Action code: WHEN CONVENIENT

Sampling of scavenge drain oil

Adjust feed rate factor in service, and monitor piston ring and cylinder liner wear

SL2023-738/IKCA
June 2023 (partly replaces SL2014-587 and SL2019-671)

Concerns

Owners and operators of MAN B&W two-stroke marine diesel engines.
Type: MC/MC-C and ME/ME-C, all fuel types

Summary

New guidelines for iron (Fe) content and base number (BN) of the scavenge drain oil. Guiding intervals for sampling and advise on interpretation of the results.

References to other Service Letters

SL2019-685, SL2023-737/NHN

Dear Sir or Madam

Controlling wear rates and good cylinder conditions are essential for optimising component service life and overhaul intervals.

The cylinder condition must be monitored by performing a monthly visual inspection through the scavenge air ports and by acquiring a scavenge drain oil analysis (SDA) from an accredited laboratory every third month or 1,500 running hours. In addition, it is recommended to supplement the laboratory SDA by doing onboard SDAs at short intervals (100–200 running hours).

By monitoring the cylinder condition closely, the cost of ownership can be reduced by:

- Optimising the cylinder oil feed rate
- Wear control
- Optimising overhaul intervals

This Service Letter addresses:

- Drain oil sampling
- Drain oil analysis
    - Evaluation of analysis results from accredited laboratories ashore
    - Methods for onboard drain oil analysis
    - Recommended values and dilution
- Sweep test
- Recommended schedules for drain oil sampling.

Yours faithfully

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Introduction

Drain oil is used cylinder oil scraped down from the liner which is drained off from the bottom of the scavenge air space. Scavenge drain oil analysis (SDA) is a commonly used method for monitoring wear and cylinder oil utilisation on individual cylinder units.

In general, drain oil samples can be analysed by laboratories ashore or onboard by the crew.

Drain oil is collected in small quantities and therefore the analysis result is sensitive to contamination. It is essential to keep the sampling environment and equipment clean to get valid results:

- Clean the scavenge box bottom frequently. Deposits may be a source of contamination.
- Keep the drain line open during operation
- To collect a drain oil sample:
  1. Close the drain valve.
  2. Open the sample valve. Make sure to flush out all impurities.
  3. Close the sample valve. Keep the sample valve closed sufficiently long to draw a full sample quantity.
  4. Open the sample valve and draw the sample.
  5. Close the sample valve and open the drain valve.
- To avoid contamination, use only clean sampling bottles and devices:
  - Sample directly into the sample/ forwarding container when sampling for analysis by an accredited laboratory.
  - Use disposable containers for onboard sampling where possible.
  - Alternatively, sample only in pre-cleaned and dried containers.
  - Ensure that the onboard test equipment is always cleaned before use.

To determine a potential dilution of the drain oil with system oil, take a sample of system oil (oil in use, not new system oil) and a sample of new cylinder oil, together with the drain oil samples for laboratory analysis.

Laboratory analyses

A laboratory analysis is accurate and can determine residual base number (BN), magnetic index (PQ index), water content, wear particles, contaminants, and additives.

Typically, an iron (Fe) content is specified as "total iron content" which is the sum of corrosive (non-magnetic) and abrasive/adhesive (magnetic) iron particles. The wear type and the extent can be assessed from the iron content, residual BN, and magnetic index of the drain oil. Table 1 shows a simplified assessment guidance.

Wear type and iron (Fe) type				
Wear type	Possible cause	Iron type		
		Total	Non-magnetic	Magnetic
Abrasive	Cat fines in fuel Sand and dust in air	x		x
Adhesive	Water carryover Lack of cylinder oil	x		x
Corrosive	Sulphuric acid Too low cylinder oil dosage	x	x	

Table 1: Typical correlation between wear cause and iron content in the drain oil

The presence of other metals or elements in the drain oil can indicate wear of the piston skirt, running-in wear, contamination, or dilution with system oil. See Appendix I.

System oil dilution lowers the iron content and lowers the BN of the drain oil and the analysis results may be misleading, if the drain oil is excessively diluted. High dilution levels can indicate excessive leakage from the stuffing box or the piston, but it can also be the result of low cylinder scrape down volumes combined with minor unavoidable system oil leakages. This does not indicate a defect which needs attention.

Lube oil laboratories should be able to determine the dilution level of the samples, provided analysis results of used system oil (drawn together with SDA samples) and new cylinder oil are available.

Sampling frequency

Laboratory analyses should be carried out at intervals of maximum 1,500 running hours, or every third month, depending on which criteria is met first.

Onboard drain oil analyses are considered an effective monitoring and optimisation measure, but they cannot substitute drain oil analyses made by an accredited laboratory. MAN Energy Solutions only accepts analysis results from accredited laboratories as documentation of the condition.

Onboard analyses

Drain oil analyses done onboard is considered supplementary to analyses done at laboratories ashore. However, onboard analyses done at short intervals enable early detection, correction or mitigation of abnormal conditions which can occur, for example, when operating on contaminated fuels. Onboard monitoring of the drain oil may also support decisions in an optimisation of the cylinder oil feed rate.

Three analysis methods are available: X-ray fluorescence (XRF), chemical reaction, and magnetic detection. When evaluating the drain oil analysis, both the fuel type and the used analysis method must be considered.

Drain oil iron content

The iron content in the drain oil depends on fuel sulphur content, cylinder oil grade and feed rate, engine type, and engine condition.

For evaluation of the measured iron content, the analysis method must be considered. The iron content can be measured as magnetic particles, as iron oxide (non-magnetic), or as the total iron content.

Wear to cylinder unit components is unavoidable, but a high wear rate may be critical. To distinguish between different degrees of wear, four categories are considered:

1. "Normal" wear indicates a good cylinder condition and adequate lubrication with low wear.
2. "Raised" wear indicates acceptable and uncritical wear within the limits of the component service life.
3. "Abnormal" wear is acceptable for shorter periods, however, it indicates increased wear.
   It is recommended to make (onboard) drain oil analyses more frequently. Observe that the wear level neither remains abnormal nor escalates. When successive or repeated abnormal values are recorded, the cause must be identified and addressed. Typically, increased wear is caused by water in the scavenge air, contaminants in the fuel, or insufficient neutralisation of sulphur (high-sulphur fuel). However, do not rule out other causes.
   Abnormal wear is expected during running-in of new liners and new piston rings.
4. "Alert" indicates an ongoing high-wear situation which must be identified immediately and corrected. Continuous operation in the critical range can lead to engine damage and/or reduced service life of components.

Tables 2 and 3 show guiding drain oil values for total iron content and magnetic iron content, respectively, for the four wear categories. These values correspond to a feed rate of 1.0 g/kWh. An iron content obtained at a given feed rate must be corrected to reflect the content at 1.0 g/kWh, considering the same iron quantity (absolute wear).

See Equation 1 and the following example.

$$Fe_{Corr1.0} = Fe_{Act} \cdot FR_{Act} \qquad \text{Eq. (1)}$$

Example: An iron content (Fe_{Act}) of 35 ppm at feed rate (FR_{Act}) 0.80 g/kWh corresponds to 28 ppm at feed rate 1.0 g/kWh.

Guiding total iron (Fe) content in drain oil [mg/kg]				
Fuel type	**Normal**	**Raised**	**Abnormal**	**Alert**
ULSFO ≤0.1% S	≤25	25–40	>40	>300
VLSFO 0.10–0.50% S	≤40	40–80	>80	>300
HSFO 0.50–3.5% S	≤100	100–200	>200	>800

Table 2: Guiding values in four wear categories for total iron content in drain oil, depending on the fuel type

Guiding magnetic iron (Fe) content in drain oil [mg/kg]				
Fuel type	**Normal**	**Raised**	**Abnormal**	**Alert**
ULSFO ≤0.1% S	≤25	25–40	>40	>300
VLSFO 0.10–0.50% S	≤30	30–70	>70	>300
HSFO 0.50–3.5% S	≤40	40–100	>100	>600

Table 3: Guiding values in four wear categories for magnetic iron content in drain oil, depending on the fuel type

Drain oil residual base number

The cylinder oil BN reduction mainly depends on the sulphur content of the fuel. The lower the sulphur content, the lower the utilisation of cylinder oil BN for neutralisation. Table 4 shows guiding values for drain oil residual BN.

Guiding BN values for drain oil in percentage of fresh cylinder oil BN [%]			
Fuel type	**Normal**	**Abnormal**	**Alert**
ULSFO (including LNG, LPG, and methanol) ≤0.1% S	>80%	50–80%	<50%
VLSFO 0.10–0.50% S	>80%	40–70%	<40%
HSFO 0.50–3.5% S	>30–50%*	<30%*	<20%*

*to be based on sweep test result

Table 4: Guiding values for drain oil residual BN

The use of a fuel without sulphur, or a low-sulphur fuel results in a small BN reduction. It means that the drain oil can have a correspondingly high residual BN which is not critical in terms of cylinder condition.

The piston cleaning ring (PC-ring) scrapes possible surplus calcium deposits off the piston top land. Observe that a low deposit level is always maintained on the piston top land. Calcium deposits accumulating on the piston crown top are not critical.
An unexpected low residual BN can be caused by water in the scavenge air or by dilution with system oil.

Fig. 1 shows the total iron content and residual BN of the drain oil and areas indicating high wear, abnormal wear, and safe conditions.

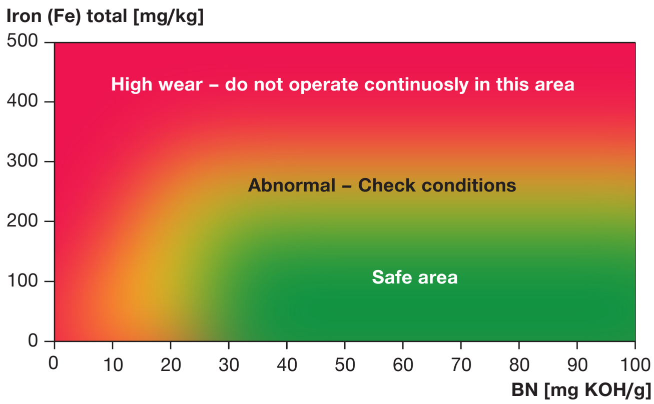

Fig. 1: Drain oil BN versus total iron (Fe) content

For operation on low-sulphur fuels, MAN Energy Solutions recommends using a cylinder oil with a BN as low as possible without compromising detergency requirements. Reference is made to SL2023-737/NHN.

For cermet-coated piston rings in service on high-sulpur fuels, both SDA results and piston ring coating wear rates must be considered when evaluating the cylinder oil feed rate. Inadequate sulphur neutralisation increases the coating wear and should be adressed if the wear rate is too high. Reference is made to SL2019-685.

Sampling schedule

Onboard analyses can be done as a supplement to the regular laboratory analyses. More frequently, onboard analyses are used as an extra control between the regular analysis every third month, or after 1,500 running hours. When operating on a high-sulphur fuel, evaluation of drain oil BN is important to make sure that the level of corrosion is under control.

Table 5 shows guiding intervals [running hours] for sweep test, drain oil laboratory analyses, and onboard drain oil analyses, respectively.

Guiding intervals for sweep test, drain oil laboratory analyses, and onboard drain oil analyses [running hours]				
Analysis		**≤0.1% S LNG, LPG, MeOH**	**0.5% S residual fuel**	**>0.5% S HSFO residual fuel**
Sweep test*** (high-sulphur fuel)		not applicable	not applicable	Initial sweep test after approx. 500 running hrs*
Drain oil analyses - laboratory ashore		1,500	1,500	1,500
Drain oil analyses - onboard	Fe	200**	100–120**	100–120**
	BN	not applicable	not applicable	

*to be done when running-in is completed

**reduce the interval if the iron content is abnormal or critical

***see Appendix II

Table 5: Guideline intervals [running hours] for drain oil sampling

Appendix I

List of substances and possible origins

Substance	Chemical symbol	Typical origin
Iron	Fe	Wear to liner, uncoated pistons rings, and base material of coated piston rings
Chromium	Cr	Wear to piston ring grooves and piston rings
Molybdenum	Mo	Wear to piston skirt (if molybdenum coated) and/or cermet coating on piston rings
Copper	Cu	Running-in of alu-coated piston rings Wear to stuffing box bronze parts Wear to piston skirt
Lead	Pb	Dilution with system oil/bearing wear
Tin	Sn	Dilution with system oil/bearing wear
Aluminium	Al	Cat fines in residual fuels Dilution with system oil/bearing wear[1]
Vanadium	V	Fuel oil remains (residual fuels only)
Silicon	Si	Cat fines in residual fuels Lube oil additive[2]
Calcium Magnesium Zinc Phosphorus Boron	Ca Mg Zn P B	Lube oil additive[2]
Silver Potassium Nickel Barium	Ag K Ni Ba	Contamination – not additives or wear components. Should only be observed in insignificant concentrations.
Sodium	Na	Seawater (via scavenge air or fuel oil)

[1] Metals used in bearings. Can be carried over by leaked system oil. Check for system oil dilution. Check system oil

[2] Additives in cylinder oil and/or system oil. Levels will vary, depending on brand and grade.

Appendix II

Sweep test result

A sweep test is only applicable for engines operated on high-sulphur fuel. The sweep test establishes engine corrosiveness and should be done after completion of running-in and before reducing the initial feed rate factor (FRF) below 0.40 g/kWh/%S.

A sweep test must also be done:

- If the engine specification is altered
- If the operating conditions have changed.

The sweep test consists of a series of four (or five) sets of drain oil samples collected under the following conditions:

- Collect samples at feed rates: 1.4, 1.2, 1.0, 0.8 (and 0.6) g/kWh
- Operate the engine on fuel with minimum 2.8% S
- Engine conditions should be uniform during the sweep test:
  - Stable engine load at a typical navigational speed
  - Stable air temperature and humidity
- Maintain the feed rate for 24 hours before sampling.

Find detailed instructions on how to perform a sweep test in the latest sweep test protocol available on our extranet NEXUS.

The FRF [g/kWh/%S] must be calculated for each sample set.

The iron content and the residual BN results from the analyses of the samples have to be correlated by plotting both as a function of the feed rate factor in a diagram. See also Fig. 2.

Next, graphs can be drawn which show the iron content and residual BN relative to the calculated FRF. The FRF and the residual BN corresponding to the selected iron content can be established from the graphs.

The conclusion of the sweep test is an approximation which should be verified by scheduled drain oil analyses. The concluded FRF should be adjusted if the service experience deviates from the result of the sweep test.

Significant deviations in operating conditions (load, climate) affect the sweep test results. If the operating conditions change compared to the typical conditions, or if the engine has been modified, it may be required to repeat the sweep test.

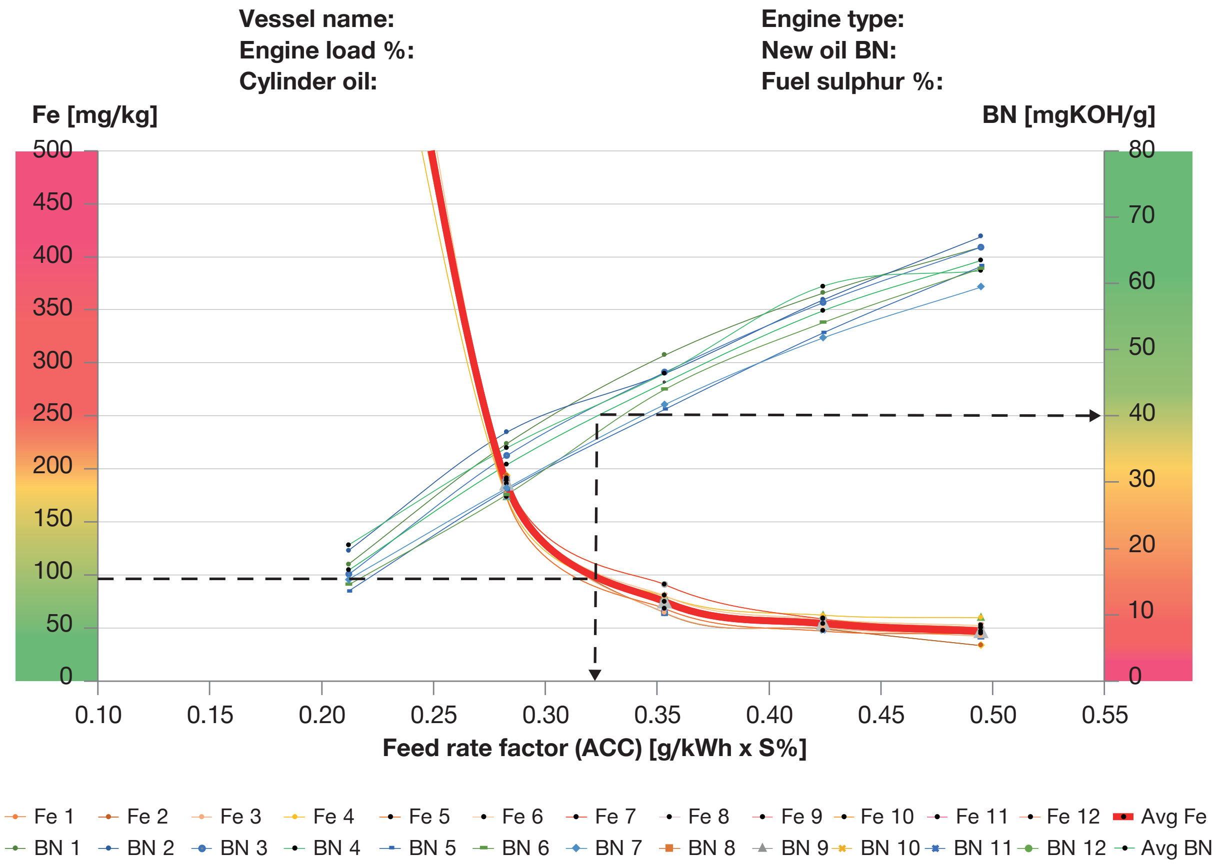

Fig. 2: The curves: fe1–fe12, Avg. Fe, and BN1–BN12, and Avg. BN show the iron content and the residual BN as a function of the feed rate factor for the sweep test, respectively. Based on a selected iron content: 100 mg/kg, the FRF must be 0.32 g/kWh/%S, and BN41 is the residual level for 100 ppm iron.