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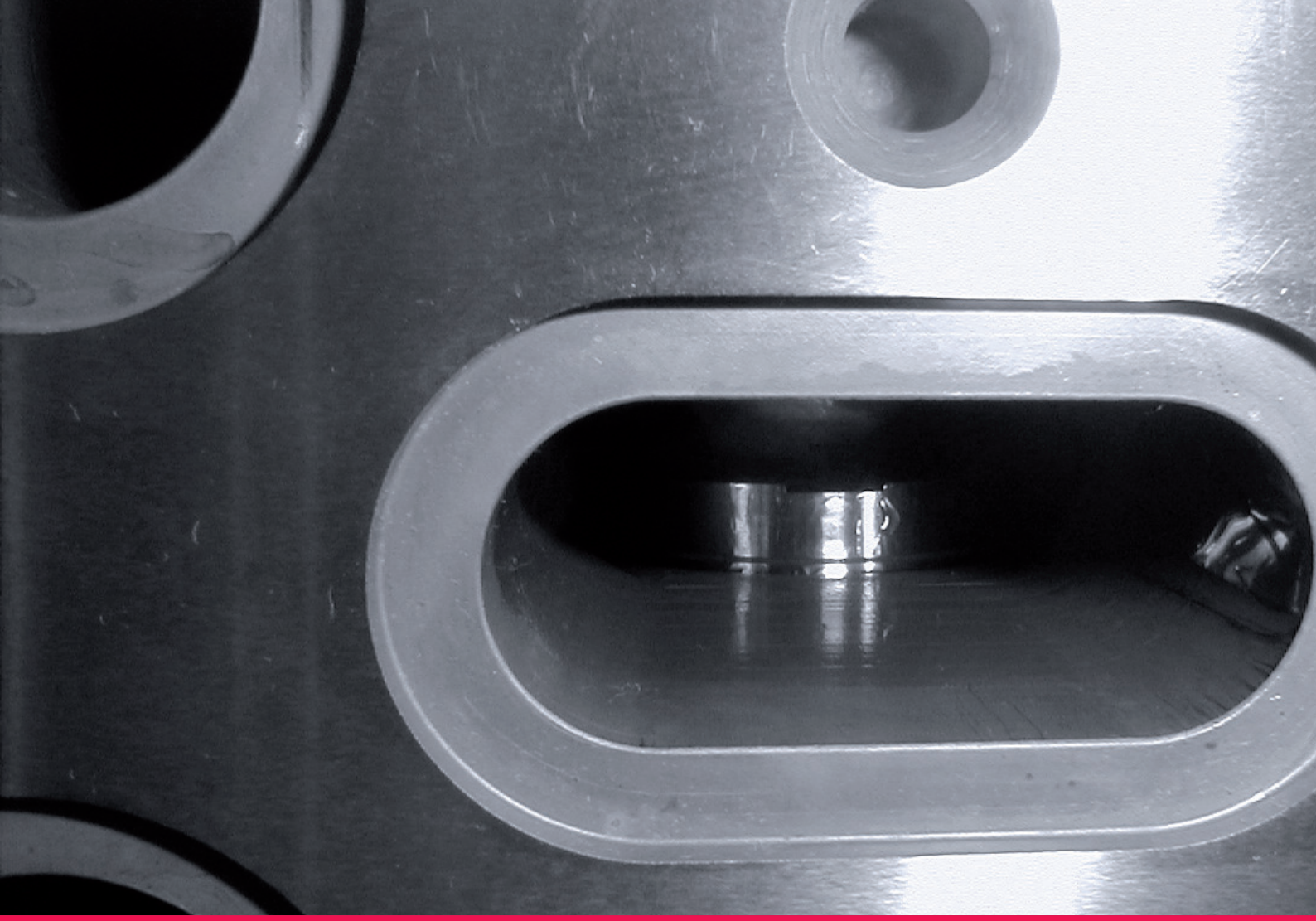


Filtration Handbook

Filtration and flushing strategy

Engineering the Future – since 1758.

MAN Diesel & Turbo

Content

Filtration Handbook

Filtration and flushing strategy

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 the hydraulic components.

To avoid the above 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 the 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.

Definitions and Standards

MAN Diesel & Turbo specifies the international ISO 4406 standard to be used when defining the quantity of solid particles in the fluid used in a given hydraulic power system.

ISO 4406

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

NAS 1638

The concept of the code can be seen in Table II. It is based on a fixed particle size distribution of the contaminants over a size range of >5 to >100 microns. 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 II.

The ISO 4406 standard is a decisive tool defining the quantity of solid particles in the fluid in MAN Diesel & Turbo installations

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

Table I

Class	Maximum particles/100 ml in specified size rang (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 II

Cleanliness requirement – ISO 4406 versus NAS 1638

The recommended standard for definition of oil cleanliness level is ISO 4406.

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

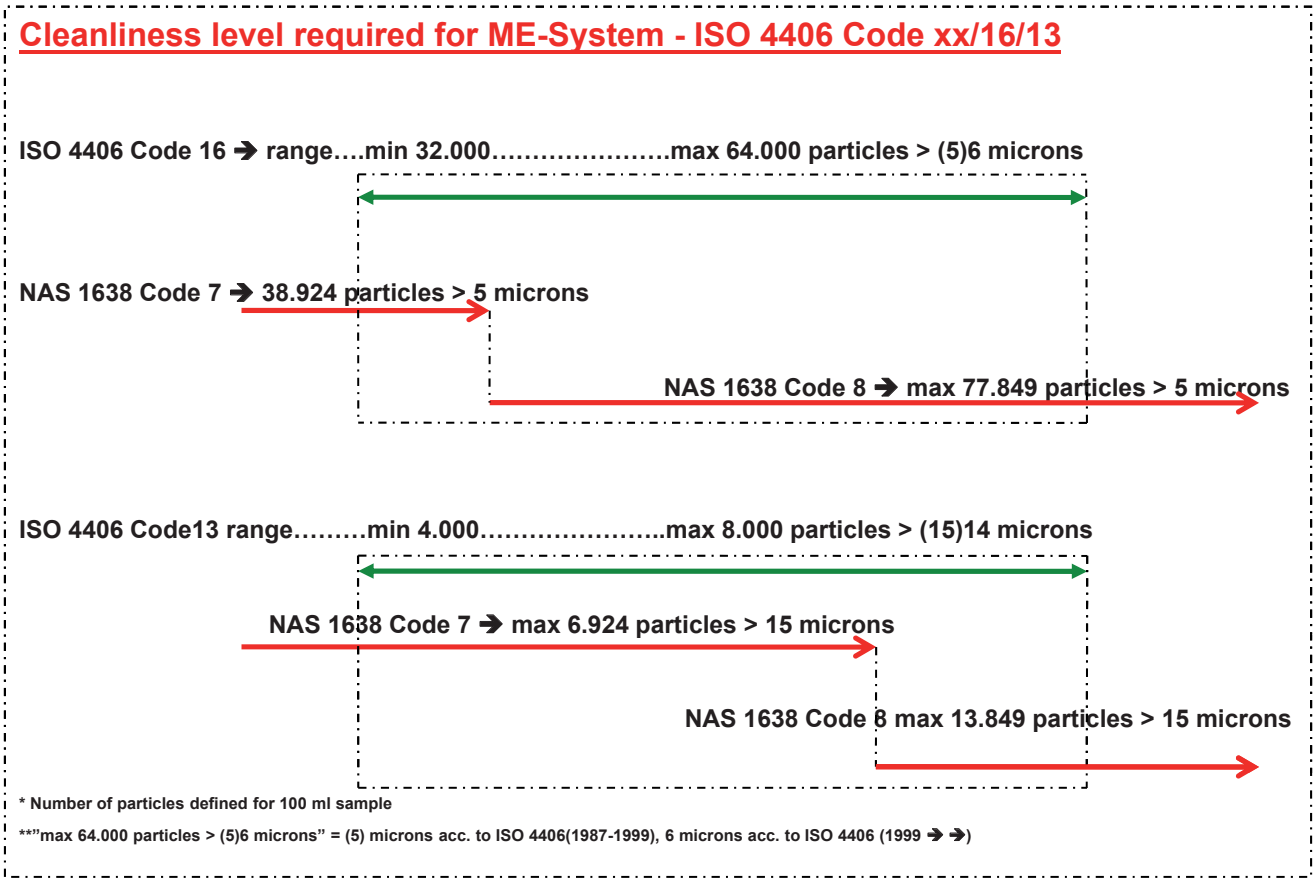


Fig. 1: ISO 4406 vs. NAS 1638 - cleanliness level required for ME/ME-C engines

Treatment of Tank

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

- any slag (and other impurities) after welding must be removed mechanically
- clean all visible impurities
- treat scale on the surface with a de-scaling 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.

Cleaned areas must be protected with anti-rust agent immediately after they have been cleaned, so as to provide protection until the system is filled up. 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 the blocks, pipes, oil tank and any other components prepared for use in the system.

Treatment of Pipes and Additional Installations

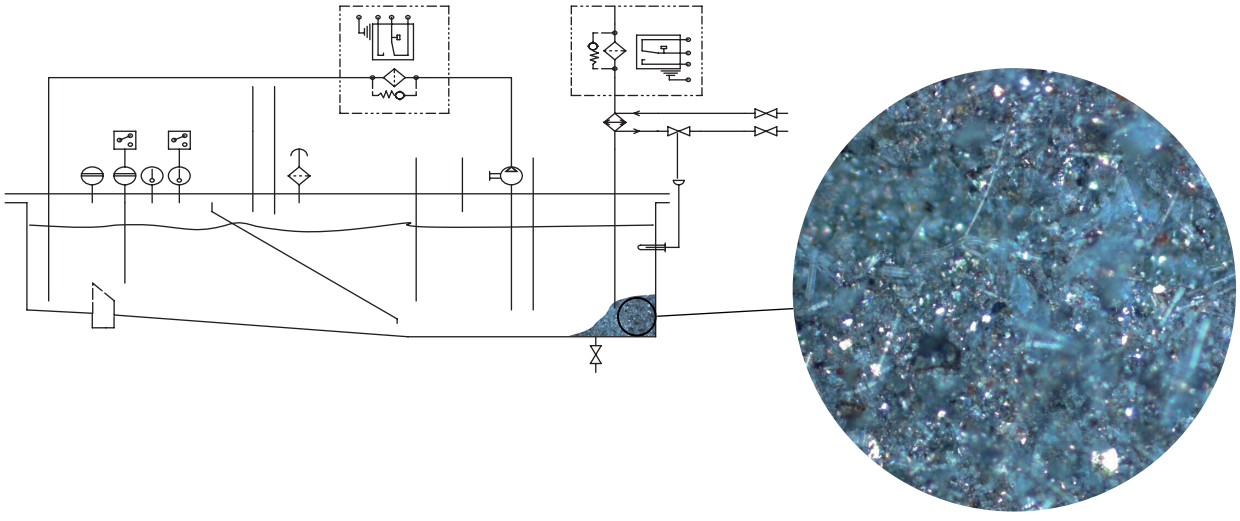
Hydraulic pipes should only be welded if absolutely necessary. If so, each welding point must be placed so that mechanical removal of any welding slag is possible.

All pipe dimensions larger than ø25 mm (externally) should be fitted with flanges if possible. The 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. Clean all visible impurities. Scale on the inner surface must be treated with a de-scaling 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 grease-dissolving liquid.
Pipes that have been treated with acid are to be neutralised or washed in a combination of cleaning/neutralising agents.

Cleaned areas must be protected with an anti-rust agent immediately after being cleaned, so as to provide protection until the system is filled up. The agent must be of a type that can be mixed 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).



Contermination found in ‘clean’ oil tank

Fig. 2: Empty hydraulic oil tank

Fluid Maintenance

All fluid stored in sealed containers or delivered from an oil company must be filled through a filter cartridge with a filtration ability of β_6 (beta) = 200.

Beta ratio: example of filtration ability, valid for particles > 6 microns

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

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

New oil is dirty!

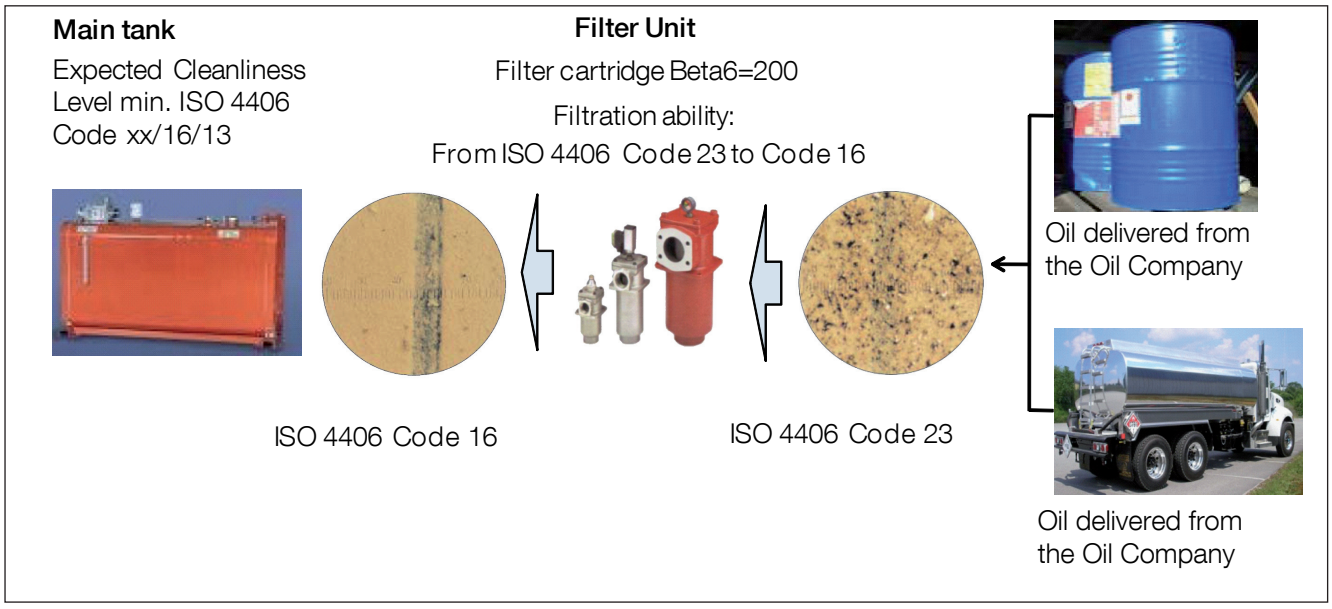


Fig. 3: Filtration ability of filter cartridge: β_6 = 200

Example of contaminants amount to be removed

The table below 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 cm³/1000 litres oil tank
Code 23 to Code 16 for particles > 6 microns (new oil at delivery date)	17.1
From Code 19 to Code 16 for particles > 6 microns	1.0
From Code 16 to Code 13 for particles > 14 microns	1.6

Table III

Filling New Oil to Tank

Example: How to choose the correct filter cartridge size.

Tasks:

- Oil amount of 48,000 litres must be moved to hydraulic tank.
- Pump equipment (flow): 200 l/min. → 12 m^3/h
- To be cleaned from ISO 4406 Code 19 to ISO 4406 Code 16 for particles > 6 microns.
- Contaminants > 6 microns to be removed, i.e. 48 m^3 x 1.0 cm^3 = 48 cm^3

Equipment needed:

- Filter element: 0250 DN 6 BN/HC /-V
- Filtration time: 48.000/200 = 240 min → 4 hours.
- Final cleanliness level: ISO 4406 Code 16 (for particles > 6 microns).

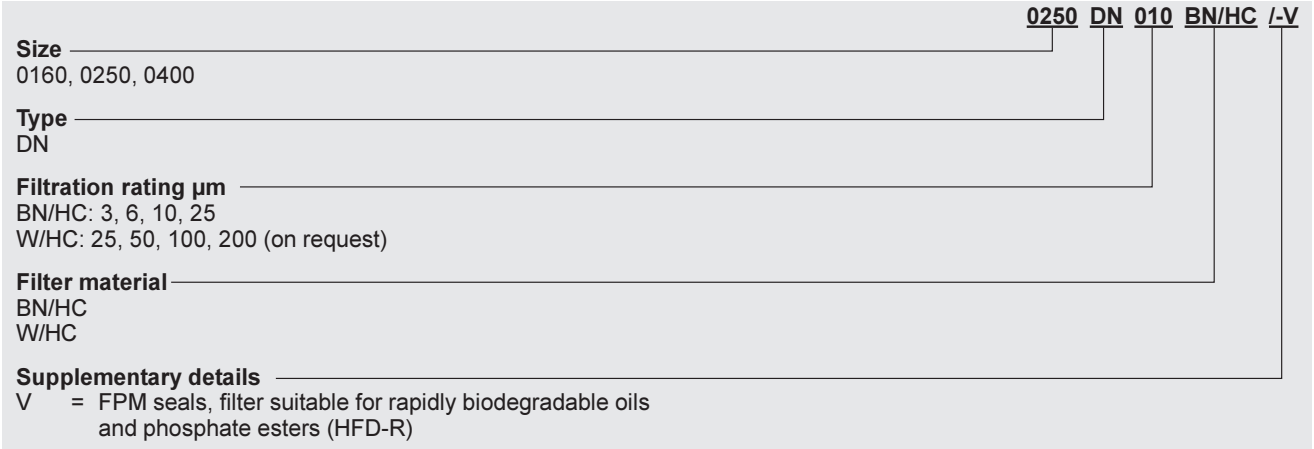


Fig. 4: Data for filter element

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

Filter surface area W/HC

Filter type	Filter surface area
160	2750 cm²
250	4400 cm²
400	6730 cm²

Table IV:

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

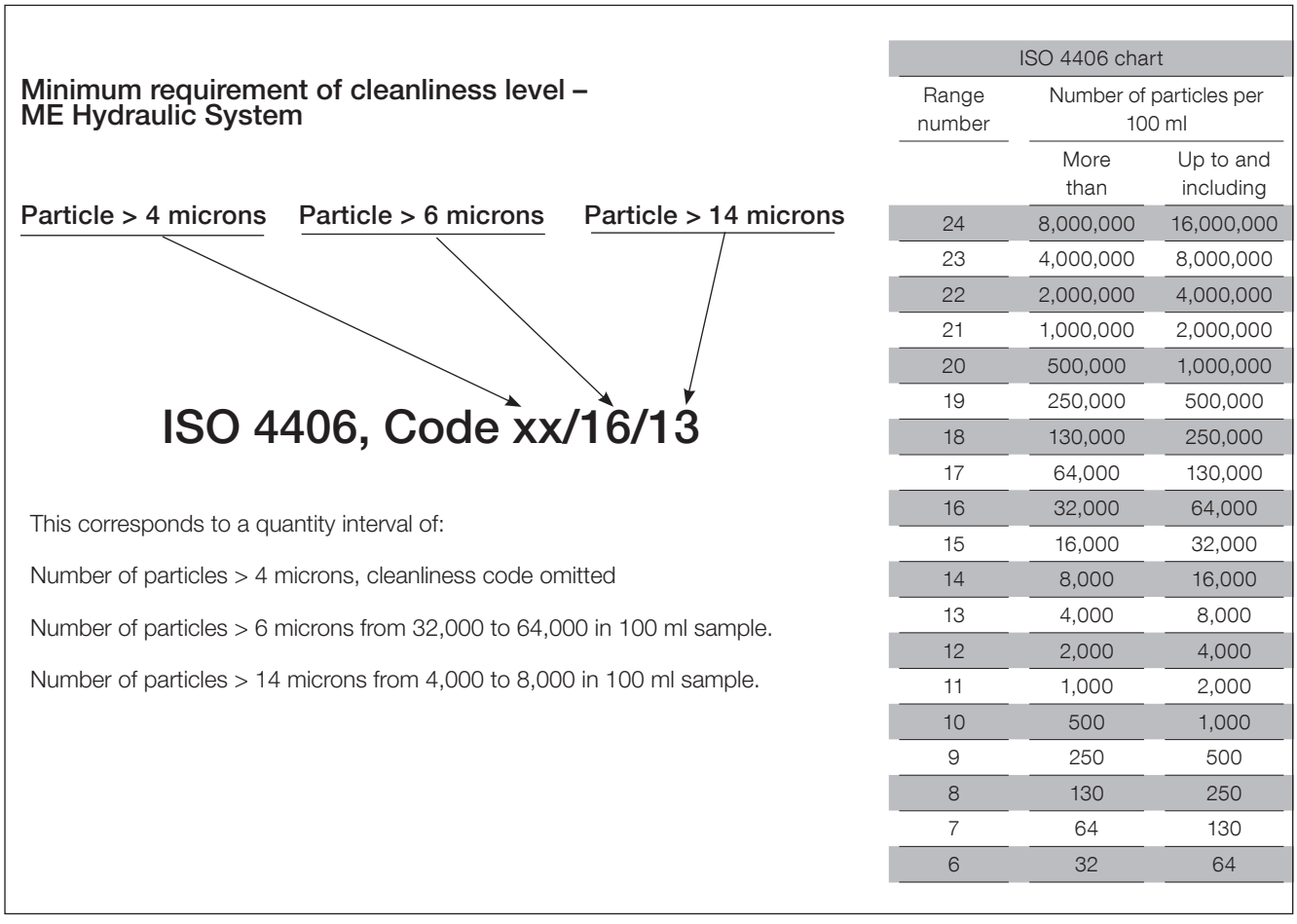
* Flange SAE 1 1/2"; 3000 psi

Table V:

How to define a filter?

The following parameters are decisive for a filter definition:

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



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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

Fig. 5: Filtration requirement for ME/ME-C/ME-B

Cleanliness Requirement

The cleanliness level of oil used for flushing must, as a minimum, be according to ISO 4406 Code xx/16/13.

When the oil cleanliness level in the tank is according to the above, flushing of the main engine and ME-system can be performed in parallel.

General Flushing Conditions

Preheat the oil to a temperature of 60-65 degrees Celsius.

To ensure a sufficiently turbulent flow in the system, the oil flow velocity must, as a minimum, reach a Reynolds number higher than 3000, see also Fig. 6..

Formula for calculating the Reynolds number:

$$Re = \frac{(V \times D)}{\sqrt{}} 1000$$

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

Example:

Reynolds number	3000
Inner pipe diameter	300 mm (0.3 m)
Oil viscosity	112 cSt

Calculation of minimum flow velocity:

$$V = \frac{(\frac{Re}{1000}) \times \sqrt{}}{D} = 1.12 m/s$$

Calculation of minimum pump flow:

$$Q = D^2 \frac{(PI)}{4} \times 1.12 \times 3600 = 285 \frac{m^3}{h}$$

Use of Flushing Equipment

For filling and topping up, always use a filter cartridge with a filtration ability of $\beta_6 = 200$.

For flushing, a filtration ability of minimum $\beta_{10} = 75$ is needed, however, MAN Diesel & Turbo recommends a filter with a minimum filtration ability of $\beta_6 = 75$.

For additional flushing filters, so-called “off-line” filters, a minimum filtration ability of $\beta_6 = 75$ is recomended, and a minimum filtration ability of $\beta_{10} = 75$ is needed.

Use of ME-filter for flushing is recommended. Backflushing oil must be returned to a separate backflushing tank and then back to the main tank via a $\beta_6 = 200$ filter cartridge.

MAN Diesel & Turbo recommends use of a purifier during flushing. And 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.

The nomograms shown in Fig. 6 can be used for estimation of the flow velocity required to reach a Reynolds number higher than 3000.

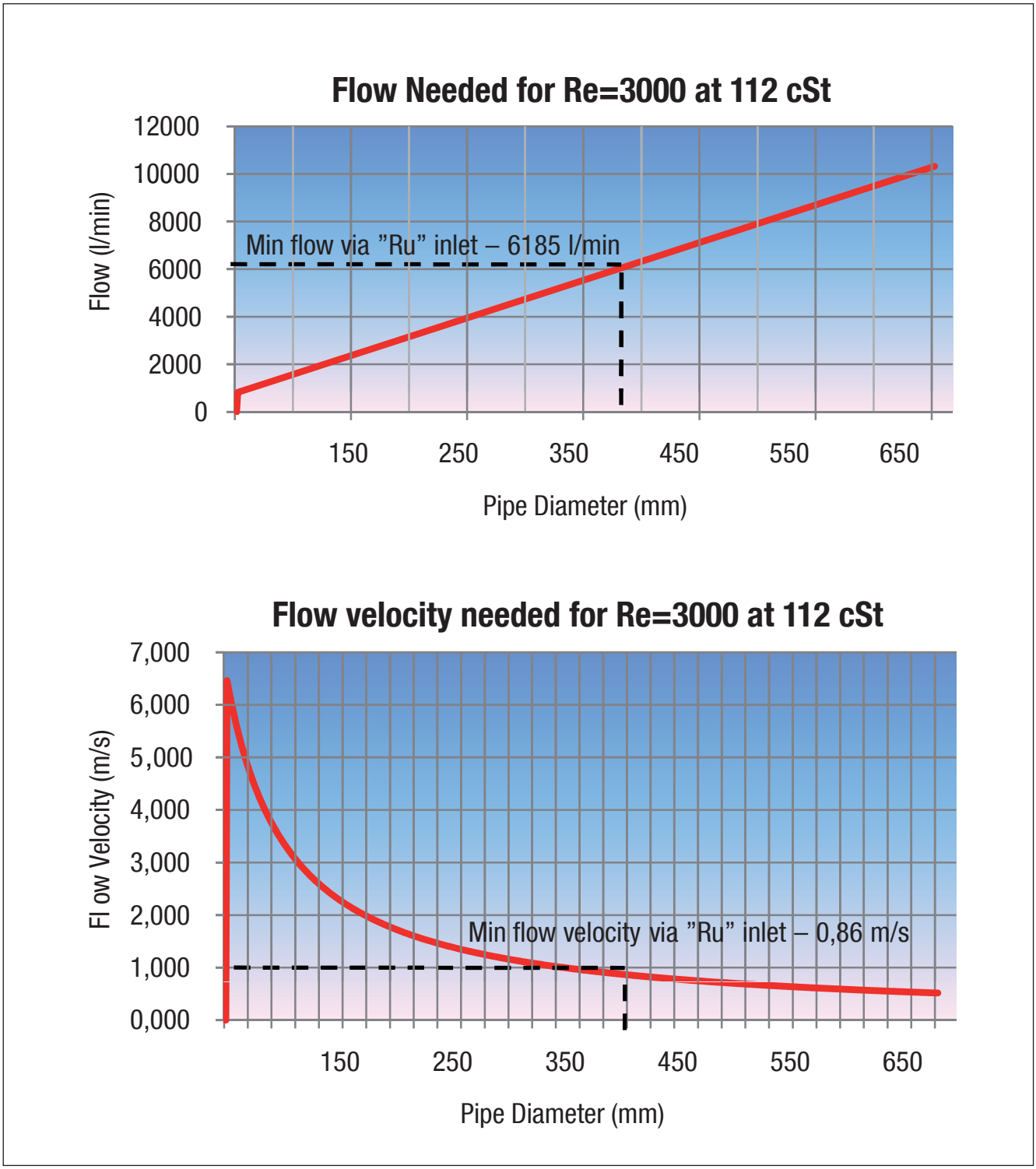

Fig. 6: Flow/flow velocity nomograms

Step I
Filling of the oil tank (on the test bed, at shipyard, on board)

Use a filter unit for filling and simultaneous cleaning (filtration during filling):

- filter cartridge with a beta rating of $\beta_6 = 200$
- filter rating in accordance with Multi Pass Test ISO 16889 defined for an operating viscosity of 100 cSt and a pressure drop of dP = 0.15 bar.

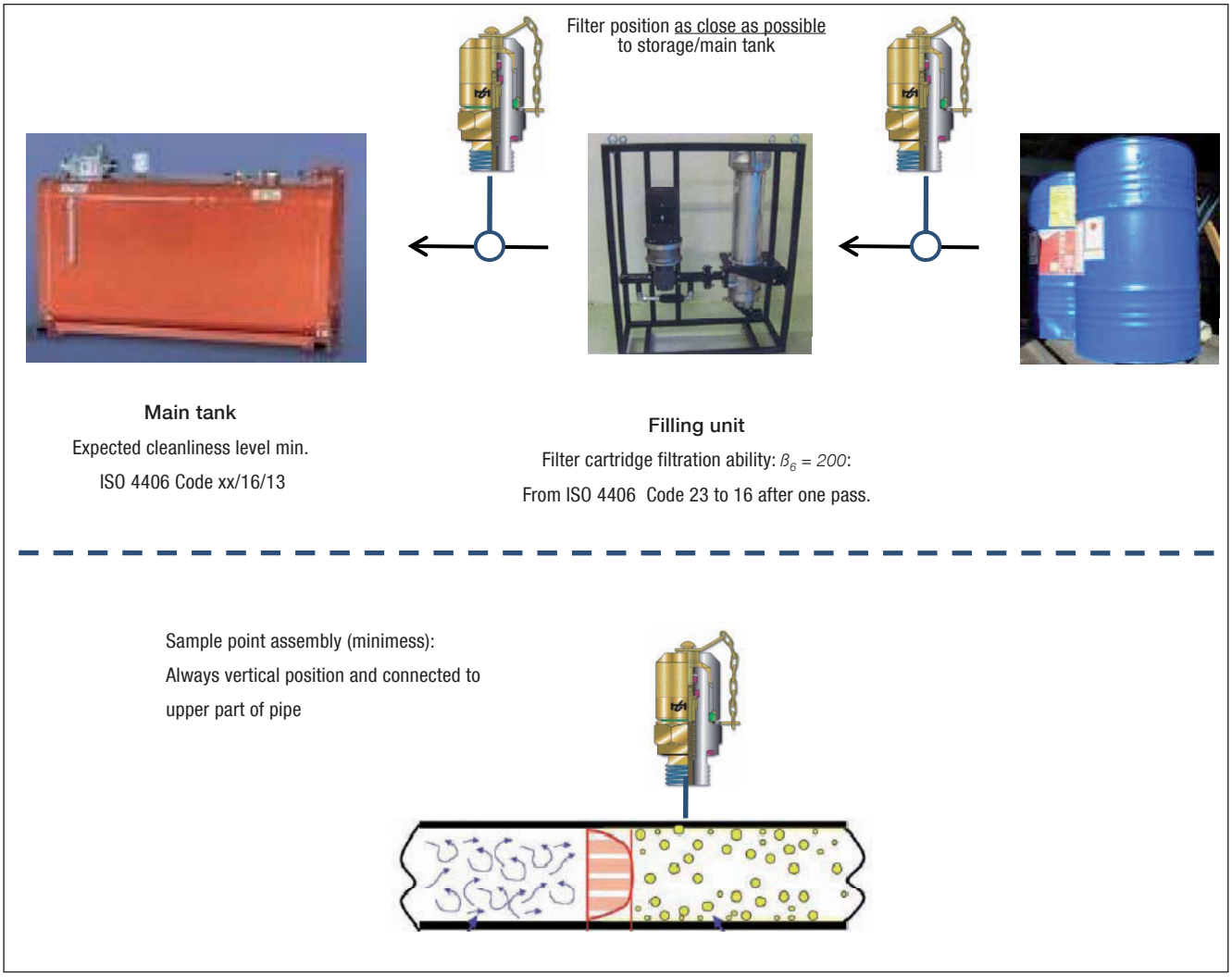

Fig. 7: Hydraulic oil tank filled

Step II

Oil cleanliness improvement in the existing tank

Flush pipes and additional installations, and use additional filter β_6 = 200 to minimise flushing time.

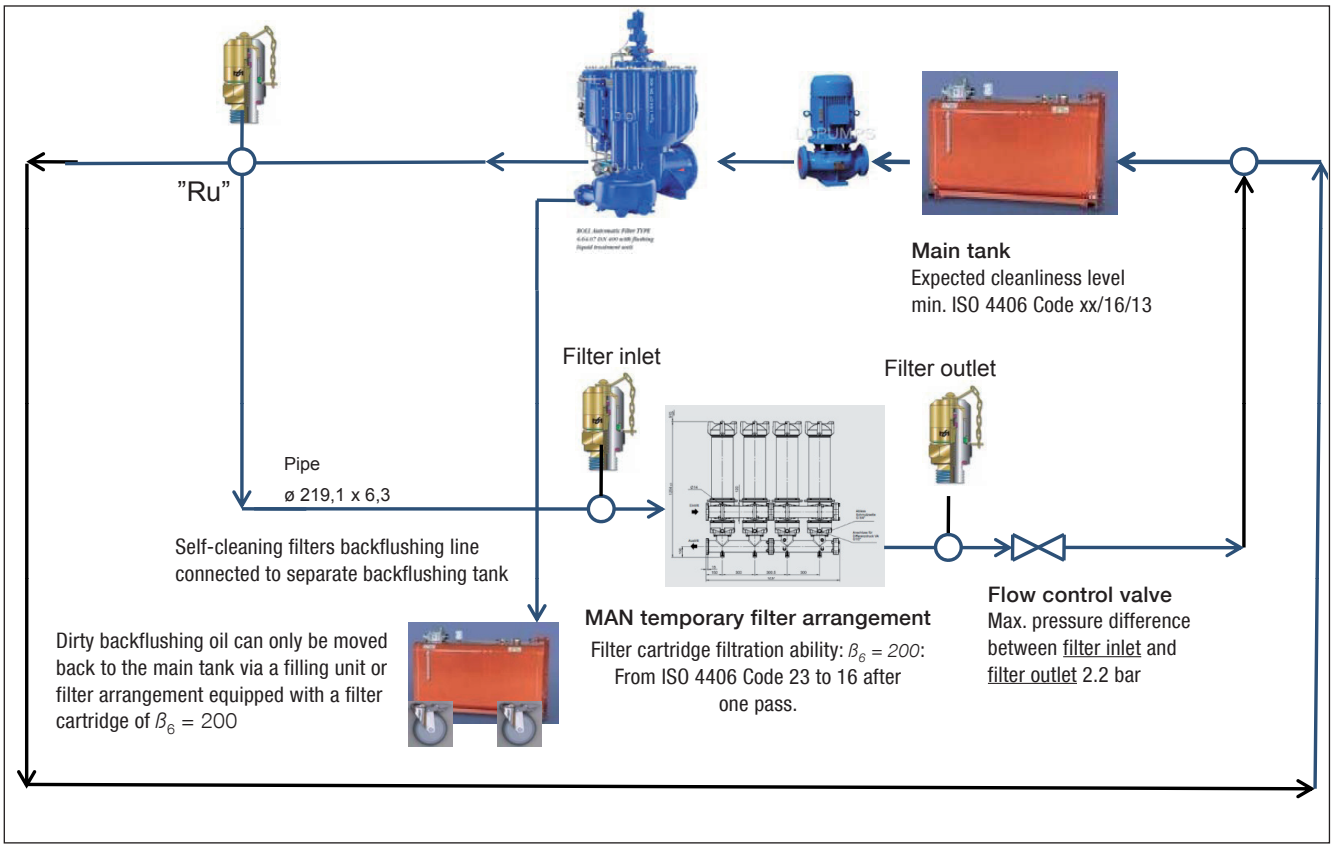

Fig. 8: Cleanliness improvement in the existing oil tank, flushing of pipes and additional installations (test bed, shipyard, on board)

Step III

Flushing of shipyard installations (piping)

MAN Diesel & Turbo recommends use of an additional filter for parallel filtration to reduce flushing time. A separate backflushing tank is also needed.

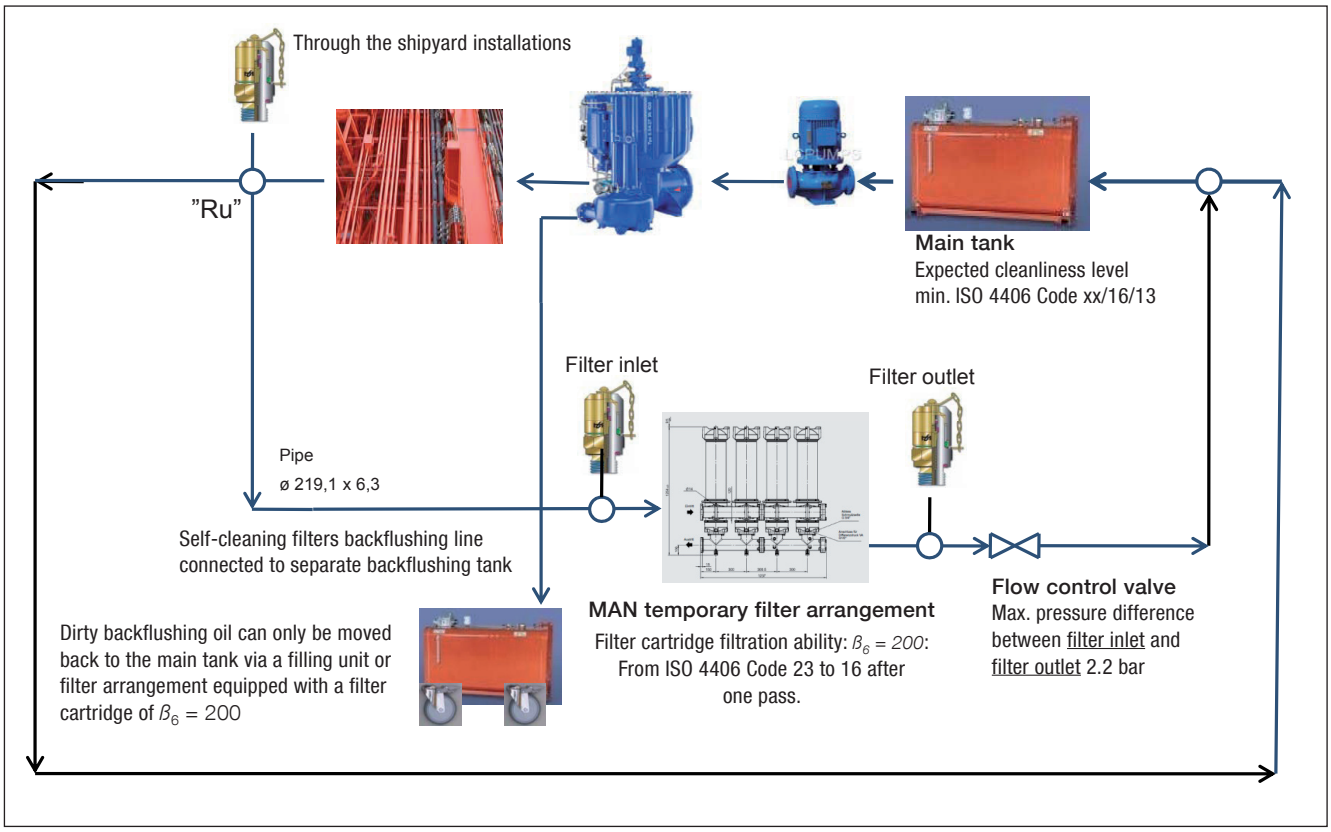

Fig. 9: Preventing hydraulic failures, flushing on the test bed and at the shipyard

Step IV
Engine flushing

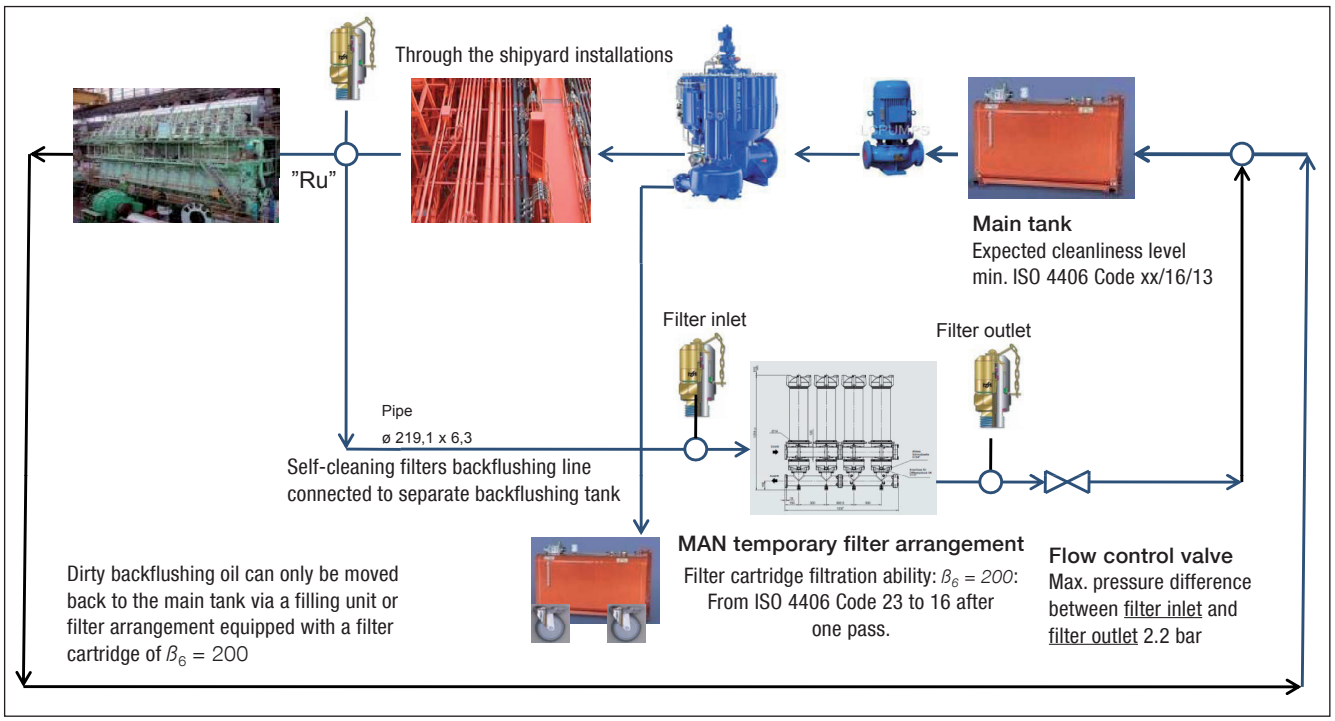

Fig. 10: Flushing of engine on the test bed and at the shipyard

Topping-up of Main Tank
(valid on test bed and for installations in service)

All fluid delivered from an oil company must be filled through a filter cartridge with filtration ability of B_6 (beta) = 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.

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

For installations without the necessary filling equipment, the following rules must be fulfilled:

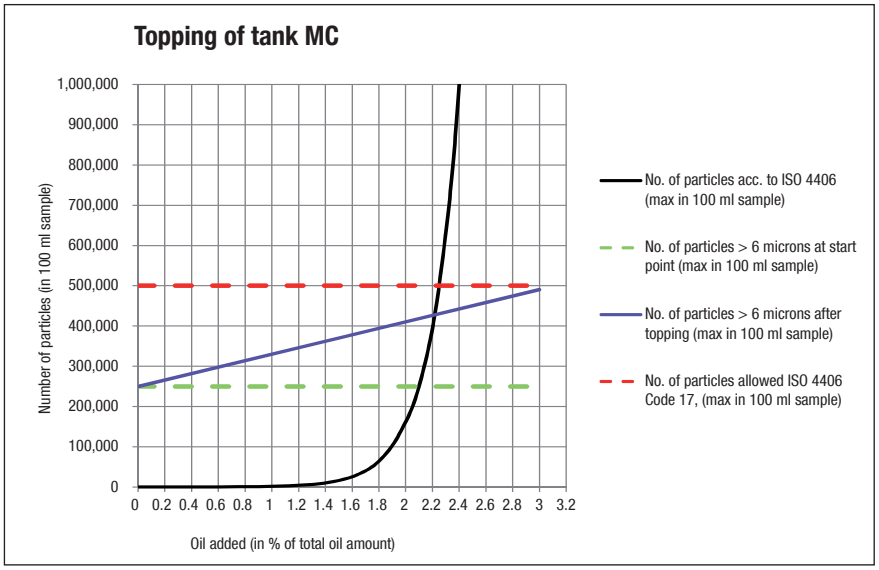

Fig. 11: Installations in service, max. 3% of tank capacity per day

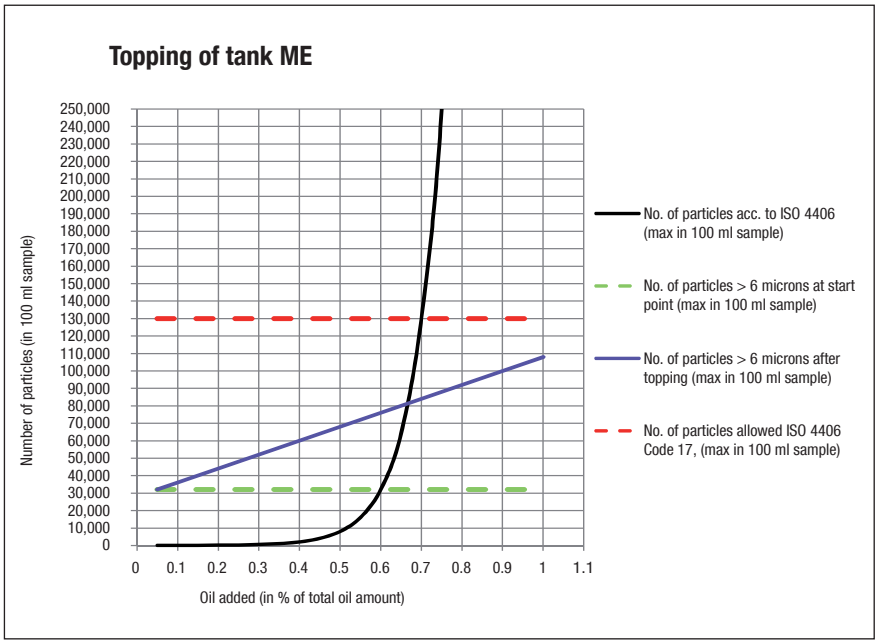

Fig. 12: Installations in service, max. 1% of tank capacity per day

Temporary Filters

A temporary filter with a mesh size of 3 microns can be used between the FIVA main valve and the FIVA pilot valve, and also the HPS pump and the pilot valve for pump control. However, the filters must be removed after sea trial.

When using these filters, the cleanliness level of the ME system oil can be according to ISO 4406 Code xx/17/14.

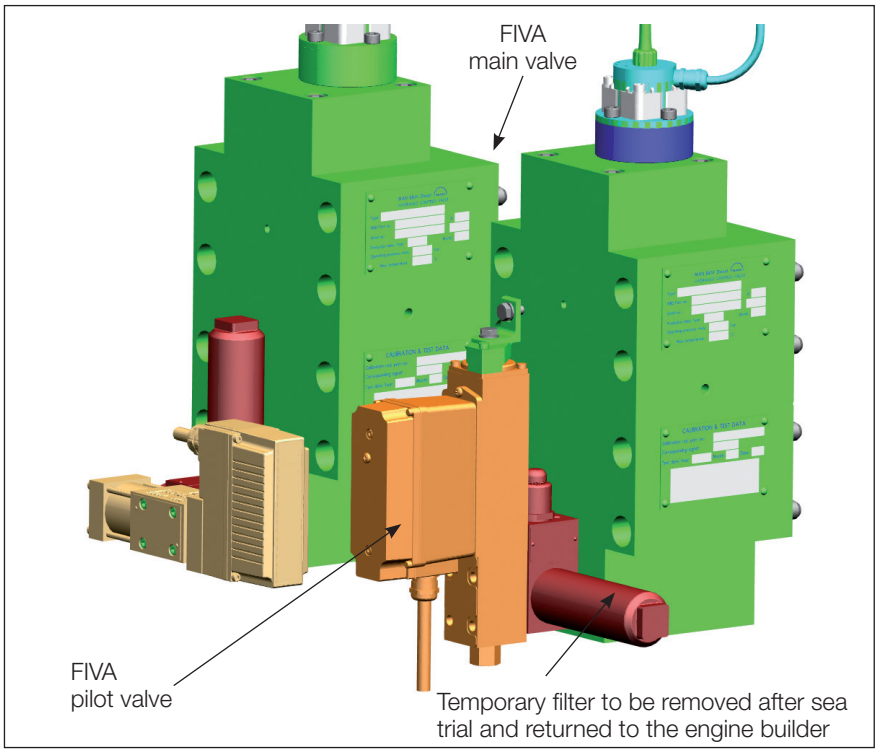

Fig. 13: FIVA unit with temporary filter

In 2010, the same type of Hydac Sandwich Filter (3 microns) was installed for testing in service two months on ELFI B3-45. The test result was positive with no performance change recorded.

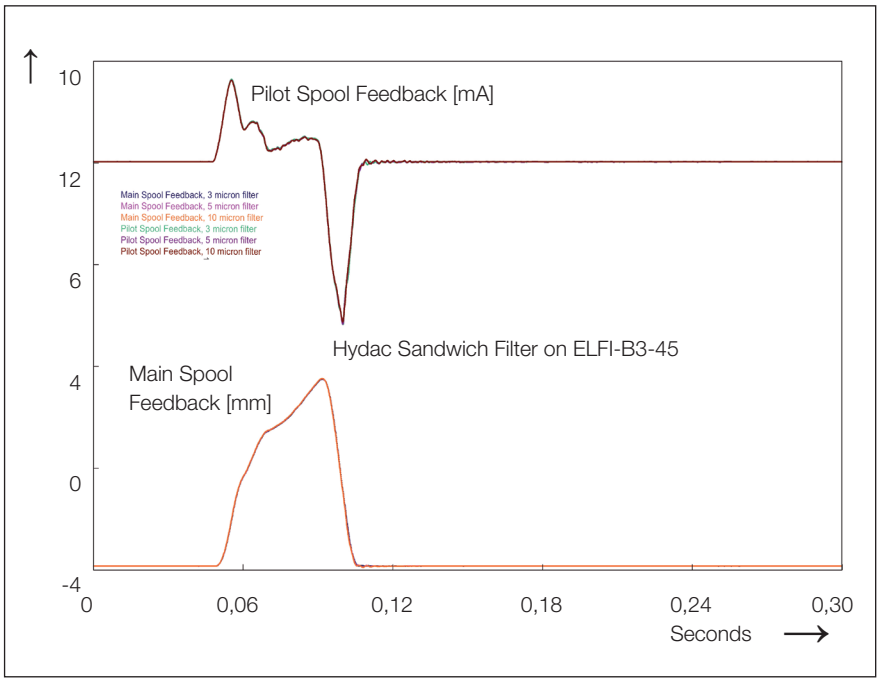

Fig. 14: The Hydra Sandwich Filter has been tested successfully without any performance change on ELFI-B3-45 at MDT-CPH research centre

How to define contamination level
(quick method).

A filter diaphragm with all contaminants from a 100 ml sample must be prepared.

Sample bottles should be clean to reduce the interference of contaminants from the bottles. Use the bottles cleaned and validated in accordance with ISO 3722 and BS 5540.

Using a vacuum pump, a representative sample of hydraulic fluid, usually 100 ml, is drawn from the 70 C preheated system through a 47 mm diameter laboratory membrane filter disc with a filter mesh size of 1.2 microns.

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

Compare a view on a prepared filter diaphragm with the ”comparator” picture with the same magnification. Use of a comparator book for this analysis is recommended.

The method described is a decisive tool for onsite system fluid analysis. This method cannot determine the exact particle count, but allows you to estimate the cleanliness level.

For documentation, particle counting can be ordered from a local laboratory.

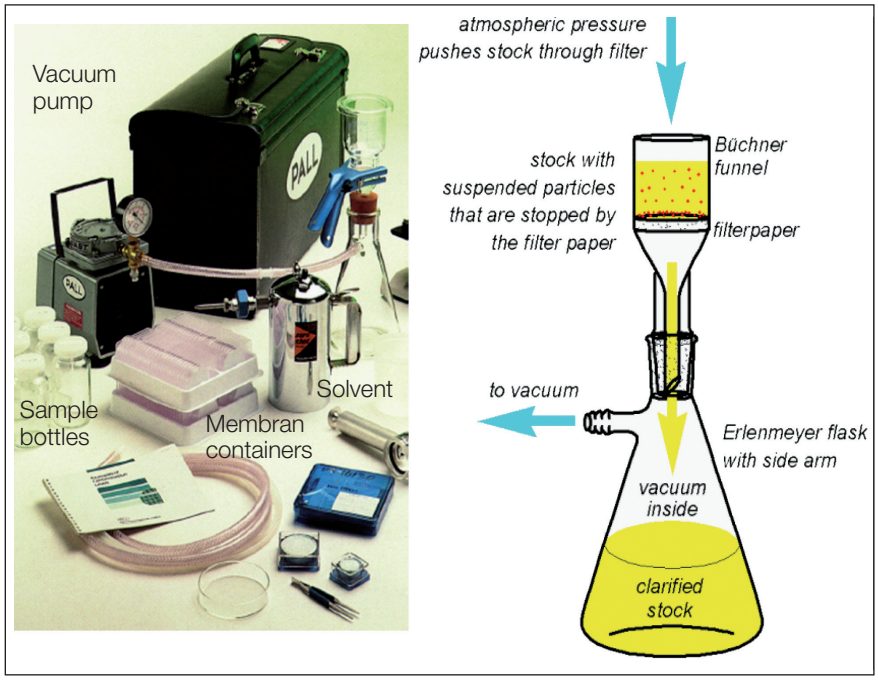

Fig.15: How to collect contaminants for examination

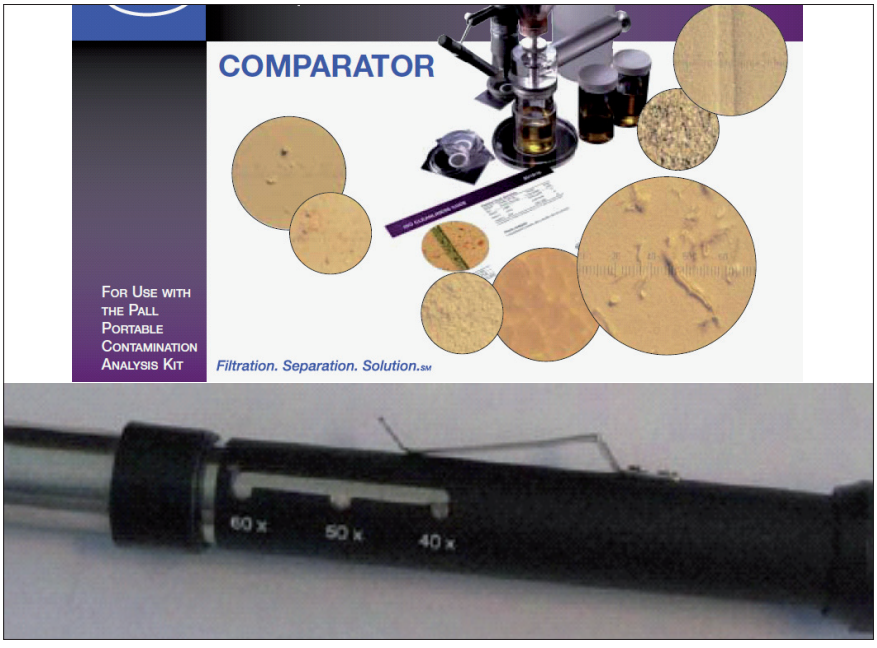

Fig. 16: Filtration on ME/ME-C/ME-B engines

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

During dismantling of the ME-system, open connections must be hermetically sealed using rubber seals and blind flanges. In this way, flushing of ME parts at the yard can be avoided.

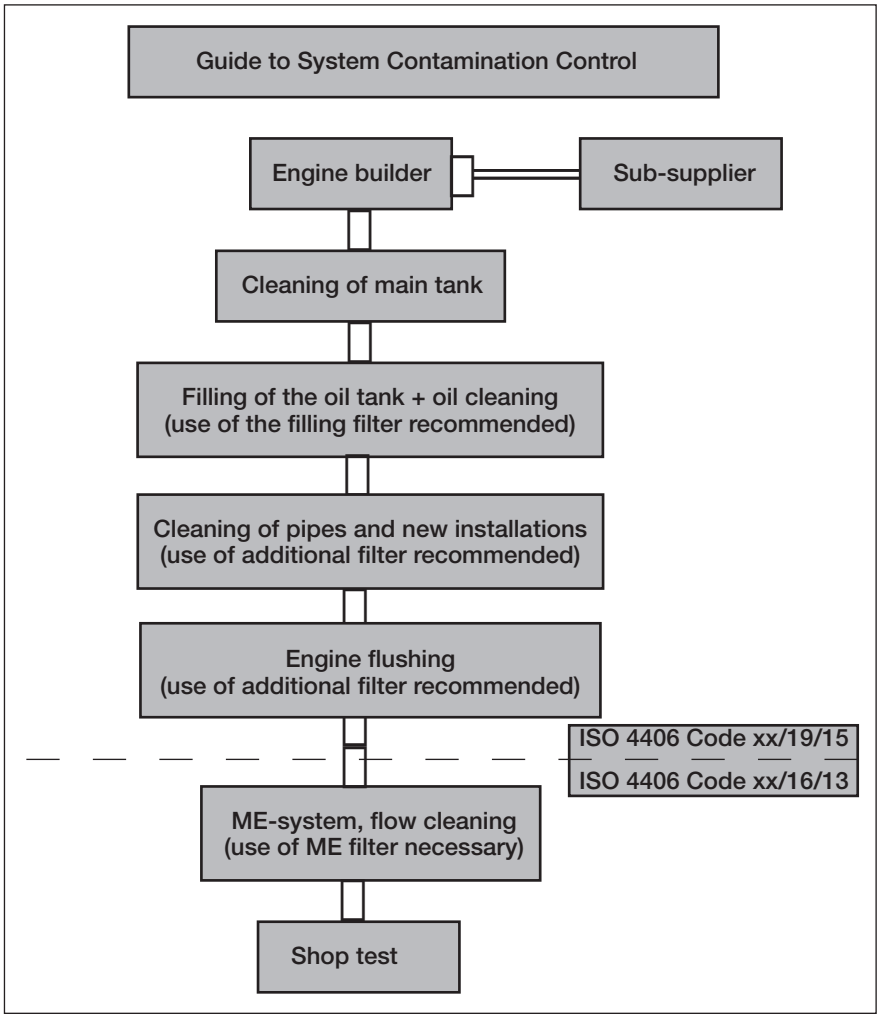

Fig. 17: Flushing at the shipyard

When the engine is delivered finish-assembled, flushing of the engine at the shipyard can be avoided. However, flushing of shipyard installations is always required.

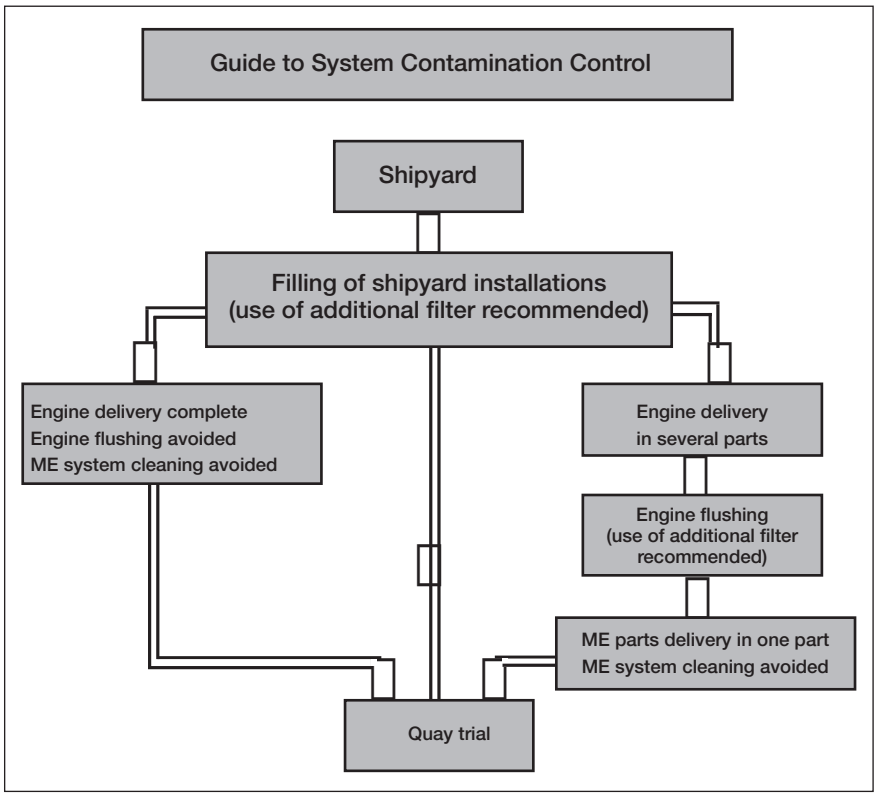

Fig. 18: Flushing of shipyard installations only

Filtration Ability of ME filter

Filtration ability for particles
> 6 microns

Metal fibre fleece can remove min. 55% of particles larger than 6 microns for every pass through the filter.

Filtration ability for particles
> 14 microns

Metal fibre fleece can remove min 95% of particles larger than 14 microns for every pass through the filter.

Example: ISO 4406 Code xx/xx/19, max 500,000 particles > 14 microns → (500,000 – (500,000 x 0.95)) = 25,000 → ISO Code 15.

The oil cleanliness level for particles > 14 microns will be improved from ISO 4406 Code 19 to Code 15 after first pass through the ME filter.

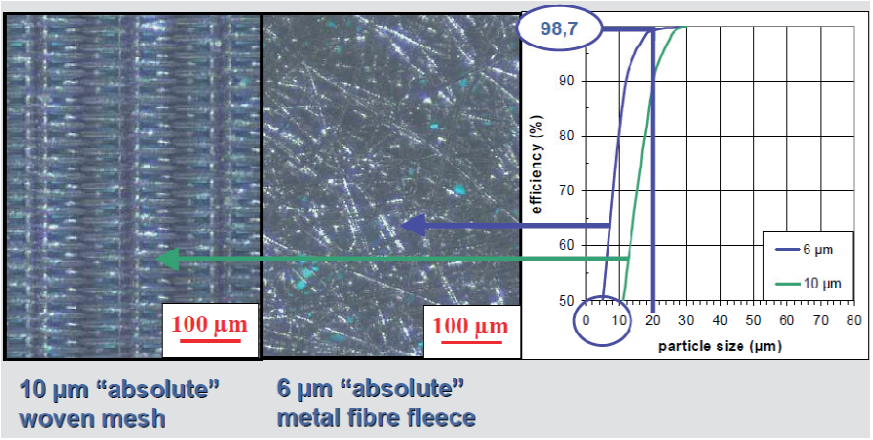

Fig. 19: Filtration ability of ME filter

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	6,4000
15	1,6000	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 VI

Summary

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

MAN Diesel & Turbo recommends following the standards and guidelines described in this paper, so as to achieve the best possible system condition on low speed B&W two-stroke diesel 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 analysis, in order to be able to control the level of contamination.