combustion.

Supplier and purchaser should agree upon the test liquid to be used in the collection process, and its maximum contaminant level, prior to the test. The test liquid should be compatible with all materials used in the part or component, as well as with the functional liquid of the final system. It should also be compatible with all test apparatus, including seals and filters, and filtered to a level suitable for the process. A low viscosity test liquid is recommended. Viscosity of the test liquid should be $\leqslant 5\ \text{mm}^2/\text{s}$ at the test temperature.

Test liquid contamination level should be sufficiently low to minimize its contribution to the total measured part or component contamination.

B.3.2 Clean sample containers

Sample containers shall be sufficiently clean so as not to affect the results of contaminant analysis. If the expected contamination level is unknown, a maximum contamination level of three particles larger than or equal to 6 µm(c), or equivalent, per millilitre of container volume is considered appropriate.

NOTE The term “µm(c)” refers to the size when counted by an automatic particle counter calibrated to ISO 11171. For particles counted using microscopic methods, 5 µm is equivalent to 6 µm(c).

B.3.3 Dispensing pressure vessel

Vessel should be outfitted with a pressure gauge capable of measuring the desired pressure range, and also preferably with a pressure relief valve. A stainless steel vessel is often used because of its chemical resistance to a variety of test liquids.

B.3.4 Liquid dispensing gun

The liquid dispensing gun should be equipped with in-line filter holder and support screens compatible with the filter (see B.3.5). This allows the liquid to be filtered as close as possible to the point of delivery. An optional in-line filter between the dispensing pressure vessel and the dispensing gun may be installed as well.

B.3.5 Filters

The filter should have a maximum pore size of 25 % of the smallest particle size to be analysed. Filter material should be compatible with test liquid. Choose the filter so as to achieve the liquid cleanliness specified in B.3.1.

B.3.6 Filter forceps

Use a flat-bladed, non-serrated forceps to handle membrane filters to avoid damage and cross contamination.

B.3.7 Collection tray and/or vessels

Clean all collection apparatus to $\leqslant$ 5 % of the presumed or allowable contamination level. Any collection apparatus should be covered after cleaning and prior to use in order to limit contamination from the environment.

NOTE It is possible for contaminant remaining on the apparatus to be transferred to the sample and included as part of the contaminant attributed to the part or component.

B.4 Procedure

B.4.1 Determine the controlled volume and/or the controlled surface area of the part or component to be analysed. Include the volumes and surface areas of all spaces that system liquid will occupy during normal operation. The volume and/or surface area of the part or component for which cleanliness is to be controlled shall be specified in the inspection document.

B.4.2 Clean non-wetted external surfaces of the test item. External surfaces should be cleaned in a different physical location from where contamination samples will be collected from the controlled surfaces of the test item. Take care not to introduce contaminant to controlled surfaces. Take care not to introduce contaminant to wetted surfaces. If the test item is large, such as a reservoir, clean only those external surfaces that could potentially contribute contaminant during the collection process. External surfaces are defined as those that will not be in contact with the system liquid during normal operation of the part or component.

B.4.3 Remove all shipping caps and plugs. If the test item contains residual liquid, the liquid should be collected in a clean tray or vessel and included as part of the final analysis volume.

B.4.4 If possible, place the test item in a clean collection tray prepared as specified above.

Many parts and components are too large to handle conveniently in a collection tray. When such parts or components are being evaluated, the primary objective should be to place the test item in a convenient position for sample retrieval. Ideally this position will allow test liquid and residue to drain into a collection container. This may require that a form of support (for example, a sling, jig, or hoist) be used to manipulate the test item into position. For parts and components, such as reservoirs, that cannot be effectively drained, a vacuum system can be used for optimum residue retrieval. All parts of the vacuum system that come into contact with the test liquid should be cleaned prior to testing to $\leqslant$ 5 % of the presumed or allowable contamination level.

B.4.5 If disassembly is required to gain access to all controlled surfaces, carefully remove the necessary parts and components.

This method of contaminant collection is most accurate for components that require no disassembly, because the disassembly process itself can generate contaminant. The operator should exercise extreme care to minimize the generation of contaminant when disassembly is necessary.

B.4.6 Set the pressure of the container to a level that will deliver a spray with optimal turbulence. If no disassembly was required in B.4.5, proceed to B.4.8.

B.4.7 Rinse contaminants from any areas of the disassembled components that come in contact with the system liquid during normal operation. These may be rinsed either into the same collection tray or into another clean collection tray or vessel.

B.4.8 When all controlled surfaces are accessible, carefully rinse them with test liquid sprayed through the dispensing gun. Make every reasonable effort to rinse any area that will come in contact with the system liquid during normal operation of the part or component to dislodge any contaminant. All residue should be rinsed into the collection tray or, where appropriate, collected by the vacuum system.

B.4.9 Combine all collected residue and liquids. Carefully rinse trays and vessels of all accumulated materials into a single collection container.

B.4.10 Analyse samples as specified in the inspection document. Refer to Annex E.

B.4.11 Repeat the procedure detailed in B.4.7 to B.4.10 two more times on the same test item, using a separate container for each sample collected.

B.4.12 Confirm the efficiency of contaminant removal by the following method:

a) For each of the three samples collected in B.4.7 to B.4.11, determine the total mass of contaminant or the total number of particles larger than the specified particle sizes.

b) Divide the result for the third sample by the sum of results for the first two samples.

c) If the calculated value is $\leqslant 0{,}10$, contaminant collection is complete. For particle counting, this $\leqslant 0{,}10$ criterion applies to the total number of particles larger than the particle size stated in the inspection document.

d) If the calculated value is $> 0{,}10$, additional sampling is required. Repeat B.4.7 to B.4.10 until the last sample gives a result $\leqslant 0{,}10$ of the total of previous samples.

B.4.13 Report data as specified in the inspection document. Refer to Annex E.

Annex C
(informative)

Contaminant collection principles — Ultrasonic vibration method

C.1 Scope

C.1.1 This annex presents contaminant collection principles for the ultrasonic vibration method. The cleanliness level of a part or component as determined by this method depends greatly upon the test parameters (such as test liquid volume, test liquid properties, and the ultrasonic power level). These parameters should be stated in the inspection document and strictly followed by testing personnel.

C.2 Summary of method

C.2.1 A tank of test liquid containing the part or component is ultrasonically agitated to remove contaminant from all controlled surfaces.

C.2.2 Immediately after agitation, collect the test liquid used.

C.2.3 Analyse the samples of test liquid in conformance to the inspection document.

C.3 Materials and equipment

C.3.1 Test liquid

WARNING — Exercise care when using test liquids with low flash points.

Supplier and purchaser should agree upon the test liquid to be used in the collection process, and its maximum contaminant level, prior to the test. The test liquid should be compatible with all materials used in the part or component, as well as with the functional liquid of the final system. It should also be compatible with all test apparatus, including seals and filters. A low viscosity test liquid is recommended. Viscosity of the test liquid should be $\leqslant 5\ \text{mm}^2/\text{s}$ at the test temperature.

Test liquid contamination level should be sufficiently low to minimize its contribution to the total measured part or component contamination.

C.3.2 Ultrasonic tank

The ultrasonic tank should be made of stainless steel. Important characteristics of the ultrasonic equipment should be specified in the inspection document.

C.3.3 Collection tray and/or vessels

Clean all collection apparatus to $\leqslant 5\ \%$ of the allowable contamination level for the part or component. Any collection apparatus should be covered after cleaning and prior to use in order to limit contamination from the environment.

NOTE It is possible for contaminant remaining on the apparatus to be transferred to the sample and included as part of the contaminant attributed to the part or component.

C.3.4 Clean sample containers

Sample containers shall be sufficiently clean so as not to affect the results of contaminant analysis. If the expected contamination level is unknown, a maximum contamination level of three particles larger than or equal to 6 µm(c), or equivalent per millilitre of container volume is considered appropriate.

NOTE The term “µm(c)” refers to the size when counted by an automatic particle counter calibrated to ISO 11171. For particles counted using microscopic methods, 5 µm is equivalent to 6 µm(c).

C.4 Procedure

C.4.1 Determine the controlled volume and/or the controlled surface area of the part or component to be analysed. The volume and/or surface area of the part or component for which cleanliness is to be controlled shall be specified in the inspection document.

C.4.2 Remove all shipping caps and plugs. Do not disassemble components. Contaminant can be generated as a result of the disassembly process.

C.4.3 Submerge the test item into either a collection container with clean test liquid or into the ultrasonic tank with the appropriate volume of clean test liquid. When testing parts and components that have cleanliness requirements only on internal surfaces, fill the test item as full as possible with test liquid, seal the test item, and submerge it in the ultrasonic bath.

C.4.4 Ultrasonically agitate the test item at the power level indicated for the appropriate period of time as required by the inspection document.

C.4.5 Collect all residual contamination from the ultrasonic bath and rinse the bath with a suitable jet of test liquid. When testing parts and components that have cleanliness requirements only on internal surfaces, remove the test item from the bath and carefully dry its outer surface using a lint-free cloth or jet of clean air. Pour the test liquid into a container and rinse the inner surface using a suitable jet of test liquid.

C.4.6 Drain and collect the test liquid for analysis or transfer it to the reservoir of an on-line particle counting system for circulation and analysis. The liquid system for an on-line particle counting apparatus associated with ultrasonic cleaning shall be validated in conformance to ISO 11943 using the cleaning liquid as the test liquid.

C.4.7 Analyse samples and report data as specified in the inspection document. Refer to Annex E.

C.4.8 Repeat the procedure detailed in C.4.3 to C.4.7 two more times on the same test item, using a separate container for each sample collected.

C.4.9 Confirm the efficiency of contaminant removal by the following method:

a) For each of the three samples collected in C.4.3 to C.4.8, determine the total mass of contaminant or the total number of particles larger than the specified particle sizes.

b) Divide the result for the second sample by the result for the first sample.

c) If the calculated value is $\leqslant$ 0,10, contaminant collection in complete. For particle counting, this $\leqslant$ 0,10 criterion applies to the total number of particles larger than the particle size stated in the inspection document.

d) If the calculated value is $>$ 0,10, additional sampling is required. Repeat C.4.3 to C.4.7 until the last sample gives a result $\leqslant$ 0,10 of the total of previous samples.

C.4.10 Report data as specified in the inspection document. Refer to Annex E.

Annex D
(informative)

Contaminant collection principles — End use simulation

D.1 Scope

D.1.1 This annex presents contaminant collection principles for the end use simulation method. The cleanliness level of a part or component as determined by this method depends greatly upon the test parameters (such as the ability of the test stand to reproduce functional conditions and requirements of the part or component, including test liquid operating flow, temperature, turbulence, and surges; test liquid circulation time; and the ability to obtain a representative sample of test liquid). These parameters shall be stated in the inspection document and strictly followed by testing personnel.

D.2 Summary of method

D.2.1 The part or component is installed on a validated test apparatus then operated with a test fluid of known cleanliness. Operation of the test apparatus removes contaminant from the part or component surfaces and transfers contaminants into the liquid.

D.2.2 Upon completion of the end-use simulation, a representative sample of test liquid is either analysed directly on-line or collected for subsequent analysis.

D.2.3 Test items should be exercised for a time sufficient to pass at least 10 times the equivalent liquid volume of the test item. End use simulation and contaminant collection should be performed with the highest practicable test liquid turbulence.

D.2.4 Analyse the samples of test liquid in conformance to the inspection document.

NOTE Unless otherwise stated in the inspection document, this method is not intended to measure contaminant generated during break-in under load.

D.3 Materials and equipment

D.3.1 Test liquid

WARNING — Exercise care when using test liquids with low flash points.

Supplier and purchaser should agree upon the test liquid to be used in the collection process, and its maximum contamination level, prior to the test. The test liquid should be compatible with all materials used in the part or component, as well as with the functional liquid of the final system. Test liquid should also be compatible with all test apparatus, including seals and filters, and filtered to the agreed initial cleanliness level. Viscosity of the test liquid should be $\leqslant 15\ \text{mm}^2/\text{s}$ at the test temperature.

The test liquid will preferably be the same as the end use liquid. Test liquid contamination level should be sufficiently low as to minimize its contribution to the total measured contamination.

D.3.2 Test fixture

Use a test fixture capable of operation of the test item at its rated flow, temperature and pressure.

D.3.3 Test stand apparatus

Use a test stand with reservoir, pump, liquid conditioning apparatus, and instrumentation that are capable of accommodating the range of flows, pressures, and volumes required by the procedure and is capable of meeting the validation requirements of D.4. See Annex F for guidance in designing an appropriate test stand.

System liquid volume shall be as small as feasible to prevent aeration.

D.3.4 Clean-up filter

A clean-up filter capable of providing the initial system contamination level specified in D.4.6 shall be fitted in the system.

D.3.5 Liquid sampler

The liquid sampler shall conform to ISO 4021 and be fitted in the system downstream of the test item.

D.3.6 Particle counter

Select a particle counter appropriate to the analytical requirements. Calibrate optical automatic particle counters in conformance to ISO 11171 and validate them in conformance to ISO 11943.

D.3.7 Clean sample containers

Sample containers shall be sufficiently clean so as not to affect the results of contaminant analysis. If the expected contamination level is unknown, a maximum contamination level of three particles larger than or equal to 6 µm(c), or equivalent, per millilitre of container volume is considered appropriate.

NOTE The term “µm(c)” refers to the size when counted by an automatic particle counter calibrated to ISO 11171. For particles counted using microscopic methods, 5 µm is equivalent to 6 µm(c).

D.4 Test equipment validation

D.4.1 Validate the test stand following its initial construction and whenever the stand is modified.

D.4.2 Install a dummy test item.

NOTE A clean steel tube is often an acceptable dummy test item.

D.4.3 Fill the system to a known volume and record the volume of test liquid used.

D.4.4 Operate system pump to clean the circuit using the system clean-up filter.

D.4.5 Maintain temperature within ± 2 °C of the specified value.

D.4.6 Operate test stand at rated flow until test liquid cleanliness at particle sizes larger than or equal to 10 µm is $\leqslant$ 0,10 particles per millilitre, preferably determined using on-line analysis. Alternatively, collect samples in clean sample bottles for subsequent analysis. If sample bottles are used, bottle cleanliness shall be included in the test liquid cleanliness specification.

D.4.7 Remove or bypass system clean-up filter.

D.4.8 Add 5 mg of ISO Medium Test Dust (ISO 12103-A3) per litre of test liquid.

D.4.9 Begin analysis or sample collection 15 min after addition of test dust. Perform on-line analysis or collect a 200 mL sample of the test liquid in a certified clean bottle every 3 min until a total of 10 samples have been collected.

D.4.10 For each sample, determine the cumulative particle count, starting with the smallest size of interest. The particle count obtained for a given size at each sample interval shall not deviate more than ± 15 % from the average particle count of all sample intervals for that particle size.

D.4.11 Test equipment is validated if the particle count conforms to D.4.10.

D.5 Procedure

D.5.1 Determine the controlled volume and/or controlled surface area of the part or component to be analysed. Include the volumes and surface areas of all spaces that system liquid will occupy during normal operation.

D.5.2 Clean external surfaces of the test item. Take care not to introduce contaminant to controlled surfaces. External surfaces are defined as those that will not be in contact with the system liquid during normal operation.

Do not disassemble components. Contaminant can be generated as a result of the disassembly process.

D.5.3 Remove all shipping caps and plugs from the item.

D.5.4 Install and bypass test item

D.5.5 Measure to ± 2 % the volume of test liquid used in the test stand.

D.5.6 Operate the test fixture with a clean-up filter until cleanliness conforms to D.4.6.

D.5.7 Remove or bypass clean-up filter.

D.5.8 Perform end use simulation using test parameters specified in the inspection document.

D.5.9 Unless otherwise specified, operate test circuit until three consecutive particle counts taken at 2 min intervals are within ± 15 % of the mean.

D.5.10 Perform on-line analysis or collect samples of test liquid for subsequent analysis. Samples shall be $\geqslant$ 100mL in volume.

D.5.11 Analyse samples and report data as specified in the inspection document. Refer to Annex E.

Annex E
(informative)

Contaminant analysis and data reporting principles

E.1 Scope

This annex presents information on the analysis of contamination samples obtained from any of the contaminant collection methods described in annexes A, B, C and D, and on the reporting of data generated by such analyses.

E.2 Analysis

E.2.1 Gravimetric

Prepare and analyse samples in conformance to the inspection document. Refer to ISO 4405.

E.2.2 Particle size

Prepare and analyse samples in conformance to the inspection document. Refer to ISO 4407. For particle size, select the pore size of the filter disc/membrane that is commensurate with the size of particle being monitored, to ensure that it is not plugged prematurely by sizes much smaller than the size of interest. It has been found convenient to pre-filter the contaminated test liquid through a coarse screen and then flush the larger dirt off onto the analysis membrane.

E.2.3 Chemical composition

Prepare and analyse samples in conformance to the inspection document.

E.2.4 Particle size distribution

E.2.4.1 Prepare and analyse samples in conformance to the inspection document. Use either bottle samples or on-line particle counting. Calibrate particle counters in accordance with the relevant standard.

E.2.4.2 When extracting aliquots from a bulk sample of test liquid, agitate the bulk sample for about 30 s to suspend the particles, then immediately decant a portion of the liquid into a clean sample bottle. Fill the bottle to 50 % to 70 % full, then cap immediately. Analyse the test sample in accordance with an approved particle counting method.

E.2.4.3 Ensure that particle concentrations are well below the maximum for accurate particle counting by the method being used. Dilute samples where appropriate, or use smaller liquid volumes for microscopic counting methods. Record the dilution factor and the liquid volume used for analysis.

E.2.4.4 For each sample, determine the particle count (in particles per millilitre) at the selected sizes. Multiply this count by any dilution factor from E.2.4.3 to determine the concentration of particles (in particles per millilitre) in the test liquid.

E.2.4.5 To determine particles per part or particles per component, multiply the value determined in E.2.4.4 by the total volume of test liquid.

E.2.4.6 To determine particles per controlled volume, divide the value determined in E.2.4.5 by the controlled volume of the part or component.

E.2.4.7 To determine particles per controlled area, divide the value determined in E.2.4.5 by the controlled area of the part or component.

E.2.4.8 The calculated value from E.2.4.5, E.2.4.6, or E.2.4.7 is the particle count level of the part or component.

E.3 Report

E.3.1 Methods

Cleanliness of parts and components may be reported per one or more of the methods given in E.3.2 to E.3.5.

E.3.2 Contaminant mass

Report gravimetric cleanliness in terms of mass per area (for example, mg/m^2), mass per part, or mass per component.

NOTE Mass per component is generally not applicable for assembled components.

E.3.3 Particle size

Report particle size in terms of maximum contaminant particle size or the number of particles larger than a specified size.

E.3.4 Chemical composition

Report information on the chemical composition of selected contaminant particles.

E.3.5 Particle size distribution

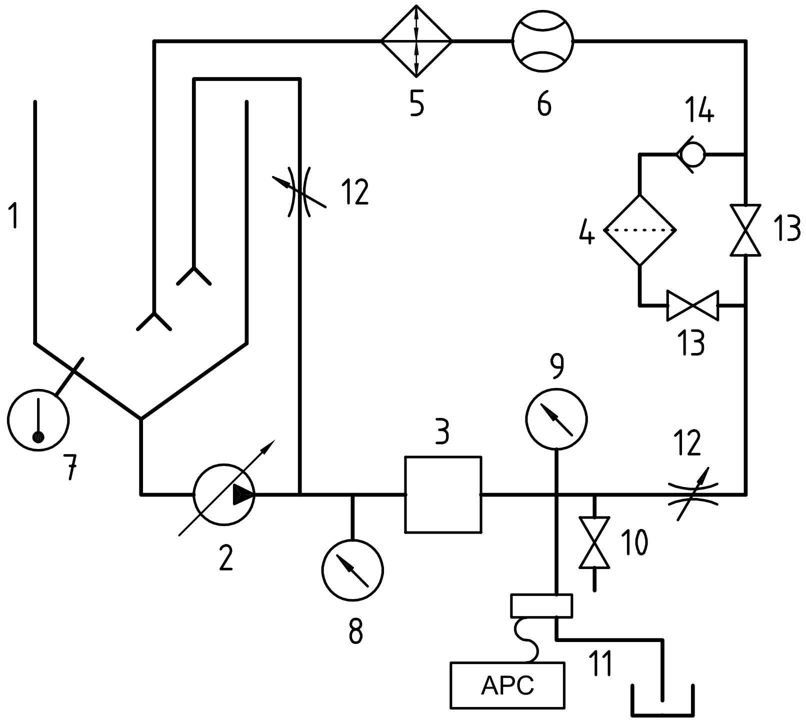
Report cleanliness in terms of number of particles per millilitre of controlled volume, number of particles per part, number of particles per component, or number of particles per area for each required size.

Annex F
(informative)

Test stand for end use simulation — Design guidelines

F.1 Scope

This annex provides some basic guidelines for constructing a test stand that is intended to meet the test equipment validation requirements of annex D for end use simulation. Conformance to these guidelines does not guarantee successful validation of the equipment. A typical test stand circuit diagram is shown in Figure F.1.



Key

1	Reservoir
2	Pump
3	Test item
4	Clean-up filter
5	Heat exchanger
6	Flowmeter
7	Temperature sensor
8	Upstream pressure sensor
9	Downstream pressure sensor
10	Sampling valve
11	Particle counting system
12	Restriction valve
13	Ball valve
14	Check valve

Figure F.1 — Circuit diagram for typical test stand

F.2 End use simulation test stand

F.2.1 General guidelines

F.2.1.1 Lines

All lines should be sized to provide turbulent mixing flow. Long straight runs should be avoided.

F.2.1.2 Connectors

Connectors should not have internally exposed threads or lips that may act as contaminant traps.

F.2.1.3 Arrangement of lines and connectors

Lines and connectors should be arranged to eliminate dead flow zones. Where possible, vertical runs are preferable to horizontal runs.

F.2.1.4 Valves

Ball valves are preferable to other types of valves, because they have a self-cleaning action and do not act as contaminant traps.

F.2.2 Test system elements

F.2.2.1 Reservoir

Use a reservoir constructed with a conical bottom with an included angle of $\leqslant 90^\circ$ with the entering liquid diffused below the liquid surface.

NOTE 1 This construction technique eliminates horizontal surfaces that may promote contaminant settling.

NOTE 2 Reservoirs with conical bottoms and included angles between 60° and 90° offer the best balance between ease of construction and the ability to discriminate between the various liquids.

Install a monitoring device to confirm that the liquid level in the reservoir remains constant.

F.2.2.2 Pump and drive

Use a type of pump that is relatively insensitive to contaminant at the desired operating pressures.

The system pump should exhibit flow pulsation of $< 10\,\%$.

The system pump should not significantly alter the test contaminant particle size distribution as a result of its pumping mechanism.

The pump drive should be the variable speed type capable of adjusting the test flow rate.

The pump drive should be relatively insensitive to changes in load so as to maintain a constant speed.

NOTE Variable frequency AC drives and DC drives exhibit these desirable characteristics.

F.2.2.3 Clean-up filter

The system clean-up filter shall be capable of providing an initial system contamination level as specified in D.4.6.

F.2.2.4 Heat exchanger

Depending upon system power capabilities, heating or cooling of the system liquid may be required.

A conventional shell and tube heat exchanger may be used. A vertical mounting configuration, with the liquid entering the tube side from the bottom, is recommended to reduce the possibility of particle sedimentation or capture in the heat exchanger. Side and multi-pass heat exchangers have also been used successfully.

Some data indicate that up to a 65 % loss in thermal transfer may occur when operating with the liquid on the tube side. Care should be taken to size the heat exchanger accordingly.

Liquid heating, if required, may be achieved by use of heating tapes on external surfaces or by use of a second heat exchanger with a high temperature liquid on the shell side.

F.2.2.5 Flowmeter

The flowmeter should be located between the test item and the downstream sample port to read the true flow in the test section. Flowmeters in other locations may require correction for sample flows that may not be measured. Turbine flowmeters using sealed bearings have proven suitable.

F.2.2.6 Temperature sensor

A temperature sensor shall be fitted in the system to monitor test liquid temperature to an accuracy of ± 0,5 °C over the expected temperature range.

F.2.2.7 Upstream pressure gauge

A pressure gauge shall be fitted in the system to monitor pressure at the inlet of test item.

F.2.2.8 Downstream pressure gauge

A pressure gauge shall be fitted in the system to monitor pressure at the outlet of test item.

F.2.2.9 Sampling valve

The sampling valve shall conform to ISO 4021.

F.2.2.10 Particle counting system

Calibrate optical automatic particle counters in accordance with ISO 11171, and validate them in accordance with ISO 11943.

Annex G
(informative)

Equivalent spherical area of complex enclosed surfaces

G.1 Scope

This annex may be used when it is impractical directly to calculate the wetted surface area of a complex shaped part or component and when this method is permitted by the inspection document.

G.2 Approximate equivalent area

Approximate equivalent area is used to report amount of contaminant per unit of wetted surface area. Approximate equivalent area is obtained by first measuring an actual part or component volume, by considering this volume to be spherical, and then calculating a surface area of the sphere using the following basic relationships:

$$V = \pi d^3/6 \rightarrow d = (6V/\pi)^{1/3}$$

$$A_\mathrm{s} = \pi d^2$$

where

V is the spherical volume;

d is the spherical diameter;

A_s is the spherical surface area.

Finally, because a sphere always has the absolute minimum surface area for an enclosed volume, an adjustment factor is added as the last step in calculating an approximate equivalent area:

$$A_\mathrm{e} = 1{,}2 A_\mathrm{s}$$

where

A_e is the approximate equivalent area;

A_s is the calculated spherical area.

G.3 Determination of approximate equivalent area

G.3.1 External wetted surfaces

G.3.1.1 Perform G.3.1.2 to G.3.1.5 for external wetted surfaces when the part or component is surrounded by the system liquid.

G.3.1.2 Seal any internal passages.

G.3.1.3 Submerge the test item.

G.3.1.4 Measure displaced volume of liquid.

G.3.1.5 Calculate the approximate equivalent area per G.2.

G.3.2 Internal wetted surfaces

G.3.2.1 Perform G.3.2.2 to G.3.2.6 for internal wetted surfaces when the part or component encloses the system liquid.

G.3.2.2 Seal all exit passages.

G.3.2.3 Fill the test item with liquid.

G.3.2.4 Measure the amount of liquid required to fill the test item

G.3.2.5 When filling the test item with liquid, avoid entrapping air.

G.3.2.6 Calculate the approximate equivalent area per G.2.

G.3.3 External and internal wetted surfaces

G.3.3.1 Perform G.3.3.2 to G.3.3.4 for external and internal wetted surfaces when the part or component both encloses and is surrounded by the system liquid.

G.3.3.2 Calculate the approximate equivalent area for the external wetted surfaces per G.3.1.

G.3.3.3 Calculate the approximate equivalent area for internal wetted surfaces per G.3.2.

G.3.3.4 Calculate the total approximate equivalent area by adding the results from G.3.3.1 and G.3.3.2.

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