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Hydraulic fluid power — Method to relate the cleanliness of a hydraulic system to the cleanliness of the components and hydraulic fluid that make up the system

Transmissions hydrauliques — Méthode de relation entre propreté d'un système hydraulique et propreté des composants et du fluide hydraulique qui composent le système

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Foreword

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

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Introduction

The initial cleanliness level of a hydraulic system can affect its performance and useful life. Unless removed, particulate contaminants present after manufacture and assembly of a system can circulate through the system and cause damage to the system's components. To reduce the probability of such damage, the fluids and the internal surfaces of the hydraulic fluid power system and of its components should be cleaned to a specified level.

The final cleanliness level of the complete system can be theoretically predicted as the sum of the particulate contamination brought in by both the components that make up the system and the filling fluid.

As a reciprocal, the required cleanliness level of each individual component and of the filling fluid can be predicted from the required cleanliness level of the final system. This Technical Report explains the theoretical basis for such predictions.

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Hydraulic fluid power — Method to relate the cleanliness of a hydraulic system to the cleanliness of the components and hydraulic fluid that make up the system

1 Scope

This Technical Report describes methods that can be used to:

— relate the cleanliness of a hydraulic system to the cleanliness of its components and the hydraulic fluid belonging to the system;

— estimate the final cleanliness level of an assembled hydraulic system filled with the hydraulic fluid, upon its release from the manufacturing area. The estimation of the final cleanliness level is based on the cleanliness level of each component in the system and on the cleanliness level of the filling fluid;

— calculate and manage cleanliness requirements of components and subassemblies that make up a system and of the fluid filling it so as to achieve a required cleanliness level (RCL) for the final system.

These methods can apply whatever the particle size considered and can also be used for other types than hydraulic fluid power.

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2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

3 Terms and definitions

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

3.1
wetted surface area
A
surface area of the component or system that is exposed to the system liquid in normal operation, as agreed between parties

Note 1 to entry: Subscripts C or S are added to the symbol *A* when it refers to the wetted surface area of, respectively, a component or a system.

EXAMPLE Consider a hydraulic gear pump with two gears (see Figure 1). The wetted surface area can be calculated as the sum of the internal surfaces of the pump body (two plates and one flange with two ports) plus the external surface of the two gears.

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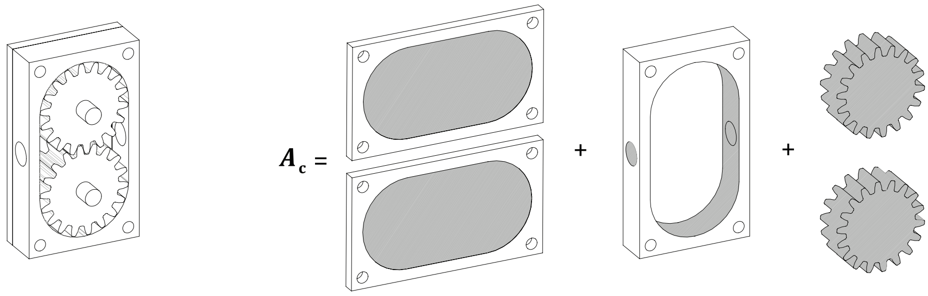

Figure 1 — Wetted surface of an external gear hydraulic pump

3.2
wetted volume
contained volume
V
volume of a component or system in which the system liquid is to be found in end-use operating conditions, as agreed between parties

Note 1 to entry: Subscripts C or S are added to the symbol *V* when it refers to the wetted volume of, respectively, a component or a system.

EXAMPLE Consider a hydraulic gear pump with two gears (see Figure 2). The wetted volume can be calculated as the volume of the body minus the volume of the two gears or measured as the filling volume of the complete pump.

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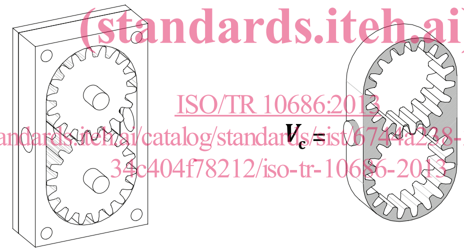

Figure 2 — Wetted volume of an external gear hydraulic pump

4 Symbols and units

The symbols and units related to the cleanliness of fluids, systems and components used in this Technical Report are given in Table 1.

Table 1 — Symbols and units

Symbol	Description or explanation	Unit
N_A	Number of particles of a given size introduced during assembly	number of particles
N_C	Number of particles of a given size in a component	number of particles
N_{Ci}	Number of particles of a given size in component *i*	number of particles
N_S	Number of particles of a given size in an empty system (without fluid)	number of particles
N_F	Number of particles of a given size in a fluid used to fill system	number of particles
N_{SF}	Number of particles of a given size in a system filled with system fluid	number of particles
N_X	Number of particles of a given size in an item *X*	number of particles

a If the relevant particle sizes are those covered in ISO 4406 [i.e. 4 µm(c), 6 µm(c), 14 µm(c) for automatic counting, 5 µm or 15 µm for microscopic counting], the cleanliness level can be expressed using the code system specified in ISO 4406.

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Table 1 *(continued)*

Symbol	Description or explanation	Unit
A_C	Wetted surface area of a component	cm^2
A_S	Wetted surface area of an empty system (without fluid)	cm^2
V_C	Wetted volume of a component	cm^3 or ml
V_{Ci}	Wetted volume of component *i*	cm^3 or ml
V_S	Wetted volume of an empty system (without fluid)	cm^3 or ml
V_F	Volume of fluid used to fill system	cm^3 or ml
V_{SF}	Wetted volume of a system upon its release from the manufacturing area	cm^3 or ml
V_X	Wetted volume of an item	cm^3 or ml
C_C	Cleanliness level of a component – N_C / V_C	number of particles per cm^3 or ml
C_{Ci}	Cleanliness level of component *i*	number of particles per cm^3 or ml
C_S	Cleanliness level of an empty system (without fluid) – N_S / V_S	number of particles per cm^3 or ml
C_F	Cleanliness level of fluid used to fill system – N_F / V_F	number of particles per cm^3 or ml [a]
C_{SF}	Cleanliness level of a system upon its release from the manufacturing area – N_{SF} / V_{SF}	number of particles per cm^3 or ml

a If the relevant particle sizes are those covered in ISO 4406 [i.e. 4 µm(c), 6 µm(c), 14 µm(c) for automatic counting, 5 µm or 15 µm for microscopic counting], the cleanliness level can be expressed using the code system specified in ISO 4406.

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5 Basic considerations

5.1 Particulate contamination

5.1.1 Basic principles

The physical and chemical principles that explain the presence and the behaviour of particulate contaminants in a hydraulic system are numerous and complex. This subclause covers some basic principles on which this Technical Report's approach to cleanliness is based.

5.1.2 Homogeneity of distribution of contamination in the system

In the absence of a system or flushing filter when the system is operated for the first time and stabilized, particulate contaminants are considered to be distributed homogeneously in the whole system, i.e. particulate contamination is in the fluid everywhere in the components and the system and on the wetted surfaces of the components. This assumes that all of the fluid and all the surfaces on which it flows are at the same cleanliness level.

5.1.3 Actual location of contaminants in items and fluid

Particulate contaminants are either deposited on the surface area of the components or suspended in the hydraulic fluid (see Figure 3). Even if particles are deposited on the entire surface of a component, only those deposited on the wetted surface are taken into consideration because they are the only ones likely to move into the fluid and potentially to damage the system.

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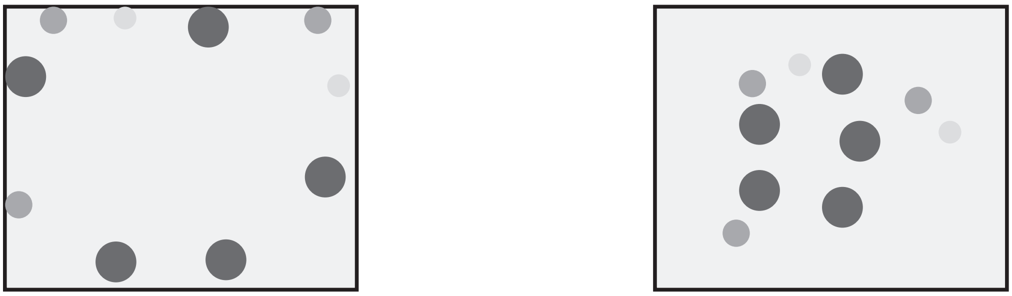
5.1.4 Theoretical location of contaminants in items

To apply the cleanliness prediction method described in this Technical Report, it is necessary to consider that the particulate contaminants deposited on the wetted surface areas of hollow components and assemblies are in suspension in the void volume of the items [see Figure 3 b)].

This concept applies because only particulate contaminants moving from the surface of the component into the hydraulic fluid add to the fluid contamination and become capable of damaging the system.



a) Actual situation – Contaminants on the surface **b) Cleanliness concept – Contaminants in the volume**

Figure 3 — Concept of cleanliness per unit volume

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The cleanliness level of hollow components, subassemblies and systems can be compared to the cleanliness level of fluids.

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5.1.5 Overall cleanliness approach

5.1.5.1 Cleanliness level of assembled components

In the majority of hydraulic circuit configurations, the following statements apply.

— When components are assembled in subassemblies and when subassemblies are assembled in a system, the numbers of their contaminant particles are summed and their wetted volumes are also summed.

— The cleanliness level of an empty assembled system not yet filled with fluid is the ratio of the sum of the numbers of contaminant particles in or on each component to the sum of the wetted volume of all components.

— The cleanliness level of an empty assembled system is neither the sum nor the average of the cleanliness levels of the components it is made of.

See Table 2 for an illustration of these concepts.

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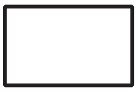
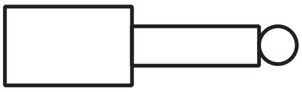
Table 2 — Illustration of how cleanliness levels can and cannot be used in calculations

Item	Number (N_i) of contaminant particles	Volume, V_i	Cleanliness level, C_i
		ml	N/ml
Component 1: 	5	10	5/10 = 0,5
Component 2: 	5	2	5/2 = 2,5
Component 3: 	2	1	2/1 = 2
Assembly 4: 	$N_4 = \sum N_i$ $N_4 = 12$	$V_4 = \Sigma V_i$ $V_4 = 13$	$C_4 = \sum N_i / \sum V_i$ 12/13 = 0,92
Note – $C_4 \neq C_1 + C_2 + C_3$ and $C_4 \neq (C_1 + C_2 + C_3) / 3$			

5.1.5.2 Cleanliness level of items filled with fluid

When a hollow item of volume V_X contaminated with N_X particles of a given size per ml is fully filled in with a fluid contaminated with N_F particles of the same size per ml, the resulting cleanliness level of the item filled with fluid is $(N_X + N_F) / V_F$.

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5.2 System knowledge requirements

5.2.1 System structure

It is necessary to know precisely the components located upstream and downstream of the component being considered, as well as the subassembly the components are part of and the whole system the subassemblies are part of.

It is necessary to know how to manage the cleanliness of each part (i.e. make items cleaner to allow a relaxation in the cleanliness of other items), so that the overall cleanliness complies with the RCL.

5.2.2 Geometrical characteristics

5.2.2.1 Wetted volume (V_X)

The wetted volume of the item can be either measured experimentally or calculated using computerised engineering drawing tools or from the ratio V/A of the complete system. See Annex A for further details.

5.2.2.2 Wetted surface area (A_X)

The wetted surface area of the item, if required, can be calculated using computerised engineering drawing tools.

5.2.2.3 Volume-to-surface area (V/A) ratio

Some cleanliness requirements are expressed per unit surface area. To apply the cleanliness prediction method, they need being transformed to requirements per unit volume. See Annex D to do such transformation.

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6 Prediction from component cleanliness to system cleanliness (the bottom-up approach)

6.1 Principles

6.1.1 It is assumed that the assembly process does not introduce any particles into the components.

NOTE It is recognized that this assumption is not true in reality. However, it is possible to estimate the contamination introduced during assembly by measuring the actual cleanliness level of the assembled components and comparing the measured number of contaminant particles to the theoretical cleanliness level calculated in accordance with this Technical Report.

6.1.2 If the contamination brought in by the assembly process is known, it can be added to the contamination brought in by each component or subassembly assembled to make the relevant item.

6.1.3 The particulate contamination of a new hydraulic system upon its release from the manufacturing area is the sum of the particles brought in by each subassembly that makes up the system and by the filling fluid.

6.1.4 The particulate contamination of a subassembly is the sum of the particles brought in by each component that makes up the subassembly.

6.1.5 Thus, if the cleanliness level of each component (i.e. the bottom) and of the fluid is known, then the final cleanliness of the system (i.e. the top) can be theoretically determined or predicted. This is the cleanliness prediction (CP) method illustrated in Figure 4.

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Operating system	V_F; $N_{SF} = N_F + N_S$	$C_{SF} = (N_F + N_S) / V_F$ (N/ml)
↑		
Fluid	V_F; N_F	$C_F = N_F / V_F$ (N/ml)
↑		
System (empty)	$V_S = \Sigma V_{ci}$; $N_S = \Sigma N_{ci}$	$C_S = N_S / V_S$ (N/ml)
↑		
Components	V_C ; N_C	$C_C = N_C / V_C$ (N/ml)

Figure 4 — Relationship of cleanliness levels of components, empty system, fluid and operating system in an assembling process used in the cleanliness prediction (CP) method

6.2 Determination of the cleanliness level of a component

6.2.1 General

The cleanliness level of a component, C_C, can be expressed by a number of particles per unit wetted volume of component, that is N/ml, and can be measured or calculated from the cleanliness level of the parts it has been made of (see Annex E).

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