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CIMAC

RECOMMENDATIONS FOR THE LUBRICATION OF GAS ENGINES

The International Council on Combustion Engines

Conseil International des Machines à Combustion

CIMAC is an international organisation, founded in 1950 by a French initiative to promote technical and scientific knowledge in the field of internal combustion engines (piston engines and gas turbines). This is achieved by the organisation of congresses and working groups.

It is supported by engine manufacturers, engine users, technical universitites, research institutes, component suppliers, fuel and lubricating oil suppliers and several other interested parties.

The National Member Associations and previous CIMAC Recommendations still available are listed in the back of this publication.

This document has been elaborated by the CIMAC Working Group „Marine Lubricants" and approved by CIMAC in August, 2000.

FOREWORD BY THE PRESIDENT

Gas engines have taken second place to the diesel for many years. Now things are changing and probably more development work has been done on gas engines in the last 20 years than in the previous 100. This development to increase rating, reduce fuel consumption and reduce emissions has paid off and now gas, where available, is the preferred fuel for most power generation applications for CHP (co-generation). How fitting then that more attention is now being paid to gas engine lubricants which play such a vital part.

The CIMAC lubricants working group started in 1987. It has been extremely active and produced many recommendations. These Recommendations For Lubrication Of Gas Engines follow the same patent of being easy to read and providing a lot of technical information and sound advice. The glossary of terms at the end will be of particular use to those not so familiar with the world of gas engines.

CIMAC working groups have a long tradition of preparing recommendations and guidelines for the internal combustion industry and its users. In performing this work we take the advantage of our unique position of having a wide and competent international membership. If you would like to join CIMAC or would like more information please browse our webside on www.cimac.com.

Once again our thanks go to all those members of the working group who have put in so much effort to produce these recommendations which I feel will be widely used. We also acknowledge the support given to our members by their respective organisations.

Stephen. G. Dexter, President
August 2000

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PREFACE

This document brings together insights into and current practices for the lubrication of gas engines, excluding rotary and automotive types. Its objective is to contribute to the efficient and reliable operation of such machinery.

1. INTRODUCTION

Combustion processes in gas engines are different from those in internal combustion engines burning liquid fuels. Therefore, their lubrication requires solutions different from those typically used in Diesel and spark ignited gasoline engines.

The CIMAC Working Group "Lubricants", therefore, - having completed guidelines for the lubrication of medium and low speed Diesel engines burning heavy fuel oil [1, 2] - has decided to produce recommendations for the lubrication of gas engines.

This document compiles insights into the lubrication of gas engines, generated by the Working Group's members who represent users, engine and equipment manufacturers, institutions as well as additive and lubricant suppliers.

2. GAS ENGINES

Gas engines are internal combustion engines fueled by a variety of combustible gases. These gases generally must not self-ignite like Diesel fuels. A gas engine, therefore, needs a device initiating ignition in a place and at a time as designed by the manufacturer.

2.1 Types and Principles

Depending on how the gas is ignited the basic differentiation is between **Spark Ignited** and **Diesel Gas** or **Dual Fuel** engines.

The **Spark Ignited (SI)** gas engine is similar to the gasoline engine, because a spark plug fitted in the combustion chamber ignites an air/gas mixture charged into it.

The **Diesel Gas** or **Dual Fuel (DF)** engines ignite the air/gas mixture present in the combustion chamber by means of a pilot injection of liquid fuel that self-ignites there, triggering the Diesel combustion process of the main air/gas charge present. A pilot injection representing 1 - 10 % of the full load energy is sufficient to ignite the main gas charge providing more than 90 % of the total energy generated.

The mechanical design of gas engines is normally derived from that of Diesel engines. Often gas engines – optimized by lean burn technology and high energy ignition systems –are built on basis of existing Diesel engine constructions. Therefore, two-stroke crosshead designs are found as well as trunk piston four-stroke models. A speciality is the design of gas engines with integrated piston compressors. These are often used in gas & oil field, pipe line, processing and refinery applications.

Economical and environmental considerations press designers and operators to run gas engines at high compression ratios and with lean gas/air mixtures. With varying gas quality the anti-knock rating (expressed in the Methane Number) may change considerably. In case the MN requirement is not met, abnormal combustion and even detonation of the gas/air charge may lead to serious engine damage. Modern designs, therefore, employ knock sensors to adjust the ignition timing or air/fuel ratio. Lean burn technology as well as higher temperatures by a process known as nitration severely stress the lubricant and its additivation. Viscosity increase, formation of insolubles and acids are the consequence.

3. APPLICATION AND FUELS FOR GAS ENGINES

Gas engines are used in a wide variety of applications which include power generation, combined heat/power generation (CHP, occasionally plus CO_2 utilization in greenhouses), gas & oil field and refinery applications, sewage plants, land fill sites, LNG/LPG boil off on gas tankers, etc. They are seen as effective power units where inflammable gas is readily available at economical conditions or, where gases, - even such with harmful and/or toxic components, - must be disposed of in a safe and environmentally acceptable way. Correspondingly wide is the variety of gaseous fuels used : LPG, natural gas, sweet and sour oil field gases, refinery gases, sewage gases, landfill gases and gases from biomass.

Table No. 1 compiles the most important gases used in gas engines together with typical data relevant for the application of gas engine lubricants.

Table No. 1 : Fuels for Gas Engines and their typical Data :

Gas type	Main Components	Heating Value, lower [MJ/Nm³]	Wobbe Index [-]	Methane Number [-]	Harmful Components	Changes in Quality
Natural Gas	Methane, Ethane	36 - 40	50	70 - 100	H2S	yes
LPG	Propane, Butane	89 - 116	75	32 - 10		no
Oil Field Gas sweet & sour	Methane, Eth.,Prop.,Butane	36 - 89	60	40 - 100	H2S	no
Refinery Gas	Prop., Butane	89 - 116	75	32 - 10	H2S	yes
Digester Gas	Methane, CO2, N2	21	25	100 -140	H2S, CHC *),	yes
Landfill Gas	Methane, CO2, N2	16 - 20	15	160	dust, H2S,CHC*), Halides	yes
Bio Gas	Methane,CO2,N2	21	20	140	H2S, CHC*)	yes

*) CHC = chlorinated hydrocarbons.
Data ex [3] [4]

4. SELECTION CRITERIA FOR GAS ENGINE LUBRICANTS

This paragraph deals with criteria of particular relevance to gas engines and their fuels. For general information the corresponding section 2.3 of the "Guidelines for the Lubrication of Medium Speed Diesel Engines [1] should be consulted.

Engine and operational features to be considered include design, air/fuel ratios, thermal stresses, running conditions, wear problems, knock sensitivity, lubricant treatment system, catalytic emission treatment, exhaust heat recovery systems, etc.

Important fuel properties to be looked at are : energy content, composition, acidic and other corrosive properties, ignition quality, contribution to NOx formation, contaminants, and significant variations in composition. Landfill gas, in particular, is subject to wide changes in composition and quality, necessitating on-site monitoring to allow adjustments to engine operation.

It is important to realize that many of the design, operational and fuel aspects can be in conflict and that the user has to compromise. A compilation of the most relevant parameters to be considered when selecting a gas engine lubricant is shown in Table No. 2.

Table No. 2 : Selection Criteria for Gas Engine Lubricants

1. Basic Type of Lubricant :				
Ash Level :	Ashless	Low	Medium	High
Sulphated Ash %wt :	0.0 - 0.099	0.1 - 0.59	0.6 – 0.99	> 1.0
2. Typical Characteristics :				
Dispersancy (ashless) :	xxx	xx	x	x
Oxidation Inhibition (ashless):	xxx	xxx	x	x
Extreme Pressure :	o	x	xx	x
NO_x Inhibition :	o	xx	xx	x
Detergency :	o	x	xx	xx
Additional Alkalinity :	o	o	x	xx(x)
Anti Wear Performance (Zinc)	o	o/x	o/x	o/x
3. Typical Application :				
LPG	r	r	nr	nr
Natural Gas	r	r	(r)	(r)*
Oil Field sweet :	r	r	nr	nr
Oil Field sour :	nr	(r)	r	r
Refinery sweet :	r	r	nr	nr
Refinery sour :	nr	(r)	r	r
Digester Gas :	nr	r	(r)	(r)
Bio Gas :	nr	r	(r)	(r)
Landfill Gas :	nr	r	(r)	(r)
S.I. Gas Engine :	r	r	(r)	(r)
D.F.Gas Engine :	nr	r	r	r
4. Preferred Type in Case of Problems :				
Spark Plug Problems :	r	r	nr	nr
Knocking :	r	(r)	nr	nr
Valve Seat Wear :	nr	(r)	r	r
Oil Thickening :	nr	r	r	(r)
Oxidation :	nr	r	r	(r)
Nitration :	(r)	r	(r)	(r)
BN Depletion :	nr	(r)	r	r
Deposits Carbon Type :	nr	(r)	r	r
Deposits Ash Type :	r	(r)	nr	nr
Deposits Lacquer Type :	nr	r	r	(r)
Catalyst Fouling by ZDTP :	r	r**	r**	r**
Symbols used :				
	x,xx,xxx -	typical	r	: recommended
	(x)	less typical	(r)	: less recommended
	o	untypical :	nr	: not recommended
* : applies to two stroke-cross head gas engines running on Natural Gas/MFO				
** : low phosphorus essential. Limits to be set by catalyst manufacturer				

4.1 Oil Maintenance

Again information provided in this paragraph is restricted to criteria particular to gas engines. For general information on oil maintenance it is recommended to refer to section 4 of the "Guidelines for the Lubrication of Medium Speed Diesel Engines"[1].

Natural Gas when filtered according to OEM instructions is a clean fuel. Normally, there is little dust, particles and unburnable components. Therefore, contamination with insolubles is less critical in gas engines than with Diesel engines burning heavy fuel oil. Although oil treatment needs comparable attention, the sensitivity of the lubrication system towards fouling by insolubles is lower. Consequently, the size of purifiers can be smaller. A viable alternative could be a centrifugal oil filter or, an effective fine filter.

4.2 Used Oil Monitoring

The basic principles of used oil monitoring again have been compiled in section 5 of above mentioned "Guidelines". Correct sampling methods and locations are defined in [1, 6]. A few important criteria, however, are necessary to assess the fitness for purpose of a gas engine lubricant in use. These are as follows :

Gas engines tend to operate at higher combustion temperatures than Diesel engines. Consequently, the lubricant is subjected to increased risks of oxidation. This leads to :-

- the formation of organic acids that contribute to the Total Acid Number (TAN),
- viscosity increase
- and to nitration (a reaction between oil components and the NOx formed in the combustion processes).

Therefore, additional procedures are included in the analytical monitoring of the oil in service.

4.2.1 Differential Infra-Red Spectroscopy

Levels of both oxidation and nitration may be detected using modern Infra-Red (FTIR - Fourier Transform Infra-Red) spectroscopy techniques. Typically, OEM guidelines refer to differential FTIR (DIR) data measured in units of absorbance / cm at wavelengths of 5.8 and 6.1 µm, for oxidation and nitration, respectively. For unequivocal identification of nitration, absorptions at 6.1, 6.4, 7.9 and 11.8 µm should be present in the FTIR spectrum. Figures may vary due to chemistry.

4.2.2 Total Acid Number, Strong Acid Number and pH Value

As both oxidation inhibition and BN are depleted, weak organic acids may build up in the oil. These are detected by the ASTM D 664 Total Acid Number (TAN) method. Changes in TAN values relative to the fresh oil value should be rated as a potential increase in oxidation. Such might subsequently lead to corrosion of copper/lead bearing overlays.

The Strong Acid Number (SAN) is included for completeness. A detectable value indicates the presence of mineral acids that cause severe corrosion. This makes the lubricant unfit for further use.

The measurement of the pH Value may be reported. It is defined as the negative log of the hydrogen ion concentration . The lower the pH value the more acidic is the sample. Only values much greater than 4.5 may be considered acceptable.

4.3 <u>Quality Limits for the Oil in Use</u>

In principle the engine builder is responsible for indicating either the recommended oil drain interval or what level of deterioration of a lubricant his engine can tolerate during operation. Compliance with these limits appears to be mandatory.

For general guidance a table of oil criteria was compiled together with limits for precautionary and mandatory action that the CIMAC Working Group "Lubricants" considers as safe for the operation of a gas engine. These are shown in **Table No.3**.

Table No. 3 : Limits for Precautionary and Mandatory Action

	Method :	Precautionary Action	Mandatory Action
Viscosity [mm^2/s]			
- at 100 °C or	ISO 3104	+ / - 15 %	+ / - 25 %
- at 40 °C	ISO 3104	+ / - 25 %	+ / - 35 %
Flash Point °C (Closed C.)	ISO 2719	<190	<180
Total Insolubles % m.	IP 316	>0.5	>1.0*
BN*** depletion in mg KOH/g	ASTM D 2896	<60 % of new oil	<50 % of new oil
TAN in mg KOH/g	ASTM D 664	>new oil + 1.5	>new oil + 4.0
pH Value	IP 177	< 4.5	< 4.0
SAN in mg KOH/g	ASTM D 664	> 0	> 0
Water in % vol	ISO 3733	> 0.2	> 0.3
Oxidation in abs/cm	FTIR (DIR)	>15	>25
Nitration in abs/cm	FTIR (DIR)	>15	>25
Wear Metals	ASTM D 5185	**	**

* : For Dual Fuel Gas Engines burning MFO limits of the CIMAC Guidelines Nr 13 apply.

** : Due to varieties in engine design and materials used no general limits can be specified. Engine manufacturer and oil supplier should advise. Look in particular for chlorine in landfill gas engine installations.

*** : Previously called " TBN ".

5. PROBLEMS AND TROUBLE SHOOTING

Problems with the lubrication of a gas engine can have oil related as well as engine related reasons. **Table No. 4** shows the most common problems in both categories, the potential causes and options for overcoming them.

Table No. 4 : Problems with Gas Engine Lubrication

Problem :	Potential Reason :	Oil Options :	Engine Options :	Remarks :
Oil Related :				
1. Rapid Oil Thickening	Oxidation, Nitration, Evaporation, Insolubles	More thermostable, ox./nitr. Inhibition, less volatile base oil	Reduce oil stress, increase oil consumption and sump capacity, reduce blow-by	Check ring tightness, see also 2.,3., 4.
2. Severe Oxidation :	Thermal / oxidative stress	More / better oxidation inhibitors	Reduce peak temperature in oil circuit, increase content of system	Preference on ashless inhibitors. More ZDTP leads to spark plug trouble, see 7.
3. BN-Depletion	Sulphur / other acidic components in gas	More BN	Reduce oil change interval, desulphurize gas	More BN results in more ash, leading to deposits on piston
4. Nitration	High temperatures, high NOx concentration in combustion gas, wrong air / gas ratio	More / better nitration inhibitors	Adjust air / gas ratio, ignition timing and spark plugs.	Check oil condition by FTIR (DIR) spectrum
5. Deposits Carbon Type :	Oil degradation, lack of air, high oil consumption	More / better additives	Adjust air / fuel ratio, improve cooling, check engine for mechanical problems.	Control air intake
6. Deposits, Lacquer / Varnish type	Oil degradation, oxidation, nitration	More / better oxidation / nitration inhibitor	Improve cooling, reduce oil change intervals	
Engine Related :				
7. Knocking	Change of gas MN, poor ignition timing, ash deposits	Use oil with less ash, reduce oil consumption	Adjust ignition timing to gas MN, install knock or a/f ratio sensors	Digester and Natural Gas can vary in composition and hence MN
8. Spark Plug Failures	Conductive layers on spark plug insulators	Use oil with less ZDTP	Change to spark plug of higher / lower heat value	Observe effect of low / no ZDTP on wear and oxidation stability of oil
9. Valve Seat Wear	Low / no ash type lubricant	Change to low / medium ash type lubricant	Use stellite coated valve seats, oil mist lubrication	Observe effect of more ash on piston / spark plug deposits.

6. GLOSSARY – specific for gas fueled engines

Absorption : Variation of peaks at specific wave lengths in FTIR (DIR), indicating deterioration, oxidation, nitration, reduction in additive concentration. See also "DIR" and "FTIR".

Air/Fuel ratio : Ratio of air mass to fuel mass present in cylinder at start of combustion.

Biogas : Gases derived from microbial or biochemical decomposition processes. Main components : methane, carbon dioxide, often H_2S.

CARB : California Air Resources Board.

CHP : Combined Heat & Power. Term for all engines generating heat and power (co-generation)

Detonation : Uncontrolled ignition/combustion with very high flame speed. Severe pressure waves with hard noise known as knocking. High risk of mechanical/thermal damage.

Differential Infrared Spectroscopy (DIR) : Method comparing fresh and used oil by showing different peaks at specific wave lengths. Method widely used to assess deterioration of gas engine oils with reference to oxidation and nitration.

Digester Gas : See "Sewage Gas".

Dry Gas : Natural gas containing no hydrocarbons heavier than butane and pentane. Can contain up to 99 % methane.

Dual Fuel : Term used for gas engines running on combustible gas ignited by controlled "pilot" injection of 1 – 10 % fuel with adequate ignition quality, i.e., gas oil or heavy fuel oil.

FTIR : Fourier Transform Infrared Spectrometry. Digital generation of spectral information.

H2S : Hydrogen Sulphide, acidic, poisonous, flammable gas found in bio and natural gases. Disagreeable odour. Robust alkalinity of gas engine lubricant required when present.

Knocking : Hard metallic noise heard when gas engine fires in uncontrolled mode due to poor knock rating of gas. See "Methane Number" and "Detonation".

Lambda Value : Ratio of combustion air actually charged to combustion air theoretically required. LV = 1 is defined as "stoichiometric condition". Lean burn engines run at LV > 1.

Landfill gas : Produced by anaerobic decomposition of household and industrial waste. Generally contains 40 – 60 % methane, 40 – 50 % CO_2, and 10 % N_2. May also contain H_2S, chlorinated hydrocarbons and silicon compounds.

Lean Burn Engine : Gas engines running on air excess, except in pre-chambers where gas is ignited. See also "Lambda Value" and "Stoichiometric Condition".

LPG : Liquefied Petroleum Gas. Consists mainly of propane or butane or mixtures thereof. Liquid at ambient temperature when kept under pressure.

Methane No. (MN) : Figure rating the anti-knock performance of a gaseous fuel. Pure methane was given the methane number 100, hydrogen has 0. Other gases may have higher or lower MNs. Gas mixtures may have wide ranges due to changes in composition.

Natural Gas : Gas from gas or oil fields. Mixture of gases, mainly methane, varying amounts of propane, butane, CO_2, N_2, occasionally H_2S. Transport normally by pipeline, occasionally liquefied by cooling to - 165 °C max (LNG = Liquefied Natural Gas).

NG 1, 2, 3 : Gas engine oil classification system proposed by SAE/ASTM. Categories are : NG1 – stoichiometric engines, NG2 – lean burn engines, NG3 – automotive gas engines.

Nitration : Process in which nitrogen oxides formed during combustion attack the lubricant, resulting in additive depletion, viscosity increase and deposit formation.

Oxidation : Process in which oxygen reacts with hydrocarbon molecules, forming insoluble carbonaceous residues and resins. This results in viscosity increase and deposit formation .

Oxidation Catalyst : Used in very lean burn engines. Operating at 250 – 500 °C able to reduce hydrocarbons and carbon monoxide. Sensitive to some additive components, in particular phosphorus. A limit of 300 ppm max in the oil, therefore, is often placed.

Pilot Fuel : Small quantity of liquid fuel injected into combustion chamber of dual fuel engine to effect ignition of a gas with poor ignition quality. Pilot fuel is normally gas oil but occasionally heavy fuel oil.

Selective Catalytic Reduction (SCR) : Exhaust gas treatment system with urea or ammonia injected into exhaust gas to reduce NO_x. Catalyst poisoned by sulphur.

Sewage gas : Particular form of biogas generated by bacterial decomposition of sludges from sewage. Generally contains 50 – 70 % methane, 20 – 30 % CO_2 and often H_2S.

Silica : Dust particles from landfill gas appearing in the lubricant. Very abrasive, resulting in excessive wear.

Sour gas : Natural gas that contains a significant amount of H_2S (up to 5 %).

Spark Ignited : Term used for gas engines in which the air/ fuel charge is ignited by spark plugs.

Stoichiometric Condition : The theoretically exact amount of air needed for complete combustion of the fuel.

Sweet gas : Natural gas containing less than 10 ppm H_2S.

Three Way Catalyst : Generally used in stoichiometric engines to convert harmful combustion components to H_2O, CO_2 and N_2.

Valve Recession : Excessive wear of valve seat and face caused by combined effects of metal abrasion, high temperature corrosion, functional sliding and adhesion.

Valve Guttering and Torching : Damage to exhaust valves due to high temperature corrosion.

Wet Gas : Natural Gas containing heavier hydrocarbons like ethane, propane, butane plus small quantities of hydrocarbons liquid at ambient temperatures.

Wobbe Index : Ratio of a gas's calorific value to the square root of it's specific gravity. Indicates thermal input provided by gas at given temperature.

ZDTP : Zinc Dithio Phosphate. Lubricant additive used to fight oil oxidation and wear.

Zeppelin : Big gas container carrying militant non-smokers.

7. REFERENCES

[1] - , Guidelines for the Lubrication of Medium Speed Diesel Engines, CIMAC Publication No. 13, London 1994

[2] - , Guidelines for the Lubrication of Two-Stroke Crosshead Diesel Engines, CIMAC Publication No. 15, Frankfurt/M, 1997

[3] Zareh, A., Gas Engines, Lubrication, Vol.81, No.4, 1995, Texaco Technical Publication, Brussels

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[5] - , U.S. Experience with Gas and Dual-Fuel Engines, Lubrication, Volume 17, No. 2, California Texas Corporation, New York 1962

[6] - , CEC L - 47- T - 97, Recommended Standard Methods Analysis of Used Oil from Large Diesel Engines, Brussels 1997

8. ACKNOWLEDGEMENT

By endorsing this document, CIMAC acknowledges the work accomplished by the CIMAC Working Group "Lubricants" through its worldwide membership. A detailed listing of participating companies, institutions and associations is given on the inside of the back cover.

Availability of CIMAC Recommendations

Copies of this and other CIMAC publications can be ordered (subject to availability) from:

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