TECHNICAL BULLETIN

Wärtsilä 2-stroke
Technical Services

RT-161
Issue 2, 21 September 2015

Cylinder Lubrication

Information to all Owners and Operators of Wärtsilä 2-stroke engines.

Next opportunity

Affected products
All Wärtsilä 2-stroke engines.

Current situation
Keeping piston-running parts in a more optimum condition for reliable engine operation requires closer attention to cylinder lubrication feed rate settings as well as a more active approach to monitoring and adjustment according to actual operating conditions.

Preventive action
To ensure the best performance and operation of Wärtsilä 2-stroke engines, it is important to read the information and follow the guidelines about cylinder lubrication stated in this Technical Bulletin.

Validity / Issue
This Technical Bulletin remains valid from the date of issue until further notice.

Note
This Technical Bulletin (issue 2) supersedes the previous version (Technical Bulletin RT 161 issue 1, dated 28th March 2014). Reasons:

- A new procedure for setting the cylinder lubricating oil feed rate that is based on measured value of residual BN and iron has been added to the content.
- A new selection procedure to help choose the most suitable cylinder lubricating oil has been included.
- A new permitted “Minimum Continuous Cylinder Lubrication Feed Rate” has been defined.

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Contents

1 Introduction

This Technical Bulletin RT-161, Issue 2, provides information and guidance concerning the cylinder lubrication of Wärtsilä 2-stroke engines.

NOTE:

- The new Technical Bulletin RT-161 provides information about residual BN and iron dependent cylinder lubrication.
- This Technical Bulletin RT-161, Issue 2, supersedes Technical Bulletin RT-161, Issue 1 dated 28 March 2014.

Reasons:

- A new residual BN and iron dependent lubrication has been added, allowing all operators to adapt the lubrication to the engine profile.
- A new residual BN and iron screening process has been added
- A new supporting tool, “Piston underside drain oil analysis” has been developed (appendix 2)
- A new permitted “Minimum Continuous Cylinder Lubrication Feed Rate” has been defined.
- For more information about the latest validated lubricating oils – cylinder and system oils – and recommendations about the application areas of the lubricants including sample analysis, see the Data & Specifications bulletin RT-138 entitled “Lubricating oils”.

The piston running behaviour of 2-stroke engines is exhibiting an ever growing complexity. The key factors are the changes of operation patterns (e.g. slow steaming). New tuning options including fuel saving retrofit packages have to be considered as well. On the other hand, the very wide range of cylinder lubricant specifications, the use of various fuels due to complex environmental regulations and the corresponding solutions constitute external factors that may significantly influence the piston running behaviour of the engine.

This Technical Bulletin supports operators to adjust lube oil feed rates in an optimal way to:

- Ensure the optimal and fit for purpose supply of lubricant to the piston ring – cylinder liner system to lubricate and protect components from corrosion (see Figure 1).
- Ensure the reliable operation of piston running components.
- Ensure the achievement and/or the extension of the time between overhauls of the piston running components.

Investigations have shown, that engines of the same design may experience very different piston running behaviours. Operation pattern, engine load, fuel, the cylinder lubricant applied or the specific engine tuning are possible influencing factors.

As a consequence the wear behaviour in general and the corrosion resistance behaviour in particular may vary widely depending on the engine which is considered.

This bulletin describes the procedures that should always be applied to optimally tune the lube oil system.

The first priority is to monitor the actual piston running behaviour by following these recommendations:

- Regular analysis of the piston underside drain oil in regards to residual BN, Fe content and Cr content (see Figure 5).
- Regular visual piston underside inspections.
- The fuel should be analysed by a laboratory to stablish its quality and sulphur content before using it, in order to choose the correct cylinder oil.

2 Base feed rate lubrication, engine load dependent

The cylinder lubrication has various functions:

- Build an optimal oil film between the cylinder liner and the piston rings.
- Neutralize the sulphuric acid formed during combustion.
- Keep the piston, piston rings and cylinder liner free of deposits with the detergent and dispersant properties of the cylinder lubricating oil.

The fulfilment of these functions require a load dependent correction of the adjusted base feed rate.

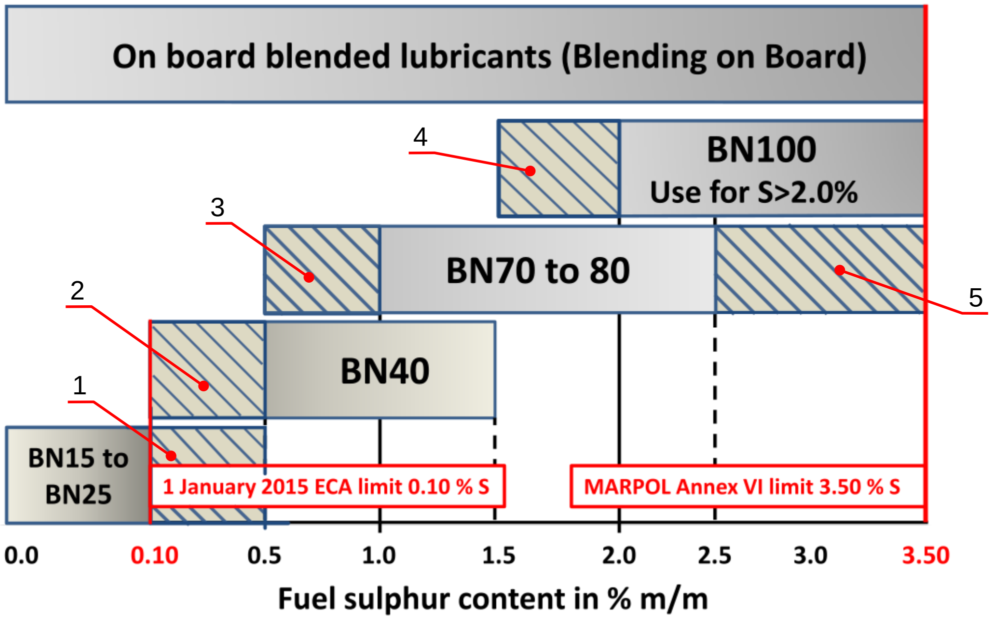
3 Effective feed rate

The cylinder oil feed rate set in the control system is the specific feed rate in g/kWh at 100% CMCR. At part load, a correction factor is applied in order to ensure sufficient quantity of oil at lower loads. The effective specific feed rate at part load is therefore higher than the set feed rate.

4 Selection of the cylinder lubricating oil

The proper BN selection of the cylinder lubrication oil should be driven by the results from piston underside drain oil analysis or the fuel sulphur content. As general guidance for suitable combinations Figure 1 provides both, BN selection for the optimization process and recommendations in case piston underside drain oil monitoring is not executed.

Wärtsilä recommends to bunker the highest possible BN cylinder oil selectable according to Figure 1 (e.g. if a vessel bunkers fuel oil which is generally between 1.5% ≤ Sulphur ≤ 3.5% it is recommended to use a BN 100 cylinder lubricating oil).



1. ***0.1% < Sulphur < 0.5% m/m:*** *On board piston underside drain oil monitoring must be strictly followed, residual BN must not be lower than BN10, iron (Fe) must be measured as well and should be below 500 mg/kg. Additionally, piston and piston ring condition must be inspected through scavenge ports in regular intervals. The cylinder lubrication oil feed rate may be increased above 1.2 g/kWh if required.*
2. ***0.1% ≤ Sulphur < 0.5%*** *Operation only permitted if strictly followed on board piston underside drain oil monitoring and regular inspections of piston rings and liners guarantee operation in safe area according to Figure 5.*
3. ***0.5% ≤ Sulphur < 1.0% m/m:*** *Operation only permitted if strictly followed on board piston underside drain oil monitoring and regular inspections of piston rings and liners guarantee operation in safe area according to Figure 5.*
4. ***1.5% ≤ Sulphur < 2.0% m/m:*** *Operation only permitted if strictly followed on board piston underside drain oil monitoring and regular inspections of piston rings and liners guarantee operation in safe area according to Figure 5.*
5. ***2.5% < Sulphur ≤ 3.5% m/m:*** *Operation only permitted if strictly followed on board piston underside drain oil monitoring and regular inspections of piston rings and liners guarantee operation in safe area according to Figure 5.*

Figure 1: Relationship between fuel sulphur content and cylinder oil BN

5 Residual BN and iron dependent lubrication

5.1 Introduction

Service experience has shown that during any load operation, cold corrosion can be observed on the cylinder liner and piston rings, in some cases leading to scuffing. This corrosion indicates that the neutralisation and detergency provided by the lubricant at the given feed rate are inadequate. Increasing lubricant BN and/or feed rates enhance the supply of neutralising and cleaning additives.

The neutralisation of acidic components is achieved by the alkaline additives which are present in the cylinder lubricating oil.

NOTE:
The neutralisation of the sulphuric acid produced during engine operation by the calcium based additives follows the simplified equation:

$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + CO_2 + H_2O$

Some cylinder oil formulations contain ashless detergents which also neutralise sulphuric and other acids formed during fuel combustion in engines.

Moreover, one has to bear in mind that the piston running relevant functions of the oil and additives are:

- Creation of a protective boundary film between the cylinder liner and piston ring surface
- Provision of dispersancy and detergency
- Neutralisation of acids

In order to enhance the amount of protective chemicals in the system while observing a low residual BN value, increased iron content or signs of corrosion on piston rings and cylinder liners, it is recommended to adjust the cylinder lubricating oil feed rate and consider the following:

- The current feed rate in g/kWh.
- The piston underside drain oil residual BN and iron content.
- The HFO sulphur content, i.e. the sulphur content in % by mass of the heavy fuel oil in use.
- The cylinder oil BN, i.e. the BN of the cylinder lubricating oil in use in mg KOH/g.

As a consequence of the above mentioned points, it is advised to apply a residual BN and iron dependent feed rate.

ATTENTION:
The Bunker Delivery Note (BDN) and bunker analysis can show inaccuracy in measuring the sulphur content and possibly different HFO composition. The sulphur content used to set the correct feed rate must be the higher value of the BDN or the bunker analysis to ensure safe operation.

Figure 2 is an example of the possible feed rate variation between various same type engines with a BN 100 cylinder oil

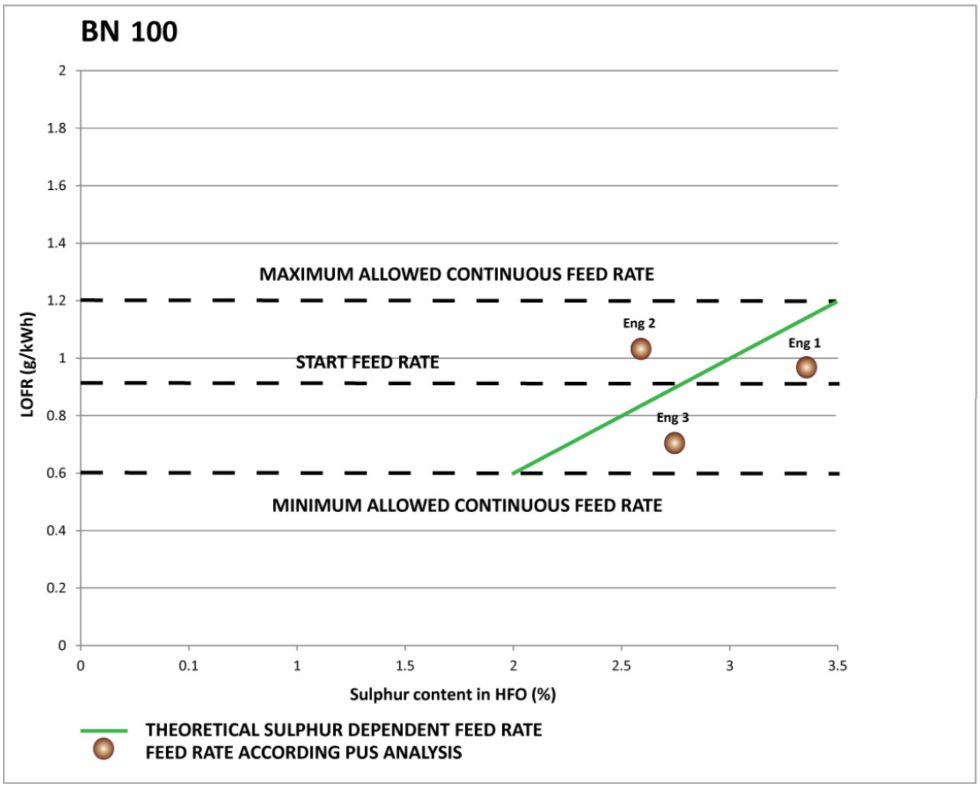


Figure 2: Example of feed rates for engines using BN 100

An incorrect lubrication setup can cause cold corrosion that may lead to faster or even severe wear of the piston running components.

As a consequence, the wear behaviour in general and the corrosion resistance of the piston running components may vary widely.

In order to accomplish good performance of the piston running components, a sequence of steps is described in this Technical Bulletin:

- Engine screening process
- Analysis of the PUS oil sample
- Cylinder lubrication feed rate optimisation

ATTENTION:
It is extremely important to do a correct cylinder lubrication change-over in alignment with the fuel change-over described in the Technical bulletin RT-82, “Operation on distillate fuels” (especially with the change-over from MGO to HFO). Possible consequences of a mismatch between fuel sulphur content and cylinder lubricant BN are:

- Low BN used with high sulphur fuel: Corrosion of piston rings and liners
- High BN used with low sulphur fuel: Liner polishing caused by deposits on piston top lands and high wear on piston rings and liners caused by deposits in the piston ring grooves

Wärtsilä recommends to monitor the cylinder lubricating oil change-over, as well as consider the cylinder lubricating oil consumption and cylinder lubricant quantity in the measuring tank and pipe, to avoid the incorrect use of the cylinder lubricants with the selected fuel (see following calculation). It is also recommended to start switching over from low BN to high BN cylinder oil already inside ECA zone to avoid operation of high sulphur fuel with low BN cylinder oil.

Cylinder lubricant quantity in piping and measuring tank:

Volume piping: $\sum V = \sum \frac{d^2 * \pi}{4} * l$ $\qquad [V] = m^3 \qquad [d] = m \qquad [l] = m$

Mass: $m = \rho * V$ $\qquad [m] = kg \qquad [\rho] = \frac{kg}{m^3} \qquad [V] = m^3$

The density of the cylinder lubricant can be found in the technical data sheet. If not available, an average value of 920 $\frac{kg}{m^3}$ is suitable for this purpose.

Total mass: *Mass of cylinder oil in measuring tank [kg]*
+
Mass of cylinder oil in piping [kg]

Lead time until new lubricant is in use:

$$consumption = effective\ feed\ rate * current\ power\ output * 1000$$

$$lead\ time = \frac{total\ mass}{consumption}$$

$$[consumption] = \frac{kg}{h} \quad [effective\ feed\ rate] = \frac{g}{kWh} \quad [current\ power\ output] = kW$$

$$[lead\ time] = h \quad [m] = kg \quad [consumption] = \frac{kg}{h}$$

NOTE:
Consider the lead time value to initiate the cylinder lubricant change-over at the right time.

5.2 Engine Residual BN and iron screening process

The previous issue of the Data & Specification Bulletin RT-138, instructs engine operators to do the piston underside (PUS) drain oil sampling after approximately every 10% load change when the fuel in use has a sulphur content of higher than 2.5%.

These requirements have now changed. Instead of doing PUS drain oil sampling after a 10% load change, which means a lot of sampling is required even if the engine has run on similar loads before, the sampling results from previous tests at respective engine loads can now be used to set up the required feed rate for a specific cylinder lubricant.

Also, the requirement to only sample when using fuels which contain more than 2.5% sulphur, is now changed due to the new minimum allowed continuous feed rate of 0.6 g/kWh. Higher BN oils can be applied for fuel with a low sulphur content as long as the PUS drain oil sampling results are within an acceptable range (see Figure 3 and Figure 4). Therefore, the PUS drain oil sampling now needs to be carried out when the engine is running on fuels with a sulphur content above 1.5%.

In order to create an overview of all the PUS drain oil sampling results a new tool called the “Piston underside drain oil analysis” (see appendix 2), will help in structuring all the PUS drain oil sampling results collected over a period of time. The tool will also give recommendations for all the sample results entered into it

ATTENTION:
The piston underside drain oil analysis tool is intended to be used for cylinder lubrication oils with BN ≥ 40.

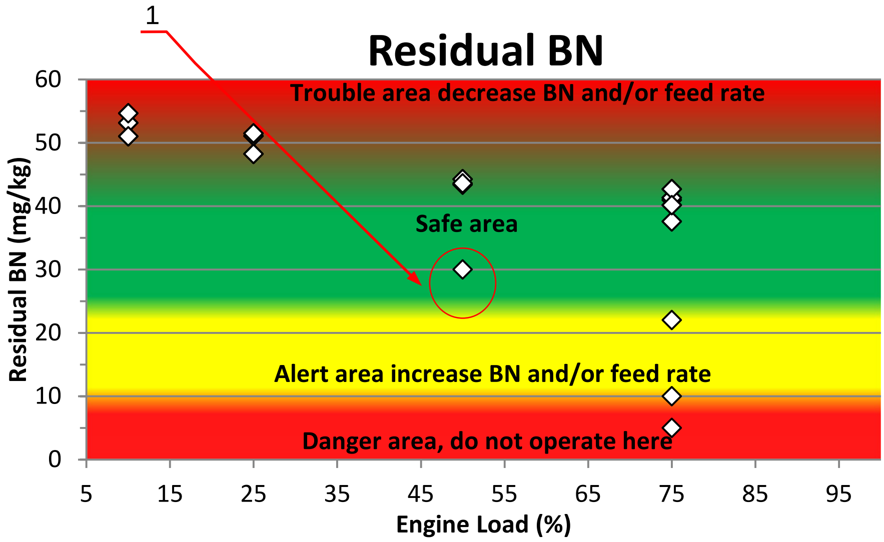
If no PUS drain oil sampling results have been collected yet, it is recommended to start taking PUS drain oil sampling after the first running-in period with the highest available BN oil suitable for the fuel in use (according to Figure 1) and using a baseline feed rate of 0.9 gr/kWh at different loads, e.g. 10%, 20%, 30% CMCR etc., whatever the ships operating schedules allows. This is called the Residual BN and Iron Screening Process and creates a reference scale for future benchmarking. When the results from the PUS drain oil samplings are received, these are to be entered into the tool and a recommendation will be automatically given of what actions the operator must take, if any, for that specific fuel with that specific cylinder lubricating oil.

The next time a fuel oil with the same sulphur (± 0.125% sulphur) is bunkered and the same cylinder lubricating oil is used, the feed rate can be set according to the recommendation previously given by the tool for those same conditions. It is strongly recommended for the operator to do at least PUS drain oil sampling at similar loads to the previous screening, purely for confirmation purposes. The results of those “new” PUS drain oil sampling shall then again be entered into the tool as a cross-check that the previous recommendations remain valid and to check if anything can/needs to be optimised.

Based on the results and recommendations in the tool, one can decide to keep the feed rate settings in the Safe Zone or whether required adjustments into the Alert Zone (see Figure 3 and Figure 4), where frequent PUS inspections are then also necessary.

5.3 Analysis of the piston underside (PUS) drain oil samples

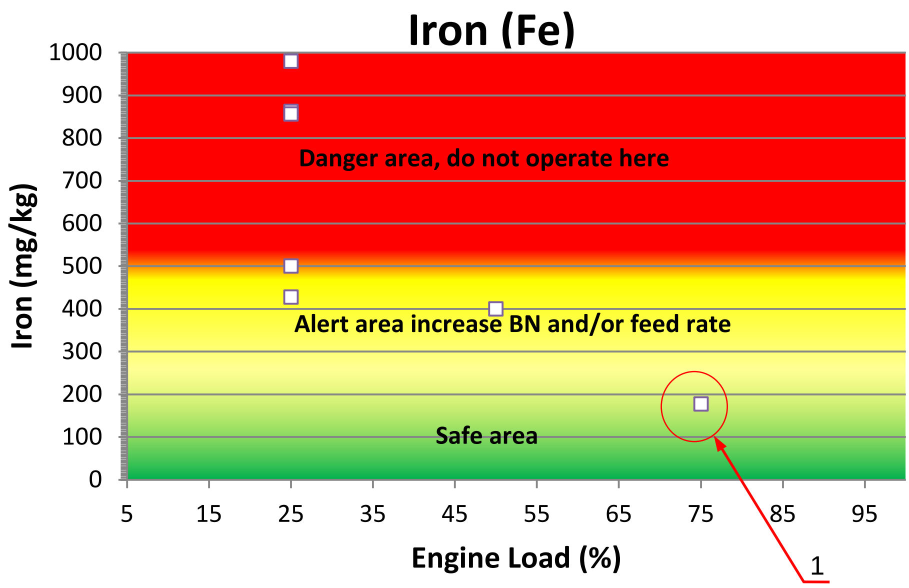
In order to optimise the feed rate, the PUS drain oil samples results must be compared using Figure 3 and Figure 4. The results need to be filled in the piston underside drain oil analysis tool (provided by Wärtsilä) which includes the mentioned graphics. The link to the tool can be found in appendix 2.



1. Residual BN

Figure 3: Residual BN screening diagram for cylinder lubricants with BN 40 or higher

NOTE:
If the engine is using a fuel of sulphur content < 0.1 % while the cylinder lubricating oil has BN in range 15 to 25, then a residual BN of the PUS drain oil sample measured at a value above 10 is considered safe. Check Figure 1 for more information.



1. Iron content

Figure 4: Iron content screening diagram for cylinder lubricants with BN 40 or higher

Fuel sulphur in the range 0.5 < Sulphur % < 3.5 m/m and cylinder oil with 40 < BN < 100

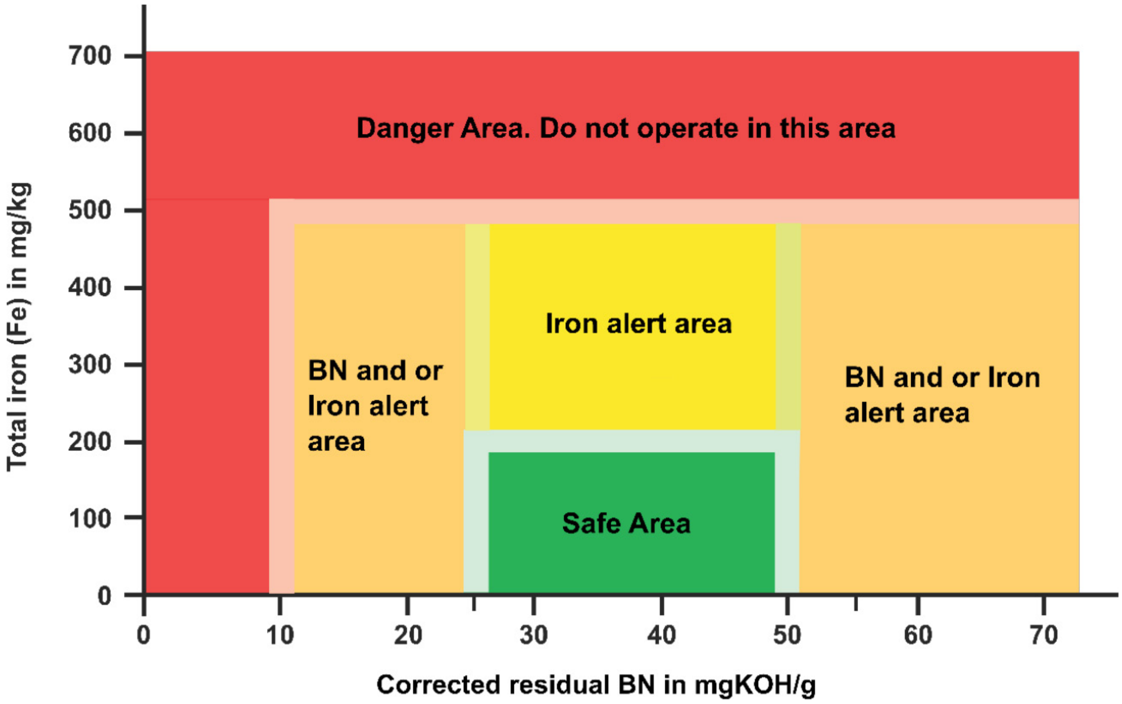


Figure 5: Piston Underside (PUS) drain oil residual BN and iron (Fe)

NOTE:
There are smooth transitions between the various areas as shown in Figure 5.

ATTENTION:

- If the feed rate is kept while operating in the alert area, regular visual inspections of liners, pistons and piston rings are required.
- An increase of the total iron content is an indication of an increased corrosive and/or abrasive wear. However, if a visual inspection of the piston running components does not show any abnormalities it is recommended to check the condition of the piston rod

Depending on the adjusted feed rate, the actions for the different areas are varying. Please check the piston underside drain oil analysis tool to find the specific recommendations in Appendix 2.

The chromium content in the piston underside drain oil sample is also an important indicator of corrosion or wear on the piston ring running surface, if chrome ceramic piston rings are fitted. Chromium values less than 25 mg/kg indicate that there is little corrosion and wear on the piston ring running surfaces. Values above about 25 mg/kg indicate that corrosion and/or wear are occurring which may reduce piston ring and liner life. The chrome content of the piston underside oil should not exceed 25 mg/kg for long periods of time.

5.4 Cylinder lubrication feed rate optimisation

In order to have a satisfactory piston running behaviour and based on customers operation procedures, Wärtsilä recommends the following strategies to choose the correct cylinder lubrication of the engine.

5.4.1 Feed rate optimisation with regular PUS inspections and PUS drain oil sampling

This strategy is intended for operators that perform PUS inspections and PUS drain oil sampling on regular basis. First, follow the recommendations mentioned in chapter 5.2 and chapter 5.3. Check if one or more residual BN points are in the alert zone of Figure 3 and compare it with the iron content results of Figure 4; if the iron content is not exceeding the allowed value of 500 mg/kg the feed rate can be kept, but frequent piston underside inspections are recommended.

ATTENTION:
Wärtsilä recommends to operate the engine in the safe area of residual BN and iron content. If the engine is operating in the alert zone described in Figure 3 and Figure 4, a PUS drain oil sampling must be done and analysed every 2 days in order to check, if the values have changed.

If the iron content in the results of the PUS drain oil sampling is more than 500 mg/kg, the feed rate must be increased by 0.1 g/kWh steps, until the value of the iron content drops below 500 mg/kg. Conversely, if the iron content in the results of the PUS drain oil sampling is below 500 mg/kg and the residual BN is in the safe zone 25 ≤ BN ≤ 50, the feed rate can be reduced in steps of 0.1 g/kWh until one of the values reach the alert zone.

Frequent PUS inspections should be done to check upon the piston rings and liners appearance. Wärtsilä recommends to check the coating thickness of the rings every 1500 - 2000 running hours.

The engine can be operated in different loads than the mentioned in chapter 5.2. These PUS drain oil sampling analysis results can be added in the piston underside drain oil analysis tool diagrams, as shown in Figure 3 and Figure 4, to create an improved screening of the engine.

5.4.2 Feed rate optimisation with irregular PUS inspections and PUS drain oil sampling

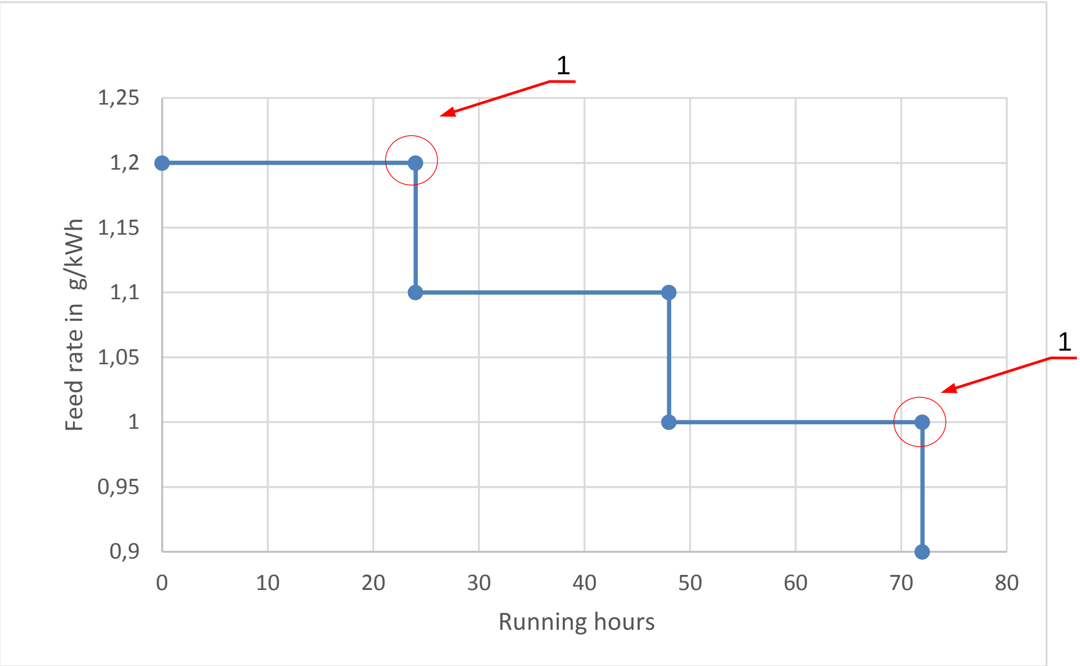
This strategy is intended for operators that do not perform PUS inspections and PUS drain oil sampling on regular basis. First, follow the recommendations mentioned in chapter 5.2 and chapter 5.3. If one or more residual BN results are in the alert zone of Figure 2, the feed rate must be increased in steps of 0.1 g/kWh and a PUS drain oil sampling at the lowest load that showed the lowest residual BN must be done again. This procedure must be repeated until the residual BN of this lowest load point is in the safe area of Figure 2.

ATTENTION:
It is advised to do a PUS drain oil sampling after every bunker change with different sulphur content than the previous fuel on board (difference > +/- 0.125 %S).

6 Running-in of newly fitted cylinder liners / piston rings

Each time is changed a component of the piston running system, as for any mechanical system, it is crucial to follow some procedures. Wärtsilä defined surface and material specifications of cylinder liner and piston rings that allow to complete the running-in of the component within shortest time. No time consuming running-in of piston rings and cylinder liners is necessary anymore. The running surface of the new cylinder liners is executed with a plateau honing, a state of the art procedure in engine industry (standard since the year 2000). The piston rings of portfolio engines are chromium ceramic coated, profile ground and afterwards lapped, so that they are gas and light-tight when installed into a new cylinder liner. Both components are therefore fit to be loaded up in a normal manner after installation, following the normal engine load up program. The same applies for new piston rings that are installed into an already used cylinder liner. Provided that running surface is free of surface damages, loading up can be done according to control system settings.

A special attention is required that cylinder liner and piston ring surface are well lubricated after the overhaul. Since lube oil feed rates are as low as possible, to keep operational costs low, a longer time is needed to fresh up the entire lube oil film. This situation is considered in our running-in guideline with slightly higher feed rates. Figure 6 shows the recommended running-in feed rates for newly fitted cylinder liners and/or piston rings.



1. *Inspection of liner and rings is recommended after 24 hours and 72 hours after fitting a new component.*

Figure 6: Running-in feed rate for newly fitted cylinder liners and piston rings

NOTE:
After the running-in procedure of 72 hours, the feed rate can be set to normal settings.

Wärtsilä does not request a special loading up of the engine after component overhaul anymore. Any load, fuel, lube oil type / feed rate plus ambient condition change leads to a different thermal, chemical and finally wear situation in the combustion space. In other words, there is a theoretical continuous running-in procedure ongoing on very low wear rate level for the entire engine lifetime. So engines can be operated up to the required load and no special running-in is required when engine load increases or decreases later.

ATTENTION:
Wärtsilä recommends to follow the running-in procedure described in the operation manual for engines equipped with older executions than full chromium ceramic ring pack and plateau honed liner.

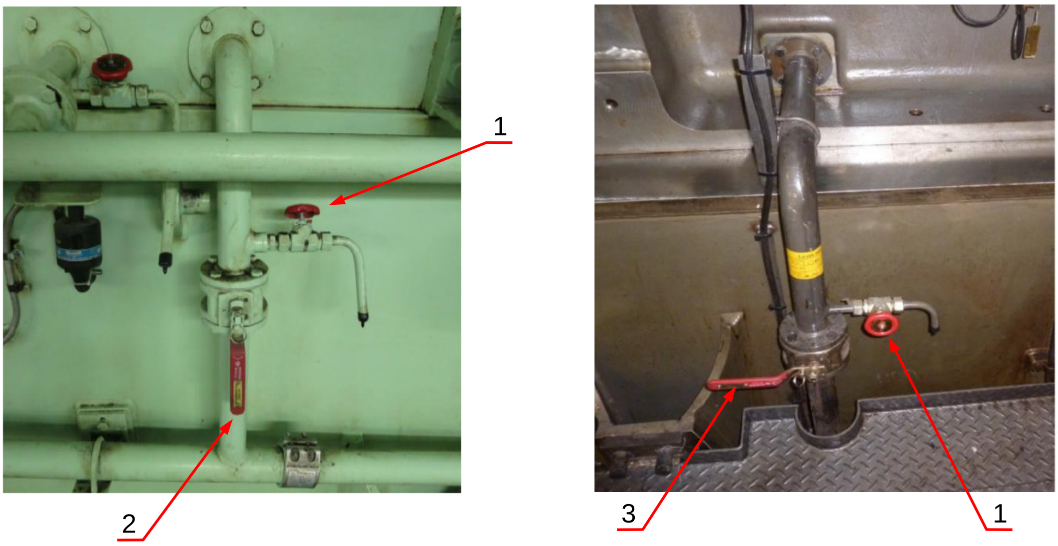
For particular attention, the following parameters should be adhered to.

Table 1, Running-in recommendations

Medium	**Recommendation**
Fuel oil	Running-in can be done on any fuel. HFO to be correctly treated and preheated to the recommended injection viscosity before the engine is started.
Cylinder lubricating oil	Fuel-suitable cylinder lubricating oil has to be selected as for normal operation.
VIT / FQS / ICC	VIT (Variable Injection Timing) system should be switched off. FQS (Fuel Quality Setting) set to zero. ICC (Intelligent Combustion Control) system should be switched off.
Cylinder cooling water	Check the stability and the level of the cylinder cooling water temperature frequently. Temperature fluctuations should be avoided as far as possible: +/- 2 °C at constant load +/- 4 °C during transient conditions
Cylinder liner wall temperature	The monitoring tool MAPEX PR is of great advantage as it allows close monitoring of the cylinder liner wall temperature for safe running-in.

7 PUS drain oil sampling and analysis

7.1 Piston underside (PUS) drain oil sampling



1. Sampling cock
2. Oil drain valve in normal position
3. Oil drain valve in sampling position

Figure 7: PUS, Scrapedown or drip oil sampling

Oil sampling should only be done when the engine has been in a stable operating condition on a known fuel with the same cylinder oil feed rate, engine load and other variable factors for at least 12 hours. Further samples should be taken under similar conditions to improve data trending information.
The procedure how to take oil samples is described in paragraph 7.1.1, entitled "Flushing" and paragraph 7.1.2, entitled "Sampling".

7.1.1 Flushing

The system should be flushed to prevent non representative accumulated debris from entering the sample bottle.

1. Close the oil drain valve to allow oil to accumulate for about 30 minutes to 60 minutes, depending on engine load, oil feed rate, etc.
2. After enough oil has accumulated, open the sampling cock slowly and carefully blow any old oil into a bucket. When the sampling cock and sampling pipe are thoroughly flushed, close the sampling cock.
3. Open the drain valve to allow the remaining oil to be blown down the drain pipe, this only takes a few seconds.
4. When this is completed, close the oil drain valve again.
5. Record the engine operating conditions, fuel parameters, cylinder oil feed rate and other data required on the used oil analysis form.

7.1.2 Sampling

Complete this procedure for every cylinder of the engine.

1. Wait for 10 minutes to 60 minutes to accumulate enough oil to fill the sample bottles. These are normally 100 ml sample bottles but may vary.
2. Open the sampling cock slowly and carefully fill the sample bottle. Ensure that the sample bottle has the cylinder number and references marked so that it can be clearly identified.
3. Close the sampling cock.
4. Open the oil drain valve into the normal position again so that surplus oil can drain away.
5. Proceed to the next cylinder and perform the same procedure.
6. It is good practice to also submit a sample of fresh cylinder oil taken at the engine inlet pipe after the filter for analysis. There are sometimes contaminations, because wrong oil may have been delivered or placed in the wrong tank. This is important to ensure that cylinder oil change over has been correctly performed and the appropriate oil is in the system.
7. Ensure that the sample bottle caps are closed securely and the bottles are accurately marked before submitting them for analysis. The sample bottles must be securely packed to prevent leakage when dispatching the parcel by postal or courier service to the laboratory.

7.2 PUS drain oil analysis

There are different options available in the market for the monitoring of PUS oil condition. Several widely used systems need consumables (chemicals) and the results are based on the accurate handling of the equipment. As an alternative, there is a recommended product available without consumables and highly accurate for TBN (mgKOH/g) measurements, the FluidScan® Q1200 family by Spectro Scientific. It requires only a droplet of sample, therefore, sampling time is below one minute.

Figure 8: FluidScan® Q1200 family by Spectro Scientific

For inquiries, contact your nearest Wärtsilä representative or your key account manager.

8 Cylinder lubrication: Blending on Board (BoB)

There is a significant choice of cylinder lubricants on the market to address the need for different BN-values based on the operation profile of the engine. A growing and interesting concept to reduce the variety of oils on board is the blending of needed lubrication oil on board, by means of a blending unit.

This solution is able to mix two different oils to produce a fit for purpose and tailored cylinder lubricant. The major application is to mix the system oil as a base oil and add the correct quantity of over based additives. An alternative solution is to mix system oil with high-BN oil used for running with high sulphur fuel or also mix oils with different BN-values to have the needed BN-value available.

Various BN oils can therefore be produced on board. The key interest is that there will not be a need to adjust the feed rate to various operation conditions. Instead the BN-value of the cylinder oil will be adjusted to keep the feed rate constant. In addition the usage of the system oil is keeping the quality of the system oil high and the crankcase clean and the variety of different lubrication oils on board is reduced to a minimum.

To be able to profit most from the blending system, the use of an on board PUS oil condition monitoring system is needed. The residual BN-value will give a clear indication whether the base number of the lubrication oil is sufficient. Adjusting the BN-value of the lubrication oil by means of the blender to fit to the residual BN-value will improve the corrosion protection as well as the detergency.

BOB appears to be technically the most viable solution for vessels operating on a variety of fuels and operating conditions, as it covers the range from low sulphur fuels to high sulphur fuels.

Table 2 provides a guidance for operation without regularly updated values of the PUS oil monitoring, but during the operation, this table can be optimised by the operator as a function of the residual BN of the PUS.

Table 2, BN values for BoB depending on sulphur content for base feed rate of 0.8 g/kWh

Sulphur content (%)	Normal operation (above 60 % CMCR)	Low load (below 60 % CMCR)	In case or corrosion on cylinder liners or piston rings
1.0	40	40	40
1.1	40	40	40
1.2	40	40	40
1.3	40	40	40
1.4	40	40	40
1.5	40	40	50
1.6	50	50	50
1.7	50	50	50
1.8	50	50	60
1.9	50	50	60
2.0	50	50	60
2.1	50	50	60
2.2	50	70	60
2.3	50	70	70
2.4	50	70	70
2.5	50	70	70
2.6	50	70	70
2.7	50	70	80
2.8	50	70	80
2.9	51	72	80
3.0	53	75	90
3.1	55	77	90
3.2	57	80	90
3.3	59	82	100
3.4	61	85	100
3.5	63	87	100

9 Appendix

1. Wärtsilä cylinder lubrication systems (Appendix 1)
2. Link to tool – Piston underside drain oil analysis and Brochure – Guide for judging condition of relevant piston running components (Appendix 2 and Appendix 3): http://www.wartsila.com/products/marine-oil-gas/engines-generating-sets/low-speed-rt-flex-engines#
3. Link to Brochure – Wärtsilä Blending On Board system for 2-stroke engines (Appendix 4): http://www.wartsila.com/docs/default-source/Service-catalogue-files/Engine-Services---2-stroke/blending-on-board-system-for-2-stroke-engines.pdf?sfvrsn=0

10 Limitation

The lubrication procedure as described in Chapter 5 and Chapter 8 may not be used in the territorial waters of Germany, China, the Republic of Korea or Japan unless it is used on a vessel registered in a country being a contracting party to the Paris Convention for the Protection of Intellectual Property, except Germany, China, the Republic of Korea or Japan and unless said vessel is travelling in said territorial waters only temporarily.

10.1 Contracting parties to the Paris Convention

Albania, Algeria, Andorra, Angola, Antigua and Barbuda, Argentina, Armenia, Australia, Austria, Azerbaijan, Bahamas, Bahrain, Bangladesh, Barbados, Belarus, Belgium, Belize, Benin, Bhutan, Bolivia (Plurinational State of), Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Canada, Central African Republic, Chad, Chile, China, Colombia, Comoros, Congo, Costa Rica, Côte d'Ivoire, Croatia, Cuba, Cyprus, Czech Republic, Democratic People's Republic of Korea, Democratic Republic of the Congo, Denmark, Djibouti, Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Equatorial Guinea, Estonia, Finland, France, Gabon, Gambia, Georgia, Germany, Ghana, Greece, Grenada, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Holy See, Honduras, Hungary, Iceland, India, Indonesia, Iran (Islamic Republic of), Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Kyrgyzstan, Lao People's Democratic Republic, Latvia, Lebanon, Lesotho, Liberia, Libya, Liechtenstein, Lithuania, Luxembourg, Madagascar, Malawi, Malaysia, Mali, Malta, Mauritania, Mauritius, Mexico, Monaco, Mongolia, Montenegro, Morocco, Mozambique, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Republic of Korea, Republic of Moldova, Romania, Russian Federation, Rwanda, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, San Marino, Sao Tome and Principe, Saudi Arabia, Senegal, Serbia, Seychelles, Sierra Leone, Singapore, Slovakia, Slovenia, South Africa, Spain, Sri Lanka, Sudan, Suriname, Swaziland, Sweden, Switzerland, Syrian Arab Republic, Tajikistan, Thailand, The former Yugoslav Republic of Macedonia, Togo, Tonga, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Uganda, Ukraine, United Arab Emirates, United Kingdom, United Republic of Tanzania, United States of America, Uruguay, Uzbekistan, Venezuela, Viet Nam, Yemen, Zambia, Zimbabwe

11 Contacts

11.1 How to contact Wärtsilä

For questions about the content of this Technical Bulletin, or if you need Wärtsilä assistance, services, spare parts and/or tools, please contact your nearest Wärtsilä representative.
If you do not have the contact details at hand, please follow the link “Contact us” – “24h Services” on the Wärtsilä webpage:
www.wartsila.com

11.2 Contact details in case of emergency

11.2.1 Operational support

For questions concerning operational issues, please send your enquiry to:
technicalsupport.chts@wartsila.com
or phone 24hrs support: +41 52 262 80 10.

11.2.2 Field service

If you need Wärtsilä Field Service, please send your enquiry to:
ch.fieldservice@wartsila.com
or phone 24hrs support: +41 79 255 68 80.

11.2.3 Spare parts

If you need Wärtsilä spare parts and/or tools, please contact your nearest Wärtsilä representative or your key account manager.