



International
Standard

ISO 21018-1

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

**Part 1:
General principles**

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

Partie 1: Principes généraux

**Second edition
2024-10**

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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 document 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).

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

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

This second edition cancels and replaces the first edition (ISO 21018-1:2008), which has been technically revised. The main changes are as follows:

- [3.1](#) contains an updated definition for automated particle counter;
- [3.2](#) contains an updated definition for particle contamination model;
- [3.10](#) contains an updated definition for mesh;
- [3.11](#) now contains a note for the particle size definition;
- [B.8.1](#) has been updated to accurately describe the capabilities of image analysis.

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

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

Introduction

In hydraulic fluid power systems, power is transmitted through a liquid under pressure within a closed circuit. The liquid is both a lubricant and a power-transmitting medium. The presence of solid particulate contamination in the liquid interferes with the ability of the hydraulic liquid to lubricate and causes wear to the components. The extent of this form of contamination in the liquid has a direct bearing on the performance and reliability of the system and it is necessary to control this to levels that are considered appropriate for the system concerned. Hydraulic oil filters are used to control the amount of particulate contamination to a level that is suitable for both the contaminant sensitivity of the system and the level of reliability required by the user.

Operators of hydraulic equipment are gradually defining maximum particle concentration levels for components, systems and processes. These are often referred to as the required cleanliness level (RCL). This cleanliness level is obtained by sampling the hydraulic liquid and measuring the particulate contamination level. If the contamination level is above the RCL, then corrective actions are necessary to reduce the contamination level. To avoid taking unnecessary actions, which can often prove costly, precision in sampling and measuring the particulate contamination level is required.

A comprehensive range of measurement equipment is available, but the instruments used are usually laboratory-based. This often requires that the equipment is operated in a special environment by specialist laboratories and this delays delivery of the test result to the user. To overcome this disadvantage, instruments are being continuously developed to determine the particulate contamination level, either using equipment that can be operated in or near the workplace or directly using on-line or in-line techniques. For equipment operated in the workplace, direct traceability to national measurement standards can be inappropriate, or irrelevant, as the instruments are used to monitor the general level of particulate contamination or to inform the user of a significant change in the level. When a significant change in the particulate contamination level is detected, the actual level is then usually qualified by using an approved particle-counting method. Also, these monitors can have simplified circuitry compared to similar laboratory units and this means that they can be less accurate and precise.

In addition, some instruments are designed to work on the “go/no-go” principle and their ability to rapidly evaluate the cleanliness level has resulted in an increase in their usage both in the fluid power industry and other markets. Unfortunately, the lack of a standardized method for their use, recalibration (if applicable) and means of checking the output validity means that the variability in the measurement data is at a level higher than is desirable.

This document has been developed to provide uniform and consistent procedures for instruments that are used for monitoring the contamination levels in hydraulic systems, especially those where direct traceability to national measurement standards is not possible or is not applicable.

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

Part 1: General principles

1 Scope

This document specifies methods and techniques that are applicable to the monitoring of particulate contamination levels in hydraulic systems that cannot be calibrated in accordance with ISO 11171. It also describes the relative merits of various techniques, so that the correct monitor for a given application can be selected.

The techniques described in this document are suitable for monitoring:

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

This document can also be applicable for other liquids (e.g. lubricants, fuels and process liquids).

NOTE Instruments used to monitor particulate contamination that cannot be calibrated according to ISO 11171 are not considered as or claimed to be particle counters, even if they use the same physical principles as particle counters

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 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 4406, *Hydraulic fluid power — Fluids — Method for coding the level of contamination by solid particles*

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

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

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

3 Terms and definitions

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

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

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

3.1

automatic particle counter

APC

instrument that automatically:

- a) senses individual particles suspended in a controlled volume of fluid using optical light extinction or light scattering principles;
- b) measures the size of particles;
- c) sorts or compiles particles into size ranges;
- d) counts particles in each size range;
- e) reports the number of particles in each size range per unit volume; and
- f) facilitates instrument calibration according to this document.

Note 1 to entry: APC used for *particle size* (3.11) determination with hydraulic fluids, aviation and diesel fuels, engine oil and other petroleum-based fluids shall be calibrated per the requirements of ISO 11171.

[SOURCE: ISO 11171:2022, 3.1]

3.2

particle contamination monitor

PCM

instrument that automatically measures the concentrations of particles suspended in a fluid at certain sizes and cannot be calibrated in accordance with ISO 11171, and whose output may be as a *particle size* (3.11) distribution at limited sizes or as a contamination code

[SOURCE: ISO 21018-4:2019, 3.3]

3.3

coincidence error

error resulting from the presence of more than one particle in the sensing volume at one time

3.4

dynamic range

ratio of the largest and smallest *particle size* (3.11) that a sensor can analyse

3.5

filter media

filtration material that removes and retains particles as the fluid passes through

3.6

gel

semi-solid material that lacks a specific shape and can interfere with the counting or monitoring process

Note 1 to entry: Gels are usually formed by chemical reaction with the hydraulic liquid.

3.7

in-line analysis

analysis of a fluid sample of the liquid by an instrument that is permanently connected to a working flow line and where all the liquid in that line passes through the sensor

3.8

off-line analysis

analysis of a fluid sample by an instrument that is not directly connected to the hydraulic system

3.9

on-line analysis

analysis performed on a fluid supplied directly to the instrument by a continuous line from the hydraulic system

Note 1 to entry: The instrument can be either permanently connected to the flow line or connected prior to analysis.

3.10

mesh

type of *filter media* (3.5) with a uniform pore structure that is made by weaving strands of wire or material filaments, or fabricated directly

3.11

particle size

characteristic dimension of a particle that defines the magnitude of the particle in terms of a physically measurable dimension related to the analysis technique used, such as the longest dimension or the equivalent spherical diameter

Note 1 to entry: For automatic particle counters and light extinction particle contamination monitors, ISO 11171 defines particle size as the projected area equivalent diameter of particles. The equivalent diameter is determined by NIST using scanning electron microscopy traceable through a NIST length standard or an APC calibrated according to ISO 11171.

3.12

pore size

equivalent diameter of the holes in *filter media* (3.5) as determined by direct microscopic measurement or calculated from permeability data

3.13

qualitative data

data that have less precision or accuracy than quantitative methods and usually give results in ranges rather than exact numbers

3.14

quantitative data

data in the form of an exact numerical value of a parameter

3.15

required cleanliness level

RCL

hydraulic fluid cleanliness level required for a system, process or specification

[SOURCE: ISO 12669:2017, 3.9, modified — Note to entry has been omitted.]

3.16

silt

very small particles (< 3 µm in size) that are present in the liquid, often below the minimum detection size of the technique used

Note 1 to entry: Silt can interfere with the effectiveness of the instrument either by obscuring particles or by coincidence error effects.

Note 2 to entry: They can be small wear particles or products of hydraulic liquid degradation.

3.17

suction (sip) sampling

process of drawing a sample from a reservoir using a vacuum

3.18

suction (sip) analysis

analysis of a sample drawn by instrument pump from a non-pressurized container and delivered to the instrument sensor

4 Health and safety

4.1 General

Operate the instrument in accordance with the manufacturer's instructions and follow local health and safety procedures at all times. Personal protective equipment shall be used when required.

4.2 Electric power

Take care when connecting the instrument to an electrical power source and follow the manufacturer's instructions.

4.3 Mechanical fluid power

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

Ensure that internal pressure has been dissipated before taking off any fittings or closures.

NOTE See [Clause 6](#) for guidance regarding sampling from pressurized lines.

4.4 Process liquids

4.4.1 Flammable or combustible liquids

If test liquids are flammable or combustible, they shall be used as follows:

- a) in accordance with all local requirements;
- b) in accordance with the relevant material safety data sheet (SDS).

The transfer of volatile liquids from one container to another container shall be carried out carefully due to the risk of sparking.

NOTE Follow the precautions for safe handling and usage described in the safety data sheet(s) of all fluids.

4.4.2 Chemical compatibility

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

4.5 Electrical earthing/grounding

Apparatus used for filtering or dispensing solvents or any volatile flammable liquid shall be electrically earthed to avoid the risk of static discharge.

4.6 Environmental

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

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

5 Selection of monitoring technique

5.1 General

The choice of instrument, or monitoring technique, depends upon, but is not limited to, the following aspects:

- a) how the instrument is to be used, i.e. the mode of operation ([A.2.4](#));
- b) the purpose for which the analysis is required ([A.2.2](#));
- c) the parameter(s) to be measured ([A.2.3](#));
- d) the properties of the liquid ([A.2.5](#)).

5.2 Selection

Select the instrument and monitoring technique by considering the operational parameters detailed in [Annex A](#) and [Annex B](#), and choose a combination that satisfies the individual requirements for monitoring.

NOTE [A.1](#), explains the modes of operation and analysis and [A.2](#), gives guidance on the various aspects to consider during selection and includes a selection matrix. [Annex B](#) gives a brief explanation of the different techniques and their advantages and disadvantages.

6 Procedures and precautions

6.1 General

Whichever monitoring or measurement technique is selected, there are a number of precautions that shall be taken to ensure that valid data are produced and errors are minimized.

This document gives general procedures that limit errors. Precautions relating to a specific technique are given in the relevant part of the ISO 21018 series.

6.2 Sampling

6.2.1 Obtaining representative samples

6.2.1.1 Select the sampling position consistent with the reasons for sampling (see ISO 4021).

NOTE 1 It is extremely important to use the correct sampling technique(s). The use of equipment connected to or mounted in or on the active flow line reduces the errors associated with extraneous contamination.

NOTE 2 The particulate contamination added to the sample from the sampling process can be much higher than the particulate concentration that exists in the liquid of some filtered systems.

The guidelines described in [6.2.2](#) to [6.2.3](#) are typical good practice for obtaining reliable results and should be read in conjunction with ISO 4021.

6.2.1.2 Use sampling valves that conform to ISO 4021.

6.2.1.3 For general monitoring, take the sample when the system is running and conditions are stable. Sampling 30 min after start-up is suitable.

6.2.1.4 For periodic monitoring of a machine or process, take repeat samples from the same place, in the same manner, when the machine or process is running normally and when operating conditions have stabilized.

6.2.2 Off-line sampling

6.2.2.1 Use sample bottles that have been cleaned and verified in accordance with ISO 3722.

6.2.2.2 Site the sampling valve consistent with the reason for sampling.

6.2.2.3 Position the sampling valve in a location where good mixing conditions exist.

6.2.2.4 Flush the sampling valve and transfer line at a flow rate of at least 2 l/min with a minimum flushing volume of 500 ml. Use higher flushing volumes (1 l to 3 l) if:

- a) valves do not conform to the requirements of ISO 4021;
- b) long transfer lines are used;
- c) the system liquid is expected to be clean (i.e. $\leq 14/12/9$ in accordance with ISO 4406).

6.2.2.5 Take the sample in a manner that minimizes the ingress of environmental contamination.

6.2.2.6 Cap the sample immediately after it is taken and label with a unique identification.

6.2.2.7 Do not take samples from drain valves.

6.2.3 Off-line analysis

6.2.3.1 Take the sample from a location where the liquid is in motion.

6.2.3.2 Shake and mix well the contents of containers before extracting the sample.

NOTE This method is the least-favoured option as the potential for errors and variability is greatest.

If mixing the contents of a bulk container is impractical, a note shall be made in the report.

6.2.3.3 Clean the area(s) surrounding the location where the sample is taken so that contamination does not fall into the sample, the container or reservoir.

6.2.3.4 Flush the sampling system with at least 10 complete volumes (instrument and connecting pipes) utilizing fluid from the system being tested.

6.3 Analysis

6.3.1 On-line analysis

6.3.1.1 Use sampling valves and procedures defined in ISO 4021.

6.3.1.2 Provide sufficient supply pressure to avoid instrument starvation or cavitation.

6.3.1.3 Flush the sampling lines with a minimum of 1 l of liquid sample after connection and before analysis.

6.3.2 In-line analysis

Install the sensor in a location where the fluid is well mixed.

6.3.3 Off-line analysis

6.3.3.1 Follow ISO 11500 for off-line sample analysis.

NOTE Suction (sip) samples are frequently analysed off-line.

6.3.3.2 Continue the analysis until the data from two successive samples satisfy one of the following requirements.

- a) The results are within the limits set by the instrument manufacturer.
- b) The difference in test results is less than 10 % of the mean of consecutive results at the smallest particle size being monitored if the required output is particle count.
- c) The same contamination code in accordance with ISO 4406 is recorded.

6.4 Calibration procedures

Although the principle of calibration may not apply to some techniques, the requirements and principles of International Standards for measurement traceability shall be followed for applicable techniques. For instance, where the instruments are automatic, they shall be calibrated or checked using ISO 12103-1 A3 medium test dust. In this way, any differences in the data measured using automatic particle counters (APC) calibrated using either ISO 11171 or ISO 11943 and data from those monitors calibrated/checked with suspensions of ISO 12103-1 A3 medium test dust in oil are minimized.

6.5 Checking data repeatability

6.5.1 Develop a means of checking the data to ensure the prompt detection of errors before reporting the data. Use the procedures detailed below, as appropriate.

6.5.2 For automatic instruments, repeat the analysis until two successive data sets satisfy one of the following conditions.

- a) The results are within the limits set by the instrument manufacturer.
- b) The difference in test results is less than 10 % of the mean of consecutive results at the smallest particle size being monitored if the required output is particle count.
- c) The same ISO 4406 code is recorded.

6.5.3 Review the test data and confirm that they are of the same order as:

- a) previous data obtained from the same system or process;
- b) previous data obtained from a similar system(s) using the same filtration level.

6.5.4 For off-line instruments where the sample is collected in a sample bottle, examine the sample for conditions that can interfere with the effectiveness of the instrument, such as the ones given in a) to d).

- a) The presence of large particles that can block small passageways, orifices or the sensor in the instrument. The presence of large particles can also indicate the presence of high numbers of smaller particles.
- b) Test-liquid cloudiness, which can indicate the presence of another liquid such as water in oil, oil in water-based liquids, mixtures of liquids, etc., and which can interfere with instruments using the transmission of light to detect particles.
- c) A clear but dark appearance in a test liquid, which often indicates the presence of finely divided particles (e.g. wear debris or oxidation products). The presence of finely divided particles in the test liquid can interfere with the effectiveness of the test instrument due to coincidence error effects.

- d) The presence of air bubbles in the test liquid, which interferes with the passage of light. Remove air bubbles in accordance with ISO 11500 before any analysis is performed.

6.6 Training

Train operators both in the technique and in the specific instrument used. Operator training shall be competence-based (where applicable).

NOTE The importance of proper and comprehensive training in both instrument use and the technique employed cannot be overstated, as it is only with knowledge and experience that errors can be recognized and minimized.

Develop a training program that includes, but is not limited to:

- a) an explanation of the principles of the technique to be used, giving the advantages and disadvantages,
- b) an explanation of the main features of the instrument;
- c) training in the use of the instrument especially when dealing with samples that can give rise to difficulties;
- d) basic problem solving.

It is recommended that users maintain operator training records.

6.7 Controlling the precision of the technique

6.7.1 Develop procedures to evaluate the competence of operators involved with using a technique where the results obtained are dependent upon operator competence.

6.7.2 Keep records to evaluate the level of reproducibility of the technique and whether operators are consistent. Retrain operators if there is a significant departure from the normal level of variability.

7 Test report

Report the results obtained from sample analysis and include the following as a minimum:

- a) sample designation;
- b) date of analysis;
- c) instrument designation;
- d) mode of analysis used;
- e) analysis results and, if applicable, any action required;
- f) any comments relating to the sample or results;
- g) the International Standard used;
- h) any deviations from the International Standard used.

Annex A (informative)

Summary of various technique attributes

A.1 Modes of sampling and analysis

A.1.1 General

There are five methods for sampling and analysing liquid samples as shown diagrammatically in [Figure A.1](#) and described in [A.1.2](#) to [A.1.5](#).

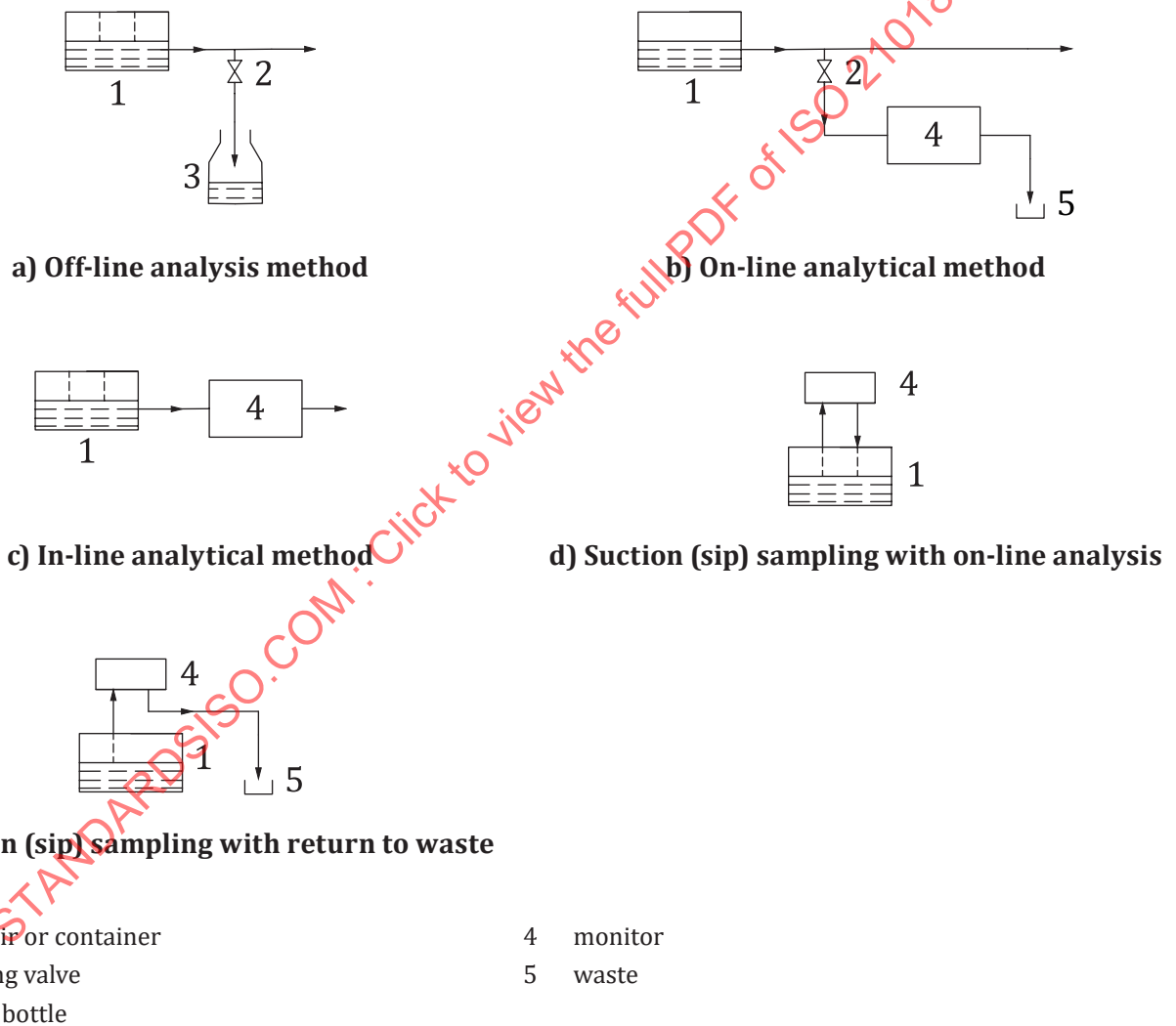


Figure A.1 — Operational mode diagram

A.1.2 Off-line analytical method

Off-line sampling and analysis are the most frequently used methods and a wide range of techniques are available for use.

Off-line analysis involves the extraction of a representative liquid sample from the system, its collection in either a sample bottle or suitable container and subsequent analysis. The sample can be analysed in-house or by an external laboratory.

As a result of these processes, errors and hence variability in data can be introduced into the measured results and it is necessary to adopt appropriate procedures to limit the introduction of extraneous contamination into the sample (see [6.2.1.1](#)).

NOTE Contamination can be introduced into the sample from:

- a) the sampling process;
- b) the ambient environment (including the pipe work);
- c) the analysis process;
- d) the storage and/or transport conditions.

A.1.3 On-line analytical method

For on-line analysis, the measuring instrument is connected either directly to the pipe work that is exposed to the active flow or to a subsidiary flow line attached to it.

On-line analysis overcomes the problems associated with the introduction of environmental contamination into the sample. However, contamination can be introduced into the sample as a result of connecting the measuring instrument to the system and then making the analysis before any residual contamination in the connecting line has been flushed out (see [6.3.1.3](#)).

Most on-line instruments use a low flow rate (20 ml/min to 100 ml/min) which can be insufficient to flush the lines after connection, and pre-flushing of the connecting lines can be required. The flow rate used can be unable to generate sufficient disturbance at the sampling point to ensure that a representative sample is taken. In addition, small analytical volumes (e.g. 10 ml or 20 ml) can be inadequate for determining the true cleanliness level where particle numbers are low (see ISO 4406).

A.1.4 In-line analytical method

Instruments working in-line are permanently connected to the pipe work that is exposed to the active flow and provide a continuous measurement of cleanliness level. The errors associated with sampling described in [A.1.2](#) are not experienced. This method requires good mixing conditions upstream of the measurement point so that the number of particles in the sensing volume is representative of those in the active pipe.

A.1.5 Suction (sip) analysis

For suction analysis, the measuring instrument is used to analyse the liquid from a non-pressurized container, for example a barrel of oil or a system reservoir (see [Figure A.1](#)). The requirement to transfer the liquid sample from the container to the sensor (e.g. by using an internal pump) can be a source of error. If it is necessary for the pump to lift the liquid to the instrument, a negative pressure (vacuum) is generated and this can draw air out of solution or through fittings. The presence of air in the liquid being analysed can interfere with the operation of the instrument and create errors. Additional errors can be introduced if the pump is positioned upstream of the sensor, where it can generate particles during operation and hence give unrepresentative test data.

Other sources of error are described in ISO 4021.

A.2 Selection of the most appropriate monitor

A.2.1 General

The choice of which instrument or technique is chosen depends on, but is not limited to, the criteria listed in [5.1](#).

This subclause gives details of the parameters that it is necessary to consider before selecting the most suitable method to use. A summary of the attributes, in matrix form, is shown in [Table A.7](#) and the various techniques are briefly described in [Annex B](#). The categories identified do not always fully describe the application under consideration and it is necessary to verify the suitability of the choice with the instrument manufacturer.

A.2.2 Reason for measuring or monitoring

The intended use of the measurement data and the desired accuracy govern the method chosen and dictate the level of instrument precision required.

For the general evaluation of cleanliness level and trend plotting, the measurement data can be qualitative ([3.13](#); e.g. as in ISO 4406 contamination codes) and the use of a monitor can be a more appropriate alternative.

Certification of system or product cleanliness normally requires quantitative data ([3.14](#)).

A.2.3 Particle physical parameters

A.2.3.1 General

The choice of physical parameter relates closely to the purpose of the analysis (e.g. if a contamination code is required, then a size feature has to be chosen).

The various techniques that can be used are shown in [Table A.1](#) to [Table A.2](#). In addition, guidance is given as to whether the technique gives qualitative or quantitative data.

A.2.3.2 Particle size

[Table A.1](#) shows the techniques that can be applied to obtain information on the size of the particles, which is required to evaluate the likelihood of a particle causing interference with clearances and/or of passageways.

Table A.1 — Particle size analysis techniques

Parameter	Quantitative data	Qualitative data
Length	Direct measurement (e.g. rule, micrometer) Image analysis Optical microscope Automatic particle counter Scanning electron microscope	None
Area	Image analysis Automatic particle counter Scanning electron microscope	None
Volume	Electrical sensing zone	Laser diffraction

A.2.3.3 Particle quantity

[Table A.2](#) shows the techniques that can be applied to obtain information on the quantity of contaminant, which is used to evaluate both the extent of contamination and the probability of particle-induced problems.

Table A.2 — Particle quantity analysis techniques

Parameter	Quantitative data	Qualitative data
Particle count at specific sizes (size distribution)	Electrical sensing zone Image analysis Optical microscope counting Scanning electron microscope counting Automatic particle counting	Laser diffraction Filter blockage
Concentration at specific sizes	—	Laser diffraction Filter blockage Comparative membrane filter
Overall concentration (e.g. an index of severity covering a wide range of sizes)	Gravimetric analysis	Magnetic detection Thin film abrasivity Turbidity

A.2.4 Mode of operation

[Table A.3](#) to [Table A.6](#) show how the monitor analyses the fluid sample in off-line, on-line, in-line or suction (sip) modes. See also [A.1](#).

Table A.3 — Off-line operation analysis techniques

Quantitative data	Qualitative data
Direct measurement Electrical sensing zone Image analysis Magnetic detection Automatic particle counting Optical microscope counting Scanning electron microscopic counting	Comparative membrane filter Laser diffraction Filter blockage techniques Magnetic detection Thin film abrasivity Turbidity

Table A.4 — On-line operation analysis techniques

Quantitative data	Qualitative data
Automatic particle counting Image analysis Magnetic detection	Laser diffraction Filter blockage techniques Thin film abrasivity Turbidity

Table A.5 — In-line operation analysis techniques

Quantitative data	Qualitative data
Automatic particle counting Magnetic detection	Laser diffraction

Table A.6 — Suction operation analysis techniques

Quantitative data	Qualitative data
Automatic particle counting Image analysis	Laser diffraction Filter blockage Thin film abrasivity

A.2.5 Liquid types

It is necessary to consider the type of liquid only when the particles are analysed in the liquid itself and the condition of the liquid can interfere with the operation of the chosen technique.

A.2.6 Sample liquid characteristics and optical properties

A.2.6.1 Single, clear phase

Liquids analysed using light-based instruments shall be clear and homogeneous and have a homogeneous refraction index (single-phase liquid).

A.2.6.2 Multi-phase liquid

Multi-phase liquids can be either intentional (e.g. emulsions) or unintentional (e.g. tramp oils, water in oil, air in oil) and contain an optical interface between the phases. Any interface present in the sample interferes with the transmission of light through the liquid and erroneous data can be produced by instruments using optical techniques.

A.2.6.3 Opaque liquid

Opaque liquids can totally or partially obstruct the transmission of light through them, which interferes with the operation of the instrument. Light-based instruments, therefore, are not useable in these circumstances as there is insufficient light transmitted through the sample for accurate detection to take place.

A.2.7 Electrical properties

It is necessary to consider the conductivity of the liquid only when using the electrical sensing zone technique.

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Table A.7 — Summary of various technique attributes

Technique	Operational mode				Size (µm)			Output				Output precision	Sample suitable for other analysis	Reference
	Inline	On-line	Offline	Suction (sip)	min	max.	Dynamic range	Size	Number	ISO codes	Other			
Automatic counting	Y	Y	Y	Y	1,0	3 000+	100	Y	Y	Y	N	Quantitative	N	B.7
Microscope counting	N	N	Y	N	2,0	3 000+	200	Y	Y	Y	Type	Quantitative	Y	B.8
Image analysis	N	Y	Y	Y	2,0	3 000+	200	Y	Y	Y	Shape	Quantitative	Y	B.8
Laser diffraction	Y	Y	Y	Y	0,2	2 000+	10 000	Y	Y	Y	Volume	Qualitative	N	B.2
Filter blockage	N	Y	Y	Y	14	14	3,5	Y	N	Y	N	Qualitative	N	B.4
SEM	N	N	Y	N	0,01	3 000+	5 000	Y	Y	Y	Type and shape	Quantitative	Y	B.9
Direct measurement	N	N	Y	N	100	3 000+	N/A	Y	N/A	N	N	Quantitative	Y	N/A
Electrical sensing zone	N	N	Y	N	0,5	1 500+	100	Y	Y	Y	Volume	Quantitative	N	B.3
Comparison membrane	N	N	Y	N	5,0	3 000+	N/A	N	N	Y	Type	Qualitative	Y	B.1
Gravimetric	N	N	Y	N	1,0	3 000+	N/A	N	N	N	Mass	Quantitative	Y	B.5
Thin film	Y	Y	Y	Y	5,0	3 000+	N/A	N	N	N	Abrasivity Index	Qualitative	Y	B.9

Y = yes; N = no; N/A = not applicable

Annex B

(informative)

Description and relative merits of different contaminant monitoring techniques

B.1 Comparative membrane filter techniques

B.1.1 Outline

The comparative membrane filter technique is based upon an optical comparison of particles deposited on the surface of the sample membrane filter used in the test with a series of previously prepared reference membrane filters (or photographs of them) that represent different cleanliness levels. The sample membrane filters are prepared either off-line or on-line using the same filter pore size and analysis volume as the reference membrane filters.

After preparing the test sample membrane filter or images, the operator looks at the general concentration of particles on it using an optical microscope set at the same magnification used for viewing the reference filter membranes. The particle concentration is then compared to a series of reference membrane filters showing differing cleanliness levels. The reference membrane filter that is equal to or dirtier than the sample membrane filter is selected as being the cleanliness level for that sample.

This technique is often called the “patch test,” as the membrane filter is frequently referred to as a “patch”.

B.1.2 Key features

The following key features have been identified.

- a) It takes approximately 5 min to prepare and analyse a sample.
- b) It is low cost and cost effective.
- c) A trained operator is required.
- d) Problems with sample liquid can be seen.
- e) It can be used to identify particle types and hence can be used as a diagnostic tool.
- f) It can be used as a go/no-go technique.

B.1.3 Limitations

The following key limitations have been identified.

- a) It can be used only as an off-line technique.
- b) The total test time is dependent on the filtering time.
- c) It is of limited use in the field where clean liquid levels occur due to environmental influence.
- d) Samples require careful preparation to limit variability.
- e) It does not give particle count or size analysis.
- f) Particles can be obscured by silt and gels.

- g) The degree of agreement with the reference sample is dependent on the relative particle-size distributions.

B.2 Laser diffraction analysers

B.2.1 Outline

Laser diffraction analysers are a form of light-scattering particle analyser that can be applied to a wide range of particle sizes and concentrations. Laser-diffraction analysers operate by directing a beam of filtered, low-power laser light, expanded to produce a parallel beam, across a sensing passage. As particles pass through the parallel beam, the light is scattered or diffracted at different angles depending on the size of the particle(s). The diffracted beam is then brought into focus on a multi-element solid-state detector. The particle-size distribution can then be established, either by calculation based upon the measured light-beam diffraction or by calibration using a specific test dust.

B.2.2 Key features

The following key features have been identified.

- a) It can be used off-line, on-line and in-line with a glass-walled measurement section.
- b) It can analyse a wide particle size range (0,2 μm to 2 000 μm).
- c) It can be used to analyse high particle concentrations, e.g. > 20/18/15 (see ISO 4406).
- d) Typical analysis time is 5 min.

B.2.3 Limitations

The following key limitations have been identified.

- a) It requires a high concentration of particles for accurate detection, approximately 19/17/14 (see ISO 4406).
- b) The particle size distribution is based upon particle volume.
- c) It is not generally used in the fluid power industry.
- d) The test set-up can be bulky.
- e) It cannot be used with multi-phase liquids.

B.3 Electrical sensing zone

B.3.1 Outline

An electrically conducting liquid is drawn through a small, electrically insulated orifice having electrodes positioned in the liquid on either side of the orifice. When no particles are present, the impedance between the electrodes remains constant. When a particle having a conductivity different from that of the liquid passes through the orifice, it generates an electrical pulse proportional to the volume of the particle.

This type of unit is not frequently used for monitoring oil-based systems as the analysis process involves a number of other stages, either separating the particles and re-suspending them in an electrolyte or preparing a series of chemicals to make the oil conducting. The technique can be used in systems with water-based liquids.

See also ISO 13319.

B.3.2 Key features

The following key features have been identified.

- a) It can accommodate a wide particle size range (0,5 µm to 1 500 µm) by using different analytical orifices.
- b) It provides precise, volumetric measurements.
- c) It gives the particle-size distribution.
- d) It typically has an analysis time of 5 min if the sample is analysed directly.

B.3.3 Limitations

The following key limitations have been identified.

- a) It can be used only for off-line analysis.
- b) It requires the test liquid to be electrically conducting.
- c) It is necessary that the electrical conductivity of the particulate contamination present in the test sample be different from that of the carrier liquid.
- d) The sample time is extended (typically by 20 min to 40 min) when the sample liquid is non-conducting.
- e) It is not widely used in the fluid power industry.

B.4 Filter blockage method

B.4.1 Outline

The principle of the filter-blockage method is the determination of the change in the characteristics of a filter mesh or screen having a known number of uniform openings (or pores) as the contaminated liquid passes through it. Particles greater than the pore size cause the filter to gradually block up. This causes either the differential pressure across the filter to increase (constant-flow principle) or a reduction in the flow rate through the filter (constant-differential-pressure principle). Multiple meshes or filters may be used to obtain data for different sizes.

The concentration of particles in the test liquid sample with a size greater than the filter pore size can then be estimated either by considering the number of blocked pores (degree of blockage) and the volume of liquid that passed through the filter or by calibration. The test result can be reported as a cleanliness code (see ISO 4406).

As the pressure drop across the filter is proportional to the viscosity, it may be necessary to correct the data from constant flow units for changes in viscosity during the analysis cycle. The degree of correction depends on the instrument. Density changes over the analysis cycle have only a marginal effect.

See also ISO 21018-3.

B.4.2 Key features

The following key features have been identified.

- a) Several analytical modes are available:
 - 1) on-line from high- and low-pressure lines;
 - 2) suction mode from reservoirs and containers;

- 3) off-line via sample bottles.
- b) It can operate using a wide range of liquids (e.g. mineral and synthetic oils, emulsions, solvents, fuels, wash solutions and water-based liquids).
- c) It can operate using liquids with optical interfaces (e.g. water in oil, air in liquids and immiscible liquids) provided the condition of the liquid remains constant over the analytical cycle.
- d) It can operate over a wide range of contamination levels with a single unit.
- e) It has a typical analysis time of 3 min to 15 min depending on the type of instrument.

B.4.3 Limitations

The following key limitations have been identified.

- a) It has a restricted size range (current models usually have either one or two filters).
- b) Constant-differential-pressure instruments cannot measure low levels of particulate contamination (e.g. < ISO 4406 code */13/11).
- c) Constant-flow instruments have a longer analysis time (about 8 min) for measuring low levels of particulate contamination (e.g. < ISO 4406 code */10/8).
- d) It does not analyse and record single particles, so it is limited to monitoring general particulate-contamination levels.

B.5 Gravimetric analysis

B.5.1 Outline

In gravimetric analysis, the particles in the sample are separated from the liquid by vacuum filtration and deposited on a pre-weighed membrane filter ($\leq 1,0 \mu\text{m}$ pore size). After de-oiling and drying, the membrane filter is re-weighed and the mass of particles computed for the sample.

See also ISO 4405.

B.5.2 Key features

The following key features have been identified.

- a) It allows the measurement of large amounts of contaminant.
- b) The contaminated membrane filter can be used in other analytical techniques.

B.5.3 Limitations

The following key limitations have been identified.

- a) The technique is subject to significant errors at low contamination levels.
- b) It is not suitable for clean systems (< 17/15/12; see ISO 4406) unless large volumes of contaminated liquid are analysed.
- c) It has a typical sample analysis time of 35 min.
- d) It does not provide a measure of particle-size distribution.
- e) It requires support equipment (e.g. ovens and balances).