Fluids and Lubricants Specifications

Gas engines and gas engine-generator sets
Series 4000 gas engine – marine application
Series 4000 gas engine – Generator application and engine-generator set
Series 4000 gas engine – Engine-generator set in Oil&Gas
Series 400 gas engine – Engine-generator set
Series 500 gas engine – Engine-generator set

A001072/07E

A Rolls-Royce solution

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1 Preface

1.1 General information

These Fluids and Lubricants Specifications contain general instructions for the proper and safe operation of your product from the manufacturer Rolls-Royce Solutions.

Used symbols and means of representation

The following instructions are highlighted in the text and must be observed:

Important
This field contains product information which is important or useful for the user. It refers to instructions, work and activities that have to be observed to prevent damage or destruction to the material.

Note:

A note provides special instructions that must be observed when performing a task.

Fluids and lubricants

The service life, operational reliability and function of the drive systems are largely dependent on the fluids and lubricants employed. The correct selection and treatment of these fluids and lubricants are therefore extremely important. This publication specifies which fluids and lubricants are to be used.

mtu ValueCare Portfolio

With mtu ValueCare, Rolls-Royce Solutions offers approved oils and coolant tuned to the engine.

Test standard	Designation
DIN	Federal German Standards Institute
EN	European Standards
ISO	International Standards Organization
ASTM	American Society for Testing and Materials
IP	Institute of Petroleum
DVGW	German Gas and Water Industry Association

Table 1: Test standards for fluids and lubricants

Important
Approved fluids and lubricants may not be mixed.

Important
The customer must comply with the instructions specified in the safety data sheets of the respective manufacturers.

Applicability of this publication

The Fluids and Lubricants Specifications will be amended or supplemented as necessary. Prior to use, ensure that the most recent version is available. The most recent version can be consulted under:

http://www.mtu-solutions.com

If you have any questions, your contact person will be happy to help you.

Warranty

Use of the approved fluids and lubricants, either under the brand name or in accordance with the specifications given in this publication, constitutes part of the warranty conditions.

The supplier of the fluids and lubricants is responsible for the worldwide standard quality of the named products.

Important

Fluids and lubricants for drive systems may be hazardous materials. Certain regulations must be obeyed when handling, storing and disposing of these substances.

These regulations are contained in the manufacturers' instructions, legal requirements and technical guidelines valid in the individual countries. Great differences can apply from country to country and a generally valid guide to applicable regulations for fluids and lubricants is therefore not possible within this publication.

Users of the products named in these specifications are therefore obliged to inform themselves of the locally valid regulations. Rolls-Royce Solutions accepts no liability whatsoever for improper or illegal use of the fluids and lubricants which it has approved.

When handling fluids and lubricants the "Rules for the protection of the environment" (see Operating Instructions, Safety Regulations, Disassembly and Disposal) must be observed since they are hazardous to health and flammable.

Incorrect use of fluids and lubricants causes environmental pollution:

- Fluids and lubricants must not enter the ground or the sewerage system.
- Used fluids and lubricants must be disposed of through used oil recycling or hazardous waste disposal.
- Used filter elements and cartridges must be disposed of with hazardous waste.

Important

The customer / operator bears the responsibility for observing the fuel values.

Preservation

All information on preservation, represervation and depreservation including the approved preservatives is available in the Preservation and Represervation Specifications (publication number A001070/...). The most recent version can be consulted under:

http://www.mtu-solutions.com

2 Lubricants

2.1 General Information

2.1.1 Engine oil

The selection of a suitable engine oil for gas engines depends primarily on the type of gas used to power the engine. The gas engine must only be operated with approved engine oil.

Approved engine oils are specified in the following chapters:
- For Series 4000 (→ Page 15)
- For Series 400 (→ Page 20)
- For Series 500 (→ Page 26)

An essential factor is the share of interfering contamination in the fuel gas. This requires that the operator regularly carries out gas checks. The gas engine oils to be used are characterized by the lowest possible ash content. This prevents increased ash deposits which can lead to reduced catalytic converter performance or combustion knocking.

During operation with biogas, in certain circumstances the engine oil contains corrosive contaminants which are created when the pollutants contained in the gas (chlorine, fluorine and sulfur compounds) are burned. These corrosive constituents can only be neutralized to a limited extent even by special additives engine oil.

Corrosion damage to the oil-lubricated engine components can only be avoided by more frequent oil changes. To improve buffering of concentration peaks when oil is subjected to corrosive contaminants, an increased engine oil volume is urgently recommended.

Important

Dispose of used fluids and lubricants in accordance with local regulations.

Important

Viscosity grade SAE 40 is stipulated for gas engines.
Multigrade oils are not permitted.

Important

Mixing different engine oils is strictly prohibited.

Important

Changing to another oil grade can be accomplished in the course of an oil change provided certain conditions are met. Contact the Service of Rolls-Royce Solutions.

Important

For applications with biogas, sewage gas or landfill gas, the quantity of oil in the engine oil pan is not adequate. A larger volume of oil is required.

2.1.2 Engine oil limit values for Series 4000 and Series 400

Oil change intervals for gas engines

Engine oil change intervals depend on the engine-oil quality, its conditioning, the operating conditions and the fuel used.

An oil sample must therefore be extracted on a regular basis depending on the engine oil volume, type of gas and series and the oil analysis must be compared with the limit values from (→ Table 2). The oil samples must always be taken under the same site conditions (engine at operation temperature) and at the designated point (extraction nozzle on oil filter housing).

If the limit values in accordance with (→ Table 2) are reached or exceeded, an oil change must be carried out immediately.

When using an extended volume of oil, the limit values for wear elements must be reduced inversely proportional to the volume enlargement. The maximum permissible reduction of limit values for the wear elements is 50% of the limit value (→ Table 2).

Fixed oil change intervals without oil analysis are permitted following consultation with Rolls-Royce Solutions.

Limit values for used gas engine oils SAE 40

	Test method	Limit values for Series 4000	Limit values for Series 400
Viscosity at 100 °C (mm^2/s)	ASTM D445 DIN 51562	Max. 17.5 Min. 11.5	New oil value +30 % **
Total base number TBN (mgKOH/g)	ASTM D2896 ISO 3771	Min. 2.5 and TBN > TAN	New oil value -60 % **
Total acid number, TAN (mgKOH/g)	ASTM D664	max. new oil value +2.5	On request from factory
iph value	ASTM D7946	Min. 4	Min. 4
Water (% by vol.)	ASTM D6304 EN 12937 ISO 6296	Max. 0.2	Max. 0.2
Glycol (mg/kg)	ASTM D2982	Max. 100	On request from factory
Oxidation (A/cm)	DIN 51453	Max. 20	Max. 30
Nitration (A/cm)	DIN 51453	Max. 20	Max. 30
Wear elements:	DIN 51399-1/-2		
Iron (Fe) (mg/kg)		Max. 30	Max. 50
Lead (Pb) (mg/kg)		Max. 20	Max. 30
Aluminum (Al) (mg/kg)		max. 10	Max. 20
Copper (Cu) (mg/kg)		Max. 20 ***	Max. 50
Tin (Sn) (mg/kg)		Max. 5	Max. 15
Silicon (Si) (mg/kg)		Max. 15 *	Max. 10 *

* The limit value for the wear element Si only refers to natural gas operation.
** New oil value can be requested from the factory
*** During the 1st oil change (max. 3000 op. hrs.), the limit value is 50 ppm.

Table 2: Limit values for used gas engine oils SAE 40

Used-oil analysis

The results of the oil analyses must be archived.

From the indicated test methods and limit values, (→ Table 2) you can derive when the result of a single oil sample analysis is to be viewed as abnormal. An abnormal result (e.g. increased wear of the oil) requires an immediate investigation and rectification of the detected irregular operating condition (e.g. check of the gas preparation or analysis of the gas samples).

The limit values relate to individual oil samples. If the limit values are reached or exceeded, an oil change must be carried out immediately. The results of the oil analysis do not necessarily indicate the wear taking place on specific elements and components.

Aside from the analytical limit values, the condition, operating condition and possible malfunctions of the engine and the periphery of the system are also of equal importance.

2.1.3 Engine oil limit values Series 500

Limit values for used gas engine oils

The following limit values must be observed when determining the oil change intervals for the corresponding series and modules.

Important

With an installed lube oil volume extension, the following limit values for iron, lead, aluminum, tin, chromium, copper and silicon must be halved in each case.
The reason for the limit value adaptation is the greater mixing of particles in the total oil filling volume. Without an adaptation of the limit values the measures for damage prevention can not be introduced.

Characteristics	Test method	Limit values Series 500
Viscosity at 100 °C (mm2/s)	ASTM D445 DIN 51562	Max. 17.5
Total base number TBN (mgKOH/ g	ASTM D2896 ISO 3771	Min. 2.5
Total acid number TAN (mgKOH/ g	ASTM D664	Fresh oil valve +2.5
iph value	ASTM D7946	Min. 4
Water (% by vol.)	ASTM D6304 EN 12937 ISO 6296	Max. 0.2
Glycol (vol. %)	ASTM D2982 DIN 51375	Max. 0.02
Oxidation (A/cm)	DIN 51453	Max. 20
Nitration (A/cm)	DIN 51453	Max. 20
Wear elements	DIN 51399-1/-2 DIN 51396	
Iron (Fe), ppm per 1000h		Max. 20
Lead (Pb), ppm per 1000h		Max. 35
Aluminum (Al), ppm per 1000h		Max. 15
Copper (Cu), ppm per 1000h		Max. 15
Tin (Sn), ppm per 1000h		Max. 10
Silicon (Si), ppm		Max. 15*
Chromium (Cr), ppm per 1000h		Max. 5
Sodium (Na), ppm		Max. 20
*** For sewage gas applications, the limit value is increased to 100 mg/kg**		

Table 3: Limit values for used gas engine oils

2.1.4 Silicon compounds in the fuel gas

Silicon compounds in the gas lead to deposits and promote wear. Even catalytic converters are deactivated by these compounds. Damage caused by silicon compounds is not covered by the warranty.

Silicon operational value Si_B

During operation with gases containing silicon, take particular note of the increased silicon content in the oil. For this purpose, the silicon operational value Si_B must be calculated with the help of the formula below.

$$Si_B = \text{Delta Si oil analysis B - A [ppm]} \times \frac{\text{(Oil fill quantity + top-up quantity) [liters]}}{\text{generated electrical work [kWh]}}$$

Compliance with the Si_B must be seamlessly verified by the operator's analyses.

Silicon operational value Si_{BG}

With regard to the silicon operational limit values Si_{BG}, a distinction is made between operating with a catalytic converter and operating without one.

Operation	Si_{BG}
With catalytic exhaust gas cleaning	0
Without catalytic exhaust gas cleaning	< 0.01 (Series 4000)
Without catalytic exhaust gas cleaning	< 0.02 (Series 400)

Experience has shown that for the required use of oxidation catalytic converters, the impossibility of verification must be requested ($Si_B = 0$).

Nevertheless, due to the high sensitivity of the catalytic converter, premature activity loss can occur, particularly at formaldehyde conversion.

Important

Rolls-Royce Solutions excludes damage caused by silicon to the engine and catalytic converter from the warranty.

Example for calculating the silicon operating value Si_B

Example data for calculating the silicon operating value Si_B		
Delta Si between oil analysis A and B	20	ppm (mg/kg)
Oil fill quantity in circulation	800	dm^3
Topped up oil quantity	200	dm^3
Generated electrical work between oil analysis A and B	2000000	kWh

$$SI_B = 20 \text{ [ppm]} \times \frac{(800 + 200) \text{ [dm}^3\text{]}}{2000000 \text{ [kWh]}} = 0.01$$

2.1.5 Fluorescent dyestuffs for detecting leaks in the lube oil circuit

The fluorescent dyestuffs listed below are approved for detection of leaks in the lube oil circuit.

Manufacturer	Product name	Working concentration	Material number	Container size	Storage stability[1)]
Chromatech Europe B.V.	D51000A Chromatint Fluorescent Yellow 175	0.04 % - 0.07 %	X00067084	16 kg	2 years
Cimcool, Cincinnati	Producto YFD-100	0,5 % - 1,0 %		5 gallons (canister) 55 gallons (barrel)	6 months

Table 4:

[1)] = ex works delivery, based on original and hermetically sealed containers in frost-free storage (> 5 °C).

The fluorescence (light-yellow color tone) of both dyestuffs is made visible with a UV lamp (365 nm).

2.1.6 Lubricating greases

Requirements

The conditions for the approval of lubricating greases are specified in the delivery standard MTL 5050, which can be ordered under this reference number.

Grease manufacturers are notified in writing if their product is approved.

Lubricating greases for general applications

Use lithium-saponified grease for all grease lubrication points.

Exceptions are:
- Compressor bypass, fitted between turbocharger and intercooler
- Coupling internal centering

Lubricating greases for applications at high temperatures

High-temperature grease (up to 250 °C) must be used for the compressor bypass installed between turbocharger and intercooler:
- Aero Shell Grease 15
- Optimol Inertox Medium

General purpose greases suffice for the compressor bypass located before the turbocharger or after the intercooler.

Greases for internal centerings of couplings

Greases for internal centerings:
- Esso Unirex N 3 (temperature-stable up to approx. 160 °C)

Lubricants for special applications (only Series 4000)

Oil for turbochargers

Exhaust turbochargers with integrated oil supply are generally connected to the engine lube oil system.

For ABB turbochargers which are not connected to the engine lube oil system, mineral-based turbine oils with viscosity grade ISO-VG 68 must be used.

Lubricating greases for curved tooth couplings

Depending on the application, the following lubricants have been approved for curved tooth couplings:
- Make: Klüber: Structovis BHD MF (highly-viscous lube oil)
- Make: Klüber: Klüberplex GE11–680 (adhesive gearbox/transmission lubricant)

Guidelines on use and service life are contained in the relevant Operating Instructions and Maintenance Schedules.

2.1.7 Lubricating greases for general applications

For details and special features, see chapter "Lubricating greases" (→ Page 7)

Manufacturer	Brand name	Notes
Aral AG	Mehrzweckfett Arallub HL2	
BP p.l.c.	Energrease LS2	
Castrol Ltd.	Spheerol AP2	
Chevron	Multifak EP2	
SRS Schmierstoff Vertrieb GmbH	SRS Wiolub LFK2	
Shell Deutschland GmbH	Shell Gadus S2 V220 2	
Total	Total Multis EP2	
Veedol International	Multipurpose	

Table 5:

2.2 Series 4000 gas engine

2.2.1 Approved engine oils

For details and special features, see chapter 'General' (→ Page 7).

mtu ValueCare engine oils for Series 4000 gas engines

Manufacturer	Product/Brand name	SAE viscosity class	Model type						Comments / material number
			4000L61 / L62 / L63	4000L64 / L64FNER / T24N	4000L32 / L33 / L32FNER	4000L32FB	4000L62FB*	4000Mx5xN	
Rolls-Royce Solutions GmbH	GEO BG Power B2L	40				X	X		20 l container: X00072870 205 l container: X00072871 IBC: X00072872 Tank: X00073862
	GEO NG Power X2L	40	X						20 l container: X00072874 205 l container: X00072875 IBC: X00072876 Tank: X00073865
	GEO NG Power X3L	40	X	X	X			X	20 l container: X00072877 205 l container: X00072878 IBC: X00072879 Tank: X00073866
X = Approval for model type * = With this model type, the additional information in the Technical Description under the item Lube oil system must be observed when selecting the approved engine oil.									

Table 6: Engine oils for Series 4000 gas engines

Alternative engine oils for Series 4000 gas engines

Manufacturer	Brand name	SAE viscosity class	Model type					
			4000L61 / L62 / L63	4000L64 / L64FNER / T24N	4000L32 / L33 / L32FNER	4000L32FB	4000L62FB**	4000Mx5xN
Addinol	MG 40 Extra LA	40				X	X	
	MG 40 Extra Plus	40					X	
	Eco Gas 4205 XD	40	X	X				
BayWa AG	Tectrol MethaFlexx HC Premium	40				X	X	
	Tectrol MethaFlexx NG	40	X					
Castrol Ltd.	Castrol Duratec L	40	X		X *			
Exxon Mobil Corporation	Mobil Pegasus 705	40	X		X *			
	Mobil Pegasus 805 (55 gallons: 23538056)	40	X		X *			
	Mobil Pegasus 1005 (55 gallon drum: 800019)	40	X	X				X
Fuchs Europe Schmierstoffe GmbH	Titan Ganymet Ultra	40				X	X	
	Titan Ganymet LA	40	X					
NILS S.p.A.	Burian	40					X	
Shell International Petroleum Company	Shell Mysella S3 N 40	40	X		X *			
	Shell Mysella S5 N 40	40	X	X	X			
SRS Schmierstoff Vertrieb GmbH	SRS Mihagrun LA 40	40	X		X *			
Total Deutschland	Nateria MH40	40	X		X *			
	Nateria MJ40	40					X	
	Nateria MP40	40	X	X	X	X	X	X
Petro-Canada Europe Lubricants Ltd.	Sentron CG 40 (205 l drum: 800262)	40				X	X	
	Sentron LD 5000	40	X					
	Sentron LD 8000 (205 l drum: 800315)	40	X	X	X			X

X = Approval for model type
* The use of these engine oils shortens the service life.
** = With this model type, the additional information in the Technical Description under the item Lube oil system must be observed when selecting the approved engine oil.

Table 7: Alternative engine oils for Series 4000 gas engines

TIM-ID: 0000077948 - 008

Important

With engine operation only with oil pan and automatic refilling, an oil sample must be extracted every 250 op. hrs.
With engine operation (8V and 12V) with extended circulation volume, with oil volumes > 1000 l the oil samples can be extracted every 500 op. hrs.
With engine operation (16V and 20V) with extended circulation volume, with oil volumes > 2000 l the oil samples can be extracted every 500 op. hrs.
From a run time of 3000 op. hrs. onward, or if the limit values are being approached, the sampling interval must be reduced to 250 op. hrs.
The limit values must be observed (→ Page 8).

2.2.2 Lubricating greases for generators

The generator manufacturers lubricate the bearings before shipment.

Lubricant must be added when the unit is out into operation.

Important
The specifications on the generator plate are always applicable. Observe the manufacturer's specifications on the generator nameplate.

The manufacturers provide the following information on the generator:
- Lubricating grease to be used
- Amount of grease to be added
- Lubricating interval

The applicable Maintenance Schedule must be complied with.

Further information is available in the manufacturer's documentation.

Important
The temperature of the generator bearings should be monitored during the first operating hours.

Important
Poor lubrication can lead to excessive temperatures and damage to the bearings.

Lubricating greases for generators with Series 4000 gas engines

Generator manufacturer	Lubricating grease (mtu material number)
Leroy-Somer	Shell Gadus S3 V220C2 (X00067217) *
	Mobil Polyrex™ EM: grade NLGI 2 (X00071899) *
Cummins	KLUEBER ASONIC GHY72 (09110145007)
Hitzinger	LUKOIL SIGNUM EPX2 (X00071900)
* According to the manufacturer, operation with a mixture of the two lubricating greases is not permitted. Observe the manufacturer's specifications on the generator nameplate.	

2.2.3 Gear oils

Approved lubricating oils

Only applies for 60 Hz applications.

Manufacturer/Supplier	Designation	SAE Viscosity class	Com-ment
Mobil	Mobilgear SHC XMP320 (5 gallons: 800233 / (55 gallons: 800232)	40	S
Mobil	SHC 632 (5 gallons: 800235 / (55 gallons: 800234)	40	S
Klüber	GEM4-320N	40	S
Shell	Omala S4 GX 320	40	S
Total	Carter SH320	40	S
S = synthetic lube oil			

Table 8: Approved lubricating oils

Important
Only synthetic gear oil types are permitted.

Capacity

Type of transmission	Engine	Liters
GU 320	8V4000Lx 12V4000Lx	65
GU 395	16V4000Lx 20V4000Lx 20VT24N	92

Table 9: Capacity

The test run is carried out at Rolls-Royce Solutions with Mobil SHC 632.

mtu material number:
- 09110149525 – gear oil MOBIL SHC 632 (barrel)
- 09110149555 – gear oil MOBIL SHC 632 (canister)

Oil change intervals:
- Also refer to the Maintenance Schedule from Rolls-Royce Solutions and the operating instructions of the gearbox manufacturer
- First oil change after 500 operating hours, then every 6000 operating hours
- Regular oil analysis in accordance with the Maintenance Schedule

Fill cold gear oil exactly up to the middle of the sight glass. During operation, the oil level at the sight glass initially sinks but can subsequently rise above it due to temperature expansion. Ventilation takes place via the labyrinth seal at the shafts.

2.3 Series 400 gas engine – Engine-generator set

2.3.1 Approved engine oils

mtu ValueCare engine oils for naturally-aspirated Series 400 engines

Manufacturer/Supplier	Product/Brand name	SAE viscosity class	Comment	
Rolls-Royce Solutions GmbH	GEO NG POWER X2L [2)]	40[1)]	M	E, P
	GEO NG POWER X3L [3)]	40[1)]	M	E. P

Table 10: Engine oils for naturally-aspirated Series 400 engines

1) Approval conditional on engine ambient temperature being > +10 °C.
2) 20 l container: X00072874 / 205 l container: X00072875 / IBC: X00072876 / Tank: X00073865
3) 20 l container: X00072877 / 205 l container: X00072878 / IBC: X00072879 / Tank: X00073866

M Mineral engine oil
E Natural gas
P Propane

Alternative engine oils for naturally-aspirated Series 400 engines

Manufacturer/Supplier	Brand name	SAE viscosity class	Comment	
Addinol Lube Oil GmbH	ECO GAS 4000 XD	40[1)]	M	E, P
	MG 40 Extra LA	40[1)]	M	E, P
AVIA AG	LA 40	40[1)]	M	E, P
	LA Plus 40	40[1)]	M	E, P
Castrol	Duratec XPL	40[1)]	S	E, P
Chevron Texaco	HDAX 7200	40[1)]	M	E, P
C+M GmbH	C+M Sevelub E9038-04	40[1)]	S	E, P
BayWa AG	TECTROL Methaflexx HC Premium	40[1)]	M	E, P
	TECTROL Methaflexx NG	40[1)]	M	E, P
Eni Schmiertechnik GmbH	Eni Geum 40	40[1)]	M	E, P
ExxonMobil	SHC Pegasus 40	40[1)]	S	E, P
	Pegasus 605	40[1)]	M	E, P
	Pegasus 705	40[1)]	M	E, P
	Pegasus 805	40[1)]	M	E, P
	Pegasus 1005	40[1)]	M	E, P
	Pegasus 1107	40[1)]	M	E, P
Fuchs Europe Schmierstoffe GmbH	Titan Ganymet LA	40[1)]	M	E, P
	Titan Ganymet Ultra	40[1)]	M	E, P
Kuwait Petroleum	Q8 Mahler MA	40[1)]	M	E, P
Petro-Canada Europe Lubricants Ltd.	Sentron LD 5000	40[1)]	M	E, P
	Sentron LD 8000	40[1)]	M	E, P

Manufacturer/Supplier	Brand name	SAE viscosity class	Comment	
Shell International Petroleum Company	Shell Mysella S5 N 40	40[1)]	M	E, P
	Shell Mysella S5 S 40	40[1)]	M	E, P
Total Deutschland	Total Nateria MP40	40[1)]	M	E, P

Table 11: Alternative engine oils for naturally-aspirated Series 400 engines

1) Approval conditional on engine ambient temperature being > +10 °C.
S Synthetic engine oil
M Mineral engine oil
E Natural gas
P Propane

mtu ValueCare engine oils for Series 400 turbo engines

Manufacturer/Supplier	Product/Brand name	SAE viscosity class	Comment		
Rolls-Royce Solutions GmbH	GEO BG POWER B2L [2)]	40 [1)]	M	B	K
	GEO NG POWER X2L [3)]	40 [1)]	M	E, P	K
	GEO NG POWER X3L [4)]	40 [1)]	M	E, P	K, SCR

Table 12: Engine oils for Series 400 turbo engines

1) Approval conditional on engine ambient temperature being > +10 °C.
2) 20 l container: X00072870 / 205 l container: X00072871 / IBC: X00072872 / Tank: X00073862
3) 20 l container: X00072874 / 205 l container: X00072875 / IBC: X00072876 / Tank: X00073865
4) 20 l container: X00072877 / 205 l container: X00072878 / IBC: X00072879 / Tank: X00073866
M Mineral engine oil
E Natural gas
P Propane
B Biogas
K Suitable for catalytic converters
SCR Suitable for SCR catalytic converters

Alternative engine oils for Series 400 turbo engines

Manufacturer/Supplier	Brand name	SAE viscosity class	Comment		
AVIA AG	HA 40	40 [1)]	M	B	K
	LA 40	40 [1)]	M	E, P	K
	LA Plus 40	40 [1)]	M	E, P	K
Addinol Lube Oil GmbH	ECO GAS 4000 XD	40 [1)]	M	E, P	K
	MG 40 Extra Plus	40 [1)]	M	B	K
	MG 40 Extra LA	40 [1)]	M	E, P	K
BayWA AG	TECTROL Methaflexx D	40 [1)]	M	B	K
	TECTROL Methaflexx GE-M	40 [1)]	M	B	K
	TECTROL Methaflexx HC Plus	40 [1)]	M	B	K
	TECTROL Methaflexx HC Premium	40 [1)]	M	E, P	K
	TECTROL Methaflexx HC Premium	40[1)]	M	B	SRK
	TECTROL Methaflexx NG	40 [1)]	M	E, P	K

Manufacturer/Supplier	Brand name	SAE viscosity class	Comment		
Castrol	Duratec XPL	40 [1)]	S	E, P	K
Chevron Texaco	HDAX 7200	40 [1)]	M	E, P	K
Eni Schmiertechnik GmbH	Eni Geum 40	40[1)]	M	E, P	K
ExxonMobil	SHC Pegasus 40	40 [1)]	S	E, P	K
	Pegasus 605	40 [1)]	M	E, P	K
	Pegasus 605 Ultra	40 [1)]	M	B	K, SCR
	Pegasus 610	40 [1)]	M	B	K
	Pegasus 610 Ultra	40 [1)]	M	B	K
	Pegasus 705	40 [1)]	M	E, P	K
	Pegasus 710	40 [1)]	M	B	K
	Pegasus 805	40 [1)]	M	E, P	K
	Pegasus 1107	40 [1)]	M	E, P	K
Fuchs Europe Schmierstoffe GmbH	Titan Ganymet	40 [1)]	M	B	K
	Titan Ganymet LA	40 [1)]	M	E, P	K
	Titan Ganymet Plus	40 [1)]	M	B	K
	Titan Ganymet Ultra	40 [1)]	M	E, P	K
	Titan Ganymet Ultra	40 [1)]	M	B	SRK
Hessol Lubrication GmbH	Hessol Gasmotorenöl	40 [1)]	M	B	K
Kuwait Petroleum	Q8 Mahler HA	40 [1)]	M	B	K
	Q8 Mahler MA	40 [1)]	M	E, P	K
NILS	Burian	40 [1)]	M	B	K
Petro-Canada Europe Lubricants Ltd.	Sentron CG 40	40 [1)]	M	B	K
	Sentron LD 5000	40 [1)]	M	E, P	K
	Sentron LD 8000	40 [1)]	M	E, P	K, SCR
Shell International Petroleum Company	Shell Mysella S5 N 40	40 [1)]	M	E, P	K
	Shell Mysella S5 S 40	40 [1)]	M	E, P, B	SCR
Total Deutschland	Total Nateria MJ40	40[1)]	M	B	K
	Total Nateria MP40	40 [1)]	M	E, P	K

Table 13: Alternative engine oils for Series 400 turbo engines

1) Approval conditional on engine ambient temperature being > +10 °C.
S Synthetic engine oil
M Mineral engine oil
E Natural gas
P Propane
B Biogas
K Suitable for catalytic converters
SRK Suitable for sulfur-resistant catalytic converters
SCR Suitable for selective catalytic reduction catalytic converter (SCR)

2.3.2 Engine oil change intervals

ValueCare Öl – Engine oil system with oil bleed system and additional volume

If the additional volume is increased, e.g. to 800 l for the E3066Dx, the oil change interval will also increase 4-fold in comparison to the case where the additional volume is 200 l.

Oil analyses for evaluation of the wear state of the engine should be carried out shortly before the oil change if a concrete reason exists.

With an increase in the oil volume, the change intervals of the oil filters in acc. with the service plan still apply.

Designation	Engine oil system with oil bleed system and additional capacity	
Module / engine-generator set with engine model	Oil change based on operating hours	Min. additional capacity
E3066D1-D3	2500	160 l
E3066D4	3000	160 l
E3066Lx/Zx	2000	200 l
E3042D1-D3	1250	160 l
E3042D4	1500	160 l
E3042Lx/Zx	1000	160 l
E3042Lx/Zx	5000 (or oil analysis)	800 l
B3066Lx/Zx	1000	160 l
B3042Lx/Zx	1000	240 l

Table 14: ValueCare Öl – Engine oil system with oil bleed system and additional volume

Mineral oil, engine oil system with oil bleed system and additional capacity

If the additional volume is increased, e.g. to 800 l for the E3066Dx, the oil change interval will also increase 4-fold in comparison to the case where the additional volume is 200 l.

Oil analyses for evaluation of the wear state of the engine should be carried out shortly before the oil change if a concrete reason exists.

With an increase in the oil volume, the change intervals of the oil filters in acc. with the service plan still apply.

Designation	Engine oil system with oil bleed system and additional capacity	
Module / engine-generator set with engine model	Oil change based on operating hours	Min. additional capacity
E3066D1-D3	2500	200 l
E3066D4	3000	200 l
E3066Lx/Zx	1000	120 l
E3042D1-D3	1250	200 l
E3042D4	1500	200 l
E3042Lx/Zx	1000	200 l
E3042Lx/Zx	5000 (or oil analysis)	1000 l
B3066Lx/Zx	1000	200 l
B3042Lx/Zx	1000	300 l

Table 15: Mineral oil, engine oil system with oil bleed system and additional capacity

Mineral oil, engine oil system with fresh-oil replenishment function only (no oil bleed system)

Designation	Engine oil system with fresh-oil replenishment function only (no oil bleed system)	
Module / engine-generator set with engine model	Oil change based on operating hours	Recommended capacity of fresh-oil tank
E3066D1-D3	600	60 l
E3066Lx/Zx	300	60 l
E3042D1-D3	600	60 l
E3042Lx/Zx	300	60 l

Table 16: Mineral oil, engine oil system with fresh-oil replenishment function only (no oil bleed system)

Synthetic oil, engine oil system with oil bleed system and additional capacity

If the additional volume is increased, e.g. to 800 l for the E3066Dx, the oil change interval will also increase 4-fold in comparison to the case where the additional volume is 200 l.

Oil analyses for evaluation of the wear state of the engine should be carried out shortly before the oil change if a concrete reason exists.

With an increase in the oil volume, the change intervals of the oil filters in acc. with the service plan still apply.

Designation	Engine oil system with oil bleed system and additional capacity	
Module / engine-generator set with engine model	Oil change based on operating hours	Min. additional capacity
E3066Lx/Zx	2000	200 l
E3042Lx/Zx	1000	160 l
E3042Lx/Zx	8000 (or oil analysis)	1000 l

Table 17: Synthetic oil, engine oil system with oil bleed system and additional capacity

Synthetic oil, engine oil system with fresh-oil replenishment function only (no oil bleed system)

Designation	Engine oil system with fresh-oil replenishment function only (no oil bleed system)	
Module / engine-generator set with engine model	Oil change based on operating hours	Recommended capacity of fresh-oil tank
E3066D1-D3	1250	50 l
E3066D4	1500	50 l
E3066Lx/Zx	600	50 l
E3042D1-D3	1250	100 l
E3042D4	1500	100 l
E3042Lx/Zx	600	100 l

Table 18: Synthetic oil, engine oil system with fresh-oil replenishment function only (no oil bleed system)

2.3.3 Lubricating greases for generators

Lubricating greases for generators in Series 400

Generator manufacturer	Lubricating grease
Leroy-Somer	Lubricated for life

Important information
Observe the manufacturer's specifications on the generator nameplate.

2.4 Series 500 Gas Engine - Engine-Generator Set

2.4.1 Approved engine oils

Special gas engine oils must be used for the gas engines and be evaluated according to described criteria.

Approved products for all series including the corresponding sample sets can be obtained directly from Rolls-Royce Solutions.

Important
The use of oil additives is prohibited.

If pollutant values that negatively influence the oil level are exceeded (in particular, hydrogen sulfide (H_2S)), the oil change intervals must be shortened following consultation with Rolls-Royce Solutions.

Manufacturer/Supplier	Brand name
Shell	Mysella S5 S40
Mobil	Pegasus 1005
Addinol	Eco Gas 4000 XD

Table 19: Approved oils for natural gas (biogas, sewage gas)

The oil volume is composed as follows:

Engine	Engine oil pan	Auxiliary tank in the base frame (option)	Total
12V500	90 l	190 l	280 l
8V500	60 l	140 l	200 l
6R500	40 l	100 l	140 l

Table 20: Composition of the oil volume

2.4.2 Engine oil change intervals

The engine oil service lives must be determined based on regular oil analyses depending on the operating conditions.

The oil change must always be carried out depending on the engine oil condition.

Oil sample intervals

During the first oil interval, sample intervals of 250 op. hrs. starting after 250 op. hrs. must be observed. After the third sample extraction, i.e. after 750 op. hrs., an oil change must be carried out in all circumstances.

Based on the last sample, a service life forecast can be made for the next oil interval. With the first three oil fillings of an engine, Rolls-Royce Solutions recommends to always start sampling at the latest at 500 op. hrs. with sampling in a 250 op. hrs. cycle because considerable changes in the oil load are still possible in the running-in phase of an engine.

Important

Rolls-Royce Solutions recommends continuous monitoring of the gas quality. The sampling intervals can only be guaranteed if the required gas quality is observed and fluctuations are low. Insufficient monitoring of the gas quality makes shorter oil sampling intervals necessary.
The oil change must be carried out based on the condition. The operating company must ensure that the trend resulting from the analyses does not result in the named limit values being exceeded (→ Page 10). With the use of biogas in particular, it is recommended to observe a buffer between the maximum oil limit values. Rolls-Royce Solutions recommends an oil change when 80% of the wear values have been reached. After major repair measures (e.g. after an inspection) or after changing the oil grade, the procedure for determining the oil change intervals in accordance with the above instructions must be carried out again.

For each engine of a plant, after testing the plant-specific oil service life every additional oil filling must also be analyzed again. For the further analytical operational monitoring or low-risk maximization of the oil usage time,
- at approx. 60%,
- at approx. 80% and
- at approx. 100%

of the tested or statistically evaluated oil service life, used oil analyses are prescribed.

Independently of the oil change interval, you must always ensure that the oil analysis interval does not exceed 500 op. hrs. With a biogas application with seriously fluctuating fuel gas quality, a considerably reduced maximum oil analysis interval of 100 operating hours can be expected.

Before carrying out an oil change, a sample must be taken and sent for analysis.

Biogas operation

In biogas operation, it can be anticipated that a reduction in the oil service life is necessary depending on the given fuel gas quality.

A reduction in the oil change intervals is necessary if a constant gas quality can not be guaranteed or if the gas quality is subject to major fluctuations (e.g. with the use of syngases).

Oil filter

The oil filter(s) must be replaced during every oil change.

In the case of long oil service lives (> 1000 h) or with a low annual utilization of the engine, the oil filter must be replaced at least once a year independently of the oil change or be replaced during all scheduled maintenance.

2.4.3 Oil volume

Oil volume extension and line systems

If the resultant oil service life is not fully satisfactory, by increasing the engine oil capacity with the option "Oil volume extension" the oil service life can be extended.

Procedure to change to a different oil grade

To keep the described influences to a minimum, Rolls-Royce Solutions recommends the following oil change-over procedure:

1. Drain the oil of the original brand as completely as possible.
2. Fill the new oil grade up to the minimum marking of the engine.
3. Run the engine for 2 hours at full load.
4. Carry out an oil and filter change.

The achievable oil service life must be checked again using the described procedure, see (→ Page 27).

Important
The oil supply tank and all lines must be flushed accordingly with the new oil in order to keep the influences here also to a minimum.

2.4.4 Lubricating greases for generators

Lubricating greases for generators in Series 500

Generator	Lubricating grease
LSAH 44.3 LSA 49.1 / 49.3 optional LSA 46.3 / 46.1 / 47.2	Esso Unirex N3

Important
Observe the manufacturer's specifications on the generator nameplate.

3 Coolants

3.1 General Information

3.1.1 Coolant definition

Important

Ensure that used fluids and lubricants are collected in sufficiently large collecting containers. Observe safety data sheets and dispose of used fluids and lubricants in accordance with country-specific regulations.

Coolant =	coolant additive (concentrate) + fresh water to predefined mixing ratio • Ready for use in engine
Antifreeze =	Corrosion inhibitor + glycol + additives + water • The predecessor version of the Fluids and Lubricants Specifications used the term 'corrosion inhibiting antifreeze'. For clarity purposes, this publication uses the term 'antifreeze'.

Antifreeze is necessary for engine operation in areas where below-freezing temperatures may occur.

The relevant concentration range for use is listed in the section on operational monitoring.

Coolant without antifreeze =	Corrosion inhibitor + additives + water • The predecessor version of the Fluids and Lubricants Specifications used the term 'water-soluble corrosion inhibitors'. This designation will be replaced with immediate effect with 'coolant without antifreeze'.

The coolants approved by Rolls-Royce Solutions ensure adequate corrosion protection provided the correct concentrations are used. The relevant concentration range for use is listed in the section on operational monitoring.

Approved coolant additives are specified in the following chapters:
- For Series 4000 gas engine – Marine application (→ Page 44)
- For Series 4000 gas engine - Generator application, engine-generator set and engine-generator set in Oil&Gas (→ Page 55)
- For Series 4000 gas engine – Engine-generator set (→ Page 64)
- For Series 500 gas engine – Engine-generator set (→ Page 67)

.

Special arrangements presently in effect remain valid.

Important

Coolant additives containing nitrite must not be used in conjunction with coolers that contain brass.

Important

Flushing with water is required at every change to a different coolant product. For flushing and cleaning specifications for engine coolant circuits, see (→ Page 68)

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Note

- The product BASF Glysantin® G30®pink is available for use at extremely low temperatures (-60 °C/arctic regions).

The corrosion-inhibiting effect of coolants is only ensured with the coolant circuit fully filled.

Only corrosion inhibitors approved for internal preservation of the coolant circuit also provide proper corrosion protection when the medium is drained. This means that after draining the coolant the cooling circuit must be preserved if no more coolant is to be filled. The procedure is described in the Preservation and Represervation Specifications A001070/...

Coolants must be prepared from suitable fresh water and a coolant additive approved by Rolls-Royce Solutions. Conditioning of the coolant must take place outside the engine.

Important

Mixtures of different coolant additives and supplementary additives (also in coolant filters and filters downstream of plant components) are not permitted.

Important

For ready mixtures, the percentage of coolant additive (concentrate) is always named first.
Example: Coolant AH 40/60 Antifreeze Premix = 40% by volume Coolant additive / 60% by volume Freshwater

3.1.2 Operational monitoring / coolant conditioning for Series 4000 and Series 400 engines

Inspection of the freshwater and continuous monitoring of the coolant are essential for trouble-free engine operation. Fresh water and coolant should be checked at least once per year and with each fill-up. Inspections can be carried out using the mtu test kit, or by an authorized laboratory. The mtu test kit contains the necessary equipment, chemicals and instructions for use.

Analysis	Method for on-site checks (mtu test kit)	Method for lab analysis
Determination of the water hardness	Titration	Determination of the Ca and Mg content by means of ICP and calculation of the hardness in °dH or mmol/l
Determination of the pH value	Litmus paper strips for an appropriate measuring range	ASTM D 1287
Determination of the chloride content	Titration	IC
Determination of the sulfate content	-	IC
Determination of the silicon content	-	ICP
Determination of additive concentration in aqueous coolant solutions	Brix refractometer, compare degree(s) Brix against table (→ Table 23) and read off concentration in % by volume.	Refractometer method DIN 51423, compare Brix degree against table (→ Table 23) and read off % by volume.
Determination of antifreeze concentration	Glycol refractometer, concentration in % by volume can be read off directly	Refractometer method DIN 51423, calculation through refraction index or product-specific factor
Determination of germ total for aqueous media	-	Dip slides (tube with culture medium, e.g. by VWR Prolabo No. 535112D or equivalent) incubation time: 4 days at 30 °C

Table 21: Minimum requirements and methodology for coolant monitoring

Orders for freshwater and coolant analysis may be placed with Rolls-Royce Solutions. In particular cases, operational monitoring can cover more checks that those listed in table (→ Table 21). Please contact your partner if necessary.

Permissible concentrations of antifreezes

	Minimum			Maximum
Antifreeze on ethylene glycol basis	35% by volume	40% by volume	45% by volume	50% by volume
With antifreeze protection up to*	-20 °C	-25 °C	-31 °C	-37 °C
BASF Glysantin® G30® pink	65% by volume for application at outside temperatures of up to -60 °C in arctic regions			
* = Antifreeze specifications determined as per ASTM D 1177.				

Table 22: Permissible concentrations of antifreezes

Important
After flushing the engine coolant circuit, the concentration of antifreeze must not exceed 35% by volume.

Add antifreeze to the fresh water with a concentration of at least 35% by volume when antifreeze protection to minus - 20 °C is sufficient. If lower ambient temperatures are expected, the concentration must be increased accordingly. A concentration of above 50% by volume is impermissible.

Mixtures containing a proportion of antifreeze below 35% by volume do not guarantee adequate corrosion protection.

If the coolant concentration is undershot, corrosion can occur on the metallic components in the cooling circuit. In spite of a subsequence increase in coolant concentration to the prescribed value, this corrosion can continue to gradually increase on the relevant component. Undershooting of the coolant concentration must be avoided.

Use the treated water in both summer and winter operation. Compensate for coolant losses in such a way as to maintain the antifreeze concentration.

Permissible concentrations, coolant without antifreeze for all applications

Permissible concentration range	Manufacturer	Product/Brand name	Reading on hand refractometer[1] at 20 °C (= degrees Brix) vol%					
			7	8	9	10	11	12
9 to 11% by volume	Rolls-Royce Solutions GmbH	Coolant CS 100 Corrosion Inhibitor Concentrate	3.5	4.0	**4.5**	**5.0**	**5.5**	6.0
		Coolant CS 10/90 Corrosion Inhibitor Premix	3.5	4.0	**4.5**	**5.0**	**5.5**	6.0
	Rolls-Royce Solutions America Inc.	Power Cool ® Plus 6000	3.5	4.0	**4.5**	**5.0**	**5.5**	6.0
	BASF SE	Glysacorr G93 green	3.5	4.0	**4.5**	**5.0**	**5.5**	6.0
	CCI Corporation	A 216	4.9	5.6	**6.3**	**7.0**	**7.7**	8.4
	CCI Manufacturing IL Corporation	A 216	4.9	5.6	**6.3**	**7.0**	**7.7**	8.4
	Detroit Diesel Corporation	Power Cool Plus 6000	4.9	5.6	**6.3**	**7.0**	**7.7**	8.4
	Drew Marine	Drewgard XTA	3.5	4.0	**4.5**	**5.0**	**5.5**	6.0
	ExxonMobil	Mobil Delvac Extended Life Corrosion Inhibitor	4.9	5.6	**6.3**	**7.0**	**7.7**	8.4
	Ginouves	York 719	3.5	4.0	**4.5**	**5.0**	**5.5**	6.0
	Old World Industries Inc.	Final Charge Extended Life Corrosion Inhibitor (A 216)	4.9	5.6	**6.3**	**7.0**	**7.7**	8.4
	Valvoline	OEM Advanced 93	3.5	4.0	**4.5**	**5.0**	**5.5**	6.0
		Zerex G-93	3.5	4.0	**4.5**	**5.0**	**5.5**	6.0
[1] = Concentration determined by means of suitable hand refractometer								

Table 23: Permissible concentrations, coolant without antifreeze for all applications

Calibrate the hand refractometer with clean water at coolant temperature. The coolant temperature should be 20 °C. Observe the specifications of the manufacturer.

Important
After flushing the engine coolant circuit, the specified minimum concentration of the corrosion inhibitor must not be undershot.

Permissible concentrations, additional coolant without antifreeze exclusively for marine (free of light metals)

Permissible concentration range	Manufacturer	Brand name	Reading on hand refractometer[1] at 20 °C (= degrees Brix) vol%					
			7	8	9	10	11	12
7 to 11% by volume	Arteco	Havoline Extended Life Corrosion Inhibitor XLI [EU 32765]	**2.6**	**3.0**	**3.4**	**3.7**	**4.1**	4.4
	Chevron Lubricants	Delo XLI Corrosion Inhibitor- Concentrate	**2.6**	**3.0**	**3.4**	**3.7**	**4.1**	4.4
	Nalco Water An Ecolab Company	Alfloc™ 3443	**1.75**	**2.0**	**2.25**	**2.5**	**2.75**	3.0
		Alfloc™ 3477	**1.75**	**2.0**	**2.25**	**2.5**	**2.75**	3.0
	Chiron Chemicals Pty Ltd	PrixMax RCP	**2.6**	**3.0**	**3.4**	**3.7**	**4.1**	4.4
	Total	WT Supra	**2.6**	**3.0**	**3.4**	**3.7**	**4.1**	4.4
3 to 4% by volume	Improchem	COOL-C18	Please use test kit of manufacturer.					
	Nalco Water An Ecolab Company	Nalcool® 2000						
[1] = Concentration determined by means of suitable hand refractometer								

Table 24: Permissible concentrations, additional coolant without antifreeze exclusively for marine (free of light metals)

Calibrate the hand refractometer with clean water at coolant temperature. The coolant temperature should be 20 °C. Observe the specifications of the manufacturer.

Important
After flushing the engine coolant circuit, the specified minimum concentration of the corrosion inhibitor must not be undershot.

Permissible concentrations, antifreeze on ethylene glycol basis

The concentration is determined using a suitable glycol refractometer and direct reading of the scale value in % by vol.

Limit values for coolants

pH value when using		
– Antifreeze	Min. 7.5	Max. 9.0
– Coolant without antifreeze for engines containing light metal	Min. 7.5	Max. 9.0
– Coolant without antifreeze for engines free of light metal	Min. 7.5	Max. 11.0
– Silicon (valid for coolants containing Si)	Min. 25 mg/l	

Important

For a holistic appraisal of a coolant function, apart from the above-mentioned limit values the respective coolant-specific characteristic data and the fresh water quality used must be taken into consideration (lab examination).
The check of the current pH value must be carried out together with the check of the antifreeze concentration, however, at least every 3000 op. hrs. For a rapid on-site examination, pH indicator strips are suitable (recommend measuring range 6.5 to 10.0). The results must be documented.

3.1.3 Coolant concentrates – Storage capability

The storage capability specifications refer to coolant concentrates in original, hermetically sealed packing with storage temperatures up to max. 30 °C.

Observe manufacturer's instructions.

Coolant concentrate	Limit value	Brand name / Comments
Antifreeze	Approx. 3 years	Observe manufacturer's specifications
Coolant without antifreeze	2 years	ImproChem Cool-C18 Nalco Nalcool® 2000 PrixMax RCP
	3 years	BASF Glysacorr G93 green Drew Marine Drewgard XTA Ginouves York 719 Rolls-Royce Solutions Coolant CS100 Rolls-Royce Solutions America Inc. Power Cool® Plus 6000 Nalco Alfloc™ 3477 Valvoline OEM Advanced 93 Valvoline ZEREX G-93
	5 years	Arteco Havoline XLI CCI Corporation A216 CCI Manufacturing IL A216 Chevron Delo XLI Corrosion Inhibitor Concentrate Detroit Diesel Corp. Power Cool Plus 6000 ExxonMobil Mobil Delvac Extended Life Corrosion Inhibitor Old World Industries Final Charge Extended Life Corrosion Inhibitor (A216) Total WT Supra

Table 25: Coolant concentrates – Storage capability

Note

- For reasons of corrosion protection, do not store in galvanized containers. Take this requirement into account when transferring coolant.
- Containers must be hermetically sealed and stored in a cool, dry place. Frost protection must be provided in winter.
- Further information can be obtained from the product and safety data sheets for the individual coolants.

3.1.4 Color additives to detect leakage in the coolant circuit

The following listed fluorescent dyes are approved as additives for coolant without antifreeze for the detection of leaks.

Approved color additives

Manufacturer	Product name	Material number	Container size	Storage stability[1)]
Chromatech Inc. Chromatech Europe B.V.	D11014 Chromatint Uranine Conc	X00066947	20 kg	2 years
[1)] = Based on original and hermetically sealed containers in frost-free storage (> 5 °C)				

Table 26:

Application:

Add approx. 40 g of dye per 180 l of coolant.

This dye quantity is already very generous and must not be exceeded.

The fluorescence (yellow tone) is easily recognizable in daylight. UV light with a wavelength of 365 nm can be used in darker rooms.

3.1.5 Preventing damage to cooling system

- When topping up (following loss of coolant), ensure that not only water but also concentrate is added. The specified antifreeze and/or corrosion inhibitor concentration must be maintained.
- Do not exceed an antifreeze concentration of 50% by volume Use antifreeze. Concentrations in excess of this reduce antifreeze protection and heat dissipation. Only exception: BASF Glysantin® G30® pink (special application)
- The coolant must not contain any oil or copper residue (in solid or dissolved form).
- The majority of corrosion inhibitors currently approved for internal coolant circuit preservation are water-soluble and do not provide antifreeze protection. Make sure that the engine is stored safe from frost, because a certain amount of coolant remains in the engine after draining.
- A coolant circuit can usually not be drained completely, i.e. residual quantities of used coolant or freshwater from a flushing procedure remain in the engine. These residual quantities can result in the dilution of a coolant to be filled (mixed from a concentrate or use of a ready mixture). This dilution effect is higher the more add-on components there are on the engine. Check the coolant concentration in the coolant circuit and adapt it if necessary.

Important

All coolants approved in these Fluids and Lubricants Specifications generally relate only to the coolant circuits of mtu engines / systems. In the case of complete propulsion plants, the fluids and lubricants approvals of the component manufacturer must be observed.

Important

For corrosion-related reasons, it is not permissible to operate an engine with pure water without the addition of an approved corrosion inhibitor.

3.1.6 Unsuitable materials in the coolant circuit

Components made of copper, zinc and brass materials

Unless various preconditions are observed, components made of copper, zinc and brass materials or with galvanized surfaces in the coolant circuit (incl. supply and drain lines) can cause an electrochemical reaction with base metals (e.g. with aluminum). As a result, components made of base metals are subject to corrosion or even corrosive pitting. The coolant circuit becomes leaky at these points.

Non-metallic materials

- Do not use EPDM or silicon elastomers if emulsifiable corrosion inhibitor oils are used or other oils are introduced to the coolant circuit.

Coolant filter / filter downstream of plant components

- If such filters are used, only products that do not contain additives may be used.
  Supplementary additives such as silicates, nitrites etc. can diminish the protective effect or service life of a coolant and, possibly, attack the materials installed in the coolant circuit.

Information:

Consult the relevant specialist department of Rolls-Royce Solutions in case of doubt about the use of materials on the engine / externally mounted components in coolant circuits.

3.1.7 Fresh water requirements, Series 4000

Only clean, clear water with values in accordance with those in the following table must be used for conditioning the coolant with and without antifreeze. If the limit values for the water are exceeded, de-mineralized water can be added to reduce the hardness or mineral content.

Parameter	Unit	Limit value
Sum of alkaline earth metals *) (Water hardness)	mmol/l °dH	2.7 15
pH value at 20 °C	–	5.5 to 8.0
Bacteria	CFU (colony forming unit)/ml	10^3
Chloride and fluoride	mg/l	100
Sulfates	mg/l	100
Anions total	mg/l	200
Fungi, yeasts	are not permitted	

Table 27: Fresh water requirements, Series 4000

*) Common designations for water hardness in various countries:

1 mmol/l = 5.6 °dH = 100 mg/kg $CaCO_3$

- 1 °dH = 17.9 mg/kg $CaCO_3$, USA hardness
- 1 °dH = 1.79° French hardness
- 1 °dH = 1.25° English hardness

Note:

If an exhaust gas heat exchanger is integrated in the engine coolant system, the manufacturer must be consulted with regard to the water quality.

3.1.8 Fresh water requirements, Series 400

Only clean, clear water with values in accordance with those in the following table must be used for preparing the coolant. If the limit values for the water are exceeded, de-mineralized water can be added to reduce the hardness or mineral content.

Parameter	Unit	Limit value
Sum of alkaline earth metals *) (Water hardness)	mmol/l °dH	0.9 to 1.3 5 to 7
pH value at 25 °C	–	7.4 to 8.5
Electric conductivity (25 °C)	µS/cm	< 300
Bacteria	CFU (colony forming unit)/ml	< 10^3
Chlorides	mg/l	< 80
Iron	mg/l	< 0.2
Sulfates	mg/l	< 70
Fungi, yeasts	are not permitted	
odor	Neutral	
Appearance	Colorless, clear, free of mechanical contaminants	

Table 28: Fresh water requirements, Series 400

*) Common designations for water hardness in various countries:

1 mmol/l = 5.6 °dH = 100 mg/kg $CaCO_3$

- 1 °dH = 17.9 mg/kg $CaCO_3$, USA hardness
- 1 °dH = 1.79° French hardness
- 1 °dH = 1.25° English hardness

Note:

If an exhaust gas heat exchanger is integrated in the engine coolant system, the manufacturer must be consulted with regard to the water quality.

3.1.9 Fresh water requirements Series 500

Potable tap water with the limiting analysis values in the following table is suitable for producing the mixture.

Parameter	Unit	Limit value
Sum of alkaline earth metals *) (Water hardness)	mmol/l °dH	0.02 max. 0.1 max.
pH value at 25 °C	–	8.2 to 8.5
Electric conductivity (25 °C)	µS/cm	250 max.
Chlorides	mg/l	10 max.
Phosphate (PO_4)	mg/l	5 to 10
Sulfates	ppm	150 max.
odor	Neutral	
Appearance	Colorless, clear, free of mechanical contaminants	

Table 29: Mixture water limit values

*) Common designations for water hardness in various countries:

1 mmol/l = 5.6 °dH = 100 mg/kg $CaCO_3$

- 1 °dH = 17.9 mg/kg $CaCO_3$, USA hardness
- 1 °dH = 1.79° French hardness
- 1 °dH = 1.25° English hardness

Important

The named limit values for the mixture water serve for technical orientation from which no legal claims can be asserted because the water ratios are too different depending on the location.
The water can thus have numerous unknown combinations of secondary substances. The customer is responsible for safe operation.
Rolls-Royce Solutions recommends the use of a ready-mixed water-antifreeze mixture.

3.2 Series 4000 gas engine – Marine application

3.2.1 Coolants – General information

Important

The coolant change depends on the operating time (max. op. hours or runtime in years) of the engine and on which operating time is reached first.

Operating hours = preheating time + engine operating time

Important

All details are based on the coolant circuit on the engine side, no allowance is made for external add-on components.

Important

In the case of an engine coolant circuit with no light metal elements but with add-on components containing light metal (e.g. external cooling system), the coolant approvals for cooling systems containing light metal shall apply. If you have any doubts about a coolant application, consult your contact person.

Important

The use of products other than those listed will invalidate the warranty.

For details and special features, see 'General' (→ Page 30) and 'Unsuitable materials in the coolant circuit' (→ Page 39).

Any deviating special agreements between the customer and Rolls-Royce Solutions remain valid.

3.2.2 Coolants without antifreeze – Concentrates for cooling systems not containing light metal

For details and special properties, see chapter 'Coolants' (→ Page 30).

Coolants without antifreeze – concentrates

Manufacturer	Product/Brand name	Inhibitors							Runtime Hours/Years	Comments / Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
Rolls-Royce Solutions GmbH	Coolant CS100 Corrosion Inhibitor Concentrate		X					X	6000 / 2	X00057233 (20 l) X00057232 (210 l) Also available from Rolls-Royce Solutions Asia Pte. Ltd.
Rolls-Royce Solutions America Inc.	Power Cool ® Plus 6000 Concentrate		X					X	6000 / 2	Colored green 23533526 (1 gallon) 23533527 (5 gallons) Available from Rolls-Royce Solutions America Inc.
Arteco NV	Havoline XLI	X						X	6000 / 2	
BASF SE	Glysacorr G93 green		X					X	6000 / 2	X00054105 (barrel) X00058062 (canister)
CCI Corporation	A 216	X				X			6000 / 2	
CCI Manufacturing IL Corporation	A 216	X				X			6000 / 2	X00051509 (208 l)
Chevron	Delo XLI Corrosion Inhibitor - Concentrate	X						X	6000 / 2	
Chiron Chemicals Pty Ltd	PrixMax RCP	X						X	6000 / 2	
Detroit Diesel Corp.	Power Cool Plus 6000	X				X			6000 / 2	Colored red
Drew Marine	Drewgard XTA		X					X	6000 / 2	
ExxonMobil	Mobil Delvac Extended Life Corrosion Inhibitor	X				X			6000 / 2	
ImproChem	COOL-18		X	X			X		6000 / 2	
Nalco Water An Ecolab Company	Alfloc ™ 3477	X						X	6000 / 2	
	Nalcool ® 2000		X	X			X		6000 / 2	
Old World Industries Inc.	Final Charge Extended Life Corrosion Inhibitor (A 216)	X				X			6000 / 2	
Total Lubrifiants	Total WT Supra	X						X	6000 / 2	

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Manufacturer	Product/Brand name	Inhibitors							Runtime Hours/Years	Comments / Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
Valvoline	Zerex G-93		X					X	6000 / 2	
	OEM Advanced 93		X					X	6000 / 2	
YORK SAS	York 719		X					X	6000 / 2	

Table 30: Coolants without antifreeze – concentrates

3.2.3 Coolant without antifreeze – Ready mixtures for cooling systems not containing light metal

For details and special properties, see chapter on 'Coolants' (→ Page 30)

Coolant without antifreeze, ready mixtures

Manufacturer	Product/Brand name	Inhibitors							Runtime Hours/Years	Comments / Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
Rolls-Royce Solutions GmbH	Coolant CS 10/90 Corrosion Inhibitor Premix		X					X	6000 / 2	X00069385 (20 l) X00069386 (210 l) (Sales region: Italy)
Chiron Chemicals Pty Ltd	PrixMax RCP Premix (8 %)	X						X	6000 / 2	
Nalco Water An Ecolab Company	Alfloc ™ 3443 (7%)	X						X	6000 / 2	

Table 31: Coolant without antifreeze, ready mixtures

3.2.4 Antifreeze – Concentrates for cooling systems free of light metal

For details and special properties, see chapter 'Coolants' (→ Page 30).

Antifreeze, concentrates

Manufacturer	Product/Brand name	Inhibitors							Runtime Hours/Years	Comments / Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
Alliance Automotive Service GmbH	NAPA Premium Kühlerschutz N48	X	X				X	X	9000 / 5	
Arteco NV	Havoline XLC (1040112)	X						X	9000 / 3	
AVIA AG	Antifreeze APN	X	X				X	X	9000 / 5	
	Antifreeze APN-S	X							9000 / 3	
	AVIA Coolant APN-S	X						X	9000 / 3	
BASF SE	Glysantin ® G48 ® blue green	X	X				X	X	9000 / 5	X00058054 (25 l) X00058053 (210 l)
	Glysantin ® G40 ®pink	X	X						9000 / 3	X00066724 (20 l) X00066725 (210 l) Application concentration 40 to 50% by volume
	Glysantin ® G30 ® pink	X							9000 / 3	X00058072 (canister) X00058071 (barrel)
BayWa AG	Tectrol Coolprotect	X	X				X	X	9000 / 5	
BP Lubricants	ARAL Antifreeze Extra	X	X				X	X	9000 / 5	
Castrol	Castrol Radicool NF	X	X				X	X	9000 / 5	
CCI Corporation	L415	X				X			9000 / 3	
Chevron	Delo XLC Antifreeze/ Coolant-Concentrate	X						X	9000 / 3	
Classic Schmierstoff GmbH + Co. KG	Classic Kolda UE G48	X	X				X	X	9000 / 5	Product is no longer manufactured. Remaining stocks of this product can be used up as long as the shelf life has not expired.
COPARTS Autoteile GmbH	CAR1 Premium Longlife Kühlerschutz C48	X	X				X	X	9000 / 5	
Daimler Trucks North America	Alliance OAT Extended Life Coolant	X				X			9000 / 3	
Detroit Diesel Corp.	Power Cool Plus Coolant	X				X			9000 / 3	
Drew Marine	Drewgard ZX	X							9000 / 3	
ExxonMobil	Mobil Delvac Extended Life Coolant	X				X			9000 / 3	

Manufacturer	Product/Brand name	Inhibitors							Runtime Hours/Years	Comments / Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
Finke Mineralölwerk GmbH	AVIATICON Finko-freeze F30	X							9000 / 3	
	AVIATICON Finko-freeze F40	X	X						9000 / 3	Application concentration 40 to 50% by volume
	AVIATICON Finko-freeze F48	X	X				X	X	9000 / 5	
Fuchs Petrolub SE	Maintain Fricofin	X	X				X	X	9000 / 5	Product is no longer manufactured. Remaining stocks of this product can be used up as long as the shelf life has not expired.
	Maintain Fricofin DP	X	X						9000 / 3	Application concentration 40 to 50% by volume
	Maintain Fricofin G12 Plus	X							9000 / 3	X00058074 (canister) X00058073 (barrel)
	Maintain Fricofin LL	X						X	9000 / 3	
Kuttenkeuler	Kuttenkeuler Antifreeze ANF KK48	X	X				X	X	9000 / 5	
	Glyostar ® ST48	X	X				X	X	9000 / 5	
Kuwait Petroleum Research & Technology BV	Q8 Mahler Cool	X						X	9000 / 3	
	Roloil Rol-ICE SNF	X						X	9000 / 3	
Mitan Mineralöl GmbH	Alpine C30	X							9000 / 3	
	Alpine C48	X	X				X	X	9000 / 5	
MJL Bangladesh Limited	Omera Premium Coolant	X							9000 / 3	
MOFIN Deutschland GmbH & Co KG	MOFIN Kühlerschutz M40 Extra	X	X						9000 / 3	Application concentration 40 to 50% by volume
	MOFIN Kühlerschutz M48 Premium Protect	X	X				X	X	9000 / 5	
MOL-Lub Kft.	EVOX Premium concentrate	X						X	9000 / 3	
Moove Lubricants Limited	Mobil Antifreeze Extra	X	X				X	X	9000 / 5	
Motorex AG	Motorex Coolant G48	X	X				X	X	9000 / 5	
	Motorex Coolant M 4,0 Concentrate	X	X						9000 / 3	Application concentration 40 to 50% by volume

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Manufacturer	Product/Brand name	Inhibitors							Runtime Hours/Years	Comments / Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
Nalco Water An Ecolab Company	Nalcool NF 48 C	X	X				X	X	9000 / 5	
Navistar Inc.	Fleetrite Nitrite-Free Extended Life Coolant	X				X			9000 / 3	
Old World Industries Inc.	Blue Mountain Heavy Duty Extended Life Coolant	X				X			9000 / 3	
	Final Charge Global Extended Life Coolant Antifreeze	X				X			9000 / 3	
LAEMMLE Chemicals AG	Roxor Anti-Frost MT-325	X	X				X	X	9000 / 5	
Puma Energy International S.A.	Puma HD Hybrid Coolant	X	X						9000 / 3	Application concentration 40 to 50% by volume
	Puma HD XLC Coolant	X						X	9000 / 3	
Raloy Lubricantes	Antifreeze Long Life NF-300 Concentrate	X	X				X	X	9000 / 5	
Recochem Inc.	HD Expert ™ Endurance	X				X			9000 / 3	
SMB - Sotragal / Mont Blanc	Antigel Power Cooling Concentrate	X	X				X	X	9000 / 5	
Total Lubrifiants	Glacelf Auto Supra	X						X	9000 / 3	
	Glacelf MDX	X	X				X	X	9000 / 5	
Valvoline	Zerex G-48	X	X				X	X	9000 / 5	
	Zerex G-40	X	X						9000 / 3	Material number (USA): 800 180 (Drum) Application concentration 40 to 50% by volume
	Zerex G-30	X							9000 / 3	
	OEM Advanced G30	X							9000 / 3	
	OEM Advanced G40	X	X						9000 / 3	Application concentration 40 to 50% by volume
	OEM Advanced G48	X	X				X	X	9000 / 5	
Volvo Trucks	Road Choice Nitrite-Free OAT Extended Life Coolant	X				X			9000 / 3	

Table 32: Antifreeze, concentrates

3.2.5 Antifreeze – Concentrates for special applications

For details and special properties, see chapter on 'Coolants' (→ Page 30)

Concentrates for special applications

Manufacturer	Brand name	Inhibitors							Runtime Hours/Years	Comments / Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
BASF SE	Glysantin®G30® pink	X							9000 / 3	Application concentration 40 to 65% by volume For use in arctic regions X00058072 (canister) X00058071 (barrel)

Table 33: Concentrates for special applications

Working concentration

Application concentration antifreeze on ethylene glycol basis	Antifreeze in accordance with ASTM D 1177
40% by volume	-25 °C
45% by volume	-31 °C
50% by volume	-37 °C
55% by volume	-45 °C
60% by volume	-52 °C
65% by volume	-60 °C

Table 34:

Important
From approx. 65% by vol. onwards, there is a reversal of the antifreeze behavior (bath effect), i.e. with an increasing application concentration, antifreeze protection is no longer increased but is reduced.

3.2.6 Antifreeze – Ready mixtures for cooling systems free of light metals

Antifreeze, ready mixtures

For details and special properties, see chapter 'Coolants' (→ Page 30).

Manufacturer	Product/Brand name	Inhibitors							Runtime Hours/Years	Comments / Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
Rolls-Royce Solutions GmbH	Coolant AH 35/65 Antifreeze Premix	X	X				X	X	9000 / 5	X00069382 (20 l) X00069383 (210 l) X00069384 (1000 l) (Sales region: Italy)
	Coolant AH 40/60 Antifreeze Premix	X	X				X	X	9000 / 5	X00070533 (20 l) X00070532 (1000 l) (Sales region: England, Spain)
	Coolant AH 50/50 Antifreeze Premix	X	X				X	X	9000 / 5	X00070528 (20 l) X00070527 (1000 l) (Sales region: England)
Rolls-Royce Solutions America Inc.	Power Cool ® Universal 35/65 mix	X	X				X	X	9000 / 5	800085 (5 gallons) 800086 (55 gallons)
	Power Cool ® Universal 50/50 mix	X	X				X	X	9000 / 5	800071 (5 gallons) 800084 (55 gallons)
BayWa AG	Tectrol Coolprotect Mix 3000	X							9000 / 3	Antifreeze protection down to -24 °C
Castrol	Castrol Radicool NF Premix (45 %)	X	X				X	X	9000 / 5	
CCI Corporation	L 415 (50 %)	X				X			9000 / 3	
Cepsa Comercial Petróleo S.A.U	Xtar Super Coolant Hybrid NF 50 %	X	X				X	X	9000 / 5	
Daimler Trucks North America	Alliance 50/50 Prediluted OAT Extended Life Coolant	X				X			9000 / 3	
Detroit Diesel Corp.	Power Cool Plus Prediluted Coolant (50/50)	X				X			9000 / 3	
Fast Chmical SRL	Fast Coolant G30 50% (Ready Mix)	X							9000 / 3	
ExxonMobil	Mobil Delvac Extended Life Prediluted Coolant (50/50)	X				X			9000 / 3	

Manufacturer	Product/Brand name	Inhibitors							Runtime Hours/Years	Comments / Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
Finke Mineralölwerk GmbH	AVIATICON Finko-freeze F30 RM 40:60 +	X							9000 / 3	
	AVIATICON Finko-freeze F48 RM 50:50	X	X				X	X	9000 / 5	
Fuchs Petrolub SE	Maintain Fricofin LL 50	X						X	9000 / 3	
Moove Lubricants Limited	Mobile Coolant Extra Ready Mixed -36 °C	X	X				X	X	9000 / 5	
Kuwait Petroleum Research & Technology BV	Q8 Mahler Cool premixed 4060	X						X	9000 / 3	
	Roloil Rol-ICE SNF 4060	X						X	9000 / 3	
Motorex AG	Motorex Coolant G48 ready to use (50/50)	X	X				X	X	9000 / 5	
	Motorex Coolant M 4,0 ready to use	X	X						9000 / 3	Antifreeze protection up to -38 °C (50% by vol.)
Navistar Inc.	Fleetrite 50/50 Prediluted Nitrite-Free Extended Life Coolant	X				X			9000 / 3	
Old World Industries Inc.	Blue Mountain Heavy Duty Extended Life Prediluted Coolant (50/50)	X				X			9000 / 3	
	Final Charge Global Extended Life Predilluted Coolant / Antifreeze (50/50)	X				X			9000 / 3	
Puma Energy International S.A.	Puma HD Hybrid Coolant 5050	X	X						9000 / 3	(50% by vol.)
	Puma HD XLP Coolant	X						X	9000 / 3	50% premix
Raloy Lubricantes	Antifreeze Long Life NF-300 Ready-to-Use (50/50)	X	X				X	X	9000 / 5	
Recochem Inc.	HD Expert™ Endurance 50-50 Prediluted	X				X			9000 / 3	
SMB - Sotragal / Mont Blanc	L.R.-30 Power Cooling (44 %)	X	X				X	X	9000 / 5	
	L.R.-38 Power Cooling (52 %)	X	X				X	X	9000 / 5	
Tedom Schnell GmbH	Schnell Protrect Coolant (Ready Mix 40/60 bis max. -27 °C)	X	X				X	X	9000 / 5	

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Manufacturer	Product/Brand name	Inhibitors							Runtime Hours/Years	Comments / Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
Total Lubrifiants	Coolelf Auto Supra -37 °C	X						X	9000 / 3	50/50 premix
	Coolelf Auto Supra -26 °C	X						X	9000 / 3	40/60 premix
	Coolelf MDX -26 °C	X	X				X	X	9000 / 5	
	Coolelf MDX -37 °C	X	X				X	X	9000 / 5	
A. Roth GmbH & Co KG	CRO Coolant Plus -25 °C Ready	X							9000 / 3	
Valvoline	Zerex G-48 premix 50%	X	X				X	X	9000 / 5	
	OEM Advanced 48 premix 50%	X	X				X	X	9000 / 5	
Volvo Trucks	Road Choice 50/50 Prediluted Nitrite-Free OAT Extended Life Coolant	X				X			9000 / 3	
YPF S.A. Argentina	Kriox MTL50	X				X			9000 / 3	

Table 35: Antifreeze, ready mixtures

3.3 Series 4000 gas engine - Generator application, engine-generator set and engine-generator set in Oil&Gas

3.3.1 Coolants – General information

Important

The coolant change depends on the operating time (max. op. hours or runtime in years) of the engine and on which operating time is reached first.

Operating hours = preheating time + engine operating time

Important

All details are based on the coolant circuit on the engine side, no allowance is made for external add-on components.

Important

In the case of an engine coolant circuit with no light metal elements but with add-on components containing light metal (e.g. external cooling system), the coolant approvals for cooling systems containing light metal shall apply. If you have any doubts about a coolant application, consult your contact person.

Important

The use of products other than those listed will invalidate the warranty.

For details and special features, see 'General' (→ Page 30) and 'Unsuitable materials in the coolant circuit' (→ Page 39).

Any deviating special agreements between the customer and Rolls-Royce Solutions remain valid.

3.3.2 Coolant without antifreeze – Concentrates for cooling systems containing light metal

For details and special properties, see chapter 'Coolants' (→ Page 30).

Important

For Series 1163-03 and 1163-04 marine engines, only coolants marked with an asterisk * in the product/ brand name may be used!

Coolants without antifreeze – concentrates

Manufacturer	Product/Brand name	Inhibitors							Runtime Hours/Years	Comments / Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
Rolls-Royce Solutions GmbH	Coolant CS100 Corrosion Inhibitor Concentrate*		X					X	6000 / 2	X00057233 (20 l) X00057232 (210 l) Also available from Rolls-Royce Solutions Asia Pte. Ltd.
Rolls-Royce Solutions America Inc.	Power Cool ® Plus 6000 Concentrate*		X					X	6000 / 2	Colored green 23533526 (1 gallon) 23533527 (5 gallons) Available from Rolls-Royce Solutions America Inc.
BASF SE	Glysacorr G93 green*		X					X	6000 / 2	X00054105 (barrel) X00058062 (canister)
CCI Corporation	A 216	X				X			6000 / 2	
CCI Manufacturing IL Corporation	A 216	X				X			6000 / 2	X00051509 (208 l)
Detroit Diesel Corp.	Power Cool Plus 6000	X				X			6000 / 2	Colored red
Drew Marine	Drewgard XTA*		X					X	6000 / 2	
ExxonMobil	Mobil Delvac Extended Life Corrosion Inhibitor	X				X			6000 / 2	
Old World Industries Inc.	Final Charge Extended Life Corrosion Inhibitor (A 216)	X				X			6000 / 2	
Valvoline	ZEREX G-93*		X					X	6000 / 2	
	OEM Advanced 93*		X					X	6000 / 2	
YORK SAS	York 719*		X					X	6000 / 2	

3.3.3 Coolant without antifreeze – Ready mixtures for cooling systems containing light metal

For details and special properties, see chapter 'Coolants' (→ Page 30).

Important
For Series 1163-03 and 1163-04 marine engines, only coolants marked with an asterisk * in the product name may be used.

Coolant without antifreeze, ready mixtures

Manufacturer	Product name	Inhibitors							Runtime Hours/Years	Comments / Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
Rolls-Royce Solutions GmbH	Coolant CS10/90 Corrosion Inhibitor Premix*		X					X	6000 / 2	X00069385 (20 l) X00069386 (210 l) (Sales region: Italy)

Table 36: Coolant without antifreeze, ready mixtures

3.3.4 Antifreeze – Concentrates for cooling systems containing light metal

For details and special properties, see chapter 'Coolants' (→ Page 30).

Antifreeze, concentrates

Manufacturer	Product/Brand name	Inhibitors							Runtime Hours/Years	Comments / Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
Alliance Automotive-Service GmbH	NAPA Premium Kühlerschutz N48	X	X				X	X	9000 / 5	
AVIA AG	Antifreeze APN	X	X				X	X	9000 / 5	
	Antifreeze APN-S	X							9000 / 3	
BASF SE	GLYSANTIN ® G05 ®		X	X			X		9000 / 5	
	GLYSANTIN ® G48 ® blue green	X	X				X	X	9000 / 5	X00058054 (25 l) X00058053 (210 l)
	GLYSANTIN® G30 ® pink	X							9000 / 3	X00058072 (canister) X00058071 (barrel)
	GLYSANTIN ® G40 ® pink (concentrate)	X	X						9000 / 3	X00066724 (20 l) X00066725 (210 l) Concentration for use: 40 to 50% by volume
BayWa AG	Tectrol Coolprotect	X	X				X	X	9000 / 5	
BP Lubricants	ARAL Antifreeze Extra	X	X				X	X	9000 / 5	
Castrol	Castrol Radicool NF	X	X				X	X	9000 / 5	
CCI Corporation	L415	X				X			9000 / 3	
Classic Schmierstoff GmbH + Co. KG	Classic Kolda UE G48	X	X				X	X	9000 / 5	Product is no longer manufactured. Remaining stocks of this product can be used up as long as the shelf life has not expired.
COPARTS Autoteile GmbH	CAR 1 Premium Longlife Kühlerschutz C48	X	X				X	X	9000 / 5	
Daimler Trucks North America	Alliance OAT Extended Life Coolant	X				X			9000 / 3	
Detroit Diesel Corp.	Power Cool Plus Coolant	X				X			9000 / 3	
	Power Cool Diesel Engine Coolant		X	X					9000 / 3	
Drew Marine	Drewgard ZX	X							9000 / 3	
ExxonMobil	Mobil Delvac Extended Life Coolant	X				X			9000 / 3	
	Mobil Heavy Duty Coolant		X	X					9000 / 3	
	Mobil Mining Coolant		X	X					9000 / 3	

Manufacturer	Product/Brand name	Inhibitors							Runtime Hours/Years	Comments / Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
Finke Mineralölwerke GmbH	AVIATICON Finko-freeze F30	X							9000 / 3	
	AVIATICON Finko-freeze F40	X	X						9000 / 3	Concentration for use: 40 to 50% by volume
	AVIATICON Finko-freeze F48	X	X				X	X	9000 / 5	
Fuchs Petrolub SE	Maintain Fricofin	X	X				X	X	9000 / 5	Product is no longer manufactured. Remaining stocks of this product can be used up as long as the shelf life has not expired.
	Maintain Fricofin DP	X	X						9000 / 3	Concentration for use: 40 to 50% by volume
	Maintain Fricofin G12 Plus	X							9000 / 3	X00058074 (canister) X00058073 (barrel)
Krafft S.L.U	Refrigerante ACU 2300		X	X			X		9000 / 3	X00058075 (barrel)
Kuttenkeuler	Kuttenkeuler Antifreeze ANF KK48	X	X				X	X	9000 / 5	
	Glyostar ® ST48	X	X				X	X	9000 / 5	
Mitan Mineralöl GmbH	Alpine C30	X							9000 / 3	
	Alpine C48	X	X				X	X	9000 / 5	
MJL Bangladesh Limited	Omera Premium Coolant	X							9000 / 3	
MOFIN Deutschland GmbH & Co KG	MOFIN Kühlerschutz M48 Premium Protect	X	X				X	X	9000 / 5	
	MOFIN Kühlerschutz M40 Extra	X	X						9000 / 3	Concentration for use: 40 to 50% by volume
Moove Lubricants Limited	Mobil Antifreeze Extra	X	X				X	X	9000 / 5	
Motorex AG	Motorex Coolant G48	X	X				X	X	9000 / 5	
	Motorex Coolant M 4,0 Concentrate	X	X						9000 / 3	Concentration for use: 40 to 50% by volume
Nalco Water An Ecolab Company	Nalcool NF 48 C	X	X				X	X	9000 / 5	
Navistar Inc.	Fleetrite Nitrite-Free Extended Life Coolant	X				X			9000 / 3	

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Manufacturer	Product/Brand name	Inhibitors							Runtime Hours/Years	Comments / Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
Old World Industries Inc.	Blue Mountain Heavy Duty Extended Life Coolant	X				X			9000 / 3	
	Fleetcharge SCA Pre-charged Coolant/ Anti-freeze		X	X					9000 / 3	
	Final Charge Global Extended Life Coolant Antifreeze	X				X			9000 / 3	
	Peak Heavy Duty Coolant		X	X					9000 / 3	
LAEMMLE Chemicals AG	Roxor Anti-Frost MT-325	X	X				X	X	9000 / 5	
Penske Power Systems	Power Cool - HB500 Coolant Concentrate	X	X				X		9000 / 3	
Puma Energy International S.A	Puma HD Hybrid Coolant	X	X						9000 / 3	Concentration for use: 40 to 50% by volume
Raloy Lubricantes	Antifreeze Long Life NF-300 Concentrate	X	X				X	X	9000 / 3	
Recochem Inc.	R542	X	X				X		9000 / 3	
	HD Expert™ Endurance	X				X			9000 / 3	
SMB - Sotragal / Mont Blanc	Antigel Power Cooling Concentrate	X	X				X	X	9000 / 5	
Total Lubrifiants	Glacelf MDX	X	X				X	X	9000 / 5	
Valvoline	Zerex G-05		X	X			X		9000 / 5	
	Zerex G-48	X	X				X	X	9000 / 5	
	Zerex G-30	X							9000 / 3	
	Zerex G-40	X	X						9000 / 3	Concentration for use: 40 to 50% by volume Material number (USA): 800180 (Drum)
	OEM Advanced 30	X							9000 / 3	
	OEM Advanced 48	X	X				X	X	9000 / 5	
	OEM Advanced 40	X	X						9000 / 3	Concentration for use: 40 to 50% by volume
Volvo Trucks	Road Choice Nitrite-Free OAT Extended Life Coolant	X				X			9000 / 3	

Table 37: Antifreeze, concentrates

3.3.5 Antifreeze – Concentrates for special applications

For details and special properties, see chapter on 'Coolants' (→ Page 30)

Concentrates for special applications

Manufacturer	Brand name	Inhibitors							Runtime Hours/Years	Comments / Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
BASF SE	Glysantin®G30® pink	X							9000 / 3	Application concentration 40 to 65% by volume For use in arctic regions X00058072 (canister) X00058071 (barrel)

Table 38: Concentrates for special applications

Working concentration

Application concentration antifreeze on ethylene glycol basis	Antifreeze in accordance with ASTM D 1177
40% by volume	-25 °C
45% by volume	-31 °C
50% by volume	-37 °C
55% by volume	-45 °C
60% by volume	-52 °C
65% by volume	-60 °C

Table 39:

Important
From approx. 65% by vol. onwards, there is a reversal of the antifreeze behavior (bath effect), i.e. with an increasing application concentration, antifreeze protection is no longer increased but is reduced.

3.3.6 Antifreeze – Ready mixtures for cooling systems containing light metals

For details and special properties, see chapter 'Coolants' (→ Page 30).

Antifreeze, ready mixtures

Manufacturer	Product/Brand name	Inhibitors							Runtime Hours/Years	Comments / Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
Rolls-Royce Solutions GmbH	Coolant AH 35/65 Antifreeze Premix	X	X				X	X	9000 / 5	X00069382 (20 l) X00069383 (210 l) X00069384 (1000 l) (Sales region: Italy)
	Coolant AH 40/60 Antifreeze Premix	X	X				X	X	9000 / 5	X00070533 (20 l) X00070532 (1000 l) (Sales region: England, Spain)
	Coolant AH 50/50 Antifreeze Premix	X	X				X	X	9000 / 5	X00070528 (20 l) X00070527 (1000 l) (Sales region: England)
Rolls-Royce Solutions America Inc.	Power Cool ® Universal 35/65 mix	X	X				X	X	9000 / 5	800085 (5 gallons) 800086 (55 gallons)
	Power Cool ® Universal 50/50 mix	X	X				X	X	9000 / 5	800071 (5 gallons) 800084 (55 gallons)
	Power Cool ® Off-Highway Coolant 50/50 Premix		X	X			X		9000 / 5	23533531 (5 gallons) 23533532 (55 gallons)
BayWa AG	Tectrol Coolprotect Mix 3000	X							9000 / 3	Antifreeze protection down to -24 °C
Castrol	Castrol Radicool NF Premix (45 %)	X	X				X	X	9000 / 5	
CCI Corporation	L 415 (50 %)	X				X			9000 / 3	
Cespa Comercial Petróleo S.A.U.	Xtar Super Coolant Hybrid NF 50%	X	X				X	X	9000 / 5	
Detroit Diesel Corp.	Power Cool Plus Prediluted Coolant (50/50)	X				X			9000 / 3	
	Power Cool Prediluted (50/50) Diesel Engine Coolant		X	X					9000 / 3	

Manufacturer	Product/Brand name	Inhibitors							Runtime Hours/Years	Comments / Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
ExxonMobil	Mobil Delvac Extended Life Prediluted Coolant (50/50)	X				X			9000 / 3	
	Mobile Heavy Duty 50/50 Prediluted Coolant		X	X					9000 / 3	
	Mobile Mining 50/50 Prediluted Coolant		X	X					9000 / 3	
Fast Chemical SRL	Fast Coolant G30 50%	X							9000 / 3	
Finke Mineralölwerk GmbH	AVIATICON Finkofreeze F30 RM 40:60 +	X							9000 / 3	
	AVIATICON Finkofreeze F48 RM 50:50	X	X				X	X	9000 / 5	
Fuchs Petrolub SE	Maintain Fricofin 50	X	X				X	X	9000 / 5	
	Maintain Fricofin DP 50	X	X						9000 / 3	
Motorex AG	Motorex Coolant G48 ready to use (50/50)	X	X				X	X	9000 / 5	
	Motorex Coolant M 4,0 ready to use	X	X						9000 / 3	Antifreeze protection up to -38 °C (50% by vol.)
Moove Lubricants Limited	Mobil Coolant Extra Ready Mixed -37° C	X	X				X	X	9000 / 5	
Navistar Inc.	Fleetrite 50/50 Prediluted Nitrite-Free Life Coolant	X				X			9000 / 3	
Old World Industries Inc.	Blue Mountain Heavy Duty Extended Life Prediluted Coolant (50/50)	X				X			9000 / 3	
	Final Charge Global Extended Life Predilluted Coolant / Antifreeze (50/50)	X				X			9000 / 3	
	Fleet Charge SCA Precharged 50/50 Prediluted Coolant		X	X					9000 / 3	
Penske Power Systems	Power Cool - HB500 Premix 50/50	X	X				X		9000 / 3	
	Power Cool - HB500 Premix 35/65	X	X				X			
Puma Energy International S.A.	Puma HD Hybrid Coolant 5050	X	X						9000 / 3	(50% by vol.)
Raloy Lubricantes	Antifreeze Long Life NF-300 Ready-to-Use (50/50)	X	X				X	X	9000 / 5	

Manufacturer	Product/Brand name	Inhibitors							Runtime Hours/Years	Comments / Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
Recochem Inc.	HD Expert™ Endurance 50-50 Prediluted	X				X			9000 / 3	
	R 542 35/65	X	X				X		9000 / 3	
SMB - Sotragal / Mont Blanc	L.R.-30 Power Cooling (44 %)	X	X				X	X	9000 / 5	
	L.R.-38 Power Cooling (52 %)	X	X				X	X	9000 / 5	
Tedom Schnell GmbH	Schnell Protect Coolant (Ready Mix 40/60 bis max. -27°)	X	X				X	X	9000 / 5	
Total Lubrifiants	Coolelf MDX -26 °C	X	X				X	X	9000 / 5	
	Coolelf MDX -37 °C	X	X				X	X	9000 / 5	
A. Roth GmbH	CRO Coolant Plus -25 °C Ready	X							9000 / 3	
Valvoline	Zerex G-05 50/50 Mix		X	X			X		9000 / 5	
	Zerex G-48 premix 50%	X	X				X	X	9000 / 5	
	OEM Advanced 48 premix 50%	X	X				X	X	9000 / 5	
Volvo Trucks	Road Choice 50/50 Prediluted Nitrite-Free OAT Extended Life Coolant	X				X			9000 / 3	
YPF S.A. Argentina	Kriox MTL50	X				X			9000 / 3	

Table 40: Antifreeze – Ready mixtures for cooling systems containing light metals

3.4 Series 400 gas engine – Engine-generator set

3.4.1 Approved coolants

Important
The use of products other than those listed will invalidate the warranty.

Antifreeze, ready mixtures (silicate-free)

Manufacturer/Supplier	Designation
BayWa AG	Tectrol Coolprotect MIX3000*
Montana	Kühlerfrostschutz BHKW -25°*
A. Roth GmbH & Co KG	CRO Coolant Plus -25° Ready*
* Extended change interval possible	

Table 41: Antifreeze, ready mixtures (silicate-free)

Antifreeze, concentrates

Manufacturer/Supplier	Designation
BASF	Glysantin ® G30 ®pink
Aral	Antifreeze Silikatfrei

Table 42: Antifreeze, concentrates

Information on warranty

It is strongly recommended to use ready mixed antifreezes for the engine cooling circuit.

If these ready mixtures are used, the following requirements will be met:
- The ratio of water to antifreeze is set correctly.
- The used (fresh) water complies with the specifications set out in 'Requirements of engine coolant'.

The service lives of components will be shortened if the water used does not comply with the specifications. In such a case, there is a risk of deposits forming for many components, which can lead to a reduction in heat transfer and thus a reduction in functionality (heat exchanger) or to overheating of the components.

Observe the following with "self-mixing" of coolant:
- Only use the approved silicate-free antifreezes with the specified ratio to water.
- A form must be signed confirming that the water used fulfills the requirements set out in the Fluids and Lubricants Specifications.

Check the concentration at regular intervals in accordance with the maintenance schedule. The coolant should be checked once a year or each time it is added, whichever comes first. Due to aging, the coolant filling must be replaced after 25,000 operating hours or after 3 years at the latest.

3.5 Series 500 Gas Engine - Engine-Generator Set

3.5.1 Coolants – General information

Antifreezes checked and approved by Rolls-Royce Solutions guarantee sufficient protection against frost, corrosion and cavitation, do not attack gaskets and hoses and do not foam, see (→ Page 67).

To ensure continuous, trouble-free operation of engine-generator sets, the coolant used must always have a suitable composition all year round that guarantees protection against frost and corrosion.

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3.5.2 Coolant – Check and replacement

The coolants used by Rolls-Royce Solutions are subject to natural aging and their condition must therefore be checked regularly.

Coolant losses must always be replaced with a mixture of water and antifreeze. The mixing volume ratio depends on the engine and selected antifreeze.

Rolls-Royce Solutions expressly points out that the water quality must be checked when topping up supplementary water and that the values must be observed, see (→ Page 42).

For topping up, Rolls-Royce Solutions recommends the use of a ready-mixed water-antifreeze mixture.

To maintain the cooling capacity of the engine, the coolant quality must be checked after 2,000 operating hours. The following must be observed in this case:
- Check the coolant concentration every three months using a hydrometer or refractometer.
- Never allow the antifreeze concentration to fall below 40% by volume.
- The coolant must be replaced completely at the latest after the interval predefined in the Maintenance Schedule of the respective plant.
- Observe the limit values (→ Table 42)
- Vent the cooling system, adjust coolant pressure if necessary

Important
Coolants must not be mixed. Otherwise there is a danger of engine damage. Cooling systems only work reliably if they are operated with sufficient upstream pressure and are correctly vented. On Rolls-Royce Solutions plants, the respective minimum pressure is saved as a warning value in the control system. This may deviate, however, due to local conditions. It is recommended to always set the pressure to the upper limit.

When extracting a sample to check the coolant, fill a clean vessel using a suitable hose. 100 ml are already sufficient. Select a suitable extraction point, the vent points of the coolant circuit. As the plants are under pressure, for safety reasons the sample must be extracted at low temperatures below 60 °C. Otherwise explosive evaporation of the coolant is possible. It is essential to observe the respective safety instructions!

Limit values for coolants

Characteristic	Unit	Limit value
Appearance	-	Change with brown discoloration
pH value at 25 °C	-	Min. 7.5
odor	-	Change in case of odor of solvents
Antifreeze	°C	Min. -20

3.5.3 Approved coolants

Only approved antifreezes provide the protection for the engine cooling system according to Rolls-Royce Solutions requirements. The concentrates and the ready-mixed water-antifreeze mixtures also provide the necessary corrosion protection.

Approved coolants

Coolant manufacturer	Product	Mixing volume ratio	Operating hours hour / year	Comment
BASF	Glysantin® G48® bluegreen	Concentrate/water 50/50 or ready-mixed	16000/2	Contains borat and 2-EHS
Caltex, Chevron, Texaco	Havoline® ELC Dex-Cool®	Concentrate/water 50/50 or ready-mixed	16000/2	Alternatively, only for America, ethylene-glycol-based.
Caltex, Chevron, Texaco	Delo® ELC PG	Concentrate/water 50/50 or ready-mixed	16000/2	Alternatively, only for America, propylene-glycol-based.
Vavoline	Zerex G48	Concentrate/water 50/50 or ready-mixed	16000/2	Alternatively, only for America, ethylene-glycol-based. Contains borat and 2-EHS

Table 43: Approved coolants

Avoid coolant concentrations above 50%.

Important

The coolant change depends on the operating time (hours/years) of the engine and on which operating time is reached first.

Important

All details are based on the coolant circuit on the engine side, no allowance is made for external add-on components.

4 Flushing and Cleaning Specifications for Engine Coolant Circuits

4.1 Flushing and Cleaning Specifications for Series 400 and 4000 Engines

4.1.1 General information

In the course of time, sludge deposits from aging coolant additives can accumulate in the coolant circuits. Reduced cooling capacity, clogged vent lines and drain points, and dirty coolant level sight glasses can result.

Inadequate water quality or incorrect coolant preparation can also heavily contaminate the system.

If such conditions occur, the coolant circuit is to be flushed out with freshwater, repeatedly if necessary.

If these flushing sequences are insufficient or if the system is too heavily contaminated, the coolant circuit and all affected assemblies must be cleaned.

Only clean freshwater (no river or seawater) must be used for flushing.

Freshwater requirements are listed for
- Series 4000 in section 3.1.7 (→ Page 40) and
- Series 400 in section 3.1.8 (→ Page 41)

.

Only products approved by Rolls-Royce Solutions or equivalent products at the specified concentrations may be used for cleaning, see (→ Page 69). The specified cleaning procedure must be complied with.

Immediately after flushing or cleaning, fill the coolant circuits with prepared engine coolant as stipulated in the current Fluids and Lubricants Specifications. Otherwise there is a danger of corrosion!

Important

Fluids and lubricants (e.g. treated engine coolant), used flushing water, cleaning agents, and cleaning solutions can be hazardous materials. Certain regulations must be observed when handling, storing, and disposing of these substances.
These regulations are contained in the manufacturer's instructions, statutory requirements, and technical guidelines valid in the individual countries. Great differences can apply from country to country, and a generally valid statement on applicable regulations is therefore not possible within these flushing and cleaning specifications.
Users of the products named in these specifications are therefore obliged to inform themselves of the locally applicable regulations. Rolls-Royce Solutions accepts no liability whatsoever for improper or illegal use of the fluids and lubricants / cleaning agents which it has approved.

Important

Scrap oil heat exchangers from engines with bearing or piston seizures or friction damage.

Test equipment, auxiliary materials, and fluids and lubricants

mtu test kit or electrical pH value measuring instrument

Required auxiliary materials:
- Compressed air
- Superheated steam

Required fluids and lubricants:
- Freshwater
- Prepared engine coolant

4.1.2 Approved cleaning agents

Manufacturer	Product name	Working concentration		Order no.
For coolant systems:				
Kluthe	Hakutex 111 [1, 5)]	2% by volume	Liquid	X00065751
	Decorrdal 20-1 [8)]	10% by volume	Liquid	[7)]
	Hakupur 50-706-3 [4)]	2% by volume	Liquid	X00055629
For cooling circuit assemblies:				
Henkel	Bonderite C-AK FD [2)]	1 to 10% by weight	Powder	[7)]
	Bonderite C-MC 11120 [3)]	2 to 10% by weight	Powder	[7)]
Kluthe	Hakutex 60 mtu [9)]	100% by volume	Liquid	X00070585 (25 kg)
For coolant circuits contaminated with bacteria, fungi or yeast:				
Thor	Acticide MV14[6)]	0.01% by volume	Liquid	X00079756

Table 44: Approved cleaning agents

[1)] For light lime deposits, light corrosion

[2)] For lime deposits containing oil and grease

[3)] Preferred for heavy lime deposits

[4)] For oily and greasy residues. Not suitable for galvanized surfaces

[5)] Bacteria contamination up to 10^4

[6)] Bacteria contamination up to > 10^4, contamination with fungi and yeast

[7)] Not stocked by Rolls-Royce Solutions

[8)] With serious corrosion; not permitted for aluminum materials

[9)] Solvent cold cleaner for oily and greasy residues

Important
The technical data sheets and safety data sheets of the product must be observed!

The cleaning agents are available world-wide through the branches of the manufacturers or their trading partners.

4.1.3 Engine coolant circuits – Flushing

Use of Kluthe Hakutex 111:

If the pH value of the engine coolant used is below 7.5, the cooling system must be flushed completely. This serves to neutralize residual coolant in the system and to remove incipient corrosion or already existing residual corrosion.

Use of Hakupur 50-706-3:

For oily and greasy residues. Not suitable for galvanized surfaces

Series 4000

1. Drain engine coolant.
2. Measure pH value of the freshwater using the mtu test kit or electrical pH value measuring device.
3. Fill coolant circuit with freshwater.

Important

Never pour cold water into a hot engine!

4. Preheat, start, and run engine until warm.
5. Shut down the engine.
6. Take flushing water sample at engine-coolant-sample extraction cock.
7. Drain flushing water.
8. Measure the pH value of the flushing water sample and compare with the pH value of the freshwater.
   a) pH value difference < 1: Fill system with treated coolant and start engine.
   b) pH value difference > 1: Fill system with fresh flushing water and repeat flushing process.
   c) If the pH value difference is still > 1 after 4 to 5 flushing operations: The coolant circuit must be cleaned, see (→ Page 71). The assemblies may also have to be cleaned, see (→ Page 72).

Important

Refer to the Operating Instructions of the engine for additional information

Series 400

Important

The procedure for applications 1 to 6 must be observed in all circumstances. Flushing must not be interrupted.

Application duration of the cleaning agent Kluthe Hakutex 111 / Hakupur 50-706-3: max. 4 hours
Application temperature, normal coolant temperature approx. 95 °C
Application:

1. Remove old coolant from the coolant circuit.
2. Fill coolant circuit with added cleaning agent Hakutex 111 or Hakupur 50-706-3 (application concentration in table on (→ Page 69)).
3. Normal engine operation (max. 4 hour at normal coolant temperature = approx. 95 °C)
4. Remove cleaning agent.
5. Immediately after this: Flush engine coolant circuit twice with water.
6. Immediately after this: Fill the engine coolant circuit with NEW coolant in acc. with the Maintenance and Repair Instructions.

4.1.4 Engine coolant circuits – Cleaning

Series 4000

1. Mix cleaner to the specified concentration with freshwater. Use warm freshwater (45 °C) if the engine is warm.
2. In the case of powdered products, stir until the cleaning agent is completely dissolved and without sediment.
3. Fill prepared cleaning agent into coolant circuit.
4. Start engine and run until warm.
5. Select temperature and duration of 4 hours residence time at 96 °C acc. to manufacturer's specifications.
6. Shut down the engine.
7. Drain off cleaning agents and flush the engine coolant circuit with fresh water.
8. Take flushing water sample at engine-coolant-sample extraction cock.
9. Measure the pH value of the flushing water sample and compare with the pH value of the freshwater.
   a) pH value difference < 1: Fill system with treated coolant and start engine.
   b) pH value difference > 1: Clean assemblies, see (→ Page 72).

Important

Refer to the Operating Instructions of the engine for additional information

Series 400

Removal of serious corrosion and corrosion particles with Decorrdal 20–1

1. Drain all coolant from engine coolant circuit.
2. Fill engine coolant circuit with fresh water and flush the cooling system.
3. Drain flush water completely.
4. Fill coolant circuit completely with a water solution containing 10% Decorrdal 20-1.
5. Start engine and run to operating temperature, 20 minutes.
6. Perform cleaning cycle with the engine running, with circulating Decorrdal 20-1, duration: 4 hours
7. Vent the coolant circuit several times while running the cleaning cycle to ensure complete filling.
8. Allow the engine to cool down to approx. 45 °C.
9. When the temperature reaches 45 °C, drain Decorrdal 20-1.
10. 1st flushing cycle: Immediately after draining, fill the coolant circuit with approved antifreeze and corrosion inhibitor ready mixture, chap. 3.4.1 (→ Page 72).
11. Operate the engine for 30 minutes, vent the coolant circuit several times.
12. Allow the engine to cool down to approx. 45 °C.
13. Drain the flushing solution, antifreeze and corrosion inhibitor ready mixture.
14. 2nd flushing cycle: After drain, fill the coolant circuit once again with approved antifreeze and corrosion inhibitor ready mixture, chap. 3.4.1 (→ Page 72).
15. Operate the engine for 30 minutes, vent the coolant circuit several times.
16. Allow the engine to cool down to approx. 35 °C.
17. Drain flushing solution.
18. Fill engine with coolant.
19. Rust removal is complete.
20. Put engine into operation

Important

The engine coolant circuit must always be vented properly to ensure complete filling. This applies when filling the engine with water, cleaning agent, corrosion inhibitor and coolant as well as in engine operation with one of the mentioned media.
In zones where air is present, neither rust removal nor preservation take place, and corrosion occurs again.
All crankcase openings, hose connection openings, etc. must be closed immediately if no longer required.
There is a risk of corrosion in the area of the openings.

4.1.5 Engine coolant circuit assemblies – Cleaning

1. Remove, disassemble and clean assemblies in the engine coolant circuit that are exposed to heavy sludge deposits e.g. expansion tanks, preheating units, heat exchangers (coolant cooler, oil heat-exchanger, inter-cooler, charge-air preheater, fuel preheater etc.) and lower sections of pipework.
2. Before cleaning, examine degree of contamination on water sides.
3. In case of lime deposits that contain oil and grease, degrease the water side first.
4. Deposits in intercoolers caused by oil mist can be removed using Kluthe Hakutex 60.
5. Remove hard lime deposits with a decalcifying product. In the event of stubborn lime deposits, if necessary a 10% inhibited hydrochloric acid solution may have to be used.
6. Dissolve deposits on and in heat-exchanger elements in a heated cleaning bath. Observe the manufacturer's specifications and use only approved cleaning agents in the permissible concentration, see (→ Page 69)

   Important

   Deposits on the oil side can also be dissolved in a kerosene bath.
   The dwell time in the cleaning bath depends on the type and degree of contamination, as well as the temperature and activity of the bath.

7. Clean individual components such as housings, covers, pipes, sight glasses, heat-exchanger elements with superheated steam, a nylon brush (soft) and a powerful water jet.

   Important

   In order to avoid damage:
   Do not use hard or sharp-edged tools (steel brushes, scrapers, etc.) (oxide protective layer).
   The pressure of the water jet must not be ≤ 60 bar (to avoid damage, e.g. of the cooler fins).

8. After cleaning, blow through the heat exchanger elements with low-pressure steam in the direction opposite to operational flow, rinse with clear water (until pH value difference is < 1) and blow dry with compressed or hot air.
9. Check that all components are in perfect condition, repair or replace as necessary.
10. After installing all assemblies, flush engine coolant circuit once, see (→ Page 29).
11. Check coolant system for leaks during initial operation of engine.

    Important

    Refer to the Maintenance Manual of the engine concerned for more information

4.1.6 Coolant circuits contaminated with bacteria, fungi or yeast

Disinfection and prevention

Microbiologically contaminated systems:

The disinfecting agent is added to the contaminated coolant.

The prerequisite for effective disinfection of the engine coolant system is that the disinfecting agent has a sufficiently long reaction time and can reach all areas of the cooling system. All external storage tanks and pipes must also be reached by the disinfecting agent.

Dwell time:	Not less than 12 hours
Temperature:	Maximum temperature 55 °C (higher temperatures destroy the disinfecting agent)

Prevention:

If an engine is to be shutdown for a long period, disinfecting agent can be added as a preventive measure. Before the engine is put back into operation, always ensure that the coolant is still in good condition. During return to operation, the coolant containing disinfecting agent can remain in the system and be reused.

The dosing (→ Page 69) and work safety specifications must be strictly observed.

Flushing

When the coolant is drained, the cooling circuit must be flushed with freshwater. The coolant circuit must be flushed as long as visible contamination can be detected and the flushing water has the same pH value as the fresh water used (maximum deviation of pH value < 1).

Refill

Before refilling with coolant, ensure that the cooling system is free of contaminants.

Refilling must be performed directly after flushing to avoid the risk of corrosion!

4.2 Flushing and Cleaning Specifications for Series 500 Engines

4.2.1 General information

Only clean freshwater (no river or seawater) must be used for flushing.

Only the P3 Standard cleaning agents must be used for cleaning, see (→ Page 75). The specified cleaning procedure must be complied with.

Freshwater requirements are listed for
- Series 500 in section 3.1.9 (→ Page 42)

.

Immediately after flushing or cleaning, fill the coolant circuits with prepared engine coolant as stipulated in the current Fluids and Lubricants Specifications. Otherwise there is a danger of corrosion!

Important

Fluids and lubricants (e.g. treated engine coolant), used flushing water, cleaning agents, and cleaning solutions can be hazardous materials. Certain regulations must be observed when handling, storing, and disposing of these substances.
These regulations are contained in the manufacturer's instructions, statutory requirements, and technical guidelines valid in the individual countries. Great differences can apply from country to country, and a generally valid statement on applicable regulations is therefore not possible within these flushing and cleaning specifications.
Users of the products named in these specifications are therefore obliged to inform themselves of the locally applicable regulations. Rolls-Royce Solutions accepts no liability whatsoever for improper or illegal use of the fluids and lubricants / cleaning agents which it has approved.

Important

Scrap oil heat exchangers from engines with bearing or piston seizures or friction damage.

Test equipment, auxiliary materials, and fluids and lubricants

mtu test kit or electrical pH value measuring instrument

Required auxiliary materials:
- 2 x 200 l steel barrel
- Hose for bypass as plate-core heat exchanger
- Spare flushing barrel
- 1-10 or 1-5 softening cartridge for water conditioning

Required fluids and lubricants:
- Freshwater

4.2.2 Approved cleaning agents

Approved cleaning agents

Cooling system cleaning agents: P3 Standard, non-foaming powder.

25% phosphoric acid cartridge.

Important
The technical data sheets and safety data sheets of the product must be observed!

The cleaning agents are available through the branches of the manufacturers or their trading partners.

4.2.3 Engine cooling system – Cleaning

Draining engine coolant

1. Connect fresh water hose on the thrust side of the engine coolant pump and connect to engine coolant pump.
2. Connect hose with waste water hose to intake side of engine coolant pump and place in a barrel.
3. Drain old water-glycol mixture and dispose of in accordance with the manufacturer's specifications.
4. Remove plate-core heat exchanger and replace with a bypass.
5. If the plate-core heat exchanger is seriously contaminated (pressure loss > 500 mbar), remove it (see step 4). Replace the old plate-core heat exchanger with a cleaned or new plate-core heat exchanger.

Preflushing engine coolant circuit

Note:
- Engine is not was started.
- Never pour cold water into a hot engine (> 60 °C)!

1. Preflush engine coolant circuit with fresh water.
2. Flush out coarse dirt particles.
3. Drain water.

Mixing in cleaning solution

Note:
- Plant is filled with demineralized water.
- The water must be softened. For softening, a water conditioning cartridge must be cut in through which the fresh water is directed.
- If hard water is used for flushing, there is a danger from a temperature of < 60 °C that limescale falls out and irreparably clogs the heat exchanger.

1. Fill the mixing barrel until half full.
2. Provide a flushing barrel.

Note:
- Do not allow the coolant pressure in the engine to exceed 1.5 bar.
- Regulate the pressure via the inlet and supply volume.

.

3. Allow the water from the plate-core heat exchanger in the engine circuit to drain via the hose into the barrel.
4. Extract water with electric pump out of barrel and add again to the engine circuit behind the plate-core heat exchanger.
5. Start engine and run at 60% power up to operating temperature.
6. Add the P3 solution in steps via the flushing barrel until a pH value of approx. 13 is reached.
7. Run the CHP at 60% power for approx. one hour.
8. Switch off engine.
9. Drain P3 solution and replace with fresh, demineralized water until a pH value of 10 is reached.
10. Start the CHP.
11. Close all valves that lead to the flushing barrel.
12. Run the CHP at 60% power over night.
13. Pump off P3 solution.
14. Neutralize in the flushing barrel with 25% phosphoric acid until a pH value of 7 is reached.

Flushing out cleaning solution

1. Flush out cleaning solution with the plant in operation.
2. Reflush with approx. 2 m^3 water.

Refill

Note: If necessary, install plate-core heat exchanger.

1. Fill fresh water-glycol mixture.
2. Document pressure losses in the plant folder.

5 Cleaning the Product Externally

5.1 General information

Important
The Series 400 / 500 and 4000 gas engines must not be cleaned with pressure jet devices.

6 Fuels

6.1 General Information

6.1.1 Fuels – Usage

Important

The specified limit values for moisture in the fuel must be observed because otherwise the warranty shall become void.

Important

The fuel must not contain any compounds which are highly corrosive and cause abrasive wear (e.g. water condensate, siloxanes, phosphor, arsenic, heavy metal, sulfur, ammonia, chlorine, fluorine, bromide and iodine compounds).
Exceeding of the limit values can result in a safety hazard and lead to limitations on warranty claims.

Gas engines must only be operated with the gases approved for the respective gas engine type.

The use of natural gas containing hydrogen for operation of gas engine-generator sets from Rolls-Royce Solutions is limited exclusively to the supply from public gas distribution systems. Local admixing of hydrogen from systems belonging to the operating company, or systems that are not part of the public gas supply, leads to the voiding of guarantee and warranty claims.

For operation with natural gas from the public grid, the following must be confirmed by the responsible gas utility company prior to commissioning of the engine at the latest:
- Whether the minimum methane number and calorific value range specified on the respective data sheet are observed.
- Whether butane or a propane-air mixture are added at times.
- Whether biogas feeding into the natural gas grid is also possible (coordinate through factory request). A gas analysis must be available.
- Whether hydrogen infeed to the natural gas grid takes place, and the possible bandwidth and frequency at which the hydrogen admixing takes place.

To assure trouble-free operation, the gases used must be checked and documented with regard to
- composition and
- harmful elements in the gas

at regular intervals, but at least semi-annually. The performance of complete gas analyses is recommended if the gas supplier is changed or if changes in the gas supply have been announced.

In the entire application and operating range of the engine, the use of fuels is restricted to purely gaseous fuels. Liquid fuels are not permitted.

The fuel must be technically free of mist, dust and liquid. Condensation in the gas system must be prevented by suitable measures (dehumidification, protection against cooling down, heating, etc.). Corrosive elements must only be present in the concentrations listed below in the following chapters of the series Marine S4000, Genset S4000 / S400 and S500).

If the quality of the raw gas exceeds the sulfur limit values, a gas desulferization system that is designed for the quality of the gas must be installed.

6.1.2 Main constituents of natural gas and fuel gases of biogenic origin

Generally applicable limits for the main constituents of natural gas and fuel gases of biogenic origin

Natural gas is a naturally occurring gas that consists mainly of methane (70 to 98 mass percent). The remaining components, such as ethane, propane, butane, pentane and the share of inert gases nitrogen and carbon dioxide, vary according to the place of extraction. Free hydrogen is not usually present in natural gas sources or in biogenic deposits. If only traces are found, it is usually bound to sulfur as hydrogen sulfide. Any hydrogen sulfide that is present will be removed during desulfurization.

Components that may be used for gas engines are listed in the following tables:
- Generally applicable limits for the main constituents of natural gas (→ Table 45)
- Generally applicable limits for the main constituents of fuel gases of biogenic origin

Typical main constituents of natural gas, pipeline gases

Component	Unit	Value range (maximum value)
CH_4	vol%	80 to 100
C_2H_6 (or sum of C_2H_x)	vol%	< 12
C_3H_8 (or sum of C_3H_x)	vol%	<9
C_4H_{10} (or sum of C_4H_x)	vol%	< 2
C_5H_{12}	vol%	<0.3
Hydrocarbons C5+	vol%	< 0.1
CO_2	vol%	< 10[*)]
N_2	vol%	<15
Sum of CO_2 + N_2	vol%	<15
O_2	vol%	< 3[**)]
H_2	vol%	No information
CO	vol%	<0.2
Contents of CO_2 and O_2 in gases in the gas supply connected to the pipeline are usually considerably lower than described above (see DIN EN 16726).		

Table 45: Typical main constituents of natural gas, pipeline gases

The above-listed components apply to natural gas compositions in the application for gas engines from Rolls-Royce Solutions GmbH. Components other than those listed above (as well as trace elements) are not permitted for natural gas compositions.

Knock resistance of gas compositions

The knock resistance of the gas composition is characterized by its methane number. Here, the methane number is a measure for the knock characteristics of a gaseous fuel gas composition. It specifies the percentage of substance amount of methane in a methane-hydrogen mixture which, in a test engine under standard conditions, has the same knocking behavior as the gaseous fuel to be tested. The knock resistance is calculated for the gas compositions based on the standardized procedures described in EN 16726.

Main components of fuel gases of biogenic origin, mainly from fermentation processes (values are specified air-free)

Component	Unit	Value range (maximum value)
CH_4	vol%	40 to 85
CO_2	vol%	20 to 55
N_2	vol%	< 10
O_2	vol%	< 3
H_2	vol%	< 2
CO	vol%	<0.2

Table 46: Main components of fuel gases of biogenic origin, mainly from fermentation processes (values are specified air-free)

The above-listed components apply to fuel gases of biogenic origin. Components other than those listed above (as well as trace elements) are not usual for such gas fuels.

If the components of the natural gas exceed the listed maximum values, consultation must be made with Rolls-Royce Solutions before using this biogas.

6.1.3 Natural gas/hydrogen mixtures

Natural gas/hydrogen mixtures

The public natural gas grid should be used in future as an additional energy accumulator for hydrogen. As a result, band widths of hydrogen, which have not yet been more closely regulated, can be available in a natural gas mixture for application in the engine.

Based on the considerable differences in the technical combustion-related properties of hydrogen and the natural components of the natural gas, an adverse effect on engine operation through the addition of hydrogen can be anticipated. This relates, in particular, to emission behavior and knock resistance.

With lower hydrogen shares up to 10% by volume, the influence is low and, in many model types, can be compensated for by suitable engine parameter adjustment.

The hydrogen content of natural gas for the operation of gas engines from Rolls-Royce Solutions is currently limited to a constant hydrogen content. The setting for hydrogenous natural gas is made by a corresponding parameter adjustment of the engine controller. The permissible hydrogen shares and fluctuation ranges are engine-specific and, depending on the emission setting, can be obtained from the corresponding technical contractual documents.

With higher hydrogen contents, nonlinear changes of the fuel parameters can generally be taken into consideration:

- Lowering of the volumetric calorific value via the admixing rate
- Lowering of the density via the admixing rate
- Extended ignition range (OEG = upper explosion limit)
- Change of the explosion pressure ratio over the admixing rate in particular to lean fuel-air mixtures
- Lowering of the ignition energy requirement depending on the set combustion air ratio and the H2 admixing rate
- Knock resistance reduction depending on the admixing rate.

Normal natural gas compositions are in the range of 65-90 methane numbers. When admixed to the natural gas, hydrogen reduces the knock resistance almost directly proportionally to the volumetric mixing ratio. At the same time, the gradient for lowering of the methane number as a function of the H_2 admixing rate depends heavily on the knock resistance of the basic composition of the natural gas. The lower the methane number of the basic composition, the flatter the methane number gradient in relation to the hydrogen rate, see Figure 1.

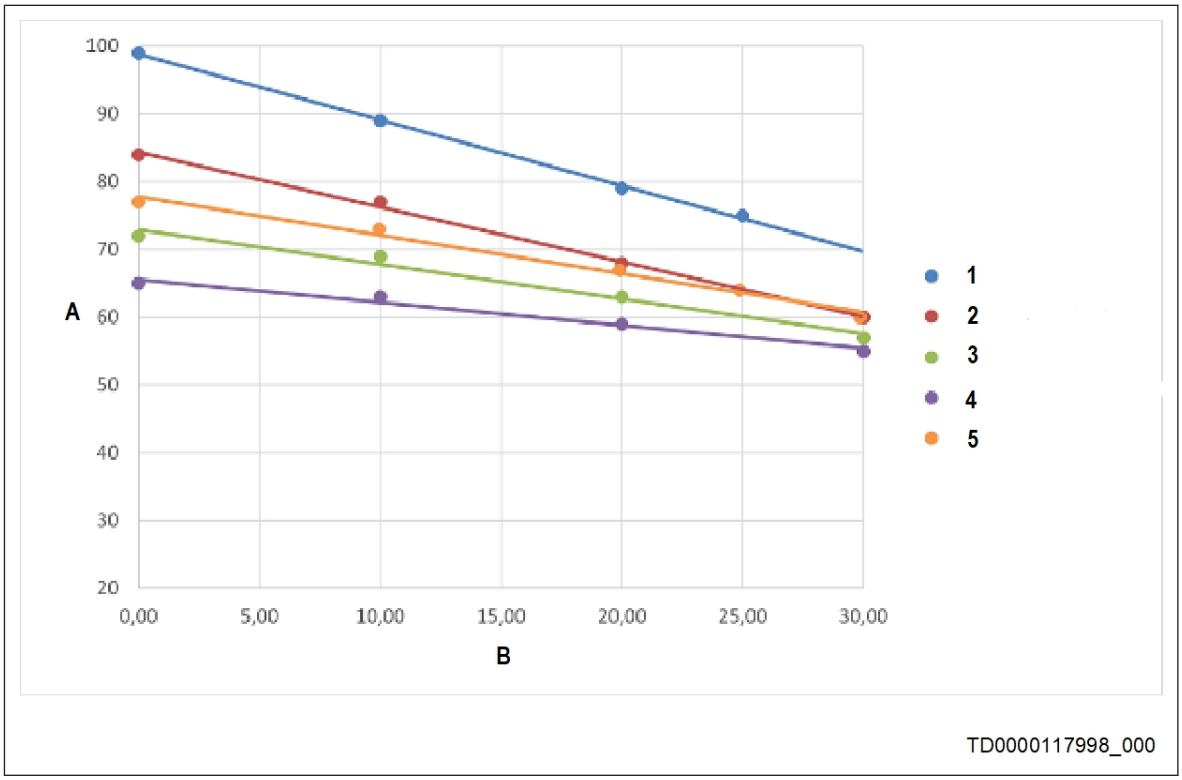

Figure 1: Methane number (acc. to DIN EN 16726 calculation method) of natural gas-hydrogen mixtures for different natural gas qualities

A Methane number MN [--]

B H_2–content in fuel gas [Vol.%]

1 Methane CH_4 MN 100

2 Netherlands MN 84

3 Norway MN 72

4 USA Shale Gas MN 65

5 Egypt MN 77

The lowering of the methane number can lead to adaptations of the maximum power of the engine through knock monitoring of the engine. Knock monitoring/control during engine operation with natural gas compositions containing hydrogen has absolute priority over other engine settings to prevent combustion knock. With sustained knocking events, engine power is reduced or the engine is shut down.

If there are significant H_2 shares in the fuel gas, with an increasing hydrogen share the exhaust gas temperatures decrease, which also leads to a reduction in the enthalpy supplied to the exhaust turbine. A direct consequence of this is a decreased exhaust gas temperature downstream of the exhaust turbine and a lower level of useful exhaust gas heat recovery and possibly also a reduction in the charge-air reserve. Depending on the model type and site conditions, the max. ramp speed can have a negative effect on load acceptance or the load stages.

More exact details on the effects of fluctuations of the hydrogen content in natural gas must be requested project-specifically.

6.1.4 Liquid Natural Gas (LNG)

Notes on Liquid Natural Gas (LNG)

Note that the LNG Bunker Delivery Note in the IGF Code specifies component fractions as mass percent. The representation deviates significantly from other common representations in Mol or volume percent.

LNG tanks may only be filled with LNG to 90% of their overall volume. Any additional heat in the tank causes small amounts of liquid gas to vaporize and accumulate as gas in the “boil-off” phase. The composition of this boil-off gas depends on the composition of the liquid phase. The N_2 component in the boil-off phase may by 20x greater than the nitrogen content in the liquid phase. In general, boil-off gas can contain 20 % by volume nitrogen and 80 % by volume methane as well as traces of ethane.

LNG as per EN1160 has a lower methane limit mass fraction of 75% and an upper nitrogen limit mass fraction of 5%.

The use of LNG with a nitrogen content of <1 m/m% is recommended to avoid rollover effects.

The term “rollover” is used to describe vaporization and the subsequent increase in pressure this entails as a result of stratification and the rapid mixing of superheated liquid from the lower layer with the upper layer under the hydrostatic head exerted by the latter.

LNG contains no significant, or only traces of CO_2, as CO_2 solidifies at temperatures below -56 °C and the pressures around 5.2 bar which generally prevail in such tanks. CO_2 sublimates at -78.5 °C under normal pressure conditions.

6.1.5 Silicon and sulfur compounds in the fuel gas

Silicon compounds in the gas lead to deposits and promote wear. Even catalytic converters are deactivated by these compounds. Damage caused by silicon and sulfur compounds is not covered by the warranty.

For determination of the Si concentration in the lube oil and its limit value, refer to chapter Lubricants (→ Page 11).

Determination of silicon concentration and sulfur content in the fuel gas from gas analysis

To determine the silicon or sulfur concentration, the measured concentrations or the sulfur content of the individual compounds are multiplied by the Si or S mass fractions.

The result is based on the calorific value of the fuel gas and standardized at 10 kWh energy content (equals 1 m^3 NTP CH_4).

Measured silicon share from the gas analysis (or sulfur concentration)

Concentration of silicon in sewage gas	K Si	5.1 mg/m^3 NTP
CH_4 content of the sewage gas	K CH_4	65% by volume
Calorific value – sewage gas	Hi_n	6.5 kWh/m^3 NTP

Example: Calculated concentration of silicon limited to Hi_n = 10 kWh/m^3NPT

$$K_{Si}\ 10\ (mg/m^3 i.N) = K_{Si\ measured} \quad x \quad \frac{Hi_{n\ measured}}{10\ (kWh/m^3 NTP)} =$$

$$5.1\ (mg/m^3\ NTP) \quad x \quad \frac{10}{6.5} = 7.8\ (mg/m^3\ NTP)$$

See section 2.1.4 (→ Page 11) for determination of the silicon compounds in the fuel.

6.2 Series 4000 gas engine – Marine application

6.2.1 General information

Important

There is no warranty in case of impairments and / or damage (corrosion, contamination, etc.) caused by gases or substances whose existence was not known or agreed upon at the time of signing the contract.

6.2.2 Requirements of fuel gas for marine applications

Requirements and boundary conditions for mtu gas engines in marine applications

Designation	Unit	Limit value	Comment
Type of gas			Natural gas Applies to natural gas H, other gases are currently not approved.
Methane number	--	≥70: Engine configuration for standard water content in intake air ≥75: Engine configuration for high water content in intake air	Adjustments may prove necessary depending on model type, power and fuel consumption. Observe the Operating Instructions (Technical data). Consult with the manufacturer before operating with lower values as a gas analysis is required in such case. Reduction of engine power through knock monitoring Methane number calculated in accordance with DIN EN 16726.
Calorific value Hi,n	kWh/m^3 $_n$	9.2 <Hi,n < 11.5	Consult the manufacturer before operating with lower or higher limit values.
Wobbe index WI i,n[1), 2)]	kWh/m^3 $_n$	11.77 <WI i,n <14.18	The Wobbe index is related to the calorific value. The Wobbe index values must be respected.
Admissible rate of calorific value change[1)]	kWh/m^3 $_n$/min	0.067	Constant linear change necessary with a frequency of 1/h
Gas density[2)]	kg/m3n	0.73 to 0.84	The gas density can vary according to the composition; for a specific gas type it is constant. When using gas from different gas supply areas, the density may vary.
Minimum gas pressure upstream of gas regulation unit	bar(g)	1	Relevant for idle and low-load operation Consult the specifications for the gas train of the relevant project / engine type.
Permissible range for gas pressure before the gas train for full engine power and acceleration capacity	bar(g)<supscrpt />	6.0 ... 10.0	Consult the specifications for the gas train of the relevant project / engine type.
Gas pressure deviation from setpoint	bar	±0.5	The setting value for gas pressure upstream of the gas train must not be undershot.
Permissible change speed of gas pressure upstream of gas train	bar/s	0.3	Constant change rate for transient and steady state engine condition.

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Designation	Unit	Limit value	Comment
Gas temperature	°C	10 … 40	Condensation of water vapor at <10 °C, thermal aging of NBR materials (seals, diaphragms) and impact of higher temperatures on elasticity Minimum temperatures also apply to the starting sequence. Consult the specifications for the gas train of the relevant project / engine type. Consult the manufacturer before operating with lower or higher temperatures.
Admissible rate of gas temperature change	K/min	10	
Water: dew point	°C	0	At operating pressure No water vapor condensation in pressure and temperature range Gas must be dried if values are higher. Value valid for whole gas temperature range
Oil vapors (HC with carbon number >5)	mg/m^3_n	< 10	No condensation in lines carrying fuel gas and fuel gas-air mixture No formation of condensable oil mists
HC solvent vapors	mg/m^3_n	0	Analysis and consultation with manufacturer is required
Organically-bound silicon (e.g. hydrosilicons, siloxanes, silicons)	mg/m^3_n CH_4	< 1.0	Analysis and consultation with manufacturer is required
Inorganically-bound silicon	mg/m^3_n	< 5	With Si > 5 mg/m^3N based on 100% CH_4 fuel gas content, wear products must be taken into consideration during the oil analysis.
Dust 3 to 10 µm	mg/m^3_n	< 5	DVGW worksheet G260
Dust < 3 µm	mg/m^3_n	Analysis	Analysis required
Hydrogen sulfide	mg/kg	7	DIN 51624
Total sulfur	mg/kg	10	DIN 51624
Chlorine (Cl)	mg/m^3_n		Technically free Consult the manufacturer in case of higher values and an analysis is required
Fluorine (F)	mg/m^3_n		Technically free Consult the manufacturer in case of higher values and an analysis is required
Ammonia (NH_3)	mg/m^3	10[3)]	Consult the manufacturer in case of higher values and an analysis is required

Table 47:

[1] = Calorific value
The amount of heat which would be released by complete combustion of a given amount of gas in air, whereby the pressure p at which the reaction takes place remains constant and all combustion products return to the same temperature t as that of the reactants. All these combustion products are in gaseous form.
The standard enthalpy of calorific value and Wobbe index specified here are referenced to a temperature of 25 °C. Please note that reference temperatures of 15 °C are commonly used in US publications.
Base conversion to other reference temperatures on EN ISO 6976 or EN ISO 14912.

[2] = Volumetric quantities are based on the standard state specified in DIN 1343. The standard state is the reference state defined by standard temperature T_n = 273.15 K or t_n = 0 °C and standard pressure p_n = 101325 or Pa = 1.01325 bar.
Please note that the standard enthalpy references for heating and calorific values and Wobbe index are based on 15 °C in US publications and more recent standards such as DIN EN 16726, and that volumetric quantities are defined by the standard temperature T_0 = 288.15 K or t_0 = 15 °C and standard pressure p_n = 101325 or Pa = 1.01325 bar.

[3] = The limit values are based on a calorific value of 10 kWh/$m^3{}_n$. This corresponds to a reference to fuels with 100% by vol. methane, or the existence of other combustible components in the fuel with the same energy equivalent and the same input of hazardous materials.

6.2.3 Specifications for the medium in the gas piping leak chamber for marine applications

General

IGF 5.5.2 stipulates that all piping bearing fuel gas routed in engine rooms complying with the "safe machinery concept" shall feature a double-wall or jacketed design. This leak chamber surrounding the fuel piping shall facilitate the detection of leaking fuel gas by means of a suitable medium and appropriate measuring technology. The IGF code basically envisages two ways of accomplishing this:

1. Purging/ventilating the leak chamber with air
2. Pressurizing the chamber surrounding the fuel pipe with an inert gas at a higher pressure than that of the fuel gas.

The gas system of the mtu marine engine is designed for operation in either of these scenarios. The gas train itself can only be used in conjunction with the air purging concept. The media in the leak chamber surrounding the gas piping are specified as follows:

1. Air purging concept

Designation	Unit	Limit value	Note
Medium type		Air	Intake from outside the vessel via a separate air tract
Medium temperature at engine inlet	°C	0-50	
Humidity (abs)	$g_{water}/kg_{dry\ air}$	37.7	
Saline content in intake air	ppm	50	
Volumetric flow	m^3/h	11.5 - 30	The lower limit value is based on the max. volume including gas train and supply pipework. The lower limit value ensures the minimum air change rate per hour. The upper limit value should not be exceeded to avoid excessive pressure loss.

Table 48:

2. Pressurized inert gas concept

Designation	Unit	Limit value	Note
Medium type		Nitrogen	Nitrogen from a generator or cylinders
Medium temperature at engine inlet	°C	0-80	
Water content	vol.‰	≤ 50	Nitrogen value 2.8
Nitrogen purity	% by vol.	≥99.8	Nitrogen value 2.8
Oxygen content	vol.‰	≤100	Nitrogen value 2.8
Medium pressure range	bar (abs)	< 11	

Designation	Unit	Limit value	Note
Chamber volume on engine (excl. gas train) (jacketing)	m^3_N	0.079 - 0.095	
Leakage	$g_{nitrogen}/h$	3 - 5	Facilitates specification of refilling volume/intervals

Table 49:

Detailed information on integration in the gas system and design concepts for monitoring and arranging the various components are provided in the Safety Concept, schematic drawings and installation specifications.

6.3 Series 4000 gas engine – Generator application and engine-generator set

6.3.1 General information

Important

There is no warranty in case of impairments and / or damage (corrosion, contamination, etc.) caused by gases or substances whose existence was not known or agreed upon at the time of signing the contract.

Correction of the methane number with regard to inert gas content

Inert gases carbon dioxide, oxygen and nitrogen are included in the calculation of the methane number (gas analysis). However, only carbon dioxide is assessed as knock-reducing in the programs according to EN 16726.

For Series 400 gas engines charged for a lean mixture, it has been shown that a correction of the methane number is necessary if larger shares of carbon dioxide (CO_2 content > 2.5% by vol.) are present in the fuel gas. Below a CO_2 content of 2.5% by vol., a correction of the methane number is not required. For gas engines from Rolls-Royce Solutions charged for a lean mixture, during the recalculation of the methane number with the named programs the CO_2 content of the gas composition must be reduced by 85%:

$x_{CO2\text{-}corr} = (x_{CO2} - 2.5) * 0.15 + 2.5$

This share of CO_2 is added in the program input to the nitrogen, which has no knock-reducing effect in the methane number calculation.

$x_{N2\text{-}corr} = (x_{CO2} - 2.5) * 0.85 + x_{N2}$

6.3.2 Natural gas – Requirements of the fuel gas

Requirements for fuel gas

Designation	Unit	Limit value	Comment
Natural gas group H Mixtures of natural gas H with constant hydrogen content			methane-rich, high-calorific gases of group H (DVGW G260:2021), and mixtures of natural gas H with constant hydrogen content
Wobbe index Ws,n	kWh/m³ NTP	13.4 ≤ Ws,n ≤ 15.7	
Natural gas group L, coal bed methane			methane-rich, low-calorific gases of group L (DVGW G260:2021), methane-rich coal bed methane from undeveloped coal deposits (premining coal bed methane)
Wobbe index Ws,n	kWh/m³ NTP	11≤ Ws,n ≤ 13.4	
Maximum hydrogen content in the fuel gas mixture	vol%	10	Applies to mixtures of natural gas H with constant hydrogen content. Changes within the maximum admixing rate are adapted by suitable parameter settings during commissioning. Mixtures of hydrogen and low-calorific methane-rich gases (e.g. natural gas L or coal bed methane) are currently not approved, even for hydrogen content < 10% by volume, without a change in the series equipment and without consultation with Development.
Maximum H_2 mixture tolerance from the setting value	vol%	No information	Fluctuation ranges are limited engine- and emission-specifically. See Technical data
Methane number	MN	≥ 65	See Technical data With a methane number lower than that specified in the technical data sheet, engine power is reduced.
Methane number change	-/min.	5	Linear constant change with a frequency of max. 1/h
Calorific value Hi,n	kWh/m³ NTP	8.0 < Hi,n < 11.0	Consult the manufacturer in case of lower or higher values.
Calorific value deviation from the setting value	%	± 5**	Consultation with manufacturer required for higher values.

*** = For engines with exhaust gas aftertreatment and/or exhaust gas heat recovery, lower limit values may apply. When using oxidation catalysts, analysis and consultation with Rolls-Royce Solutions are required**
**** = For the optional operating mode Energy balancing mode with quick-start feature 120 seconds*, a limit value of ± 3% from the setting applies.**

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Designation	Unit	Limit value	Comment
Setting range of the gas flow pressure pF	$mbar_{(rel)}$	80 ≤ pF ≤ 250	The gas flow pressure before the gas dosing device is an engine- and plant-specific variable. The gas flow pressure is constant. The setting value of the gas flow pressure can be obtained from the Technical data for engine and system.
Admissible change rate of calorific value in relation to set value	%/min.	1.0	Linear constant change necessary with a frequency of maximum 1/h
Gas density	kg/m³ NTP	0.73 to 0.84	The density of the gas may fluctuate depending on composition; it is constant for a certain type of gas. When using gas from different gas supply areas, the density may vary. When changing to a different gas supplier it may be necessary to adjust the mixture control.
Gas pressure deviation from the setting value	%	± 5	
Admissible gas pressure change rate	mbar/min.	1	Constant change required
Gas temperature Natural gas from the public gas supply grid Natural gas from LNG evaporator plants	°C	5 < T < 45 15 < T < 45	If there is a danger of undershooting the dew point, the gas temperature must be increased. In case of deviating temperatures, there is a danger of thermal aging of NBR materials (seals, diaphragms) and impact on elasticity. Certain pressure and calorific value combinations may restrict the temperature range. This can be compensated by pressure adjustment to guarantee operation at rated load over the complete temperature range. On plants with LNG operation, the permissible temperature range must be coordinated project-specifically. The gas evaporation system design must be analyzed on the part of Rolls-Royce Solutions for this purpose.
Gas temperature deviation from the setting value	°C	± 9	
Admissible rate of gas temperature change	K/min.	0.3	

*** = For engines with exhaust gas aftertreatment and/or exhaust gas heat recovery, lower limit values may apply. When using oxidation catalysts, analysis and consultation with Rolls-Royce Solutions are required**
**** = For the optional operating mode Energy balancing mode with quick-start feature 120 seconds*, a limit value of ± 3% from the setting applies.**

Designation	Unit	Limit value	Comment
Relative moisture in gas in the permissible temperature and pressure range Max. moisture in gas, absolute	% g/kg	< 80 < 20	In the entire gas and mixture system no condensation is permitted No water vapor condensation in pressure and temperature range No condensation permitted in lines and containers carrying fuel gas and fuel gas-air mixtures
Oils / oil fumes (HC with carbon number >8)	mg/m³ NTP	< 0.4	No condensation in lines carrying fuel gas and fuel gas-air mixture, nor formation of condensible oil mists
Long-chain hydrocarbons (C_6 - C_n)	mewl %	No information	Consultation with Rolls-Royce Solutions required
HC solvent vapors	mg/m³ NTP	0	Consultation with manufacturer and analysis necessary
Organically bound silicon	mg/m³ NTP	< 1.0	
Inorganically bound silicon	mg/m³ NTP	< 6	At Si > 5 mg/m³ NPT based on 100% CH_4 fuel gas content, wear products must be noted in the oil analysis.
Dust 3 to 10 µm	mg/m³ NTP	5	DVGW worksheet G260 Dust must be removed in such a manner that trouble-free operation of standard-conformant, or standard design gas devices and gas equipment, is ensured.
Dust < 3 µm	mg/m³ NTP	Technically free	Dust < 3 µm must be evaluated through a technical analysis, if necessary appropriate special filters must be used.
Total sulfur	mg/m³ NTP	30	DVGW worksheet G260
Mercaptan sulfur	mg/m³ NTP	6	DVGW worksheet G260
Hydrogen sulfide (H_2S)	mg/m³ NTP	5	DVGW worksheet G260
Chlorine (Cl)	mg/m³ NTP		technically free Consult the manufacturer in case of higher values as analysis is necessary.
Fluorine (F)	mg/m³ NTP		technically free Consult the manufacturer in case of higher values as analysis is necessary.
Ammonia (NH_3)	mg/m³ NTP	10*	Consult the manufacturer in case of higher values as analysis is necessary.
* = For engines with exhaust gas aftertreatment and/or exhaust gas heat recovery, lower limit values may apply. When using oxidation catalysts, analysis and consultation with Rolls-Royce Solutions are required ** = For the optional operating mode Energy balancing mode with quick-start feature 120 seconds*, a limit value of ± 3% from the setting applies.			

Table 50: Requirements and site conditions for natural gas fuel and the corresponding fuel supply

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All listed limit values for pollutants (in ppm and mg/m^3) are based on a calorific value of 10 kWh/m^3 NTP. This corresponds to a reference to fuels with 100% by vol. methane, or the existence of other combustible components in the fuel with the same energy equivalent and the same input of hazardous materials.

Example:

- Russian natural gas with a calorific value of 10 kWh/m^3 NTP is used. The permissible value for total sulfur in the gas thus corresponds exactly to the limit value specified in the table.
- When using a gas (e.g. East Hanover) with Hi,n = 8.15 kWh/m^3 NPT, the permissible maximum value for the total sulfur is calculated as follows:
  Permissible total sulfur content = 30 mg/m³ NPT · (8.15 kWh/m^{3}NPT: 10.0 kWh/m^3 NPT) = 24.5 mg/m³ NPT

6.3.3 Biogas – Requirements for fuel gas

Biogas fuel requirements

Designation	Unit	Limit value	Comment
Type of gas		Biogenic gases from fermentation processes	
Methane number	--	≥ 108	If undershot, danger of combustion knock. Gas analysis and consultation with the factory required
Nitrogen	vol%	≤ 5	Consult the manufacturer is exceeded
Calorific value Hi,n	kWh/m³ NTP	4.5 < Hi,n < 8.0	Consult the manufacturer in case of lower or higher values.
Calorific value deviation from the setting value	%	± 20	Consultation with manufacturer required for higher values.
Setting range of the gas flow pressure pF	$mbar_{(rel)}$	–	See Technical data
Maximum rate of change in the calorific value in relation to the setting value in operation	%/min.	1	<1/ h is permissible in normal operation
Fast change in calorific value during starting and start-up processes	%/min.	<10.0	with a frequency of <1/ h is permissible
Gas density	kg/m³ NTP	0.93 to 1.40	The gas density can fluctuate according to the composition. If there are changes to the main substrate and/or significant changes in the mixing ratio of the substrates, a gas analysis or, if necessary, an adaptation of the mixture control is required.
Gas pressure fluctuation in relation to setting value	%	± 10	This applies to the gas inlet at the gas control valve on the engine side.
Admissible gas pressure change rate	mbar/min.	1	This applies to the gas inlet at the gas control valve on the engine side.
Gas temperature	°C	5 < t < 45	Phase transitions in the fuel gas-air mixture during engine operation are not admissible. If there is a danger of undershooting the dew point, the gas temperature must be increased. If there are deviating temperatures, there is danger of thermal aging of NBR materials (seals, diaphragms) and the effects of changes in elasticity at higher temperatures. The limit values apply to the gas inlet at the gas control valve on the engine side.

*** = These values are recommended values for Series 4000 engines, for engine-generator sets with exhaust gas aftertreatment, lower limit values can apply.**
**** = lower values apply to the 20V4000L32FB engine. Consultation with the factory is required.**

Designation	Unit	Limit value	Comment
Gas temperature deviation from the setting value	°C	± 15	This applies to the gas inlet at the gas control valve on the engine side.
Permissible change speed of Gas temperature	K/min.	0.3	This applies to the gas inlet at the gas control valve on the engine side.
Relative gas humidity in the permissible temperature and pressure range Max. moisture in gas, absolute	% g/kg	< 80 <28	In the entire gas and mixture system no condensation is permitted No water vapor condensation in pressure and temperature range No condensation admissible in lines and tanks carrying fuel gas and fuel gas-air mixtures. Gas drying must be provided at higher values or if there is a risk of condensation in the pressure and temperature operating ranges. Phase transitions in the fuel gas and air mixture are inadmissible during engine operation in the pressure and temperature range; gas drying is to be provided in case of higher values.
Oils / oil fumes	mg/m³ NTP	< 0.4	No condensation in lines carrying fuel gas and fuel gas-air mixture, nor formation of condensable oil mists.
HC solvent vapors	mg/m³ NTP	0	
Silicon from organic compounds	mg/m³ NTP	< 4*	At Si > 2 mg/m³ NPT based on 100% CH_4 fuel gas content, wear products must be noted in the oil analysis.
Inorganically-bound silicon	mg/³ NTP	< 2*	
Dust 3 to 10 µm	mg/m³ NTP	5	DVGW worksheet G260 Dust must be removed in such a manner that trouble-free operation of standard-conformant, or standard design gas devices and gas equipment, is ensured. Dust < 3 µm must be evaluated through a technical analysis, if necessary appropriate special filters must be used.
Dust < 3 µm	mg/m³ NTP	technically free	
Silicon from organic and inorganic compounds	mg/m³ NTP	6*	
Total sulfur	mg/m³ NTP	800* / **	
Mercaptan sulfur	mg/m³ NTP	4*	
Hydrogen sulfide (H_2S)	mg/m³ NTP	850*	
Chlorine (Cl)	mg/m³ NTP		technically free Consult the manufacturer in case of higher values as analysis is necessary.
* = These values are recommended values for Series 4000 engines, for engine-generator sets with exhaust gas aftertreatment, lower limit values can apply. ** = lower values apply to the 20V4000L32FB engine. Consultation with the factory is required.			

Designation	Unit	Limit value	Comment
Fluorine (F)	mg/m³ NTP		technically free Consult the manufacturer in case of higher values as analysis is necessary.
Ammonia (NH_3)	mg/m³ NTP	10*	Consult the manufacturer in case of higher values as analysis is necessary.
* = These values are recommended values for Series 4000 engines, for engine-generator sets with exhaust gas aftertreatment, lower limit values can apply. ** = lower values apply to the 20V4000L32FB engine. Consultation with the factory is required.			

Table 51: Requirements and site conditions for biogas fuel and the corresponding fuel supply

When using the series 4000 in engine-generator sets, with and without exhaust heat coupling and/or exhaust gas aftertreatment systems, the respective instructions provided by the engine-generator set manufacturer must be complied with.

Requirements of the fuel 'low-pollutant biogas'

The following limit values define 'low-pollutant biogas'. All other limit values for low-polluted biogas correspond to the general limit values for biogas (→ Table 51).

Designation	Unit	Limit value	Comment
Silicon from organic compounds	mg/m³ NTP	< 1*	At Si > 2 mg/m³ NPT based on 100% CH_4 fuel gas content, wear products must be noted in the oil analysis.
Inorganically-bound silicon	mg/³ NTP	< 0.5*	
Silicon from organic and inorganic compounds	mg/m³ NTP	1.5*	
Total sulfur	mg/m³ NTP	140*	
Mercaptan sulfur	mg/m³ NTP	1*	
Hydrogen sulfide (H_2S)	mg/m³ NTP	150*	
Chlorine (Cl)	mg/m³ NTP		technically free Consult the manufacturer in case of higher values as analysis is necessary.
Fluorine (F)	mg/m³ NTP		technically free Consult the manufacturer in case of higher values as analysis is necessary.
Ammonia (NH_3)	mg/m³ NTP	10*	Consult the manufacturer in case of higher values as analysis is necessary.
* = These values are non-binding recommended values for Series 4000 engines, for engine-generator sets with exhaust gas aftertreatment, lower limit values can apply (→ Table 53).			

Table 52: Requirements and site conditions for low-pollutant biogas fuel and the corresponding fuel supply

All listed limit values for pollutants (in ppm and mg/m³) are based on a calorific value of 10 kWh/m³ NTP. This corresponds to a reference to fuels with 100% by vol. methane, or the existence of other combustible components in the fuel with the same energy equivalent and the same input of hazardous materials.

Example:

- Russian natural gas with a calorific value of 10 kWh/m³ NTP is used. The permissible value for total sulfur in the gas thus corresponds exactly to the limit value specified in the table.
- When using a gas (e.g. East Hanover) with Hi,n = 8.15 kWh/m³ NPT, the permissible maximum value for the total sulfur is calculated as follows:
  Permissible total sulfur content = 30 mg/m³ NPT · (8.15 kWh/m³NPT: 10.0 kWh/m³ NPT) = 24.5 mg/m³ NPT

Pollutant concentration in fuel (with exhaust gas aftertreatment / exhaust gas heat recovery)

Depending on the application, the following maximum permissible pollutant concentrations in the fuel must be observed:

Designation	Unit	Exhaust gas aftertreatment / exhaust gas heat recovery)		
		Without* / Without	With / 120 °C to 180 °C	With / Without
Sum of all sulfur compounds (calculated as S)	mg/m³ NTP	800	20	200
Hydrogen sulfide (H_2S)	ppm	560	14	70
Sum total of all chlorine compounds (calculated as Cl)	–	technically free Consult the manufacturer in case of higher values as analysis is necessary.		
Sum total of all fluorine compounds (calculated as F)	–	technically free Consult the manufacturer in case of higher values as analysis is necessary.		
Total of all silicon compounds (calculated as Si)	mg /m³ NTP	5	0	0
Ammonia (NH_3)	mg /m³ NTP	10	10	10
Heavy metals (Pb, Hg, As, Sb, Cd)	µg/m³ NTP	Upon request	10	10
*= for 'low-pollutant biogas', lower values apply accordingly (→ Table 52).				

Table 53: Pollutant concentration in the fuel

6.3.4 Engine operation with gaseous propane

Engine operation with gaseous propane

Liquid gases

Propane belongs to the group of liquid gases. Liquid gases are hydrocarbon mixtures that exist in gaseous form under atmospheric pressure, but which are readily liquefied under pressure at ambient temperature. Liquid gases or their fractions are usually created during fractioned distillation of crude oil, from cracking processes of the high-boiling fractions of the crude oil, or directly from natural gas by means of suitable separating processes, or, in rare cases, from synthesis processes (Fischer-Tropsch synthesis).

In their natural form, liquid gases are only very occasionally present on their own. The most common representatives of these liquid gases are paraffins (ethane, propane, butane) and olefins (ethylene, propylene, butylene) and their isomers.

Liquid gases obtained through the extraction and processing of crude oil and natural gas, through the synthesis of hydrocarbons and through petrochemical processes are based on specifications according to DIN 51622; liquid gases for automotive applications are specified according to DIN EN 589.

Liquid gas mixtures of these specifications are usually grouped under the term LPG (Liquid Petrol Gas) and, although propane is a noteworthy element of these mixtures, are not approved for gas engines in the Series 4000 due to the high share of C4 hydrocarbons and the resultant low knock resistance.

Propane and liquid gas mixtures are delivered and stored in commercially available pressure vessels at up to 10 bar as liquid gas.

Propane

According to DVGW G260, propane of the 3rd gas family is assigned to the so-called replacement gases that are used in the pipeline-bound public natural gas supply to improve the Wobbe Index.

Technical propane is extracted by physical separating processes from the fraction of the liquid gases. Traded "technical" propane (DIN 51622) therefore still constitutes a substance mixture and can consist of 95 mass % propane and propylene, whereby the propane content predominates. The remaining 5 mass % can consist of ethane, ethene, butane, Butylene and their isomers. The concentration of C5 hydrocarbons must not exceed 0.5 mass %.

Propane HD 5

Propane HD 5 is a trade name commonly used in the US-American market for a propane-propene mixture (95 mass % propane/propene in the overall composition) adapted to automotive applications and is characterized by lower propene values (max. 5 mass % in the C3 fraction) and butane/butenyl isomers/methane/ethane mainly of C4 hydrocarbons (max. 5 mass % in liquid gas mixture) compared to the DIN-51622 specifications. Due to the low share of alkene, HD-5 produces fewer deposits and burns largely free of soot.

Delivery form

Propane is traded as standard as a liquid gas in pressure vessels and usually stored in pressure vessels with a maximum operating pressure <= 10 bar.

Storage, provisioning

The following technical guidelines must be observed when storing liquid gas/propane:

TRGS (Technical Rules on Dangerous Substances) 509 Storage of liquid and solid hazardous materials in stationary containers and filling and draining points for transportable containers

- Chap. 8.4 Requirements of collecting areas for combustible liquids with a flashpoint ≤ 100 °C
- Chap, 9 Additional requirements for storage and filling of combustible liquids with a flashpoint ≤ 55 °C.

DVFG-TRF 2021 Technical rules for liquid gas

For the use of liquid gas in gas engines, a preheating device for the gas is mandatory which has to be adapted to the ambient conditions and removal volume from the tank supply.

Health hazards

The substance mixture is not classified as directly toxic, however, repeated or long-term exposure can result in nausea, numbness and headaches.

Also see GESTIS Substance Database.

Safety classification

The evaporated product is heavier than air and can therefore be deposited directly near the ground when it flows out. Vapors together with air form a potentially explosive mixture. Ignition group G1 (VDE), explosion class 1 (VDE), fire class C, storage class VCI 2A.

Also see GESTIS Substance Database and the safety data sheets from the propane gas supplier

Engine operation:

Propane gas has a considerably higher volumetric energy content (approx. 25 to 26 kWh/m³n) than natural gas H (approx. 10 kWh/m³n) and a clearly lower knock resistance than commercially available natural gas (approx. 70-90 methane number). The volume-based energy content of the completely evaporated product is approx. 2.5 times the energy content of natural gas H. The knock resistance of the completely evaporated propane is approx. 32-34 methane number.

To prevent condensation of the low-volatile components, preheating of the gas and combustion air dependent on the flow is necessary.

The engine control features calorific value control (calorific value adaption) and knock control which, with a stationary load profile, is capable of adapting the engine parameters for power and fuel-air mixture quality within the configured fuel quality limits.

Important
Engine operation is not enabled during filling of propane tank systems that do not have an independent supply structure.

Composition of propane gas

Component	Unit	Value range (maximum value)	Average values
CH_4	vol%	<0.2	Traces
C_2H_6 (or sum of C_2H_x)	vol%	< 1.5	0.91
C_3H_6	vol%	0 - 10	5.0
C_3H_8	vol%	90 - 100	96.3
i-C_4H_{10}	vol%	<0.2	1.12
n-C_4H_{10}	vol%	<0.2	0.15
C5+	vol%	<0.3	0.003
Aromatics as benzene	vol%	No information	-
CO_2	vol%	< 0.1	No information
N_2	vol%	< 1.0	No information
O_2	vol%	<0.3	No information
Total CO_2 + N_2 +Inert(O_2)	vol%	<1.4	No information

Component	Unit	Value range (maximum value)	Average values
H_2	vol%	< 0.02	Traces
CO	vol%	No information	No information

Table 54: Typical composition of commercially available, completely evaporated propane in propane quality DIN 51622 or propane HD 5

Requirements for fuel gas

Designation	Unit	Limit value	Comment
Type of gas		Propane	Propane corresponding to DIN EN 51 622 or propane HD 5
Methane number	MN	> 32	Knock monitoring/control during engine operation with propane has absolute priority over other engine settings to prevent combustion knock. With sustained knocking events, engine power is reduced or the engine is shut down.
Methane number change	MN / min	-	No indications possible. Methane number 32 already represents a lower limit which is defined by the propane gas composition. Methane number changes, however, can still occur when running propane gas tanks empty and the concentration increase of the higher boiling fractions of the propane gas mixture can lead to further falling of the methane number. Methane number changes depend on the supply management.
Calorific value Hi,n	kWh/m³ NTP	25.0 < Hi,n < 26.0	Calorific value of the completely evaporated product
Calorific value deviation from the setting value	%	± 2.5	Consultation with manufacturer required for higher values.
Admissible change rate of calorific value in relation to set value	%/min.	1.0	Only linear constant change permissible with a frequency of maximum 1/h
Gas density	kg/m³ NTP	2.00 to 2.03	The density of the gas may fluctuate depending on composition; it is more or less constant for a certain type of tank filling.
Gas pressure deviation from the setting value	%	± 2	
Admissible gas pressure change rate	mbar/min.	3	Only constant changes are permitted
* = For engines with exhaust gas aftertreatment and/or exhaust gas heat recovery, lower limit values may apply. When using oxidation catalysts, analysis and consultation with Rolls-Royce Solutions are required			

Designation	Unit	Limit value	Comment
Gas temperature at engine start and during idling	°C	5 < T < 45	If there is a danger of undershooting the dew point, the gas temperature must be increased. In case of deviating temperatures, there is a danger of thermal aging of NBR materials (seals, diaphragms) and impact on elasticity.
Fuel gas and combustion air temperature with engine under load	°C	15 < T < 45	If there is a danger of undershooting the dew point, the gas temperature must be increased. The permissible temperature range must be coordinated project-specifically. The gas preheating design must be coordinated with Rolls-Royce Solutions. A adapted air preheating system must be taken into consideration.
Gas temperature deviation from the setting value	°C	± 4	
Admissible rate of gas temperature change	K/min.	0.3	
Gas moisture, water: Relative moisture in gas in the permissible temperature and pressure range Max. moisture in gas, absolute	% g/kg	< 80 < 20	In the entire gas and mixture system no bedewing is permitted No water vapor condensation in pressure and temperature range No condensation permitted in lines and containers carrying fuel gas and gas-air mixtures
Gas moisture, hydrocarbons: Gap to condensation point	K	> 20	In all cases, a gap from the fuel gas temperature to the dew point of the hydrocarbons in the fuel gas of 20K must be guaranteed. Similarly, a gap of 20K from the dew point of the hydrocarbons in the mixture to the mixture temperature must be guaranteed. Monitoring systems for the treatment of potentially occurring condensate must be provided. Gas moisture shares in the form of mist or aerosols should basically be avoided through corresponding preheating.
Ethane (C_2H_6) and ethene (C_2H_4)	Mass %	< 1.10	Specifications corresponding to propane HD 5 95 mass % propane/propene + 5.0 mass % remainder (incl. C1, C2, C4, C5+)
* = For engines with exhaust gas aftertreatment and/or exhaust gas heat recovery, lower limit values may apply. When using oxidation catalysts, analysis and consultation with Rolls-Royce Solutions are required			

Designation	Unit	Limit value	Comment
Propene (C_3H_6)	Mass %	< 4.75	Specifications corresponding to propane HD 5 95 mass % propane and 5.0 mass % in the fraction of the C3 hydrocarbons
Propane (C_3H_8)	Mass %	90.25 - 100	Specifications corresponding to propane HD 5
Butane (n-, i-C_4H_{10}) and, butenyl (C_4H_8)	Mass %	< 5.00	Specifications corresponding to propane HD 5 95 mass % propane/propene + 5.0 mass % remainder (incl. C1, C2, C4, C5+)
Long-chain hydrocarbons (C5+)	Mass %	< 0.50	Specifications corresponding to propane HD 5 95 mass % Propane/propene + 5.0 mass % remainder (incl. C1, C2, C4, C5+)
Aromatics based on benzene.	Mass %	< 0.03	Consultation with Rolls-Royce Solutions required
Oils / oil fumes (HC with carbon number >8)	mg/m³ NTP	< 0.4	No condensation permitted in lines and containers carrying fuel gas and gas-air mixtures or the formation of condensable oil mist
HC solvent vapors	mg/m³ NTP	0	Consultation with manufacturer and analysis necessary
Organically bound silicon	mg/m³ NTP	< 1.0	
Inorganically bound silicon	mg/m³ NTP	< 6	At Si > 5 mg/m³ NPT based on 100% CH_4 fuel gas content, wear products must be noted in the oil analysis.
Dust < 3 µm	mg/m³ NTP	Technically free	Dust < 3 µm must be evaluated through a technical analysis, if necessary appropriate special filters must be used.
Dust 3 to 10 µm	mg/m³ NTP	5	DVGW worksheet G260 Dust must be removed in such a manner that trouble-free operation of standard-conformant, or standard design gas devices and gas equipment, is ensured.
Total sulfur	mg/m³ NTP	30	DVGW worksheet G260 (natural gas H) in propane according to DIN 51622, only 30 mg/kg or 60 mg/m³NTP are permitted
Mercaptan sulfur	mg/m³ NTP	6	DVGW worksheet G260
Hydrogen sulfide (H_2S)	mg/m³ NTP	5	DVGW worksheet G260
* = For engines with exhaust gas aftertreatment and/or exhaust gas heat recovery, lower limit values may apply. When using oxidation catalysts, analysis and consultation with Rolls-Royce Solutions are required			

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Designation	Unit	Limit value	Comment
Chlorine (Cl)	mg/m³ NTP		technically free Consult the manufacturer in case of higher values as analysis is necessary.
Fluorine (F)	mg/m³ NTP		technically free Consult the manufacturer in case of higher values as analysis is necessary.
Ammonia (NH_3)	mg/m³ NTP	10*	Consult the manufacturer in case of higher values as analysis is necessary.
* = For engines with exhaust gas aftertreatment and/or exhaust gas heat recovery, lower limit values may apply. When using oxidation catalysts, analysis and consultation with Rolls-Royce Solutions are required			

Table 55: Requirements and general conditions for propane fuel and the corresponding fuel supply

All listed limit values for pollutants (in ppm and mg/m^3) are based on a calorific value of 10 kWh/m^3 NTP. This corresponds to a reference to fuels with 100% by vol. methane, or the existence of other combustible components in the fuel with the same energy equivalent and the same input of hazardous materials.

Example:

- Natural gas with a calorific value of 10 kWh/m^3 NPT is used. The permissible value for total sulfur in the gas thus corresponds exactly to the limit value specified in the table.
- When using a gas (e.g. East Hanover) with Hi,n = 25.5 kWh/m^3 NPT, the permissible maximum value for the total sulfur is calculated as follows:
  Permissible total sulfur content = 30 mg/m³ NPT ·for gas with Hi,n = 10.0 kWh/m^3 NPT
  Permissible total sulfur content for gas with Hi,n = 25.5 kWh/m^3 NPT:
  30 mg/m³ NPT *(25.5 kWh/m^{3}NPT / 10.0 kWh/m^3 NPT) = 76.5 mg/m³ NPT

Note:

The limit value of the permissible total sulfur content for propane according to DIN 51622 is only 30 mg/kg or 60 mg/m^3 NTP.

Specifications for propane HD5 according to the US standard have considerably lower sulfur quantities as shown in the sample calculation.

6.4 Series 4000 gas engine - Engine-generator set in Oil&Gas

6.4.1 General information

Important

There is no warranty in case of impairments and / or damage (corrosion, contamination, etc.) caused by gases or substances whose existence was not known or agreed upon at the time of signing the contract.

6.4.2 Natural gas – Requirements of the fuel gas

Requirements for fuel gas

Designation	Unit	Limit value	Comment
Type of gas			Natural gas
Wobbe index Ws,n	kWh/m³ NTP	11 ≤ Ws,n ≤ 15.7	
Methane number	MN	≥ 64	See Technical data With a methane number lower than that specified in the technical data sheet, engine power is reduced.
Methane number change	-/min.	5	Linear constant change with a frequency of max. 1/h
Calorific value Hi,n	kWh/m³ NTP	8.0 < Hi,n < 11.0	Consult the manufacturer in case of lower or higher values.
Calorific value deviation from the setting value	%	± 5**	Consultation with manufacturer required for higher values.
Setting range of the gas flow pressure pF	$mbar_{(rel)}$	80 ≤ pF ≤ 250	The gas flow pressure before the gas dosing device is an engine- and plant-specific variable. The gas flow pressure is constant. The setting value of the gas flow pressure can be obtained from the Technical data for engine and system.
Admissible change rate of calorific value in relation to set value	%/min.	1.0	Linear constant change necessary with a frequency of maximum 1/h
Gas density	kg/m³ NTP	0.73 to 0.84	The density of the gas may fluctuate depending on composition; it is constant for a certain type of gas. When using gas from different gas supply areas, the density may vary. When changing to a different gas supplier it may be necessary to adjust the mixture control.
Gas pressure deviation from the setting value	%	± 5	
Admissible gas pressure change rate	mbar/min.	1	Constant change required
*** = For engines with exhaust gas aftertreatment and/or exhaust gas heat recovery, lower limit values may apply. When using oxidation catalysts, analysis and consultation with Rolls-Royce Solutions are required**			

Designation	Unit	Limit value	Comment
Gas temperature Natural gas from the public gas supply grid	°C	5 < T < 45	If there is a danger of undershooting the dew point, the gas temperature must be increased. In case of deviating temperatures, there is a danger of thermal aging of NBR materials (seals, diaphragms) and impact on elasticity. Certain pressure and calorific value combinations may restrict the temperature range. This can be compensated by pressure adjustment to guarantee operation at rated load over the complete temperature range. On plants with LNG operation, the permissible temperature range must be coordinated project-specifically. The gas evaporation system design must be analyzed on the part of Rolls-Royce Solutions for this purpose.
Natural gas from LNG evaporator plants		15 < T < 45	
Gas temperature deviation from the setting value	°C	± 9	
Admissible rate of gas temperature change	K/min.	0.3	
Relative moisture in gas in the permissible temperature and pressure range	%	< 80	In the entire gas and mixture system no condensation is permitted No water vapor condensation in pressure and temperature range No condensation permitted in lines and containers carrying fuel gas and fuel gas-air mixtures
Max. moisture in gas, absolute	g/kg	< 20	
Oils / oil fumes (HC with carbon number >8)	mg/m³ NTP	< 0.4	No condensation in lines carrying fuel gas and fuel gas-air mixture, nor formation of condensible oil mists
Long-chain hydrocarbons (C_6 - C_n)	mewl %	No information	Consultation with Rolls-Royce Solutions required
HC solvent vapors	mg/m³ NTP	0	Consultation with manufacturer and analysis necessary
Organically bound silicon	mg/m³ NTP	< 1.0	
Inorganically bound silicon	mg/m³ NTP	< 6	At Si > 5 mg/m³ NPT based on 100% CH_4 fuel gas content, wear products must be noted in the oil analysis.
Dust 3 to 10 µm	mg/m³ NTP	5	DVGW worksheet G260 Dust must be removed in such a manner that trouble-free operation of standard-conformant, or standard design gas devices and gas equipment, is ensured.
* = For engines with exhaust gas aftertreatment and/or exhaust gas heat recovery, lower limit values may apply. When using oxidation catalysts, analysis and consultation with Rolls-Royce Solutions are required			

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Designation	Unit	Limit value	Comment
Dust < 3 µm	mg/m³ NTP	Technically free	Dust < 3 µm must be evaluated through a technical analysis, if necessary appropriate special filters must be used.
Total sulfur	mg/m³ NTP	30	DVGW worksheet G260
Mercaptan sulfur	mg/m³ NTP	6	DVGW worksheet G260
Hydrogen sulfide (H_2S)	mg/m³ NTP	5	DVGW worksheet G260
Chlorine (Cl)	mg/m³ NTP		technically free Consult the manufacturer in case of higher values as analysis is necessary.
Fluorine (F)	mg/m³ NTP		technically free Consult the manufacturer in case of higher values as analysis is necessary.
Ammonia (NH_3)	mg/m³ NTP	10*	Consult the manufacturer in case of higher values as analysis is necessary.
* = For engines with exhaust gas aftertreatment and/or exhaust gas heat recovery, lower limit values may apply. When using oxidation catalysts, analysis and consultation with Rolls-Royce Solutions are required			

Table 56: Requirements and site conditions for natural gas fuel and the corresponding fuel supply

All listed limit values for pollutants (in ppm and mg/m³) are based on a calorific value of 10 kWh/m³ NTP. This corresponds to a reference to fuels with 100% by vol. methane, or the existence of other combustible components in the fuel with the same energy equivalent and the same input of hazardous materials.

Example:

- Russian natural gas with a calorific value of 10 kWh/m³ NTP is used. The permissible value for total sulfur in the gas thus corresponds exactly to the limit value specified in the table.
- When using a gas (e.g. East Hanover) with Hi,n = 8.15 kWh/m³ NPT, the permissible maximum value for the total sulfur is calculated as follows:
  Permissible total sulfur content = 30 mg/m³ NPT · (8.15 kWh/m³NPT: 10.0 kWh/m³ NPT) = 24.5 mg/m³ NPT

6.5 Series 400 gas engine – Engine-generator set

6.5.1 Natural gas – Fuel values

Fuel specifications to be complied with

The following fuel values must be observed at the inlet to the gas train (scope of supply of Rolls-Royce Solutions):

Designation	Unit	Limit value
Minimum methane number	See Technical Description	
Minimum calorific value		
Max. rate of change, calorific value	% per min	1
Max. rate of change, methane number	Change in MN per min	5
Minimum gas flow pressure (overpressure)	mbar	20
Maximum gas flow pressure (overpressure)	mbar	50
Max. gas pressure variation (brief control fluctuation)	mbar	±5
Max. rate of change of gas pressure	mbar/s	1
Max. gas temperature (no derating)	°C	35
Max. water vapor content	vol%	0.5
Max. dust particle content > 3 µm	mg/m³NPT	5
Max. oily constituents	mg/m³NPT	0.4

Table 57: Fuel specifications to be complied with

Corrosive constituents, with the exception of a max. total sulfur content of 10 mg/m³NPT, short term 20 mg/m³NPT, must not be present. In this regard, the requirements of technical regulation DVGW Sheet G 260 Edition 9/2021 apply.

Important: The supplied gas filter (mesh size: 50 µm) fitted at the inlet of the gas train does not ensure compliance with the dust limit value specified above and is used solely to protect the gas fittings.

6.5.2 Biogas – Fuel values

It is not possible to avoid variations in gas quality for biogas, sewage gas and landfill gas, the same applies to harmful impurities.

In order to allow trouble-free operation and avoid damage, however, certain limit values have to be complied with.

If it turns out during commissioning that the quality requirement for the fuel is not met, Rolls-Royce Solutions reserves the right to charge for the aborted commissioning procedure.

Compliance with the emission and consumption values specified in the data sheet applies only to the specified reference gas compositions for biogas, sewage gas and landfill gas. The CO_2 / CH_4 volume ratio is of importance here.

Important
The listed constituents / limit values listed are relevant for biogas engines. Other constituents / limit values are not permitted.

Fuel specifications to be complied with

The following fuel values must be observed at the inlet to the gas train (scope of supply of Rolls-Royce Solutions):

Designation	Unit	Limit value
Minimum methane number	See Technical Description	
Minimum calorific value		
Max. rate of change, calorific value	% per min	1
Max. rate of change, methane number	Change in MN per min	5
CO_2 / CH_4 volume ratio	-	≤ 0.65
Methane content, moist	vol%	See techn. data
Minimum gas flow pressure (overpressure)	mbar	30
Maximum gas flow pressure (overpressure)	mbar	50
Max. gas pressure variation (brief control fluctuation)	mbar	±5
Max. rate of change of gas pressure	mbar/s	1
Max. gas temperature (no derating)	°C	35
Max. oxygen content	vol%	2
Max. water vapor content	vol%	3.1
Max. dew point, gas cooling	°C	25
Max. dust particle content > 3 µm	mg/m³NPT	5
Max. oily constituents	mg/m³NPT	0.4

Table 58: Fuel specifications to be complied with

IMPORTANT: The supplied gas filter (mesh size: 50 µm) fitted at the inlet of the gas train does not ensure compliance with the dust limit value specified above and is used solely to protect the gas fittings.

6.5.3 Harmful impurities (pollutants)

The following application-dependent maximum limits for permissible pollutant concentrations in the fuel are to be complied with:

Pollutant concentration in the fuel

Catalytic exhaust gas aftertreatment Exhaust gas heat exchanger		Without 180 °C	Oxi-cat EMK / 120 °C / 180 °C	Oxi-cat EMK / Without	Oxi-cat SRK / 180 °C	Oxi-cat SRK / Without	SCR 120 °C / 180 °C
Sum total of all sulfur compounds (S)	mg/m³ NPT	1200	20	200	70	140	20
Corresponding hydrogen sulfide (H_2S)	ppm	840	14	140	50	100	14
Sum total of all chlorine compounds (Cl)	mg/m³ NPT	20	0.5	0.5	0.5	0.5	0.5
Sum total of all fluorine compounds (F)	mg/m³ NPT	10	0.5	0.5	0.5	0.5	0.5
Sum total of all silicon compounds (Si)	mg/m³ NPT	5	0	0	0	0	0
Ammonia (NH_3)	mg/m³ NPT	10	10	10	10	10	10
Heavy metals (Pb, Hg, As, Sb, Cd)	µg/m³ NPT	Upon request	10	10	10	10	10
EMK = Noble-metal catalytic converter SCR = Selective catalytic reduction catalytic converter SRK = Sulfur-resistant catalytic converter							

Table 59: Maximum permissible contamination in biogas fuel standardized to 10 kWh energy content

All listed limit values for pollutants (in ppm and mg/m³) are based on a calorific value of 10 kWh/m³ NTP. This corresponds to a reference to fuels with 100% by vol. methane, or the existence of other combustible components in the fuel with the same energy equivalent and the same input of hazardous materials.

Example:

- Russian natural gas with a calorific value of 10 kWh/m³ NTP is used. The permissible value for total sulfur in the gas thus corresponds exactly to the limit value specified in the table.
- When using a gas (e.g. East Hanover) with Hi,n = 8.15 kWh/m³ NPT, the permissible maximum value for the total sulfur is calculated as follows:
  Permissible total sulfur content = 30 mg/m³ NPT · (8.15 kWh/m³NPT: 10.0 kWh/m³ NPT) = 24.5 mg/m³ NPT

If the quality of the raw gas exceeds the appropriate limit value for sulfur, a gas desulfurization system, designed according to the quality of gas in the system, has to be installed.

With the special sulfur-resistant Rolls-Royce Solutions oxidation catalytic converter, operation without fine desulfurization is permissible as long as the specified limit value for sulfur in the fuel is complied with.

In the case of active exhaust gas heat utilization, if limit values are exceeded during operation there will be an increased build-up of corrosive deposits. Damage caused by these deposits can result in total failure of the components. Earlier cleaning of the exhaust gas heat exchanger is therefore necessary.

Due to potential fluctuations in the sulfur content in practice, Rolls-Royce Solutions is unable to offer any guarantees regarding the cleaning intervals.

During operation with the oxidizing catalytic converter without exhaust gas heat utilization, the exhaust gas temperature at the exhaust gas system opening must definitely be above 300 °C. If necessary, the exhaust pipe must be insulated.

With the SCR application, the requirements of the catalytic converter manufacturer with regard to the use of zeolite must be observed. The technological requirements in the cleaned biogas are identical to those of the noble-metal oxidation catalytic converter.

There are currently no applications for low-pollutant biogas. In the application case, the requirements are met by the oxidation catalytic converter SRK, or without a catalytic converter. The required oil volume or the oil service life is defined plant-specifically in all cases.

The maximum permissible NH_3 concentration should not be exceeded. If the NH_3 content in the fuel gas is exceeded, the NO_x concentration in the exhaust gas increases. This can make it difficult to observe the NO_x limit values.

Example:

With biogas type Nawaro with Hi = 5.0 kWh/m³ NPT, an SCR catalytic converter in combination with a 180-°C exhaust gas heat exchanger should be used. A hydrogen sulfide concentration (H_2S) in the biogas of 2.0 ppm (S = 2.9 mg/m³ NPT) was measured. No other sulfur compounds are present.

Standardized hydrogen sulfide concentration

H_2S = 2.0 ppm x (10.0 kWh/m³ NPT / 5.0 kWh/m³ NPT) = 4.0 ppm

Standardized total sulfur concentration

S = 2.9 ppm x (10.0 kWh/m³ NPT / 5.0 kWh/m³ NTP = 5.8 ppm

The measured and standardized sulfur concentrations are safely below the limit values (14 ppm H_2S and 20 mg/m³ NPT S).

6.6 Series 500 Gas Engine - Engine-Generator Set

6.6.1 Gas types

As the elements of fuel gases, in part, vary considerably, a classification of the gases based on certain properties and gas composition is necessary. A classification is carried out here based on their calorific value.

Parameters	Symbol	Limit	Unit	Remarks
Calorific value	$H_{i,N}$	< 5	kWh / Nm³	Biogas operation requires consultation with Rolls-Royce Solutions
		< 483.1	BTU/ft³	
		> 5	kWh / Nm³	Biogas operation
		> 483.1	BTU/ft³	
		> 10	kWh / Nm³	Natural gas operation
		> 966.2	BTU/ft³	

Table 60: Subdivision of fuel gases

The classification based on the calorific value provides an initial insight into whether the fuel gas can potentially be used. The following (→ Table 61) provides an overview of which main elements are contained in the respective fuel gases independently of their quantitative share.

Element	Symbol	Natural gas	Biogas/sewage gas/ landfill gas
Methane	CH_4	X	X
Ethane	C_2H_6	X	
Propane	C_3H_8	X	
Butane	C_4H_{10}	X	
Pentane	C_5H_{12}	X	
Hexane	C_6H_{14}	X	
Carbon Monoxide	CO		X
Carbon dioxide	CO_2	X	X
Hydrogen	H_2	X	
Nitrogen	N_2	X	X
Oxygen	O_2		X

Table 61: Main elements of fuel gases

For gas secondary substances that are not named in this table nor in table (→ Page 115) consultation with Rolls-Royce Solutions is required.

For biogas, make sure that gas segregation has not occurred during extended out-of-service periods or extended periods of gas storage.

6.6.2 Minimum requirements of gas composition

The following table provides information on the minimum requirements of the gas quality. The gas operating data must also be observed (→ Page 116).

In addition, special components, e.g. a catalytic converter, may require deviating limit values in certain circumstances (→ Page 118).

Important
Continuous observance of the minimum gas requirements must be guaranteed by the customer!

The large number of possible fuel gases and the different compositions necessitate a gas-dependent analysis of the gas quality limit values. For this purpose, Rolls-Royce Solutions requires a conversion of the gas analysis values based on the calorific value, see (→ Page 117).

Parameters	Symbol	Limit	Unit	Remarks
Methane Number	MN	see Technical data sheet		Methane number requirement depending on engine configuration. For exact information, refer to the Technical data sheet of the engine.
Chlorine	Cl	<8	mg / kWh	Chlorine is present as a volatile compound.
		< 5.169 x10^{-9}	lb / BTU	
Fluorine	F	< 4	mg / kWh	Fluorine is present as a volatile compound.
		< 2.584 x10^{-9}	lb / BTU	
Total chlorine + fluorine	Σ (Cl, F)	<8	mg / kWh	
		< 5.169 x10^{-9}	lb / BTU	
Dust content < 5 µm		< 1	mg / kWh	
		< 0.646 x10^{-9}	lb / BTU	
Oil vapor		< 0.02	mg / kWh	No condensation must form in the intake tract.
		< 12.9 x10^{-12}	lb / BTU	
Solvents in combustion air	VOC	< 2.5	mg / kWh	
		< 1.62 x10^{-9}	lb / BTU	
Total silicon	Σ Si	< 0.2	mg / kWh	High fluctuation in the gas. Oil analysis provides more exact information.
		< 0.129 x10^{-9}	lb / BTU	
Total sulfur	Σ S	< 40	mg / kWh	Sulfur share from hydrogen sulfide must be taken into consideration via the molar masses with total sulfur.
		< 25.83 x10^{-9}	lb / BTU	
Hydrogen sulfide	H_2S	< 42.4	mg / kWh	
		< 27.38 x10^{-9}	lb / BTU	
Ammonia	NH_3	< 3	mg / kWh	
		< 1.938 x10^{-9}	lb / BTU	
Tar	$C_xH_yR_z$	< 6.5	mg / kWh	Only with syngas Condensing must not take place in gas-carrying components. It may be necessary to install a gas reheating system.
		< 4.2 x10^{-9}	lb / BTU	

Table 62: Permissible limit values for gas components

Deviations from the limit values or the use of further constituents not listed here only after consultation with Rolls-Royce Solutions.

6.6.3 Gas operating data

Parameters	Limit	Unit	Remarks
Rate of gas pressure change	< 1	mbar / 2 s	
	< 0.0145	psi / 2 s	
Calorific value rate of change H_i	< 1	% / 30 s	
Rate of change, methane number	< 10	MN / min	
Gas flow pressure at rated load for natural gas operation	20 – 70	mbar	At inlet to gas regulating unit
	0.29 – 1.015	psi	
Gas flow pressure at rated load for biogas operation	30 – 70	mbar	At inlet to gas regulating unit
	0.4351 – 1.015	psi	
Max. assured gas pressure	500	mbar	
	7.25	psi	
Temperature of the gas mixture before gas mixer TG	10 – 30	°C	
	50 – 86	°F	
Relative humidity φ	< 60	%	No condensation must form in the intake tract and the gas regulating unit.

Table 63: General boundary conditions for fuel gas

6.6.4 Conversion of limit values from gas analysis

The large number of possible fuel gases and the associated, in part widely varying, compositions necessitate a dynamic analysis of the gas quality limit values.

For this purpose, Rolls-Royce Solutions requires a conversion of the gas analysis values depending on the calorific value based on kWh / Nm³ (BTU / ft³).

The following is an example of the calculation.

Givens:	Calorific value from gas analysis	$Hi_{,N}$	1.5 kWh / m³
	Chlorine from gas analysis	Cl	10 mg/m³
	Fluorine from gas analysis	F	5 mg/m³
	Plant without catalytic converter		

First, the measured values (MV) are converted on the basis of the calorific value $Hi_{,N}$ to a comparative value (CV). This is then compared with the matching limit value (LV):

$$CV_{Cl} = \frac{MV_{Cl}}{Hi_N} = \frac{10\ mg/m^3}{1.5\ kWh / m^3} = 6.6\ mg/kWh < LV_{Cl} = 8\ mg/kWh$$

→ OK

$$CV_F = \frac{MV_F}{Hi_N} = \frac{5\ mg/m^3}{1.5\ kWh / m^3} = 3.3\ mg/kWh < LV_F = 4\ mg/kWh$$

→ OK

The simultaneous presence of chlorine and fluorine means that a further limit value must be taken into consideration:

$$CV_{Cl,\,F} = CV_{Cl} + CV_F = 6.6\ mg/kWh + 3.3\ mg/kWh = 9.9\ mg/kWh > LV_{Cl} = 8\ mg/kWh$$

→ not OK

Important

In part, the gas composition from the gas analysis is expressed in ppm (parts per million). To make a comparison with the limit values possible, an intermediate conversion step is required. For this purpose, the respective density under normal conditions is used in accordance with the following equation:
Measured value [mg/m^3_{norm}] = measured element volume [ppm] x $density_{norm}$ [kg/m^3_{norm}]

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6.6.5 Special limit values

Deviations from the specified limit values or the use of further constituents not listed here only after consultation with Rolls-Royce Solutions.

Permissible limit values for gas components with use of catalytic converter

With the use of a catalytic converter, the limit values become stricter as follows:

Parameter/catalytic converter toxin	Symbol	Limit	Unit
Hydrogen sulfide	H_2S	< 1.52	mg / kWh
		< 0.982 x10^{-9}	lb / BTU
Sulfur	S	< 1	mg / kWh
		< 0.646 x10^{-9}	lb / BTU
Ammonia	NH_3	< 6	mg / kWh
		< 3.877 x10^{-9}	lb / BTU
Arsenic	As	< 0.2	µg / kWh
		< 0.129 x10^{-12}	lb / BTU
Mercury	Hg	< 0.2	µg / kWh
		< 0.129 x10^{-12}	lb / BTU
Lead	Pb	< 0.4	µg / kWh
		< 0.258 x10^{-12}	lb / BTU
Cadmium	Cd	< 2	µg / kWh
		1.292	lb / BTU
Zinc	Zn	< 20	µg / kWh
		< 12.92 x10^{-12}	lb / BTU
Phosphor compounds and halogens	P, F, Cl, Br, I, At, Ts	< 1	µg / kWh
		< 0.646 x10^{-12}	lb / BTU
Silicon		0	µg / kWh
		0	lb / BTU
Organic silicon - siloxane	Si	<30	µg / kWh
		< 1.938 x10^{-11}	lb / BTU
Sodium	Na	< 2	µg / kWh
		< 1.292 x10^{-12}	lb / BTU
Calcium	Ca	< 2	µg / kWh
		< 1.292 x10^{-12}	lb / BTU
Bismuth	Bi	< 0.2	µg / kWh
		< 0.129 x10^{-12}	lb / BTU
Manganese	Mn	< 2	µg / kWh
		< 1.29 x10^{-12}	lb / BTU
Potassium	K	< 2	µg / kWh
		< 1.29 x10-^{12}	lb / BTU
Antimony	Sb	< 0.2	µg / kWh
		< 0.129 x10^{-12}	lb / BTU

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Parameter/catalytic converter toxin	Symbol	Limit	Unit
Chlorine	Cl	< 2	µg / kWh
		< 1.29 x10^{-12}	lb / BTU
Iron	Fe	< 2	µg / kWh
		< 1.29 x10-^{12}	lb / BTU

Table 64: Permissible limit values for gas components with use of catalytic converter

Details not listed in the table remain unchanged.

Permissible limit values for gas components with use of activated carbon

With the use of an activated carbon filter, the limit values become stricter as follows:

Parameters	Symbol	Limit	Unit	Remarks
Oxygen max.	O_2	< 3	%	The development of explosive mixtures must be prevented
Oxygen min.	O_2	> 0.5	%	Follow manufacturer's instructions

Table 65: Permissible limit values for gas components with use of activated carbon

Details not listed in the table remain unchanged.

6.6.6 Operational malfunctions due to condensate in the fuel gas

Operational malfunctions caused by insufficient freedom from condensate in the provided fuel gases shall not be covered by the warranty.

Consequences of condensate in the fuel gas

Condensate contained in the power gas (e.g. with the lube oil of the gas compressor) can form an acidic compound/emulsion. Among other things, this can result in the following:

- Corrosion (wear)
- TAN increase or TBN/ipH decrease in lube oil
- Carbon deposits on: Valves, piston ring grooves and chases

Prevention of malfunctions due to condensate in the power gas

- No vaporization due to cooling and/or pressure release.
- Mechanical separation (e.g. cyclone or separation filters) and removal of the condensate must only take place with the engine no longer in operation. Following this, it is essential to seal the separation cock again gastight.
- The gas line leading to the engine must be designed such that the gas does not cool any further and is practically no longer depressurized through resistance or downstream pressure reducers. If necessary, insulate the fuel gas line or possibly provide trace heating.
- As a certain amount of condensate can still enter the engine in spite of freedom from condensate at the test valves, it is important that the condensate is largely free of acidifiers. To make sure of this, the pH value of the aqueous solution accumulating at the condensate separators must be checked. The stronger the acid the greater the harmful impact even with hardly detectable small amounts of condensate which can nevertheless enter the engine with the gas.
- For biogas, with continuous operation at 50% power, or with exhaust gas cooling below 170 °C, or for flexible energy balancing mode, continuous monitoring of the gas quality, in particular, H2S, is necessary. The measured value must be documented via the MMC control system based on a 4-20 mA signal. The signal can originate from a gas analysis by the customer or a specially installed H2S sensor. The gas status before the machine must be monitored. This must be guaranteed with the selection of a suitable measuring instrument with definition of the corresponding measuring points by the operating company.

7 Exhaust Gas Aftertreatment System

7.1 General

To reduce exhaust emissions on stoichiometric engines (lambda = 1, without excess air), 3-way catalytic converters are used.

To reduce exhaust emissions due to incompletely burned combustion products on engine with lean operation (operation with excess air), oxidation catalysts are used.

For additional reduction of NOx emissions with lean operation engines, SCR catalytic converters (selective catalytic reduction) can be used. The reducing agent (urea solution with an urea concentration of 32.5 %) in such catalysts reduces the nitrogen oxide emissions.

To guarantee the range of functions of the catalytic converters over a specific runtime, all specifications in the Fluids and Lubricants Specifications (with regard to fuels, intake air, lube oils) must be observed.

7.2 NOx reducing agent AUS 32 for SCR exhaust gas aftertreatment systems

To ensure efficient operation of the exhaust gas aftertreatment system, compliance of the reducing agent with the quality requirements stipulated in DIN 70070 / ISO 222 41-1 is mandatory.

In Europe, this reducing agent is often offered under the brand name “AdBlue”.

The test methods for determining the quality and characteristics of the reducing agent are specified in the standards DIN 70071 / ISO 222 41-2. The following table (→ Table 66) shows the quality characteristics of the reducing agent together with the associated test methods (extract from ISO 222 41-1).

Important

SCR systems from Rolls-Royce Solutions are usually designed for a concentration of 32.5% urea. The use of NOx reducing agent with other urea concentrations (AUS 40, AUS 48) requires a different design of the dosing systems. Systems with the corresponding design must be run with the appropriately adapted concentration.
The purity requirements of the reducing agent then comply with the standards for AUS 32.

Important

The use of antifreeze additives for AUS 32, or winter urea, is generally not approved.

Quality features and test procedures for the reducing agent

	Unit	Test method ISO	Limit values
Urea content	by weight %	22241–2 Annex B	31.8 to 33.2
Spec. grav. at 20 °C	kg/m^3	3675 12185	1087.0 to 1092.0
Refractive index at 20 °C		22241–2 Annex C	1.3817 to 1.3840
Alkalinity as NH_3	by weight %	22241–2 Annex D	Max. 0.2
Biuret content	by weight %	22241–2 Annex E	Max. 0.3
Aldehyde content	mg/kg	22241–2 Annex F	Max. 5
Non-soluble constituents	mg/kg	22241–2 Annex G	Max. 20
Phosphate content as $P0_4$	mg/kg	22241–2 Annex B	Max. 0.5
Metal contents		22241–2 Annex I	
Calcium	mg/kg		Max. 0.5
Iron	mg/kg		Max. 0.5
Copper	mg/kg		Max. 0.2
Zinc	mg/kg		Max. 0.2
Chrome	mg/kg		Max. 0.2
Nickel	mg/kg		Max. 0.2
Aluminum	mg/kg		Max. 0.5
Magnesium	mg/kg		Max. 0.5
Sodium	mg/kg		Max. 0.5
Potassium	mg/kg		Max. 0.5
Identity			Identical with the reference sample

Table 66: Quality features and test procedures for the reducing agent

Storage of reducing agent

Information on storage/packaging/transport as well as suitable/unsuitable materials in the reducing agent circuit can be obtained in the standard ISO 222 41-3. Also observe the manufacturer's specifications in this regard.

Avoid direct sunlight because it promotes the occurrence of microorganisms and the decomposition of the reducing agent.

Where possible, store and transport the reducing agent AUS 32 between -5 and +25 °C to prevent loss in quality. Long storage periods at temperatures above 25 °C can lead to destruction of the reducing agent.

Max. constant storage temperature [°C]	Min. durability [months]
≤10	36
≤25	18
≤ 30	12
≤35	6
>35	Check each batch prior to use

Table 67: Storage temperature of reducing agent

Important
The reducing agent crystallizes at -11 °C.

7.3 Exhaust condensate

Important information

Ensure that used fluids and lubricants are collected in sufficiently large collecting containers. Dispose of fluids and lubricants in accordance with the applicable national specifications. Do not burn used oil or dispose of in fuel tank.

When fuel is burned in the engine, nitrogen oxides NOx are created in addition to carbon dioxide and water vapor. These transform into nitric acid in the downstream components in the presence of condensed water. Other inorganic and organic acids, e.g. sulfuric acid or sulfurous acid, can likewise be created depending on the fuel composition. Condensate samples therefore display a lightly pungent smell and dissolved iron as a corrosion product. The hydrogen ion concentration, i.e. the pH value of such condensate samples, is usually in the strong to weak acid range of pH = approx. 0.5 to 4.

The water dew point of the exhaust gas depends on the composition of the fuel gas used as well as the air ratio at which the engine is operated. The water dew point is approx. 50 °C (lean engines) up to 80 °C (lambda = 1). Condensate starts to form, depending on the acid-forming constituent, at exhaust temperatures below approx. 170 °C (acid dew point).

Theoretically, 1.5 kg condensate can be created from 1 m^3 NTP of natural gas. When exhaust gas is cooled down to temperatures of approx. 100 °C, significant quantities of condensate only form during start-up procedures. When exhaust gas temperatures are further cooled (below T = approx. 80 °C), condensate starts to accumulate continuously.

To limit condensate formation as much as possible (in the exhaust gas heat exchanger or in the downstream exhaust silencer), you should guarantee the following with gensets with exhaust cooling:

- In the exhaust gas heat exchanger, never cool the exhaust gas temperatures below 110 °C
- Ensure exhaust lines are properly insulated
- Keep the ratio of the number of machine starts to operating hours as low as possible (average values lower than "one start" per four operating hours are recommended).

Where possible, do not merge condensate lines from different components before the siphon (or water seal) because otherwise condensate would escape continuously during operation due to circulation in the condensate line.

A free drain via a siphon (or water seal) must be provided for the condensate at a minimum height of 400 mm. In any case, however, the drain must have more than a 100 mm water column above the corresponding maximum permissible exhaust back pressure of the engine. This prevents exhaust gas emerging from the condensate line. The exhaust condensate should be neutralized in a neutralization plant before being discharged into the sewerage system. An oil separator is additionally required.

The condensate drain line must be checked regularly during operation and safeguarded against freezing in winter.

Exhaust condensate may only be discharged into the local sewage system without being treated after consultation with the local waste water authority, and must not under any circumstances be discharged to atmosphere. Municipalities in Germany, or the authorities instructed by them, are obliged to remove accumulated waste water which also contains condensate. Condensate can also be classified in the "Special waste" category.

8 Inlet Air and Combustion Air

8.1 General information

Important

No corrosive compounds must penetrate the intake air.
The specified limit values must be observed because otherwise the warranty shall become void.

The supply air (intake air) of the engine must be free of:
- Halogen compounds (e.g. for operation in swimming pools or in the vicinity of refrigerating machines)
- Sulfur compounds (e.g. in the vicinity of battery production plants)
- Vapors from aggressive cleaning agents
- Silicon compounds (e.g. in cosmetics production)
- Aromatic compounds (e.g. in paint shops)

Even small traces of these substances can have the following negative effects:
- Corrosi on in the engine and on peripheral components, e.g. electric motors of the engine-generator set
- Toxication of sensor systems and exhaust gas aftertreatment components
- Deposits and wear in/on engine
- Influence on combustion (e.g. combustion knock)
- Exceeding of regulated emission limit values (exhaust gas)

In case of doubt, consult Rolls-Royce Solutions.

The intake air must not be supplied with desorption air or off-gases from thermochemical process without prior consultation with Rolls-Royce Solutions.

The permissible temperature range with specification of the minimum and maximum temperature is stipulated in the technical data sheet of the engine / genset.

Pollutant limit values in the combustion air

The difference between the fuel gas pollutant limit value (→ Page 92) (section 4.3) and the fuel gas pollutant volume actually supplied to the engine must not exceed **a twentieth** in the combustion air.

Example of **the series 4000 gas engine - generator application** based on the limit value for total sulfur (natural gas engine):

- A fuel gas with a calorific value of 9.33 kWh/m³NPT with a sulfur content of 4.0 mg/m³NPT is used.
- The permissible total sulfur content in the fuel gas is 30 mg/m³NPT with a reference calorific value of 10.00 kWh/m³NPT, see subsection (→ Page 92) 4.3.

Calculation::

'Permissible total sulfur content of fuel gas =

$$\left(30{,}0\ \text{mg/m}^3\text{i.N.} * \frac{9{,}33\ \text{kWh/m}^3\text{i.N.}}{10{,}00\ \text{kWh/m}^3\text{i.N.}}\right) = 28{,}0\ \text{mg/m}^3\text{i.N.}$$

'Permissible total sulfur content of combustion air =

$$\left(\frac{1}{20}\right) * (28{,}0\ \text{mg/m}^3\text{i.N.} - 4{,}0\ \text{mg/m}^3\text{i.N.}) = 1{,}2\ \text{mg/m}^3\text{i.N.}$$

The calculated result must always be accurate to one decimal point.

Note: The dust load of the combustion air is covered in subsection (→ Page 128) 7.3.

8.2 Humidity

When operating gas engines in high air humidity conditions, there is a danger of condensation in the gas-air mixture. This condensation can lead to damage, e.g. corrosion on parts that make contact with the mixture. The dew point [°C] of the intake air is drawn on for assessing the permissible air humidity. The maximum possible dew point must always be converted to a site altitude of 100 m (approx. 1000 mbar barometric pressure).

The maximum dew point temperature of the intake air permitted for the engine can be obtained from the technical data sheet (TD).

Damage caused by operation with excessive air humidity shall be excluded from the warranty.

8.3 Dust load

Dust deposits reduce the heat dissipation on surfaces and can therefore lead to thermal overload and premature failure of components. The affects not only the engine and generator but also all other electrical production implements.

To prevent damaging effects by dust, filters are used in different positions which have to be changed after suitably defined maintenance intervals, or based on their condition.

The service life of the combustion air filters can be drawn on as an indicator of increased dust load because the contaminated state of this filter is recorded via a measurement of the intake depression (Series 4000 Generator application, engine-generator set and engine-generator set in Oil&Gas), or via a mechanical display (Series 4000 Marine application). If the service life of the combustion air filters has been shortened, technical measures for conditioning the machine room air / combustion air must be introduced to prevent damage to components and electrical production implements.

Damaged caused by an increased dust load in the machine room air shall not be covered by the warranty.

Design of the combustion air filtration as a fine dust filter in acc. with ISO 16890 ePM_1 50% (formerly DIN EN 779 F7).

If supply air filtration is necessary for the installation compartment, for a general dust load we recommend bag filters in accordance with ISO 16890 ePM_{10} 50% (formerly DIN EN 779 M5), in which all particles of particle class PM_{10} are separated by at least 50%. In the case of special project-specific dust loads, e.g. coarser fiber dust, sand load in desert areas, large amounts of fine-grained dust from mills, foundries or cement factories, filtration must be designed to match the existing particle load.

Specifications on particle emissions in the exhaust gas relate to particles that are created through engine-internal processes. Particles that are possibly only directed through the engine from the intake air can result in particle values higher than those specified on the emission data sheet.

Important

Only applies to engine-generator set in Oil&Gas.
If the boundary from the installation compartment to the outside can not be sealed airtight, the ventilation system must be designed such that there is underpressure in the interior area to prevent the penetration of unfiltered infiltrated air. Similarly, for this reason always ensure during operation that the access points to the installation compartment and the control cabinet doors are always sealed.

9 Heating Water

9.1 General information

Important

The specifications of Rolls-Royce Solutions with regard to conditioning / ventilation of the coolant circuits must be observed.
The specified limit values must be observed because otherwise the warranty shall become void.

Important

Requirements for the quality of heating water above 100 °C apply when an exhaust heat exchanger has been installed in the engine cooling circuit or the heating circuit.

Important

Adding sulfite is not allowed.
It is recommended to use WBcon 2347 as an alternative for the heating water circuit.
Please note that the product contains borates and sodium hydroxide, which are corrosive to materials such as aluminum and brass.

The water quality must be checked when adding large volumes of supplementary water by means of a water analysis, or at least once a year. For water quality, refer to (→ Page 37).

If the specifications of these technical instructions are not observed, the operating company must commission a specialist company with the water preparation.

Supplementary information

It is pointed out as a precaution that, in general, costs for foreseeable damage, e.g. by unsuitable water quality, are not covered by machine breakdown insurance either.

The term 'Sum total, alkaline earths' refers to the content of hardness-forming, dissolved calcium and magnesium salts. To convert to the former standard unit of measurement of 'Total hardness', the following applies:

- 1 mol/m ^{3} = 5.6 dH
- The pH value is a measure of the acidity or alkalinity of a solution.
- pH = 7 neutral, < 7 acid, > 7 alkaline.

Important

Max. permissible fluctuation of the heating water inlet temperature: Max. 3 K / min.

9.2 Information on heating water for Series 4000 and 400

Important

Adding sodium sulfite as binding agent for oxygen is not allowed.

Important

The base alkalization must occur with trisodium phosphate.

Requirements of heating water up to 100 °C

VDI Directive 2035 Sheet 1 (December 2005) and Sheet 2 (September 1998) is definitive. "Prevention of damage by corrosion and scale formation in water heating installations" with the following guide values (see also the corresponding explanations in the original):

General requirements	Clear, colorless and free from undissolved substances	
pH value (25 °C)	8.0 to 9.0	
Electric conductivity (25 °C)	< 250	µS/cm
Sum total, alkaline earths	Up to 1.5 Up to 8.4	mmol/l °dH
Chlorides	< 50	mg/l
Sulfates	< 50	mg/l
Phosphates	< 10	
Oxygen content when using oxygen binding agents	< 0.1	mg/l
Iron	< 0.2	mg/l

Table 68: Requirements of heating water up to 100 °C

If the upper limit values are not observed, the following measures are required:
- Against scale formation: Coolant conditioning (softening, complete demineralization, reverse osmosis) or hardness stabilization (ST-DOS-H products)
- Against corrosion processes: Inhibition or oxygen binding (ST-DOS-H products)

Requirements imposed on heating water above 100 °C

The definitive specification is the VdTÜV Directive TCh 1466 governing the quality of water in heating installations which are operated with a supply temperature above 100 °C. The following guide values subsequently apply for low-salt method of operation:

General requirements	Clear, colorless and free from undissolved substances	
pH value (25 °C)	8.0 to 9.0 *	
Electric conductivity (25 °C)	10 to < 250	µS/cm
Sum total, alkaline earths	< 0.02 < 0.10	mmol/l °dH
Chlorides	< 20	mg/l
Sulfates	< 5 to 10	mg/l
Oxygen content	< 0.05	mg/l
* Deviation from TCh 1466 (TÜV)		

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General requirements	Clear, colorless and free from undissolved substances	
Phosphatized	5 to 10	mg/l
Iron	< 0.2	mg/l
* Deviation from TCh 1466 (TÜV)		

Table 69: Requirements imposed on heating water above 100 °C

Measures against scale formation and corrosion processes:
- Against scale formation: Coolant conditioning (softening, complete demineralization, reverse osmosis) or hardness stabilization (ST-DOS-H products)
- Against corrosion processes: Inhibition or oxygen binding (ST-DOS-H products)

9.3 Information on Heating Water for Series 500 Engines

9.3.1 Water quality for heating water circuit Series 500

When topping up large volumes of supplementary water, or at least once a year, the water quality must be checked by means of a water analysis. For water quality, see (→ Page 133).

If the specifications of these technical instructions are not observed, the operating company must commission a specialist company with the water conditioning.

Characteristic	Unit	Limit value
Appearance	-	Clear and of neutral odor, free of sediment and suspended particles
pH value at 25 °C	-	8.2 to 10.0
Electr. conductivity (at 25 °C)	µS/cm	< 250
Oxygen content O2	mg/l	< 0.05
Total hardness *	°dH	< 0.3 (=0.05 mmol/l)
Chlorides	mg/l	< 10
Phosphate (PO_4)	mg/l	5 to 10
* If the total heating output of the heating system is less than 600 kW, higher values according to VDI 2035, Sheet 1 can be tolerated		

Table 70: Limit values for heating water circuit

9.3.2 Heating water – Water quality Series 500

Further information on observance of the water quality

- Operation with deionized water with a weak alkaline buffering is generally recommended. In particular, with a pH value that has to be closely observed this prevents the self-alkalization effect. Furthermore, this type of water conditioning removes further elements that have corrosive effects (e.g. chlorides).
- In general, corrosion effects are prevented by low conductivity of the heating water. A low-salt control mode according to VDI 2035 is with a value < 100 µS/cm. The limit values for the heating water circuit should be undershot (→ Page 132).

Important

Relevant rules and standards provide further information (DIN EN 12828, VDI 2035, VD-TÜV, Specification Sheet 1466,…).

10 Confirmation for Fluids and Lubricants

10.1 Confirmation by the operator of engine-generator sets

Important
The plant must not be put into operation without this confirmation.

Plant description:

Plant consisting of:

Factory / SAP no.:

Customer:

Operator:

Rolls-Royce Solutions project manager:

We hereby confirm that the quality of the fluids and lubricants (coolant, gas, lubricating oil, heating water, etc., where applicable) conforms to the Fluids and Lubricants Specifications of Rolls-Royce Solutions.

Rolls-Royce Solutions does not provide any warranty for damage incurred as a result of deviating fluid and lubricant quality.

City / date

Legally binding signature (customer)

11 Revision Overview

11.1 Revision overview

Changes

- Series 4000 gas engine – Engine-generator set in Oil&Gas supplemented
- Section 2.1.2 Engine oil limit values for Series 4000 and Series 400 updated
- Section 2.2.1 Approved engine oils for T24N and L64FB supplemented
- Section 2.2.3 Gear oil supplemented
- Section 2.3.1 Approved engine oils updated
- Section 2.3.2 Engine oil change intervals for Series 400 updated
- Chapter 3 Coolant revised
  – Borates and 2-EHS included in the tables
  – Approved coolants updated
- Chapter 4 was added, previously Chapter 6 Flushing and Cleaning Specifications for engine coolant circuits.
- The following chapters were updated.
  – 4.1.1 General
  – 4.1.3 Engine coolant circuits – Flushing.
  – 4.1.4 Engine coolant circuits – Cleaning.
  – 4.1.5 Engine coolant circuit assemblies – Cleaning.
  – 4.2.1 General
- Chapter 5 External cleaning of product was supplemented.
- Chapter 6 Fuels was revised, was previously Chapter 4.
- The following chapters were updated.
  – 6.1.1 Fuels – Usage
  – 6.1.2 Main constituents of natural gas and fuel gases of biogenic origin
  – 6.1.3 Natural gas/hydrogen mixtures was supplemented.
  – 6.1.5 Silicon and sulfur compounds in the fuel gas
  – 6.2.1 General
  – 6.2.2 Requirements of fuel gas for marine applications
  – 6.3.1 General
  – 6.3.2 Natural gas – Requirements of the fuel gas
  – 6.3.3 Biogas – Requirements for fuel gas
  – 6.3.4 Engine operation with gaseous propane
- Section 6.4 Series 4000 gas engine – Engine-generator set in Oil&Gas supplemented
- Section 6.5: Series 400 gas engine – Engine-generator set updated
- Chapter 8 Supply air and combustion air updated
- Section 9.1 Heating water – General updated

12 Appendix A

12.1 List of abbreviations

Abbreviation	Meaning	Explanation
ASTM	American Society for Testing and Materials	–
Bh	Betriebsstunden	Operating hours
BR	Baureihe	Series
BV	Betriebsstoffvorschrift	Fluids and Lubricants Specifications
DIN	Deutsches Institut für Normung e. V.	German national standards institute, at the same time identifier of German standards (DIN = "Deutsche Industrie-Norm")
DVGW	Deutsche Vereinigung des Gas- und Wasserfaches e.V.	German Federal Association for Gas and Water
EN	Europäische Norm	European standard
IP	Institute of Petroleum	–
ISO	International Organization for Standardization	International umbrella organization for all national standardization institutes
MZ	Methanzahl	Methane number
SAE	Society of Automotive Engineers	U.S. standardization organization
ST-DOS-H	Sicherheitsdatenblatt	Safety data sheet
VDI	Richtlinie, Normen Regeln und Standards	Guidelines, rules, and standards
VdTÜV	Technische Regeln	Technical rules
Vol.	Volumen	Volume

12.2 Conversion table of SI units

SI unit	US unit	conversion
°C	°F	°F = °C*1.8+32
kWh	BTU	1 BTU = 0.0002930711 kWh
kWh/m^3 NTP	BTU/ft^3	1 BTU/ft^3 = 00.010349707 kWh/m^3
kW	kBTU/h	1 kBTU/h = 0.2928104 kW
kW	bhp	1 bhp = 0.7457 kW
l	gal	1 gal = 3.785412 liters
mm	inch	1 inch = 25.4 mm
m	ft	1 ft = 0.3048 m
m/s	ft/s	1 ft/s = 0.3048 m/s
m^3 NTP	ft^3 NTP	ft^3 = 0.02831685 m^3 NTP
bar	psi	1 psi = 0.06894757 bar
kg	lb	1 lb = 0.4535924 kg

Table 71: Conversion table

12.3 Contact person/Service partner

Service

The worldwide network of the sales organization with subsidiaries, sales offices, representatives and customer service centers ensure fast and direct support on site and ensure the high availability of our products.

Local Support

Experienced and qualified specialists place their knowledge and expertise at your disposal.

For locally available support, go to the Internet site: http://www.mtu-solutions.com

24 h Hotline

With our 24 h hotline and high flexibility, we are your contact around the clock: during each operating phase, preventive maintenance and corrective operations in case of a malfunction, for information on changes in conditions of use and for supplying spare parts.

Your contact person in our Customer Assistance Center:

E-mail: service.de@ps.rolls-royce.com

Spare Parts Service

Quick, easy and correct identification of the spare part required for your system. The right spare part at the right time at the right place.

With this aim in mind, we can call on a globally networked parts logistics system.

Your contact at Headquarters:

Germany:
- Tel: +49 821 74800
- Fax: +49 821 74802289
- E-mail: spareparts-oeg@ps.rolls-royce.com

Worldwide:
- Tel: +49 7541 9077777
- Fax: +49 7541 9077778
- E-mail: spareparts-oeg@ps.rolls-royce.com

13 Appendix B

13.1 Index

D

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