Action code: **WHEN CONVENIENT**

Cylinder Lubrication Update

Adjusting the ACC factor in service

Replaces SL2013-571

SL2014-587/JAP

March 2014

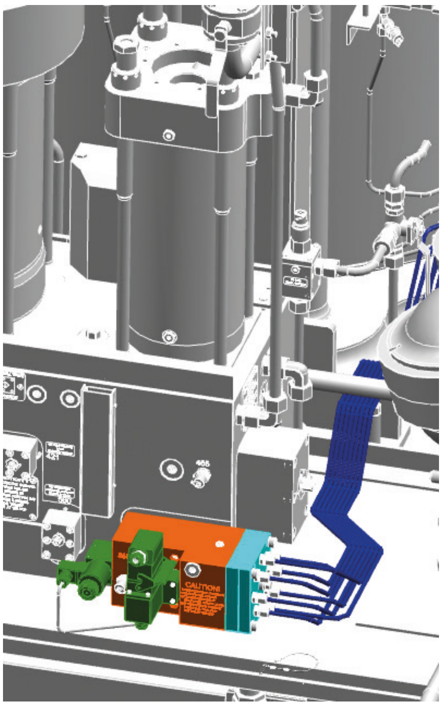
Concerns

All ME/ME-C/ME-B/MC/MC-C and ME-GI engines with electronically controlled lubricators.

Summary

New cylinder oil lubrication recommendation. Guiding ACC values for all engines: ACC100 (BN 100). Range 0.20-0.40 g/kWh x S% minimum 0.60 g/kWh.

Guidelines for mechanical lubrication are found in SL2000-385 and SL2012-553.



Dear Sirs

Recent service experience has called for an update of our guidelines on cylinder lubrication of MAN B&W low speed engines. We have seen a greater challenge for lubrication in certain applications of our newer engine types.

From delivery from the yard, the basic cylinder lube oil recommendation for Mk 8-8.1 engines and newer is therefore to use BN 100 cylinder oils and maintain a feed rate ACC100 factor of 0.4 g/kWh x S% until the actual feed rate ACC factor can be evaluated by conducting a feed rate sweep.

Engines in service may also benefit from the use of BN 100 oils because the feed rate ACC factor can be reduced thanks to the high alkalinity of BN 100 oils.

For engines where the feed rate ACC factor has already been established and confirmed, new cylinder oils with a different BN level can be used to change the feed rate ACC factor by multiplying the present feed rate ACC factor by the fraction of the BN in the present and the new cylinder oil. Afterwards, the new setting has to be confirmed, either by a feed rate sweep and/or a conventional drip oil analysis.

The individual feed rate ACC factor must be evaluated for each engine using drip oil analysis and frequent scavenge port inspections. There are many options for this evaluation, but common to them all is the fact that they cannot stand alone. Feed rate sweeps have to be followed by monthly drip oil sampling and/or scavenge port inspections, in order to assure that the engine is performing as expected.

Yours faithfully

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Introduction

Lately, MAN Diesel & Turbo has concentrated on further enhancing the fuel efficiency while at the same time fulfilling Tier I and Tier II. In order to improve the specific fuel oil consumption, the pressure in the combustion chamber has been increased on the newest engine designs. This pressure increase, together with the increased operating time at part load, has led to increased water and acid condensation on the cylinder walls, which leads to cold corrosion in the combustion chamber.

Also the most recently developed part-load and low-load tuning options utilise increased combustion chamber pressure as the main tool to ensure a low SFOC (Specific Fuel Oil Consumption) at part load, and the same result may be experienced.

Appropriate cylinder oil feed rates and ACC (Adaptable Cylinder oil Control) feed rate factor values must be obtained on the basis of service inspections, measurements and wear data from combustion chamber parts (piston rings, liner, and crown), and supplemented with scavenge drain oil analyses.

Cylinder lubrication

Cylinder oil is essential for the two-stroke engine. Today's cylinder oils are made with a complex chemistry, and the individual feed rate must therefore be assessed for each oil brand, viscosity class and BN level.

A cylinder oil is blended to achieve the necessary level of detergency and dispersancy to keep the piston rings and crown clean, and the necessary base number (BN) to neutralise the acids formed during combustion.

The cylinder oil not only serves to lubricate the moving parts, but is also designed to control the degree of corrosion on the liner surface.

This is illustrated by our feed rate guide, which sets the minimum feed rate to the level needed to keep the parts moving within a safe margin. However, so as to ensure the necessary lubrication effect, an increased formation of acid would call for a higher BN level than specified at the minimum feed rate. This is compensated for by calculating a feed rate on the basis of an ACC factor within the guide shown in Fig. 1.

MAN Diesel & Turbo recommends using cylinder lube oils characterised primarily by its BN number and SAE viscosity and to use a feed rate according to the BN in the cylinder oil and sulphur content of the fuel. MAN Diesel & Turbo is aware that some engines may be operated satisfactorily at even lower feed rates. Hence, feed rates are, just as before, based on practical experience rather than pre-calculated figures.

The above mirrors the importance of the fact that the crew should challenge the cylinder oil feed rate ACC factor, so as to find the correct ACC value that suits the actual engine configuration and engine load.

Mid-range cylinder oil

In order to simplify the lubrication process onboard the ships, as well the logistics of supply, the oil companies started the process of developing a cylinder lube oil that can lubricate the cylinders regardless of the sulphur content in the fuel.

- Such oils have BN levels that are lower than the traditional BN 70 cylinder lube oils.
- Such oils can very well be used on earlier-type MAN B&W engines that are not affected by cold corrosion, but are not applicable on newer engine designs with higher levels of cold corrosion.
- These oils can however be used as low BN oils for heavy fuel on all engine types.

Optimising the ACC factor

The best way to establish the optimum ACC factor is to measure the engine wear. If the wear rate of the liner and piston rings is too high the ACC factor must be increased to reduce the wear.

> We recommend to start out with an ACC factor in the upper end of the range, and then slowly adjust it when the engine wear response has been confirmed by measurements.

For more information on condition-based monitoring, we refer to our service letter SL2007-483.

However, the ACC factor can only be assessed when the fuel sulphur level has been high enough to ensure that the lubrication has been in the ACC active area (the blue area marked in Fig. 1), at lower fuel sulphur levels the engine is excessively protected against corrosion because of the active minimum feed rate.

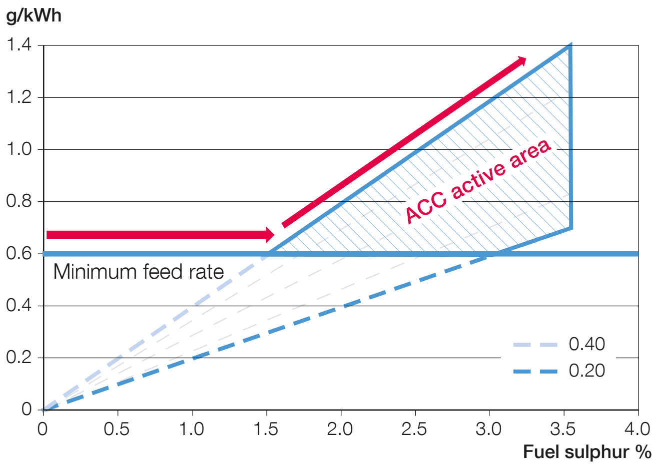

Fig. 1a: BN 100 ACC range Mk 8-8.1 and newer

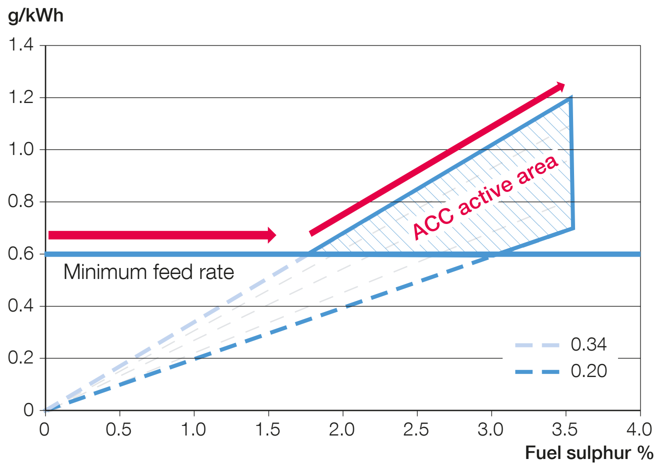

Fig. 1b: BN 70 ACC range Mk 7 and older

The acceptable wear rates must be in line with our recommendations on overhaul intervals and expected lifetime of the components, see SL2009-509. Liner wear rates are normally below 0.1 mm/1,000 running hours (rh).

High ovality in the liner wear could be a sign of corrosive wear. As the liner surface temperature is not necessarily uniform, more corrosion will occur in the colder areas.

The piston ring wear must also be kept under observation, and it must be assured that the controlled leakage (CL) groove on the piston rings is not worn below the acceptable minimum and that the POP-ring groove does not exceed its maximum allowable wear, see Encl. 3. For more information on CPR-POP rings, see SL2012-562.

Drain oil analysis

Used oil taken from the engine through the scavenge bottom drain can be used for cylinder condition evaluation.

Drain oil analysis is also a strong tool for judging the engine wear condition. Drain oil samples taken in active ACC operation will show if the oil feed rate can be optimised while keeping the BN above 10-25 mg KOH/g and the iron (Fe) content below 200 mg/kg in the drain oil (Table 1 & Fig. 2).

It is important to note that elevated iron values may be experienced as the piston ring running-in coating gradually wears off.

Onboard sets exist, but it is important to get a valid test result that shows the total content of iron (Fe). Laboratory testing according to ASTM D5185-09 is the only certain measuring method. The BN must be tested in accordance with ISO 3771:2011(E).

A cylinder oil can be degraded to a certain level where the corrosion level begins to increase. The level of depletion is different among oil brands and engines, and an individual evaluation of each engine is therefore recommended.

Scavenge Drain Oil – Guiding Values	
BN	greater than 10-25 mg KOH/g
Iron [Fe]	less than 200 mg/kg

Table 1: Drain oil values

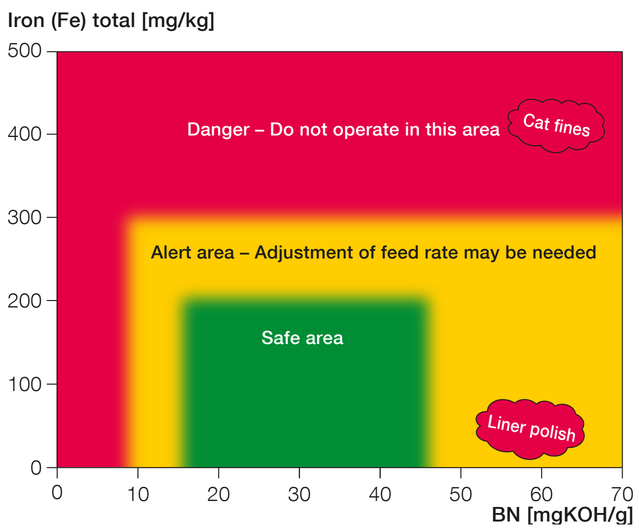

Fig. 2: Drain oil BN vs. iron (Fe)

One possibility is to perform a stress test called "feed rate sweep". This will shorten the ACC familiarization period considerably. The sweep test is based on a 4 to 6-day test at steady load and, preferably, running on fuel in the high-sulphur range of 2.8-3.5% sulphur content. The feed rate is adjusted to set values, i.e. 1.4, 1.2, 1.0, 0.8 and 0.6 g/kWh.

Each feed rate must be applied for 24 hours before taking a sample and switching to the next feed rate (Fig. 3). A detailed feed rate sweep protocol is enclosed (Encl. 6).

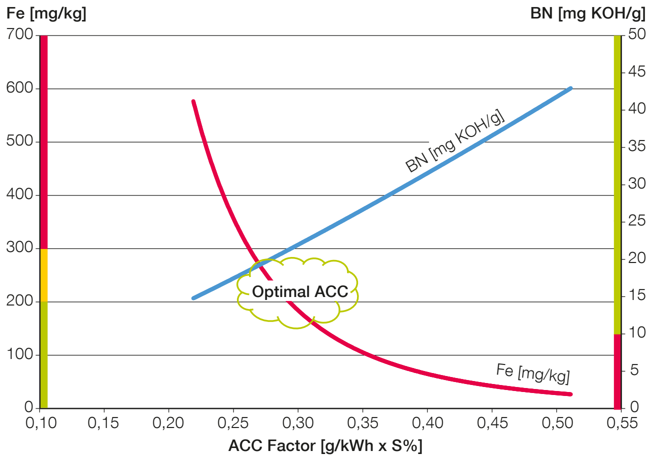

Fig. 3: Feed rate sweep

During the sweep test period the engine operation must be kept as consistent as possible to avoid interference from load up and fuel change.

Cylinder oils with different BN levels

The various oil suppliers offer cylinder oils with a broad range of BN levels. Our MAN B&W engine design is based on the 70 BN oil traditionally used, however, as new oil products have been introduced, BN levels have changed, and today's design standard is the new 100 BN oils.

When switching to a different BN level, we recommend to start out with scaling the ACC factor from 70 to the new BN level by multiplying the ACC factor with the fraction of 70 BN oil.

Example:
Using a BN 85 and ACC (BN 70) = 0.26
ACC (BN 85) = 0.26 × 70/85 = 0.21
(see Table 10 in Encl. 5)

When changing to a new oil brand or type, the ACC factor may need to be reassessed as described above, starting with an ACC factor in the upper range. After this, a gradual reduction can be carried out based on actual observed conditions or the sweep test.

Low-sulphur HFO and distillates

When running on low-sulphur residual fuel (HFO), the feed rate will be set at the minimum feed rate. High-BN cylinder oils will lead to over-additivation in the aspect of controlling the corrosion as well as lead to increased build-up of piston crown deposits.

We therefore recommend switching to a low-BN cylinder oil at the same time as switching to a low-sulphur heavy fuel. Continuous running on high-BN cylinder oils can only be recommended in special cases, and not for more than 1 to 2 weeks, see Table 2.

Application	BN
Distillate and LNG	< = 40
Low-sulphur residual fuel (≤1.5% sulphur)	40-60
High-sulphur residual fuel (≥1.5% sulphur)	70-100

Table 2: Cylinder oil guide

Also when switching to distillate fuels (MGO/MDO), we recommend switching to a low-BN cylinder oil at the same time as the switching of the fuel. We do not recommend the use of a high-BN cylinder oil when running on distillate fuels.

Slow steaming

When the vessel is slow steaming, the engine is operated at low load, and the liner surface will become cooler and, therefore, increase the risk of corrosion. Waste heat recovery and various part-load optimisation possibilities, e.g. TC cut-out, variable turbine area (VTA) turbocharger, and exhaust gas bypass (EGB), ECO cam, may call for a re-assessment of the ACC factor to accomodate the new corrosion level.

It is important to note that low-load operation (slow steaming) is not the only reason for increased cold corrosion potential. Optimisation methods on new engines or retrofitting on older engines increase the cold corrosion potential also at normal load.

Guiding values

Guiding values Mk 8-8.1 and newer

Base number (BN)	100
SAE	50
Guiding minimum feed rate	0.60 g/kWh
ACC BN100 range	0.40-0.20 g/kWh x S%

Guiding values Mk 7 and older

Base number (BN)	70-100
SAE	50
Guiding minimum feed rate	0.60 g/kWh
ACC BN70 range	0.34-0.20 g/kWh x S%

Table 3: Guiding values

Running-in operation
MAN B&W two-stroke engines require extra attention and lubrication during their first running hours.

The first 500 running hours are the most demanding. This is the period where the liners are run in, which is also referred to as the breaking-in period.

The purpose of the breaking-in period is to flush away wear particles and facilitate running-in of the liner surface and rings.

The breaking-in period is followed by a familiarization period, where the crew must asses the engine wear and cylinder condition to select the right ACC factor for the engine application.

Breaking-in (0-500 rh)
Cylinder liner and piston ring breaking-in takes 500 running hours maximum (see Fig. 5, Encl. 2).

During this breaking-in period, the running-in coating on the piston rings will gradually wear off, and the wave cut shape on the cylinder liner surface will smoothen. During this process, extra lubrication oil is required to flush away wear particles and assure a satisfactory oil film between the relatively rough sliding surfaces.

During breaking-in, we recommend checking piston rings and cylinder liners through scavenge air port inspections for every 100 hours. Do not proceed to the next lubrication step if the scavenge air port inspection reveals seizures or other irregularities.

The feed rate during breaking-in must not be set lower than the fuel sulphur content depending feed rate (fuel sulphur x feed rate ACC factor). The highest feed rate of the two must be used.

Hours	g/kWh
0-5 hours	1.70 g/kWh
5-100 hours	1.50 g/kWh
100-200 hours	1.30 g/kWh
200-300 hours	1.10 g/kWh*
300-400 hours	0.90 g/kWh*
400-500 hours	0.70 g/kWh*

** Only if the ACC dependent (fuel sulphur x ACC factor) feed rate is lower than the step, if not then the ACC dependent feed rates are to be used.*

Table 4: Breaking-in

Familiarization of the ACC factor
After the breaking-in period, the engine ACC factor should be assessed over a period of steps of 600 hours (see Fig. 6, Encl. 2).

To be able to asses the engine wear, the steps must be completed with a fuel sulphur content that is high enough to assure that the cylinder oil feed rate is in the ACC active range. This means that the feed rate must be above the minimum 0.60 g/kWh.

Before moving to the next step, the cylinder condition and wear must be assessed through a scavenge port inspection. The feed rate ACC factor should not be reduced unless the cylinder condition permits it.

In some cases, this familiarization period extends substantially. However, the period can be substantially shortened by means of scavenge drain analyses, where the laboratory results will show the remaining BN and Fe (iron) content. If the samples taken during the ACC active feed rates repeatedly show high BN and acceptable Fe levels, the ACC factor can be lowered.

After the feed rate ACC factor has been adjusted according to the sweep, the drain oil must to be monitored to verify the ACC setting or make possible adjustments.

Once the ACC factor has been confirmed and the wear is under control, the best choice of cylinder oil can be made. In special cases where the ACC factor is reasonably low, and/or the fuel sulphur level usually experienced is low, the best choice of cylinder oil could be a grade with a lower BN, depending on feed rate and price.

Please direct any inquiries and questions regarding tables or condition-based overhaul to our Operation Department at leo@mandieselturbo.com or to our Service Department at PrimeServ-cph@mandieselturbo.com.

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Guiding cylinder oil feed rates
All ME/ME-C/ME-B/ME/MC/MC-C and ME-GI engines
With electronically controlled lubrication system

	Mk 8-8.1 and newer Standard BN 100	Mk 7 and older Standard BN 70-100
Viscosity range	SAE 50	SAE 50
ACC setting	0.40-0.20 g/kWh x S%	0.34-0.20 g/kWh x S%
Guiding minimum feed rate	0.60 g/kWh	0.60 g/kWh
Maximum feed rate during running-in	1.7 g/kWh	1.7 g/kWh
Part-load control	Proportional with load. At lower loads control is automatically changed to proportional with rpm. Breakpoint from power to rpm-dependent lubrication to be set to 25% load.	
Running-in new or reconditioned liners and new piston rings	**Feed rate:** First 5 hours: 1.7 g/kWh From 5 to 500 hours: Stepwise reduction from 1.5 - 0.6 g/kWh or ACC factor x fuel sulphur (using the highest feed rate) **Engine load:** Test bed: Stepwise increase to max. load over 5 hours In service: 50% to max. load in 16 hours	
Familiarizing ACC Factor	Starting at 0.40 g/kWh x S% (Fig. 6a)	Starting at 0.34 g/kWh x S% (Fig. 6b)
	Reducing in steps of 0.04 g/kWh x S% after min. 600 hours where the feed rate has been sulphur dependent (above min. feed rate) or using feed rate sweep or continuous drain oil analysis. If the engine is retrofitted with means to improve part or low-load fuel consumption, the ACC factor must be reassessed.	
Running-in new rings in already run-in and well running liners	From 50% to max. load in 5 hours Feed rate 0.9 g/kWh for 24 hours. If the fuel sulphur and applied ACC factor combination results in a specific feed rate higher than 0.9 g/kWh (use the calculation feed rate), no extra lubrication is needed.	
Manoeuvring and load change situations	During starting, manoeuvring and load changes, increase feed rate by means of the “LCD” by 25% of the actual figure and kept at this level for ½ hour after the load has stabilised.	
Lubrication of cylinders that show abnormal conditions	Frequent scavenge port inspections of piston rings and cylinder liners are very important for maintaining a safe cylinder condition. If irregularities are observed, adjustments of the lube oil feed rate should be considered. In case of scuffing, sticking piston rings or high liner temperature fluctuations, raise the feed rate to 1.20 g/kWh and lower the pmax and mep. As soon as the situation has been stabilised, set the lubrication feed rate and pressures back to normal. In case of high corrosive wear, the ACC factor is to be increased to the highest ACC factor (0.40 g/kWh x S% for BN 100)) and be reduced in steps of only 0.02 g/kWh x S% when the wear has been confirmed as normal.	

Table 5: Guiding cylinder oil feed rates

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Breaking-in New Liners

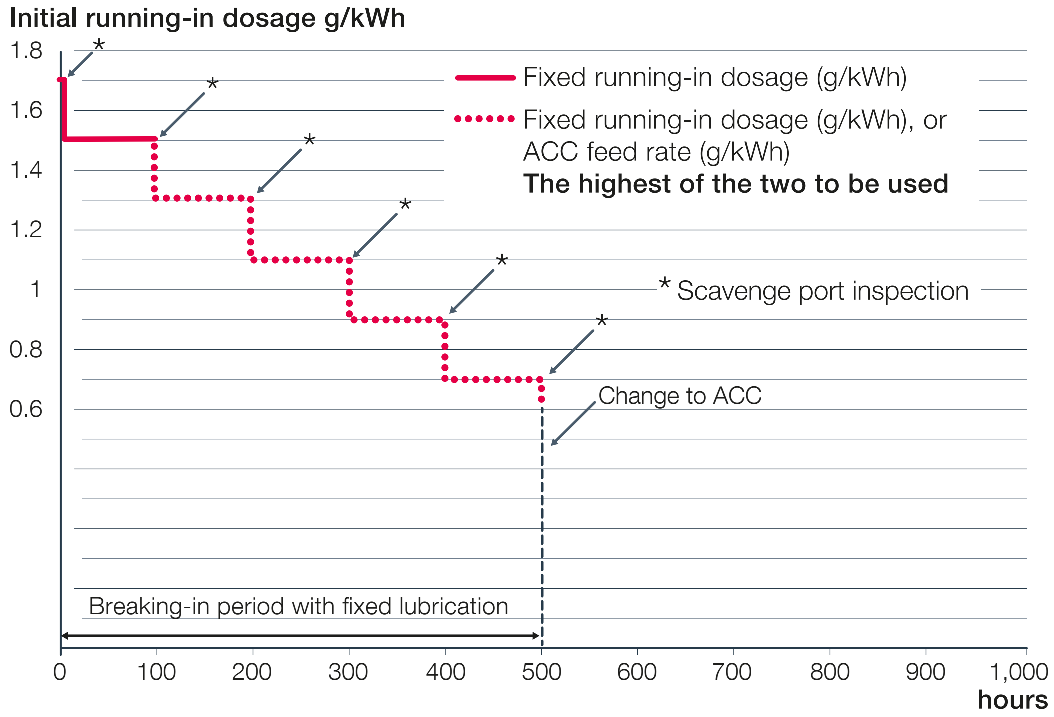

Fig. 5: Breaking-in schedule

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New ACC Running-in Schedule (liner and rings)

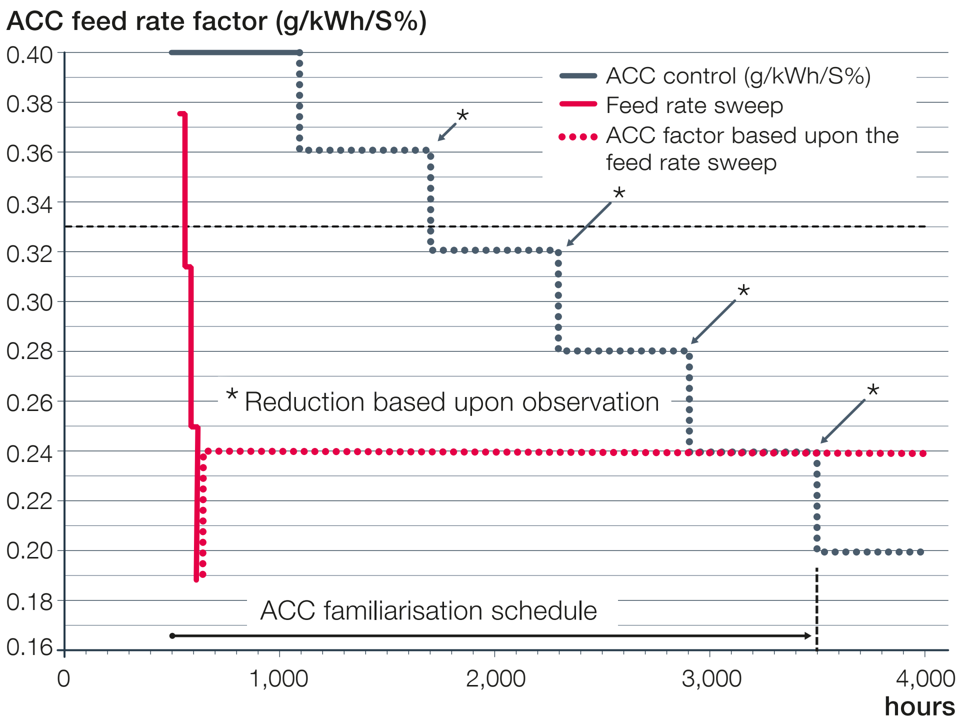

Fig. 6a: ACC familiarisation schedule for Mk 8-8.1 and newer

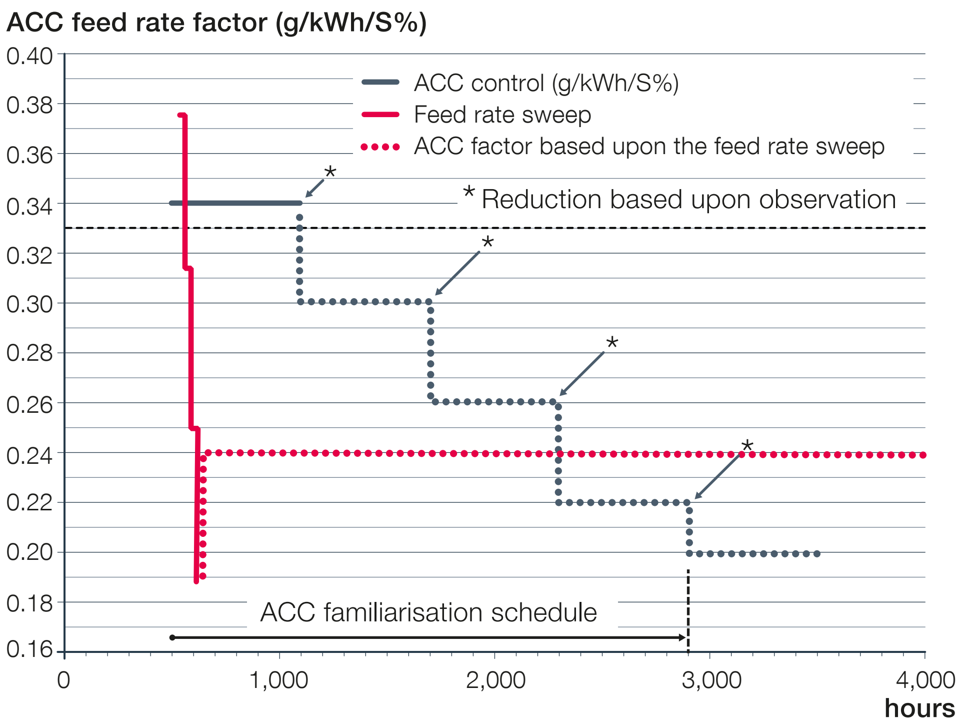

Fig. 6b: ACC familiarisation schedule for Mk 7 and older

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Guiding Wear Rate Values

Bore size [cm]	Max. radial ring wear [mm]	Max. width of leakage groove (use feeler gauge) [mm]
26 cm	1.8	6.6
30 cm	2.0	7.0
35 cm	2.2	7.4
40 cm	2.2	7.4
42 cm	2.2	7.4
45 cm	2.2	7.4
46 cm	2.2	7.4
50 cm	3	9

Table 6: CPR-POP top ring wear

Engine bore	CL-groove new depth	Minimum depth
26 cm	2.0 mm	0.6 mm
30 cm	-	-
35 cm	2.5 mm	0.8 mm
40 cm	2.5 mm	0.8 mm
42 cm	2.5 mm	0.9 mm
45 cm	-	-
46 cm	2.5 mm	1.0 mm
50 cm	3.0 mm	1.1 mm
60 cm	3.5 mm	1.3 mm
65 cm	3.5 mm	1.4 mm
70 cm	3.5 mm	1.6 mm
80 cm	4.0 mm	1.8 mm
90 cm	(Cermet 4.0 mm) 5.0 mm	2.0 mm
98 cm	(Cermet 4.5 mm) 5.5 mm	2.2 mm

Table 7: CPR-CL top ring wear

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ACC settings for lubricating oils for MC/MC-C engines

Alpha Lube ACC High BN Cylinder Oil											
ACC factor g/kWh × S%										g/kWh	HMI setting
0.20	0.24	0.26	0.28	0.30	0.32	0.34	0.36	0.38	0.40		
Sulphur content %											
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.59	54
3.1	2.6	2.4	2.2	2.1	1.9	1.8	1.7	1.6	1.5	0.62	56
3.2	2.7	2.5	2.3	2.1	2.0	1.9	1.8	1.7	1.6	0.64	58
3.3	2.8	2.5	2.4	2.2	2.1	1.9	1.8	1.7	1.7	0.66	60
3.4	2.8	2.6	2.4	2.3	2.1	2.0	1.9	1.8	1.7	0.68	62
	2.9	2.7	2.5	2.3	2.2	2.1	2.0	1.9	1.8	0.70	64
	3.0	2.8	2.6	2.4	2.3	2.1	2.0	1.9	1.8	0.73	66
	3.1	2.9	2.7	2.5	2.3	2.2	2.1	2.0	1.9	0.75	68
	3.2	3.0	2.8	2.6	2.4	2.3	2.1	2.0	1.9	0.77	70
	3.3	3.0	2.8	2.6	2.5	2.3	2.2	2.1	2.0	0.79	72
	3.4	3.1	2.9	2.7	2.5	2.4	2.3	2.1	2.0	0.81	74
	3.5	3.2	3.0	2.8	2.6	2.5	2.3	2.2	2.1	0.84	76
		3.3	3.1	2.9	2.7	2.5	2.4	2.3	2.1	0.86	78
		3.4	3.1	2.9	2.8	2.6	2.4	2.3	2.2	0.88	80
		3.5	3.2	3.0	2.8	2.7	2.5	2.4	2.3	0.90	82
			3.3	3.1	2.9	2.7	2.6	2.4	2.3	0.92	84
			3.4	3.2	3.0	2.8	2.6	2.5	2.4	0.95	86
			3.5	3.2	3.0	2.8	2.7	2.5	2.4	0.97	88
				3.3	3.1	2.9	2.8	2.6	2.5	0.99	90
				3.4	3.2	3.0	2.8	2.7	2.5	1.01	92
				3.4	3.2	3.0	2.9	2.7	2.6	1.03	94
					3.3	3.1	2.9	2.8	2.6	1.06	96
					3.4	3.2	3.0	2.8	2.7	1.08	98
					3.4	3.2	3.1	2.9	2.8	1.10	100
						3.3	3.1	3.0	2.8	1.12	102
						3.4	3.2	3.0	2.9	1.14	104
						3.4	3.2	3.1	2.9	1.17	106
						3.5	3.3	3.1	3.0	1.19	108
							3.4	3.2	3.0	1.21	110
							3.4	3.2	3.1	1.23	112
							3.5	3.3	3.1	1.25	114
								3.4	3.2	1.28	116
								3.4	3.2	1.30	118
								3.5	3.3	1.32	120
									3.3	1.33	121
									3.4	1.34	122
									3.4	1.35	123
									3.4	1.36	124
									3.4	1.38	125
									3.5	1.39	126
									3.5	1.40	127

Table 8: Feed rate ACC factor

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Specific feed rate in relation to fuel sulphur % and feed rate factor

Basic Feed Rate											
Fuel Sulphur %	Feed rate ACC factor										
	0.20	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.36	0.38	0.40
0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
0.9	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
1.1	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
1.3	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
1.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
1.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.61	0.65	0.68
1.9	0.6	0.6	0.6	0.6	0.6	0.6	0.61	0.65	0.68	0.72	0.76
2.1	0.6	0.6	0.6	0.6	0.6	0.63	0.67	0.71	0.76	0.80	0.84
2.3	0.6	0.6	0.6	0.6	0.64	0.69	0.74	0.78	0.83	0.87	0.92
2.5	0.6	0.6	0.6	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00
2.7	0.6	0.6	0.65	0.70	0.76	0.81	0.86	0.92	0.97	1.03	1.08
2.9	0.6	0.64	0.70	0.75	0.81	0.87	0.93	0.99	1.04	1.10	1.16
3.1	0.62	0.68	0.74	0.81	0.87	0.93	0.99	1.05	1.12	1.18	1.24
3.3	0.66	0.73	0.79	0.86	0.92	0.99	1.06	1.12	1.19	1.25	1.32
3.5	0.70	0.77	0.84	0.91	0.98	1.05	1.12	1.19	1.26	1.33	1.40

Table 9: Feed rate ACC factor

Correlation between feed rate ACC factors and cylinder oil BN

Feed rate ACC factor	Cylinder oil BN			
	70	**80**	**90**	**100**
	0.20	0.18	0.16	0.14
	0.22	0.19	0.17	0.15
	0.24	0.21	0.19	0.17
	0.26	0.23	0.20	0.18
	0.28	0.25	0.22	0.20
	0.30	0.26	0.23	0.21
	0.32	0.28	0.25	0.22
	0.34	0.30	0.26	0.24
	0.36	0.32	0.28	0.25
	0.38	0.33	0.30	0.27
	0.40	0.35	0.31	0.28
	0.42	0.37	0.33	0.29
	0.44	0.39	0.34	0.31
	0.46	0.40	0.36	0.32
	0.48	0.42	0.37	0.34
	0.50	0.44	0.39	0.35
	0.52	0.46	0.40	0.36
	0.54	0.47	0.42	0.38
	0.56	0.49	0.44	0.39
	0.58	0.51	0.45	0.41

Table 10: Feed rate ACC factor and cylinder oil BN

MAN Diesel & Turbo

To whom it may concern

LDF1/ JUSV/ case no: 8002-2014 25 February 2014

Sweep Test Procedure for MAN B&W Two-Stroke Diesel Engines Finding the Optimal Cylinder Lube Oil Feed Rate Factor

Continuous monitoring of drain oil samples is a good way to optimise the cylinder oil feed rate and consumption and to safeguard the engine against excessive wear. The fastest way to evaluate the corrosive behaviour of an engine and optimise the feed rate is to do a stress test, a so-called sweep test. It can also be used in the ACC familiarization period to find the suitable lube oil feed rate for your particular engine, operating pattern and lube oil used.

During the sweep test, the vessel should be running on fuel with a sulphur content above 2.7%. The sweep test takes 6 days and should be performed during a longer voyage where the engine load remains constant. The feed rate of the cylinder oil is set to fixed steps and drain oil samples are taken after 24 hours, before lowering to the next step (figure 1).

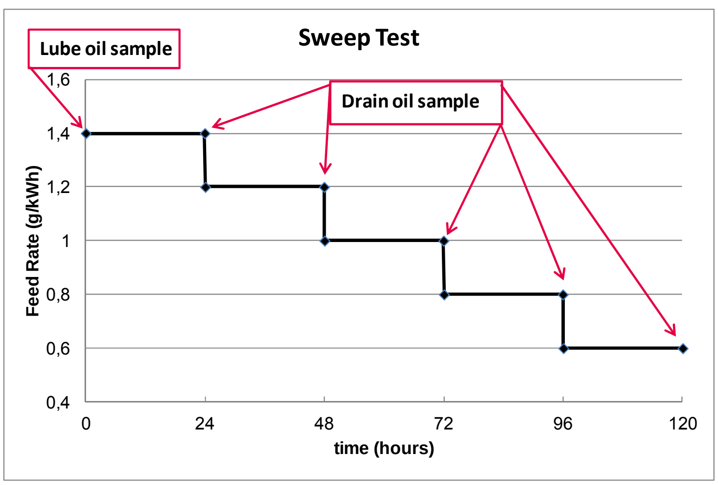

Figure 1. Overview of the sweep test procedure

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Samples and analysis methods

Before the test starts, a port inspection should be completed, and samples of the fuel, system oil in use and fresh (unused) cylinder oil should be taken. When the test has been completed, all samples should be sent ashore to a certified laboratory. The iron (Fe) content and the BN value should be analysed. The Fe content should be analysed using the ASTM D5185-09 and the BN should be analysed using the ISO 3771:2011(E) method. The Fe concentration will be the measurement of corrosion and wear. The BN in the drain oil is an evaluation of the performance of the oil and the need for neutralization in the engine. When the results are received, the suitable ACC factor/feed rate can be established for the particular engine, fuel, and lube oil and operation pattern.

The BN and Fe content of the drain oil can also be measured by various onboard analysis equipments (please refer to CL 118681-2013/LEO and CL 140942-2013/LEO). When measuring Fe with onboard analysis equipment, it is important to choose an instrument which measure total Fe content. Information about onboard analysis equipment will be updated regularly. Onboard equipment gives fast results, however, we recommend sending the samples to a laboratory in order to secure accurate results.

Test Procedure

Read all the instructions carefully before starting the Sweep test. The sweep test is to be made above the lubrication breakpoint. In most cases this breakpoint is at an engine load of 25%. When the lubricator is below the breakpoint, the cylinder feed rate for each cylinder changes from a number to "low load" on the MOP-screen. A sweep test should not be made when the MOP screen states "low load".

Before starting the sweep test: Normal running condition

Figure 2 shows a MOP-screen under normal running conditions, after the initial running in of the engine, i.e. the first 500 hours. The "Running In" mode should be "Off" (0.00) and the "Feed Rate Adjust Factor" should be "1.00" (= 100%).

In this mode, the fuel oil sulphur content "S%" and the "Feed Rate Factor" gives the "Basic Feed Rate" which is also shown for each cylinder as the "Actual Feed Rate. In this example, the S% was 2.82 and the "Feed Rate Factor" was 0.50 g/kWhS%, which resulted in the "Basic Feed Rate" of 1.41 g/kWh (Figure 2).

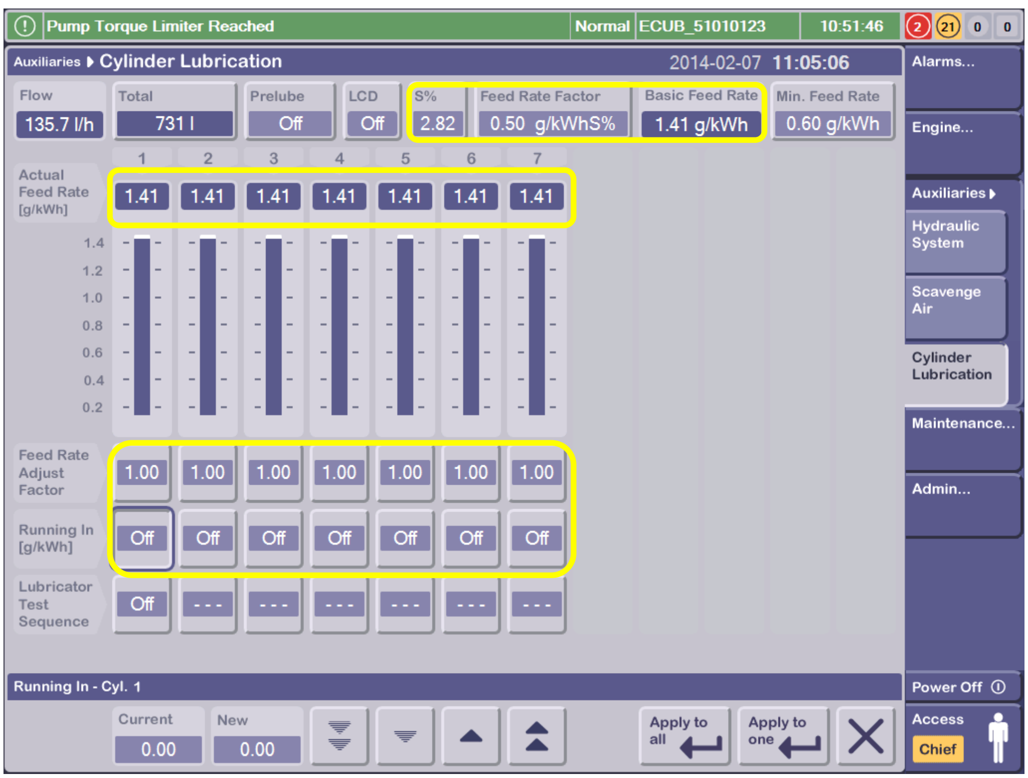

Figure 2. MOP-screen showing settings at normal running conditions. Running-in mode is turned OFF

Day 1: Start of sweep test (at least 24 hours after departure)

When starting the sweep test, the easiest way to set the desired cylinder oil feed rate is to use the "Running In" mode. This mode overrules the normal running mode, as shown in Figure 2. However, the minimum feed rate will never be lower than the "Min. Feed Rate" (here 0.60 g/kWh), even if the "Running In" mode is set to a lower value than "Min. Feed Rate". For the first 24 hours of the sweep test, the "Running In" setting should be "1.40" g/kWh, as shown in Figure 3.

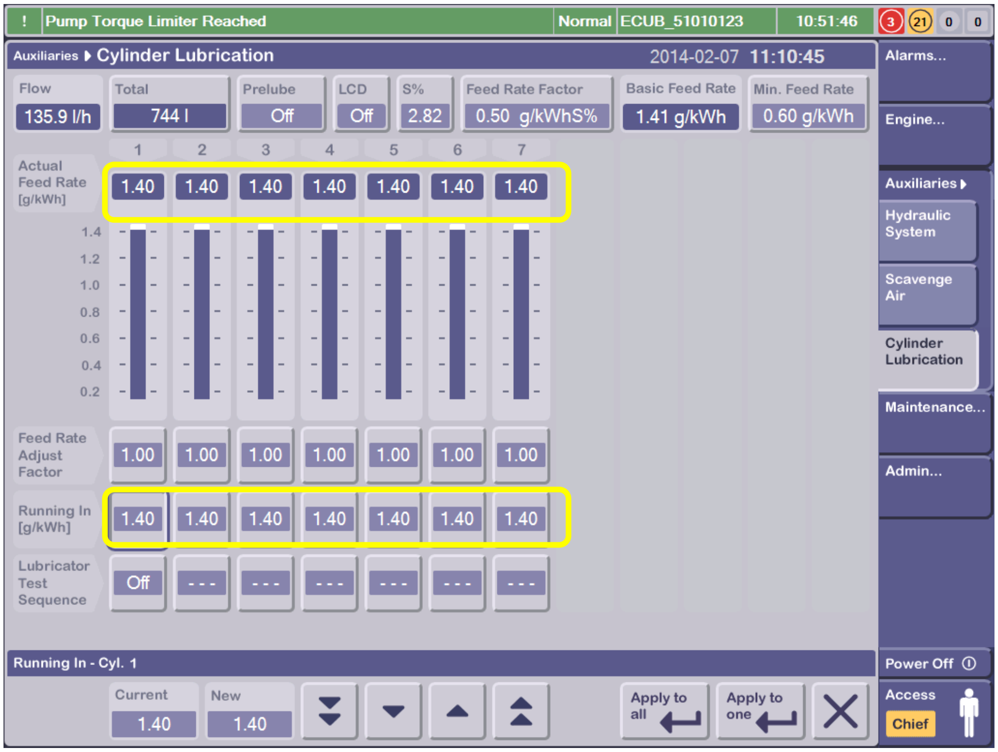

Figure 3. Day 1 of sweep test. The Running In mode is used and set to 1.4 g/kWh

Be sure that the correct cylinder oil is used, and take reference samples of fresh cylinder oil and fuel. Adjust the feed rate of the cylinder oil to 1.4 g/kWh as shown in figure 3. Write down the following information in the sweep test protocol:

a. Name of ship and type of engine
b. Date and time of starting the test.
c. Name and brand of the cylinder oil, BN and SAE viscosity number
d. Engine load

Day 2 Take drain oil samples from all cylinders after running 24 h on a cylinder oil feed rate of 1.4 g/kWh.

Important: Make sure to flush the drain valve into a bucket before taking the sample. Only use clean bottles, and make sure not to mix drain oil form one unit with another. Mark the bottles with the following information:

a. Cylinder no.
b. Date and time
c. The name and BN number of the cylinder oil
d. Feed rate of cylinder oil
e. Engine load

Also, write down the information in the test protocol. After this, the cylinder oil feed rate should be adjusted to 1.2 g/kWh as shown in Figure 4.

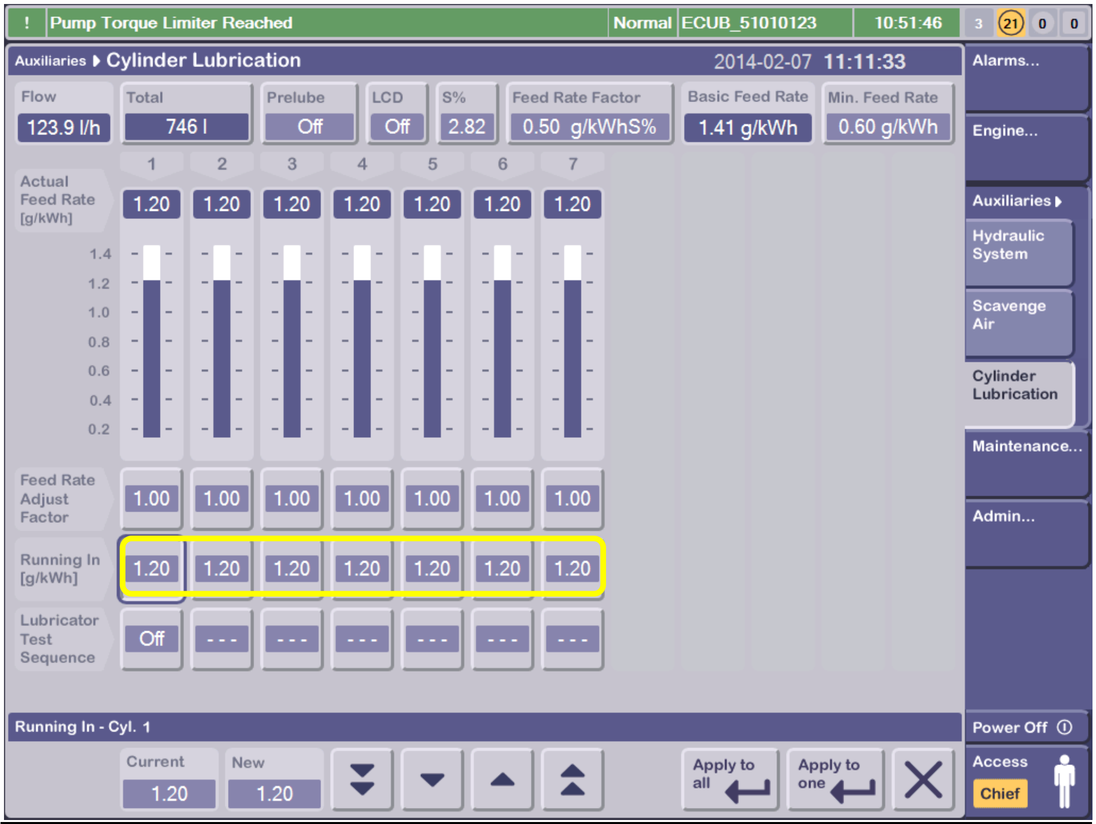

Figure 4. Day 2 of sweep test. The Running In mode is used and set to 1.2 g/kWh

Day 3 Take drain oil samples from all cylinders after running for 24 h on a cylinder oil feed rate of 1.2 g/kWh. Sample-procedure same as Day 2. After this, the cylinder oil feed rate should be adjusted to 1.0 g/kWh

Day 4 Take drain oil samples from all cylinders after running for 24 h on a cylinder oil feed rate of 1.0 g/kWh. Sample-procedure same as Day 2.
After this, the cylinder oil feed rate should be adjusted to 0.8 g/kWh

Day 5 Take drain oil samples from all cylinders after running for 24 h on a cylinder oil feed rate of 0.8 g/kWh. Sample procedure same as Day 2. After this, the cylinder oil feed rate should be adjusted to 0.6 g/kWh

Day 6 Take drain oil samples from all cylinders after running for 24 h on a cylinder oil feed rate of 0.6 g/kWh. Sample-procedure same as Day 2.

When the last drip oil samples have been taken, the “Running In” setting is set to “Off” (0.00) to run in normal cylinder oil feed rate mode, as shown in Figure 2. When results have come back and been analysed, the suitable Feed Rate Factor can be calculated and used.

Sweep Test Protocol

Fill in the required information. Samples should be sent to a certified laboratory for analysis. Before the test starts, a port inspection should be carried out, and samples of the fuel and system oil in use and fresh (unused) cylinder oil should be taken. Use clean bottles and mark them with the information stated on page 2.

Name of Ship:.. IMO no:...

Engine type:.............................. Load:.............. Total running hours:..............................

Name of cylinder oil:....................... BN: .... SAE Viscosity:................................

Sulphur content of fuel:...............%

Start date and time:....................... End date and time:..............................

Please fill in the **Running Hours** for the following

Cylinder	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Cylinder liners												
Piston crowns												
Piston rings												
Fuel valves												

Cylinder oil	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**
Feed rate (g/kWh)	1.4	1.2	1.0	0.8	0.6	Back to normal

Please fill in this table when taking the samples

	Cylinder	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Day 2 Date	Feed rate												
	Engine load			Deck temp °C				Humidity %					
Day 3 Date	Feed rate												
	Engine load			Deck temp °C				Humidity %					
Day 4 Date	Feed rate												
	Engine load			Deck temp °C				Humidity %					
Day 5 Date	Feed rate												
	Engine load			Deck temp °C				Humidity %					
Day 6 Date	Feed rate												
	Engine load			Deck temp °C				Humidity %					

How to Evaluate a Sweep Test

The aim of the test is to show the correlation between the engine's corrosive impact and the lube oil's ability to counteract this. When the results from the sweep test are returned from the laboratory, the data needs to be evaluated.

Calculating the actual ACC factor for a sweep test made on a load above the lubricator part-load breakpoint

During the sweep test, the feed rate was set to fixed steps. The ACC factor for each step can be calculated by dividing the feed rate step with the sulphur % of the fuel (Eq. 1).

$$ACC_{Calculated}\left[\frac{g}{kWh\times S\%}\right] = \frac{Feed\ rate\left[\frac{g}{kWh}\right]}{Fuel\ Sulphur[S\%]} \qquad \text{(Eq.1)}$$

Example 1
Sulphur content of the fuel is 2.8 %.

$$\frac{1.4}{2.8} = 0.5\frac{g}{kWh \times S\%}$$

Feed rate step [g/kWh]	Fuel Sulphur [S%]	ACC (Calculated) [g/kWh xS%]
1.4	2.8	0.50
1.2	2.8	0.43
1.0	2.8	0.36
0.8	2.8	0.28
0.6	2.8	0.21

END of Example 1

The ACC $_{calculated}$ values are used to correlate the Fe and BN values in the samples. In Tables 1 and 2, you can fill in the ACC $_{calculated}$ and the Fe and BN values. Two graphs can then be made where the ACC $_{calculated}$ is the horizontal axis (x-axis) and the Fe values are the vertical axis (y-axis) in graph 1 and BN in graph 2. You can also plot Fe and BN in the same graph. Fe should be the left vertical axis and BN the right (view Figure 2 as an example).

Table 1. Write the ACC $_{calculated}$ in the left column and the corresponding Fe value for each cylinder. These values are then used to make a graph in Excel.

Cylinder	1	2	3	4	5	6	7	8	9	10	11	12
ACC $_{calculated}$↓	Fe values											

Table 2. Write the ACC $_{calculated}$ in the left column and the corresponding BN value for each cylinder. These values are then used to make a graph in excel

Cylinder	1	2	3	4	5	6	7	8	9	10	11	12
ACC $_{calculated}$↓	BN values											

Figure 5 illustrates how to evaluate a sweep test. In the normal case, the Fe concentration slowly rises until a point where it will rapidly increase. The acceptable ACC factor is found just before the rapid increase in Fe, in other words, before the Fe concentration reach the red area (Figure 5). The choice of an ACC factor that corresponds to acceptable Fe levels means that the corrosion is controlled. After the ACC factor has been found in accordance with the Fe, the corresponding BN value can be found. It shows the possible level of BN depletion of the oil, which will not jeopardize the performance of the oil.

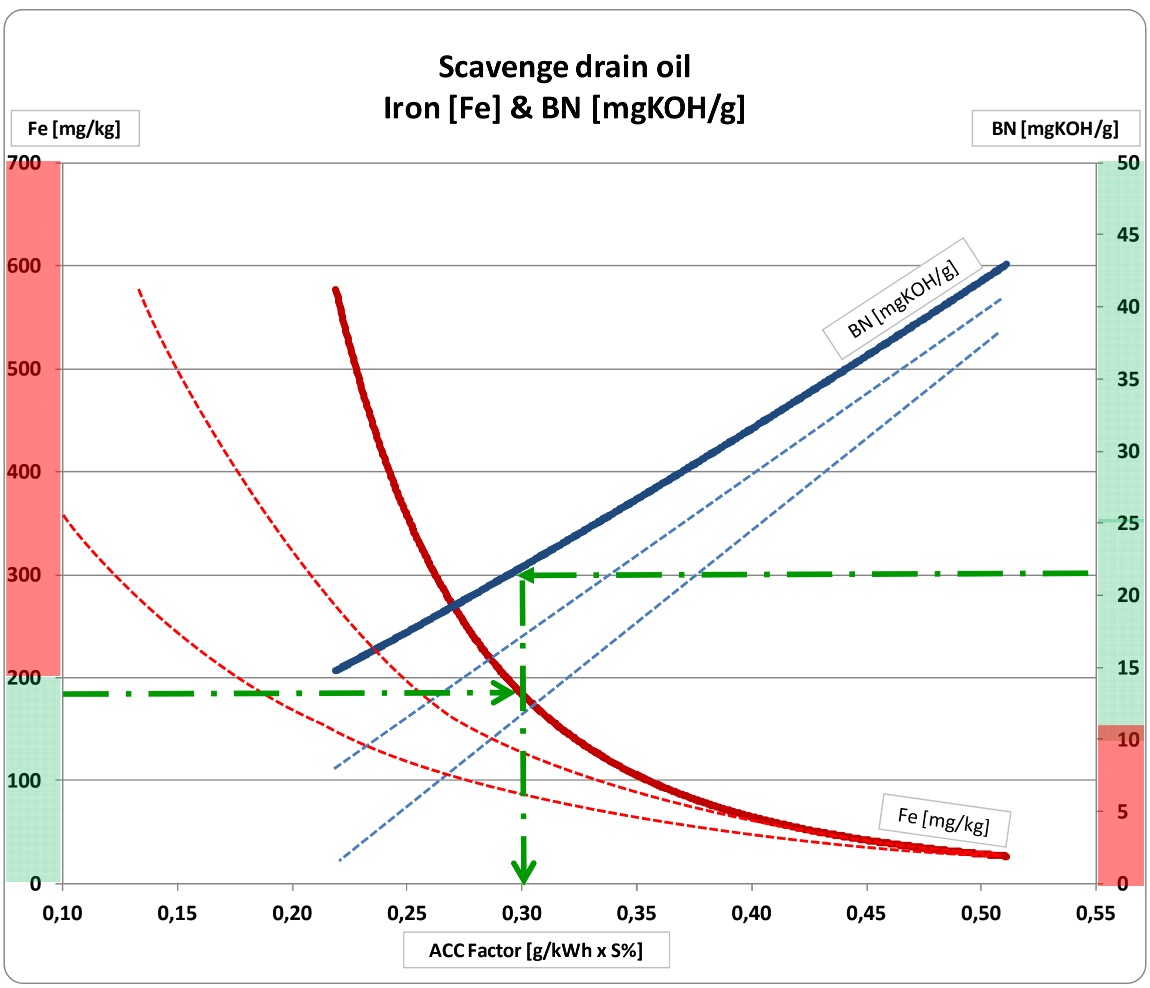

Figure 5. The ACC factor (g/kWhxS%) is shown on the x-axis. The Fe concentration (mg/kg) is depicted with red lines and the result is read on the left y-axis. The axis is divided into three parts. The green bar is showing safe operation condition, 0-200 Fe (mg/kg). When the Fe concentration exceeds 200 mg/kg (the red bar), the wear or corrosion starts to increase a lot, and the lube oil feed rate should also be increased.

The rest BN concentration (mg KOH/g) is depicted with blue lines, and the result is read on the right y-axis. The axis is divided in two parts. The red bar (0-10 BN) means that the neutralisation ability of lube oil has started to deplete, and the risk of corrosion is increased. The green bar (10-50 BN) shows safe operation.

The thick blue line and the thick red line are the BN and Fe values from a sweep test. In order to find the correct ACC factor, the procedure is as follows:

Follow the thick red line and find the Fe concentration for safe operation. In this example it would be 200, because after this the slope of the thick red line increases rapidly. The corresponding ACC factor is found on the x-axis and, in this case, is 0.30 g/kWhxS%.

The rest-BN value, which corresponds to this safe operation, is found by using the BN curve (in this graph, the blue thick line) and read the result of the right x-axis. In this case, the ACC factor 0.3 corresponds to 22 BN. The dashed lines are examples of what other sweep tests with other lube oils may look like.

Please direct any inquiries and questions regarding tables or condition-based overhaul to our Operation Department at leo@mandieselturbo.com or to our Service Department at PrimeServ-cph@mandieselturbo.com.