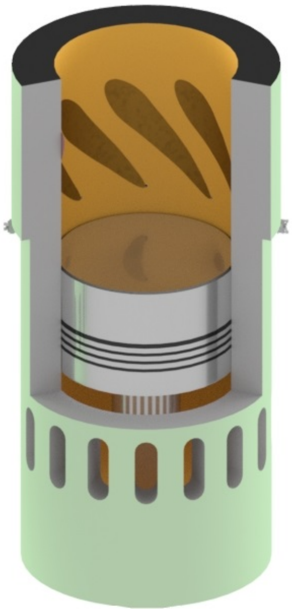
How to succeed with HJ SIP



FOR INFORMATION

Information on HJ SIP:
The purpose of this Service Letter is to guide the user in optimizing the cylinder oil feed rate, so the full saving potential and better cylinder condition made possible by the Hans Jensen's Swirl Injection Principle (HJ SIP) valves can be realized. For first time readers, please read this Service Letter in its entirety, else it may be used as a reference book.

Challenge:
Not adjusting the Specific Lube Oil Consumption (SLOC) to the HJ SIP valve, will result in unnecessary high cylinder lube oil consumption and risk of over-lubrication.

Solution:
Optimizing the SLOC to HJ SIP valves, will ensure the optimal cylinder condition, while minimizing cylinder lube oil consumption.

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1 Introduction

The main challenge of cylinder lubrication is a general issue, independent of operating conditions. It is to get the cylinder oil to the top of the liner and obtaining a uniform distribution. To lubricate a cylinder effectively, oil and additives are needed on the whole liner surface, that is in contact with the piston rings. However the top of the liner requires more of both lubricant and additives. The reasons are: Firstly, lubrication regime will move from hydrodynamic to boundary lubrication, due to the low piston speed at, or close to Top Dead Center (TDC). Secondly, the acids formed during combustion primarily condensate in the top. Finally, oil degradation is a bigger problem at the top due to the higher temperature. The top is also the most critical part of the cylinder because the pressure is at its highest, when the piston is around TDC. A good seal between the piston rings and the liner wall is critical here, to avoid excessive blow-by gasses and to effectively convert the thermal energy of the combustion into the mechanical energy of the piston.

Besides the main challenge, changes in engine operation have also affected cylinder lubrication. There are three major contributors, that have affected the engine operation in the shipping industry in recent years:

- The introduction of slow steaming, or part load operation.
- New IMO requirements.
- New engine designs.

Part load operation In recent years a majority of vessels have been operating on part load, also called slow steaming. This enables a reduction of overall world fleet capacity, while saving on fuel oil costs. However a lower engine load typically means lower engine speed and leads to a colder combustion chamber.

In a slower running engine the cylinder gasses have more time to mix, leading to a greater formation of sulphur trioxide (SO_3).

In a colder combustion chamber, water vapours (H_2O) formed in the combustion process condensate and react with the SO_3 to create sulphuric acid (H_2SO_4).

Part of this sulphuric acid is deposited on the cylinder liner wall, resulting in a phenomenon known as cold corrosion.

New IMO requirements In 2005 the International Maritime Organization (IMO) introduced caps on sulphur emissions from marine vessels. This was done on a global level and more restrictively in special Emission Control Areas (ECAs).Today the sulphur emission requirements are 0.10 % within ECAs and 3.50 % outside of ECAs.This effectively mean, that the fuel oil sulphur content must be within these limits. Moving in and out of ECAs presents a challenge, as there is a significant difference in the lubrication requirements for running on high and low sulphur fuel oils respectively. Not changing cylinder oil feed rate or Base Number (BN) when going from high to low sulphur fuel oil, can lead to irreversible deposit build-up.

New engine designs In new engine designs, the piston stroke is longer and the combustion pressure is higher. The standard electronic lubricators provided by the engine manufacturer, typically rely solely on intermittent lubrication to adjust cylinder oil quantity.

A longer piston stroke, means a larger surface area per cylinder volume, where the sulphuric acid can be deposited. It also typically means a longer distance between the lubrication quills and the top of the cylinder liner.

Higher combustion pressure means a higher dew point temperature, leading to more water and sulphuric acid condensation.

Intermittent lubrication will lead to a stressed oil film, especially in the top of the cylinder liner, where the cylinder oil is highly exposed to heat degradation.

Cold corrosion The combination of part load operation and new engines designs have made cold corrosion a major problem in the shipping industry. Challenges with cold corrosion occur in the top of the liner and is primarily due to these factors.

- Colder combustion chambers, due to part load operation and a higher combustion pressure, due to new engine designs, are mutually reinforcing factors contribute adversely to the sulphuric acid formation on the liner wall.
- Getting the cylinder oil's acid neutralizing additives to the top of the liner, where it is needed, is difficult – especially with long piston strokes.
- Intermittent lubrication. Going several engine revolutions without fresh cylinder oil, stresses the oil film and depletes the additives.

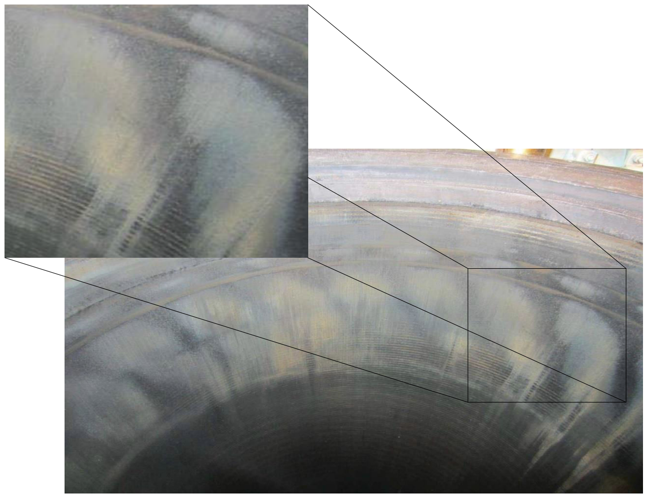

Figure 1: A example of what cold corrosion can look like. Please note the discolourations around the circumference of the liner, where the machine markings are no longer visible.

Even under these difficult operating conditions, experience has shown that HJ SIP valves are able to perform with excellent results.

The simple reason behind the superior performance of the HJ SIP valves, is the optimal placement and distribution of cylinder oil that they allow. Please note that the HJ SIP vales themselves are passive components, in that they rely on the lubricators to ensure proper timing and frequency of injection for optimal lubrication.

Reservations. The guidelines found within this document are general recommendations based on experience. Many engine specific conditions may influence the engine condition and Hans Jensen Lubricators A/S cannot be held accountable for any consequences when following these recommendations. Only the user will be able to assess the engine condition continually and therefore, **the final responsibility lies with the user.**

2 Cylinder lubrication

The quality of cylinder lubrication is dependent on many contributing factors such as piston bore and stroke length, engine load and speed, fuel oil sulphur content, liner temperature and humidity of the scavenge air. In this section the more directly related contributing factors will be discussed, that is the cylinder oil, the lubricators and the injection valves.

2.1 The cylinder oil

The cylinder oil has multiple purposes. Most important are:

- Neutralising the acids formed in the combustion process.
- Lubricating the moving parts and providing a gas seal between the piston rings and the liner.
- Keeping the liner, piston rings and -crown clean by:
  - Preventing or minimizing build-up of deposits.
  - Flushing out particles from wear and formed in the combustion process.

The cylinder contains various additives each with a purpose. A central feature in the cylinder oil additives is the BN. This provides both the alkaline and cleaning properties of the oil. The BN along with the quantity determines the base introduced into the cylinder and thereby the acid neutralization capabilities of the oil. However too much BN will lead to deposit build up of the unused base and will in turn lead to a poor cylinder condition.

The quality of the base oil should also be considered. This among other things determines the thermal stability of the oil, which is especially important if the cylinder liner and piston ring temperature is high. The light elements of the base oil may vaporize if exposed to high temperatures.

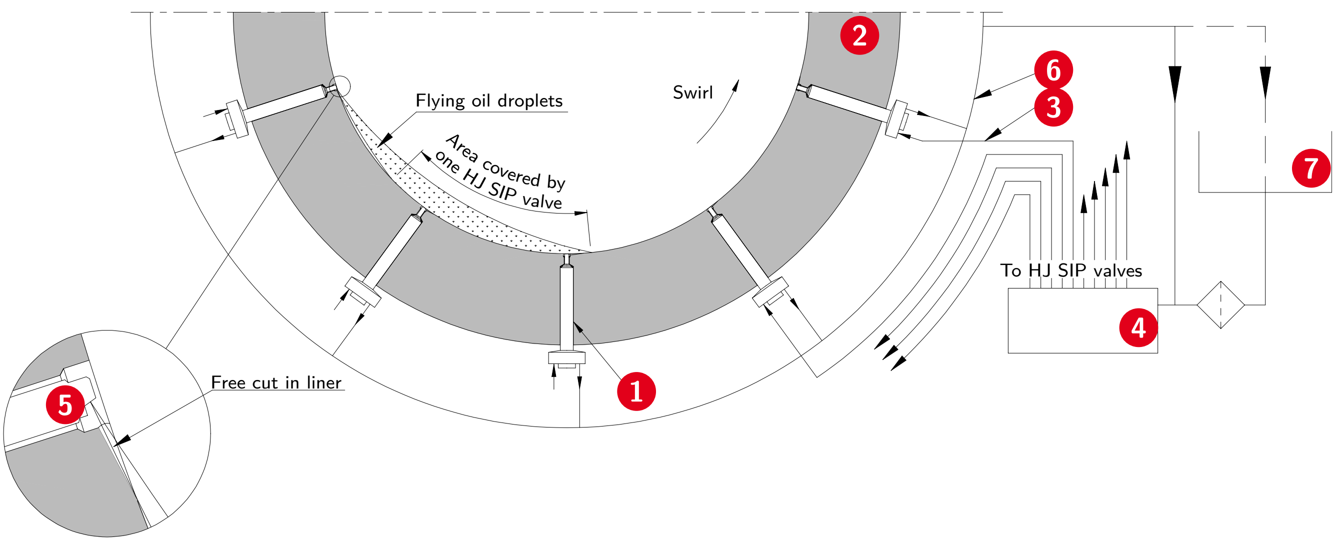

Figure 2: HJ SIP valves placement. Cut view of half a liner.

1. HJ SIP valve
2. Cylinder liner
3. Pressure pipe(s)
4. Lubricator (may be of various kinds)
5. HJ SIP nozzle
6. Drain pipe
7. Supply tank

2.2 The lubricators

The lubricators are an important part of the lubrication process in that they control the amount, the timing and the frequency of injection. The HJ SIP valves require special timing compared to traditional Non-Return Valves (NRVs) and this must be set at the lubricator. It is also here that the feed rate is adjusted.

2.3 HJ SIP

This leads to the final part, the injection valves, which are described in detail, in the following sections.

The Hans Jensen's Swirl Injection Principle is radically different from traditional non-return injection valves. The HJ SIP valve works by spraying cylinder lubrication oil onto the cylinder liner surface during the piston's upward motion, before it passes the lubrication quills. The scavenge air swirl helps distribute the oil and force it outward to the liner wall. This ensures optimal distribution and places the oil at the top of the cylinder liner where the additives and oil film are needed the most, please see Figure 3.

Please note that HJ SIP is a type of valve, not a lubricator. HJ SIP can be used in conjunction with all Hans Jensen Lubricators A/S (HJL) lubricators and some third party electronic lubricators, please contact HJL for more information. The HJ SIP valves provide the potential for a reduced SLOC, but it is the lubricator that must realise this potential, please see Figure 2.

By applying this equipment, the ship owners may reach the objective of considerable reduction in SLOC, while also experiencing lower liner wear rates. This will result in prolonged Time Between Overhauls (TBO). Additional advantages are a cleaner exhaust system, reduced particle emissions and improved cylinder condition. The HJ SIP valve is patented by HJL.

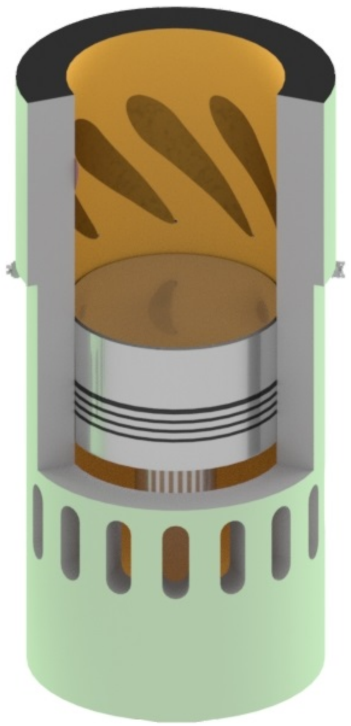

Figure 3: Cylinder oil distribution using HJ SIP valves. Piston position shown approximately at injection timing.

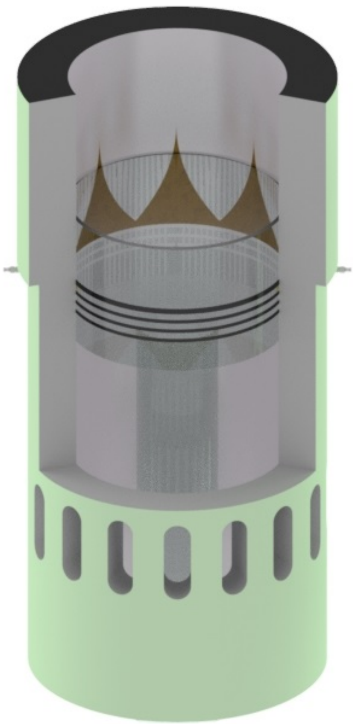

Figure 4: Cylinder oil distribution using traditional non-return injection valves. Piston position shown approximately at injection timing.

2.3.1 HJ SIP vs. Non-Return Valve

When the Cylinder Lubrication Oil (CLO) is injected by means of the conventional non-return valves, it is injected into the piston ring pack during the piston's compression stroke, relying on the piston rings to distribute the oil. This results in poor distribution on the liner surface and often little or no distribution at all in the upper part of the liner, please see Figure 4. To address this challenge, the SLOC is traditionally increased, to achieve acceptable results.

2.3.2 Expected wear profile

The wear profile of the liner is usually different when using HJ SIP, than what would be expected from lubrication by means of non-return valves. Figure 5 shows a graphical representation of the expected wear profile for a cylinder liner lubricated by means of non-return valves and one lubricated by HJ SIP valves respectively. The Figure shows two cross sectional views of half a liner. A straight line represents the liner's original profile and the line curved at the top shows the worn liner's profile. These lines are exaggerated to show the difference in tendency between lubrication by means of HJ SIP valves and non-return valves.

It can be seen in Figure 5 that the corrosive and abrasive wear in the top of the liner decreases significantly, but the wear in the rest of the liner may increase slightly, when using HJ SIP. The result is a more uniform wear profile and a much lower total wear rate. It should be noted that this behaviour is seen with a considerably lower SLOC when using HJ SIP valves.

A test conducted on an engine with both standard non-return injection valves and HJ SIP valves mounted, showed much less wear in the top and no increased wear in the middle of the liner.

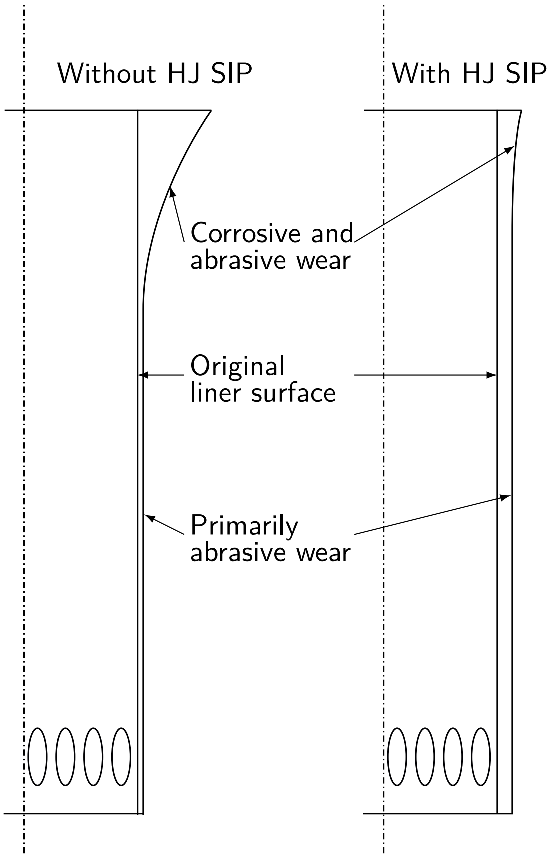

Figure 5: Exaggerated graphical representation of the expected wear profile without and with HJ SIP respectively.

This test was run in periods with the same feed rate on all cylinders and in periods with a lower feed rate on the cylinders with HJ SIP valves. The results of liner measurement after 11,978 engine hours can be seen on Figure 6 for the two cylinders with HJ SIP and Figure 7 for the three cylinders with NRVs.

With an understanding the advantages of HJ SIP, it is clear that the cylinder oil consumption should be optimized for HJ SIP. Depending the the lubrication system, this may be done by optimizing the Adaptive Cylinder Control (ACC) factor or the feed rate. The following sections will detail the procedure for optimizing cylinder oil consumption.

In the following it is assumed that the reader is familiar with the Sulphur Regulation Algorithm (S-RA) and ACC factor. In case of any doubts Appendix A provides a short introduction to S-RA and ACC factor.

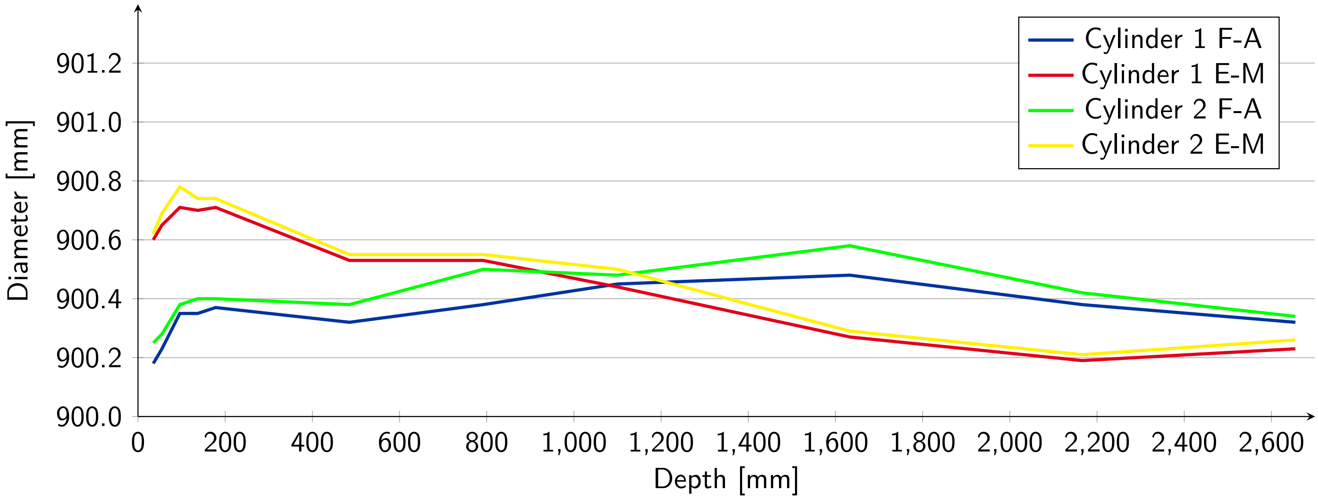

Figure 6: Liner wear measured after 11,978 engine hours. Cylinder 1 and 2 with HJ SIP valves.

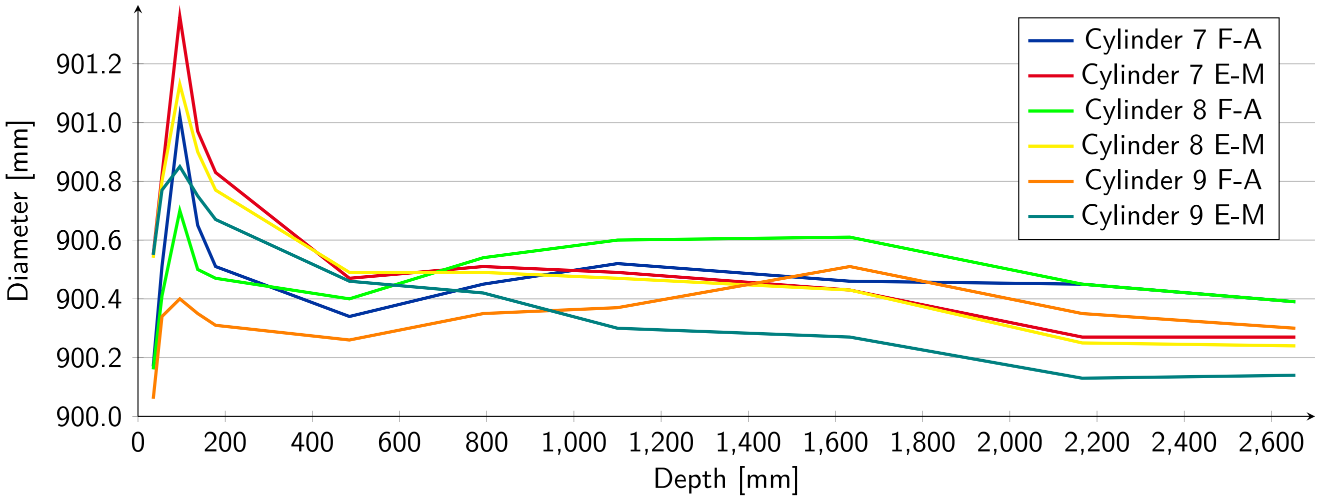

Figure 7: Liner wear measured after 11,978 engine hours. Cylinder 7, 8 and 9 with non-return injection valves.

3 Optimizing cylinder oil consumption

> **Please note!**
> The engine maker's and designer's guidelines must always be followed during the warranty period of the engine.

After completing installation of the HJ SIP cylinder lubrication valves without overhauling the piston and/or replacing the cylinder liner, the SLOC should be adjusted.

3.1 Adjusting SLOC using port inspection

To optimize the cylinder oil consumption using port inspections, first consider whether using BHP dependent Regulation Algorithm (BHP-RA) or Sulphur Regulation Algorithm (S-RA). If using BHP-RA please go to section 3.1.1, if using S-RA, please go to section 3.1.2.

3.1.1 Cylinder oil feed rate reduction

The procedure for feed rate reduction is shown in the flow chart in Figure 10 on page 14. Figure 8 shows a graph of the cylinder oil feed rate reduction over time assuming a start feed rate of 0.90 g/kWh and satisfactory cylinder condition verified through port inspections. Please make sure to target 100 running hours between adjustment and inspection.

3.1.2 ACC factor reduction

The procedure for ACC factor reduction is shown in the flow chart in Figure 11 on page 15, please use an ACC factor of 0.20 g/kWh% for older engines such as MAN Energy Solutions (MAN-ES) engines Mk 7 and older, and 0.33 g/kWh% for MAN-ES engines Mk 8-8.1 and newer. Figure 9 shows a graph of the ACC factor reduction over time assuming a start ACC factor of 0.20 g/kWh% and satisfactory cylinder condition verified through port inspections. Please make sure to target 100 running hours between adjustment and inspection.

> **Please note!**
> Please ensure that the algorithm is in its active area when conducting this reduction. If the minimum feed rate is reached, either wait to continue the test at a higher fuel oil sulphur content or consider reducing the minimum feed rate, please see Appendix A.1.

3.1.3 Inspection

Always inspect the cylinder liner and piston ring condition prior to reduction of cylinder oil consumption. Both the cylinder liner and the piston rings should be in good condition, or show signs of over-lubrication, prior to reduction.

Periodic port inspections should be continued, even after the familiarization period. These should be conducted at least monthly, more often if adverse cylinder conditions have previously been observed.

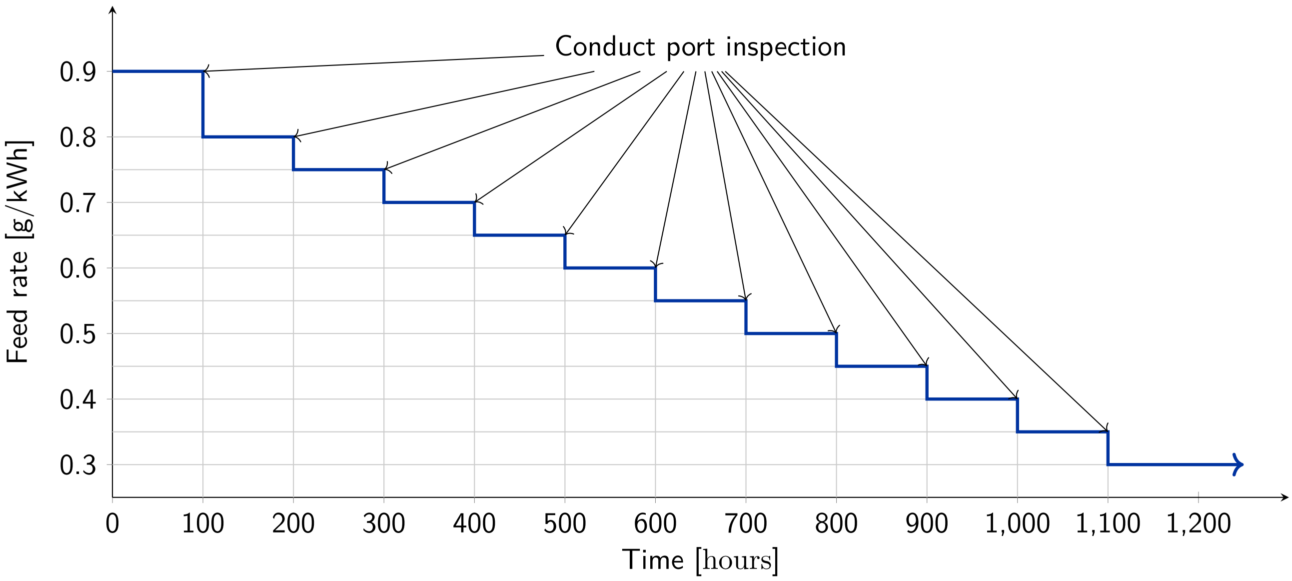

Figure 8: Feed rate familiarization.

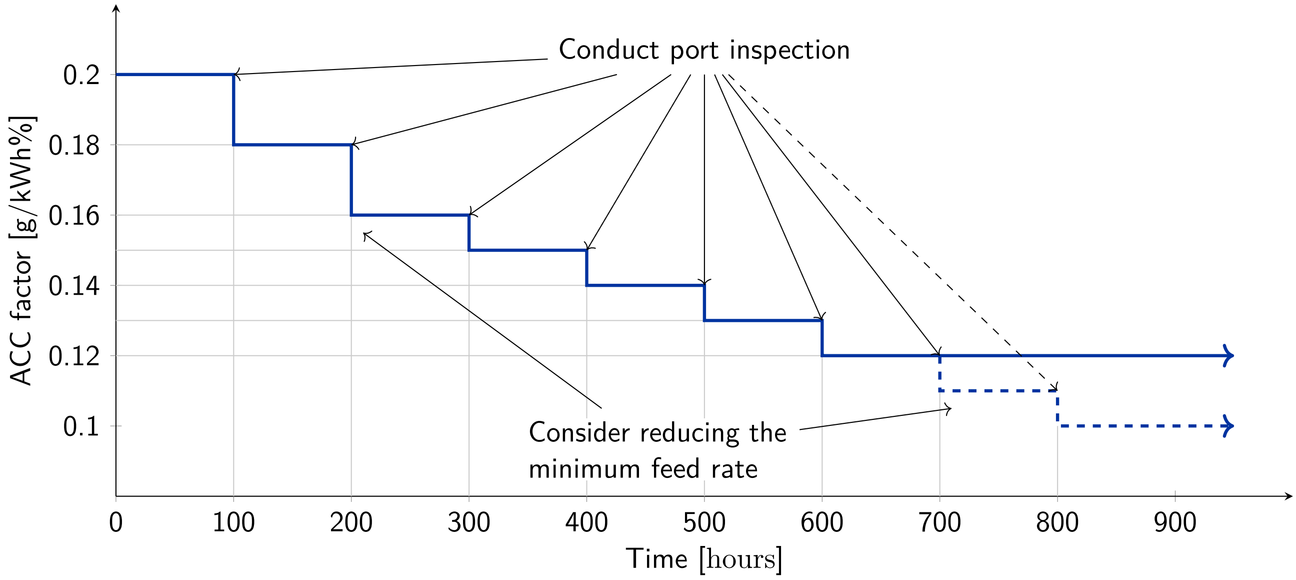

Figure 9: ACC factor familiarization on MAN-ES engines Mk 7 and older. For MAN-ES Mk 8-8.1 and newer, please start at 0.33 g/kWh%.

3.1.4 Suspicion of under-lubrication

If under-lubrication is suspected consider the following:

- Has the fuel oil sulphur level changed?
- Has the cylinder oil BN changed?
- Has the operation of the engine changed? Such as:
  - Large change in load.
  - Higher rate of manoeuvring.
  - Treatment of the fuel oil.
  - Number of turbochargers in operation.
- Have any parts on the engine been replaced or had service?
- Have any external parameters changed? Such as:
  - Changes is ambient temperature or humidity.

If any changes can be made to ensure that the current cylinder oil feed rate is sufficient, e.g. treatment of the fuel oil, please consider doing this first. If the under-lubrication is likely due to a parameter that cannot be altered, e.g. changes in ambient temperature or humidity, or seems to be a result of feed rate/ACC factor reduction, please increase the feed rate/ACC factor. The magnitude of increment must be assessed based on the cylinder condition.

After an increase in cylinder oil consumption, please continue to conduct port inspections at intervals of 100 running hours and increase the feed rate/ACC factor in steps until a satisfactory result is achieved.

> **Please note!**
> Issues regarding cylinder condition are rarely due to under-lubrication. Observations show that about 50 % do not have an optimal SLOC and in most cases it is due to over-lubrication. Around 43 % have problems with cat fines in the fuel oil. Around 25 % show evidence of a water washing problem [1].

3.2 Using SDA to monitor cylinder condition

The method of reducing SLOC based on port inspections, can advantageously be combined with periodic Scrape Down or drain oil Analyses (SDAs). This will provide a better basis for decision with regard to SLOC adjustment. For instructions on how to retrieve an oil scrape down sample, please see:

- *920259-05 Scrape Down Analysis sampling for 2-stroke engines*

If done with an on board analysis kit, or by a third party, please be aware of the special acceptable content of residual BN and iron in SDAs specific to the HJ SIP as shown in Figure 12 and 13 on page page 16.

The colours in Figure 12 and 13 on page page 16 are interpreted as follows:

Green: Safe operation area.

Yellow: Warning area. Please refer to Table 3 to identify probable causes.

Red: Alarm area. Please refer to Table 3 to identify probable causes.

The reasons for these HJ SIP specific acceptable limits are:

- The HJ SIP valve allows for a more complete reaction between the acids formed and the base in the cylinder oil. This means that the BN in the scrape down or scavenge drain oil will be smaller.
- The iron content is measured as a concentration of iron in the scrape down or drain oil. Cylinder oil consumption optimized for HJ SIP means reduced cylinder oil consumption. Less oil will lead to a relatively higher concentration of iron even if the absolute iron content is unchanged or even lower.

3.3 Sweep test

Alternatively a sweep test can be made for a faster way of determining the optimal feed rate. Please see:

- *920467-00 Conducting a sweep test*

for further details regarding a sweep test. This Service Letter may be requested by contacting HJL.

4 Guideline values

This section describes general recommendation on ACC factor and feed rate values. This information is a result of many years of experience and is what the optimization recommendations in the later sections are based on.

Table 1: Recommended correlation between cylinder oil BN and fuel oil sulphur level.

Fuel oil sulphur level [%]	Cylinder oil BN [mg KOH/g]
≤0.1	≤25
0.1 - 0.5	25 - 40
0.5 - 1.5	40 - 70
≥1.5	70

Table 2: Recommended correlation between cylinder oil BN and fuel oil sulphur level for MAN-ES engines Mk 8-8.1 or newer.

Fuel oil sulphur level [%]	Cylinder oil BN [mg KOH/g]
≤0.1	≤ 40
0.1 - 0.5	25 - 60
0.5 - 1.5	40 - 70
≥1.5	70 - 100

The recommended combination of cylinder oil BN and fuel oil sulphur level is seen in Table 1. In Table 2 are special recommendations for MAN-ES engines Mk 8-8.1 and newer when operating at low loads.

If operating outside the recommendations shown in Table 1 or 2, please monitor the cylinder condition closely and consider adjusting the cylinder oil feed rate, if using BHP-RA.

When using the S-RA please keep the ACC factor within 0.12–0.33 g/kWh%.

When using BHP-RA, please refer to Figure 14 to 16 on page 17. Here the recommended feed rate operating areas are shown. Although it is generally never recommended to go outside of the coloured areas, there may be extraordinary instances where going outside of these areas is advisable, e.g. when running-in new liners, please see section 5. Limits for minimum and maximum recommended fuel sulphur levels are represented with red lines.

The areas in Figure 14 to 16 on page 17 are:

Green: Safe operation area.

Blue: Be attentive when first operating in this area.

Red: Use caution, may be safe for shorter periods of time, but not recommended for prolonged periods.

Please note! ECA

When operating in and out of ECAs, special attention must be paid to the cylinder oil BN content. When using high BN cylinder oil (BN 100 or above), if the BN content is not adjusted when the fuel oil sulphur level is altered significantly, there is a high risk of damaging the engine. Please implement a change-over procedure for changing cylinder oil. When making this procedure, take into account the rate by which the CLO in the day tank and pipes is replaced. The change-over of cylinder oil should be timed, so the replacement of high to low BN cylinder oil is complete, before changing from high to low sulphur fuel. The combination of high sulphur fuel with low BN cylinder oil should be avoided for longer periods of time, but the combination of low sulphur fuel with high BN cylinder oil should be avoided for *any* period of time.

5 Breaking-in and running-in

Please note!
The engine maker's and designer's guidelines for breaking-in must always be followed during the warranty period of the engine.

In Figure 17 on page 18 the procedure for running-in new liners and new piston rings can be seen. In Figure 18 on page 19 the procedure for running-in new piston rings only can be seen. If the effective feed rate under normal operation, exceeds any of the recommended settings below, please use the higher of the two.

The procedure for running-in new liners and new piston rings is:

1. Set the feed rate to 1.20 g/kWh.
2. Increase the load from approximately 25 % to 40 % Normal Continuous Rating (NCR) over the first 4 hours.
3. Increase the load incrementally to 100 % NCR over the first 24 hours.
4. After 24 running hours reduce the feed rate to 1.1 g/kWh.
5. After 50 running hours reduce the feed rate to 1.0 g/kWh.
6. After 100 running hours reduce the feed rate to 0.9 g/kWh.
7. After 200 running hours follow the instructions in section 3.1 for further reduction.

Always use the higher of the feed rate given above or the feed rate used under normal operation, e.g. by ACC factor calculation.

The procedure for running-in new piston rings only is:

1. Set the feed rate to 0.90 g/kWh, unless the feed rate under normal operation is higher than 0.90 g/kWh.
2. Increase the load from approximately 50 % to 100 % NCR over the first 5 hours.
3. After 24 running hours reset the feed rate to the value it had before replacing the piston rings, or follow the instructions in section 3.1.

6 Maintenance

The HJ SIP requires regular overhauls to ensure optimal performance. The TBO for HJ SIP valves is 12 000–15 000 running hours. This may be done on board by the crew, but HJL strongly recommends entering into a HJ SIP overhaul service agreement.

If done by the crew, please request the following Service Letters from HJL, depending on the particular HJ SIP valve or refer to the manual.:

- *920152 - SIPI Overhaul*
- *920160 - SIPII Overhaul*

- *920161 - SIPIII Overhaul*
- *920294 - SIPII Slim Overhaul*

More information on the HJ SIP overhaul service agreement can be found in:

- *HJ SIP Overhaul Service by Hans Jensen Lubricators*.

Please contact our sales department for the above mentioned handout, or a quote for an HJ SIP overhaul service agreement. HJ SIP overhaul service agreements are always tailored for each customer.

Exceeding the TBO may result in:

- Inadequate spray distribution of the cylinder oil. This leads to a risk of reduced performance in increasing corrosive and abrasive wear.
  - This may be partially addressed by increasing the SLOC. According to HJL's experience, this can require an increase in SLOC of 30–50 %.
- Blocked valves which can potentially increase the liner and piston ring wear.
  - A blocked valve will output an alarm on HJLs electronically controlled lubricators, HJ Lubtronic and HJ Lubtronic 2.0.
  - On mechanical lubricators a blocked valve may break the corresponding sight glass. This is a predetermined break point, designed to limit the damage and alert the user of a blocked valve. Replacing both the HJ SIP valve and the sight glass is required after a blockage has been detected.

Maintain the TBO and assure:

- The HJ SIP valves will be fully functional.
- The upkeep of the intended spray and thereby optimal distribution is maintained.
- The full potential benefit of HJ SIP valves, meaning reduced SLOC and improved cylinder condition.
- Preventive maintenance reduces risk of unexpected disruptions in operation.

What are the additional benefits of the HJ SIP overhaul service agreement?

- Maintain the warranty: By using genuine spare parts and authorized workshops, the warranty on new parts is maintained.
- Highest quality work done by the HJL workshop ensures correct overhaul of the HJ SIP valves.
- Fixed costs for HJ SIP maintenance (include in budget).
- Administration is handled by HJL - will advise when it is time for maintenance and coordinate exchange of the valves directly with the vessel.
- Vessel crew will save time to focus on other tasks.
- Tailor made overhaul service program to suit the needs of the individual customer.
- Maintenance carried out by maker.
- Maintaining the full benefits of the HJ SIP valves, means that the costs of the HJ SIP service agreement are covered (fully or partly) by the savings that are achieved from better performance of the injectors.

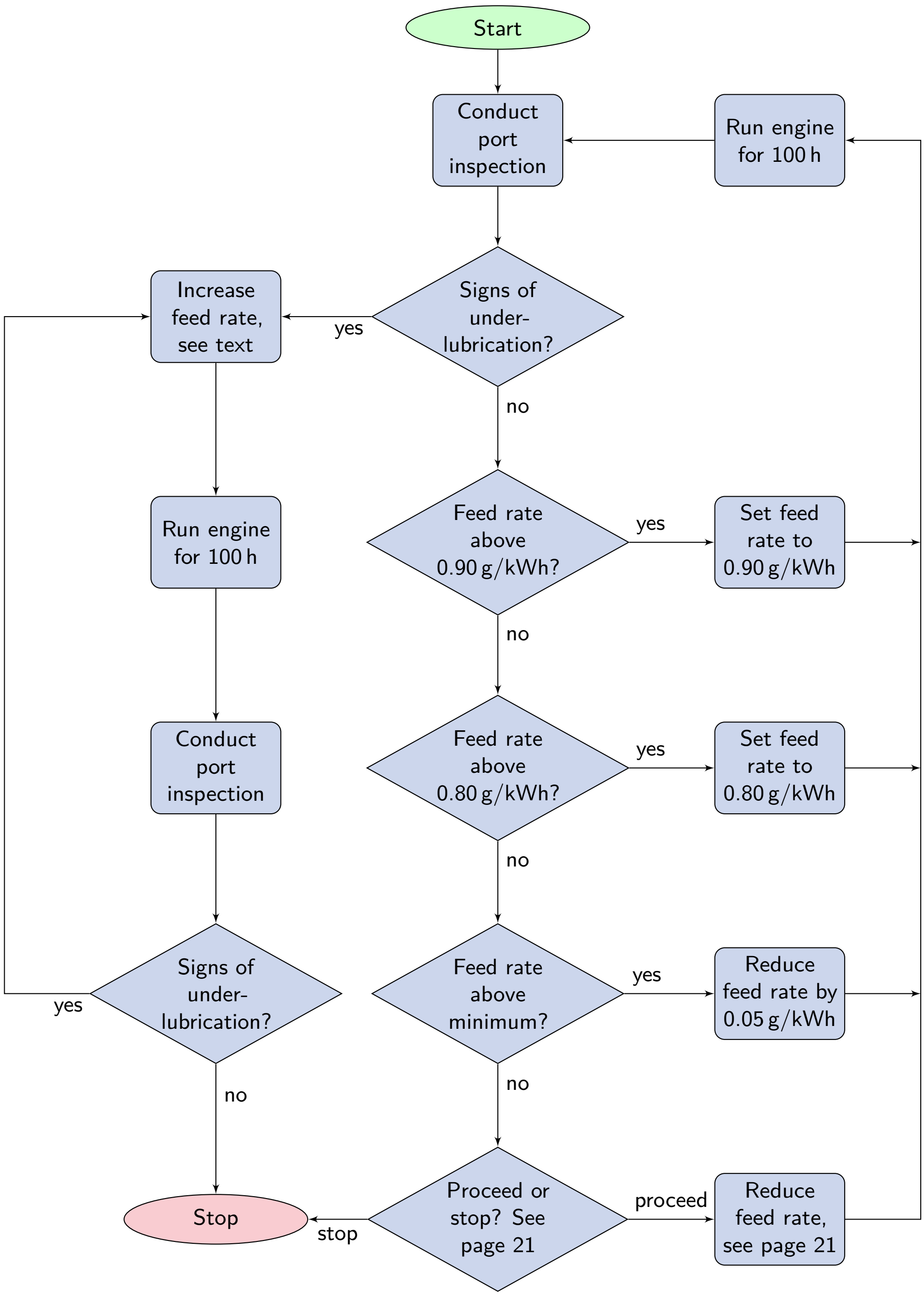

Figure 10: A flow chart of cylinder oil feed rate reduction. Please see section 3.1.1 on page 8 for details.

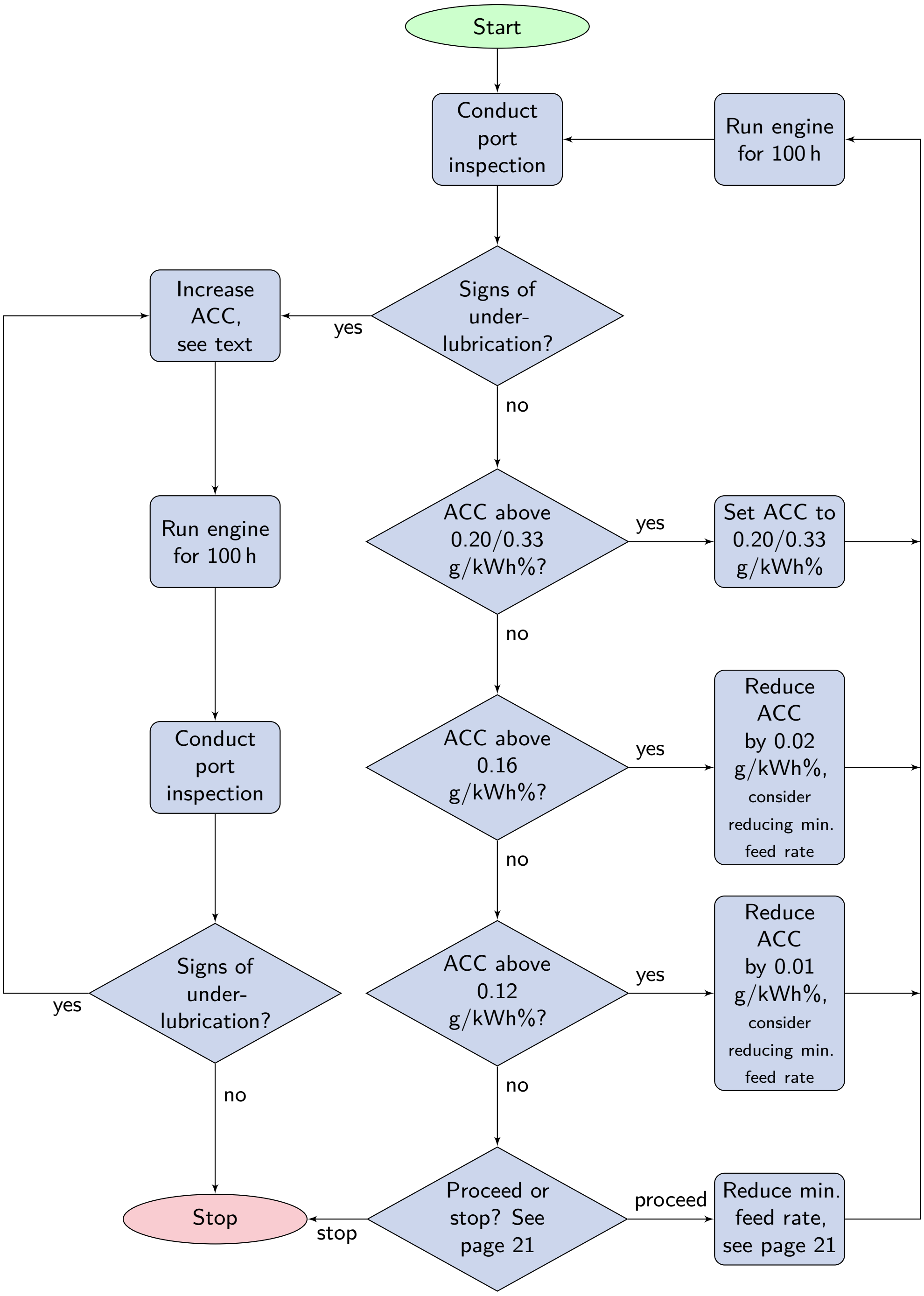

Figure 11: A flow chart of ACC factor reduction. Please start at 0.20 g/kWh% for MAN-ES engines Mk 7 or older and 0.33 g/kWh% for MAN-ES engines Mk 8-8.1 and newer. Please see section 3.1.2 on page 8 for details.

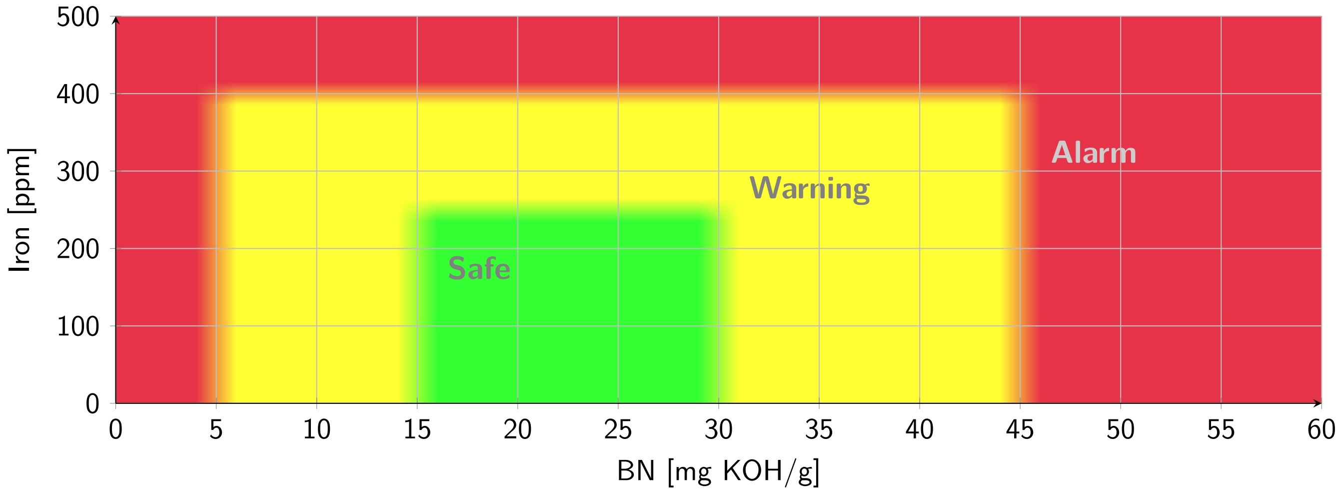

Figure 12: Recommendations for remaining BN and iron content in scrape down oil when using HJ SIP while burning a **fuel oil with a sulphur content above 0.5 %**. Please see section 3.2 on page 10 for details.

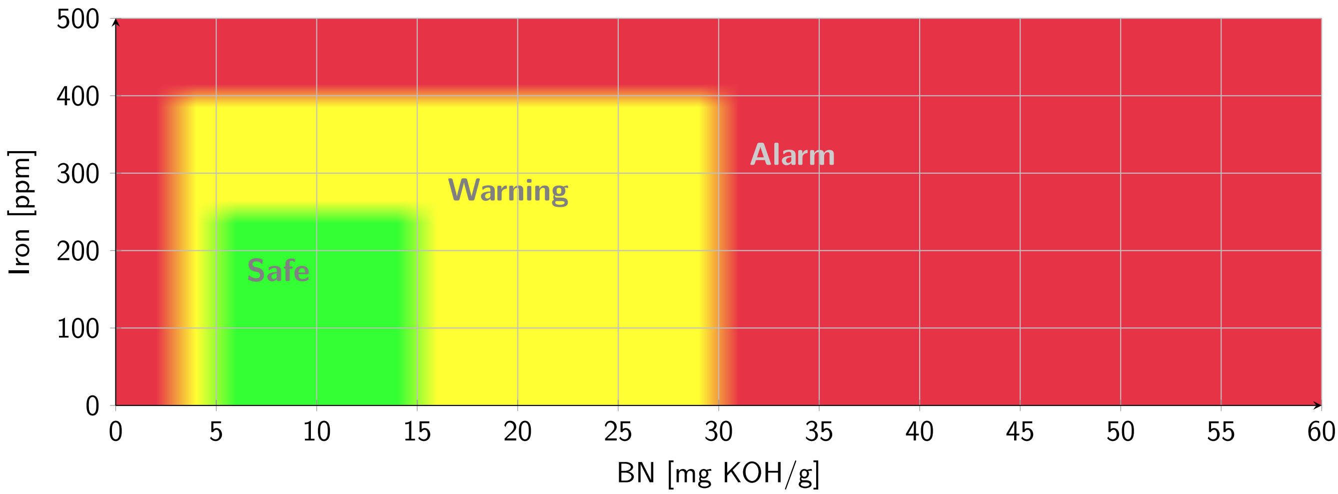

Figure 13: Recommendations for remaining BN and iron content in scrape down oil when using HJ SIP while burning a **fuel oil with a sulphur content at 0.5 % or below**. Please see section 3.2 on page 10 for details.

Table 3: The probable causes and solutions to SDA results.

		BN: **Low**	BN: **Normal**	BN: **High**
Iron	**High**	Under-lubrication Increase feed rate	Fuel oil quality (e.g. cat fines) Water carry-over from scavenge cooler Check fuel oil purifier Check cooling water temperature Check drain from water mist catcher	Too much BN Deposit build-up Reduce BN or feed rate
Iron	**Low**	Not enough BN Increase BN or feed rate	Safe area of operation	Too much BN Reduce BN or feed rate

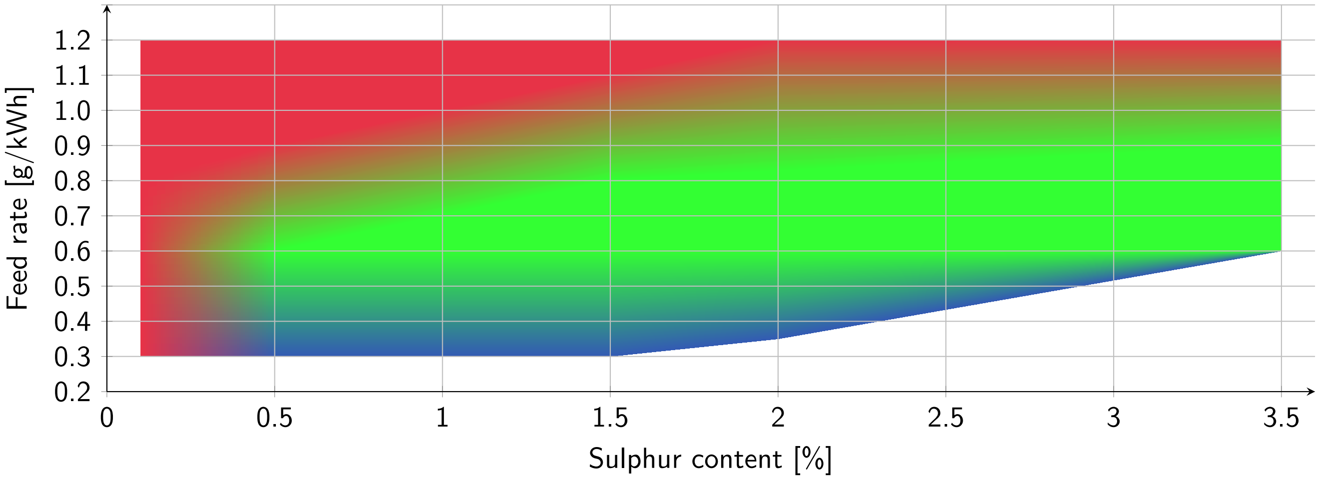

Figure 14: Feed rate recommendations when using a BN 70/100 oil. Please see section 4 on page 10 for details.

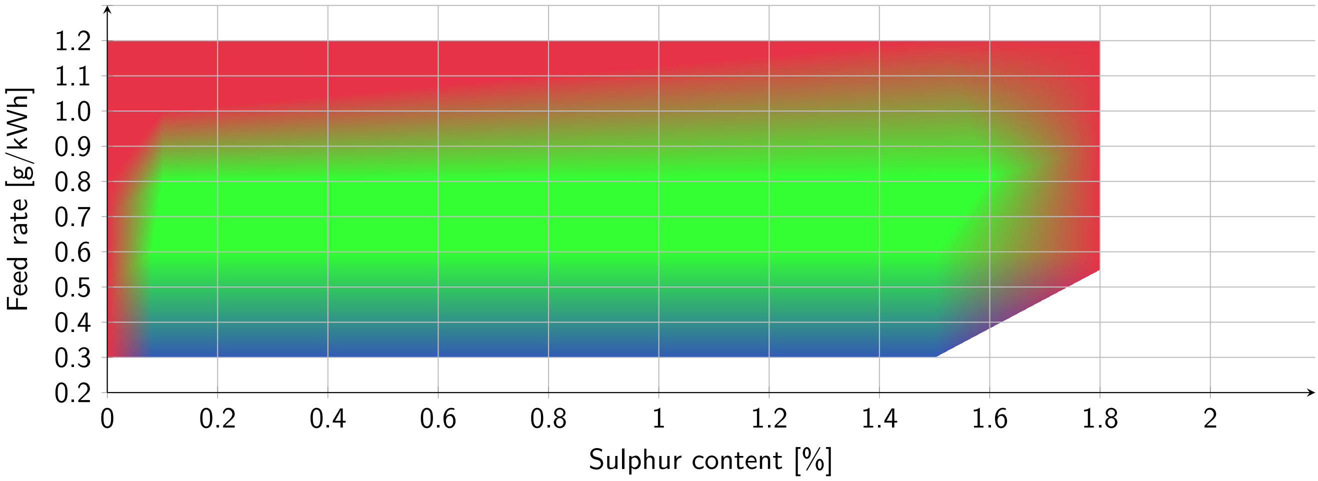

Figure 15: Feed rate recommendations when using a BN 40 oil. Please see section 4 on page 10 for details.

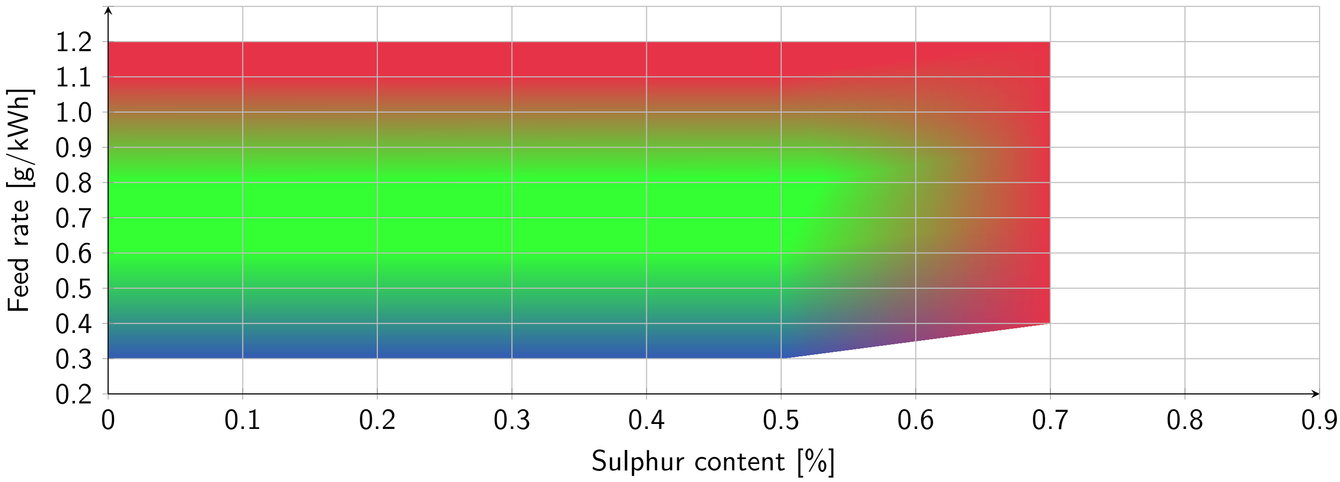

Figure 16: Feed rate recommendations when using a BN 25 oil or lower. Please see section 4 on page 10 for details.

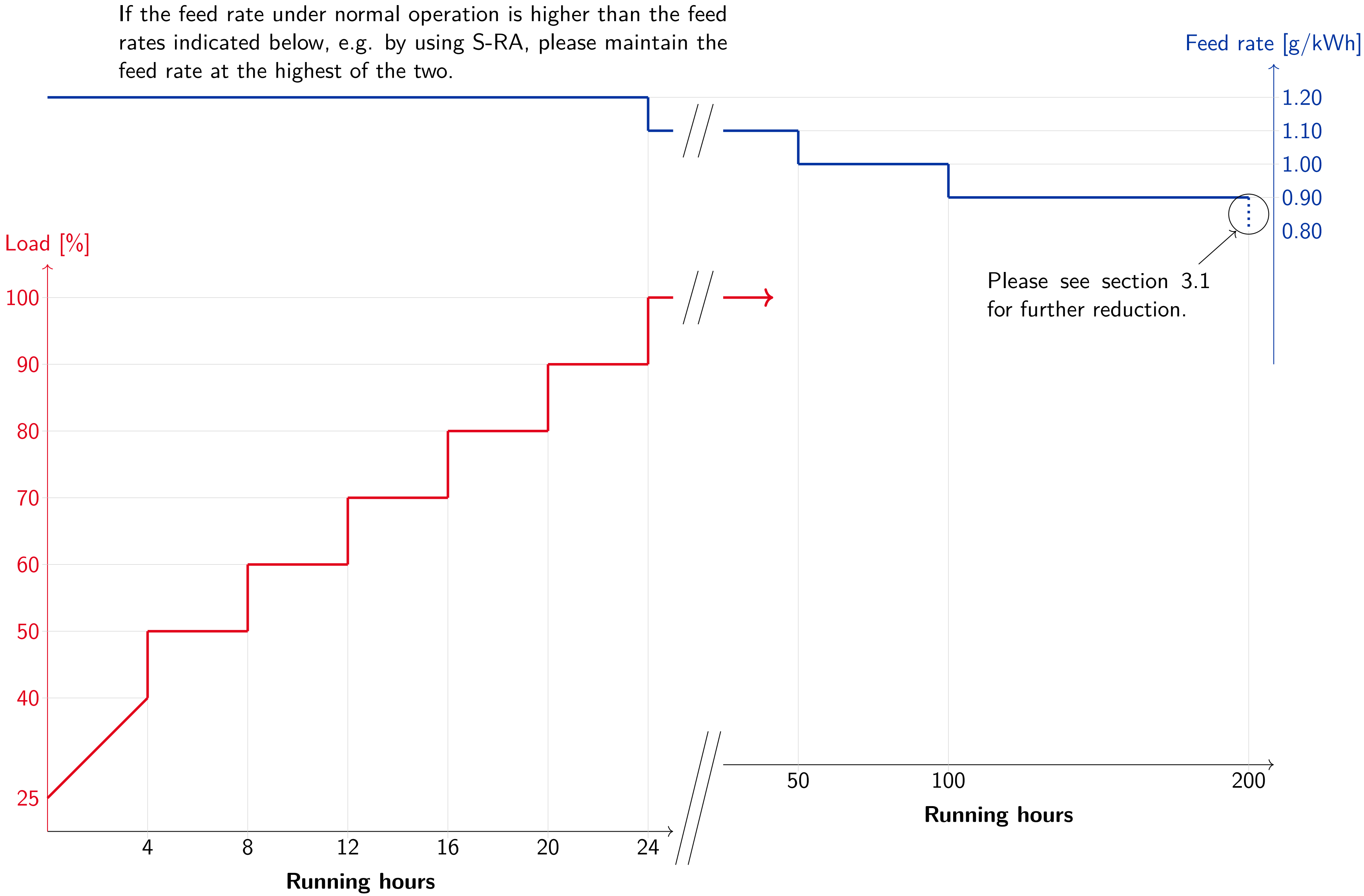

Figure 17: Running-in recommendations with new liners and piston rings. Please see section 5 on page 12 for details.

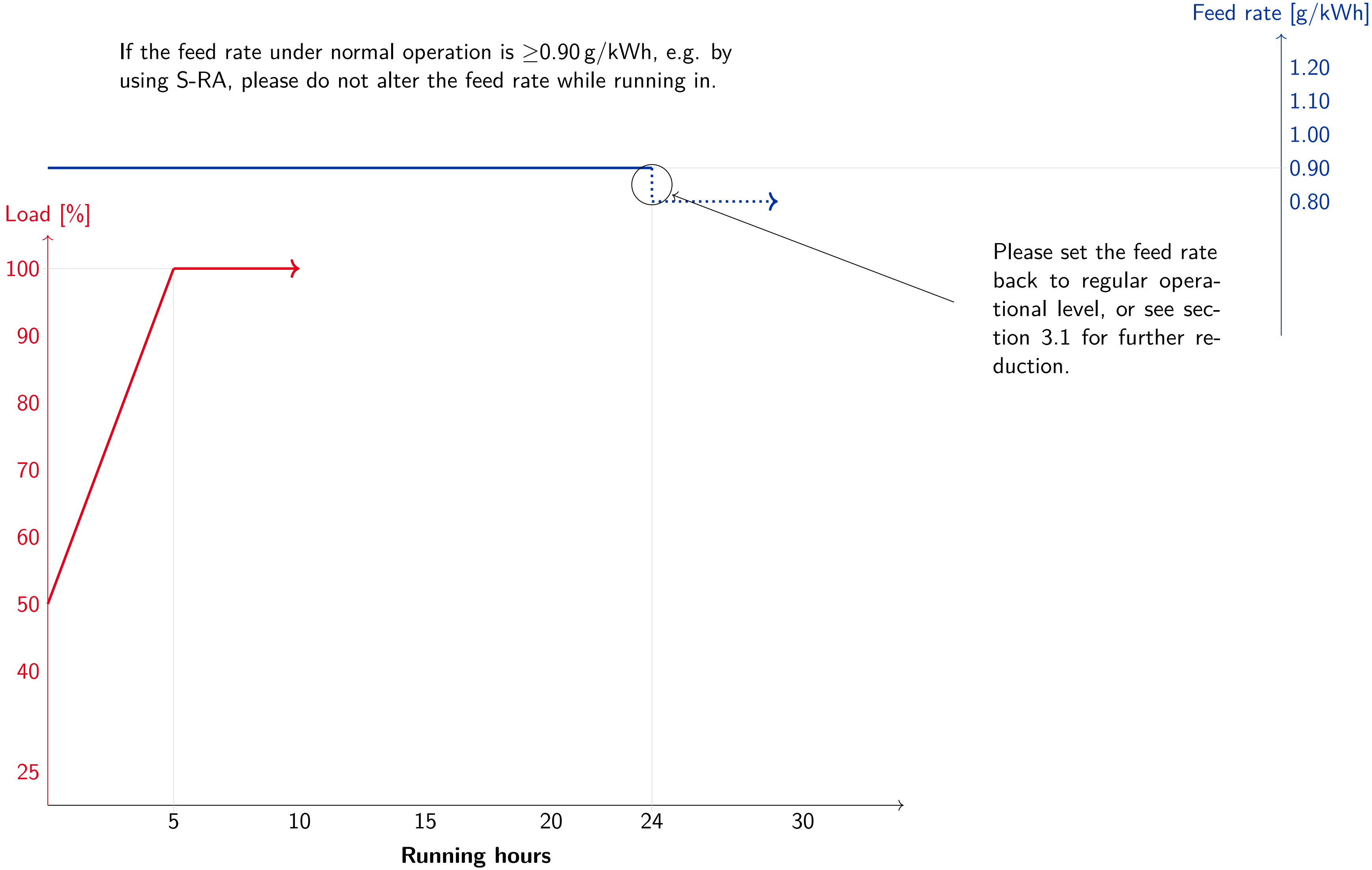

Figure 18: Running-in recommendations with new piston rings only. Please see section 5 on page 12 for details.

A Introduction to S-RA and ACC factor

Sulphur Regulation Algorithm (S-RA) is a method for automatically calculating the cylinder oil feed rate, based on fuel oil sulphur level and cylinder oil BN. With the feed rate calculated, the S-RA follows the load dependent BHP-RA.

When using BHP-RA the cylinder oil feed rate is entered into the system to control the quantity. When using S-RA an ACC factor is entered into the system instead of the cylinder oil feed rate. As shown in Figure 19, after the feed rate has been either entered or calculated, the system uses the same algorithm to calculate the actual quantity.

The ACC factor is a variable that is used to adjust the feed rate. In the HJL software, the current fuel oil sulphur content of the fuel oil, BN level of the cylinder oil and ACC factor are all included in calculating the feed rate. This means that the crew must keep fuel oil sulphur content and cylinder oil BN updated in the HJL software. It ensures that when the right ACC factor has been found, changing the fuel oil sulphur content and/or the cylinder oil BN will automatically optimize the feed rate for the new conditions. Software from other manufacturers than HJL may use other algorithms to calculate feed rate. Please contact HJL if in any doubt about how to proceed, with the lubrication system at your disposal.

The formula HJL uses for calculating the feed rate is:

$$Q_{\text{fr}} = Q_{\text{ACC}} \cdot S_{\%} \cdot \frac{100}{n_{\text{BN}}} \qquad [\text{g/kWh}] \quad (1)$$

Where:

Q_{fr}	is the cylinder oil feed rate	[g/kWh]
Q_{ACC}	is the ACC factor	[g/kWh%]
$S_{\%}$	is the fuel oil sulphur content	[%]
n_{BN}	is the cylinder oil BN	[mg KOH/g]

As the unit for the feed rate is given in g/kWh and the sulphur content is given in %, the unit for the ACC factor is g/kWh%.

Equation (1) can be rewritten to find an ACC factor from a given feed rate:

$$Q_{\text{ACC}} = Q_{\text{fr}} \cdot \frac{n_{\text{BN}}}{S_{\%} \cdot 100} \qquad [\text{g/kWh\%}] \quad (2)$$

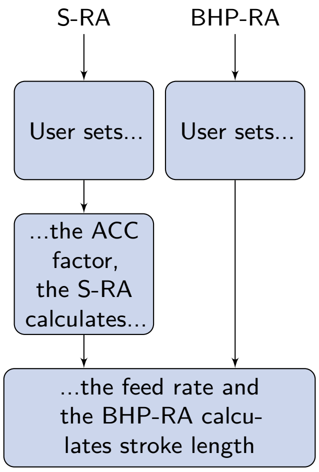

Figure 19: The differences and similarities in S-RA and BHP-RA.

The current calculated feed rate is always shown in the HJL software's "Status" and "Operation" tabs.

> **Please note!**
> Make sure to update the cylinder oil BN and fuel oil sulphur level in the software, every time one or both are altered. Please alter the ACC factor as part of an optimization only.

A.1 Minimum feed rate

The HJL software has a minimum feed rate to ensure that the S-RA cannot reduce below this feed rate, or an operator by mistake cannot enter an arbitrarily low feed rate. This minimum feed rate is a variable and may be lowered while optimizing.

The minimum feed rate is per default set to 0.60 g/kWh. This is a conservative limit, set to always ensure a sufficient oil film, to maintain proper hydrodynamic lubrication. However the actual minimum feed rate for a specific engine, will vary depending on engine type and operating conditions. Experience has shown that this limit predominantly should be lowered to ensure optimal engine condition.

A.2 ACC factor and feed rate

The correlation between ACC factor and feed rate depends on fuel oil sulphur content and cylinder oil BN as evident in equation (1).

Figure 20 shows an example of the correlation between ACC factor, fuel oil sulphur and feed rate. In the example a BN 70 cylinder oil and a minimum feed rate of 0.30 g/kWh is used. This shows how the minimum feed rate will be dominate when using low sulphur fuels.

Table 4 to 7 has been made to show the correlation at different cylinder oil BNs. Table 4 shows this correlation using a BN 100 cylinder oil, at 5 different fuel oil sulphur contents. Table 5 shows this correlation using a BN 70 cylinder oil. Table 6 shows this correlation using a BN 40 cylinder oil. Table 7 shows this correlation using a BN 25 cylinder oil. A minimum feed rate of 0.30 g/kWh is used.

You are always welcome to contact HJL in case you have any questions or are in doubt about the condition of your cylinders. We at HJL are pleased to place our knowledge, experience and expertise at your disposal.

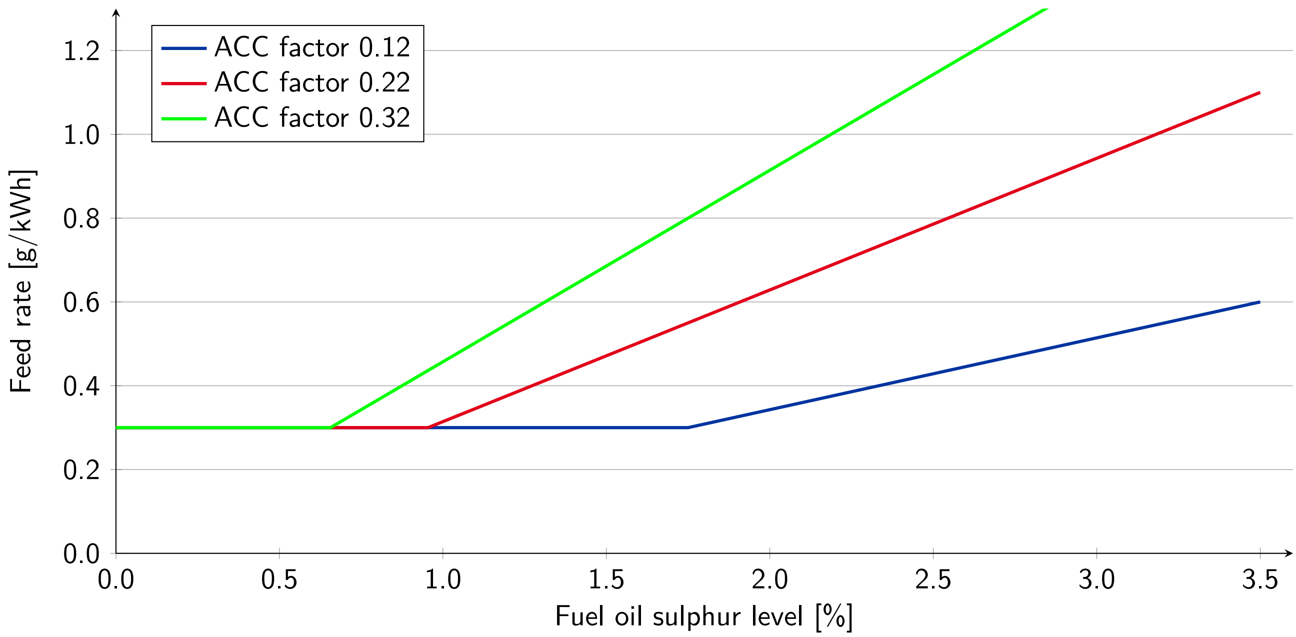

Figure 20: Correlation between ACC factor, fuel oil sulphur content and feed rate. A BN 70 cylinder oil and a minimum feed rate of 0.30 g/kWh is used.

Table 4: Correlation between ACC factor and feed rate using a BN 100 cylinder oil.

ACC factor		Fuel oil sulphur content [%]				
		0.5	1.0	1.5	2.5	3.5
0.12	Cylinder oil feed rate [g/kWh]	0.30	0.30	0.30	0.30	0.42
0.14		0.30	0.30	0.30	0.34	0.48
0.16		0.30	0.30	0.30	0.40	0.56
0.18		0.30	0.30	0.30	0.45	0.62
0.20		0.30	0.30	0.30	0.50	0.70
0.22		0.30	0.30	0.33	0.55	0.77
0.24		0.30	0.30	0.36	0.60	0.84
0.26		0.30	0.30	0.39	0.65	0.90
0.28		0.30	0.30	0.42	0.70	0.98
0.30		0.30	0.30	0.45	0.75	1.05
0.32		0.30	0.32	0.48	0.80	1.12
0.34		0.30	0.34	0.51	0.84	1.18

Table 5: Correlation between ACC factor and feed rate using a BN 70 cylinder oil.

ACC factor		Fuel oil sulphur content [%]				
		0.5	1.0	1.5	2.5	3.5
0.12	Cylinder oil feed rate [g/kWh]	0.30	0.30	0.30	0.43	0.59
0.14		0.30	0.30	0.30	0.50	0.70
0.16		0.30	0.30	0.34	0.57	0.80
0.18		0.30	0.30	0.39	0.64	0.90
0.20		0.30	0.30	0.43	0.71	1.00
0.22		0.30	0.31	0.47	0.79	1.10
0.24		0.30	0.34	0.51	0.86	1.20
0.26		0.30	0.37	0.56	0.93	1.29
0.28		0.30	0.40	0.59	1.00	1.40
0.30		0.30	0.43	0.64	1.07	1.50
0.32		0.30	0.45	0.68	1.14	1.60
0.34		0.30	0.48	0.73	1.21	1.70

Table 6: Correlation between ACC factor and feed rate using a BN 40 cylinder oil.

ACC factor		Fuel oil sulphur content [%]				
		0.3	0.5	1.0	1.5	1.8
0.12	Cylinder oil feed rate [g/kWh]	0.30	0.30	0.30	0.45	0.54
0.14		0.30	0.30	0.34	0.52	0.62
0.16		0.30	0.30	0.40	0.60	0.72
0.18		0.30	0.30	0.45	0.67	0.81
0.20		0.30	0.30	0.50	0.75	0.90
0.22		0.30	0.30	0.55	0.82	0.99
0.24		0.30	0.30	0.60	0.90	1.08
0.26		0.30	0.32	0.65	0.97	1.17
0.28		0.30	0.34	0.70	1.04	1.26
0.30		0.30	0.37	0.75	1.12	1.35
0.32		0.30	0.40	0.80	1.20	1.44
0.34		0.30	0.42	0.84	1.27	1.53

Table 7: Correlation between ACC factor and feed rate using a BN 25 cylinder oil.

ACC factor		Fuel oil sulphur content [%]				
		0.2	0.3	0.4	0.5	0.7
0.12	Cylinder oil feed rate [g/kWh]	0.30	0.30	0.30	0.30	0.34
0.14		0.30	0.30	0.30	0.30	0.39
0.16		0.30	0.30	0.30	0.32	0.45
0.18		0.30	0.30	0.30	0.36	0.50
0.20		0.30	0.30	0.31	0.40	0.56
0.22		0.30	0.30	0.35	0.44	0.62
0.24		0.30	0.30	0.38	0.48	0.67
0.26		0.30	0.31	0.42	0.51	0.73
0.28		0.30	0.34	0.45	0.56	0.78
0.30		0.30	0.36	0.48	0.60	0.84
0.32		0.30	0.38	0.51	0.64	0.90
0.34		0.30	0.40	0.54	0.68	0.95

B Glossary and bibliography

Below are complete lists of all the abbreviations and mathematical symbols used in this Service Letter.

Abbreviations

ACC Adaptive Cylinder Control

BHP-RA BHP dependent Regulation Algorithm
BN Base Number

CLO Cylinder Lubrication Oil

E-M Exhaust-Manoeuvring
ECA Emission Control Area

F-A Forward-Aft

HJL Hans Jensen Lubricators A/S
HJ SIP Hans Jensen's Swirl Injection Principle

IMO International Maritime Organization

MAN-ES MAN Energy Solutions

NCR Normal Continuous Rating
NRV Non-Return Valve

SDA Scrape Down or drain oil Analysis
S-RA Sulphur Regulation Algorithm
SLOC Specific Lube Oil Consumption

TBO Time Between Overhauls
TDC Top Dead Center

Nomenclature

H_2O [-] water

H_2SO_4 [-] sulphuric acid
KOH [-] potassium hydroxide
SO_3 [-] sulphur trioxide

Q_{ACC} [g/kWh%] ACC factor

n_{BN} [mg KOH/g] cylinder oil BN

Q_{fr} [g/kWh] cylinder oil feed rate

L [%] load

$S_{\%}$ [%] fuel oil sulphur content

Bibliography

[1] Marcus Hand. Exxonmobil cylinder monitoring programme reveals unexpected issues. *Seatrade Maritime News*, June 2017. http://www.seatrade-maritime.com/news/europe/exxonmobil-cylinder-monitoring-programme-reveals-unexpected-issues.html.