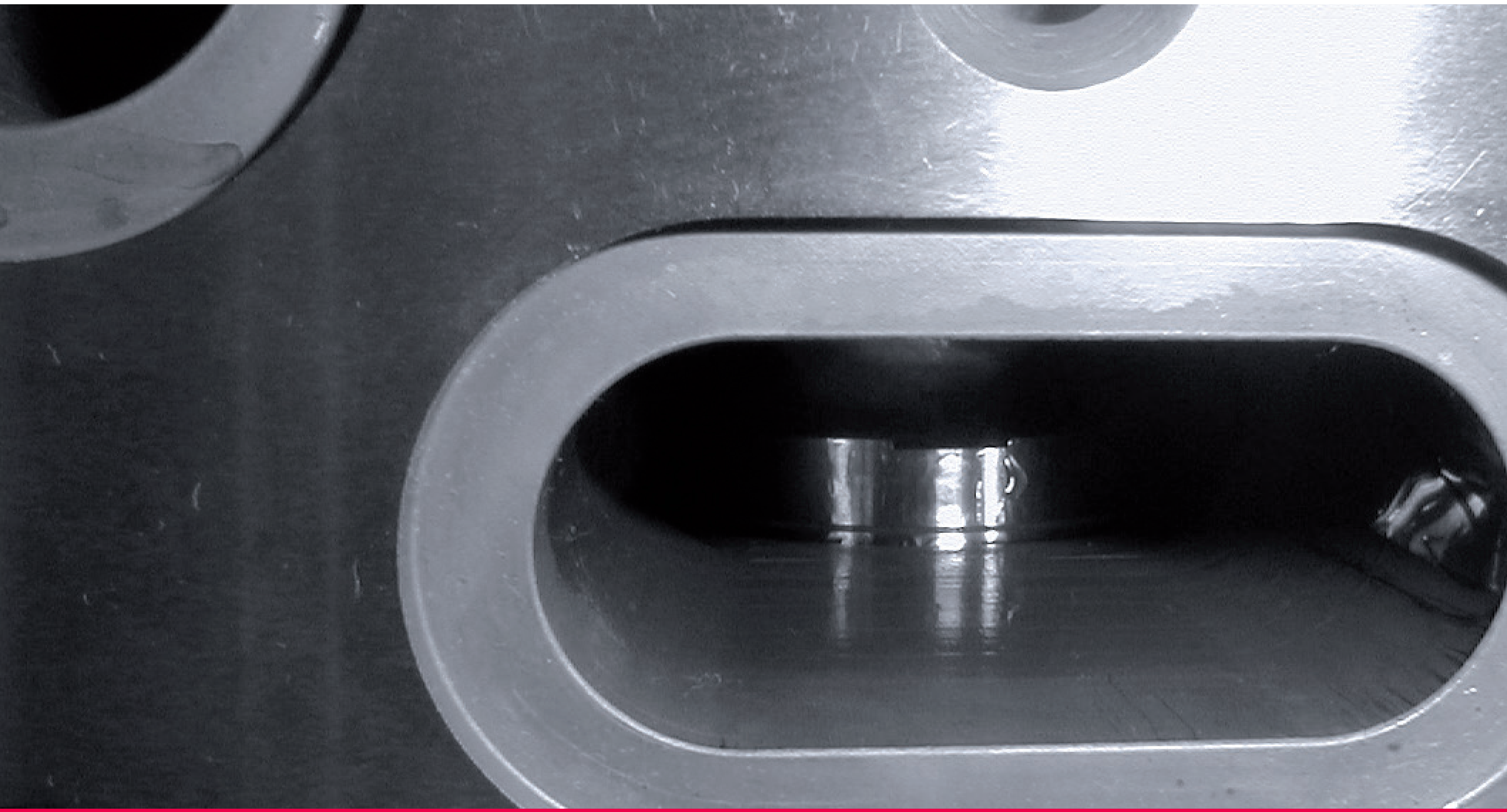
Everllence B&W
two-stroke
marine engines



Filtration and flushing strategy

Filtration handbook

Contents

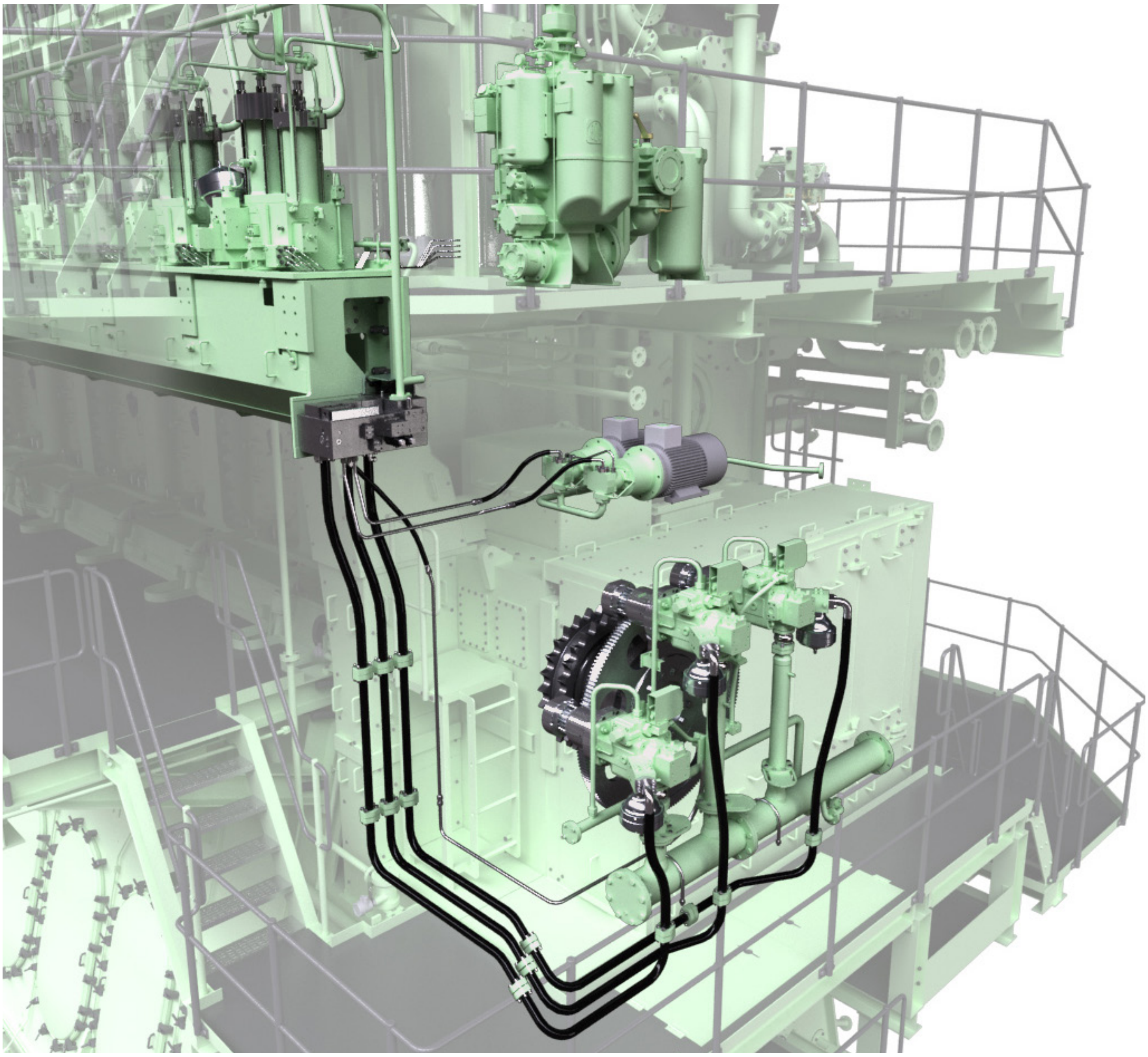
Filtration handbook

Introduction

The exacting tolerances in today's hydraulic systems require tight control of the system contamination.

Experience has shown that impurities found in the system originate from the installation and from new oil.

If not removed, particles will cause damage to valves, pumps, and bearings and, eventually, lead to malfunction of the system and increased wear on hydraulic components. To avoid this and reduce flushing time to a minimum, the whole system must be absolutely clean before filling up with oil and starting up the engine.



Purpose of this paper

It is vital that hydraulic system installations are carried out in accordance with best practices, as described in this paper.

This will prevent difficulties during start-up of the equipment and reduce the risk of suffering damage to the system.

By following the guidelines given in this paper, a quicker and more efficient flushing process is achieved.

NOTE: The guidelines in this document are for reference only. For more detailed information regarding flushing, reference is made to quality specifications from Everllence.

Definitions and standards

Everllence specifies the use of the international standard ISO 4406 when defining the quantity of solid particles in the fluid used in a given hydraulic power system.

ISO 4406

The range numbers are allocated according to the number of particles per 100 ml of the fluid sample. A step ratio of two between the upper and lower limits for the number of particles per 100 ml has been adopted. This step ratio has been chosen to keep the range numbers within a reasonable limit and to ensure that each step is meaningful, see Table 1.

NAS 1638

NAS 1638 is an older American standard developed in 1964 by the National Aerospace Standard to define classes of contamination in aircraft components and hydraulic fluids.

The classes refer to the maximum number of particles in 100 ml in different size classes. Table 2 shows the concept of the NAS 1638 code. It is based on a fixed particle size distribution of the contaminants in the size range >5 to >100 µm. From this basic distribution, a series of classes covering clean or dirty levels has been defined.

The interval between each class is double the contamination level, see Table 2.

The standard officially became invalid in 2001, therefore Everllence specifies the use of the international standard ISO 4406.

ISO 4406 chart

	Number of particles per 100 ml	
Range number	**More than**	**Up to and including**
24	8,000,000	16,000,000
23	4,000,000	8,000,000
22	2,000,000	4,000,000
21	1,000,000	2,000,000
20	500,000	1,000,000
19	250,000	500,000
18	130,000	250,000
17	64,000	130,000
16	32,000	64,000
15	16,000	32,000
14	8,000	16,000
13	4,000	8,000
12	2,000	4,000
11	1,000	2,000
10	500	1,000
9	250	500
8	130	250
7	64	130
6	32	64

Table 1: The ISO 4406 standard is a decisive tool defining the quantity of solid particles in the fluid in installations designed by Everllence

Class	**Maximum particles/100 ml in specified size ranges (µm)**				
	5-15	**15-25**	**25-50**	**50-100**	**>100**
0	125	22	4	1	0
0	250	44	8	2	0
1	500	89	16	3	1
2	1,000	178	32	6	1
3	2,000	356	63	11	2
4	4,000	712	126	22	4
5	8,000	1,425	253	45	8
6	16,000	2,850	506	90	16
7	32,000	5,700	1,012	180	32
8	64,000	11,400	2,025	360	64
9	128,000	22,800	4,050	720	128
10	256,000	45,600	8,100	1,440	256
11	512,000	91,200	16,200	2,880	512
12	102,400	182,400	32,400	5,760	1,024

Table 2: Maximum number of particles in a 100 ml sample for different particle size classes according to NAS 1638

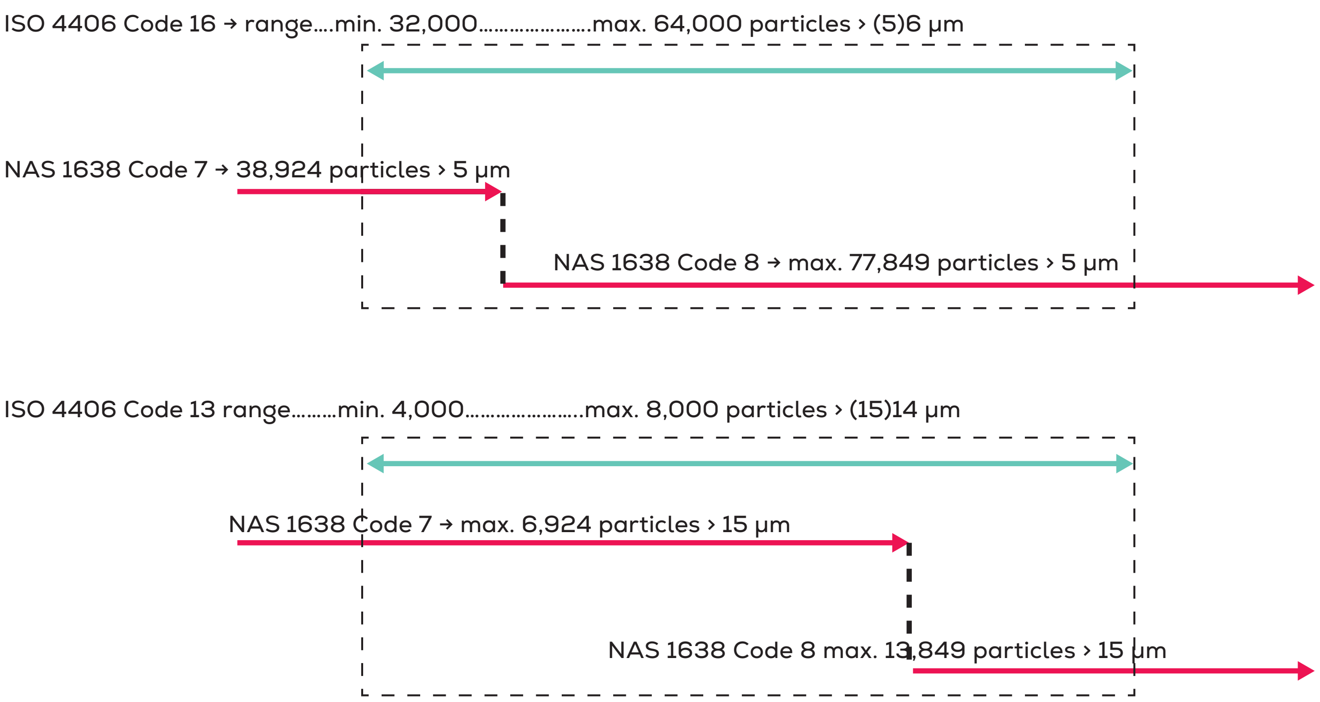
Cleanliness requirement – ISO 4406 versus NAS 1638

The recommended standard for defining the oil cleanliness level is ISO 4406.

If NAS 1638 is used, the number of particles in a 100 ml sample, which are larger than 6 and/or 14 µm must be within the range specified by ISO 4406.

Fig. 1 shows a comparison between ISO 4406 and NAS 1638 standards regarding the cleanliness levels required for ME systems. Fig. 2 shows the filtration requirement for ME systems and provides a more detailed description of the ISO 4406 code terminology.

Cleanliness level required for ME system - ISO 4406 Code xx/16/13



* Number of particles defined for 100 ml sample

** "max 64,000 particles › (5)6 µm" = (5) µm acc. to ISO 4406(1987–1999), 6 µm acc. to ISO 4406 (1999 →→)

Fig. 1: ISO 4406 vs. NAS 1638 - cleanliness level required for ME/ME-C engines

Filtration ability

There are many different ways to make filter elements. Although they have the same size, interface, and flow capacity, they can be very different regarding their ability to clean the oil from large and small particles.

Many producers and users tend to mention “Absolute” and “Nominal” filtration ratings when specifying and talking about filters.

The absolute rating of a filter refers to the diameter of the maximum particle, which can pass through the filter. Typically, the filtration rating in a datasheet is refered to as absolute 3 µm, 6 µm, 10 µm, etc.

However, no matter how precise the filtration media is made, it is impossible to ensure that all open areas fulfil these sizes. Particles are also not perfectly symmetrical in shape. They may be small in one direction, but large in another direction.

The absolute rating can also be seen as a non-realistic definition, since no particles larger than the rating may pass through the filter, which is not correct. In this respect, the nominal rating is more realistic, since it indicates the filter's ability to prevent the passage of solid particles greater than the rating together with an efficiency percentage.

For the nominal rating, no industry standard has been made for this efficiency percentage, which makes it difficult to compare similar filters from different suppliers. They might define their filters with different filtration efficiencies. Due to this, Everllence prefers to use the beta ratio (β) when defining and talking about filtration ability.

The beta ratio is a method based on laboratory multi-pass tests, where a specified contaminate of known sizes is added regularly in measured quantities to the oil, which is pumped through the filter. Oil samples are taken at timed intervals at the inlet and outlet of the filter. Hereafter, the particles in each sample are measured and counted. Based on these results, the beta ratio is determined by dividing the number of particles of a particular size in the inlet with the number of particles of the same size in the outlet flow.

For example, if the number of 6 µm particles are halved from inlet to outlet, the beta ratio is 2/1 = 2. This also means that the filtration efficiency is 50% and that 50% of 6 µm particles are retained in the filter element.

How is a filter defined?

The following parameters are decisive for a filter definition:

- oil flow
- system pressure
- pressure drop
- operating viscosity
- filtration ability.

Minimum requirement of cleanliness level – ME hydraulic system

ISO 4406, Code XX/16/13

Particles › 14 µm

Particles › 6 µm

Particles › 4 µm

This corresponds to a quantity interval of:

Number of particles › 4 µm, cleanliness code omitted

Number of particles › 6 µm from 32,000 to 64,000 in 100 ml sample.

Number of particles › 14 µm from 4,000 to 8,000 in 100 ml sample.

Fig. 2: Filtration requirement for ME/ME-C/ME-B

ISO 4406 chart

Range number	Number of particles per 100 ml	
	More than	Up to and including
24	8,000,000	16,000,000
23	4,000,000	8,000,000
22	2,000,000	4,000,000
21	1,000,000	2,000,000
20	500,000	1,000,000
19	250,000	500,000
18	130,000	250,000
17	64,000	130,000
16	32,000	64,000
15	16,000	32,000
14	8,000	16,000
13	4,000	8,000
12	2,000	4,000
11	1,000	2,000
10	500	1,000
9	250	500
8	130	250
7	64	130
6	32	64

Fluid maintenance

It is recommended that all fluid stored in sealed containers, or delivered from an oil company, is filled to the main tank through a filter cartridge with a filtration ability of $\beta_6 = 200$. See the example, Fig. 3, and Table 3 for more information about this specific filtration ability.

Example of filtration ability β_6, valid for particles > 6 µm.

$$\beta_6 = \frac{8{,}000{,}000 \text{ particles} > 6\ \mu m \text{ at filter inlet}}{40{,}000 \text{ particles} > 6\ \mu m \text{ at filter outlet}} = 200 \rightarrow \beta_6 = 200$$

From ISO 4406 Code 23 to ISO 4406 Code 16 after the first filter pass

New oil is dirty!

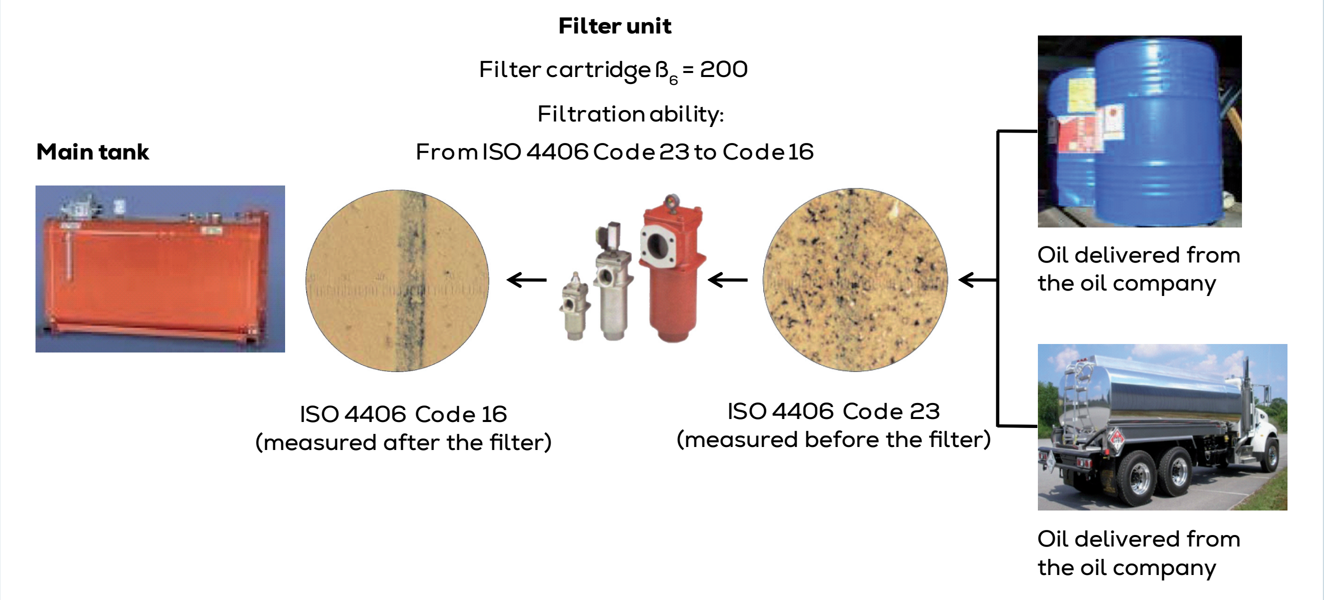


Fig. 3: Filtration ability of filter cartridge, $\beta_6 = 200$

Example: Contaminants amount to be removed

We assume that the particles, which should be removed, are cubic in shape.
For example, 6 µm => (0.0006 x 0.0006 x 0.0006) x particle amount in specific ISO 4406 code (100 ml) x 10,000 = cm³/1,000 liter oil tank. Table 3 can be used to define the filter-cartridge dirt and contaminants capacity.

ISO 4406 Code xx → Code xx	Max. contaminants amount to be removed in cm³/1,000 liter oil tank
Code 23 to Code 16 for particles > 6 µm (new oil at delivery date)	17.1
From Code 19 to Code 16 for particles > 6 µm	1.0
From Code 16 to Code 13 for particles > 14 µm	6.6

Table 3: Dirt and contaminants capacity of filter cartridge

Filling new oil to a tank

Data sheets of filter elements often mention retention capacity in gram at a certain pressure drop, since the test method is to weigh the filter elements after testing.

To use this for sizing a filter element, we can assume that 1 gram = 1 cm^3.

Steel and rust particles are heavy, but normally there are fewer of these particles compared to the lighter dust and cloth particles

Example: How is the correct filter cartridge size chosen?

Steps to follow

- Oil amount of 48,000 liter must be moved to a hydraulic tank.
- Pump equipment (flow): 200 l/min. → 12 m^3/h
- Oil should be cleaned from ISO 4406 Code 19 to ISO 4406 Code 16 for particles › 6 µm = 1.0 cm^3/m^3 (Table 3).
- Contaminants › 6 µm should be removed, i.e., 48 m^3 x 1.0 cm^3/m^3 = 48 cm^3 (from a look-up in Table 4: Filtertype 250 and 6 µm).

Conclusion

- Filter element: 0250 DN 6 BN/HC/-V – see Table 4 and Table 5 for detailed filter specifications.
- Filtration time: 48,000/200 = 240 min → 4 hours.
- Final cleanliness level: ISO 4406 Code 16 (for particles › 6 µm).

0250 DN 010 BN/HC /-V

Size
0160, 0250, 0400

Type
DN

Filtration rating µm
BN/HC: 3, 6, 10, 25
W/HC: 25, 50, 100, 200 (on request)

Filter material
BN/HC
W/HC

Supplementary details
V = FPM seals, filter suitable for rapidly biodegradable oils and phosphate esters (HFD-R)

Fig. 4: Data for filter element

3.2.1 Element specifications

Filter type	ISOMTD contamination retention capacity in g at Δp = 5 bar for BN/HC elements			
	3 µm	6µm	10µm	25µm
160	27.5	29.3	33.1	36.7
250	46.0	49.0	55.2	61.3
400	76.2	81.3	91.4	101.5

3.2.2 Filter surface area W/HC

Filter type	Filter surface area
160	2,750 cm^2
250	4,400 cm^2
400	6,730 cm^2

4. FILTER SPECIFICATIONS

Filter type	Port	Element size	Weight [kg] with element
160	G 1 ¼	0160 DN...	10.3
250	G 1 ½	0250 DN...	11.6
400	DN 38 *	0400 DN...	13.0

* Flange SAE 1 1/2"; 3000 psi

Table 4: Filter element specification and filter surface area, respectively
Table 5: Filter specification

Cleanliness requirement

The cleanliness level for the lubricating oil used for flushing the main engine must comply with ISO 4406 Code xx/19/15.

The cleanliness level for the lubricating oil used for flow cleaning the ME system must comply with ISO 4406 Code xx/16/13.

However, if using an ME-filter with a filtration ability of β_6 = min. 8, it is possible to clean the oil from ISO code xx/19/15 to ISO code xx/16/13 in a single pass through the filter. Such a filter is often installed in the redundancy part of the ME filter arrangement and known as a super-fine filter (SFF).

Using this filter gives the opportunity to begin flushing of the ME-system when the cleanliness level is minimum ISO 4406 Code xx/19/15, measured before the ME-filter. When the oil cleanliness level complies with this, flushing of the main engine and ME-system can be performed in parallel.

The oil must be circulated longer during flushing, since particles entrapped in the system will be loosened, affecting the cleanliness of the oil.

We recommend to follow the flushing procedures from Everllence.

General flushing conditions

When preheating is available, Everllence recommends preheating the oil to a temperature of 60-65°C.

To ensure a sufficiently turbulent flow in the system, the oil flow velocity must as a minimum reach a Reynolds number higher than 3,000.

Fig. 5 and Fig. 6 show nomograms, which can be used for estimating the flow and the flow velocity, respectively, required to reach a Reynolds number higher than 3,000.

Formula for calculating the Reynolds number:

$$Re = \frac{(V \times D)}{\eta} 1{,}000$$

Re – Reynolds number
η – kinematic viscosity (cSt)
V – flow velocity (m/s)
D – inner pipe diameter (mm)

Example:

Reynolds number	3,000
Inner pipe diameter (0.3 m)	300 mm
Oil viscosity	112 cSt

Calculation of minimum flow velocity:

$$V = \frac{\left(\frac{Re}{1{,}000}\right) \times \eta}{D} = 1.12 \text{ m/s}$$

Calculation of minimum pump flow:

$$Q = D^2 \frac{(\pi)}{4} \times 1.12 \times 60{,}000 = 4{,}750 \text{ l/min}$$

Use of flushing equipment

For filling and topping up, it is recommended to use a filter cartridge with a filtration ability of β_6 = 200.

For flushing, a filtration ability of minimum β_{10} = 75 is needed, however, Everllence recommends using a filter with a minimum filtration ability of β_6 = 75.

For so-called "offline" filters, a minimum filtration ability of β_6 = 75 is recommended, and a minimum filtration ability of β_{10} = 75 is needed.

Using the ME-filter for flushing is recommended. First, the backflushing oil must be returned to a separate backflushing tank and then back to the main tank via a β_6 = 200 filter cartridge.

Everllence recommends using a purifier during flushing. A portable vibrator or hammer can be used on the outside of the lube oil pipes to loosen impurities in the piping system.

It is also recommended to circulate oil through the system at maximum pump capacity, but not higher than the maximum capacity of the filters.

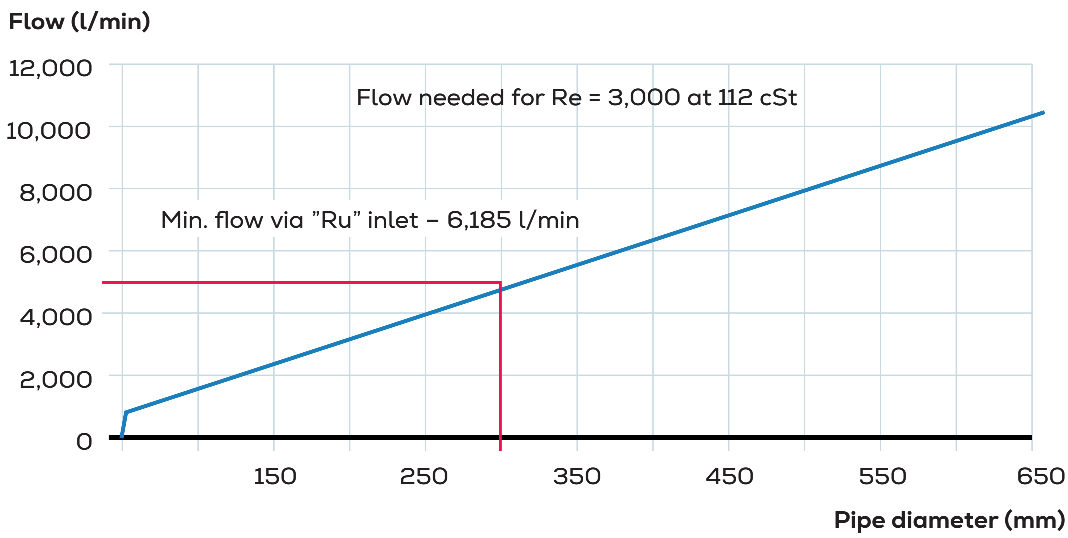


Fig. 5: Flow velocity nomogram

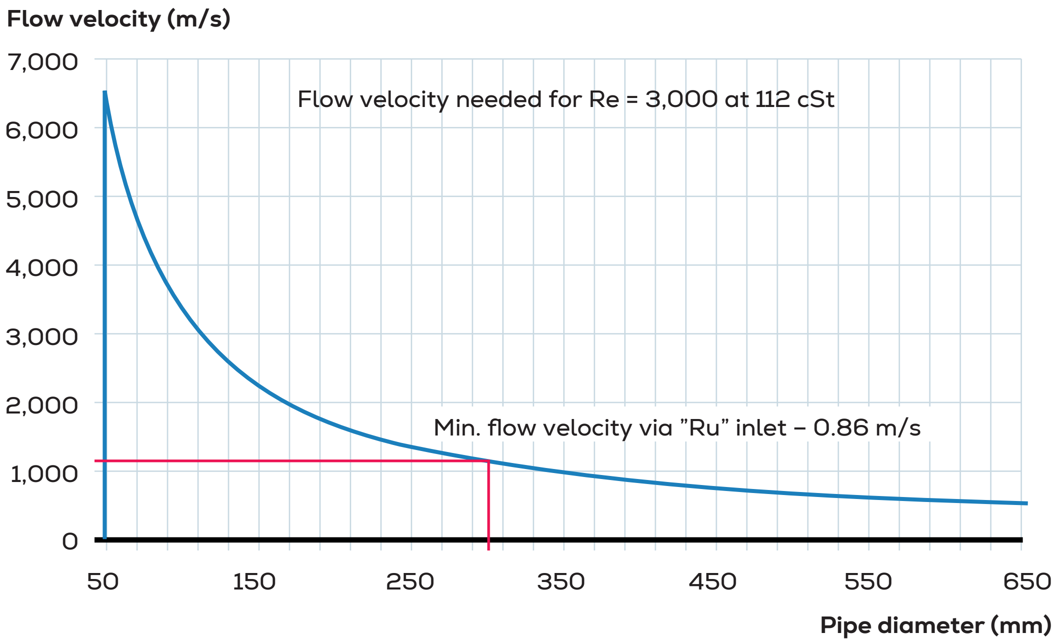


Fig. 6: Flow velocity nomogram

Treatment of tank

Each single surface of the tank, horisontal and vertical, must be cleaned as described below:

- mechanically remove any slag (and other impurities) after welding
- remove all visible impurities by cleaning
- treat scale on the surface with a descaling agent
- if rust is found, treat the surface with de-rust agent
- use a vacuum cleaner to remove small particles from the surface and corners
- wash the surface with grease-dissolving liquid.

To provide protection until the system is filled with oil, cleaned areas must be protected with antirust agent immediately after cleaning. The agent must be of a type that can be mixed with lubricating oil.

Cleaning of the oil tank
New or repaired components are often the carriers of contamination. Before final assembly, this built-in contamination must be removed from blocks, pipes, oil tank (Fig. 7), and any other component prepared for use in the system.

Treatment of pipes and additional installations

Hydraulic pipes should only be welded if absolutely necessary. If so, each welding point must be placed so that mechanical removal of any welding slag is possible.

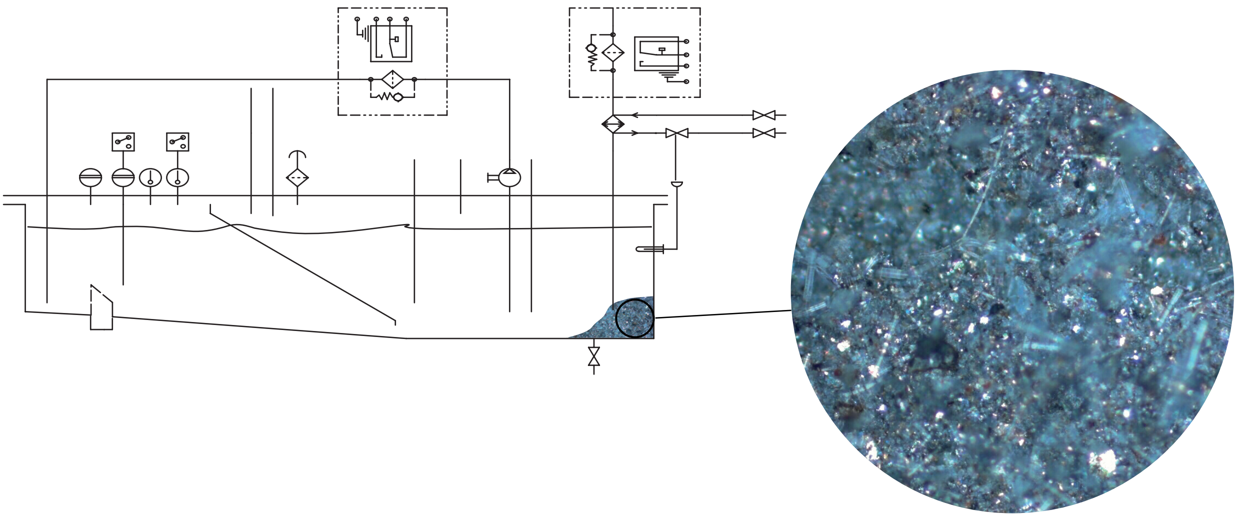
If possible, all pipe dimensions larger than ø25 mm (externally) should be fitted with flanges. Flanges and pipes must always follow the requirements of the class.

All cut surfaces must be ground, and the inner surface must be smooth. Any slag (and other impurities) must be removed mechanically. Remove all visible impurities by cleaning.

Scale on the inner surface must be treated with a descaling agent. If rust is found, the inner surface must be treated with de-rust agent. Use compressed air to remove small particles from the surface. Degrease all pipes using a grease-dissolving liquid. Pipes that have been treated with acid must be neutralised or washed in a combination of cleaning/neutralising agents.

Cleaned areas must be protected with an antirust agent immediately after cleaning to provide protection until the system is filled with oil. The agent must be mixable with lubricating oil.

When a pipe is treated with an internal protection agent, open connections must be blanked off (remember to remove all temporary gaskets and plugs, before assembly).



Contaminated 'clean' oil tank

Fig. 7: Empty contaminated hydraulic oil tank

Everllence advices to use a filter for filling of the oil tank on the test bed, at the shipyard, and on board.

Use a filter unit for simultaneous filling and cleaning (filtration during filling) and a filter cartridge with a beta rating of β_6 = 200, see Fig. 8.

For flushing of the system, please follow the quality specifications of Everllence.

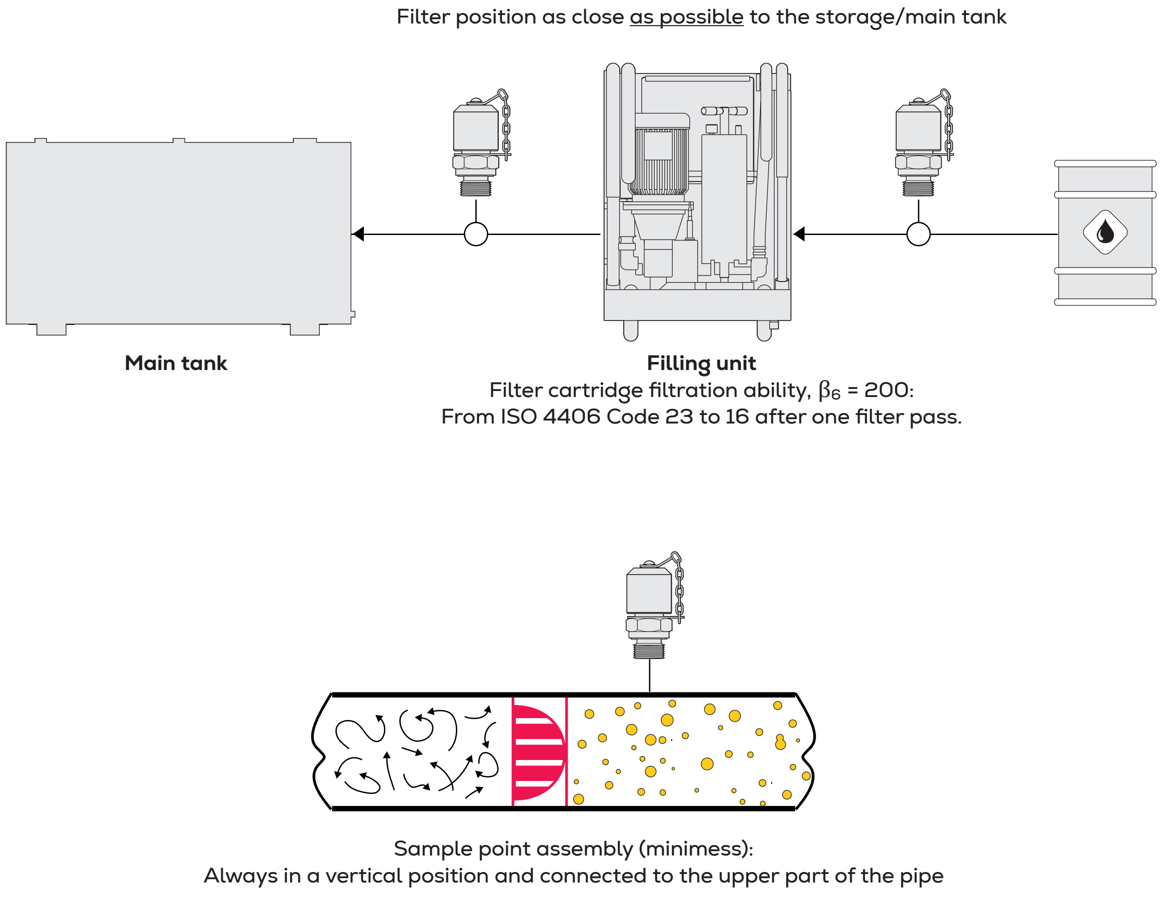


Fig. 8: Filling of hydraulic oil tank

Flushing procedure for ME-installations when using the standard ME-filter (redundancy filter).

For newer installations, an ME-filter which meets Everllence's specifications in the Extended filtration concept may be used, for example, ME filters such as the Filtrex DACV-FL or the Boll & Kirch 6.49/8.49. Here the main filter is ß6 = 8, and the required oil filtration can be done without any changes to the filter.

The time required to clean the ME system to ISO 4406 Code xx/16/13 cleanliness level can be greatly reduced by fitting a filter cartridge with a filtration ability of minimum $\beta_6 = 8$ to the ME redundancy filter and then directing the main lube oil flow through this filter. Fig. 9 shows the use of a $\beta_6 = 8$ filter cartridge and the operation.

It is recommended to apply the described configuration on all new installations on test bed, during quay trial and sea trial, and the following 14 days.

After this period, the ME lube oil flow can be switched back to pass through the main filter (Pos. 106) for normal engine operation.

This solution is time saving for the crew and has no negative effects on the service life of the redundancy filter.

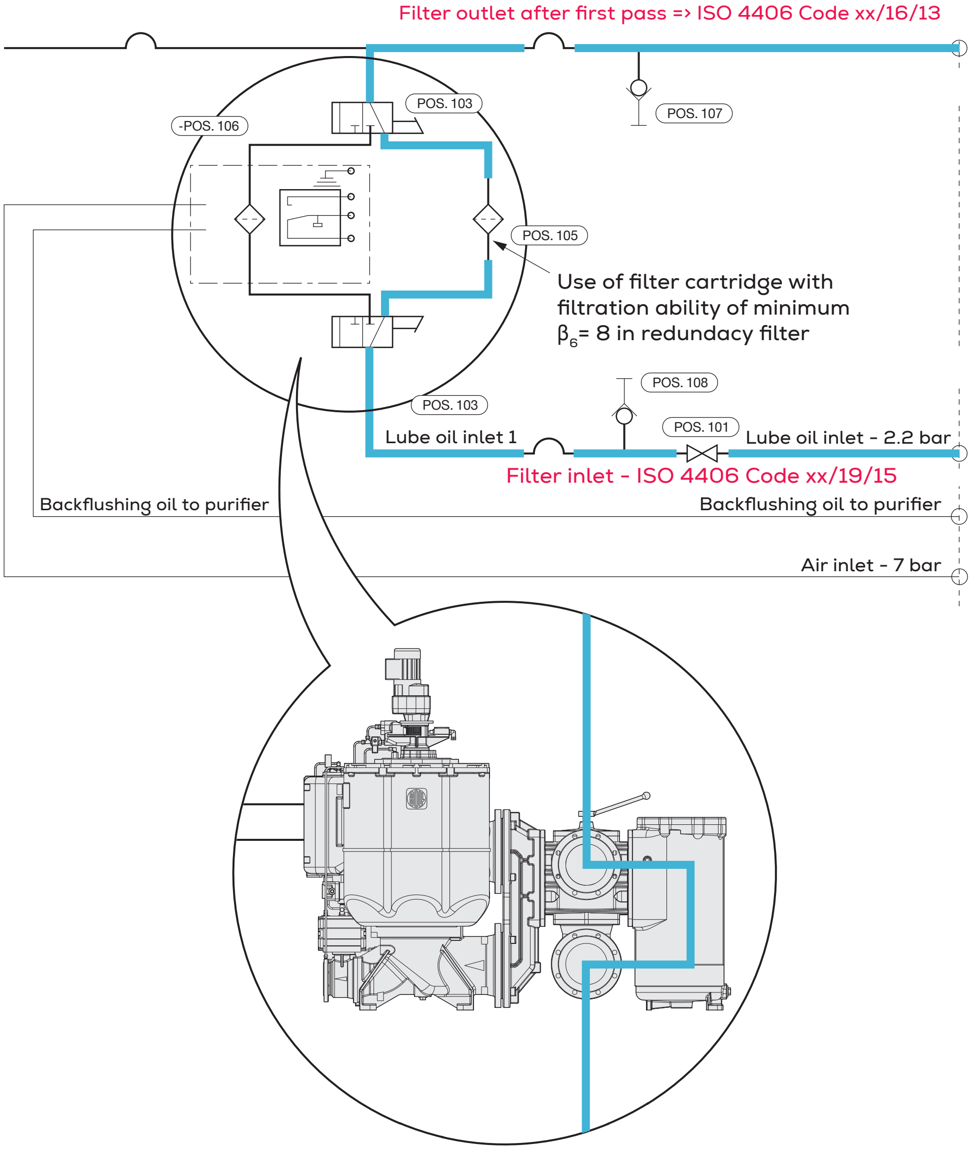


Fig. 9: Flushing through ME redundancy filter fitted with a filter cartridge with high-filtration ability

Topping-up of main tank

Valid on test bed and for installations in service
All fluid delivered from an oil company must be filled into the tank through a filter cartridge with a filtration ability of β_6 = 200.

As mentioned, this is not only important to prevent difficulties during start-up, but also when topping up the main tank for installations in service, see Fig. 10 and Fig. 11.

Unlimited topping-up of the main tank without the above filter will result in increased wear of valves, pumps, and bearings and will, eventually, lead to malfunction of the systems.

For installations without the necessary filling equipment, the rules described in the following must be observed.

The cleaning efficiency of the system and the release of particles from the system increases when using a new oil or when partly refilling the system with new oil.

Therefore, you will see that the number of particles caught in the filter system increases in the period after refilling with new oil, independent of whether filtered new oil was added or not.

The cleaning additives in a new oil simply work better than in an old oil.

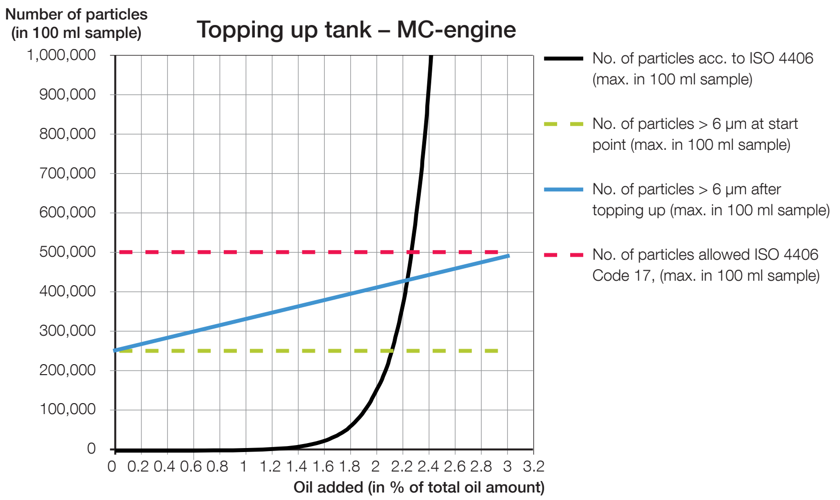


Fig. 10: Information valid for installations in service, max. 3% of tank capacity per day

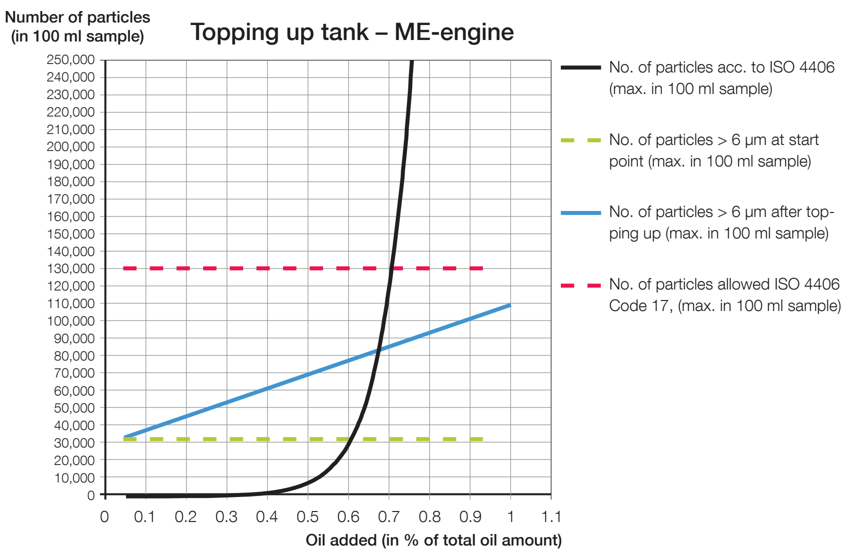


Fig. 11: Information valid for installations in service, max. 1% of tank capacity per day

Temporary filters

A temporary filter can be used between the fuel injection valve actuator (FIVA) main valve and the FIVA pilot valve (Fig. 12), and also between the high-pressure supply (HPS) pump and the pilot valve for pump control. However, the filters must be removed after sea trial.

The reason is that the filter provides an extra protection of all control valves. These require a high oil cleanliness since the first hours of engine running will release particles that the flushing did not catch, as illustrated in Fig. 13.

In 2010, the same type of Hydac sandwich filter was installed on ELFI B3-45 for two months of testing in service. As Fig. 14 shows, the test result was positive with no performance change recorded.

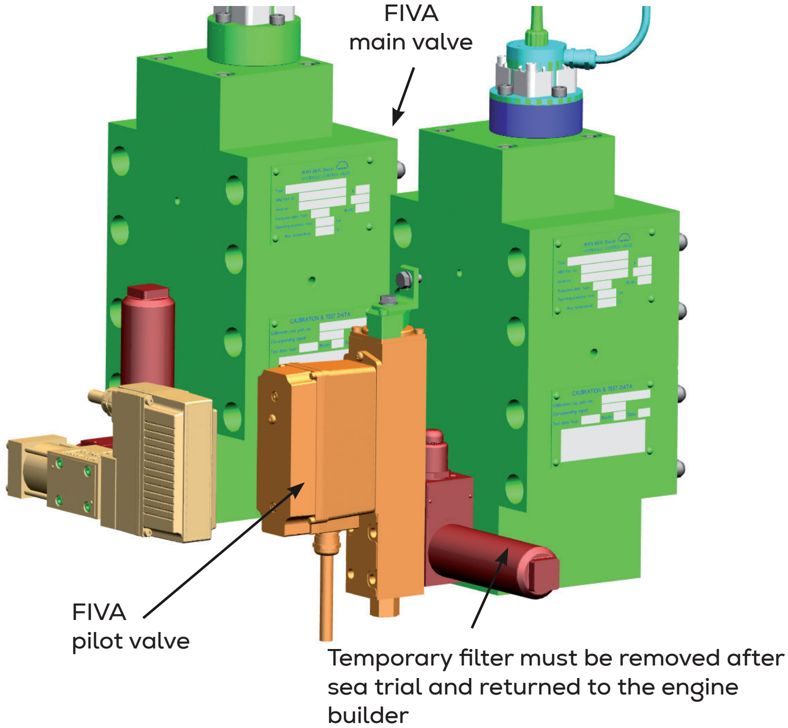


Fig. 12: FIVA unit with temporary filter

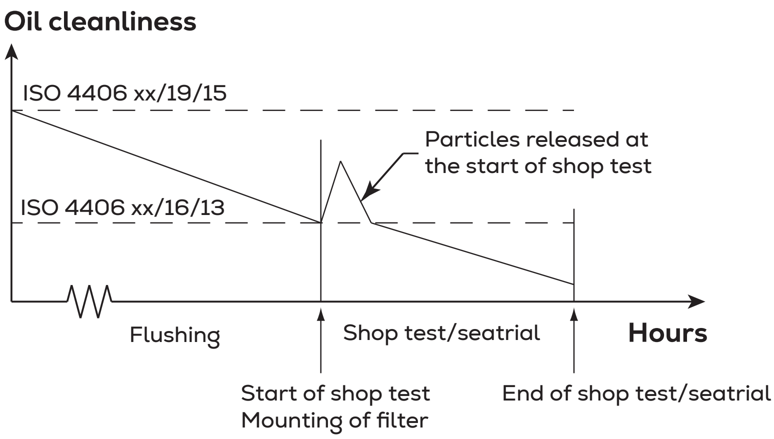


Fig. 13: Oil cleanliness as a function of time in use

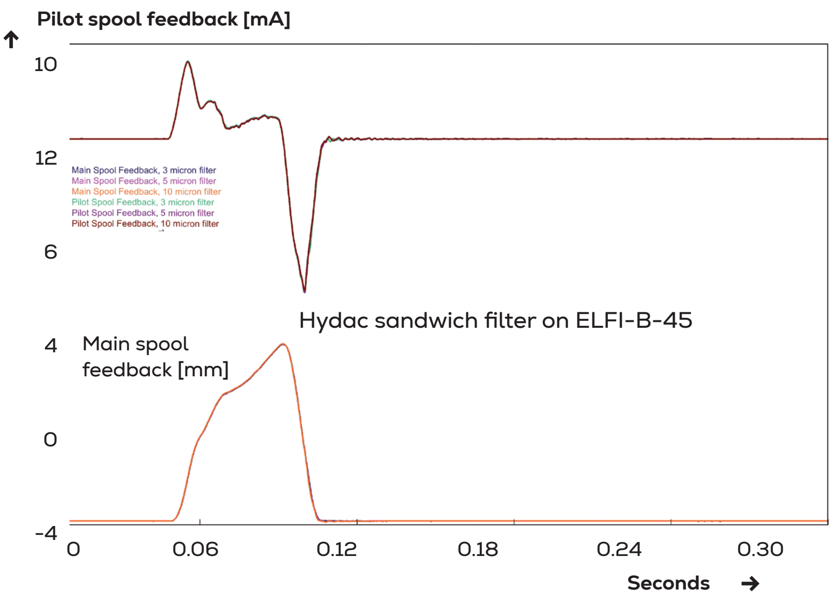


Fig. 14: The Hydac sandwich filter has been tested successfully without any performance change on ELFI-B-45 at the Everllence research centre in Copenhagen

Safety screen filter at multiway valves

I 2019, we introduced multiway valves like FIVA, electronic fuel injection (ELFI), electronic valve actuation (ELVA), and proportional exhaust valve actuator (PEVA) with a safety screen filter in the oil line for controlling the proportional valve (Fig. 15).

As Fig. 16 shows, the safety screen is a small filter strainer with a mesh size of 100 µm, which minimises the risk of larger particles entering and disturbing the function of the controlling proportional valve.

After a service test of almost 6,000 running hours, the safety screen filter was inspected and large particles were found (Fig. 17), which could have resulted in a malfunction of the valve.

All multiway valves equipped with a safety screen filter will need an inspection and cleaning of the filter strainer every 6,000 running hours, or approximately once a year.

Service Letters SL2025-768 and SL2021-709 contain additional information about the safety screen filter, ordering of spare parts, or obtaining the complete safety screen filter as a retrofit.

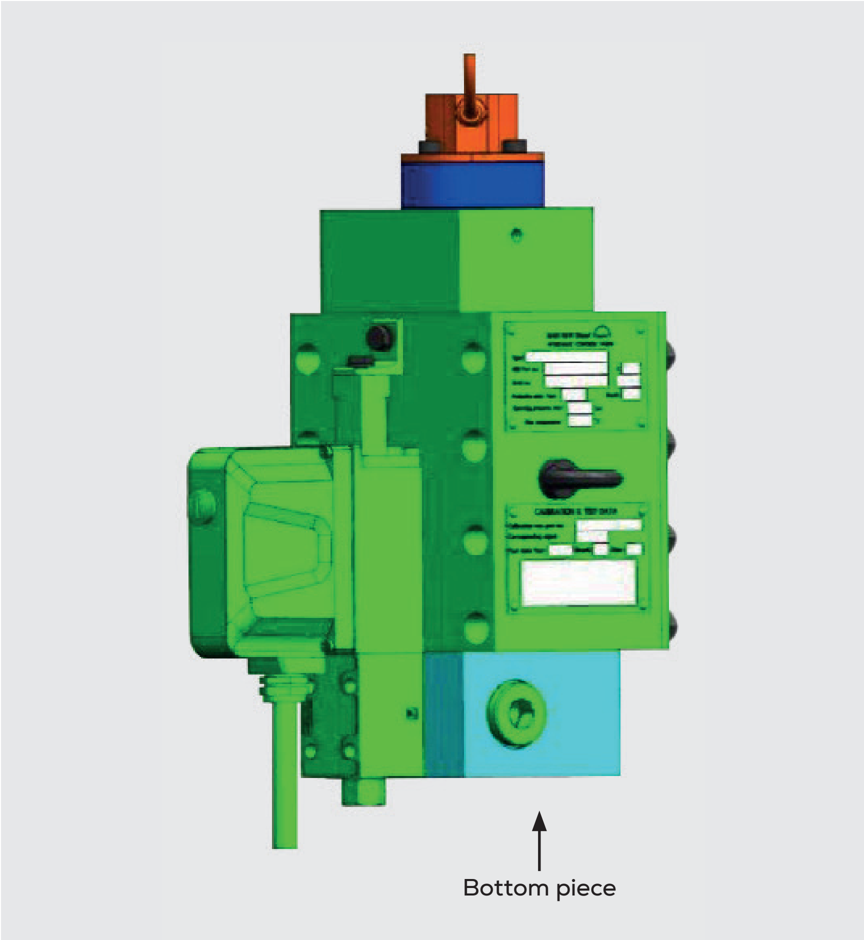


Fig. 15: FIVA with new bottom piece for permanent safety screen filter

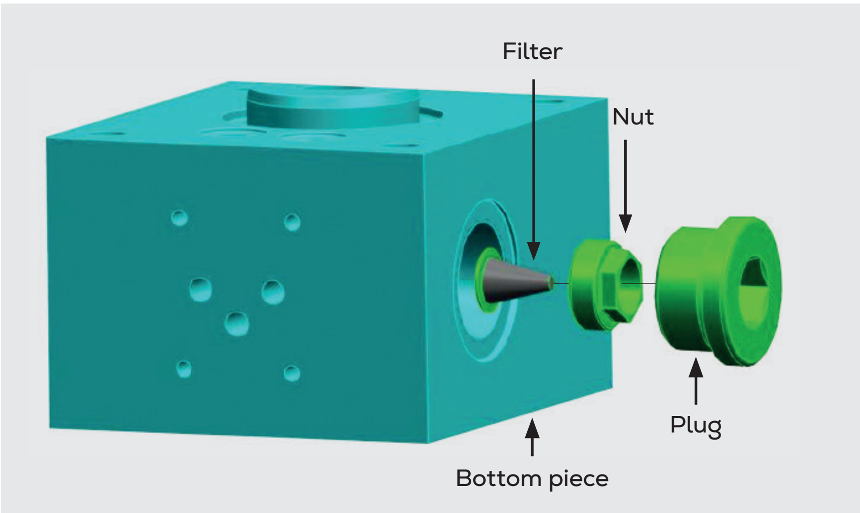


Fig. 16: New bottom piece showing the safety screen filter placement and assembly order

Fig. 17: Safety screen filter with large particles

How to define contamination level?

Cleanliness of hydraulic oil is normally examined with the laser method. However, this is not a suitable method for system oil, as it is black and contains soot, small water droplets, air bubbles, etc. The laser method (ISO 11500) counts these as particles, but they do not harm the engine components. The microscope method removes the soot, etc. and merely considers actual particles. Everllence therefore recommends to use the microscope method (ISO 4407).

Results show that the microscope method measures 4-6 cleanliness classes below the laser method for used oil samples.

When lube oil samples are sent ashore for analysis, Everllence recommends that a particle count is also performed regularly on the ME hydraulic system oil according to ISO 4407, which is particle counting with the microscope method.

A filter diaphragm with all contaminants from a 100 ml sample must be prepared. In the ME system, the recommended sample point positions are diagram Pos. 340 or Pos. 425 in the P2 line. Minimess sample points at the ME-filter inlet and outlet are also recommendable.

Only clean sample bottles should be used to reduce interference with contaminants from the bottles. Use the bottles cleaned and validated according to ISO 3722 and BS 5540.

Using a vacuum pump, a representative sample of hydraulic fluid, usually 100 ml, is drawn from the system preheated to 70°C, through a laboratory membrane filter disc (Fig. 18). The filter disc is 47 mm in diameter and with a filter mesh size of 1.2 μm.

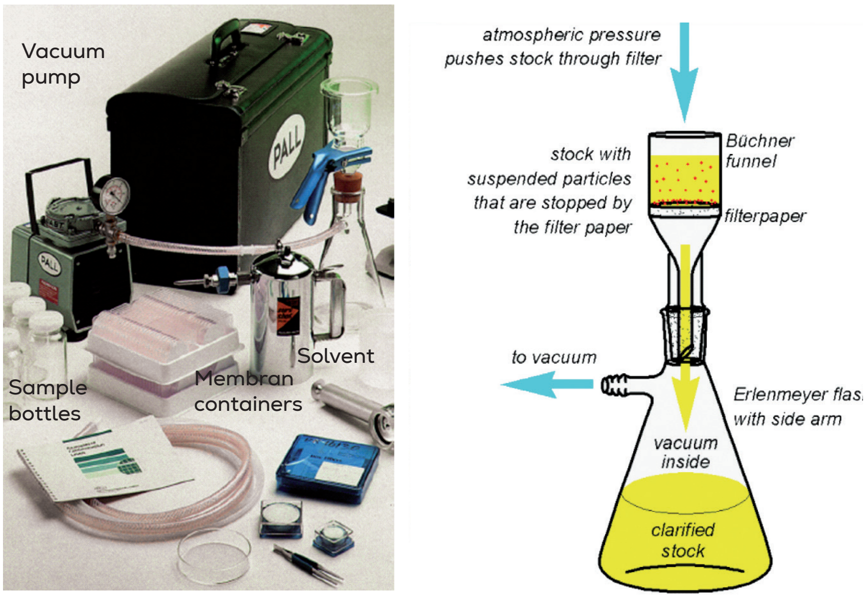


Fig. 18: How to collect contaminants for examination

All contaminants larger than 1.2 μm are collected on the surface of the filter disc. Residual sample fluid is washed from the filter disc using a suitable solvent which has been filtered through a 1.2 μm filter mesh. The membrane filter disc is transferred to a suitable and protected container.

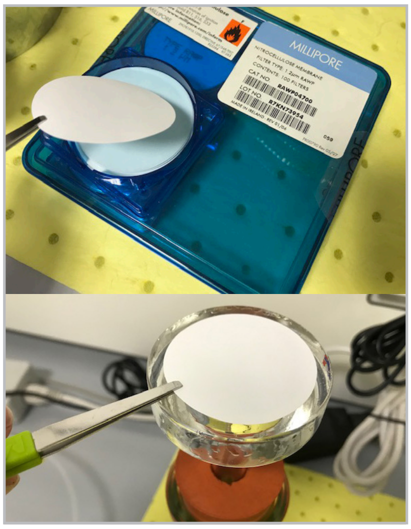
Fig. 19: Magnifier and comparator

Analyse the membrane filter disc under microscope and compare a view on a prepared filter diaphragm with the "comparator" (Fig. 19) picture with the same magnification. It is recommended to use a comparator book for this analysis.

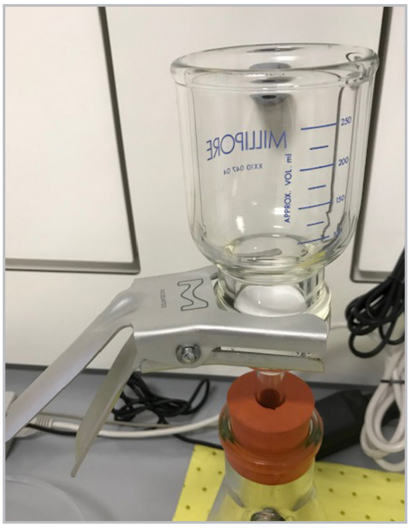
Oil analysis procedure

1. Heat oil samples to around 70°C in an oven. This usually takes one hour. The heating of oil samples are important to be able to draw the oil though the filter discs.

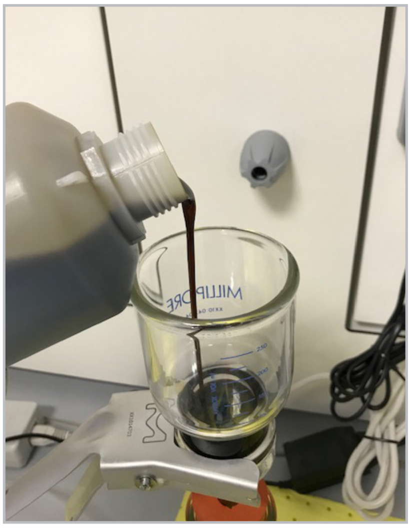
2. Prepare the test equipment.



3. Use forceps to place a 1.2 µm filter disc at the top of the funnel.



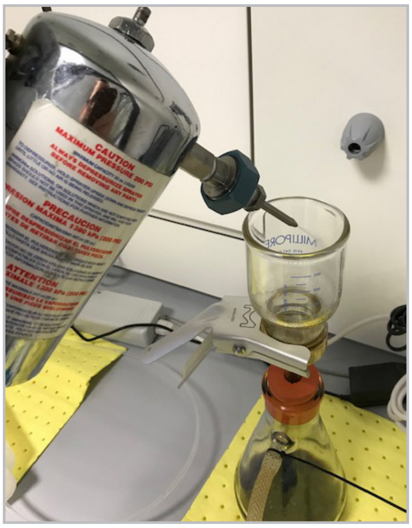
4. Clamp the measuring glass on the top.



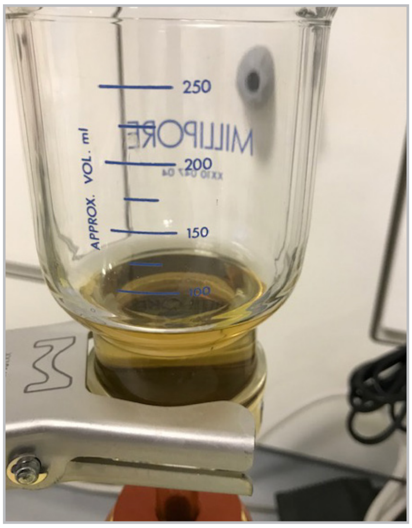
5. Take a well-heated oil sample and shake it thoroughly for half a minute. Remove the screw cap and fill the measuring glass to the 100 ml mark.

6. Start the vacuum pump and the oil will be drawn through the filter disc to the bottle below.

   Stop the vacuum pump when the oil is in the bottle.



7. Spray solvent/benzine onto the sides of the measuring glass and wait a minute for the solvent to dissolve the black soot particles.



8. Start the vacuum pump and the solvent/benzine will be drawn through the filter disc. Stop the vaccum pump afterwards and re-move the clamp together with the measuring glass.

9. Use forceps to place the filter disc in a suitable container.

   Now the filter disc is ready for ex-amination under the microscope.

Normally, the filter disc will visually look fairly clean since our eyes cannot see particles smaller than 40 µm. However, sometimes it is possible to determine whether the cleanliness is okay or not before analysing the filter disc under the microscope.

Fig. 20: Example of too dirty filter disc

Air amount in lubricating oil

In addition to maintaining a clean lubricating oil, another important aspect is deaerating the oil, i.e. minimising the amount of air. A high air content will decrease the efficiency of the hydraulic system, and increase cavitation and wear of the hydraulic components.

It is the ship designer's responsibility to ensure that the air amount present in the oil (xair), which is pumped into the main engine by the main lubricating oil pumps, does not exceed a maximum of 1.5%. This must be confirmed on sea trial with the engine running at 100% load.

The formula for calculating the air content:

$$x_{air} = (1 - \frac{V_{final}}{V_{init}}) \cdot 100\% < 1.5\%$$

V_{init} and V_{final} are two volumes of an oil sample measured with a 21 hours interval, as described in the following procedure.

Collect an oil sample from the low-pressure main supply line on the main engine, downstream the deaerating nozzle shown in the diagram of the main lubricating oil system. The oil sample must be collected using a container similar to the one shown in Fig. 21.

First, note the volume of the initial oil sample. Second, evaluate the sample volume again after 24 hours, after which it can be assumed that there is no air in the final oil sample.

Besides the tank design considerations described next, one way to minimise the air content is by ensuring that the oil level in the tank never drops below the minimum level.

Considerations regarding the lubricating oil bottom tank design

The following recommendations for the design of the lubricating oil bottom tank are based on specific functions required for two-stroke combustion engines. The functions are briefly outlined here:

- Prevent the main lubricating oil pumps from drawing in air by complying with the suction condition requirements set by classification societies and SOLAS
- Contain the oil volume necessary to avoid a too high oil circulating rate
- Settle solid particles that will be removed by the centrifuges
- Deaerate and degas the lubricating oil
- Storage tank for the total volume of lubricating oil.

The bottom tank is placed below the crankcase oil pan to facilitate the oil flow from the crankcase outlets. To avoid bedplate distortions, the tank must be designed with a symmetrical cross-section.

As Fig. 22A shows, a ship often has a cofferdam below the lubricating oil bottom tank.

When there is no cofferdam (Fig. 22B), the lubricating oil outlet from the main engine

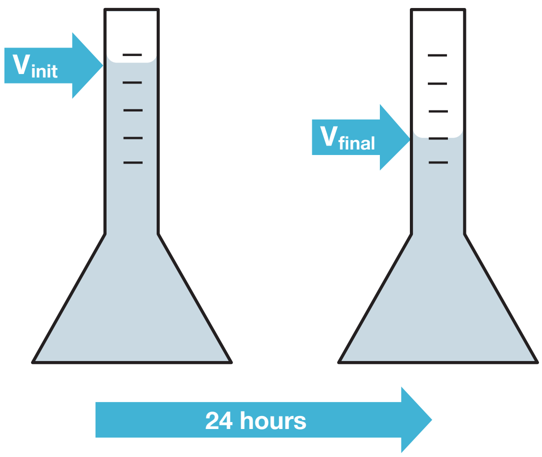


Fig. 21: Oil sample container, and examples of initial and final oil sample volumes

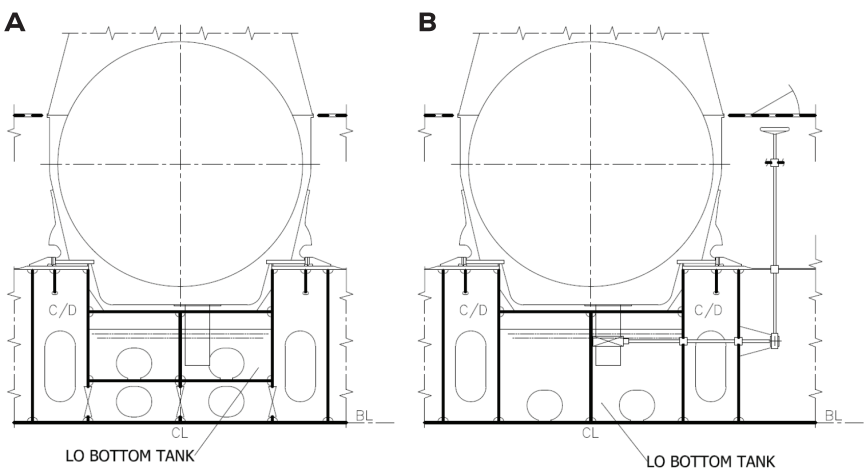


Fig. 22: A) Cofferdam below the lubricating oil (LO) bottom tank and B) No cofferdam below the bottom tank, and valves in oil outlets

can be equipped with valves, if required by the classification society. A valve arrangement in the main engine lubricating oil outlet must include an emergency suction arrangement from the engine oil drain pan, to be used when the valves are closed.

When designing the lubricating oil bottom tank, including the oil flow pattern, remember that the main objective is to allow enough time for solid particles to settle and for oil deaeration. Fig. 23 and Fig. 24 show examples of lubricating oil flow patterns in the lubricating oil bottom tank.

The circulation of lubricating oil in the bottom tank must prevent stagnant zones where sludge can accumulate.

Labyrinth oil circulation will automatically prevent quick oil displacement.

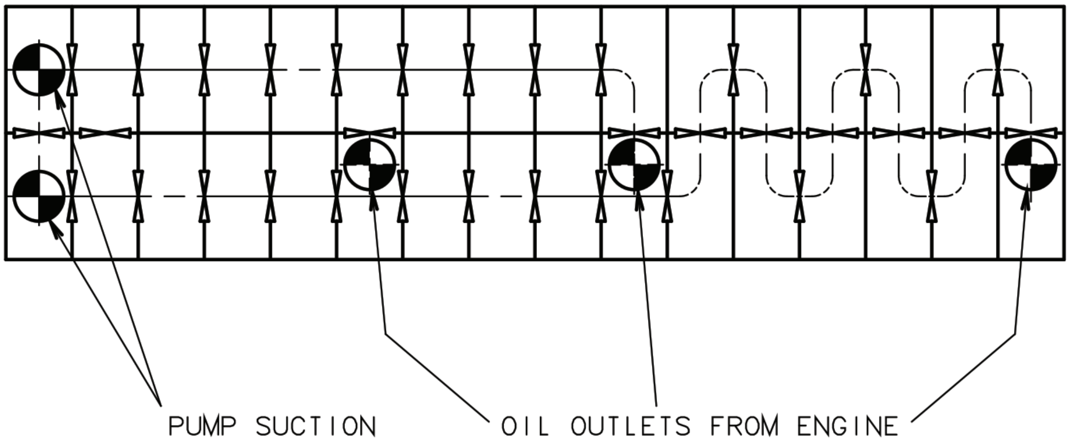


Fig. 23: Lubricating oil flow through the bottom tank, from the foremost outlet and to the pump

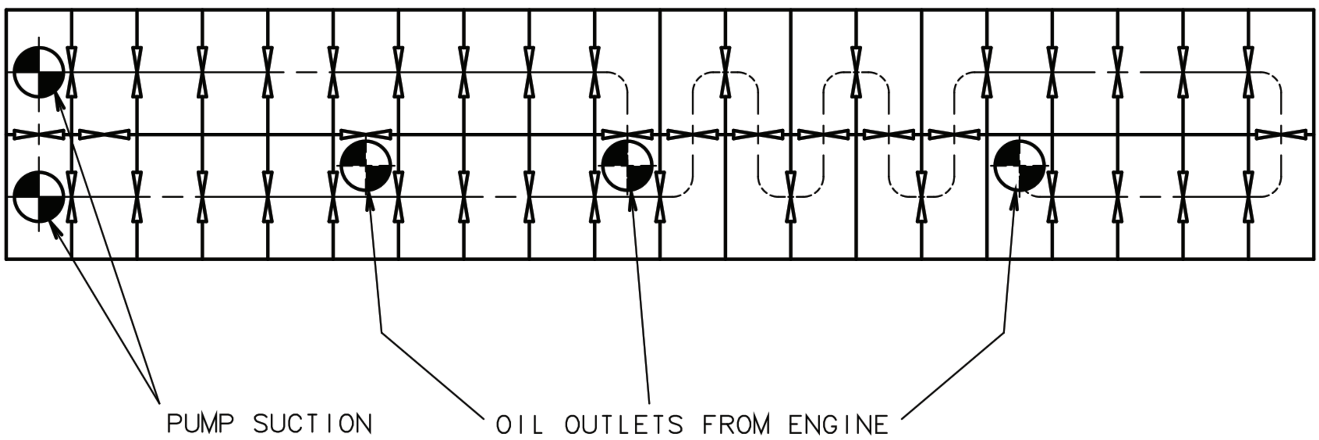


Fig. 24: Lubricating oil flow through the bottom tank, when the tank extends longer than the foremost outlet

Requirements for lubricating oil bottom tank volume and main lubricating oil pump suction conditions

This section describes the important requirements of Everllence and classification societies for designing the lubricating oil bottom tank:

1. Based on the lubricating oil pump flow, the tank size must comply with a maximum circulation rate per hour (requirement of Everllence)

2. According to the main engine installation design, ship designers must verify that the engine will be fully operational, considering trim and heeling conditions of the vessel. This means they must ensure that the lubricating oil pump will not lose suction capability (classification society requirement).

It is an iterative process to meet the design requirements when determining the tank size and the position of the lubricating oil pump suction because of the interrelation between operational tank volume and pump suction. If the pump suction requirement is not met, for example, which requires changes to tank boundaries, a new calculation is required to check whether the tank meets both requirements.

The following subsection briefly describes the requirements to the maximum circulation rate per hour, and the minimum volume of the lubricating oil bottom tank.

Maximum lubricating oil circulation rate per hour

To settle solid particles and deaerate the lubricating oil, the volume of the lubricating oil bottom tank must be large enough to avoid a too high circulation rate. The minimum volume of the lubricating oil bottom tank must be dimensioned according to the main lubricating oil pump capacity in CEAS, and our recommended maximum circulating rate of 18 times per hour.

The CEAS platform is available here: CEAS engine calculations

This means that the minimum tank volume is equal to the pump capacity from CEAS divided by 18. If the tank size turns out to have a lower, or even much lower circulation rate than 18 shifts per hour, this is fully acceptable.

The next subsection describes the calculation of the operational oil amount in the engine, which is needed when designing the bottom tank.

Operational oil amount in engine

Designing the lubricating oil bottom tank, including fulfilling lubricating oil pump suction conditions, requires knowledge about the amount of oil in the main engine when the lubricating oil pump is running. This oil amount can be calculated with the formula:

Oil amount (m^3/h) = $((Q_e + Q_h) \times 0.8 + Q_p)/850$, where:

- Q_e: Mass of oil in engine system (kg)
- Q_p: Mass of oil in oil pan (kg)
- Q_h: Mass of oil in hydraulic system (kg)

When designing the lubricating oil bottom tank, one of the most important parameters to consider is the location of the main lubricating oil pump suction. The following section describes SOLAS and classification society requirements related to the lubricating oil pump suction.

Lubricating oil pump suction

The pump suction must always be submerged in oil to avoid any risk of drawing in air when the vessel is inclined (trim and list combined) during normal operation and in rough sea. Drawing in air could cause lubricating oil supply failure, even momentarily, which could seriously damage the main engine bearings.

The position of the oil pump suction pipe must ensure that the lower minimum suction height is always obtained (i.e., the suction pipe is covered by oil up to a certain height). This is also a requirement, even with a minimum oil level in service, and during simultaneous athwartships and fore, or aft, inclinations.

Normally, classification societies only require that static inclinations are considered, since the lubricating oil bottom tank is divided into many compartments based on girders plates and floor plates with man-hole openings making flow restrictions. However, the classification society can interpret their own rules and set their recommendations in this regard.

To determine if the lubricating oil pump suction conditions comply with SOLAS and classification society requirements, we recommend that the shipyard or ship design company use a ship design software, for example NAPA, or another equivalent design tool, to facilitate the evaluation. A ship design software is the most applicable tool but simple 3D

CAD drawing tools can also be used for the evaluation.

By using a fictive sounding position at the location proposed in Fig. 25 for evaluating the suction capability, it is possible to check whether the required minimum suction height has been reached.

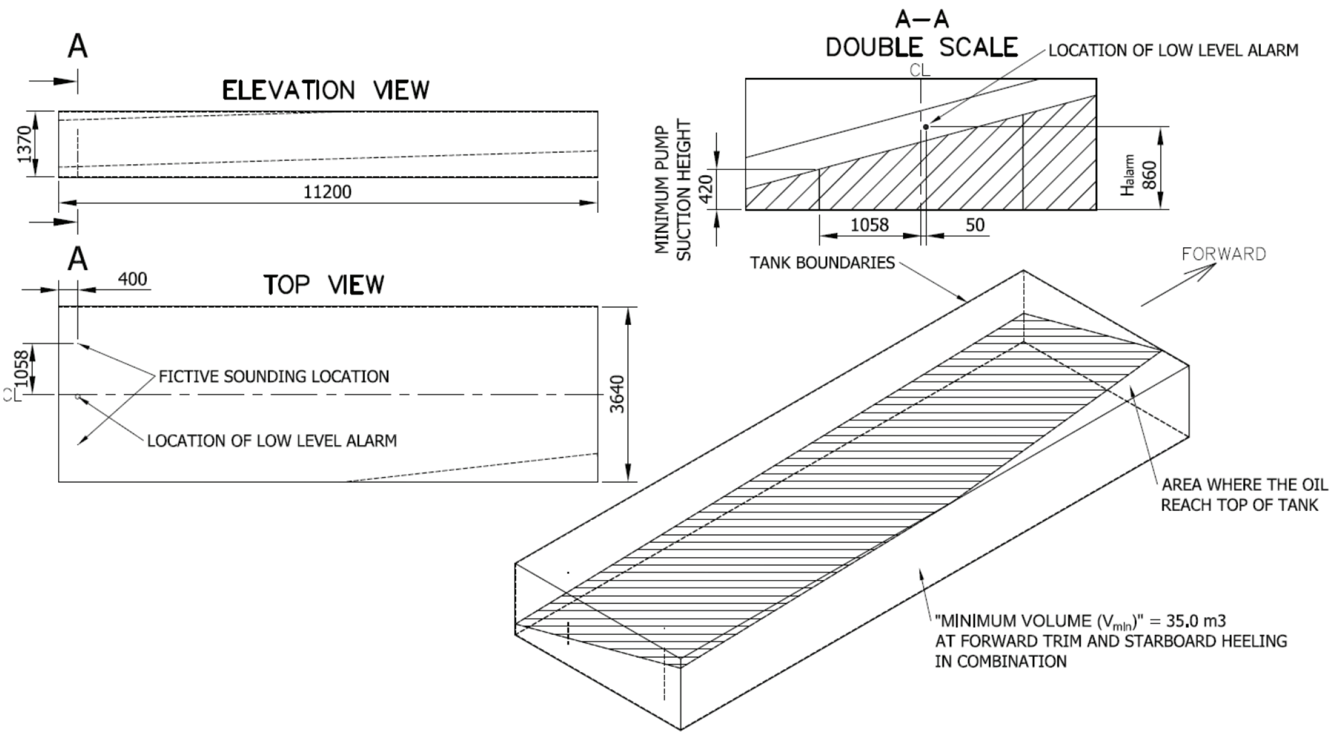


Fig. 25: Example of a 3D-sketch of tank and oil volume for evaluating the pump suction capability for a trimmed and heeled ship

Guide to contamination control

When the engine is delivered in several parts, flushing of the engine at the shipyard is needed.

Dismantling of ME parts before sending to yard
If the ME-system is dismantled before being sent to the shipyard, flushing of the system must be performed on board, see Fig. 26.

Even when delivered assembled, flushing of the main engine must be performed at the shipyard, see Fig. 27. If the main engine is delivered without opening the ME-system, flushing of the ME-system can be omitted.

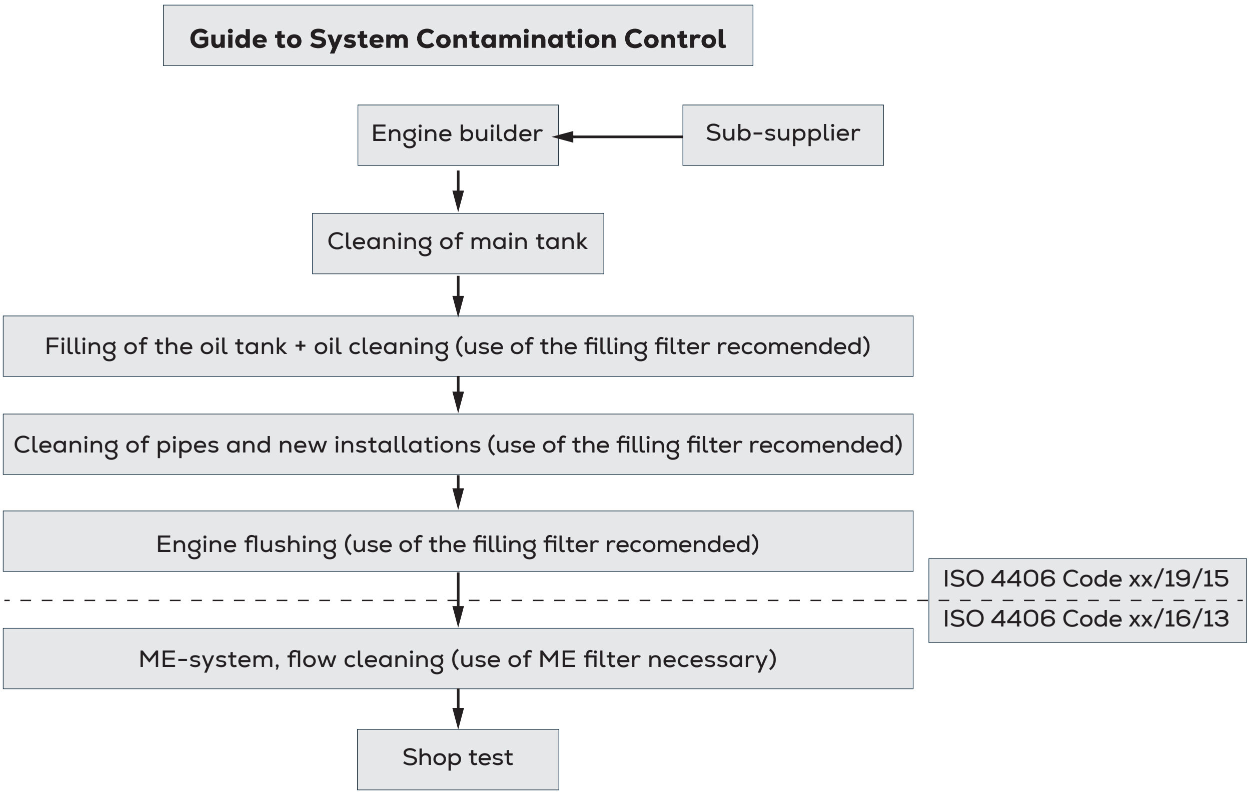


Fig. 26: Flushing at the shipyard

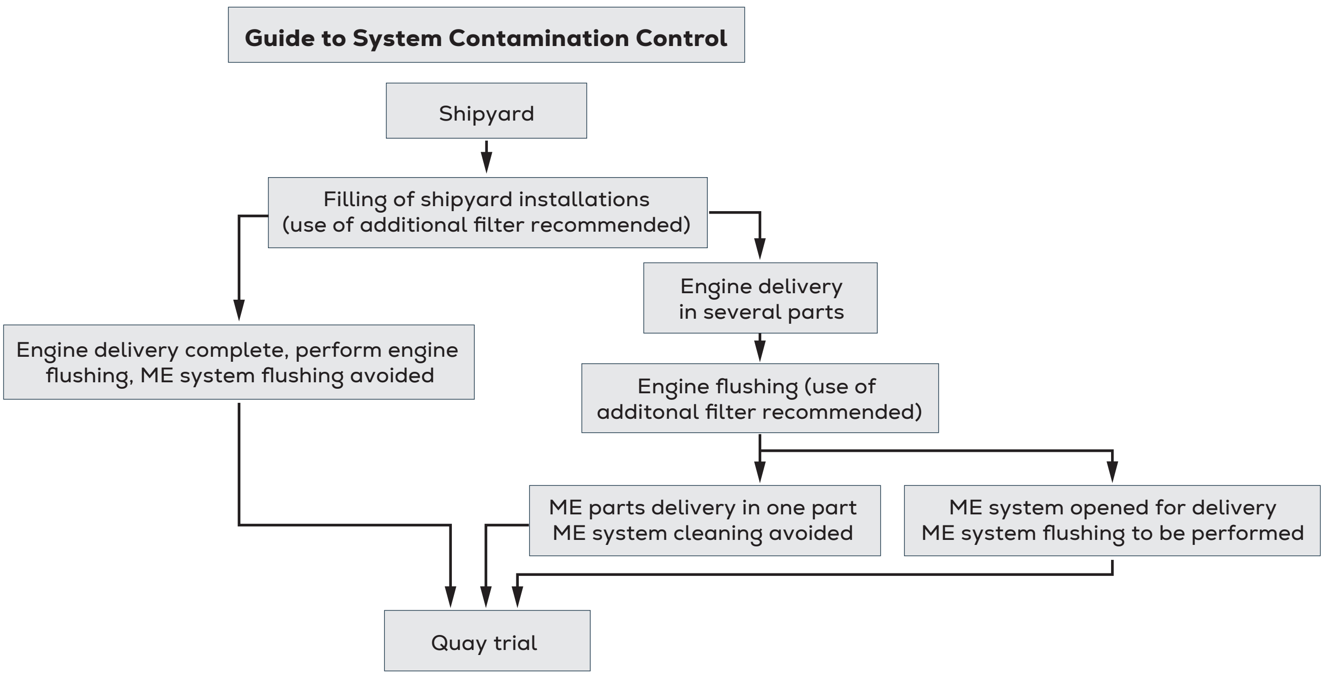


Fig. 27: Flushing of shipyard installations only

Summary

The starting point for every filtration and flushing strategy is that all new oil is dirty. The proper cleaning and flushing of hydraulic systems is therefore vital to ensure reliable and longterm operation without unexpected downtime of the system for maintenance and repair.

Everllence recommends following the standards and guidelines described in this paper to achieve the best possible system condition on low-speed Everllence B&W two-stroke engines.

This includes application of the ISO 4406 standard and use of the proper filter cartridges for filtration and the proper filters for flushing. Furthermore, it is important to monitor the cleanliness level of the oil by means of onsite fluid analyses, to be able to control the level of contamination.

Everllence
2450 Copenhagen SV, Denmark
P + 45 33 85 11 00
info@everllence.com
www.everllence.com