

ALL

SUBJECT: Lube Oil Recommendations

MODELS AFFECTED: All INNIO's Waukesha Engines

TOPIC: Lubrication System

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SUMMARY

The organization and content of this bulletin has changed significantly. Change bars have been added to the margin to highlight some of the changes. Be sure to read and understand this bulletin in its entirety.

Use this service bulletin to identify the lube oil needs and specifications of all INNIO Waukesha engines. Listing is by current production model and fuel type.

This bulletin revision provides current lube oil recommendations as a guideline for the selection of an appropriate lube oil only. It is the responsibility of the person(s) in charge of maintenance to choose the appropriate lube oil for the engine and conditions that it is operating under.

To obtain lube oil recommendations for INNIO's Waukesha Engine models not listed in this bulletin, please contact INNIO's Waukesha Engine's service department.

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INFORMATION AND INSTRUCTIONS

- INNIO's Waukesha Engines are heavy-duty industrial-type engines which require heavy-duty lube oils. The basic requirements are high lubricating quality, high thermal stability and good control of contaminants.
- INNIO's Waukesha Engine's product line consists of spark-ignited industrial gas engines from the VGF through the 16V 275GL + models. The lube oil requirements and systems change greatly between each model and fuel type.

LUBE OIL PERFORMANCE

There are hundreds of commercial crankcase lube oils marketed today. Obviously, engine manufacturers or users cannot completely evaluate the numerous commercial lube oils. The performance of a lubricant, like that of any manufactured product, is the responsibility of the refiner and supplier. The standard express limited warranty that accompanies an INNIO's Waukesha Engine does not include coverage for the performance of any lube oil. INNIO's Waukesha Engine's warranty is limited to the repair or replacement of parts that are found to be defective in material or workmanship during the warranty period.

- INNIO's Waukesha Engine strongly recommends monitoring the condition of the lube oil through the use of a good lube oil analysis program.

LUBE OIL DESIGNATIONS

Lube oil is designated in several ways: American Petroleum Institute (API), Society of Automotive Engineers (SAE), American Society for Testing and Materials (ASTM) performance classifications and Military Designation. Since no gas engine industry lube oil performance designations exist, it is the responsibility of the engine operator to verify with their lube oil supplier that the lube oil they select has proven field performance in their specific engine make and model. This lube oil must also meet the minimum requirements specified by INNIO's Waukesha Engine as listed in the included tables.

SUPPLEMENTARY LUBE OIL ADDITIVES

Quality lube oils formulated specifically for natural gas engines have sufficient additives to meet requirements. INNIO's Waukesha Engine does not recommend the addition of lube oil additives to these lube oils.

CATALYST CONTAMINANTS

The following contaminants are known catalyst deactivators and should be avoided when selecting lube oils for installations with catalysts since they contribute to shortened catalyst life: heavy and base metals such as lead, mercury, arsenic, antimony, zinc, copper, tin, iron, nickel, chrome, sulfur and phosphorus. Generally these individual elements should not exceed 1 ppm or collectively exceed 5 ppm at the catalyst inlet. Specific exceptions: phosphorus or silicon compounds at the catalyst inlet are not to exceed 1 ppm and sulfur compounds at the catalyst inlet are not to exceed 100 ppm. Always consult the catalyst supplier for specific recommendations for the catalyst being used.

Do not confuse the concentration of these elements in the exhaust gas flow *AT THE CATALYST INLET* with the concentration of these elements in the lube oil itself.

LUBE OIL RECOMMENDATIONS

INNIO's Waukesha Engine requires the use of lube oil formulated specifically for natural gas engines that meet minimum ash requirements based on engine model. The ash-forming constituents in lube oil formulations provide detergency, corrosion protection and anti-wear protection. In addition, the ash produced during combustion of these additives will provide protection against valve face and seat recession. However, use of lube oils containing a higher ash level than specified in the tables may increase engine deposits and decrease component life.

NOTICE

INNIO's Waukesha Engine requires lube oils formulated specifically for natural gas engines. INNIO's Waukesha Engine does not recommend gasoline or diesel lube oil formulations for use with its engines. Use of gasoline or diesel formulations may cause severe engine damage. The standard express limited warranty that accompanies an INNIO's Waukesha Engine does not include coverage for the performance of any lube oil. INNIO's Waukesha Engine's warranty is limited to the repair or replacement of parts that are found to be defective in material or workmanship during the warranty period.

Table 1: Lube Oil Recommendations by Engine Model

GAS ENGINE MODELS		SULFATED ASH WT% *, **, ***
VGF SERIES	F18, H24, L36, P48 G, GL, GLD	0.45 – 0.75
	F18, H24, L36, P48, GSI, GSID	0.35 – 0.55
	ANY ENGINE MODEL WITH WAUKESHA FACTORY-SUPPLIED CATALYST	0.35 – 0.55
VHP SERIES	F352I, L5790, L7042, P9390 G, GSI, GL	0.35 – 1.0
	ALL SERIES 4 AND SERIES 5 MODELS WITHOUT WAUKESHA FACTORY-SUPPLIED CATALYST	0.45 – 0.75
	ALL SERIES 4 AND SERIES 5 MODELS WITH WAUKESHA FACTORY-SUPPLIED CATALYST	0.45 – 0.50
275GL/GL+ SERIES	12V, 16V	0.35 – 1.0
APG SERIES	16V150LTD	0.4 – 0.55
	12V220GL, 18V220GL	See Table 3

* Lube oils must be specifically formulated for gas engines using highly refined mineral oil base stocks. The ash requirements are a percentage by weight with both metallic and ashless additive systems. A maximum of 0.10% zinc is recommended.

** Lube oil with 0.35% ash or less may be used in naturally aspirated and catalyst-equipped naturally aspirated or turbocharged engines with the understanding that valve recession may occur, thus shortening the normally expected valve and seat life.

*** Use 1.0% ash lube oil for the VHP and 275GL engines only if needed due to higher than normal valve recession rates.

COGENERATION INSTALLATIONS

- Based on actual field experience, the lube oils listed in *Table 2* are specified for cogeneration installations with forced hot water cooling systems at 212° – 265°F (100° – 129°C) or ebullient cooling at 250°F (121°C).

It is especially important that the lube oils used in cogeneration applications utilize base stocks with good thermal stability. With a minimum of 4,000+ hours of experience, the lube oils listed in *Table 2* are known to give satisfactory performance in high-temperature cooling systems applications.

NOTE: See *Table 1* for lube oil sulfated ash recommendations for gas engine models.

Additions to the list of approved lube oils may be made with substantiating data for a lube oil meeting the following criteria:

- Used in similar applications with 212° – 265°F (100° – 129°C) jacket water temperatures.
- A minimum of 6 months operation with documented engine inspection data.
- No signs of lube oil degradation, carbon or lacquering problems (based on normal lube oil change intervals, the engine should be clean).

Table 2: Recommended Lube Oils for Cogeneration / Gas Compression Applications (Using Pipeline Quality Gas)

BRAND	TYPE	SULFATED ASH (%W) ASTM D 874 (TYPICAL)
American Refining Group Brad Penn [®] Supreme DDO LA	SAE 40	0.58
Castrol Duratec G	SAE 40	0.50
Castrol Duratec LD	SAE 40	0.50
Chevron HDAX 5200 Low Ash	SAE 40	0.50
Chevron HDAX 7200 Low Ash	SAE 40	0.50
Chevron HDAX 9200 Low Ash	SAE 40	0.50
CHRONUS ECO DYN GAS ENGINE OIL	SAE 40	0.48
CITGO Pacemaker GEO 1940 XL	SAE 40	0.51
CITGO Pacemaker GEO 1640	SAE 40	0.50
CITGO Pacemaker 1640 AE	SAE 40	0.50
Conoco Elmar LA4 EXD	SAE 40	0.50
GS Caltex – GS Generator Low Ash	SAE 40	0.51
Guloco LA Supreme 40	SAE 40	0.50
Mobil Pegasus 1 (Synthetic)	SAE 15W40	0.50
Mobil Pegasus 1005	SAE 40	0.50
Mobil Pegasus 905	SAE 40	0.50
Mobil Pegasus 805	SAE 40	0.50
Mobil Pegasus 710	SAE 40	1.00
Mobil Pegasus SHC40	SAE 40	0.50
Mobil Pegasus 1105	SAE 40	0.50
Mobil Pegasus 805 Ultra	SAE 40	0.50
Peak Navitus LA	SAE 40	0.50
Peak Navitus HA	SAE 40	0.90
Pertamina NG Lube Long Life (LL)	SAE 40	0.53
PETROBRAS Lubrax Gas LDI 40	SAE 40	0.50
Petro Canada, Sentron CG40	SAE 40	0.92
Petro Canada, Sentron LD 3000	SAE 40	0.47
Petro Canada Sentron LD 5000	SAE 40	0.57
Petro Canada Sentron LD 8000	SAE 40	0.52
Petro-Canada Sentron LD Synthetic Blend	SAE 15W40	0.51
PetroChina Kunlun KCN 7905	SAE 40	0.52
PETRONAS GEO S40	SAE 40	0.50
PETRONAS GEO SNG	SAE 40	0.50
Puma LA Natural Gas S	SAE 40	0.50
Q8 Mahler MA	SAE 40	0.50
Q8 Mahler HA	SAE 40	0.90
REPSOL GENERATOR EXTRA LONG LIFE GAS 4005	SAE 40	0.50
REPSOL GENERATOR SUPER LONG LIFE GAS 4005	SAE 40	0.50
Roloil Mogas (Italy)	SAE 40	0.50
Roloil Mogas-AC (Italy)	SAE 40	0.90
Sinopec GS200-L Stationary Gas Engine Oil (Premium)	SAE 40	0.51
Shell Mysella S3 S (was Mysella MA)	SAE 40	0.90*

Table 2: Recommended Lube Oils for Cogeneration / Gas Compression Applications (Using Pipeline Quality Gas)

BRAND	TYPE	SULFATED ASH (%W) ASTM D 874 (TYPICAL)
Shell Mysella S5 N (was Mysella XL)	SAE 40	0.48*
Tongyi Hephaestus SGO LA40	SAE 40	0.50
TOTAL Nateria MP 40	SAE 40	0.48
TOTAL Nateria MWX40	SAE 40	0.50
Valvoline GEO LA40	SAE 40	0.58
Valvoline Premium Blue GEO LA ES 40	SAE 40	0.51
YPF Vectis G540	SAE 40	0.50
YPF Vectis G740	SAE 40	0.51
76 Triton 5005 EXD	SAE 40	0.50

NOTE: See Table 1 for sulfated ash recommendations for INNIO's Waukesha Engine models.

* PER ISO 3987

12V/18V220GL INSTALLATIONS

INNIO's Waukesha Engine does not ordinarily recommend lube oils by brand name for specific products. However, based on actual field experience, the lube oils listed in Table 3 are specified for all 220GL installations.

It is especially important that the lube oils used in cogeneration applications utilize virgin base stocks with good thermal stability. The lube oils listed in Table 3 are known to give satisfactory performance in high-temperature cooling system applications.


Table 3: Recommended Lube Oils for All 220GL Applications (Using Pipeline Quality Gas)


SUPPLIER	BRAND NAME	TYPE	SULFATED ASH (%W) ASTM D 874
Exxon Mobil	Mobil Pegasus 705	SAE 40	0.50
	Mobil Pegasus 805*	SAE 40	0.50
	Mobil Pegasus 805 Ultra	SAE 40	0.50
	Mobil Pegasus 905	SAE 40	0.50
	Mobil Pegasus 1005	SAE 40	0.50
	Mobil Pegasus 1105	SAE 40	0.50
	Mobil Pegasus 1 (Synthetic)	SAE 15W40	0.50
Total	Nateria MH 40	SAE 40	0.45
	Nateria P 405	SAE 40	0.42
	Nateria X 405 (Synthetic)	SAE 15W40	0.45
Shell	Mysella S3 N (was Mysella LA)	SAE 40	0.45**
	Mysella S5 N (was Mysella XL)	SAE 40	0.48**
Texaco	Geotex LA	SAE 40	0.45
Chevron	HDAX 5200 Low Ash (HDAX Low Ash)	SAE 40	0.50
Castrol	Duratec L	SAE 40	0.45
BP	Energas NGL	SAE 40	0.45
Idemitsu	Appolloil GHP 40L	SAE 40	0.45
Petro-Canada	Sentron LD 5000	SAE 40	0.57

* For use outside Americas

** PER ISO 3987

SOUR GAS, DIGESTER GAS, ALTERNATIVE FUEL GAS AND LANDFILL GAS RECOMMENDATIONS


WARNING



INNIO's Waukesha Engine assumes no liability or responsibility for potential damage to the environment or any personal injury or death caused by using landfill gases or sour gases as fuel. It is solely the engine owner's/customer's responsibility to carefully analyze any fuel gases they choose to use. Use of these gases is at the owner's/customer's own risk.

NOTE: Low BTU fuel gases 400–660 BTU/FT³ LHV must meet the requirements specified in the latest edition of *Service Bulletin 9-2702, Gaseous Fuel Specification*.

Alternative fuel sources are attracting increasing interest today as a low-cost fuel or because of their environmental benefits. However, there are issues that arise due to the sulfur compounds (H₂S, etc.), siloxanes and halide constituents in these fuels. Hydrogen sulfide (H₂S), siloxanes and total organic halide as chloride (TOH/Cl) bring with them totally different challenges for the engine and lube oil. See the latest edition of *Service Bulletin 9-2702, Gaseous Fuel Specification*, for additional information.

The use of landfill, digester or other waste gas makes the selection of an engine lube oil, lube oil analysis and lube oil drain intervals far too complicated to address completely here because the lube oil requirements change as the TOH/Cl level increases. Anyone operating with landfill, digester or other waste gas must review the latest edition of *Service Bulletin 9-2702, Gaseous Fuel Specification*, to fully understand the ramifications of operating an engine with that type of fuel gas.

RECOMMENDED LUBE OILS FOR LANDFILL GAS APPLICATIONS

INNIO's Waukesha Engine recommends lube oil specifically formulated for landfill gas applications. Always follow the lube oil manufacturer's instructions and do not use the lube oil beyond their recommendations. Some landfill gas formulated lube oils can cause excessive buildup of abnormal ash deposits in the combustion chamber when used outside of their recommendations. Landfill gas engine lube oils should only be used in engines applied to landfill gas operation and not digester gas operation.

Table 4: Recommended Lube Oils – Landfill Gas Applications

BRAND	TYPE	PERCENT OF SULFATED ASH
Mobil Pegasus 610	SAE 40	1.00*
Mobil Pegasus 605	SAE 40	0.60
Mobil Pegasus 605 Ultra 40	SAE 40	0.50
Chevron HDAX 5500 LFG (HDAX LFG)	SAE 40	0.71

* These lube oils have a higher sulfated ash level than specified in *Table 1* for the F18, H24, L36, P48, G, GSI, GSID, GL, GLD and F3514, F3524, L5794, L7044, GSI, L5774, L5794, LT engines. These lube oils may be used but be aware that engine life cycle may decrease due to an increase in engine deposits.

The best approach to improving engine life cycle is to filter out or absorb contaminants in the fuel gas before they reach the engine. There are various companies manufacturing and promoting gas filtration and absorption processes. However, INNIO's Waukesha Engine makes no endorsement of these products or services. Their performance is solely the responsibility of their respective manufacturers.

The following lube oil recommendations will minimize corrosion problems normally encountered with fuel gas containing H₂S and TOH/Cl:

Recommendation #1

Contact your lube oil supplier for an appropriate choice. Also follow the appropriate ash content percent by weight for the specific engine model.

Recommendation #2

Used lube oil analysis is mandatory for alternative fuel applications. Lube oil change periods are determined by TBN (Total Base Number), TAN (Total Acid Number), oxidation and nitration level in the used lube oil samples. The user must change the lube oil when the TBN level falls to 30% of the new lube oil value or TAN increases by 2.5 – 3.0 above the new lube oil value. The method of measuring TBN in used lube oil is shown in *Table 12*.

The DEXSIL® Corporation has developed the Q2000 field test kit. This kit is used to determine the chlorine contamination of engine lube oil exposed to chlorine containing fuels such as landfill gas. This field test kit is highly accurate and allows the operator to obtain timely test results in the field. The lube oil must be sampled every 50 hours in order to establish an initial "trend." Ordering information may be obtained from the DEXSIL Corporation, One Hamden Park Drive, Hamden, CT 06517.

NOTICE

TOH/CI does not affect TBN levels the same as sulfur compounds. Therefore, the 30% TBN depletion (50% TBN depletion on 220GL engines) as an indicator of a change interval only applies to the applications where fuel gas does not contain halides.

Recommendation #3

Increase the jacket water temperature to 210° – 235°F (99° – 113°C) and lube oil temperature to 185° – 200°F (85° – 93°C). 275GL/GL+ series engines are limited to a maximum of 180°F (82°C) lube oil temperature. 220GL series engines are limited to a maximum of 212°F (100°C) jacket water outlet temperature, and 176°F (80°C) lube oil inlet temperature. Increased temperatures will reduce condensation which will reduce the concentration of acids within the crankcase. High-temperature thermostats are available for most models.

Any question on lubricants to be used with alternative fuel gases should be directed to the Field Service Department or Sales Engineering Department prior to selecting a lube oil.

LUBE OIL SELECTION

LUBE OIL VISCOSITY SELECTION

The operating temperature of the lube oil in the sump or header is the best guide for selecting the proper SAE grade of lube oil. When the lube oil temperature is unknown, add 120°F (67°C) to the ambient temperature to obtain an estimated lube oil sump temperature.

Table 5: VGF / VHP Sump and Header Temperatures and SAE Number

SUMP TEMPERATURE	HEADER TEMPERATURE	SAE NUMBER
160° – 230°F (71° – 110°C)	160° – 195°F (71° – 91°C)	40
Below 160°F (71°C)	Below 160°F (71°C)	30

Table 6: 275GL/GL+ Sump and Header Temperatures and SAE Number

SUMP TEMPERATURE	HEADER TEMPERATURE	SAE NUMBER
160° – 230°F (71° – 110°C)	160° – 180°F (71° – 82°C)	40

Table 7: 220GL Sump and Header Temperatures and SAE Number

SUMP TEMPERATURE	HEADER TEMPERATURE	SAE NUMBER
194° – 203°F (90° – 95°C)	167° – 176°F (75° – 80°C)	40

Table 8: 16V150LTD / APG 1000 Sump and Header Temperatures and SAE Number

SUMP TEMPERATURE	HEADER TEMPERATURE	SAE NUMBER
195° – 205°F (90° – 96°C)	180° – 190°F (82° – 88°C)	40 or 30

NOTE: Do not operate engines with a lube oil header temperature below 140°F (60°C). Engines that exceed 195°F (91°C) header temperature or 215°F (102°C) sump temperature should have reduced lube oil change intervals based upon lube oil analysis (see Table 12).

MULTI-VISCOSITY LUBE OILS

Use multi-viscosity lube oils only for engines in cold starting applications. Multi-viscosity lube oil may deteriorate in continuous operation, allowing the lube oil to lose viscosity through shearing. In this state, the lube oil may not supply sufficient lubricating film and/or pressure. Therefore, utilize a lube oil analysis program to determine the lube oil change interval.

SYNTHETIC LUBE OILS

Based on developments by lube oil manufacturers and the release of their synthetic lube oils, INNIO's Waukesha Engine now recognizes these products as being suitable for all INNIO's Waukesha Engine models including stoichiometric ("rich burn") and lean burn gas engines. *Table 2* and *Table 3* include synthetic lube oils.

When synthetic lube oils are selected, INNIO's Waukesha Engine suggests contacting its Field Service or Sales Engineering Departments for lube oil change interval recommendations if lube oil analysis is not done. However, a lube oil analysis program is always recommended. Actual lube oil change intervals must be established through a lube oil analysis program and visual inspection of engine components. Typical areas to look for lube oil breakdown are exhaust valve stems, piston ring area and piston undercrown. Synthetic lube oil change intervals are 3 to 5 times longer than those of mineral oils. However, lube oil filter change intervals remain at 1,000 to 1,500 hours of operation, so that contaminant buildup does not result in excessive lube oil filter pressure drop.

Synthetic lube oils are not recommended for alternative fuel gas applications. INNIO's Waukesha Engine suggests obtaining prior approval before using a synthetic.

LOW AMBIENT TEMPERATURE OPERATION

At low ambient temperatures, use a lube oil which will provide proper lubrication when the engine is hot and working. For engines of 1,000 cu. in. (16.4 L) displacement and above, operating at ambient temperatures below 50°F (10°C), lube oil and jacket water heaters are required to warm lube oil and water for faster starting and load application. Information on these starting devices is available upon request.

220GL ENGINES

To avoid any troubles when starting under cold ambient conditions, and because of the extra pressure drop involved by the external circuit, it is mandatory that lube oil temperature in the external circuit does not fall down below 68°F (20°C).

This minimum temperature can be achieved by two different means:

- Either the external circuit (piping, control valve and cooler) is located in a warm area where temperature never falls below 68°F (20°C), such as inside a building rather than outside.
- Or the external circuit is fitted with a warming system (electrical resistance or preheaters and circulation) which regulates lube oil temperature to a minimum of 68°F (20°C).

LUBE OIL FILTRATION REQUIREMENTS

The quality of lube oil filtration will directly affect engine component life. The basic filtration requirement for INNIO's Waukesha Engine models is 90% efficient at 15 microns for all full-flow sock and paper elements, and 98% efficient at 25 microns for fiberglass disposable and cleanable full-flow metal mesh elements. **Mesh or screen sizes larger than 25 microns are not acceptable.**

Lube oil filter elements are to be changed based on the lube oil change intervals listed in *Table 9* or when the maximum pressure drop listed in the in the Operation & Maintenance manual for that engine is reached – whichever comes first. It is also recommended to change lube oil filters whenever the lube oil is changed. This will prevent the used lube oil in the filters from contaminating the fresh lube oil.


RECOMMENDED LUBE OIL CHANGE INTERVALS

INNIO's Waukesha Engine recommends establishing lube oil change intervals using a lube oil analysis program and visual inspection of power cylinder components. When lube oil analysis is not possible, the intervals listed in *Table 9* and *Table 10* serve as a guideline for engines running on pipeline quality natural gas. Lube oil change intervals may be extended beyond those listed in *Table 9* and *Table 10* if the following conditions are met:

- Lube oil analysis is performed per *Table 12*.
- INNIO's Waukesha Engine factory-supplied lube oil filtration system is used.
 - See "LUBE OIL FILTRATION REQUIREMENTS" on page 9.
- A factory-supplied centrifugal oil filter is installed and maintained for proper function.
- A visual inspection of power cylinder components after two oil change intervals of run time under the expected running conditions and the desired/extended lube oil change interval.
 - Part deposit inspection pass/fail criteria must hinge on acceptable industry standards of deposit evaluation of varnish, lacquer and carbon on valve stems, piston ring grooves and piston undercrown.
 - Inspections are to be performed on 2 cylinders.

NOTE: More frequent lube oil changes may be necessary with some types of lube oil as well as with the presence of other factors including, but not limited to, a dusty environment, a marginal installation, the internal engine condition and/or operation of an engine that has malfunctioning carburetion equipment. The lube oil drain should be as complete as possible, including draining of used lube oil from low-lying plumbing in the lubrication system. INNIO's Waukesha Engine recommends that the lube oil be monitored with a professional lube oil analysis program. However, extended lube oil change intervals may cause varnish deposits, lube oil oxidation or sludge conditions to appear in the engine which a lube oil analysis program may not detect. Contact your local INNIO's Waukesha Engine Distributor for periodic engine maintenance recommendations.

TAKING AN OIL SAMPLE

! WARNING	
	Engine lube oil is extremely hot and is under pressure. Use caution when sampling engine lube oil for analysis. Personal protection equipment (PPE) including insulated gloves and safety glasses are required when oil samples are being taken. Failure to follow proper procedures could cause severe personal injury or death.

Select INNIO's Waukesha Engine models are equipped with oil sampling valves.

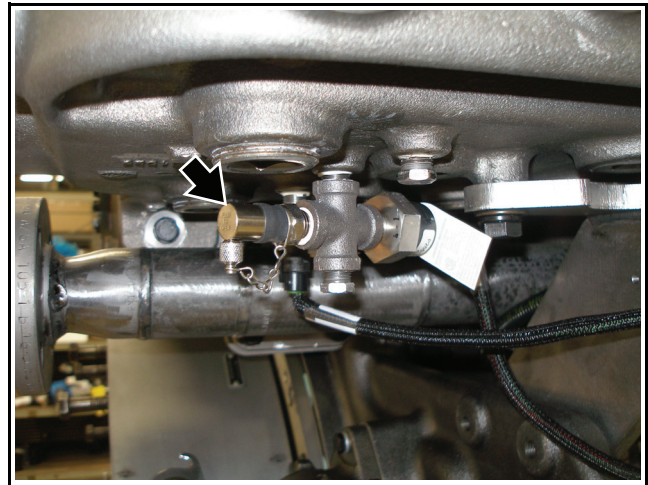


Figure 1: Oil Sample Port

On models equipped with an oil sampling valve, before taking a lube oil sample, clean the sample outlet valve. This prevents any debris in the sample outlet valve from contaminating the lube oil sample. Draw the lube oil sample at engine operating temperature.

On models not equipped with oil sampling valves, take the oil sample before the full-flow lube oil filters.

For all oil samples, record the following information on the oil sample container:

- Engine model
- Engine serial number
- Engine total hours
- Lube oil sample hours

Table 9: Lube Oil Change Intervals for Engines Receiving Normal Maintenance and Using Commercial Quality Natural Gas Fuel When Lube Oil Analysis Is Not Possible

ENGINE MODEL	ISO STANDARD OR CONTINUOUS POWER RATING	ENGINES OPERATED IN EXCESS OF ISO STD POWER OR PEAK SHAVING	EBULLIENT COOLED OR HOT WATER SYSTEM WITH ENGINE WATER TEMPERATURE OF 211°F (99°C) OR ABOVE	STANDBY DUTY
FOR ENGINES OPERATING WITH LUBE OIL HEADER TEMPERATURE OF 195°F (91°C) OR BELOW				
VGF G, GL, GLD LOW CAPACITY Natural Gas and HD-5 Propane	1,000 hours	500 hours	500 hours	500 hours or annually
VGF G, GL, GLD HIGH CAPACITY Natural Gas and HD-5 Propane	2,100 hours	1,000 hours	1,000 hours	500 hours or annually
VGF GSD, GSI LOW CAPACITY Natural Gas and HD-5 Propane	720 hours	500 hours	500 hours	500 hours or annually
VGF GSD, GSI HIGH CAPACITY Natural Gas and HD-5 Propane	1,500 hours	720 hours	720 hours	500 hours or annually
VGF SE Natural Gas and HD-5 Propane	1,500 hours		–	500 hours or annually
VHP SERIES LOW CAPACITY Natural Gas and HD-5 Propane	1,000 hours	500 hours	500 hours	500 hours or annually
VHP SERIES HIGH CAPACITY Natural Gas with Extender Package	3,000 hours ¹ 1,500 hours ²	–	–	500 hours or annually
VHP SERIES FIVE	4,000 hours	–	–	
275GL/GL+ SERIES Natural Gas	4,000 hours			
APG SERIES				
16V150LTD Natural Gas	Normal 1,500 hours	Not Allowed	Not Allowed	Not Allowed
12V/18V220GL Natural Gas	3,000 hours for early engines – 1,500 hours for filters only For WEDA 460 engines after March 2011 – filters changed at 3,000 hours	Not Allowed	Not Allowed	500 hours or annually

- 1 Oil change interval requires that oil analysis not exceed INNIO's Waukesha Engine-specified condemning limits, listed in Table 12.
 2 Oil change interval without oil analysis

Table 10: Recommended Lube Oil Change Intervals for Engines Receiving Normal Maintenance and Using Gaseous Fuel Containing H₂S of 50 µg/BTU or Less (see the latest edition of Service Bulletin 9-2702, Gaseous Fuel Specification)

ENGINE MODEL	ISO STANDARD OR PRIME POWER RATING	ENGINES OPERATED IN EXCESS OF ISO STD POWER OR PEAK SHAVING	EBULLIENT COOLED OR HOT WATER SYSTEM WITH ENGINE WATER TEMPERATURE OF 211°F (99°C) OR ABOVE	STANDBY DUTY
FOR ENGINES OPERATING WITH ELEVATED LUBE OIL SUMP TEMPERATURE				
VGf SERIES	360 hours	250 hours	360 hours	250 hours or annually
VHP SERIES	360 hours	250 hours	360 hours	250 hours or annually
NOTE: 275GL series engines are limited to a maximum of 180°F (82°C) lube oil temperature.				
275GL/GL+ SERIES Natural Gas	500 hours or sooner by lube oil analysis. Sample every 100 hours.		See Table 12 for condemning limits.	

Table 11: Duty Cycle Definitions

ISO STANDARD OR CONTINUOUS POWER RATING:	The highest load and speed which can be applied 24 hours a day, 7 days a week, 365 days per year, except for normal maintenance. It is permissible to operate the engine at up to 10 percent overload, or the maximum load indicated by the intermittent rating, whichever is lower, for two hours each 24-hour period.
GENERATOR STANDBY POWER RATING:	In a system used as backup or secondary source of electrical power, this rating is the output the engine will produce continuously (no overload), 24 hours a day, for the duration of the prime power source outage.
INTERMITTENT POWER RATING:	This rating is the highest load and speed that can be applied in variable speed mechanical system application only. Operation at this rating is limited to a maximum of 3,500 hours per year.
GENERATOR PEAK SHAVING:	Peak shaving is operation of an engine for a limited time to meet the short-term peak power requirements. Speed, loading and hours per year of operation will affect the recommended lube oil change interval.

LUBE OIL CONDEMNING LIMITS

CAUTION

Engine lube oil is extremely hot and is under pressure. Use caution when sampling engine lube oil for analysis. Failure to take adequate precautions may result in personal injury.

Lube oil condemning limits are established by the engine manufacturer's experience and/or used lube oil testing. Laboratory testing, using the parameters shown in Table 12, will help determine the used lube oil's suitability for continued use.

Table 12: Used Lube Oil Testing and Recommended Condemnation Limits

Natural gas fuel engine lube oil samples should be taken based on trend experience or @ 500 hours maximum.

ANALYSIS METRICS	STANDARD TEST METHOD USED	CONDEMNING LIMITS	
		12V/18V220GL	ALL OTHER INNIO'S WAUKESHA ENGINES
WEAR METALS:			
Iron (Fe)	ASTM D5185	30 ppm max	Wear metals by trend analysis. (Investigate source(s) of rising wear metal(s). Change lube oil based upon analysis report recommendations.)
Aluminum (Al)		10 ppm max	
Copper (Cu)		15 ppm max	
Lead (Pb)		20 ppm max	
Tin (Sn)		10 ppm max	
Chromium (Cr)		10 ppm max	
Nickel (Ni)		10 ppm max	
Silver (Ag)		Wear metals by trend analysis. Change lube oil based upon Report recommendations.	
Titanium (Ti)			
CONTAMINANTS:			
Silicon (Si)	ASTM D5185	20 ppm max	Follow analysis report recommendations
Sodium (Na)		Any detectable amount (> 5 ppm) as coolant leak indicator	Any detectable amount (> 5 ppm) as coolant leak indicator
Potassium (K)			
Chlorine (Cl)	ASTM D6443 (XRF) or ASTM D2622 (XRF)	900 ppm max	900 ppm max
Soot	FTIR	Above 2.5% by volume	Above 2.5% by volume
Water % by IR & Karl Fischer	ASTM D1744 or ASTM D6304-04A	Above 0.3% by weight (3,000 ppm)	Above 0.1% by weight (1,000 ppm)
Glycol (pos/neg)	ASTM D2982	(Na & K) Any detectable amount (> 5 ppm)	(Na & K) Any detectable amount (> 5 ppm)
MULTI-SOURCE:			
Boron (B)	ASTM D5185	Multi-source by Analysis Report Recommendations (if contaminant)	Multi-source by Analysis Report Recommendations (if contaminant)
Molybdenum (Mo)			
Antimony (Sb)			
Manganese (Mn)			
ADDITIVES:			
Magnesium (Mg)	ASTM D5185	Additive levels are information only	Additive levels are information only
Calcium (Ca)			
Barium (Ba)			
Phosphorous (P)			
Zinc (Zn)			
CHARACTERISTICS:			
Viscosity (40°C)	ASTM D445	+50% change	-20/+30% change
Viscosity (100°C)		+25% change	
TAN	ASTM D664	2.5 rise over new lube oil **	3.0 rise over new lube oil **
TBN	ASTM D2896 (new & used lube oil)	Drop to 50% of new TBN **	Drop to 30% of new TBN ** Not applicable to TOH/CI
Oxidation	ASTM E2412-04 ANNEX A2	40 Abs/cm Peak Height (Single Point Baseline) Method	40 Abs/cm Peak Height (Single Point Baseline) Method
Nitration			
Oxidation	ASTM E2412-04 ANNEX A1 *	25 Abs @ 1700 cm ⁻¹ Peak Area Method	25 Abs @ 1735 cm ⁻¹ Peak Area Method
Nitration		20 Abs @ 1625 cm ⁻¹ Peak Area Method	25 Abs @ 1625 cm ⁻¹ Peak Area Method
Flash Point	ASTM D92 (Cleveland Open Cup)	356°F (180°C)	356°F (180°C)

Continued on next page

Table 12: Used Lube Oil Testing and Recommended Condemnation Limits (Continued)

Natural gas fuel engine lube oil samples should be taken based on trend experience or @ 500 hours maximum.

ANALYSIS METRICS	STANDARD TEST METHOD USED	CONDEMNING LIMITS	
		12V/18V220GL	ALL OTHER INNIO'S WAUKESHA ENGINES
PARTICLE COUNTS:		MAXIMUM MONITORED LEVELS ***	MAXIMUM MONITORED LEVELS ***
ISO Code	ISO 4406	24/24/20	24/24/20
4 micron	ISO 11500	160,000 particles/ml	160,000 particles/ml
6 micron		80,000	80,000
10 micron		30,000	30,000
14 micron		5,000	5,000
21 micron		1,000	1,000
38 micron		100	100
70 micron		12	12
100 micron		8	8

* Specified condemning limit (abs/cm) is the allowed change compared to unused oil of the same formulation. Measure values in both used and new oil. Subtract the value of the used oil from the value of new oil. If the differential value is greater than the value shown in Table 12, the oil is condemned.

** Sweeten the sump lube oil by adding new lube oil when TBN and/or TAN level falls below condemning limits. Resample sweetened lube oil to verify proper TAN/TBN levels. If TAN/TBN condemning limits are reached and sump sweetening is not done, the lube oil must be changed to re-establish proper lube oil alkalinity protection from acid formation.

*** Do not condemn the lube oil based solely on particle count levels unless a severe rise in any micron level occurs in the 500 hour lube oil sample analysis. Inspect the engine filtration system (improperly seated elements, holes in elements, a stuck open filter bypass valve, a non-functional centrifuge, etc.) if an early hour excessive rise is seen in particle counts. Longer term, consider other lube oil condemning limits in Table 12 along with rising particle counts in the decision to change lube oil and filters.

In order to obtain a reasonable life expectancy for INNIO's Waukesha Engine models operating on gas containing some level of halogens, our experience dictates the following:

- To achieve a life expectancy equivalent to an engine operating on pipeline quality natural gas, remove all halogen compounds and abrasives from the fuel gas.
- Reasonable life can be expected if the Total Organic Halide as Chloride (TOH/Cl) concentration of the fuel does not exceed 8.5 micrograms per BTU ($\mu\text{g}/\text{BTU}$) (150 $\mu\text{g}/\text{liter}$). Total Organic Halide as Chloride equals the sum of all halogenated compounds expressed as chloride (Cl) in micrograms per BTU ($\mu\text{g}/\text{BTU}$) (or $\mu\text{g}/\text{liter}$) at Standard Temperature and Pressure (STP). See the latest edition of *Service Bulletin 9-2702, Gaseous Fuel Specification*. Reasonable life can also be expected with increased maintenance and operating adjustments to the engine, such as:

Typical changes in maintenance and operation at this chloride level are:

- Decreased lube oil change interval (150 hours to start)
- Condemn the lube oil when the 900 ppm chlorine limit in used lube oil is reached. This will aid in establishing a lube oil change interval.

- Perform a lube oil analysis at least every 50 hours to start.
- Elevate the jacket water temperature to 212° – 235°F (100° – 113°C).
- Elevate the lube oil temperature to 185° – 200°F (85° – 93°C), 180°F (82°C) maximum for 275GL models, and 176°F (80°C) for 220GL models.
- Use of high TBN oil (7.0 – 13.0)
- Bypass lube oil filtration. INNIO's Waukesha Engine has introduced the factory-supplied centrifugal oil filter cleanable lube oil filtering system. The factory-supplied centrifugal oil filter system utilizes the cleaning capabilities of a centrifuge coupled with cleanable filter elements. The factory-supplied centrifugal oil filter system utilizes INNIO's Waukesha Engine's current lube oil filtration canister for the cleanable elements. The centrifuge is installed as a bypass system working in conjunction with the cleanable filter elements.
- A fuel gas containing a TOH/Cl concentration above 8.5 $\mu\text{g}/\text{BTU}$ (150 $\mu\text{g}/\text{liter}$) requires pre-treatment of the fuel in order to make it suitable for use in an INNIO's Waukesha Engine.

LUBE OIL CONSUMPTION GUIDELINES

Typical gross lube oil consumption rates for INNIO's Waukesha Engine models are:

Table 13: Typical Gross Lube Oil Consumption Rate

MODEL	LBS/ HP-HR	GRAMS/ HP-HR	GRAMS/ KW-HR
VGf SE	0.0002	0.091	0.121
VHP Series Four GSI	0.0002	0.091	0.121
VHP Series Five	0.0005	0.227	0.302
275GL+	0.0003	0.137	0.182
All other	0.0002 – 0.002	0.091 – 0.910	0.121 – 1.22

NOTE: Lube oil consumption rates given above are a general guide and not meant to be used as condemning limits or for determining overhaul requirements. Lube oil treatment, losses and changes not included.

NOTE: Oil consumption will vary depending on site conditions, engine load, engine speed, and the age of the engine. When sizing an oil makeup tank double the values above to plan for oil consumption increase as the engine ages.

FORMULAS FOR DETERMINING LUBE OIL CONSUMPTION RATE

The following formulas may be useful for determining the engine lube oil consumption rate.

$$\frac{\text{LBS}}{\text{HP-HR}} = \frac{7.3 \times \text{Number of Gallons of Lube Oil Used}}{\text{HP} \times \text{Hours of Operation}}$$

$$\frac{\text{LBS}}{\text{HP-HR}} = \frac{1.82 \times \text{Number of Quarts of Lube Oil Used}}{\text{HP} \times \text{Hours of Operation}}$$

$$\frac{\text{Grams}}{\text{HP-HR}} = \frac{875 \times \text{Number of Liters of Lube Oil Used}}{\text{HP} \times \text{Hours of Operation}}$$

$$\frac{\text{Grams}}{\text{kW}_b\text{-HR}} = \frac{875 \times \text{Number of Liters of Lube Oil Used}}{\text{kW}_b(\text{corrected}) \times \text{Hours of Operation}}$$

ESM2 ENGINE RUNTIME HOURS FEATURE

The following features are available on ESM2 Engines and can assist in determining engine operating hours between oil changes.

During the life of an ECU or engine it may be desirable to change or reset the displayed engine hours. After events such as an engine rebuild or an ECU replacement, an update of the “Engine Runtime” parameter, which is based off of the “Engine Hours Update” user calibration, may be needed.

The “Engine Runtime” feature is handled slightly different than other user calibrations and requires a unique procedure. This is to help protect against accidental changes.

Before starting procedure, verify the “Software ID” version is S005xxxx or later. Go to the “Systems” tab, then the “Controller” table and verify the “Software ID.”

If S005xxxx or later software is present, proceed to the “Engine Runtime” user calibration hours update.

Controller	
Engine Model	L7044-S5
Application Calibration ID	A005H008
Base Calibration ID	B005-000
Software ID	S005F 137
Configuration Type	H000A
ECU Serial Number	1251
Engine Serial Number	0
Temperature	23 °C

Figure 2: Verify Software ID

44	ProgOp 1	1	
45	ProgOp 2	3	
46	ProgOp 3	6	
21	IMAT ALM/SD Offset	0	°F
22	Oil Temperature ALM/SD Offset	0	°F
23	Coolant Temperature ALM/SD Offset	0	°F
24	Oil Pressure ALM/SD Offset	0	kPa
25	Cylinder Exhaust Temperature ALM Offset	0	°F
55	Cylinder Exhaust Temperature SD Offset	0	°F
74	EXT Deviation Threshold	180	°F
48	MODBUS Baud Rate	19200	bd
49	MODBUS Slave ID	1	
71	Engine Hours Update	0	h
72	Trip Hours Reset	<input type="checkbox"/>	

Figure 3: Trip Hours Reset

ENGINE RUNTIME HOURS UPDATE

Use the following procedure to properly set the starting value of “Engine Runtime” on ESM2-equipped engines.

- 1. Shut down engine.
- 2. Login to the HMI as Customer. Go to User, Customer and Login.
- 3. Set all parameters to desired values (if changes are needed) by going to the “Parameters” tab. After setting any needed parameters go to ADV, Advanced Settings.

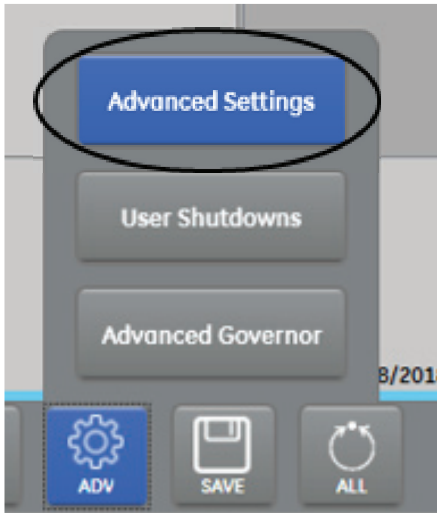


Figure 4: Advanced Settings

- 4. Set “Engine Hours Update” to 0 (zero).

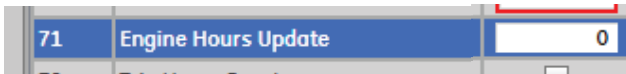


Figure 5: Set Engine Hours Update to Zero

- 5. Save parameters.



Figure 6: Save Parameters

- 6. Power cycle ECU.
- 7. Set “Engine Hours Update” to the desired value.

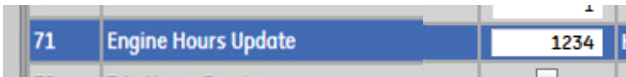


Figure 7: Set Engine Hours Update

- 8. Power cycle ECU.

The “Engine Hours Update” user calibration will read “0” after the power cycle.

“Engine Runtime” will now update to the value set in Step 7 and continue to increment while the engine is running.

Operating Hours	
ECU Engine Runtime	153 h
ECU On Time	1192 h
Engine Runtime	1234 h

Figure 8: Engine Runtime