



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

A001072/08E



A Rolls-Royce
solution

Rolls-Royce Solutions refers to Rolls-Royce Solutions GmbH or an affiliated company pursuant to §15 AktG (German Stock Corporation Act) or a controlled company (joint venture), and Rolls-Royce Solutions Ruhstorf GmbH.

© Copyright Rolls-Royce Solutions

This publication is protected by copyright and may not be used in any way, whether in whole or in part, without the prior written consent of Rolls-Royce Solutions. This particularly applies to its reproduction, distribution, editing, translation, microfilming, and storage and/or processing in electronic systems including databases and online services.

All information in this publication was the latest information available at the time of going to print. Rolls-Royce Solutions reserves the right to change, delete, or supplement the information provided as and when required.

Export Control Information table	
This document is subject to the following export control information:	
DE:	Not subject to export control.

Table of Contents

1	Preface			
1.1	General information	5		
2	Lubricants			
2.1	General Information	7		
2.1.1	Engine oil	7		
2.1.2	Engine oil limit values for Series 4000 and Series 400	8		
2.1.3	Engine oil limit values Series 500	10		
2.1.4	Silicon compounds in the fuel gas	11		
2.1.5	Fluorescent dyestuffs for detecting leakage in the lube oil circuit	12		
2.1.6	Lubricating greases	13		
2.1.7	Lubricating greases for general applications	14		
2.2	Series 4000 gas engine	15		
2.2.1	Approved engine oils	15		
2.2.2	Lubricating greases for generators	18		
2.2.3	Gear oils	19		
2.3	Series 400 gas engine – Engine-generator set	20		
2.3.1	Approved engine oils	20		
2.3.2	Engine oil change intervals	24		
2.3.3	Lubricating greases for generators	26		
2.4	Series 500 Gas Engine - Generator Set	27		
2.4.1	Approved engine oils	27		
2.4.2	Engine oil change intervals	28		
2.4.3	Oil volume	29		
2.4.4	Lubricating greases for generators	30		
3	Coolants			
3.1	General Information	31		
3.1.1	Coolant definition	31		
3.1.2	Operational monitoring / coolant conditioning for Series 4000 and Series 400 engines	34		
3.1.3	Coolant concentrates – Storage stability	38		
3.1.4	Color additives to detect leakage in the coolant circuit	39		
3.1.5	Preventing damage to cooling system	40		
3.1.6	Unsuitable materials in the coolant circuit	41		
3.1.7	Freshwater requirements for Series 4000 and 400	42		
3.1.8	Fresh water requirements Series 500	43		
3.2	Series 4000 gas engine – Marine application	44		
3.2.1	Coolants – General information	44		
3.2.2	Coolant without antifreeze – Concentrates for cooling systems not containing light metal	45		
3.2.3	Coolant without antifreeze – Ready mixtures for cooling systems not containing light metal	47		
3.2.4	Antifreeze – Concentrates for cooling systems free of light metal	48		
3.2.5	Antifreeze – Concentrates for special applications	51		
3.2.6	Antifreeze – Ready mixtures for cooling systems free of light metal	52		
3.3	Series 4000 Gas Engine - Generator Application, Generator Set, and Generator Set in Oil&Gas	55		
3.3.1	Coolants – General information	55		
3.3.2	Coolant without antifreeze – Concentrates for cooling systems containing light metal	56		
3.3.3	Coolant without antifreeze – Ready mixtures for cooling systems containing light metal	57		
3.3.4	Antifreeze – Concentrates for cooling systems containing light metal	58		
3.3.5	Antifreeze – Concentrates for special applications	61		
3.3.6	Antifreeze – Ready mixtures for cooling systems containing light metal	62		
3.4	Series 400 gas engine – Engine-generator set	65		
3.4.1	Approved coolants	65		
3.5	Series 500 Gas Engine - Generator Set	66		
3.5.1	Coolants – General information	66		
3.5.2	Coolant – Check and replacement	67		
3.5.3	Approved coolants	68		
4	Flushing and Cleaning Specifications for Engine Coolant Circuits			
4.1	Flushing and Cleaning Specifications for Series 400 and 4000 Engines	69		
4.1.1	General information	69		
4.1.2	Approved cleaning agents/disinfecting agents	70		
4.1.3	Flushing engine coolant circuits	71		
4.1.4	Engine coolant circuits – Cleaning	72		
4.1.5	Engine coolant circuit assemblies – Cleaning	74		
4.1.6	Coolant circuits contaminated with bacteria, fungi or yeast	75		
4.2	Flushing and Cleaning Specifications for Series 500 Engines	76		
4.2.1	General information	76		
4.2.2	Approved cleaning agents	77		
4.2.3	Engine cooling system – Cleaning	78		

		6.6.4 Conversion of limit values from gas analysis	125
		6.6.5 Special limit values	126
		6.6.6 Operational malfunctions due to condensate in the fuel gas	128
5	Cleaning the Product Externally		
5.1	General information	79	
6	Fuels		
6.1	General Information	80	
6.1.1	Fuels – Usage	80	
6.1.2	Main constituents of natural gas and fuel gases of biogenic origin	81	
6.1.3	Natural gas/hydrogen mixtures	83	
6.1.4	Liquid Natural Gas (LNG)	84	
6.1.5	Silicon and sulfur compounds in the fuel gas	85	
6.1.6	Knock resistance of gas compensation	86	
6.2	Series 4000 gas engine – Marine application	87	
6.2.1	General information	87	
6.2.2	Requirements of fuel gas for marine applications	88	
6.2.3	Specifications for the medium in the gas piping leak chamber for marine applications	91	
6.3	Series 4000 Gas Engine – Generator Application and Generator Set	93	
6.3.1	General information	93	
6.3.2	Natural gas – Requirements of the fuel gas	94	
6.3.3	Biogas – Requirements for fuel gas	98	
6.3.4	Engine operation with gaseous propane	102	
6.3.5	Engine operation with associated gas	108	
6.4	Series 4000 Gas Engine - Generator Set in Oil&Gas	114	
6.4.1	General information	114	
6.4.2	Natural gas – Requirements of the fuel gas	115	
6.5	Series 400 gas engine – Engine-generator set	118	
6.5.1	Natural gas – Fuel values	118	
6.5.2	Biogas – Fuel values	119	
6.5.3	Harmful impurities (pollutants)	120	
6.6	Series 500 Gas Engine - Generator Set	122	
6.6.1	Gas types	122	
6.6.2	Minimum requirements of gas composition	123	
6.6.3	Gas operating data	124	
		7 Exhaust Gas Aftertreatment System	
		7.1 General	129
		7.2 NOx reducing agent AUS 32 for SCR exhaust gas aftertreatment systems	130
		7.3 Exhaust condensate	132
		8 Inlet Air and Combustion Air	
		8.1 General information	133
		8.2 Humidity	135
		8.3 Dust load	136
		8.4 Heating Water	137
		8.4.1 General information	137
		8.4.2 Information on heating water for Series 4000 and 400	138
		8.4.3 Information on Heating Water for Series 500 Engines	140
		8.4.3.1 Water quality for heating water circuit Series 500	140
		8.4.3.2 Heating water – Water quality Series 500	141
		9 Confirmation for Fluids and Lubricants	
		9.1 Confirmation by the operator of engine- generator sets	142
		10 Revision Overview	
		10.1 Revision overview	143
		11 Appendix A	
		11.1 List of abbreviations	145
		11.2 Conversion table of SI units	146
		11.3 Contact person/Service partner	147
		12 Appendix B	
		12.1 Index	148

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 that have to be observed, work that has to be performed and activities that have to be carried out to prevent damage to or destruction of 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 units are largely dependent on the fluids and lubricants used. The correct selection and treatment of these fluids and lubricants is therefore extremely important. It is defined in these Fluids and Lubricants Specifications.

mtu ValueCare portfolio

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

Test standard	Designation
DIN	Deutsches Institut für Normung
EN	Europäische Normung
ISO	Internationale Norm
ASTM	American Society for Testing and Materials
IP	Institute of Petroleum
DVGW	Deutscher Verein des Gas- und Wasserfaches e.V.

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 operation, make sure that the latest 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 units 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 may apply from country to country, and a generally valid statement on applicable regulations is therefore not possible within these Fluids and Lubricants Specifications.

Users of the products named in these specifications must therefore undertake 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, reprereservation and depreservation including the approved preservatives is available in the Preservation and Reprereservation Specifications (publication number A001070/ ...). The most recent version can be called 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 27)

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 boundary 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 51659-1 DIN 51659-2 DIN 51659-3	Max. 17.5 Min. 12.5	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 volume)	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 and contamination:	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 silicon contamination 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. **** Only possible if there are no ester compounds			

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.		
Properties	Test method	Limit values Series 500
Viscosity at 100 °C (mm ² /s)	ASTM D445 DIN 51659-1 DIN 51659-2 DIN 51659-3	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 value +2.5
iph value	ASTM D7946	Min. 4
Water (% by volume)	ASTM D6304 EN 12937 ISO 6296	Max. 0.2
Glycol (% by volume)	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 1000 h		Max. 20
Lead (Pb), ppm per 1000 h		Max. 35
Aluminum (Al), ppm per 1000 h		Max. 15
Copper (Cu), ppm per 1000 h		Max. 15
Tin (Sn), ppm per 1000 h		Max. 10
Silicon (Si), ppm		Max. 15*
Chromium (Cr), ppm per 1000 h		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.

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

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

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

2.1.5 Fluorescent dyestuffs for detecting leakage in the lube oil circuit

The fluorescent dyestuffs listed below are approved for detecting leakage 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 grade	Model type							Comments / material number
			4000L61 / L62 / L63	4000L64 / L64FNER / T24N / L64FV**	4000L32 / L33 / L32FNER	4000L32FB	4000L62FB*	4000L64FB	4000M55RN	
Rolls-Royce Solutions GmbH	GEO BG Power B2L	40				X	X	X		20 l canister: X00072870 205 l canister: X00072871 IBC: X00072872 Tank: X00073862
	GEO NG Power X2L	40	X							20 l canister: X00072874 205 l canister: X00072875 IBC: X00072876 Tank: X00073865
	GEO NG Power X3L	40	X	X	X				X	20 l canister: X00072877 205 l canister: X00072878 IBC: X00072879 Tank: X00073866
X = Approval for model type * = With this model type, the additional information in the Technical Description must be observed when selecting the approved engine oil. ** = Only for natural gas										

Table 6: Engine oils for Series 4000 gas engines

Important

To determine the engine oil change intervals, oil samples must be taken every 250 op. hrs. and analyzed. The limit values must be observed.

Alternative engine oils for Series 4000 gas engines

Manufacturer	Brand name	SAE viscosity grade	Model type						
			4000L61 / L62 / L63	4000L64 / L64FNER / T24N / L64 FV***	4000L32 / L33 / L32FNER	4000L32FB	4000L62FB**	4000L64FB	4000M55RN
Addinol	MG 40 Extra LA	40				X	X		
	MG 40 Extra Plus	40					X		
	Eco Gas 4205 XD	40	X	X					X
BayWa AG	Tectrol MethaFlexx HC Premium	40				X	X		
Castrol Ltd.	Castrol Duratec L	40	X		X *				
CEPSA	Troncoll Gas SP 40	40	X	X					X
Chevron	HDAX 8200	40	X	X					X
EXOL	Taurus GEO CH G240	40	X	X					X
Exxon Mobil Corporation	Mobil Pegasus 605 Ultra 40	40				X *** *	X *** *		
	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 Ultra LA R	40	X	X					X
	Titan Ganymet PRO 4000	40	X	X					X
MOTUL	Gasma SP SAE 40	40	X	X					X
NILS S.p.A.	Burian	40					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 must be observed when selecting the approved engine oil.

*** = Only for natural gas

**** = Approval only for a maximum electrical output of 83 kW/cyl

TIM-ID: 000077948 - 009

Manufacturer	Brand name	SAE viscosity grade	Model type						
			4000L61 / L62 / L63	4000L64 / L64FNER / T24N / L64 FV***	4000L32 / L33 / L32FNER	4000L32FB	4000L62FB**	4000L64FB	4000M55RN
Shell International Petroleum Company	Shell Mysella S3 N 40	40	X		X *				
	Shell Mysella S5 N 40	40	X	X	X				
	Shell Mysella S5 S 40	40				X *** *	X *** *		
SRS Schmierstoff Vertrieb GmbH	SRS Mihagrun LA 40	40	X		X *				
TEDOM Energy Systems and Solutions GmbH	Schnell Protect Oil	40				X	X		
Total Deutschland	Nateria MH40	40	X		X *				
	Nateria MJ40	40					X		
	Nateria MP40	40	X	X	X	X	X	X	X
Petro-Canada Europe Lubricants Ltd.	Sentron CG 40 (205 L Drum: 800262)	40				X	X	X	
	Sentron LD 5000	40	X						
	Sentron LD 8000 (205 L Drum: 800315)	40	X	X	X				X
	Sentron LD 8000	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 must be observed when selecting the approved engine oil. *** = Only for natural gas **** = Approval only for a maximum electrical output of 83 kW/cyl									

Table 7: Alternative engine oils for Series 4000 gas engines

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 following information is attached to the generators by the manufacturer:

- Lubricating grease to be used
- Volume of lubricating grease
- 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 initial operating hours.

Important

Poor lubrication may lead to excessive temperatures and damage to the bearings.

Lubricating greases for generators in Series 4000 gas

Generator manufacturer	Lubricating grease (mtu material number)
Leroy-Somer	Shell Gadus S3 V220C2 (X00067217) *
	Mobil Polyrex™ EM: grade NLGI 2 (X00071899) *
	ESSO Unirex N3 (40330/1) *
Cummins	KLUEBER ASONIC GHY72 (09110145007)
	KLÜBERQUIET BQ 72-72 (X00077277)
Observe the manufacturer's specifications on the generator nameplate. * According to the manufacturer, operation with a mixture of the two lubricating greases is not possible and not permitted.	

2.2.3 Gear oils

Approved lubricating oils

Only applies for 60 Hz applications.

Manufacturer/Supplier	Designation	SAE Viscosity class	Comment
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 grade	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 canister: X00072874 / 205 l container: X00072875 / IBC: X00072876 / Tank: X00073865
 3) 20 l canister: 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 grade	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
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 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

T10-ID: 0000053541 - 011

Manufacturer/Supplier	Brand name	SAE viscosity grade	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 grade	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
	GEO NG POWER X3L ⁴⁾	40 ¹⁾	M	B	SCR

Table 12: Engine oils for Series 400 turbo engines

1) Approval conditional on engine ambient temperature being > +10 °C.

2) 20 l canister: X00072870 / 205 l container: X00072871 / IBC: X00072872 / Tank: X00073862

3) 20 l canister: X00072874 / 205 l container: X00072875 / IBC: X00072876 / Tank: X00073865

4) 20 l canister: X00072877 / 205 l container: X00072878 / IBC: X00072879 / Tank: X00073866

M Mineral engine oil

E Natural gas

P Propane

B Biogas (cleaned / fully desulfurized)

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 grade	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, SCR
	ECO GAS 4000 XD	40 ¹⁾	M	B	SCR
	MG 40 Extra Plus	40 ¹⁾	M	B	K
	MG 40 Extra LA	40 ¹⁾	M	E, P	K

Manufacturer/Supplier	Brand name	SAE viscosity grade	Comment		
BayWA AG	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
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
	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 Plus	40 ¹⁾	M	B	K
	Titan Ganymet Ultra	40 ¹⁾	M	E, P	K
	Titan Ganymet Ultra	40 ¹⁾	M	B	SRK
	Titan Ganymet Ultra EVO	40 ¹⁾	M	B	SRK, SCR
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
	Sentron LD 8000	40 ¹⁾	M	B	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	K, SCR
	Shell Mysella S5 S 40	40 ¹⁾	M	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

T10-ID: 0000053541 - 011

- 1) Approval conditional on engine ambient temperature being $> +10\text{ }^{\circ}\text{C}$.
- S Synthetic engine oil
- M Mineral engine oil
- E Natural gas
- P Propane
- B Biogas (cleaned / fully desulfurized)
- 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 Module / engine-generator set with engine model	Engine oil system with oil bleed system and additional capacity	
	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 Module / engine-generator set with engine model	Engine oil system with oil bleed system and additional capacity	
	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 - 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 (H₂S)), 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 28).

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) + freshwater 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 45)
- For Series 4000 gas engine – Generator application, generator set and generator set in Oil&Gas (→ Page 56)
- For Series 4000 gas engine – Generator set (→ Page 65)
- For Series 500 gas engine – Generator set (→ Page 66)

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 69)

Note

The following products are available for use at extremely low temperatures (-60 °C/arctic regions):

- BASF Glysantin® G30® pink
- BASF Glysantin® G30ECO pink BMB 100
-

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 coolant circuit must be preserved if no more coolant is to be added. Refer to Preservation and Represervation Specifications A001070/ ... for a description of the preservation procedure.

Coolants must be prepared from suitable freshwater 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

Notes on mtu ValueCare coolants

Important

The production and distribution of the coolants CS 100 and CS10/90 will be discontinued by RRPS for operational reasons.

The alternative products listed in table (→ Table 21) are compatible when refilling and in the presence of residual quantities when changing coolant.

For all other coolants specified in the RRPS Fluids and Lubricants Specifications, topping up is not permitted and flushing is necessary when changing the coolant brand.

mtu ValueCare – Product name	Alternative products	Manufacturer
Coolant CS 100 Corrosion Inhibitor Concentrate	Power Cool® Plus 6000	Rolls-Royce Solutions America Inc.
	Drewgard XTA	Drew Marine
	Glysacorr G93	BASE SE
	Fricofin ME	Fuchs SE
	Zerex G-93	Valvoline
	OEM Advanced 93	Valvoline
	York 719	YORK SAS
Coolant CS 10/90 Corrosion Inhibitor Premix	No alternative ready mixture available. CS 100 concentrate must be prepared with appropriate freshwater.	

Table 21:

Important

The production and distribution of the coolant AH 100, and ready mixtures based on it, will be discontinued by RRPS for operational reasons.

The alternative products listed in table (→ Table 22) are compatible when refilling and in the presence of residual quantities when changing coolant.

The products listed in table (→ Table 22) are based on the latest knowledge available at the time of publication of this edition of RRPS Fluids and Lubricants Specifications.

For all other coolants specified in the RRPS Fluids and Lubricants Specifications, topping up is not permitted and flushing is necessary when changing the coolant brand.

mtu ValueCare – Product name	Alternative products	Manufacturer
Coolant AH 100 Antifreeze Concentrate	Glysantin G48 blue green	BASF SE
	Tectrol Coolprotect	BayWa AG
	Castrol Radicool NF	Castrol
	CAR 1 Premium Longlife Kühlerschutz C48	COPARTS Autoteile GmbH
	Classic Kolda UE G48	Classic Schmierstoff GmbH & Co. KG
	AVIATICON Finkofreeze F48	Finke Mineralölwerk GmbH
	Fricofin	Fuchs SE
	Alpine C48	Mitan Mineralöl GmbH
	Mobil Antifreeze Extra	Moove Lubricants Limited
	Motorex Coolant G48	Motorex AG
	Nalcool NF48 C	Nalco Water An Ecolab Company
	Roxor Anti-Frost MT-325	LAEMMLE Chemicals AG
	Antifreeze Long Life NF-300 Concentrate	Raloy Lubricantes
	Glacelf MDX	Total Lubrifiants
	Zerex-G48	Valvoline
	OEM Advanced 48	
Coolant AH 35/65 Antifreeze Premix	Power Cool® Universal 35/65 mix	Rolls-Royce Solutions America Inc.
Coolant AH 40/60 Antifreeze Premix	Castrol Radicool NF Premix (45%)	Castrol
	Coolelf MDX -26 °C	Total Lubrifiants
	Schnell Protect Coolant (Ready mix 40/60 to max. -27 °C)	Tedom Service GmbH
Coolant AH 50/50 Antifreeze Premix	Power Cool® Universal 50/50 mix	Rolls-Royce Solutions America Inc.
	XTAR Super Coolant Hybrid NF 50%	Cepsa Comercial Petróleo S.A.U.
	AVIATICON Finkofreeze F48 RM 50/50	Finke Mineralölwerk GmbH
	Fricofin 50	Fuchs SE
	Mobil Coolant Extra Ready -36 °C	Moove Lubricants Limited
	Motorex Coolant G48 (Ready to use (50/50))	Motorex AG
	Antifreeze Long Life NF-300 Ready-to-use (50:50)	Raloy Lubricantes
	Coolelf MDX -37 °C	Total Lubrifiants
	Zerex G-48 premix 50%	Valvoline
	OEM Advanced 48 premix 50%	

Table 22:

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

Analysis of the freshwater and continuous monitoring of the coolant are essential for trouble-free engine operation. The freshwater and the coolant should be checked at least once a year or each time they are topped up. This can be carried out with the test kit or by an authorized laboratory. The test kit contains all the necessary equipment, chemicals and instructions for use.

Important		
Rolls-Royce Solutions recommends the test kit produced by CM Technologies GmbH (https://www.cmtechnologies.de).		
Analysis	On-site method (Test kit)	Lab method
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 with suitable 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 25) and read off concentration in % by volume.	Refractometer method DIN 51423, compare Brix value against table (→ Table 25) 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 bacterial count for aqueous media	-	Dip slides (tube with culture medium, e.g. by VWR Prolabo No. 535112D or equivalent) incubation time: Four days at 30 °C

Table 23: Minimum requirements and methodology for operational monitoring for coolant

Orders for freshwater and coolant analysis may be placed with Rolls-Royce Solutions. In specific cases, operational monitoring can cover more checks than those listed in table (→ Table 23). Please contact your partner if necessary.

The routine check of the coolant in accordance with table (→ Table 23) identifies minimum requirements. If there are noticeable problems with the coolant with regard to

- Appearance (color, clouding, contamination, etc.)
- Odor

and in the results of the specified examinations, then a laboratory analysis is recommended (see A001080/.. 'Handling of laboratory samples'). In the case of silicon-containing coolants, the silicon content must generally be checked in the laboratory, because no rapid test that can be applied is available.

Permissible concentrations of antifreezes

	Minimum			Maximum
Antifreeze based on ethylene glycol	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			
BASF Glysantin® G30® pink BMB 100				
* = Antifreeze specifications determined as per ASTM D 1177.				

Table 24: Permissible concentrations of antifreezes

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

Important

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

Add antifreeze to the freshwater 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 subsequent 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-held refractometer ¹⁾ at 20 °C (= degree(s) Brix) % by volume					
			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
	Fuchs SE	Fricofin ME	3.5	4.0	4.5	5.0	5.5	6.0
	Ginouvès	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
	Penske Power Systems	PowerCool Pyroshield GF Coolant	4.9	5.6	6.3	7.0	7.7	8.4
	Recochem Inc.	HD Expert TM Endurance WB Prediluted Coolant	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-held refractometer

Table 25: 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.

T1M-ID: 000078628 - 008

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

Permissible concentration range	Manufacturer	Brand name	Reading on hand-held refractometer ¹⁾ at 20 °C (= degree(s) Brix % by volume)					
			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 And 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
	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 from manufacturer.					
	Nalco Water And Ecolab Company	Nalcool® 2000						

¹⁾ = Concentration determined by means of suitable hand-held refractometer

Table 26: 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.

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 freshwater 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 (recommended measuring range 6.5 to 10.0). The results must be documented.

3.1.3 Coolant concentrates – Storage stability

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	Brand name/comments
Antifreeze	Approx. 3 years	Observe manufacturer's specifications
Coolant without antifreeze	Two years	ImproChem Cool-C18 Nalco Nalcool® 2000
	3 years	BASF Glyscorr G93 green Drew Marine Drewgard XTA Ginouves York 719 Fuchs SE Fricofin ME 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) Penske Power Systems PowerCool Pyroshield GF Coolant Recochem Inc. HD Expert TM Endurance WB Prediluted Coolant Total WT Supra

Table 27: Coolant concentrates – Storage stability

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 leakages.

Approved color additives

Manufacturer	Product category (TIM)	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 28:

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 attained.
- The corrosion inhibitor concentration must not exceed 50% by volume Use antifreeze. Concentrations in excess of this diminish antifreeze protection and heat dissipation. Only exceptions: BASF Glysantin® G30® pink (special application) and BASF Glysantin® G30® pink BMB 100
- 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 preserved engines are 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 attachments there are on the engine. Check the coolant concentration in the coolant circuit and adjust as necessary.

Important

All coolants approved in these Fluids and Lubricants Specifications generally relate only to the coolant circuits of mtu engines. 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 Freshwater requirements for Series 4000 and 400

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
Sum of alkaline earth metals *) (water hardness)	mmol/l °dH	2.7 max. 15 max.
pH value at 20 °C	–	5.5 to 8.0
Bacteria	CFU (colony forming unit)/ml	10 ³ max.
Chloride and fluoride	mg/l	100 max.
Sulfates	mg/l	100 Max.
Total anions	mg/l	200 Max.
Fungi, yeasts	are not permitted	
Odor	Neutral	
Appearance	Colorless, clear, free of mechanical contaminants	

Table 29: Freshwater requirements for Series 4000 and 400

*) Common designations for water hardness in various countries:

1 mmol/l = 5.6 °dH = 100 mg/kg CaCO₃

- 1 °dH = 17.9 mg/kg CaCO₃, 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 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 30: Mixture water limit values

*) Common designations for water hardness in various countries:

1 mmol/l = 5.6 °dH = 100 mg/kg CaCO₃

- 1 °dH = 17.9 mg/kg CaCO₃, 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 31) and 'Unsuitable materials in the coolant circuit' (→ Page 41).

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

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

For details and special properties, see the chapter on "Coolants" (→ Page 31).

Coolant without antifreeze – Concentrates

Manufacturer	Product/brand name	Inhibitors						Runtime Hours/years	Comments/ material no.
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates		
Rolls-Royce Solutions GmbH	Coolant CS100 Corrosion Inhibitor Concentrate	X					X	6000/2	No longer included in portfolio. Remaining stocks of this product can be used up as long as they are within their shelf life.
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	
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	
Fuchs SE	Fricofin ME	X					X	6000/2	
ImproChem	COOL-18	X	X				X	6000/2	
Nalco Water An Eco-lab 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	

Manufacturer	Product/brand name	Inhibitors							Runtime Hours/years	Comments/ material no.
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
Valvoline	Zerex G93		X					X	6000/2	
	OEM Advanced 93		X					X	6000/2	
YORK SAS	York 719		X					X	6000/2	

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

For details and special properties, see the chapter on "Coolants" (→ Page 31)

Coolant without antifreeze – Ready mixtures

Manufacturer	Product/brand name	Inhibitors						Runtime Hours/years	Comments/ material no.
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates		
Rolls-Royce Solutions GmbH	Coolant CS 10/90 Corrosion Inhibitor Premix		X					X 6000/2	No longer included in portfolio. Remaining stocks of this product can be used up as long as they are within their shelf life.
Nalco Water An Eco-lab Company	Alfloc™ 3443 (7%)	X						X 6000/2	
Penske Power Systems	PowerCool Pyroshield-GF Coolant	X				X		6000/2	
Recochem Inc.	HD Expert™ Endurance WB Prediluted Coolant	X				X		6000/2	

3.2.4 Antifreeze – Concentrates for cooling systems free of light metal

For details and special properties, see chapter 'Coolants' (→ Page 31).

Antifreeze – Concentrates

Manufacturer	Product/brand name	Inhibitors						Operating time Hours/year	Comments/ Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates		
Arteco NV	Havoline XLC (1040112)	X					X	9000 / 3	
AVIA AG	Antifreeze APN-S	X						9000 / 3	
BASF SE	Glysantin® G48® blue green	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 con- centration 40 to 50% by volume
	Glysantin® G40® ECO pink BMB 100	X	X					9000 / 3	
	Glysantin® G30® pink	X						9000 / 3	X00058072 (canis- ter) X00058071 (barrel)
	Glysantin® G30® ECO pink BMB 100	X						9000 / 3	
BayWa AG	Tectrol Coolprotect	X	X				X	9000 / 5	
Castrol	Castrol Radicool NF	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	9000 / 5	
	Classic Kolda UE G40 ®	X	X					9000 / 3	
	Classic Kolda UE G30 ®	X						9000 / 3	
COPARTS Autoteile GmbH	CAR1 Premium Long- life Kühlerschutz C48	X	X				X	9000 / 5	
Daimler Trucks North America	Alliance OAT Extended Life Coolant	X			X			9000 / 3	
Detroit Diesel Corp.	Power Cool Plus Cool- ant	X			X			9000 / 3	
Drew Marine	Drewgard ZX	X						9000 / 3	
ExxonMobil	Mobil Delvac Extended Life Coolant	X			X			9000 / 3	

T1M-ID: 0000060984 - 009

Manufacturer	Product/brand name	Inhibitors							Operating time Hours/year	Comments/ Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
Finke Mineralölwerk GmbH	AVIATICON Finkofreeze F30	X							9000 / 3	
	AVIATICON Finkofreeze F40	X	X						9000 / 3	Application concentration 40 to 50% by volume
	AVIATICON Finkofreeze F48	X	X				X	X	9000 / 5	
Fuchs SE	Fricofin	X	X				X	X	9000 / 5	
	Fricofin DP	X	X						9000 / 3	Application concentration 40 to 50% by volume
	Fricofin G12 Plus	X							9000 / 3	X00058074 (canister) X00058073 (barrel)
	Fricofin LL	X						X	9000 / 3	
Kuwait Petroleum Research & Technology BV	Q8 Mahler Cool Premixed 5050	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
Moove Lubricants Limited	Mobil Antifreeze Extra	X	X				X	X	9000 / 5	
Motorex AG	Motorex Coolant G48	X	X				X	X	9000 / 5	
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	
	Roxor Anti-Frost MT-650	X	X						9000 / 3	

Manufacturer	Product/brand name	Inhibitors						Operating time Hours/year	Comments/ Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS	
Puma Energy International S.A.	Puma HD Hybrid Coolant	X	X						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
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 30	X							9000 / 3
	OEM Advanced 40	X	X						9000 / 3
									Application concentration 40 to 50% by volume
	OEM Advanced 48	X	X				X	X	9000 / 5
Volvo Trucks	Road Choice Nitrite-Free OAT Extended Life Coolant	X				X			9000 / 3

Table 31: Antifreeze – Concentrates

3.2.5 Antifreeze – Concentrates for special applications

For details and special properties, see chapter on 'Coolants' (→ Page 31)

Concentrates for special applications

Manufacturer	Brand name	Inhibitors						Runtime Hours/Years	Comments / Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates		
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 32: 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 33:

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 metal

Antifreeze, ready mixtures

For details and special properties, see chapter 'Coolants' (→ Page 31).

Manufacturer	Product/brand name	Inhibitors							Operating time Hours/year	Comments/ Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
Rolls-Royce Solutions GmbH	Coolant AH 35/65 Anti-freeze Premix	X	X				X	X	9000 / 5	No longer included in portfolio. Remaining stocks of this product can be used up as long as they are within their shelf life.
	Coolant AH 40/60 Anti-freeze Premix	X	X				X	X	9000 / 5	No longer included in portfolio. Remaining stocks of this product can be used up as long as they are within their shelf life.
	Coolant AH 50/50 Anti-freeze Premix	X	X				X	X	9000 / 5	No longer included in portfolio. Remaining stocks of this product can be used up as long as they are within their shelf life.
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)
Artego NV	Halvoline XLC Pre-mixed 50/50 (1033073)	X						X	9000 / 3	
	Halvoline XLC Pre-mixed 40/60 (1033069)	X						X	9000 / 3	
	Halvoline XLC + B2 35/65 (OF13) (2000214)	X						X	9000 / 3	
BayWa AG	Tectrol Coolprotect Mix 3000								9000 / 3	Antifreeze protection down to -24 °C
BASF SE	Glysantin® G40® RM/50 ECO pink BMB 100	X	X						9000 / 3	50% Premix
	Glysantin® G30® RM/50 ECO pink BMB 100	X							9000 / 3	50% Premix

T1M-ID: 0000060966 - 008

Manufacturer	Product/brand name	Inhibitors							Operating time Hours/year	Comments/ Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
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 Chemical SRL	Fast Coolant G30 50% (Ready Mix)	X							9000 / 3	
ExxonMobil	Mobil Delvac Extended Life Prediluted Coolant (50/50)	X				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	
Friedrich Scharr KG	UNIL Metis RTU GC -26	X							9000 / 3	
	UNIL Metis RTU GC -38	X							9000 / 3	
Fuchs SE	Fricofin 50	X	X				X	X	9000 / 5	(Ready Mix 50/50)
	Fricofin DP 50	X	X						9000 / 3	(Ready Mix 50/50)
	Fricofin LL 50	X					X		9000 / 3	(Ready Mix 50/50)
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	
Motorex AG	Motorex Coolant G48 ready to use (50/50)	X	X				X	X	9000 / 5	
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 Prediluted Coolant / Antifreeze (50/50)	X				X			9000 / 3	

Manufacturer	Product/brand name	Inhibitors						Operating time Hours/year	Comments/ Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates		
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	9000 / 5	
Recochem Inc.	HD Expert™ Endurance 50-50 Prediluted	X			X			9000 / 3	
SMB - Sotragal / Mont Blanc	Liquide de refroidissement -37°C FRICO-TECH MBT SMB AUTO 50/50	X	X					9000 / 3	
Tedom Service GmbH	Schnell Protect Coolant (Ready Mix 40/60 bis max. -27 °C)	X	X				X	9000 / 5	
Tedom Service GmbH	Tedom Supercool OAT (Ready Mix 40/60 bis max. -25 °C)	X						9000 / 3	
Total Lubrifiants	Coolelf Auto Supra -37 °C	X					X	9000 / 3	
	Coolelf Auto Supra -26 °C	X					X	9000 / 3	
	Coolelf MDX -26 °C	X	X				X	9000 / 5	
	Coolelf MDX -37 °C	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	9000 / 5	
	OEM Advanced 48 premix 50%	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 34: Antifreeze, ready mixtures

3.3 Series 4000 Gas Engine - Generator Application, Generator Set, and 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 31) and 'Unsuitable materials in the coolant circuit' (→ Page 41).

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 the chapter on "Coolants" (→ Page 31).

Important

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

Coolant without antifreeze – Concentrates

Manufacturer	Product/brand name	Inhibitors						Runtime Hours/years	Comments/ material no.
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates		
Rolls-Royce Solutions GmbH	Coolant CS100 Corrosion Inhibitor Concentrate*	X					X	6000/2	No longer included in portfolio. Remaining stocks of this product can be used up as long as they are within their shelf life.
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	
Fuchs SE	Fricofin ME*		X				X	6000/2	
Old World Industries Inc.	Final Charge Extended Life Corrosion Inhibitor (A 216)	X			X			6000/2	
Valvoline	ZEREX G93*		X				X	6000/2	
	OEM Advanced 93*		X				X	6000/2	
YORK SAS	York 719*		X				X	6000/2	

TIM-ID: 0000019105-014

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

For details and special properties, see the chapter on "Coolants" (→ Page 31).

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 no.
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates		
Rolls-Royce Solutions GmbH	Coolant CS10/90 Corrosion Inhibitor Premix*		X					X 6000/2	No longer included in portfolio. Remaining stocks of this product can be used up as long as they are within their shelf life.
Penske Power Systems	PowerCool Pyroshield-GF Coolant	X				X		6000/2	
Recochem Inc.	HD Expert™ Endurance WB Prediluted Coolant	X				X		6000/2	

3.3.4 Antifreeze – Concentrates for cooling systems containing light metal

For details and special properties, see chapter 'Coolants' (→ Page 31).

Antifreeze – Concentrates

Manufacturer	Product/brand name	Inhibitors						Operating time Hours/year	Comments/ Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates		
AVIA AG	Antifreeze APN-S	X						9000 / 3	
BASF SE	GLYSANTIN® G05®		X	X			X	9000 / 5	
	GLYSANTIN® G48® blue green	X	X				X	9000 / 5	X00058054 (25 l) X00058053 (210 l)
	GLYSANTIN® G30® pink	X						9000 / 3	X00058072 (canister) X00058071 (barrel)
	GLYSANTIN® G30® ECO pink BMB 100	X						9000 / 3	
	GLYSANTIN® G40® pink (concentrate)	X	X					9000 / 3	X00066724 (20 l) X00066725 (210 l) Concentration for use: 40 to 50% by volume
	GLYSANTIN® G40® ECO pink BMB 100	X	X					9000 / 3	
BayWa AG	Tectrol Coolprotect	X	X				X	9000 / 5	
Castrol	Castrol Radicool NF	X	X				X	9000 / 5	
CCI Corporation	L415	X				X		9000 / 3	
Classic Schmierstoff GmbH + Co. KG	Classic Kolda UE G48	X	X				X	9000 / 5	
	Classic Kolda UE G40 ^{<sup>sc</sup>}	X	X					9000 / 3	
	Classic Kolda UE G30 ^{<sup>sc</sup>}	X						9000 / 3	
COPARTS Autoteile GmbH	CAR 1 Premium Long- life Kühlerschutz C48	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	

TIM-ID: 000006087 - 008

Manufacturer	Product/brand name	Inhibitors						Operating time Hours/year	Comments/ Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates		
Finke Mineralölwerke GmbH	AVIATICON Finkofreeze F30	X						9000 / 3	
	AVIATICON Finkofreeze F40	X	X					9000 / 3	Concentration for use: 40 to 50% by volume
	AVIATICON Finkofreeze F48	X	X				X X	9000 / 5	
Fuchs SE	Fricofin	X	X				X X	9000 / 5	
	Fricofin DP	X	X					9000 / 3	Concentration for use: 40 to 50% by volume
	Fricofin G12 Plus	X						9000 / 3	X00058074 (canister) X00058073 (barrel)
Krafft S.L.U	Refrigerante ACU 2300		X X				X	9000 / 3	X00058075 (barrel)
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	
Moove Lubricants Limited	Mobil Antifreeze Extra	X	X				X X	9000 / 5	
Motorex AG	Motorex Coolant G48	X	X				X X	9000 / 5	
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	
	Fleetcharge SCA Pre-charged Coolant/ Antifreeze		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	
	Roxor Anti-Frost MT-650	X	X					9000 / 3	
Penske Power Systems	Power Cool - HB500 Coolant Concentrate	X	X				X	9000 / 3	

Manufacturer	Product/brand name	Inhibitors						Operating time Hours/year	Comments/ Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates		
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	
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 35: Antifreeze – Concentrates

3.3.5 Antifreeze – Concentrates for special applications

For details and special properties, see chapter on 'Coolants' (→ Page 31)

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 36: 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 37:

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 metal

For details and special properties, see chapter 'Coolants' (→ Page 31).

Antifreeze, ready mixtures

Manufacturer	Product/brand name	Inhibitors							Operating time Hours/year	Comments/ Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
Rolls-Royce Solutions GmbH	Coolant AH 35/65 Anti-freeze Premix	X	X				X	X	9000 / 5	No longer included in portfolio. Remaining stocks of this product can be used up as long as they are within their shelf life
	Coolant AH 40/60 Anti-freeze Premix	X	X				X	X	9000 / 5	No longer included in portfolio. Remaining stocks of this product can be used up as long as they are within their shelf life
	Coolant AH 50/50 Anti-freeze Premix	X	X				X	X	9000 / 5	No longer included in portfolio. Remaining stocks of this product can be used up as long as they are within their shelf life
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)
BASF SE	Glysantin® G40® RM/50 ECO pink BMB 100	X	X							50% Premix
	Glysantin® G30® RM/50 ECO pink BMB 100	X								50% Premix
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	

TIM-ID: 000078607 - 009

Manufacturer	Product/brand name	Inhibitors							Operating time Hours/year	Comments/ Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates	2-EHS		
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	
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	
Friedrich Scharr KG	UNIL Metis RTU GC -26	X							9000 / 3	
	UNIL Metis RTU GC -38	X							9000 / 3	
Fuchs SE	Fricofin 50	X	X				X	X	9000 / 5	(Ready Mix 50/50)
	Fricofin DP 50	X	X						9000 / 3	(Ready Mix 50/50)
Motorex AG	Motorex Coolant G48 ready to use (50/50)	X	X				X	X	9000 / 5	
Moove Lubricants Limited	Mobil Coolant Extra Ready Mixed -36° 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 Prediluted Coolant / Antifreeze (50/50)	X				X			9000 / 3	
	Fleet Charge SCA Pre-charged 50/50 Prediluted Coolant		X	X					9000 / 3	

Manufacturer	Product/brand name	Inhibitors						Operating time Hours/year	Comments/ Material number
		Organic	Silicon	Nitrite	Phosphate	Molybdate	Borates		
Penske Power Systems	Power Cool - HB500 Premix 50/50	X	X				X	9000 / 3	
	Power Cool - HB500 Premix 35/65	X	X				X	9000 / 3	
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	
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	Liquide de refroidissement -37°C FRICO-TECH MBT SMB AUTO 50/50	X	X					9000 / 3	
Tedom Service GmbH	Schnell Protect Coolant (Ready Mix 40/60 bis max. -27°)	X	X				X X	9000 / 5	
Tedom Service GmbH	Tedom Supercool OAT (Ready Mix 40/60 bis max. -25°)	X						9000 / 3	
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 38: Antifreeze – Ready mixtures for cooling systems containing light metal

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*
Friedrich Scharr KG	UNIL Metis RTU GC-26
* Extended change interval possible	

Table 39: Antifreeze, ready mixtures (silicate-free)

Antifreeze concentrates (silicate-free)

Manufacturer/Supplier	Designation
BASF SE	Glysanin® G30® pink
	Glysanin® G30® ECO pink BMB 100
Aral	Antifreeze Silikatfrei

Table 40: Antifreeze concentrates (silicate-free)

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. There is a risk of deposits on many components. These can lead to reduced heat transfer and thus to reduced functionality (heat exchanger) or overheating of components.

Otherwise, there is a risk of deposits on many components. These can lead to reduced heat transfer and thus to reduced functionality (heat exchanger) or overheating of 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 at least once a year or each time it is added. 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 - 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 41).

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

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 43).

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 40)
- 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 41: 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

Over 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 may be the result.

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

If such malfunctions occur, the coolant circuit must be flushed out with freshwater, repeatedly if necessary.

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

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

Freshwater requirements for:

- Series 4000 and 400 are listed in chapter 3.1.7 (→ Page 42))

Only products approved by Rolls-Royce Solutions or equivalent products at the specified concentrations may be used for cleaning, see (→ Page 70). The specified cleaning procedure is mandatory.

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 substances. Certain regulations must be obeyed 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 must therefore undertake 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.

Important

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

Test equipment, auxiliary materials, and fluids and lubricants

Test kit or electrical pH meter

Required auxiliary materials:

- Compressed air
- Superheated steam

Required fluids and lubricants:

- Freshwater
- Treated engine coolant

4.1.2 Approved cleaning agents/disinfecting agents

Approved cleaning agents

Manufacturer	Product category (TIM)	Application concentration		Order number
For coolant circuits:				
Kluthe	Hakutex 111 ¹⁾	2% by volume	Liquid	X00065751
	Decorrdal 20-1 ²⁾	10% by volume	Liquid	X00086731
Fleetguard	Restore Plus ³⁾	10% by volume	Liquid	
For coolant circuit assemblies:				
Henkel	Bonderite C-AK FD ⁴⁾	1 to 10% by weight	Powder	⁵⁾
	Bonderite C-MC 11120 ⁶⁾	2 to 10% by weight	Powder	⁵⁾
Kluthe	Hakutex 60 mtu ⁷⁾	100% by volume	Liquid	X00070585 (25 kg)
	Hakupur 50-706-3 ⁸⁾	2% by volume	Liquid	X00055629

Table 42:

Approved disinfecting agents

Manufacturer	Product category (TIM)	Application concentration		Order number
For a coolant circuit contaminated with bacteria, fungi or yeast:				
Thor	Acticide MV14 ^{9, 10)}	0.01% by volume	Liquid	X00079756 (20 L)
	Acticide MV ^{10, 11)}	0.1% by volume	Liquid	X00088729 (5 L)

Table 43:

¹⁾ = For light lime deposits, light corrosion

²⁾ = For severe corrosion, not suitable for removing corrosion from aluminum materials

³⁾ = Can only be used for cleaning the Series 4000 generator set coolant system contaminated by copper phosphate particles

⁴⁾ = For lime deposits containing oil and grease

⁵⁾ = Not stocked by Rolls-Royce Solutions.

⁶⁾ = Preferred for heavy lime deposits

⁷⁾ = Solvent cold cleaner for oily and greasy residues

⁸⁾ = For oily and greasy residues. Not suitable for galvanized surfaces

⁹⁾ = Bacteria contamination $\geq 10^5$, contamination with fungi and yeast not permitted
Note application cases (→ Page 75).

¹⁰⁾ =

- Storage temperature 10–30 °C
- Protect against heat and solar radiation
- Minimum shelf life 18 months
- Use personal protective equipment (PPE)

For application in the field. The smaller canister is easier to handle.

Note application cases (→ Page 75).

¹¹⁾ = For application in the field. The smaller canister is easier to handle.

Note application cases (→ Page 75).

Important

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

The cleaners are available worldwide through the subsidiaries of the manufacturers or their trading partners.

4.1.3 Flushing engine coolant circuits

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 the pH value of the freshwater using the test kit or electrical pH meter.

Important

Rolls-Royce Solutions GmbH recommends the diesel engine test kit produced by CM Technologies GmbH (<https://www.cmtechnologies.de>).

3. Fill coolant circuit with freshwater.

Important

Do not pour cold water into a hot engine!
Refer to the engine operating instructions for additional information

4. Preheat, start and run engine until warm.
5. Run engine for approx. 30 minutes at increased speed.
6. Stop the engine.
7. Take a flushing water sample at the engine coolant sample extraction cock.
8. Drain flushing water.
9. Measure the pH value of the flushing water sample using the test kit or electrical pH meter 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 72). The assemblies may also have to be cleaned, see (→ Page 74).

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 min. 4 hours up to max. 12 hours

Application temperature, normal coolant temperature approx. 95 °C

Application:

Flushing with Hakutex 111

1. Remove old coolant from the coolant circuit.
2. Fill coolant circuit with mixed cleaning agent Hakutex 111 (application concentration in table on (→ Page 70)).
3. Normal engine operation (max. 4 hours up to max. 12 hours) at normal coolant temperature = approx. 95 °C.
4. Remove cleaning agent.
5. Immediately after this: Flush the 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

Cleaning agent Decorrdal 20–1 is not suitable for the Series 4000GAS engines due to the use of components made of aluminum in the gas engine.

Important

The procedure for the applications must be observed in all circumstances. Flushing must not be interrupted. It is also important after draining the cleaning agent that the coolant system is filled IMMEDIATELY with new antifreeze and corrosion inhibitor.

Application temperature is the normal coolant temperature (approx. 95 °C).

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. Stop the engine.
7. Drain off cleaning agents and flush the engine coolant circuit with freshwater.
8. Take a flushing water sample at the 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 74).

Important

Refer to the engine operating instructions for additional information

Series 400

Clean engine coolant circuit with Decorrdal 20–1

1. Completely remove all coolant from engine coolant circuit.
2. Fill engine coolant circuit with fresh water and flush the engine cooling system for 30 minutes.
3. Drain flush water completely.

1st cleaning

4. Fill coolant circuit completely with a water solution containing 10% Decorrdal 20-1.
5. Start engine and run for 20 minutes up to operating temperature.
6. Perform cleaning cycle with the engine running, with circulating Decorrdal 20-1, duration: approx. 4 hours
7. Vent the engine every now and again during cleaning to guarantee complete filling; switch off the engine after four hours.
8. Allow the cleaning fluid in the engine to cool down to approx. 45 °C.
9. When the temperature reaches 45 °C, drain the cleaning agent.

2nd cleaning

Repeat items 4 – 10 repeat (important: longer operating time of the cleaning agent during the second cleaning

- operate the engine at max. 70% load for approx. eight hours
- unsupervised normal operation possible
- then continue with the first flushing (item 10))

1st flushing

10. After draining, fill the coolant circuit once again with approved antifreeze and corrosion inhibitor ready mixture.
11. Run the engine for 30 minutes.
12. Allow the engine to cool down to approx. 45 °C.
13. Drain the flushing solution, antifreeze and corrosion inhibitor ready mixture.

2nd flushing

14. After draining, fill the coolant circuit once again with approved antifreeze and corrosion inhibitor ready mixture.
15. Operate the engine for 30 minutes and vent every now and again.
16. Allow the engine to cool down to approx. 35 °C.
17. Drain flushing solution.
18. Fill engine with final 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 70)

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 30).
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.

Important
When using Acticide MV 14 (→ Page 70), the engine coolant does not need to be changed. Flushing/refilling only takes place after express recommendation by the chemical laboratory.

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 shut down 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 70) and work safety specifications must be strictly observed.

Flushing

When the coolant is drained, the coolant 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 freshwater used (maximum deviation of pH value < 1).

Refilling

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

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 77). The specified cleaning procedure must be complied with.

Freshwater requirements are listed for

- Series 500 in section 3.1.9 (→ Page 43)

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 m³ 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 local admixing of hydrogen or other gases to the fuel gas by the operating company can lead to serious damage to the machine and danger to life and limb if not carried out correctly. In such applications, a project-specific inquiry and assessment is always required in advance – otherwise all guarantee and warranty claims will be invalidated.

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 generator sets from Rolls-Royce Solutions is usually limited 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.

An up-to-date gas analysis must be available for engine commissioning. All gas components, pollutants and gas properties must be continuously within the tolerance values of the corresponding model type.

The following must be checked and monitored, for example:

- 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 – 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, Generator set S4000 / S400 and S500).

If the quality of the raw gas exceeds the sulfur limit values, a gas desulfurization 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.

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 44)
- Generally applicable limits for the main constituents of fuel gases of biogenic origin (→ Table 45)

Maximum permissible constituents of natural gas, pipeline gases

Component	Unit	Value range (maximum value)
CH ₄	% by volume	80 to 100
C ₂ H ₆ (or sum of C ₂ H _x)	% by volume	< 16
C ₃ H ₈ (or sum of C ₃ H _x)	% by volume	<9
C ₄ H ₁₀ (or sum of C ₄ H _x)	% by volume	< 2
C ₅ H ₁₂	% by volume	<0.3
Hydrocarbons C5+	% by volume	< 0.1
CO ₂	% by volume	< 10
N ₂	% by volume	<15
Sum of CO ₂ + N ₂	% by volume	<15
O ₂	% by volume	< 3
H ₂	% by volume	(→ Page 94)
CO	% by volume	<0.2

Table 44: Maximum permissible 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.

Important

If the components of the natural gas exceed the listed maximum values, consultation with Rolls-Royce Solutions is required before using this natural gas.

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

Component	Unit	Value range (maximum value)
CH ₄	% by volume	40 to 65
CO ₂	% by volume	20 to 55
N ₂	% by volume	< 10
O ₂	% by volume	< 3

Component	Unit	Value range (maximum value)
H ₂	% by volume	< 2
CO	% by volume	<0.2

Table 45: Maximum permissible 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.

Important

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.

Due to 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.

Model types L32/L33, L64 and L64FNER are currently only approved for constant hydrogen contents. On engines in the Series 4000FV, the H₂ content can vary up to 10% by volume; with a corresponding engine adaptation, variable H₂ contents of up to 25% by volume are permitted. Consultation with the manufacturer required for higher hydrogen contents. 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.

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 H₂ 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.

Important

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 H₂ 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 boundary 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 N₂ component in the boil-off phase may be 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.

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 CO₂, as CO₂ solidifies at temperatures below -56 °C and the pressures around 5.2 bar which generally prevail in such tanks. CO₂ sublimates at -78.5 °C under normal pressure conditions.

Important

The customer must provide a monitoring system for the gas temperature in order to reliably detect if the gas temperature before the gas train of the engine falls below 15 °C and shut down the plant.

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 m³ NTP CH₄).

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/m³NPT

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

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

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

6.1.6 Knock resistance of gas compensation

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.

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 $> 1.0\%$ by vol.) are present in the fuel gas. Below a CO_2 content of 1.0% 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% :

$$x \text{ CO}_2 \text{ corr} = x \text{ CO}_2 \cdot 0.15$$

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

$$x \text{ N}_2 \text{ corr} = x \text{ N}_2 + x \text{ CO}_2 \cdot 0.85$$

This correction does not apply to biogases (including NAWaRo, landfill and sewage gases).

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	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 $H_{i,n}$	kWh/m ³ _n	9.2 < $H_{i,n}$ < 11.5	Consult the manufacturer before operating with lower or higher limit values.
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/m ³ _n	0.71 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)	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 before the gas train must not be under-shot.
Permissible change speed of gas pressure before the gas train	bar/s	0.3	Constant change rate for transient and steady-state engine condition.

T1M-ID: 0000081017 - 009

Designation	Unit	Limit	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. hydro-silicons, siloxanes, silicones)	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 ³ N 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	
Dust < 3 µm	mg/m ³ _n	Analysis	Analysis required
Hydrogen sulfide	mg/kg	7	
Total sulfur	mg/kg	10	
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 46:

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 $T_n = 273.15 \text{ K}$ or $t_n = 0 \text{ °C}$ and standard pressure $p_n = 101325 \text{ Pa}$ or $p_n = 1.01325 \text{ bar}$.

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 $T_0 = 288.15 \text{ K}$ or $t_0 = 15 \text{ °C}$ and standard pressure $p_n = 101325 \text{ Pa}$ or $p_n = 1.01325 \text{ bar}$.

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 47:

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 48:

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 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.

6.3.2 Natural gas – Requirements of the fuel gas

Requirements for fuel gas

Designation	Unit	Limit	Comment
Natural gas from the public gas supply grid			Consultation with the manufacturer is required if other sources are used
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 $H_{i,n}$	kWh/m ³ NTP	$8.0 < H_{i,n} < 11.0$	Consult the manufacturer in case of lower or higher values.
Calorific value deviation from the setting value	%	$\pm 5^{**}$	Consultation with manufacturer required for higher values.
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/m ³ NTP	0.71 to 0.84	When changing to a different gas supplier it may be necessary to adjust the mixture control. Consult the manufacturer in case of deviations
Setting range of the gas flow pressure pF at the gas control valve inlet of the engine	mbar _(rel)	$80 \leq pF \leq 200$	The gas flow pressure before the gas train of the engine is an engine- and plant-specific variable. The gas flow pressure must be applied continuously and constantly. The setting value of the gas flow pressure can be obtained from the Technical data for engine and system.
Gas pressure deviation from the setting value	%	± 5	
Admissible gas pressure change rate	mbar/min.	1	Constant change required No pulsations permissible
* = 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 $\pm 3\%$ from the setting applies.			

T1M-ID: 0000051849 - 008

Designation	Unit	Limit	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. 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.
Natural gas from LNG evaporator plants		15 < T < 45	On plants with LNG operation, the permissible pressure and temperature range must be coordinated project-specifically and monitored continuously by the customer. 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	
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	
Maximum hydrogen content in the fuel gas mixture Model type 4000L32/33 4000L64 4000L64FNER	% by volume	10	Applies to mixtures of natural gas from the public gas supply grid with constant hydrogen content. Changes within the maximum admixing rate are adapted by suitable parameter settings during commissioning.
Maximum hydrogen content in the fuel gas mixture Model type 4000L64FV	% by volume	10	Applies to mixtures of natural gas from the public gas supply grid with variable hydrogen content.
Maximum hydrogen content in the fuel gas mixture Model type 4000L64FV with special equipment	% by volume	25	Applies to mixtures of natural gas from the public gas supply grid with variable hydrogen content. Consultation with the 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.

Designation	Unit	Limit	Comment
Maximum H ₂ mixture tolerance from the setting value	% by volume	No information	Fluctuation ranges are limited engine- and emission-specifically. See Technical data
Oils / oil vapors (HC with carbon number >8)	mg/m ³ NTP	< 0.4	No condensation in lines carrying fuel gas and fuel gas-air mixture, nor formation of condensable oil mists
Long-chain hydrocarbons (C ₆ - C _n)	mol %	No information	Consultation with Rolls-Royce Solutions required
HC solvent vapors	mg/m ³ NTP	0	Consultation with manufacturer and analysis necessary
Organically bound silicon	mg/m ³ NTP	< 1.0	
Inorganically bound silicon	mg/m ³ NTP	< 6	At Si > 5 mg/m ³ NPT based on 100% CH ₄ fuel gas content, wear products must be noted in the oil analysis.
Dust 3 to 10 µm	mg/m ³ NTP	5	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/m ³ NTP	technically free	Dust < 3 µm must be evaluated through a technical analysis, if necessary appropriate special filters must be used.
Total sulfur	mg/m ³ NTP	30	
Mercaptan sulfur	mg/m ³ NTP	6	
Hydrogen sulfide (H ₂ S)	mg/m ³ NTP	5	
Chlorine (Cl)	mg/m ³ NTP	0	technically free If values are higher, consultation with the manufacturer and an analysis are required.
Fluorine (F)	mg/m ³ NTP	0	technically free If values are higher, consultation with the manufacturer and an analysis are required.
Ammonia (NH ₃)	mg/m ³ NTP	10*	If values are higher, consultation with the manufacturer and an analysis are 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
 ** = For the optional operating mode Energy balancing mode with quick-start feature 120 seconds*, a limit value of ± 3% from the setting applies.

Table 49: Requirements and boundary 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:

- Natural gas with a calorific value of 10 kWh/m³ 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 with $H_{i,n} = 8.15 \text{ kWh/m}^3 \text{ NPT}$, the permissible maximum value for the total sulfur is calculated as follows:

$$\text{Permissible total sulfur content} = 30 \text{ mg/m}^3 \text{ NPT} \cdot (8.15 \text{ kWh/m}^3 \text{ NPT} : 10.0 \text{ kWh/m}^3 \text{ NPT}) = 24.5 \text{ mg/m}^3 \text{ NPT}$$

6.3.3 Biogas – Requirements for fuel gas

Biogas fuel requirements

Designation	Unit	Limit	Comment
Type of gas			Biogenic gases from fermentation processes
Calorific value $H_{i,n}$	kWh/m ³ NTP	$4.5 < H_{i,n} < 6.5$	Consult the manufacturer in case of lower or higher values. Max. possible engine power is specified project-specifically in the Technical data
Calorific value deviation from the setting value when starting the engine	%	± 5	If the CH ₄ content varies when the engine is at a standstill, a CH ₄ sensor is recommended for startup gas data input. See Technical data Consultation with manufacturer required for higher values.
Calorific value fluctuations from setting value during engine operation	%	± 10	Linear and continuous change required. Consultation with manufacturer is required in case of higher values
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
Gas density	kg/m ³ NTP	1.2 to 1.5	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.
Setting range of the gas flow pressure pF at the gas control valve inlet of the engine	mbar _(rel)	30 to 40	The gas flow pressure before the gas train of the engine is an engine- and plant-specific variable. The gas flow pressure must be applied continuously and constantly. The setting value of the gas flow pressure can be obtained from the Technical data for engine and system. Deviations are possible, see Technical data sheet
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.
* = These values are recommended values for Series 4000 engines, for generator sets with exhaust gas aftertreatment, lower limit values can apply. ** = lower values apply to the 20V4000L32FB engine. Consultation with the manufacturer is required.			

TWM-ID: 0000051850 - 006

Designation	Unit	Limit	Comment
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. The limit values apply to the gas inlet at the gas control valve on the engine side.
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	%	< 80	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
Max. moisture in gas, absolute			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.
Nitrogen	% by volume	≤ 5	Consult the manufacturer if exceeded
Oils / oil vapors	mg/m ³ 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/m ³ NTP	0	
Silicon from organic compounds	mg/m ³ NTP	$< 4^*$	At Si > 2 mg/m ³ 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/m ³ NTP	5	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/m ³ NTP	technically free	
Silicon from organic and inorganic compounds	mg/m ³ NTP	6^*	
Total sulfur	mg/m ³ NTP	$800^* / **$	

* = These values are recommended values for Series 4000 engines, for generator sets with exhaust gas aftertreatment, lower limit values can apply.

** = lower values apply to the 20V4000L32FB engine. Consultation with the manufacturer is required.

Designation	Unit	Limit	Comment
Mercaptan sulfur	mg/m ³ NTP	4*	
Hydrogen sulfide (H ₂ S)	mg/m ³ NTP	850*	
Chlorine (Cl)	mg/m ³ NTP	0	technically free If values are higher, consultation with the manufacturer and an analysis are required.
Fluorine (F)	mg/m ³ NTP	0	technically free If values are higher, consultation with the manufacturer and an analysis are required.
Ammonia (NH ₃)	mg/m ³ NTP	10*	If values are higher, consultation with the manufacturer and an analysis are required.

* = These values are recommended values for Series 4000 engines, for generator sets with exhaust gas aftertreatment, lower limit values can apply.

** = lower values apply to the 20V4000L32FB engine. Consultation with the manufacturer is required.

Table 50: Requirements and boundary conditions for biogas fuel and the corresponding fuel supply

When using the series 4000 engine in generator sets, with and without exhaust heat coupling and/or exhaust gas aftertreatment systems, the respective instructions provided by the 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 50).

Designation	Unit	Limit	Comment
Silicon from organic compounds	mg/m ³ NTP	< 1*	At Si > 2 mg/m ³ NPT based on 100% CH ₄ fuel gas content, wear products must be noted in the oil analysis.
Inorganically-bound silicon	mg/m ³ NTP	< 0.5*	
Silicon from organic and inorganic compounds	mg/m ³ NTP	1.5*	
Total sulfur	mg/m ³ NTP	140*	
Mercaptan sulfur	mg/m ³ NTP	1*	
Hydrogen sulfide (H ₂ S)	mg/m ³ NTP	150*	
Chlorine (Cl)	mg/m ³ NTP	0	technically free If values are higher, consultation with the manufacturer and an analysis are required.
Fluorine (F)	mg/m ³ NTP	0	technically free If values are higher, consultation with the manufacturer and an analysis are required.
Ammonia (NH ₃)	mg/m ³ NTP	10*	If values are higher, consultation with the manufacturer and an analysis are required.

* = These values are non-binding recommended values for Series 4000 engines, for generator sets with exhaust gas aftertreatment, lower limit values can apply (→ Table 52).

Table 51: Requirements and boundary 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:

- 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 with $H_{i,n} = 8.15 \text{ kWh/m}^3 \text{ NTP}$, the permissible maximum value for the total sulfur is calculated as follows:
Permissible total sulfur content = $30 \text{ mg/m}^3 \text{ NTP} \cdot (8.15 \text{ kWh/m}^3 \text{ NTP} : 10.0 \text{ kWh/m}^3 \text{ NTP}) = 24.5 \text{ mg/m}^3 \text{ NTP}$

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/m ³ NTP	800	20	200
Hydrogen sulfide (H ₂ S)	ppm	560	14	70
Sum total of all chlorine compounds (calculated as Cl)	–	technically free If values are higher, consultation with the manufacturer and an analysis are required.		
Sum total of all fluorine compounds (calculated as F)	–	technically free If values are higher, consultation with the manufacturer and an analysis are required.		
Total of all silicon compounds (calculated as Si)	mg /m ³ NTP	5	0	0
Ammonia (NH ₃)	mg /m ³ NTP	10	10	10
Heavy metals (Pb, Hg, As, Sb, Cd)	µg/m ³ NTP	Upon request	10	10
*= for 'low-pollutant biogas', lower values apply accordingly (→ Table 51).				

Table 52: 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 fractionated 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).

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.

Important

Liquid gas mixtures in accordance with DIN EN 589 are usually grouped under the term LPG (Liquid Petrol Gas), although propane is a noteworthy element of these mixtures; it is not approved for gas engines in the 4000 Series due to the high share of C4 hydrocarbons and the resultant low knock resistance.

Propane

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 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/butylene 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.

Component	Unit	Value range (maximum value)
CH ₄	Mass %	<0.5
C ₂ H ₆ (or sum of C ₂ H _x)	Mass %	< 1.1
C ₃ H ₆	Mass %	5
C ₃ H ₈	Mass %	90 - 100
i-C ₄ H ₁₀	Mass %	< 2.5
n-C ₄ H ₁₀	Mass %	< 2.5
C5+	Mass %	<0.5
Aromatics as benzene	Mass %	No information
CO ₂	Mass %	< 0.1
N ₂	Mass %	< 0.65
O ₂	Mass %	< 0.25
Total CO ₂ + N ₂ + Inert(O ₂)	Mass %	< 1

Tit-ID: 0000110519 - 003

Component	Unit	Value range (maximum value)
H ₂	Mass %	< 0.001
CO	Mass %	No information

Table 53: Typical composition of commercially available, completely evaporated propane in propane quality DIN 51622 or propane HD 5

If the values deviate, a Factory Acceptance Test is required.

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

Important

To prevent the entry of liquid fuel elements or condensation of the low-volatile components, preheating of the gas and combustion air dependent on the flow is mandatory. This must be adapted to the ambient conditions and the removal volume of the tank supply and must be continuously monitored for safety.

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, or locally applicable safety requirements.

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.

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 the filling of propane tank systems.

Requirements for fuel gas

Designation	Unit	Limit	Comment
Type of gas		Propane	Propane corresponding to DIN EN 51 622 or propane HD 5 in compliance with all boundary conditions listed below
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	5	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. Linear constant change with a frequency of max. 1/h.
Calorific value $H_{i,n}$	kWh/m ³ NTP	$25.0 < H_{i,n} < 26.0$	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/m ³ 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.
Setting range of the gas flow pressure pF at the gas control valve inlet of the engine	mbar _(rel)	$80 \leq pF \leq 200$	The gas flow pressure before the gas train of the engine is an engine- and plant-specific variable. The gas flow pressure must be applied continuously and constantly. The setting value of the gas flow pressure can be obtained from the Technical data for engine and system.
Gas pressure deviation from the setting value	%	± 2	

* = 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	Comment
Admissible gas pressure change rate	mbar/min.	1	Only constant changes are permitted
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	%	< 80	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 condensate that can possibly develop must be provided. Gas moisture shares in the form of mist or aerosols should basically be avoided through corresponding preheating.
* = 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	Comment
Ethane (C ₂ H ₆) and ethene (C ₂ H ₄)	Mass %	< 1.10	Specifications corresponding to propane HD 5 95 mass % propane/propene + 5.0 mass % remainder (incl. C1, C2, C4, C5+)
Propene (C ₃ H ₆)	Mass %	< 5	Specifications corresponding to propane HD 5 95 mass % propane and 5.0 mass % in the fraction of the C3 hydrocarbons
Propane (C ₃ H ₈)	Mass %	90.25 - 100	Specifications corresponding to propane HD 5
Butane (n-, i-C ₄ H ₁₀) and, butylene (C ₄ H 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 vapors (HC with carbon number >8)	mg/m ³ NTP	< 0.4	No condensation permitted in lines and containers carrying fuel gas and gas-air mixtures or the formation of condensible oil mist
HC solvent vapors	mg/m ³ NTP	0	Consultation with manufacturer and analysis necessary
Organically bound silicon	mg/m ³ NTP	< 1.0	
Inorganically bound silicon	mg/m ³ NTP	< 6	At Si > 5 mg/m ³ NPT based on 100% CH ₄ fuel gas content, wear products must be noted in the oil analysis.
Dust < 3 µm	mg/m ³ 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/m ³ NTP	5	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/m ³ NTP	30	
Mercaptan sulfur	mg/m ³ NTP	6	
Hydrogen sulfide (H ₂ S)	mg/m ³ NTP	5	

* = 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	Comment
Chlorine (Cl)	mg/m ³ NTP	0	technically free If values are higher, consultation with the manufacturer and an analysis are required.
Fluorine (F)	mg/m ³ NTP	0	technically free If values are higher, consultation with the manufacturer and an analysis are required.
Ammonia (NH ₃)	mg/m ³ NTP	10*	If values are higher, consultation with the manufacturer and an analysis are 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

Table 54: Requirements and general conditions for propane 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:

- Natural gas with a calorific value of 10 kWh/m³ 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 with $H_{i,n} = 25.5 \text{ kWh/m}^3 \text{ NPT}$, the permissible maximum value for the total sulfur is calculated as follows:
 Permissible total sulfur content = 30 mg/m³ NPT · for gas with $H_{i,n} = 10.0 \text{ kWh/m}^3 \text{ NPT}$
 Permissible total sulfur content for gas with $H_{i,n} = 25.5 \text{ kWh/m}^3 \text{ NPT}$:
 $30 \text{ mg/m}^3 \text{ NPT} \cdot (25.5 \text{ kWh/m}^3 \text{ NPT} / 10.0 \text{ kWh/m}^3 \text{ NPT}) = 76.5 \text{ mg/m}^3 \text{ NPT}$

Note:

The limit value of the permissible total sulfur content for propane according to DIN 51622 is only 30 mg/kg or 60 mg/m³ NTP.

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

6.3.5 Engine operation with associated gas

Engine operation with associated gas

Important

A project-specific design and approval is required for each application with associated gas.

Associated gas, shale gas

Associated gas refers to gas compositions that occur as accompanying gas during oil extraction. When extracting gases from crude oil/shale deposits (shale gas), similar compounds are found in their structure and composition. The composition of associated gases depends heavily on the provenance and geological properties of the mineral deposits. Due to their geological origin and the extraction process used, the gas compositions obtained have a much broader range of compositions than H-gases used in public gas supplies. The share of saturated C_2 to C_6 hydrocarbons is clearly higher than the C_1 share (methane). As these gas compositions, unlike natural gas from the public gas supply, are not subject to generally recognized supply conditions and specifications, gas compositions must be considered and evaluated individually. Features that both main types – associated gas and shale gas – have in common are that they have high salt and water contents as well as hydrocarbon condensate contents due to the mineral deposits and extraction process (fracking). As crude gas, these two gas types can not be used for engine operation without conditioning.

When operating the gas engine with associated/shale gas, the following requirements must be observed:

Gas composition:

- A meaningful gas analysis is available for the gas compositions to be used. This was made known to Rolls-Royce Solutions at the start of the project and coordinated with the Development department.
- The gas analysis includes information on components of the alkane series and their structural isomers at least C_1 - C_6 , as well as for the inert gas shares CO_2 and N_2 .
- The fuel supplied to the engine is free of aromatics, see (→ Table 55).
- Fluctuation ranges of the components must be specified.
- The operating company (customer) guarantees that gas conditioning is available and no untreated crude gas is supplied to the engine.
Fluctuation variables correspond to the values specified in (→ Table 55).
The process scheme and the type of conditioning must be described.
- The gas humidity in relation to hydrocarbons must be limited to a difference of at least $+20\text{ °C}$ from the condensation point in the supply pressure range and the respective line pressure.
- The operating company (customer) shall guarantee that the fuel supplied to the engine does not contain shares of oxygen due to the technical process and that storage tanks and pipelines are safeguarded against flame propagation.

Engine operation

All relevant parameters of the upstream gas treatment system used (temperatures, pressures, separation efficiency, etc.) must be set and monitored using suitable limit values so that the formation of hydrocarbon condensate in the fuel gas feed can be safely avoided. If liquid hydrocarbon components are fed into the engine with the fuel gas, this can lead directly to serious engine damage! If the above-mentioned limit values are violated, therefore, an immediate emergency stop of the plant must be tripped.

The following instructions must be followed because otherwise there is a risk to life and limb:

- Associated gases do not comply with the usual regulations for feeding into a public, pipeline-based natural gas distribution network. They are subject to process-related qualitative and quantitative fluctuations and therefore require complex conditioning. As a result of this complexity, malfunctions that have a negative effect on engine operation can occur in the upstream process chain.
Entry to the engine room / container during engine operation above $35 \text{ kW}_{\text{mech}}/\text{cyl.}$ is not permitted and should also be kept to a minimum in the low load range $< 35 \text{ kW}_{\text{mech}}/\text{cyl.}$ Control and regulation systems for operating the engine such as MIP (Motor Interface Panel) and MMC (Motor Management and Control) must therefore be located in a separate room outside the machine room.
- A suitable gas treatment system is absolutely necessary to guarantee the required gas quality with regard to methane number, gap between the gas temperature and the hydrocarbon condensation point, elimination of other trace elements in accordance with the Fluids and Lubricants Specifications or separate express written approval from RRS, and other possible influences.
- A suitable function monitoring system must be installed at the interface between gas treatment system and gas engine. This is used to evaluate and record the gas quality. The function monitoring system should feature the following at a minimum:
In the event of malfunctions in the gas treatment system that result in the fuel composition no longer being guaranteed in accordance with the Fluids and Lubricants Specifications, appropriate stop signals must be transmitted to the engine system before the fuel enters the gas train engine system. Furthermore, in the case of fluctuations in the gas supply in relation to quantity, pressure and temperature, alarm and warning signals must be communicated to the engine system which permit engine operation to adapt to the malfunction situation or to stop the machine in an emergency.

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

In order to guarantee this adaptation, the following conditions must be observed in mains parallel operation and isolated operation and, in particular, during the parallel operation of several engine-driven generating sets in the isolated grid.

Mains parallel operation

- For adaptation of the engine parameters to the fuel quality, the engine must be operated for a long period without load fluctuation at a load point $> 20\%$ of the engine rated power.
- If the permissible limit values of the fuel calorific value are exceeded, an engine stop is initiated.
- The fuel calorific value during engine start must not deviate more than 10% from the fuel calorific value determined during the last trouble-free period of operation.
- To avoid combustion knock, the knock control acts in sequence to ignition timing adjustment, power adjustment and mixture quality adjustment. During this time, engine power can be limited to 50% of rated power. If all of these measures are not sufficient to reduce continuous knock events, the engine is stopped.
- Both controls are active from a parameterized minimum power, monitored for limit values and can therefore trigger an engine.

Isolated operation

All controls and processes previously listed for mains parallel operation are active in isolated operation. The operating company must therefore observe the following, in particular, during operation with associated/shale gas.

- To avoid unintended engine shutdowns, a power gap to maximum possible power is recommended in isolated operation.
- The operator has a fast load power management system that is able to reliably adapt the load power to the available engine power.
- The derating parameters for associated gas and load shift diagrams provided project-specifically by Rolls-Royce Solutions for reliable cut in and cutout of consumer loads must be followed and observed.
- The dynamic values related to the fuel supply ($\rightarrow$ Table 55) are binding.
- Overall, it should be noted that the full-load outputs specified by Rolls-Royce Solutions represent ICFN power ratings and exceeding the limits is therefore not permitted.

Maximum permissible constituents of associated gas/shale gas

Component	Unit	Maximum value
CH ₄	% by volume	up to 86
C ₂ H ₆ (or sum of C ₂ H _x)	% by volume	up to 24
C ₃ H ₈ (or sum of C ₃ H _x)	% by volume	up to 20
C ₄ H ₁₀ (or sum of C ₄ H _x)	% by volume	up to 10.6
C ₅ H ₁₂	% by volume	2.5
Hydrocarbons C5+	% by volume	2.3
Aromatics as benzene	% by volume	< 0.015
CO ₂	% by volume	9.2
N ₂	% by volume	21.0
Sum of CO ₂ + N ₂ +inert gases	% by volume	26
O ₂	% by volume	5.6
H ₂	% by volume	< 0.8
CO	% by volume	--

Table 55: Maximum composition of associated gas/shale gas

Requirements for fuel gas

Designation	Unit	Limit	Comment
Type of gas		Associated / shale gas	Applies to treated rich gases from crude oil / oil-bearing shale deposits, consultation with manufacturer is always necessary
Methane number	MN	> 43	Knock monitoring/control during operation with methane number < 65 has absolute priority over other engine settings to prevent combustion knock. With sustained knocking events, engine power is reduced.
Methane number change	MN / min	5	Linear constant change with a frequency of max. 1/h
Calorific value Hi,n	kWh/m ³ NTP	10.5 < Hi,n < 14.5	Calorific value of the completely evaporated product
Calorific value deviation from the setting value	%	± 5	Consultation with manufacturer required for higher values
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

* = 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	Comment
Gas density	kg/m ³ NTP	0.85 to 1.53	The density of the gas may fluctuate depending on composition; it is more or less constant for a certain type of deposit. When using gas from different deposits, the density may vary. When the deposit is changed, or in the case of new developed gas sources, an adaptation of the mixture control may be necessary. The gas density must be analyzed and recorded at regular intervals, but always when new gas fields or gas sources from new oil wells are started up.
Setting range of the gas flow pressure pF at the gas control valve inlet of the engine	mbar _(rel)	$80 \leq pF \leq 200$	The gas flow pressure before the gas train of the engine is an engine- and plant-specific variable. The gas flow pressure must be applied continuously and constantly. The setting value of the gas flow pressure can be obtained from the Technical data for engine and system. * = For engines with exhaust gas aftertreatment and/or exhaust gas heat recovery, lower limit values may apply.
Gas pressure deviation from the setting value	%	± 5	
Admissible gas pressure change rate	mbar/min.	1	Constant change required
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.
Gas temperature when engine is loaded	°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.
Gas temperature deviation from the setting value	°C	± 9	

* = 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	Comment
Admissible rate of gas temperature change	K/min.	0.3	
Gas moisture, water:	%	< 80	In the entire gas and mixture system no bedewing is permitted.
Relative moisture in gas in the permissible temperature and pressure range	g/kg	< 20	No water vapor condensation in pressure and temperature range.
Max. moisture in gas, absolute			No condensation permitted in lines and containers carrying fuel gas and gas-air mixtures.
Gas moisture, hydrocarbons: Gap to condensation point	K	> 20	The fuel gas supplied to the engine and the fuel gas/air mixture formed in the engine must have a temperature difference of at least + 20 K to the condensation point of the hydrocarbons in the fuel gas. Monitoring systems for the treatment of condensate that can possibly develop must be provided. Gas moisture shares in the form of mist or aerosols should basically be avoided through corresponding pre-heating.
Long-chain hydrocarbons (C ₆ to C _n)	% by vol.	No information	Consultation with Rolls-Royce Solutions required
Aromatics based on benzene	% by vol.	< 0.015	Consultation with Rolls-Royce Solutions required
Oils / oil vapors (HC with carbon number >8)	mg/m ³ NTP	< 0.4	There must be no substances in the fuel gas that tend to form mists or aerosols and condensation or sublimation in the pressure, temperature and concentration range.
HC solvent vapors	mg/m ³ NTP	0	Consultation with manufacturer and analysis necessary
Organically bound silicon	mg/m ³ NTP	< 1.0	
Inorganically bound silicon	mg/m ³ NTP	< 6	At Si > 5 mg/m ³ NTP relative to 100 % CH _{4 fuel} gas content, wear products are to be taken note of in the oil analysis
Dust < 3 µm	mg/m ³ 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/m ³ NTP	5	DVGW Worksheet 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.			

Designation	Unit	Limit	Comment
Total sulfur	mg/m ³ NTP	30	
Mercaptan sulfur	mg/m ³ NTP	6	
Hydrogen sulfide H ₂ S	mg/m ³ NTP	5	
Chlorine	mg/m ³ NTP	10*	Consult the manufacturer in case of higher values as analysis is necessary
Fluorine	mg/m ³ NTP	5*	Consult the manufacturer in case of higher values as analysis is necessary
Chlorine + fluorine	mg/m ³ NTP	10*	Consult the manufacturer in case of higher values as analysis is necessary
Ammonia NH ₃	ppm	70*	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 boundary conditions for associated / shale gas

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:

- Natural gas with a calorific value of 10 kWh/m³ 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 with $H_{i,n} = 8.15 \text{ kWh/m}^3 \text{ NPT}$, the permissible maximum value for the total sulfur is calculated as follows:
 Permissible total sulfur content = $30 \text{ mg/m}^3 \text{ NPT} \cdot \frac{H_{i,n}}{10.0 \text{ kWh/m}^3 \text{ NPT}}$
 Permissible total sulfur content for gas with $H_{i,n} = 8.15 \text{ kWh/m}^3 \text{ NPT}$:
 $30 \text{ mg/m}^3 \text{ NPT} \cdot (8.15 \text{ kWh/m}^3 \text{ NPT} / 10.0 \text{ kWh/m}^3 \text{ NPT}) = 24.5 \text{ mg/m}^3 \text{ NPT}$

6.4 Series 4000 Gas 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	Comment
Type of gas			Natural gas
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 $H_{i,n}$	kWh/m ³ NTP	$8.0 < H_{i,n} < 11.0$	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.
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/m ³ NTP	0.71 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.
Setting range of the gas flow pressure p_F at the gas control valve inlet of the engine	mbar _(rel)	$80 \leq p_F \leq 200$	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.
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	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 vapors (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 condensable oil mists
Long-chain hydrocarbons (C ₆ - C _n)	% by vol.	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	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			

Designation	Unit	Limit	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	
Mercaptan sulfur	mg/m³ NTP	6	
Hydrogen sulfide (H ₂ S)	mg/m³ NTP	5	
Chlorine (Cl)	mg/m³ NTP	0	technically free If values are higher, consultation with the manufacturer and an analysis are required.
Fluorine (F)	mg/m³ NTP	0	technically free If values are higher, consultation with the manufacturer and an analysis are required.
Ammonia (NH ₃)	mg/m³ NTP	10*	If values are higher, consultation with the manufacturer and an analysis are 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

Table 57: Requirements and boundary 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:

- Natural gas with a calorific value of 10 kWh/m³ 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 with $H_{i,n} = 8.15 \text{ kWh/m}^3 \text{ NPT}$, the permissible maximum value for the total sulfur is calculated as follows:
Permissible total sulfur content = $30 \text{ mg/m}^3 \text{ NPT} \cdot (8.15 \text{ kWh/m}^3 \text{ NPT} : 10.0 \text{ kWh/m}^3 \text{ NPT}) = 24.5 \text{ mg/m}^3 \text{ NPT}$

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/m ³ NPT	5
Max. oily constituents	mg/m ³ NPT	0.4

Table 58: 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 CO₂ / CH₄ 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/m ³ NPT	5
Max. oily constituents	mg/m ³ NPT	0.4

Table 59: 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 must 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/m ³ NPT	1200	20	200	70	140	20
Corresponding hydrogen sulfide (H ₂ S)	ppm	840	14	140	50	100	14
Sum total of all chlorine compounds (Cl)	mg/m ³ NPT	20	0.5	0.5	0.5	0.5	0.5
Sum total of all fluorine compounds (F)	mg/m ³ NPT	10	0.5	0.5	0.5	0.5	0.5
Sum total of all silicon compounds (Si)	mg/m ³ NPT	5	0	0	0	0	0
Ammonia (NH ₃)	mg/m ³ NPT	10	10	10	10	10	10
Heavy metals (Pb, Hg, As, Sb, Cd)	µg/m ³ 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 60: 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 NPT. 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/m³ 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 with $H_{i,n} = 8.15 \text{ kWh/m}^3 \text{ NPT}$, the permissible maximum value for the total sulfur is calculated as follows:

$$\text{Permissible total sulfur content} = 30 \text{ mg/m}^3 \text{ NPT} \cdot (8.15 \text{ kWh/m}^3 \text{ NPT} : 10.0 \text{ kWh/m}^3 \text{ NPT}) = 24.5 \text{ mg/m}^3 \text{ NPT}$$

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 be above 300 °C in all circumstances. 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 $H_i = 5.0 \text{ kWh/m}^3 \text{ NPT}$, 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 ($S = 2.9 \text{ mg/m}^3 \text{ NPT}$) was measured. No other sulfur compounds are present.

Standardized hydrogen sulfide concentration

$$\text{H}_2\text{S} = 2.0 \text{ ppm} \times (10.0 \text{ kWh/m}^3 \text{ NPT} / 5.0 \text{ kWh/m}^3 \text{ NPT}) = 4.0 \text{ ppm}$$

Standardized total sulfur concentration

$$S = 2.9 \text{ ppm} \times (10.0 \text{ kWh/m}^3 \text{ NPT} / 5.0 \text{ kWh/m}^3 \text{ NPT}) = 5.8 \text{ ppm}$$

The measured and standardized sulfur concentrations are safely below the limit values (14 ppm H_2S and 20 $\text{mg/m}^3 \text{ NPT S}$).

6.6 Series 500 Gas 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 / Nm ³	Biogas operation requires consultation with Rolls-Royce Solutions
		< 483.1	BTU/ft ³	
		> 5	kWh / Nm ³	Biogas operation
		> 483.1	BTU/ft ³	
		> 10	kWh / Nm ³	Natural gas operation
		> 966.2	BTU/ft ³	

Table 61: 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 62) 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 ₂ H ₆	X	
Propane	C ₃ H ₈	X	
Butane	C ₄ H ₁₀	X	
Pentane	C ₅ H ₁₂	X	
Hexane	C ₆ H 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 62: Main elements of fuel gases

For gas secondary substances that are not named in this table nor in table (→ Page 123) 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 124).

In addition, special components, e.g. a catalytic converter, may require deviating limit values in certain circumstances (→ Page 126).

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 125).

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 ₂ S	< 42.4	mg / kWh	
		< 27.38 x10 ⁻⁹	lb / BTU	
Ammonia	NH ₃	< 3	mg / kWh	
		< 1.938 x10 ⁻⁹	lb / BTU	
Tar	C _x H _y R _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 63: 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 64: 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.

Given:	Calorific value from gas analysis	$H_{i,N}$	1.5 kWh / m ³
	Chlorine from gas analysis	Cl	10 mg/m ³
	Fluorine from gas analysis	F	5 mg/m ³
	Plant without catalytic converter		

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

$$CV_{Cl} = \frac{MV_{Cl}}{H_{i,N}} = \frac{10 \text{ mg/m}^3}{1.5 \text{ kWh / m}^3} = 6.6 \text{ mg/kWh} < LV_{Cl} = 8 \text{ mg/kWh}$$

→ OK

$$CV_F = \frac{MV_F}{H_{i,N}} = \frac{5 \text{ mg/m}^3}{1.5 \text{ kWh / m}^3} = 3.3 \text{ mg/kWh} < LV_F = 4 \text{ mg/kWh}$$

→ OK

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

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

→ 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/m³_{norm}] = measured element volume [ppm] x density_{norm} [kg/m³_{norm}]

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 ₂ S	< 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

T1W-ID: 0000092034 - 003

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 65: 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 66: 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 NO_x 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 67) 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 P ₀₄	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 67: 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 68: Storage temperature of reducing agent

Important
The reducing agent crystallizes at -11 °C.

TM-ID: 000076042 - 004

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 NO_x 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 m³ 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:

- Corrosion 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 94) (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/m³i.N. with a sulfur content of 4.0 mg/m³i.N. is used.
- The permissible total sulfur content in the fuel gas is 30 mg/m³i.N. with a reference calorific value of 10.00 kWh/m³i.N., see subsection (→ Page 94) 4.3.

Calculation::

'Permissible total sulfur content of fuel gas =

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

'Permissible total sulfur content of combustion air =

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

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

Note: The dust load of the combustion air is covered in subsection (→ Page 136) 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. This 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 ePM₁ 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 ePM₁₀ 50% (formerly DIN EN 779 M5), in which all particles of particle class PM₁₀ 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 overpressure 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.

8.4 Heating Water

8.4.1 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 39).

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:

- $1 \text{ mol/m}^3 = 5.6 \text{ dH}$
- 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.

8.4.2 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 69: 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)		

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 70: 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)

8.4.3 Information on Heating Water for Series 500 Engines

8.4.3.1 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 141).

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 O ₂	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 71: Limit values for heating water circuit

8.4.3.2 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 $< 100 \mu\text{S/cm}$. The limit values for the heating water circuit should be undershot ($\rightarrow$ Page 140).

Important

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

9 Confirmation for Fluids and Lubricants

9.1 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)

TIM-ID: 0000051982 - 005

10 Revision Overview

10.1 Revision overview

Technical changes from version A001072/07 to version A001072/08

Changes

Chapter 1 Preface

- Chapter was updated.

Chapter 2 Lubricants revised

- The following chapters were updated.
 - 2.1.2 Engine oil limit values for Series 4000 and Series 400
 - 2.1.3 Engine oil limit values for Series 500
 - 2.2.1 Approved engine oils (Series 4000)
 - 2.2.2 Lubricating greases for generators
 - 2.3.1 Approved engine oils (Series 400)

Chapter 3 Coolant revised

- The following chapters were updated.
 - 3.1.1 Coolant definition
 - 3.1.2 Operational monitoring / coolant conditioning for Series 4000 and Series 400 engines
 - 3.1.3 Coolant concentrates – Storage stability
 - 3.1.5 Cooling system damage – Prevention
 - 3.1.7 Freshwater requirements for Series 4000 and 400
 - 3.2.2 Coolant without antifreeze – Concentrates for cooling systems not containing light metal (Marine application Series 4000)
 - 3.2.4 Antifreeze – Concentrates for cooling systems free of light metal (Marine application Series 4000)
 - 3.2.6 Antifreeze – Ready mixtures for cooling systems free of light metal (Marine application Series 4000)
 - 3.3.2 Coolant without antifreeze – Concentrates for cooling systems containing light metal (Marine application Series 4000)
 - 3.3.4 Antifreeze – Concentrates for cooling systems containing light metal (generator application)
 - 3.3.6 Antifreeze – Concentrates for cooling systems containing light metal (generator application Series 4000)
 - 3.4.1 Approved coolants (generator set Series 400)
 - 3.5.1 Coolant – General (generator set Series 500)
 - 3.5.3 Approved coolants (generator set Series 500)

Chapter 4 Flushing and cleaning specifications for engine coolant circuits revised

- The following chapters were updated.
 - 4.1.1 General (Flushing and cleaning specifications for Series 400 and 4000 engines)
 - 4.1.3 Engine coolant circuits – Flushing.
 - 4.1.4 Engine coolant circuits – Cleaning.

Chapter 6 Fuels revised

- 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
 - 6.1.4 Liquid Natural Gas (LNG)
 - 6.1.6 Knock resistance of gas compensation
 - 6.2.2 Requirements of fuel gas for marine applications
 - 6.3.1 General (Series 4000 gas engine – generator applications and generator set)
 - 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
 - 6.3.5 Engine operation with associated gas
 - 6.4.2 Natural gas – Requirements for fuel gas (Series 4000 gas engine – generator set in Oil&Gas)
 - 6.5.3 Harmful impurities

11 Appendix A

11.1 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

11.2 Conversion table of SI units

SI unit	US unit	conversion
°C	°F	$^{\circ}\text{F} = ^{\circ}\text{C} \times 1.8 + 32$
kWh	BTU	1 BTU = 0.0002930711 kWh
kWh/m ³ NTP	BTU/ft ³	1 BTU/ft ³ = 0.010349707 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 72: Conversion table

11.3 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

12 Appendix B

12.1 Index

A

Antifreeze

- For cooling system containing light metals
 - Concentrates 58
- For cooling systems containing light metals
 - Ready mixtures 62
- For cooling systems free of light metals
 - Concentrates 48
 - Ready mixtures 52
- Series 400 65
- Series 500 68

Applicability of the publication 5

Approved engine fluids and lubricants

- Engine oils for Series 4000 15

Approved fluids and lubricants

- Engine oils for Series 400 20
- Engine oils for Series 500 27

B

Biogas

- Main constituents 81
- Requirements
 - Series 400 119
 - Series 4000 98

C

Cleaning

- General information 79

Cleaning agents 70

- System cleaners 75

Cleaning agents Series 500 77

Cleaning instructions Series 500

- Engine coolant circuit Series 500 76
- Engine coolant circuit Series 5000 78

Cleaning specifications

- Assemblies 74
- Engine coolant circuit 69, 72
- System cleaners 75

Color additive

- Coolant circuit 39

Combustion air 133

Confirmation

- Operator 142

Contact person 147

Contaminants

- Fuel 126

Coolant

- Test kit 76
 - Antifreeze
 - Concentrates for special applications 51, 61
 - Check 67
 - Conditioning
 - Series 4000 42
 - Series 500 43
 - Coolant without antifreeze
 - Concentrates for cooling systems containing light metal 56
 - Concentrates for cooling systems not containing light metal 45
 - Ready mixtures for cooling systems containing light metal 57
 - Ready mixtures for cooling systems not containing light metal 47
 - Definition 31
 - Engine-generator set
 - Series 4000 44, 55
 - Fresh water requirements
 - Series 500 43
 - Freshwater requirements
 - Series 4000 42
 - Generator application 44, 55
 - Generator set
 - Series 500 66, 68
 - Limit values 34, 67
 - Operational monitoring 34
 - Permissible concentrations 34
 - Replacement 67
 - Series 4000
 - Antifreeze for cooling systems containing light metals 58, 62
 - Antifreeze for cooling systems free of light metals 48, 52
 - Storage capability 38
- #### Coolant circuit
- Assembly cleaning 74
 - Cleaning 69, 72
 - Cleaning agents 70
 - Flushing 71
 - Leakage 39
 - Materials 41

Coolant circuit Series 500

- Cleaning 78
- Cleaning agents Series 500 77
- Contamination 76

Coolants

- Generator set
 - Series 400 65
- Series 400 65
- Series 500 68

Cooling system

- Prevention of damage 40

D

Dust load 136

Dye additives

- Lube oil circuit 12

E

Engine

- Preservation 5

Engine coolant circuit

- Assembly cleaning 74
- Cleaning 72
- Cleaning agents 70
- Contamination 69
- Flushing 71

Engine coolant circuit Series 500

- Cleaning 78
- Cleaning agents Series 500 77
- Contamination 76

Engine oil

- Series 400 20
- Series 4000 15
- Series 500 27
- Storage and disposal 29

Engine oil 7

Engine oil change intervals

- Engine-generator set Series 400 24
- Engine-generator set Series 500 28
- Oil analysis
 - Evaluation 28
- Oil bleed system 24

Engine oil change intervals for Series 4000 and Series 400

- Limit values 8
- Engine oil limit values
- Series 4000 and Series 400
 - Used gas engine oils 8
 - Series 500 10

Exhaust aftertreatment system

- Exhaust condensate 132
- General 129
- NOx reducing agent 130

Exhaust condensate 132

F

Flushing specifications

- Assemblies 74
- Coolant circuits contaminated with bacteria, fungi or yeast 75

- Engine coolant circuit 69, 71

Flushing specifications Series 500

- Engine coolant circuit Series 500 76

Fresh water

- Limit values
 - Series 500 43

Freshwater

- Limit values
 - Series 4000 42

Fuel

- Condensate 128
- Contaminants 126
- Silicon content 11
- Usage 80

Fuel gas

- Boundary conditions 124
- Condensate 128
- Gas analysis with Series 500 125
- Generator application and engine-generator set
 - Series 400 118, 119
 - Series 500 123
- Generator application and generator set
 - Series 4000 94, 98, 102, 108, 115
- Main elements, subdivision for Series 500 122
- Marine application 88
- Silicon compounds 85
- Silicon content 11

Fuels 86, 87, 93, 114

- Associated gas
 - Series 4000 108
- Biogas
 - Series 400 119
 - Series 4000 98
- Natural gas
 - Marine application 88
 - Series 400 118
 - Series 4000 94, 115
 - Series 500 122, 123
- Propane gas
 - Series 4000 102
- Series 400
 - Impurities 120

G

Gas

- Main elements, subdivision for Series 500 122

Gas analysis

- Conversion with Series 500 125

Gas mixture

- Limit values 133

Gas operating data 124

Gear oil 19

H

Heating water

- General 137
- Water quality 141

Heating water for Series 4000 and 400

- Requirements 138

Heating water for Series 500

- Requirements 140

Hotline 147

Humidity 135

I

Impurities

- Fuels
 - Series 400 120

Information on use 5

L

Leakage

- Coolant circuit 39
- Lube oil circuit 12

Lean gas operation 28

Limit values Series 500

- Used gas engine oils 10

Liquid Natural Gas (LNG) 84

List of abbreviations 145

Lube oil

- Series 4000 15

Lube oil circuit

- Leakage 12

Lubricating grease

- Engine-generator set Series 400 26
- Engine-generator set Series 500 30
- For generators 18, 26, 30
- General application 13, 14
- Generator set Series 4000 18
- Requirements 13
- Special application 13

M

Materials

- Coolant circuit 41

Medium in the gas piping leak chamber for marine applications

- Fuels for gas engines 91

N

Natural gas

- Main constituents 81
- Requirements
 - Marine application 88
 - Series 400 118
 - Series 4000 94, 102, 108, 115
 - Series 500 123

Natural gas/hydrogen mixtures 83

NOx reducing agent

- General 130

O

Oil bleed system 24

Oil changeover procedure 29

Oil economy 29

Oil sampling 28

Oil volume extension 29

Operational monitoring

- Coolant 34, 67

Operator

- Confirmation 142

P

Preservation

- Engine 5

R

Requirements

- Coolant circuit 41
- Heating water for Series 4000 and 400 138
- Heating water for Series 500 140

Revision overview

- Revision overview 143

S

Service partner 147

Silicon compounds

- Fuel gas 85

Silicon content

- Fuel 11
- Fuel gas 11

Silicon operational value 11

Spare parts service 147

Special limit values 126

Storage

- Coolant 38

Supply air 133

T

Test kit

- Coolant 76

U

Used-oil analysis 8

Used-oil analysis Series 500 [10](#)