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Ships and marine technology — Hydraulic oil systems — Guidance for grades of cleanliness and flushing

Navires et technologie maritime — Circuits d'huile hydrauliques — Guide relatif aux degrés de propreté et de rinçage

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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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 2.

The main task of technical committees is to prepare International Standards. 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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 28521 was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, Subcommittee SC 3, *Piping and machinery*.

Ships and marine technology — Hydraulic oil systems — Guidance for grades of cleanliness and flushing

1 Scope

This International Standard specifies pipe cleaning and cleaning levels of hydraulic oil pipe systems. The cleaning of pipes and components in hydraulic oil pipe systems is essential for the trouble-free operation of hydraulic systems.

It indicates methods and equipment for the practical execution of the cleaning of specific parts of hydraulic systems with appurtenant components.

The purpose of the cleaning process is to remove installation dirt and to check that the piping and hydraulic system have been adequately cleaned.

The cleaning process of a system is considered a "washing through" process when the Reynolds number, R_e, $\leqslant$ 3 000, and a flushing process when $R_e \geqslant$ 3 000. The Reynolds number is an indicator of whether a fluid flow is considered laminar or turbulent.

This International Standard presupposes that the pipe sections of the hydraulic system have been cleaned partly by pickling and partly by mechanical cleaning. It is furthermore assumed that both dynamic and static components from system suppliers are adequately clean when delivered (see Clause 5).

The specifications given in this International Standard are supplementary to, and not a replacement for, the guidelines specified by the various manufacturers. The manufacturer's guidelines, where available, take precedence.

2 Normative references

The following referenced documents are indispensable for the application 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 3448, *Industrial liquid lubricants — ISO viscosity classification*

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

ISO 28523, *Ships and marine technology — Lubricating and hydraulic oil systems — Guidance for sampling to determine cleanliness and particle contamination*

3 Symbols

The following symbols are used throughout this International Standard.

A	(mm^2)	pipe cross-sectional area
βx	(—)	particle filtration ratio
d	(mm)	pipe diameter
Δp	(bar)	pressure drop
K_1	(—)	flushing-filter factor
R_e	(—)	Reynolds number
Q_1	(l/min)	flow rate of filter
Q_2	(l/min)	flow rate of system
v	(cSt)	viscocity
W	(m/s)	flow velocity

4 Recommended pipe cleaning levels

4.1 Pipe cleaning levels during/after prefabrication

4.1.1 Black-steel pipes and pipes of other material qualities showing oxide scale as a result of heating or welding

These should be cleaned internally after welding together of prefabricated pipes and fittings using either chemical cleaning (alkaline cleaning and pickling) or mechanical blow cleaning to achieve a cleanliness corresponding to Sa 2½ as specified in ISO 8501-1.

Steel shot should not be used because of the risk of adhesion by magnetism and subsequent rust seizure; copper (Cu) slag should be used instead. Sealing faces should be protected during the blow cleaning.

4.1.2 Precision-steel pipes and pipes of other material qualities, which are delivered, and remain, free of oxide scale (no heating or welding)

After cutting and careful deburring, pipes and fittings that are joined without being subjected to prior heating or welding processes, for example by means of clamping rings, should be cleaned by one of the following methods:

— chemically (using an alkaline cleaning process);

— blown through with pressurized air;

— by pulling through lint-free cloths.

4.2 Surface treatment

In order to maintain the afore-mentioned cleanliness of pipes and fittings until their mounting onboard, it is recommended to treat internal and external surfaces at the ends of the pipes and fittings with a suitable oil product. To prevent dust and sand entering the pipes and sticking to the surfaces, the pipe ends should be blanked off.

The applied oil product should not change the properties of the flushing or system oil.

4.3 Storage of prefabricated pipes and fittings

Cleaned and surface-treated prefabricated pipes and fittings should be blanked off and stored in dry, preferably controlled, conditions. If this is not possible, the pipes shall be protected against rain and venting should be secured on all surfaces. Inadequate storage conditions might necessitate additional cleaning and surface treatment.

5 Level of cleanliness

For pretested components and oils forming part of the system:

— Component suppliers shall be able to specify the level of cleanliness of the components delivered. This applies to suppliers of dynamic as well as static components.

— ISO/TR 10949 and ISO 18413 indicate methods according to which evaluation and documentation of the level of cleanliness can be carried out. In addition to information regarding the level of cleanliness at the time of delivery, the yard and the system supplier should agree in advance on the necessary level of cleanliness of the system oil and the cleaned system to achieve a long and reliable operation.

6 Assembly and installation of pipe system

It is important to avoid any welding, brazing, soldering or heating of the pipes (and production of oxide scales) when assembling and installing pipes. If this cannot be avoided, then the pipes in question shall be cleaned and protected again (repaired). In particular, it is important to remove soldering materials.

Protection covers should be removed as late in the installation process as possible. Preventing dirt (from the installation process) from entering the pipe system is crucial. PTFE sealing fluids and tape should be applied with great care.

7 Blow-through/pull-through of the system

Before connecting the pipe system to machines, panels, pump stations, etc., all pipes should be blown through with dry pressurized air and/or nitrogen. If this is not possible (because of the pipe dimension) then pulling through clean, lint-free cloths should clean the pipes.

The purpose of this is to remove loose dirt in the most efficient way and, at the same time, ensure that the pipes are dry internally (nitrogen helps eliminate water that has condensed in the pipes).

8 Description of coupling

8.1 Design phase

During the design phase, i.e. at the structuring of the hydraulic diagram, it is important to consider carefully how the complete system can be flushed in practical terms (including grouping).

When grouping off the pipe system, the following should be observed.

a) “Dead” areas are unacceptable during flushing (these can be avoided by changing the coupling points).

b) Circuits should always be connected in series.

c) Relevant coupling options should be considered (the objective being connection of uniform pipe diameters in order to avoid large pressure losses).

8.2 Other considerations

The following shall also be taken into account.

a) Components that might hinder a high flow velocity, or which might be destroyed by a high flow velocity, should be bypassed.

b) Built-in filter elements shall be removed before flushing.

c) Pump stations, assembled units and subcomponents that have not been pre-tested shall be flushed separately in case they are not delivered in a cleaned condition.

NOTE This also applies to pipe systems where space conditions on board do not allow flushing of the pipe systems installed.

d) It is important that sampling of oil during the actual flushing be carried out in a way that ensures a representative sample. Reference should be made to ISO 28523 and ISO 4021, which describe sampling from a dynamic system.

9 Leakage test

Before filling with flushing oil, the leak-tightness of the system can be checked in the following ways:

a) Connect the pipe system (bypass/blank off components), then pressurize in accordance with the directions of national standards, using clean, dry air or nitrogen, and perform external testing with soapy water or monitoring for pressure drop during a certain time.

b) After filling with the flushing oil, the leak-tightness of the system can be tested by means of shock or pressure testing (see Clause 11).

10 Filling with oil

For the choice of oil type and quality, see 12.3.

The filling procedure is as follows.

a) Connect the pipe system (bypass components).

b) Clean the tank in the portable pump-station and the power pack to a cleanliness level corresponding to the cleaning level of the components supplied to the system (see Clause 5).

c) Fill the system by pumping the oil through a filter until the tank is full.

The filter shall be capable of filtering the oil to a minimum of two ISO-codes below the cleanliness specified for the system, in accordance with ISO 4406. Care should be taken that air bubbles do not enter the system during the filling operation; if necessary, the system should be topped up and vented.

11 Shock testing/pressure testing

a) Connect the pipe system (bypass components). Ensure that it is completely filled.

b) Pressurize the pipe system up to the relevant testing pressure and relieve it again by opening the relief valve on the pump station. Repeat this procedure a minimum of 25 times, unless otherwise specified.

12 Flushing of yard-installed pipe system

12.1 Connection

Connect the pipe system (bypass/blank off components). Ideally, the use of a vibrating unit will be over a broad frequency range. It is appropriate to change the flow direction more than once during the flushing period.

12.2 Special pump units

Experience shows that very good results can be achieved when cleaning pipes using a hydraulic accumulator and a pulsation valve sending pressure/flow pulsations through the pipes.

In a pipe system with a small internal diameter, in which a turbulent flow can be difficult to achieve because of a large pressure drop, special gas/oil units can be used that fill the entire pipe system with gas and oil loads which are subsequently compressed; when these loads are released, the gas pockets expand, resulting in a turbulent oil flow.

12.3 Flushing filters

12.3.1 Filter capacity

The permanent filters of the systems should not be used for cleaning of flushing oil; instead, special flushing filters designed to increase the filter capacity to a predetermined extent during flushing may be used together with the portable pump station.

It is advisable to place filters on both the pressure line and the return line in order to reduce the total flushing time.

The choice of filter capacity should be made with the aim of achieving an acceptable service life for the filter element.

The service life is, all other things being equal, determined by the filter's contamination capacity.

It is difficult to determine the desired contamination capacity and to obtain information on the relevant contamination capacity from the manufacturers. For this reason, the flow capacity of the filter (expressed in l/min) is often used as the basis for achieving an acceptable service-lifetime.

The filter flow capacity, Q_1, is calculated by multiplying the flow capacity of the system, Q_2, by a factor of K_1, which normally varies between 2,5 to 3,5 for flushing filters. A high K_1 value is chosen for high-pressure systems and a low value is chosen for low-pressure systems.

The method of calculation for Q_2 is given in 12.3.3, and an example of its use given in Table 2.

A filter element which in a cleaned condition is capable of handling a flow rate of Q_1 at a pressure drop, Δp, of 0,3 bar, should be chosen according to the manufacturer's specifications.

Flushing filter elements shall be exchanged when the maximum Δp for a contaminated filter is reached during flushing (this is read from a pressure gauge or from a contamination indicator, if fitted).

The contamination indicator shall be of a type that gives a signal before the bypass valve opens. As it is impossible to calculate and obtain different filter capacities for varying flushing operations, in practice, the individual yards are encouraged, on the above basis and their own parameters, to calculate and use one or more "standard filters" that can be used within specific limits.

The following equation is proposed for calculation of choice of filter:

$$Q_1 = Q_2 \times K_1$$

where

$$Q_2 = W A$$

and

$$W = R_e/1\,000 \times v/d$$

$$A = \pi\,(d^2/4)$$

The values of Q_2, W, R_e, v, and d are explained in 12.3.2. Q_2 is also given in Table 2.

Since R_e can be fixed at, for example, 3 000, and v can also be kept constant by using flushing oil of a stadardized quality at a fixed temperature, only d and K_1 are variables.

Where pipes are of a relatively small diameter, K_1 is largest (high pressure systems), and vice versa (low pressure systems), the individual yard may find it convenient to determine a flushing filter capacity that is adequate for all general tasks at the yard.

12.3.2 Filtration characteristics and achievable level of cleanliness

The filtration characteristics of flushing filters should be chosen on the basis of the cleanliness level required by the system supplier, ie. the allowable cleanliness level (ACL) for the system in question. The ACL specifies an acceptable contamination level that is consistent with the contamination tolerance for the most sensitive system components and the desired service life. If the ACL is not specified, standard classifications according to ISO 4406 may serve as a guideline for the choice of the filter fineness; see Table 1.

For the relationship between filtration characteristics and flushing time, see 12.4.

Table 1 — ISO 4406 classifications as a guideline for choice of filter fineness

Examples of ship installations	Pressure	Flushing unit at start-up	Cleanliness on delivery after test run	Maximum allowable contamination	Typical filter service requirement
		ISO 4406	ISO 4406	ISO 4406	βx [a] > 75
Stabilizer with servo valves	> 160 bar	15/13/10	16/14/11	18/16/13	3 µm to 5 µm
Steering gear with variable pumps	> 160 bar	15/13/10	16/14/11	18/16/13	3 µm to 5 µm
Gantry crane with proportional valves	> 160 bar	16/14/11	17/15/12	20/17/14	5 µm to 10 µm
High-pressure winch with automatic tension	> 160 bar	16/14/11	17/15/12	20/17/14	5 µm to 10 µm
Hydraulic valve systems	> 160 bar	17/15/12	18/16/13	21/18/15	5 µm to 10 µm
Azimuth systems	> 160 bar	17/15/12	18/16/13	21/18/15	5 µm to 10 µm
Ramps, gates and doors	> 160 bar	17/15/12	18/16/13	21/18/15	5 µm to 10 µm
Proportional remote winch control	< 160 bar	17/15/12	18/16/13	21/18/15	5 µm to 10 µm
Variable propeller systems with servo valves	< 160 bar	17/15/12	18/16/13	21/18/15	5 µm to 10 µm
Variable propeller systems without servo valves	< 160 bar	18/16/13	19/17/14	21/18/15	10 µm to 20 µm
Bow and stern thrusters	< 160 bar	18/16/13	19/17/14	21/18/15	10 µm to 20 µm
Low-pressure winches and cranes	< 160 bar	18/16/13	21/17/14	22/19/16	10 µm to 20 µm

NOTE In general, find the component which has the finest level of cleanliness. For instance, a proportional valve typically has a cleanliness requirement of code 18/16/13. In order to maintain proper cleanliness, the service requirement will be 17/15/12, and for the flushing unit it will be 16/14/11.

[a] βx is defined in the following way: (number of particles added $\geqslant x$ µm)/(number of particles emitted $\geqslant x$ µm).

NOTE 1 Most filter manufacturers use the βx relationship, but other “classes” to illustrate filtration characteristics; International Standardization is available in this area (see ISO 16889).

NOTE 2 “Nominal Rating” and “Absolute Rating” are examples of other “classes”. For instance, 10 µm absolute rating in practice corresponds to $\beta 10 > 75$.

The guiding β value should be between 75 and 200. The use of filters with a β value higher than 75 is recommended, as higher β values shorten the total flushing time.

12.3.3 Flow velocities and capacities

The most effective flushing is achieved when the flow velocity is relatively high and/or the viscosity is relatively low, so that a turbulent flow is created in the pipe system during the flushing. Turbulent flows occur when the Reynolds number is greater than 3 000.

The Reynolds number is calculated using the following equation.

$$R_e = 1\,000 \times (W\,d)/v$$

Where $R_e > 3\,000$, the flow will always be turbulent. In order to achieve a thinner laminar boundary against the inner pipe wall, recommendations of $R_e \geqslant 4\,000$ can be used.

Moreover, flushing should be performed with a higher R_e value than that which the system will be subjected to during operation at normal service viscosity and maximum oil flow. Experience has shown that the flow velocity during flushing should be greater than twice the normal service speed, but always turbulent.

EXAMPLE 1 For flushing of a pipe system where $d = 40$ mm, a special flushing oil with $\nu = 27$ cSt is used at a temperature of 50 °C. To find the necessary capacity, Q_2, in l/min, where the system oil viscosity is ISO VG 68, use the following calculation:

$$Q_2 = W \times A$$

where

$$W = R_e / 1\,000 \times \nu / d \text{ (m/s)}$$

so in this example

$$W = 3\,000/1\,000 \times 27/40 = 2{,}025 \text{ m/s.}$$

The necessary capacity is calculated as follows:

$$Q_2 = 2{,}025 \times [\pi(d^2/4)]$$

$$Q_2 = 2{,}025 \times [3{,}141\,6 \times (0{,}001\,6/4)] = 0{,}002\,544\,7 \text{ m}^3\text{/s}$$

which can be expressed in l/min using the following conversion:

$$(0{,}002\,544\,7 \text{ m}^3\text{/s}) \times (1\,000 \text{ litres/m}^3 \times 60 \text{ s/min}) = 152{,}7 \text{ l/min}$$

which can be rounded to

153 l/min.

(See also Table 2 for given viscosity and pipe diameter.)

EXAMPLE 2 If the system oil ($\nu = 43$ cSt at 50 °C) is used for flushing, then $Q_2 \approx 244$ l/min.

EXAMPLE 3 If the system oil is only heated to 40 °C (which is not recommended), then $Q_2 \approx 385$ l/min. It can be seen, therefore, that the viscosity of the flushing oil is highly important in determining the necessary capacity.

For determining the necessary capacity, see Table 2.

12.3.4 Relationship between system types, filters and level of cleanliness

If the oil used for flushing (e.g. system oil) becomes dark and/or blurred after the flushing, then a chemical analysis should be performed to clarify the cause (e.g. oxidation or contamination with water).

Generally, the oil is considered unfit for use if

a) the viscosity has changed more than ± 15 %,

b) the water content exceeds 0,05 % mass fraction, or

c) the neutralization number is higher than 1,2 mg KOH/g.

This applies irrespective of whether the particle counting shows satisfactory results.

12.4 Flushing oil

Either system oil or a special flushing oil can be used for flushing. By using the latter, it can be assured by the supplier that the flushing oil is compatible with the system oil and that it does not attack the system components (especially gaskets). When system oil is used, there is a risk that water may be present in the oil after flushing. If this is the case, the water should be removed.

Equipment for checking for water in the oil is often available onboard newer systems. Special flushing oils have a cleaning effect on sticky particles without attacking sealing materials and without having insufficient properties in regard to lubrication, corrosion protection, etc.

The flushing oil should, especially when flushing without having adequate possibilities for heating the oil (hard frost), have a relatively low kinetic viscosity, for example, approximately 15 cSt at 40 °C (for further information see ISO 3448), and have a relatively high specific weight. The flushing oil shall meet the requirements of the system supplier.

“Zinc additive oil” can be used if the pump (bearings) is designed for it. However, this type of oil can, especially if it is contaminated with water, form breakdown products that may block fine filters.

The flushing oil is filled through a filter according to the same guidelines and filtration requirements, etc. that apply to the filling of system oil. See Clause 13, item c).

12.4.1 Temperature

Heating the flushing oil will promote the removal of hard-packed installation dirt on the pipe walls or similar. In addition, the viscosity will be reduced, which is conducive to achieving of a turbulent flow.

However, it should be ensured that the flushing oil's

a) viscosity is kept higher than the minimum required for the pump in the flushing rig, and

b) temperature is kept below 60 °C to prevent oxidation of the oil. However, if the oil becomes unfit for use after being used for flushing, an increase of the oil temperature is acceptable, but not to a temperature higher than 80 °C.

Rapid heating of the oil can be achieved by means of the overflow valve. With the correct flow volume during the actual flushing, it is normally possible to maintain the flushing oil's temperature. At low ambient temperatures and, in particular, at high wind speeds, it may be necessary to

c) supplement the heating with a heating element (using a maximum of 1 w/cm2 for stagnant oil and a maximum of 1,5 w/cm2 for circulating oil),

d) cover pipes with tarpaulins or similar protective coverings.

12.4.2 Pressure drop in pipes

To achieve the desired flow velocity, especially in pipes with a small internal diameter, it might be necessary to have a higher pressure available during flushing.

The pressure drop, Δp, in bar, is calculated as follows.

$$\Delta p = (W^2/d) \times 0{,}195\,9$$

12.4.3 Values for achievement of turbulent flow

Table 2 — Necessary oil capacity, Q_2, flow velocity, W, or pressure drop, Δp, to achieve $R_e = 3\ 000$

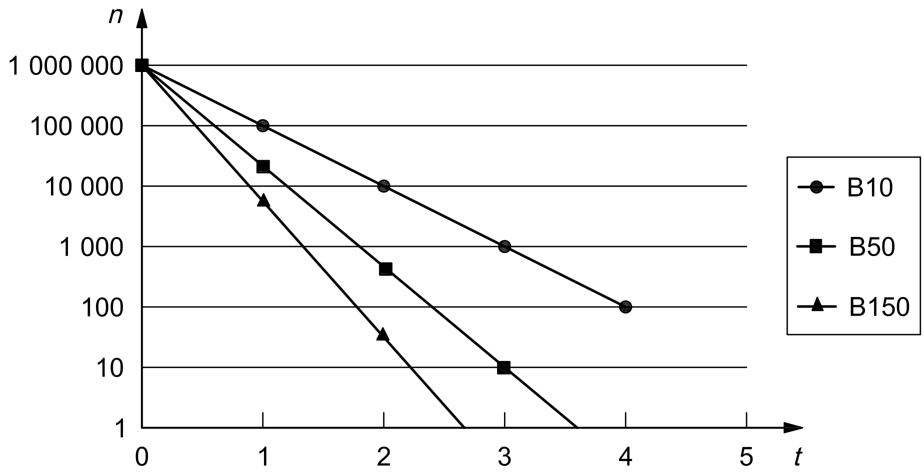
Internal pipe diameter d mm		Kinematic viscosity, ν, in cSt at flushing oil temperature												
		10	15	20	25	30	35	40	45	50	55	60	65	70
4	Q_2 in [l/min]	6	8	11	14	17	20	23	25	28	31	34	37	40
	W in [m/s]	7,50	11,25	15,00	18,75	22,50	26,26	30,01	33,76	37,51	41,26	45,01	48,76	52,51
	Δp in [bar/m]	2,76	6,20	11,02	17,22	24,80	33,76	44,09	55,81	68,90	83,37	99,21	116,44	135,04
5	Q_2 in [l/min]	7	11	14	18	21	25	28	32	35	39	42	46	49
	W in [m/s]	6,00	9,00	12,00	15,00	18,00	21,00	24,00	27,01	30,01	33,01	36,01	39,01	42,01
	Δp in [bar/m]	1,41	3,17	5,64	8,82	12,70	17,29	22,58	28,57	35,28	42,68	50,80	59,62	69,14
6	Q_2 in [l/min]	8	13	17	21	25	30	34	38	42	47	51	55	59
	W in [m/s]	5,00	7,50	10,00	12,50	15,00	17,50	20,00	22,50	25,00	27,51	30,01	32,51	35,01
	Δp in [bar/m]	0,82	1,84	3,27	5,10	7,35	10,00	13,07	16,54	20,41	24,70	29,40	34,50	40,01
7	Q_2 in [l/min]	10	15	20	25	30	35	40	45	49	54	59	64	69
	W in [m/s]	4,29	6,43	8,57	10,72	12,86	15,00	17,15	19,29	21,43	23,58	25,72	27,86	30,01
	Δp in [bar/m]	0,51	1,16	2,06	3,21	4,30	6,30	8,23	10,41	12,86	15,56	18,57	21,73	25,20
8	Q_2 in [l/min]	11	17	23	28	34	40	45	51	57	62	68	74	79
	W in [m/s]	3,75	5,63	7,50	9,38	11,25	13,13	15,00	16,88	18,75	20,63	22,50	24,38	26,26
	Δp in [bar/m]	0,34	0,78	1,38	2,15	3,10	4,22	5,51	6,98	8,61	10,42	12,40	14,55	16,88
10	Q_2 in [l/min]	14	21	28	35	42	49	57	64	71	78	85	92	99
	W in [m/s]	3,00	4,50	6,00	7,50	9,00	10,50	12,00	13,50	15,00	16,50	18,00	19,50	21,00
	Δp in [bar/m]	0,18	0,40	0,71	1,10	1,59	2,16	2,82	3,57	4,41	5,34	6,35	7,45	8,64
12	Q_2 in [l/min]	11	17	23	28	34	40	45	51	57	62	68	74	79
	W in [m/s]	1,67	2,50	3,33	4,17	5,00	5,83	6,67	7,50	8,33	9,17	10,00	10,84	11,67
	Δp in [bar/m]	0,05	0,10	0,18	0,28	0,41	0,56	0,73	0,92	1,13	1,37	1,63	1,92	2,22
15	Q_2 in [l/min]	21	32	42	53	64	74	85	95	106	117	127	138	148
	W in [m/s]	2,00	3,00	4,00	5,00	6,00	7,00	8,00	9,00	10,00	11,00	12,00	13,00	14,00
	Δp in [bar/m]	0,05	0,12	0,21	0,33	0,47	0,64	0,84	1,06	1,31	1,58	1,88	2,21	2,56
20	Q_2 in [l/min]	28	42	57	71	85	99	113	127	141	156	170	184	198
	W in [m/s]	1,50	2,25	3,00	3,75	4,50	5,25	6,00	6,75	7,50	8,25	9,00	9,75	10,50
	Δp in [bar/m]	0,02	0,05	0,09	0,14	0,20	0,27	0,35	0,45	0,55	0,67	0,79	0,93	1,08
25	Q_2 in [l/min]	35	53	71	88	106	124	141	159	177	194	212	230	247
	W in [m/s]	1,20	1,80	2,40	3,00	3,60	4,20	4,80	5,40	6,00	6,60	7,20	7,80	8,40
	Δp in [bar/m]	0,01	0,03	0,05	0,07	0,10	0,14	0,18	0,23	0,28	0,34	0,41	0,48	0,55
32	Q_2 in [l/min]	45	68	90	113	136	158	181	204	226	249	271	294	317
	W in [m/s]	0,94	1,41	1,88	2,34	2,81	3,28	3,75	4,22	4,69	5,16	5,63	6,09	6,56
	Δp in [bar/m]	0,01	0,01	0,02	0,03	0,05	0,07	0,09	0,11	0,13	0,16	0,19	0,23	0,26

Table 2 (*continued*)

Internal pipe diameter d mm		Kinematic viscosity, v, in cSt at flushing oil temperature												
		10	15	20	25	30	35	40	45	50	55	60	65	70
40	Q_2 in [l/min]	57	85	113	141	170	198	226	255	283	311	339	368	396
	W in [m/s]	0,75	1,13	1,50	1,88	2,25	2,63	3,00	3,38	3,75	4,13	4,50	4,88	5,25
	Δp in [bar/m]	0,00	0,01	0,01	0,02	0,02	0,03	0,04	0,06	0,07	0,08	0,10	0,12	0,14
50	Q_2 in [l/min]	71	106	141	177	212	247	283	318	354	389	424	460	495
	W in [m/s]	0,60	0,90	1,20	1,50	1,80	2,10	2,40	2,70	3,00	3,30	3,60	3,90	4,20
	Δp in [bar/m]	0,00	0,00	0,01	0,01	0,01	0,02	0,02	0,03	0,04	0,04	0,05	0,06	0,07
65	Q_2 in [l/min]	92	138	184	230	276	322	368	414	460	506	551	597	643
	W in [m/s]	0,46	0,69	0,92	1,15	1,38	1,62	1,85	2,08	2,31	2,54	2,77	3,00	3,23
	Δp in [bar/m]	0,00	0,00	0,00	0,00	0,01	0,01	0,01	0,01	0,02	0,02	0,02	0,03	0,03
80	Q_2 in [l/min]	113	170	226	283	339	396	452	509	566	622	679	735	792
	W in [m/s]	0,38	0,56	0,75	0,94	1,13	1,31	1,50	1,69	1,88	2,06	2,25	2,44	2,63
	Δp in [bar/m]	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,01	0,01	0,01	0,01	0,02
100	Q_2 in [l/min]	141	212	283	354	424	495	566	636	707	778	848	919	990
	W in [m/s]	0,30	0,45	0,60	0,75	0,90	1,05	1,20	1,35	1,50	1,65	1,80	1,95	2,10
	Δp in [bar/m]	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,01	0,01
125	Q_2 in [l/min]	177	265	354	442	530	619	707	795	884	972	1 061	1 149	1 237
	W in [m/s]	0,24	0,36	0,48	0,60	0,72	0,84	0,96	1,08	1,20	1,32	1,44	1,56	1,68
	Δp in [bar/m]	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
150	Q_2 in [l/min]	212	318	424	530	636	742	848	954	1 061	1 167	1 273	1 379	1 485
	W in [m/s]	0,20	0,30	0,40	0,50	0,60	0,70	0,80	0,90	1,00	1,10	1,20	1,30	1,40
	Δp in [bar/m]	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

12.5 Flushing times

The flushing time is reduced if the temperature and flow velocity are kept relatively high (see Table 2) and also at increased filtration efficiency.



Key

t time

n number of particles

Figure 1 — The βx relationship's influence on flushing time and the achievable level of cleanliness

A coarse filter (see Figure 1) requires a long flushing time without achieving a particularly high level of cleanliness. The general guideline is that the higher the βx relationship, all other things being equal, the shorter the flushing time.

An efficient filter must therefore be chosen in order to reduce the flushing time to an acceptable length. The extra cost of the more efficient filter is outweighed by the savings in flushing time. Thus, the flushing time depends on the available possibilities for promoting the flushing process.

However, the flushing must continue until the filter element chosen no longer shows an increasing loss in pressure Δp (indicated by, for instance, a contamination indicator). If necessary, the filter element is changed. If too much water is present [(see 12.3.4 b)], the flushing oil should be changed. Then the flushing oil's level of cleanliness is checked. The level of system in question must observe the level specified by the system supplier or, if such data are not available, determined according to Table 1.

12.6 Methods for checking the cleanliness level

The cleanliness level achieved by means of flushing can be established and/or documented in various ways. In the following subclauses, selections of methods are described. Method 4, perhaps supplemented with methods 1 and 3, is recommended for use at the yards to establish the cleanliness level in connection with the practical execution of the flushing process.

The true level of cleanliness of a system is reflected not only by the speed whereby a given level of cleanliness is achieved by flushing, but also by how much the level of cleanliness drops when the flushing filter is disengaged from the circuit.

The level at which contamination stabilizes itself is called the system’s true cleanliness level.

12.6.1 Methods based on evaluation of changes in pressure

Method 1: Evaluation of Δp, pressure drop across filter

By observing the Δp pressure gauge in connection with the sequential exchange of the flushing filter element in order to establish when the Δp level no longer increases in relation to $\Delta\pi$ for a new clean element (indicated by e.g. a contamination indicator), it is possible during the flushing to establish when the required level of cleanliness is reached, provided that well-established flushing filters in accordance with 12.3 are used.

It is emphasized that the condition for using this method is the correct choice of flushing filter (see 12.3). In particular, the filtration characteristics are of great significance (use βx).

