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1 Introduction

In advance to the first running of the engine it is essential to remove any dirt, especially scales, slag and spelter from the piping system.

Remaining foreign bodies due to incorrect or insufficient cleaning can cause serious damages of engine and system components, i.e. a significant influence on engine performance and high repair costs can be expected.

The effort of the cleaning procedure is related to the prior manufacturing quality of the pipe connections. Less scales, slag and spelter are to be removed with special, but more expensive welding methods, e.g. inert gas welding. Common cleaning methods are the manual cleaning by hand, blow through with working air or flushing with system oil.

However, in any case the piping system has to be finally flushed with system oil.

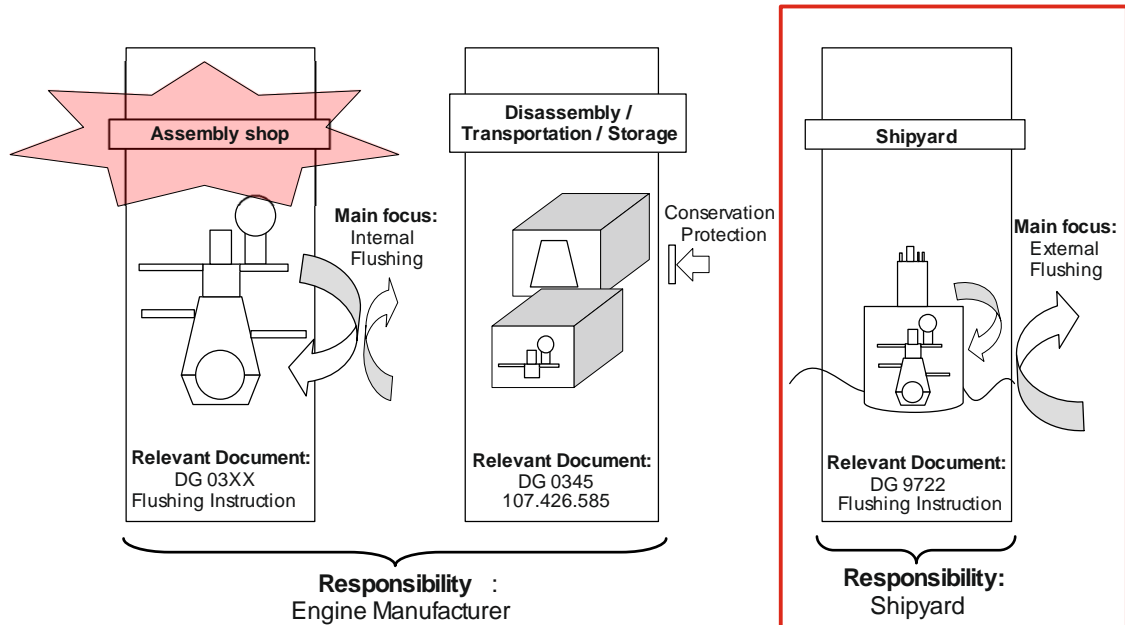
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2 Range of Application

Generally, flushing applies to the following situations:

- After engine assembly in the assembly shop at the engine manufacturer
- After engine installation in the ship on the shipyard
- After repair works of affected parts or systems



The main focus of this document is the flushing of the external system components respectively cleaning of the plant at the shipyard. The engine components are normally clean after the shop test, since the engine itself has to be flushed already at the assembly shop before the first running.

However, depending on engine delivery (e.g. with disassembled A-frame, bedplate etc.) and/or improper packing dirt might have entered into the engine. If this applies the concerned engine components have to be cleaned up again at the shipyard under consideration of the relevant instruction for engine internal flushing.

IN ANY CASE FLUSHING OF PIPING SYSTEMS SHALL BE CARRIED OUT BEFORE FIRST ENGINE START!

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3 Flushing Medium

As flushing medium system oil from the lubricating oil drain tank, continuously cleaned during flushing by the lubricating oil separators is used. The oil temperature has to be kept at approximately 40-60°C by tank heaters respectively separator pre-heaters.

4 Flushing Procedure


Before performing the system flushing an accurate preparation according to chapter 4.1 is essential.

4.1 Preparation for system flushing

1. Disconnect the system connections to the engine and led them immediately before the engine straight back into the lubricating oil drain tank by means of hoses or pipes as it is shown in figure 1 for engines without crosshead pump respectively figure 2 for engines with crosshead pumps.
2. Install temporary filters close to engine inlet with a mesh size (absolute sphere passing mesh) of max. 0.03 mm and equip them with magnetic elements. If the plant filters are used as an alternative, add magnetic inserts or supplemental filters to ensure a proper cleaning afterwards.
3. Bypass the cooler(s) and led the lubricating oil by means of hoses back into the lubricating oil drain tank.
4. To avoid condensation ensure good ventilation within engines´ crankcase by opening the crankcase doors and the crankcase round covers.
5. Fill up the lubricating oil drain tank with sufficient oil to maintain always the min. required suction level above pump inlet.

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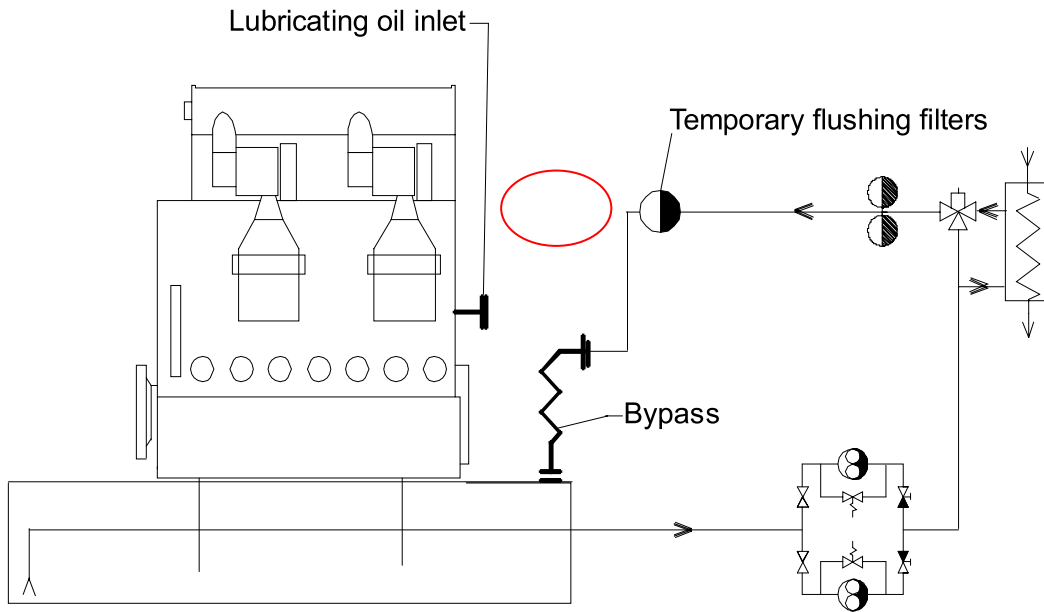


Figure 1: Preparation for system flushing for engines without crosshead pumps

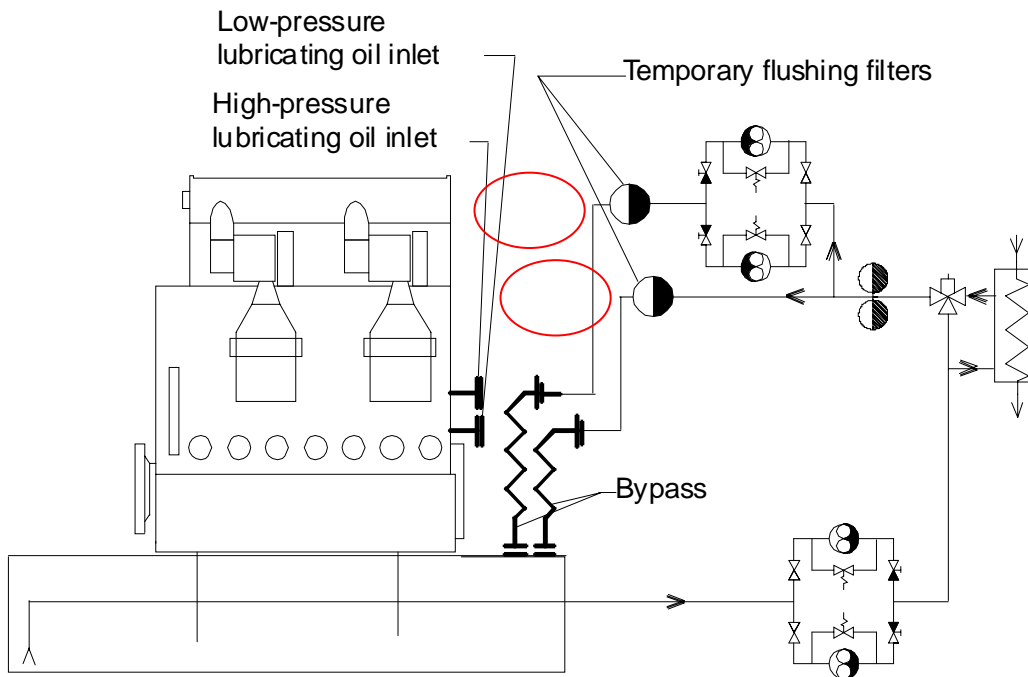


Figure 2: Preparation for system flushing for engines with crosshead pumps

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Product
W-2S

**Instruction for Flushing
Lubricating Oil System**

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4.2 Flushing of the system components


1. Flush the complete lubricating oil system by operating of the system pumps, i.e. the main lubricating oil pumps as well as simultaneously the crosshead pumps (for engines types where crosshead pumps are applied)
2. Tap the pipes periodically or apply vibrators (preferable) onto the pipes.
3. Observe the suction and discharge pump pressures carefully (take care not to run the pumps hot).
4. Observe the pressure drop through the filters and clean those periodically
5. Continue with the flushing until the lubricating oil remains clean. A first indication for clean oil is that the filter bags remain clean, no residues can be found in the filters or adhered to the magnetic filter inserts.
6. Finally the oil can be considered as being clean, as soon the contamination limits provided in chapter 7.2 are met.

4.3 Flushing of the engine components

The engine components are normally clean after the shop test, since the engine itself has to be flushed already at the assembly shop before the first running. However, depending on engine delivery (e.g. with disassembled A-frame, bedplate etc.) and/or improper packing dirt might have entered into the engine.

To remove this accumulated dirt the concerned engine components have to be cleaned up again at the shipyard under consideration of the relevant instruction for engine internal flushing and in accordance to the procedure as described in the following.

1. Check whether the system flushing according to chapter 4.2 has been successfully completed.
2. Remove all blank pieces, engine by-pass hose(s) and re-connect the engine to the lubricating oil system.
3. Prepare all pipe connections on engine side for the internal flushing according to the instruction in the relevant engine flushing instruction.
4. Flush the external system together with the engine by operating the system pumps, i.e. the main lubricating oil pumps as well as the crosshead pumps (for engines types where crosshead pumps are applied).
5. Inspect and clean the filter in the lubricating oil system periodically.
6. Continue with the flushing until the lubricating oil remains clean. A first indication for clean oil is that the filter bags remain clean, i.e. no residues can be found in the filters or adhered to the magnetic filter inserts.
7. Finally the oil can be considered as being clean, as soon the contamination limits provided in chapter 7.2 are met. For guidance, please take note that the internal flushing requires at least 8 hours.

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5 Commissioning of the lubricating oil system.

After the successful completion of the flushing procedure according to chapter 4.2 and chapter 4.3 respectively, the following steps for commissioning of the lubricating oil system have to be observed.


1. Check whether no residues, such as metallic particles adhere to the magnetic filter inserts and no residues in the bottom of the filter housings can be found.
2. When the system proves to be clean, remove all temporary flushing equipment such as blank pieces, hoses and temporary flushing filters.
3. Clean all pipe-connecting pieces, which were not flushed before separately.
4. Drain the oil from the distribution pipe to the main bearings.
5. Inspect the inside of the pipes for eventual deposits. If clean, re-fit all oil pipes.
6. Inspect the bottom of the crankcase and lubricating oil tank and clean it if necessary.
7. Clean the filter housings and insert the original lubricating oil filter cartridges.
8. Check whether all connections and components are correct attached, all screwed connections are tight and secured and ready for normal operation.
9. Remove the inspection cover of the thrust bearing in main bearing girder #2.
10. Start the system pumps i.e. the main lubricating oil pumps as well as simultaneously the crosshead pumps (for engines types where crosshead pumps are applied) and circulate the lubricating oil for approximately two hours under normal operating pressure and temperature.
11. Observe the oil flow on all bearings, spray nozzles and any other engine component such as dampers for proper oil flow.
12. Check and clean the filters periodically.
13. Turn the crankshaft with the engaged turning gear from time to time.
14. Carry out an inspection of the crankcase before refitting all the crankcase doors.

6 Cleaning of the cylinder oil supply system

In addition to the main lubricating oil system also the cylinder lubricating oil system needs to be free of foreign bodies before re-connected to the engine.

Therefore a visual inspection of the storage as well as service tanks needs to be done and if accumulated dirt is found cleaned up by hand.

The same applies for the complete piping, from the storage tank to the engine.

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7 Definition and Verification of Fluid Cleanliness

There are several methods to verify whether the piping system is sufficiently clean. A common approach to check the success of the flushing process is the visual inspection.

The visual inspection comprises:

- Filter inspection,
i.e. a judgement of the deposits found in the magnetic inserts, filter towel etc.
- Crankcase inspection,
i.e. judgement of deposits and contaminations on walls and floor and colour of oil.
- Inspection of the sludge from the separators and the back flushing filters,
i.e. judgement of appearance in comparison with other plants
- Back flushing cycles of the automatic filters,
i.e. counting of the cycles (a high rate indicates a high level of fouling)

Remark:


The visual inspection is not an approved method for the judgment of oil samples, since the verification of the fluid cleanliness highly depends on the experience of the inspecting person. Therefore to confirm the result, it is strongly recommended to execute an approved examination by particle counting according to SAE resp. ISO standard.

7.1 Contamination Classes

The following contamination classes serve as reference to judge the oil cleanliness after an examination by particle counting.

7.1.1 NAS 1638 Standard

The NAS 1638 method counts particles of different sizes and gives an upper limit of the quantity of particles for each size (differential particle count). However, the NAS 1638 standard is obsolete and not valid for new components/systems after May, 2001. Therefore the in figure 3 provided classes for particle amount limitation according to NAS 1638 specification serve just as reference.

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NAS 1638 classes		Contamination (particles per 100 ml) (1)				
Particle size in micron		5-15	15-25	25-50	50-100	>100
Classes	14	4096000	729600	129600	23040	4096
	13	2048000	364800	64800	11520	2048
	12	1024000	182400	32400	5760	1024
	11	512000	91200	16200	2880	512
	10	256000	45600	8100	1440	256
	9	128000	22800	4050	720	128
	8	64000	11400	2025	360	64
	7	32000	5700	1012	180	32
	6	16000	2850	506	90	16
	5	8000	1425	253	45	8
	4	4000	712	126	22	4
	3	2000	356	63	11	2
	2	1000	178	32	6	1
	1	500	89	16	3	1
	0	250	44	8	2	0
00	125	22	4	1	0	

Figure 3: Contamination limits according to NAS 1638

(1) Measurement devices calibrated according to ISO 4402-1991 with ACFTD (Air Cleaner Fine Test Dust). Size Range, based on longest particle dimension. Standard withdrawn in favour of ISO 11171.

7.1.2 SAE AS4059 Standard

SAE AS4059 offers two different methods for particle counting (differential and cumulative particle counts). The table below applies two acceptance criteria based on differential particle counts, and provides a definition of particulate limits for classes 00 through 14 which are based on contaminant size, count, and distribution. For this method the classes and contamination limits are identical to NAS 1638 standard.

Substitute for:						PC	Q-Code	X	X	X	X	X
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Contamination (particles/100ml)		Particle size in micron				
ISO 4402: 1991 (1)		5-15	15-25	25-50	50-100	>100
ISO 11171 (2)		6-14	14-21	21-38	38-70	>70
Classes	(14)	4096000	729600	129600	23040	4096
	(13)	2048000	364800	64800	11520	2048
	12	1024000	182400	32400	5760	1024
	11	512000	91200	16200	2880	512
	10	256000	45600	8100	1440	256
	9	128000	22800	4050	720	128
	8	64000	11400	2025	360	64
	7	32000	5700	1012	180	32
	6	16000	2850	506	90	16
	5	8000	1425	253	45	8
	4	4000	712	126	22	4
	3	2000	356	63	11	2
	2	1000	178	32	6	1
	1	500	89	16	3	1
	0	250	44	8	2	0
00	125	22	4	1	0	


Figure 4: Contamination limits according to NAS 1638

- (1) Size Range, Optical microscope, based on longest dimension as measured per ARP598 or Automatic Particle Counting (APC) calibrated per ISO 4402: 1991.
- (2) Size Range, APC Calibrated per ISO 11171 or Electron Microscope, based on projected area equivalent diameter.
- (3) Classes and contamination limits identical to NAS 1638

7.1.3 ISO 4406 Standard

The code for contamination levels according to ISO 4406 standard using automatic particle counters comprises three scale numbers, which permit the differentiation of the dimension and the distribution of the particles as follows:

- The first scale number represents the number of particles equal to or larger than 4 μm(c) per millilitre of fluid;
- The second scale number represents the number of particles equal to or larger than 6 μm(c) per millilitre of fluid;
- The third scale number represents the number of particles equal to or larger than 14 μm(c) per millilitre of fluid.


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Number of particles per 100 ml (1)		
More than	Up to and including	Class
250,000,000	—	<28
130,000,000	250,000,000	28
64,000,000	130,000,000	27
32,000,000	64,000,000	26
16,000,000	32,000,000	25
8,000,000	16,000,000	24
4,000,000	8,000,000	23
2,000,000	4,000,000	22
1,000,000	2,000,000	21
500,000	1,000,000	20
250,000	500,000	19
130,000	250,000	18
64,000	130,000	17
32,000	64,000	16
16,000	32,000	15
8000	16,000	14
4000	8000	13
2000	4000	12
1000	2000	11
500	1000	10
250	500	9
130	250	8
64	130	7
32	64	6
16	32	5
8	16	4
4	8	3
2	4	2
1	2	1
0	1	0

Figure 5: Contamination limits according ISO 4406

- (1) Measurement of particles using an optical microscope as specified in ISO 4407:1991 establishes the size of a particle as being equal to its longest dimension, whereas an automatic particle counter derives the size of an equivalent particle from its cross-sectional area, a value different in most cases from that determined using a microscope. The particle sizes to be reported for measurement by microscope, >5 µm and >15 µm, are unchanged from those specified in ISO 4406:1987

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7.2 Contamination Limits

7.2.1 Contamination limits according to SAE AS 4059 and NAS 1638 standard

For engines types **without servo oil filter** (X35, X40, X52, X62 and X72) the following cleanliness classes according to SAE AS4059 resp. NAS 1638 standard (with fresh as well as used oil) have to be kept:

Particle size (µm)	5-15	15-25	25-50	50-100	>100
Cleanliness class	13	11	9	7	5

For engines types **with servo oil filter** (RT-flex, X82 and X92) the following cleanliness classes according to SAE AS4059 resp. NAS 1638 standard (with fresh as well as used oil) have to be kept:

Particle size (µm)	5-15	15-25	25-50	50-100	>100
Cleanliness class system oil	13	11	10	8	5
Cleanliness class servo oil	13	11	8	5	0


7.2.2 Contamination limits according to ISO 4406 standard

According to ISO 4406 1999 standard the following classes are acceptable for engines with and without servo oil filter and independently whether used or fresh oil is utilized

-- / 21 / 17

Special note:

- Particles smaller than 6µm are not considered (there is no requirement to count particles equal to or larger than 4 µm)
- For particles with size above 25 µm the limits according to SAE AS4059 specification have to be kept.

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