Maintenance Procedures at 1500 Hours, or 1 Year Section 6

- Engine Hoses - check
- Engine Mounts - check
- Batteries - check
- Battery Cables and Connections - check
- Auxiliary Water Pump - check
- Spark Plug Wires - check
- Engine Assembly - clean
- Gas Filter - replace
- Coolant Filter - replace
- Overhead Set - adjust
- Engine Timing - check
- Gas Pressure to Air - Fuel Mixer - check
- Air Cleaner - replace
- Ignition Coils - check
- Ignition Couplings - check
- Throttle Linkages and Ball Joints - check
- Governor Oil - change

Maintenance Procedures at 6000 Hours, or 2 Years Section 7

- Couplings, Ignition Drive - replace
- Engine Water Pump - check
- Water Pump Idler Assembly - check
- Fan Hub - check
- Vibration Damper - check
- Turbocharger - check
- Engine Coolant - replace
- Drive Belt, Cooling Fan - check
- Drive Belt, Aftercooler - check

1. Adjust the valves at the first oil change period of 250 operating hours, and then at the interval of every 1500 hours or 1 year, whichever comes first.
2. Check the coolant additive concentration every 6 months unless the concentration is over 3.0 units. Then, check at every oil change interval until the concentration is below 3.0 units.
3. Low capacity oil pan applications **only**. See the chart at the end of this schedule.
4. High capacity oil pan applications **only**. See the chart at the end of this schedule.

Option	Sump Type/Material	Drain Location	Capacity
OP 1200	Fuel sump - Aluminum	Both sides	High 56.8 liter [15 gal] Low 26.5 liter [7 gal]
OP 1396	Rear sump - Stamped steel	Exhaust side	High 34 liter [9 gal]

Last Modified: 21-Apr-2009

Feedback / Help

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View Related Topic

Spark Plugs (Standard) (013-016)

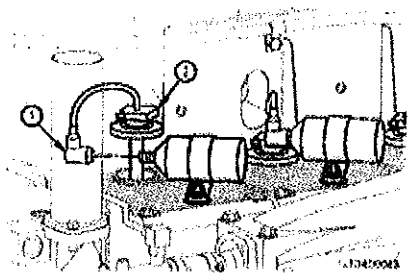
Remove

CAUTION

Do not pull on the spark plug wire during removal. Damage to the spark plug wire can result. To remove the spark plug wire, pull on the coil boot and on the spark plug adapter.

NOTE: Shown throughout this procedure is the QSK19G engine. Although different in appearance, the procedure remains the same.

Disconnect the spark plug wire (1) from the ignition coil and remove the spark plug adapter (2) by pulling on the adapter. never pull on the spark plug wire during removal.



CAUTION

Do not let the spark plug fall into its well. Damage to the insulator can result. If the spark plug falls into the well, replace it with a new spark plug.

Use a magnetic spark plug socket, extension, and a wrench to remove the

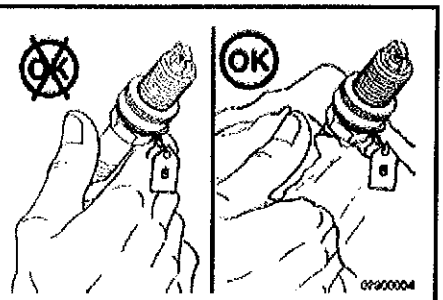
spark plug.

Clean and Inspect for Reuse

WARNING

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

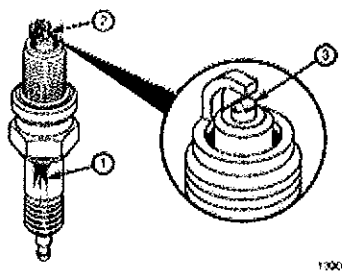
Spark plugs **must always** be kept clean. Never touch the porcelain area of the spark plug. If the porcelain becomes dirty, it **must** be cleaned before installation. Cleaning can be done with rubbing alcohol and a clean cloth.



Inspect the spark plug for the following:

1. Insulator flashover
2. Electrode deposits or fouling
3. Worn or missing electrode.

If a spark plug exhibits any of these conditions, the spark plug **must** be replaced.

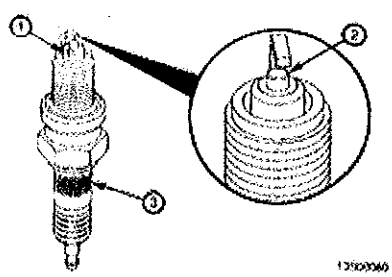


Inspect the spark plug for the following:

4. Cracked insulator

5. Electrode misalignment
6. Corona marks.

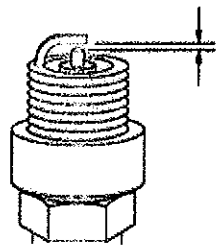
If a spark plug exhibits any of these conditions, the spark plug **must** be replaced.



Install

⚠ CAUTION ⚠

Do not force a feeler gauge into the spark plug gap. This will damage the precious metal electrodes and shorten the spark plug life.



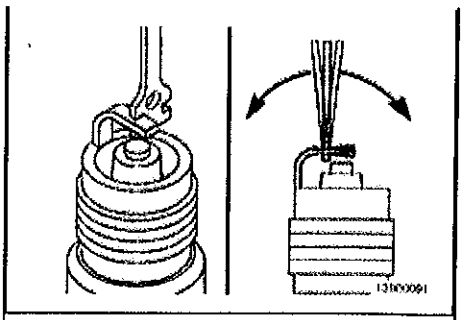
The spark plug can be serviced up to a maximum of three times.

Always replace the gasket, Part Number 3075639, whenever the spark plug is removed from the cylinder head.

Always inspect the gap of new spark plugs. The gap **must** be set to 0.508 mm [0.020 in].

Adjust the gap by bending the ground (side) electrode using the slots on the gap tool. Align the center and ground electrode. The ground electrode **must** be parallel and centered over the middle of

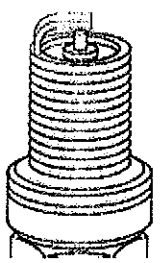
the electrode.



A magnetic spark plug socket can be used to install the spark plug.

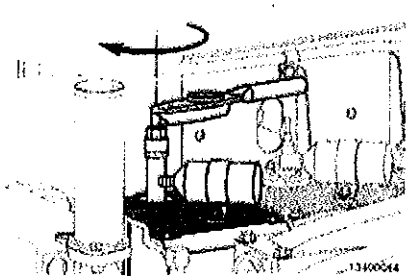
The spark plug socket used for installation **must** also be kept clean. Do **not** use a spark plug socket with a rubber insert. Rubber inserts can contaminate the spark plugs that you have just cleaned.

Spark plug threads have anti-seize plating. Anti-seize compound is generally conductive and **must not** be used on spark plugs.



Install the spark plugs.

Spark plugs **must always** be tightened to the correct torque value. On a hot engine, tighten all of the spark plugs hand tight before tightening the first spark plug with a torque wrench. This will allow all of the spark plugs to warm up to the cylinder head temperature prior to tightening.



Spark Plug Torque		
n.m		ft-lb
35	MIN	26
41	MAX	30

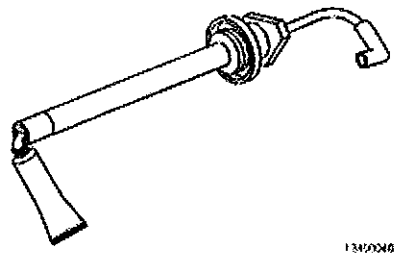
⚠ CAUTION ⚠

Never use Lubriplate™ in or on a spark plug adapter boot. Lubriplate™ is a conductor and its use can lead to spark plug flashover, resulting in engine damage.

Cummins Inc. recommends the following dielectric grease:

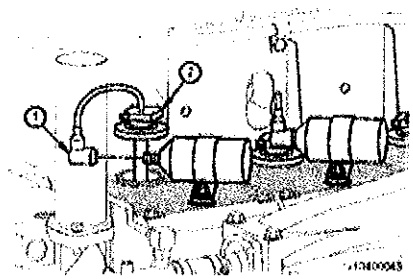
- Dupont Krytox 205, Cummins Part Number 3164956.

Always apply a pea-sized amount of dielectric lubricant to the spark plug adapter boot prior to installation. The approved dielectric grease is Cummins Part Number 3164956 or Dupont Krytox 205. This adds to the dielectric seal of the rubber boot and reduces the possibility of the boot melting onto the spark plug.



Install the spark plug adapter (2).

Install the spark plug wire (1) onto the ignition coil.



Last Modified: 02-Jun-2006

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Waukesha

SI RICE Engines fueled by Natural Gas

LUBRICATING OIL RECOMMENDATIONS FOR WAUKESHA ENGINES

Waukesha engines are heavy duty industrial type engines which require heavy duty lubricating oils. The basic requirements are high lubricating quality, high thermal stability and good control of contaminants.

Waukesha's engine product line consists of spark ignited industrial gas engines from the VSG through the 16V-AT27GL models. The lubricating oil requirements and systems change greatly between each model and fuel type.

LUBRICATING OIL PERFORMANCE

There are hundreds of commercial crankcase oils marketed today. Obviously, engine manufacturers or users cannot completely evaluate the numerous commercial oils. The current edition of the EMA Engine Fluids Data Book is available for purchase from the Engine Manufacturers' Association, Two North LaSalle Street, Chicago, IL 60602, Phone (312) 827-8700, Fax (312) 827-8737, E-Mail: ema@enginemanufacturers.org, www.enginemanufacturers.org. This document provides a tabulation of global lubricant producers and marketers together with the performance classification for which the producers have indicated their products are qualified.

The performance of a lubricant, like that of any manufactured product, is the responsibility of the refiner and supplier. The Waukesha Engine Warranty is limited to the repair or replacement of parts that fail due to defective material or workmanship during the warranty period. The Waukesha Warranty does not include responsibility for satisfactory performance of the lubricating oil.

With the exception of cogeneration, the 220GL products, and special or prototype installations, Waukesha Engine has made it a practice not to recommend oil by brand name.

Waukesha Engine strongly recommends monitoring the condition of the engine oil through the use of a good oil analysis program.

OIL DESIGNATIONS

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 oil performance designations exist, it is the responsibility of the engine operator to verify with their oil supplier, that the oil they select has proven field performance in their specific engine make and model. This oil must also meet the minimum requirements specified by Waukesha as listed in TABLE 1 on page 2.

OIL ADDITIVES

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

OIL RECOMMENDATIONS

Waukesha recommends the use of oil formulated specifically for natural gas engines and meeting minimum ash requirements based on engine model. The ash forming constituents in 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.

⚠ WARNING

Waukesha engines use specifically formulated oils. Waukesha Engine does not recommend gasoline or diesel oil formulations for use with its engines. Use of gasoline or diesel formulations may cause severe engine damage.

TABLE 1. Oil Recommendations By Engine Model

GAS ENGINE MODELS		SULFATED ASH WT% (1, 2, 3)
VSG SERIES	F11 G, GSI, GSID	0.35 – 1.0
VGF SERIES	F18, H24, L36, P48 G, GL, GLD/2	0.45 – 0.75
	F18, H24, L36, P48, GSI, GSID	0.35 – 0.50
VHP SERIES	F2895, F3521, L5790, L7042, P9390 G, GSI, GL	0.35 – 1.0
	F3524, L5794, L7044, GSI, L5774, L5794, LT	0.45 – 0.75
AT25/27GL SERIES	8L, 12V, 16V, GL	0.35 – 1.0
APG SERIES	16V150LTD	0.4 – 0.55
	12V220GL, 18V220GL	0.4 – 0.55

NOTE: *(1) 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. (2) 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. (3) Use 1.0% ash oil for the VHP and ATGL engines only if needed due to higher than normal valve recession rates.*

CATALYST CONTAMINANTS

The following contaminants are known catalyst deactivators and should be avoided when selecting lubricating 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. 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.

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.

OIL FILTRATION REQUIREMENTS

The quality of oil filtration will directly affect engine component life. Waukesha's basic filtration requirement 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 should be changed when the lube oil is changed or when the pressure drop across the lube oil filter exceeds values stated in specific engine maintenance manuals.

Waukesha's complete oil filter performance specifications are shown in Waukesha Standard Sheets S-8486 and S-8486-1.

EXTENDED OIL DRAIN INTERVALS

Extended oil drain intervals are not recommended unless a Waukesha Microspin® centrifuge that remains functional in service use as well as Waukesha supplied oil filtration components are installed. The Microspin® centrifuge, in conjunction with Waukesha supplied oil filtration components, will remove spent additives and other by-products of combustion allowing an increase in scheduled oil drain and oil filter element change intervals. See TABLE 12 on page 12 for the maximum number of hours between normal and extended oil drain and oil filter element change intervals.

Waukesha recommends that oil analysis be used to determine oil change intervals when condemning limits are reached. Please reference TABLE 5 on 7. Follow the oil change interval recommendations by engine oil hours in TABLE 12 if oil analysis cannot be used.

WAUKESHA COGENERATION INSTALLATIONS

Waukesha Engine does not ordinarily recommend lube oils by brand name. However, based on actual field experience, the oils listed in TABLE 2 on page 3 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 4000+ hours of experience, the lube oils listed in TABLE 2 are known to give satisfactory performance in high temperature cooling systems applications.

TABLE 2. Recommended Lube Oils For Cogeneration Applications (Using Pipeline Quality Gas)

BRAND	TYPE	PERCENT OF SULFATED ASH
Chevron HDAX Low Ash	SAE 40	0.50
Estor Super Exxon Co. USA, Exxon Co. International	SAE 40	0.45
Estor Elite (Synthetic) Esso Imperial Oil, Exxon Co. USA	SAE 20W40	0.45
Estor Select 40 Esso Imperial Oil, Exxon Co. USA	SAE 40	0.95
Mobil Pegasus 1 (Synthetic)	SAE 15W40	0.51
Mobil Pegasus 905	SAE 40	0.54
Mobil Pegasus 805	SAE 40	0.54
Mobil Pegasus 710 (89)	SAE 40	0.94
Petro Canada, CG40	SAE 40	0.73
Q8 Mahler HA (Europe Only)	SAE 40	0.90
Q8 Mahler MA (Europe Only)	SAE 40	0.55
Shell Mysella MA SIPC	SAE 40	0.90
Petro Canada Sentron LD5000	SAE 40	0.57
Shell Mysella XL	SAE 40	0.50
Repsol YPF Vectis LA-540	SAE 40	0.50

Additions to the list of approved oils may be made with substantiating data for an 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 oil degradation, carbon, or lacquering problems (based on normal oil change intervals the engine should be clean).

WAUKESHA APG 220GL INSTALLATIONS

Waukesha Engine does not ordinarily recommend lube oils by brand name for specific products. However, based on actual field experience, the 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	SULPHATED ASH (%w) ASTM D 874
Total	Nateria MH 40 Nateria P 405 Nateria X 405 (Synthetic)	SAE 40 SAE 40 SAE 15W40	0.45 0.42 0.45
Exxon Mobil	Mobil Pegasus 705 Mobil Pegasus 805 Mobil Pegasus 905 Mobil Pegasus 1 (Synthetic)	SAE 40 SAE 40 SAE 40 SAE 15W40	0.49 0.54 0.54 0.51
Shell	Mysella MA Mysella XL	SAE 40 SAE 40	0.45 0.45
Texaco	Geotex LA	SAE 40	0.45
Chevron	HDAX LA	SAE 40	0.50
Castrol	Duratec L	SAE 40	0.45
BP	Energas NGL	SAE 40	0.45
Idemitsu	Apolloil GHP 40L	SAE 40	0.45

Contact Dresser Waukesha Application Engineering for the potential for additions to the list of approved 220GL oils.

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

⚠ WARNING **Waukesha Engine assumes no liability or responsibility for damage to the environment or severe personal injury caused by using landfill gases or sour gases. It is the customer's sole responsibility to carefully analyze any fuel gases they choose to use. Use of these gases is at the customer's own risk**

Alternative fuel sources are attracting increasing interest today as a low cost fuel or because of environmental concerns. Waukesha, being the leader in developing engine systems to accommodate these alternative fuels, is aware of problems due to sulfur compounds (H_2S, etc.), siloxanes and halide constituents of these fuels. Hydrogen sulfide (H_2S), siloxanes and total organic halide as chloride (TOH/Cl) bring with them totally different problems to the engine and lubricating oils.

Waukesha has limited fuel trace gases to the following:

- Sulfur bearing compounds (H_2S, etc.) content in fuel gas is limited to 0.1%, (1000 ppm) by volume. However, it is not unusual to encounter biomass gas or field gas with much higher percentages of sulfur bearing compounds (H_2S, etc.). Gas exceeding 0.1% sulfur bearing compounds must be treated.
- Maximum organic halide content, expressed as chloride (TOH/Cl), in landfill gas is limited to 150 micrograms per liter (µg/l).
- Maximum liquid fuel hydrocarbons at the coldest expected engine mounted regulator fuel outlet temperature are limited to 2% total by gaseous volume.
- Maximum permissible free hydrogen content is 12% by volume.

- Maximum total siloxanes for all Waukesha engine models is 25 µg/l. If greater than 25 µg/l total siloxanes are present at the inlet to the engine mounted fuel regulator, fuel treatment is required.
- Liquid water and glycol are not permitted in the fuel gas.

When dealing with halogens or halogen compounds in landfill or other waste gas, the subject becomes far too complicated to address here as it relates to the selection of a lubricating oil, used oil analysis, and drain interval. It follows that those customers operating on landfill or other waste gas review Waukesha Engine's Fuel Specification, S7884-7 (or latest), to fully understand the ramifications of operating an engine with that type of fuel gas. This document, as well as Service Bulletin 9-2701 (or latest), prescribes specific fuel gas sampling techniques, fuel gas analysis, handling of abrasive fuel constituents, and limitations on total organic halide as chloride to achieve reasonable engine life. Lubricating oil requirements change as the TOH/Cl level increases.

RECOMMENDED LUBE OILS FOR LANDFILL GAS APPLICATIONS

Waukesha recommends lubricating oils specifically formulated for landfill gas. However, care must be taken that oils formulated for a particular fuel type are not used beyond their recommendations. Some landfill gas formulated lube oils can cause excessive build-up of abnormal ash deposits in the combustion chamber when used outside of their recommendations. Landfill gas engine oils should only be used for 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 (446)	SAE 40	0.98
Mobil Pegasus 605 (426)	SAE 40	0.48
Chevron HDAX LFG	SAE 40	0.71

The best approach is to filter or absorb corrosives in the fuel gas before they reach the engine. There are increasing claims for filtration and absorption by various companies manufacturing and promoting these types of products. Waukesha makes no endorsement of these products or service. Their performance is solely the responsibility of their manufacturers.

RECOMMENDATIONS FOR FUEL GAS FILTRATION OF SOLIDS AND LIQUIDS

Solid Particulate Removal: A coalescer shall have an absolute rating of 5 microns (0.3 microns for landfill applications) for solid particulate removal.

Liquid and Aerosol Removal From Fuel Gas: A coalescer shall remove entrained liquid and aerosol contaminants of 0.3 micron or larger.

- Fuel gas compressor lubricating oil carryover must be removed from the fuel stream. A coalescing filter with a 0.3 micron rating is adequate in most cases. Even though this oil is hydrocarbon based and combustible, it contains an additive package with calcium and other undesirable elements and compounds. Failure to remove this carryover oil can lead to fuel regulator problems, excessive spark plug and combustion chamber deposits, cylinder varnish, ring sticking, and other problems.
- Liquid water is not allowed in the fuel because it frequently results in fouling and corrosion. Particular attention must be paid to landfill and digester gases since these gases are commonly saturated with water. Due to extremely small clearances in the admission and check valves, absolutely no water can be tolerated in a prechamber fuel system. To insure that no liquid water forms in the fuel system, Waukesha specifies that the dew point of the fuel gas should be at least 20° F (11° C) below the measured temperature of the gas at the engine mounted regulators and engine remote regulator pilot valves (if so equipped). On engines without prechamber fuel systems, saturated (100% relative humidity) fuel gas at the carburetor inlet is acceptable. A 0.3 micron coalescing filter will remove any liquid water droplets being carried along with the fuel stream. The water content of the gas can then be reduced to an acceptable level by several methods:

A. Condensation of excess moisture by refrigerating the fuel gas to no higher than 40° F (4° C) followed by filtering to remove the liquids and reheating of the gas to 85 – 95° F (29 – 35° C). This process will also remove significant amounts halogenated and heavy hydrocarbons and volatile siloxanes.

B. Selective stripping with a chemical process, such as Selexol™.

C. By heating: If the gas is 30° F (17° C) or more **above** the ambient temperature, it can be cooled by passing it through a heat exchanger or refrigeration system, then reheated in manner similar to Step A. If the gas is 20° F (11° C) or more below the ambient temperature, it can be heated. In both cases the fuel system after the heating operation should be insulated. Heating of the fuel gas is limited to the maximum allowable temperature of 140° F (60° C).

- Glycol is not permitted in the fuel gas because it can affect the engine in adverse ways. The lubricating qualities of the oil may be reduced resulting in bearing failure, piston ring sticking, excessive wear, and other problems. A 0.3 micron rated coalescing filter will remove liquid glycol from the fuel stream.

Design Criteria:

A coalescing filter housing is to be of the cylindrical type and vertically mounted. The housing shall contain two sump chambers such that the lower sump collects heavier liquid dropouts immediately downstream of the gas inlet while the upper sump collects liquids draining off the coalescer cartridge(s). The coalescer design shall utilize an inside to outside gas flow path through the coalescer cartridge.

Recommended Coalescing Filter: Pall Process Filtration Company Model CC3LG7A

The following recommendations will minimize corrosion problems normally encountered with fuel gas containing H_2S and TOH/Cl:

- Recommendation # 1

Select a gas engine lubricating oil with a high alkalinity reserve, 7 to 13 TBN (Total Base Number). Alkalinity reserve in the lube oil is measured in TBN. The higher the TBN, the more reserve.

Contact your oil supplier or consult the EMA Engine Fluids Data Book for an appropriate choice. Also follow the appropriate ash content percent by weight for the specific engine model.

- Recommendation # 2

Used oil analysis is mandatory for alternative fuel applications. Lube oil change periods are determined by TBN, TAN (Total Acid Number), oxidation, and nitration level in the used oil samples. The user must change the oil when the TBN level falls to 30% of the new oil value or TAN increases by 2.5 – 3.0 above the new oil value. The method of measuring TBN in used oil is shown in TABLE 5 on page 7.

The DEXSIL® Corporation has developed the Q2000 field test kit. This kit is used to determine the chlorine contamination of engine 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 oil must be sampled every 50 hours in order to establish an initial "trend". Waukesha has experienced good results with this kit. Ordering information may be obtained from the DEXSIL® Corporation, One Hamden Park Drive, Hamden, CT 06517.

⚠ CAUTION

TOH/Cl does not affect TBN levels the same as sulfur compounds. Therefore, the 70% 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. Disregarding this information could result in product damage and/or personal injury.

- 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). ATGL 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 167° F (75° 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 Application Engineering Department prior to selecting a lubricating oil.

LUBE OIL CONDEMNING LIMITS

⚠ WARNING

Engine oil is extremely hot and is under pressure. Use caution when sampling engine oil for analysis. Failure to follow proper procedures could cause severe personal injury or death.

Lubricating oil condemning limits are established by the engine manufacturer's experience and/or used oil testing. Laboratory testing will determine the used oil's suitability for continued use. Used oil testing should include the parameters shown in TABLE 5.

The engine oil sample should be drawn before the full flow oil filters with the oil at operating temperature. Insure the sample valve outlet is clean before the sample is drawn. This insures the oil sample is not contaminated by debris of the sample valve outlet.

TABLE 5. Used Oil Testing And Condemnation Limits

(With natural gas fuel engine oil samples should be taken based on trend experience or @ 500 hours maximum)

ANALYSIS METRICS	STANDARD TEST METHOD USED	APG 220GL	CONDEMNING LIMITS Other Dresser Waukesha Engines (+non specified APG 220GL condemning limits)
WEAR METALS			
1. Iron (Fe)	ASTM D5185	30 ppm max	Wear Metals by Trend Analysis (Investigate source(s) of rising wear metal(s). Change oil based upon analysis report recommendations.)
2. Aluminum (Al)		10 ppm max	
3. Copper (Cu)		15 ppm max	
4. Lead (Pb)		20 ppm max	
5. Tin (Sn)		10 ppm max	
6. Chromium (Cr)		10 ppm max	
7. Nickel (Ni)		10 ppm max	
8. Silver (Ag)		—	
9. Titanium (Ti)		—	
CONTAMINANTS			
10. Silicon (Si)	ASTM D5185	20 ppm max	Silicon by Analysis Report; Sodium and Potassium in any detectable amount (greater than 5 ppm) as coolant leak indicators (Chlorine 900 ppm)
11. Sodium (Na)		—	
12. Potassium (K)	ASTM D6443 (XRF) or ASTM D2622 (XRF)	—	
13. Chlorine (Cl)		—	
MULTI-SOURCE			
14. Boron (B)	ASTM D5185	—	Multi-source by Analysis Report Recommendations (If contaminant)
15. Moly (Mo)			
16. Antimony (Sb)			
17. Manganese (Mn)			

ANALYSIS METRICS	STANDARD TEST METHOD USED	APG 220GL	CONDEMNING LIMITS Other Dresser Waukesha Engines (+non specified APG 220GL condemning limits)
ADDITIVES			
18. Magnesium (Mg)	ASTM D5185	—	Additive levels are information only
19. Calcium (Ca)			
20. Barium (Ba)			
21. Phosphorous (P)			
22. Zinc (Zn)			
23. Soot	FTIR	—	Above 2.5% by vol.
24. Water % by IR & Karl Fischer	ASTM D1744 or ASTM D6304-04A	Above 0.3%wt (3000 ppm)	Above 0.1% by wt. (1000 ppm)
25. Glycol (pos/neg)	ASTM D2982		(Na & K) Any detectable amount
26. Viscosity (40° C)	ASTM D445	+50% change	- 20 / +30% change
27. Viscosity (100° C)	ASTM D445	+25% change	- 20 / +30% change
28. TAN	ASTM D664	2.5 rise over new oil*1	3.0 rise over new oil*1
29. TBN	Either ASTM D2896 (new and used oil) or ASTM D4739 (new and used oil)	Drop to 50% of new oil TBN*1	Drop to 30% of new oil TBN*1 Note: (not applicable to TOHCL)
30. Oxidation	ASTM E2412 – 04 ANNEX A2		40 Abs/cm – Peak Height (Single Point Baseline) Method
31. Nitration	ASTM E2412 – 04 ANNEX A2		40 Abs/cm – Peak Height (Single Point Baseline) Method
Oxidation	ASTM E2412 – 04 ANNEX A1	25 Abs @ 1700 cm*1	25 Abs @ 1735 cm*1 – Peak Area Method
Nitration	ASTM E2412 – 04 ANNEX A1	20 Abs @ 1625 cm*1	25 Abs @ 1625 cm*1 – Peak Area Method
32. Flash Point	ASTM D92 (Cleveland Open Cup)		356° F (180° C)

ANALYSIS METRICS	STANDARD TEST METHOD USED	MAXIMUM MONITORED LEVELS*2
PARTICLE COUNTS		
33. ISO Code	ISO 4406	24/24/20
34. 4 micron	ISO 11500	160,000 particles/ml
35. 6 micron		80,000 particles/ml
36. 10 micron		30,000 particles/ml
37. 14 micron		5,000 particles/ml
38. 21 micron		1,000 particles/ml
39. 38 micron		100 particles/ml
40. 70 micron		12 particles/ml
41. 100 micron		8 particles/ml

NOTES:

*1 Sweeten the oil sump by adding new oil when TBN level falls below the TAN level so the oil can continue to neutralize acids. Resample sweetened oil to verify proper TAN/TBN levels. If TAN/TBN condemning limits are reached and sump sweetening is not done the oil must be changed to reestablish proper oil alkalinity protection from acid formation.

*[2] Do not condemn the oil based solely on particle count levels unless a severe rise in any micron level occurs in the 500 hour 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 oil condemning units with rising particle counts in the decision to change oil and filters.

⚠ CAUTION **Actual oil change intervals are determined by engine inspection and oil analysis in conjunction with the condemning limits. Disregarding this information could result in engine damage.**

In order to obtain a reasonable life expectancy for Waukesha engines operating on fuel gas laden with some level of halogens, our experience dictates the following:

- To achieve the life expectancy of 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 150 micrograms per liter (µg/l). Total Organic Halide as Chloride equals the sum of all halogenated compounds expressed as chloride (Cl) in micrograms/litre (µg/l) at Standard Temperature and Pressure (STP). Reasonable life can also be expected with increased maintenance and operating adjustments to the engine.

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

  - Decreased oil change interval (150 hours to start)
  - Condemn the oil when the 900 ppm chlorine limit in used oil is reached. This will aid in establishing an oil change interval.
  - Perform a lubricating oil analysis every 50 hours maximum
  - 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 ATGL models, and 167° F (75° C) for 220GL models.
  - Use of high TBN oil (7.0 – 13.0)
  - Bypass lubrication oil filtration. Waukesha Engine has introduced the Microspin® cleanable lube oil filtering system. The Microspin® system utilizes the cleaning capabilities of a centrifuge coupled with cleanable filter elements. The Microspin® system utilizes Waukesha'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.
- TOH/Cl above 150 micrograms chloride/litre requires pre-treatment of the fuel in order to make it suitable for use in a reciprocating engine.

The DEXSIL® Corporation, has developed the Q2000 field test kit. This kit is used to determine the chlorine contamination of engine 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 oil must be sampled every 50 hours in order to establish an initial "trend". Waukesha has experienced good results with this kit. Ordering information may be obtained from the DEXSIL® Corporation, One Hamden Park Drive, Hamden, CT 06517.

OIL VISCOSITY SELECTION

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

TABLE 6. VSG Sump Temperature And SAE Number

SUMP TEMPERATURE	SAE NUMBER
210 – 250° F (99 – 121° C)	40
160 – 210° F (71 – 99° C)	30

TABLE 7. 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 8. ATGL Sump And Header Temperature and SAE Number

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

TABLE 9. 220GL Sump And Header Temperatures And SAE Number

SUMP TEMPERATURE	HEADER TEMPERATURE	SAE NUMBER
172 – 194° F (78 – 90° C)	145 – 167° F (63 – 75° C)	40

TABLE 10. 16V150LTD/APG1000 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

NOTE: Do not operate engines with an 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 oil change intervals based upon lube oil analysis (See TABLE 5).

MULTI-VISCOSITY OILS

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

SYNTHETIC OILS

Based on developments by lube oil manufacturers and the release of their synthetic lubricating oils, Waukesha Engine now recognizes these products as being suitable for all Waukesha stoichiometric ("rich burn") and lean burn gas engines. TABLE 2 on page 3 and TABLE 3 on page 4 include synthetic oils.

When synthetic lubricating oils are selected, Waukesha Engine suggests contacting the Product Support or Application Engineering Department for oil change interval recommendations if oil analysis is not done, however oil analysis is recommended by Waukesha Engine. Typically, synthetic oil change intervals are 3 to 5 times longer than those of mineral oils. Oil filter change intervals remain at 1000 to 1500 hours of operation, however.

Synthetic oils are **not** recommended for alternative fuel gas applications without prior approval by Waukesha Engine.

Actual oil change intervals must be established through oil analysis and visual inspection of engine components.

Typical areas to look for oil breakdown are exhaust valve stems, piston ring area, and piston undercrown. Oil filter change intervals remain per the respective engine maintenance manual recommendations.

LOW AMBIENT TEMPERATURE OPERATION

At low ambient temperatures use an oil which will provide proper lubrication when the engine is hot and working. For engines of 1000 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 oil and water for fast starting and load application. Waukesha Engine will supply information on these starting devices upon request.

For 220GL Applications

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 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 engine a building rather than outside.
- Or the external circuit is fitted with a warming system (electrical resistance or preheaters and circulation) which regulate lube oil temperature to a minimum of 68° F (20° C).

LUBE OIL CONSUMPTION GUIDELINES

Typical lube oil consumption rates have been updated for all Waukesha engines.

TABLE 11. Typical Oil Consumption Rate

MODEL	LBS / HP-HR	GRAMS / HP-HR	GRAMS / kW-HR
ALL	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.

FORMULAS FOR DETERMINING OIL CONSUMPTION RATES

The following formulas may be useful in determining whether the oil consumption rate of the engine is normal:

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

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

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

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

RECOMMENDED OIL CHANGE INTERVALS

⚠ CAUTION **The use of some types of oil, as well as dusty environment, marginal installation, internal engine condition, and/or operating the engine with malfunctioning carburetion or injection equipment, may require more frequent oil changes. The lube oil drain should be as complete as possible, including, draining of used engine oil from low lying plumbing in the lube system. Waukesha Engine recommends that the lubricating oil be monitored with a professional oil analysis program. Extended oil change intervals may cause varnish deposits, oil oxidation, or sludge conditions to appear in the engine which an oil analysis cannot detect. Disregarding this information could result in engine damage. Contact your local Waukesha Distributor for periodic engine maintenance.**

NOTE: Extended oil drain intervals below can be exceeded if Microspin® oil filtration is used and remains functional, in conjunction with a good oil analysis program and minimum acceptable levels of engine part deposits.

TABLE 12. Recommended Oil Change Intervals For Engines Receiving Normal Maintenance

Table 12 is provided as a guide to engine oil change intervals when oil analysis is extremely difficult to obtain by customers/end users of Waukesha Engines.

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 OIL SUMP TEMPERATURE OF 230° F (110° C) OR BELOW.				
VSG SERIES F11 Natural Gas and HD-5 Propane	Normal 720 hours NOTE 1	300 hours	N/A	300 hours or annually
FOR ENGINES OPERATING WITH OIL HEADER TEMPERATURES OF 195° F (91° C) OR BELOW.				
VGF G, GL, GLD, GLD/2 Low Capacity Natural Gas and HD-5 Propane	Normal 1000 hours (Extended 1250 hours NOTE 2)	500 hours	500 hours	500 hours or annually
VGF G, GL, GLD, GLD/2 High Capacity Natural Gas and HD-5 Propane	Normal 2100 hours (Extended 2350 hours NOTE 2)	1000 hours	1000 hours	500 hours or annually
VGF GSID, GSI Low Capacity Natural Gas and HD-5 Propane	Normal 720 hours (Extended 900 hours NOTE 2)	500 hours	500 hours	500 hours or annually
VGF GSID, GSI High Capacity Natural Gas and HD-5 Propane	Normal 1500 hours (Extended 1750 hours NOTE 2)	720 hours	720 hours	500 hours or annually
VHP SERIES Natural Gas and HD-5 Propane	Normal 1000 hours (Extended 1500 hours NOTE 2)	500 hours	500 hours	500 hours or annually
ATGL SERIES Natural Gas	Normal 3000 hours (Extended 4000 hours NOTE 2) or sooner by analysis. Sample every 720 hours.		See LUBE OIL CONDEMNING LIMITS on page 7.	
APG SERIES Model 16V150LTD Natural Gas	Normal 1500 hours (NOTE 4)	—	—	Not Allowed
APG SERIES 220GL Models Natural Gas	1500 hours filter 3000 hours oil (NOTES 3, 4)	—	—	500 hours or annually

NOTES:

Change lube oil filter elements when lube oil is changed.

NOTE 1 Attainable with 15.5:1 air/fuel ratio (carburetor adjusted to 1.15% CO in the exhaust. If best economy carburetor setting, 17.0:1 – 17.7:1 air/fuel ratio (1.4 – 2.1% O_2 in the exhaust), is used lube oil change hours should be reduced to 300 operating hours.

NOTE 2 Extended oil drain intervals listed are acceptable if a Microspin® centrifuge that remains functional in service use in conjunction with a Waukesha supplied oil filtration system is utilized and an oil analysis program is followed (See TABLE 5), with visual inspection of power cylinder components at 4000 hrs. after start of test to determine the extended 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. Oil filter change intervals remain per the respective engines' maintenance manual recommendations. The extended oil drain interval hours shown in TABLE 12 above may be exceeded if all oil analysis metrics published in TABLE 5 remain within specification limits using engine oil analysis.

NOTE 3 Up to 6,000 hour oil change with synthetic oil on 220GL models is possible, but only based upon lube oil analysis. Filter change intervals remain at 1,500 hours.

NOTE 4 No overload allowed on APG engine models.

TABLE 13. Recommended Oil Change Intervals For Engines Receiving Normal Maintenance And Using Gaseous Fuel Containing H_2S @ 0.1% by volume (1000 ppm) or less based upon lube oil analysis (See TABLE 5). An oil change is required at the TBN/TAN crossover point.

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 OIL SUMP TEMPERATURE.				
VSG SERIES	360 hours*	250 hours	N/A	250 hours or annually
VGF SERIES	360 hours	250 hours	360 hours	250 hours or annually
VHP SERIES	360 hours	250 hours	360 hours	250 hours or annually
ATGL SERIES ** Natural Gas	500 hours or sooner by oil analysis. Sample every 100 hours.		See LUBE OIL CONDEMNING LIMITS on page 7.	

NOTES:

Change lube oil filter elements when lube oil is changed.

* Attainable with 15.5:1 air/fuel ratio (carburetor adjusted to 1.15% CO in the exhaust). If best economy carburetor setting, 17.0:1 – 17.7:1 air/fuel ratio (1.4 – 2.1% O_2 in the exhaust) is used lube oil change hours should be reduced to 300 operating hours.

** ATGL series engines are limited to a maximum of 180° F (82° C) lube oil temperature.

TABLE 14. Duty Cycle Definitions

ISO STANDARD POWER 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 ten percent overload, or the maximum load indicated by the intermittent rating, whichever is lower, for two hours in each 24 hour period.
GENERATOR STANDBY POWER RATING	In a system used as a backup or secondary source of electrical power, this rating is the output the engine will produce continuously (no overload), 24 hours per 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 3500 hours per year.
GENERATOR PEAK SHAVING	Peak shaving is operation of an engine for a limited time to meet short term peak power requirements. Speed, loading, and hours per year of operation will affect the recommended oil change interval.