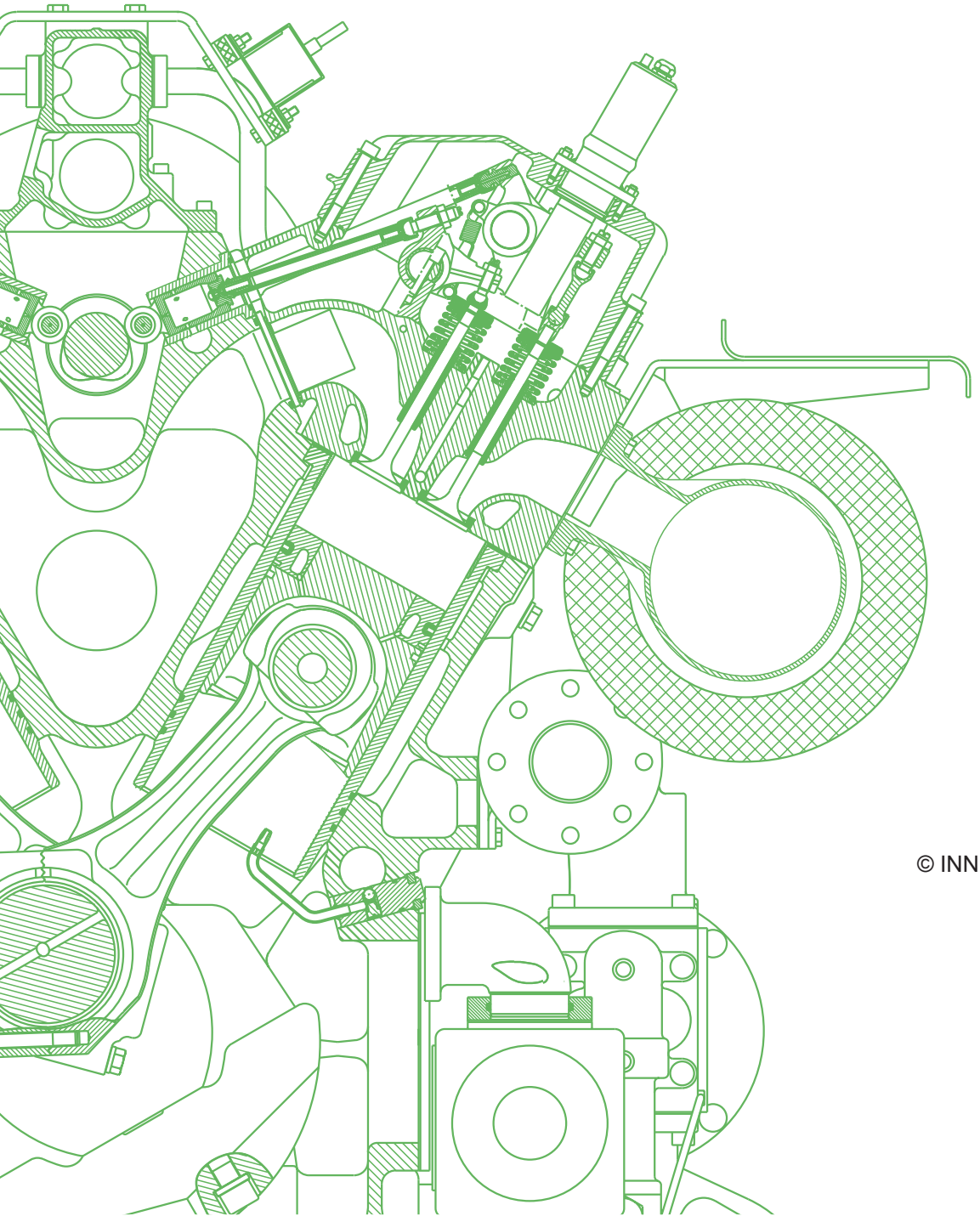
JENBACHER

TA 1000-0300

Technical Instruction

Fuel gas and combustion air requirements



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NOTE

Observance of the conditions of this technical instruction and performance of the activities described therein is the basis of safe and efficient plant operation.

Non-observance of the conditions of this technical instruction and/or non-performance of the prescribed activities or any departure from the prescribed activities may result in the loss of guarantee rights.

The activities and conditions defined in this technical instruction shall be performed and/or observed by the plant operator. This shall not apply if this technical instruction is expressly allocated to the area of responsibility of INNIO Jenbacher GmbH & Co OG or a contractual agreement between the operator and INNIO Jenbacher GmbH & Co OGprovides for a different arrangement.

1 Scope

This Technical Instruction (TA) applies to Jenbacher engines that are designed to be used with gaseous fuels.

2 Purpose

The purpose of this Technical Instruction is to illustrate the requirements and the limits that apply to the use of fuel gas in combustion engines. Specifically, these relate to the limit values and requirements placed on the gas composition, the trace substances and impurities, and the oil, condensate and particles that the mixture may contain. In addition, the requirements on the combustion air are also described.

3 General

Jenbacher engine systems make use of a broad range of gaseous fuels as fuel gas. In contrast to petrol and diesel fuels, gaseous fuels generally do not have to comply with strict specifications or classifications. Nevertheless, special requirements and defined limit levels are imposed on fuel gas. In principle, all gaseous fuels that can be used in combustion engines can be classified as "fuel gases".

The physical and chemical characteristics of gaseous fuels can vary enormously. However, from the point of view of construction and operating processes, the engines are designed to function within a very strict range of characteristics and are often very sensitive to changes to these characteristics.

The engine system is optimally matched to the contractually defined fuel-gas composition for which it was sold, and no major changes may be made to this.

The fuel gas is mixed with the combustion air to produce a usable mixture and conveyed to the engine for combustion. Impurities as well as combustion air can be aspirated into the engine. If the fuel gas or combustion air does not comply with the requirements, this can have adverse effects on engine operation. This can result in situations where the safety of the plant and its operation cannot be guaranteed.

Lubricating oil can lose its corrosion protection properties as a result of impurities in both the fuel gas and the combustion air. The results of regular lubricating oil analyses indicate whether there are any impurities in the mixture. Refer as well to the following Technical Instructions:

TA 1000-0099B – Limit levels for used oil in Jenbacher gas engines

TA 1000-0099C – Procedure for testing the plant-specific oil service life

TA 1000-0112 – Taking lubricating oil samples / lubricating oil sampling protocol

TA 1000-1109 – Lubricating oil for type 2, 3, 4 and 6 Jenbacher gas engines

TA 1000-1108 – Lubricating oils Type 9 engines

⚠ ATTENTION

Environment, health & safety

Fuel gases and their production, and the use of fuel gases in engines, can result in exposure to substances which are dangerous or harmful to the environment and human health. Before dealing with fuel gases, deposits and condensates, we therefore have to pay attention to relevant health and safety instructions and take precautionary measures.

4 Gas types

The fuel gases used in Jenbacher gas engines can be divided into the main categories listed below. Jenbacher gas engines are not confined to these main categories. Solutions for other gas types can be developed in conjunction with Jenbacher.

Natural gas

Natural gas is characterised by a high content of methane (CH_4) and has a high purity. Its methane content is between 65 and 100% by volume.

Associated petroleum gas

This class of fuel gas is characterised by a medium to high methane content. Its methane concentration can be anywhere between 35 and 90% by volume . Among the other constituents, nitrogen (N_2) or carbon dioxide (CO_2) occur in high concentrations of up to 45% by volume, as well as an increased proportion of higher-value hydrocarbons.

Biogas, sewage gas, landfill gas

These fuel gases are produced by the conversion of liquid or solid organic substances by micro-organisms. Like associated petroleum gas, they are characterised by a medium to high methane content and the constituents N_2 and CO_2 . However, as this gas emanates from highly heterogeneous substances, special care must be taken with regard to trace substances and impurities.

Coalmine gas

This fuel gas is recovered from mines and is characterised by very wide fluctuations in its methane content, which can lie between 25 and 95 vol%. Of the other constituents, N_2 in a concentration of up to 65% by volume, CO_2 with up to 15% by volume or oxygen (O_2) with up to 15% by volume may be present. This gas is frequently associated with a certain amount of dust loading, which necessitates a pre-separation stage.

Gas from thermal gasification processes

These gases are produced through the targeted gasification of biomass (e.g. wood), waste material and coal, etc., and typically exhibit high levels of hydrogen (H_2) and carbon monoxide (CO). As this gas emanates from highly heterogeneous substances, special care must be taken with regard to trace elements and accompanying substances. This type of gas is also referred to as synthesis gas.

Process gases

Process gases arise in the steel industry and are hence also referred to as steel gas. These gases fall into the following main groups:

Gas description	Main components	Origin
Coke-oven gas	$H_2/CH_4/N_2/CO$	Coking process
Blast furnace gas	$N_2/CO/CO_2/H_2$	Process gas from steel production
Converter gas	$CO/N_2/CO_2/H_2$	Process gas produced during the manufacture of steel, e.g. LD gas (Linz-Donawitz process)

Liquid gas, propane gas

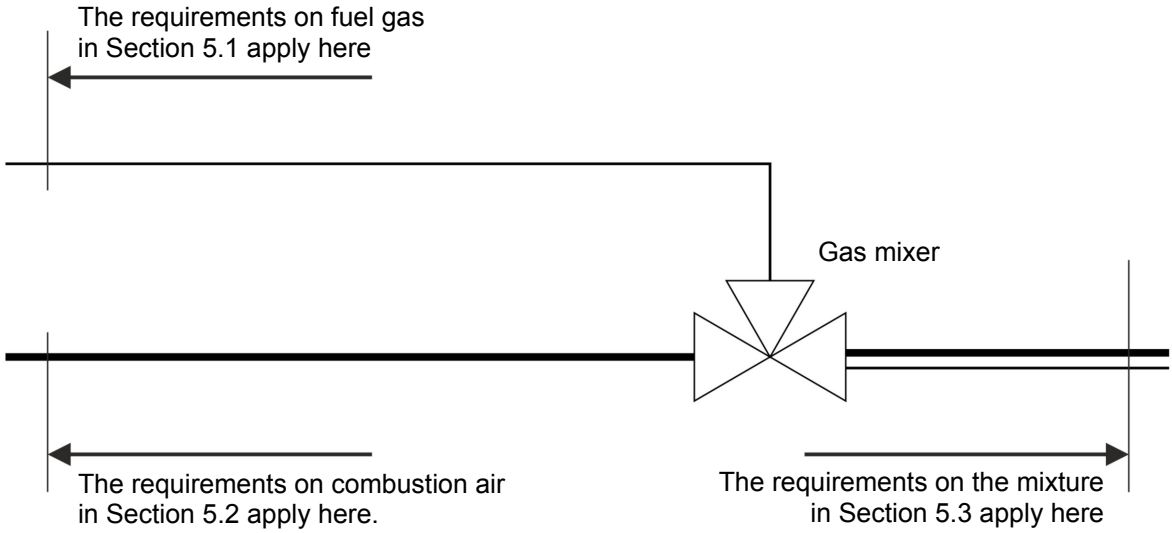
The most distinctive feature of liquid gases is that they are transported and stored in a liquid state. They are then evaporated before being used.

Liquid natural gas (LNG) consists initially of natural gas, which is liquefied by cooling it to -161°C. However, "fractionation" can occur during the evaporation process, resulting in possible deviations and fluctuations in the gas composition, such as an increase in the concentration of longer-chain hydrocarbons.

Propane gas is already in a liquid state under relatively low pressures and normal temperatures. Its main constituent is propane (C_3H_8), which is present in concentrations of 60 to 100 vol%. It may also contain high concentrations of butane (C_4H_{10}) up to 10% by volume), ethane (C_2H_6) up to 20% by volume or methane up to 40% by volume. Propane HD_5 contains >= 90% propane (C_3H_8), < 5% propane (C_3H_6) and <5% of other hydrocarbons CxHy (iso-butane C_4H_{10}, n-butane C_4H_{10}, ethane C_2H_6methane CH_4).

5 Requirements and limit values

The requirements and limits set out in this Technical Instruction for the fuel gas and combustion air apply to Jenbacher engines and plants. This ensures that the mixture aspirated by the engine meets the engine's requirements and does not cause any damage. Any ingress of unwanted substances into the engine should always be avoided in principle. The following diagram illustrates the relationship between the requirements on the fuel gas, the combustion air and the mixture.



5.1 Fuel gas requirements and limits

To guarantee trouble-free engine operation and the specified maintenance intervals, the specified fuel gas requirements must be permanently maintained at the Jenbacher interface. A summary of the requirements and limit values, together with any other special requirements, can be found in the Appendix.

Jenbacher cannot honour warranty claims relating to problems caused by exceeding one or more of the limit values specified in this Technical Instruction.

Physical fuel gas properties, main components and thermodynamic requirements

The main components determine the relevant fuel gas characteristics for physical engine operation (e.g. calorific value, combustion air ratio, combustion temperature, laminar flame propagation speed, ignition limits, knock resistance). They are normally expressed as a % by volume and must be specified in the form of a comprehensive gas analysis (see Appendix: Check list for fuel gas quality information).

Apart from a number of limiting conditions relating to the data sheet, the technical specifications also contain the fuel gas type.

In cases where the available fuel gas does not conform to what is stated in the standard product range, a special - client-specific - solution can be arranged, taking into account all technical and efficiency-related options.

It is normal for the composition of some gas types to vary substantially. In Leanox-controlled engine operation (under load), these fluctuations can to a large extent be compensated for by the engine management system. In order to guarantee a satisfactory starting behaviour, however, a certain fluctuation range is necessary and the engine management must be provided with usable information (e.g.: calorific value, CH_4 content) on the current gas quality.

The reference points are the standard conditions for temperature and pressure with a temperature of 273.15 K and a pressure of 101.325 kPa.

Physical characteristics, main components and thermodynamic requirements

Designation	Additional	Limitation	Unit	Note
Gas pressure	Fluctuation	≤ 10	mbar/s	
Gas temperature	Min.	10	°C	Higher temperatures should be checked in all cases!
	Max.	40	°C	
Relative gas humidity	Max.	80	% rel.	Must be guaranteed at any temperature and supply pressure! [1)]
	Max	50	% rel.	When using a Jenbacher active carbon filter at the intake of the active carbon system. Higher temperatures should be checked in all cases!
Lower calorific value	Fluctuation	≤ 4	%/min	Lower calorific value in KJ/Nm^3
Methane number	Speed of change	≤ 10	MN/min	According to standard calculation method (AVL)
Hydrogen $H2_2$	Speed of change	≤ 4	vol%/min	Especially in the case of process gases
Ignitability		The gas must not be ignitable. Take note of statutory regulations and limit levels!		

[1)] If a prechamber gas compressor is used for the prechamber gas system or if the plant is located in a tropical zone, the limit values set out in Section 5.3 apply.

5.2 Requirements and limits for the combustion air

The combustion air for engine plants is generally aspirated from the immediate vicinity of the plant. Ambient air when dry consists of the following gaseous constituents:

Constituent	% by volume
Nitrogen $N2_2$	78.08
Oxygen $O2_2$	20.95
Argon Ar	0.93
Carbon dioxide $CO2_2$	0.04

The reference points are the standard conditions for temperature and pressure with a temperature of 273.15 K and a pressure of 101.325 kPa.

Ambient air also includes trace gases such as neon, helium and krypton.

Air always includes a proportion of water vapour as well. This depends greatly on local ambient conditions and is also aspirated into the engine.

The following measures must be observed, depending on the humidity content of the combustion air:

Humidity content in gH2O/kgAir	Effect
≤ 15	No condensate formation and therefore no influence on engine operation expected
> 15	Check the reduction diagram

The following requirements and limits are placed on the combustion air:

Requirements and limits for the combustion air

Designation	Additional	Limitation	Unit	Note
temperature				See TA 1100-0110
Particles Total particle content		≤ 0.1	mg/Nm³	Type 2 to 6: Purity class G3 as per EN779 J920: purity class M6 as per EN779 (previously F6) A filter in the combustion air intake protects the system against particles. The value specified is the design basis for the air filter [1)]
Highly flammable components				Safety limits must not be exceeded. If the combustion air is not free of highly-flammable components, its usability must be agreed with Jenbacher.
Acid-forming and base-forming constituents				Must not enter the engine

[1)] If the filter service life stated in the maintenance plan is not reached or if the filter service life turns out to be unacceptable, the customer must take measures to improve it.

If the ambient air contains impurities (such as sulphur compounds, oil vapours, other gaseous constituents, etc.) its usability must be checked.

Care must be taken to ensure that the location where the combustion air is aspirated is not subject to any microclimate, such as warm humid zones in greenhouse applications. It must also be ensured that emissions from a wide variety of sources such as industrial air outlets, emissions from biogenous processes or solvents cannot enter the engine intake air and therefore cannot have any effect on engine operation. Jenbacher engine plants require a special air intake system which is described in the following Technical Instruction together with further boundary conditions:

- TA 1100-0110: Boundary conditions for GE Jenbacher gas engines

⚠ ATTENTION

Draught effect

When the engine is at rest, note that depending on the design of the intake system and the chimney draught effect, air may be permanently drawn through the engine. This means that the engine is exposed to ambient air even when shut down, which can result in damage if the air quality is poor.

5.3 Requirements and limits for the mixture

Jenbacher engines and plants must be protected generally against the ingress of unwanted substances into the mixture via both the fuel gas and the combustion air.

Limit values for trace substances and impurities, oil, condensate and particles

Trace substances and impurities usually enter the gas during the gas formation process, but can also come from the ambient air. They are usually impurities in the ppm range. The effects of trace substances and impurities do not become noticeable until the engine has been in operation for a certain time (cumulative effect). The same applies to oil, condensate and particles. As these effects are predominantly harmful, both the fuel gases and the ambient air should be as free as possible of trace substances and impurities. If the impurity content in the fuel gas is very high, suitable fuel gas cleaning may, under certain circumstances, be the best method of ensuring economic utilisation of the fuel gas.

To determine the suitability of a fuel gas for use in combustion engines, comprehensive knowledge of the gas analysis is required. Field experience shows that even results that were obtained under the same operating conditions can vary substantially. The effect of trace elements can therefore only be predicted to a certain extent, as very complex interrelations and cause/effect relations are often involved. In principle, the effects of trace elements are proportional to the quantity fed into the engine while it was operating. When using a fuel gas with a high calorific value, the gas flow to the engine is smaller compared with a gas with a low calorific value. As a result, the amount of trace substances introduced into the engine - and therefore their effect - differs even if there are identical concentrations of trace substances in the fuel gas. In order to be able to compare various gases, the trace substance concentration values must be related to a certain fuel gas energy amount (the fuel gas output required to generate a certain engine output is very similar for all gas types).

Jenbacher has therefore set the energy content of 1 standard cubic metre of methane to 10 kWh (rounded off).

The combustion air requirement also depends on the fuel gas and its calorific value. This results in a specific fuel gas to air mixture ratio for the gas types, which can be seen in the Appendix.

Additional trace elements or impurities not explicitly mentioned or limited in this Technical Instruction can change the properties of the fuel gas. Jenbacher does not accept responsibility for reduced output, reduced efficiency, reduced availability or possible engine damage resulting from such additional trace substances or impurities. In such cases Jenbacher is also relieved of any and all warranty obligations.

Limit levels for trace substances and impurities [1)]

Designation	Additional	Limitation	Unit	Note
Total sulphur	S	≤ 700	mg/10 kWh	Note effect on oil service life [2)]
		≤ 1200	mg/10 kWh	With limited warranty [3)]
Halogen compounds	Total Cl + 2 x F	≤ 100	mg/10 kWh	Note partial load operation [4)]
		≤ 400	mg/10 kWh	With limited warranty [3)]
Ammonia	NH_3	≤ 50	mg/10 kWh	Higher NH_3 values in the fuel gas may result in the NOx values for the engine exhaust gas stated in the specification being exceeded.
VOSC as total silicon	Total silicon as Si_{BG} (silicon operational limit value)	≤ 0.02		The operational value of silicon Si to be determined exactly by means of an oil $analysis_B$ [5)]
Highly flammable components	Acetylene (C_2H_2)	≤ 0.02	% vol.	These substances can cause uncontrolled spontaneous combustion in the system!

Designation	Additional	Limitation	Unit	Note
	Carbonyl sulphide (COS)	≤ 0.02	% vol.	

[1)] The limit values quoted in the following sections apply if Jenbacher fuel gas or exhaust gas treatment systems are used, or if engines are being used with a prechamber gas system, or if the system is installed in tropical zone countries.

[2)] The oil service life is noticeably reduced above a total sulphur content of approx. 50 mg/10 kWh and/or a total halogen content of approx. 20 mg/10 kWh (refer to TA 1000-0099 B and C). If desulphurisation units are being used, note that extremely high concentrations of sulphur can enter and damage the engine very quickly when a fault occurs in such units.

This category also includes the limit values for hydrofluoric acid (HF) and hydrochloric acid (HCl). Please also refer to the sample calculation for converter gas in the appendix.

[3)] Assuming a service life reduction of all engine and plant components that come into contact with the fuel gas, engine oil or exhaust gas and an increase in maintenance activities, the limits can be increased. In order to achieve a satisfactory minimum oil service life (approx. 500 Oh) a suitably large additional lubricating oil tank must be fitted, as designed by Jenbacher.

[4)] For plants using heat recovery, care must be taken to ensure that the temperature does fall below the acid dew point in the waste heat boiler, taking partial load operation into account.

[5)] When a fuel gas with traces of volatile oxidisable silicon compounds is used, it is not possible to specify a limit level in the fuel gas due to severe fluctuations and the difficulty of performing an analysis. The operational value Si_B, determined on the basis of two analyses, is the determining value for the amount of silicon fed to the engine. This must not exceed the operational limit value Si_{BG}. The calculation method is explained in the appendix.

Limit levels for oil, condensate and particles

Designation	Additional	Limitation	Unit	Note
Particles				A filter in the gas train protects the system against particles The filter in the gas train is not used as a work filter [6)]
Total oil content		≤ 0.2	mg/10 kWh	
Tar	CxHyRz	No tar in the intake system		Where gases (particularly wood gas) contain tar, the gas train must be fitted with a trace heating system and thermal insulation! [7)]
Condensate or sublimate		No condensate and no sublimation of water or tars in components that come into contact with gas and/or mixture. [8)]		

[6)] If the filter service life as stated in the maintenance plan is not achieved or the filter service life is found to be unacceptable or the operation of the gas pressure control system is compromised, measures must be taken by the customer to improve the situation.

If a work filter is necessary, it must have a filtration efficiency of at least 99.99% with particle diameters greater than 3 µm.

[7)] In mixtures or gases in which the hydrocarbons form solid, liquid or highly viscous products when the mixture or gas cools to below the dew point, the condensation or sublimation products are described as tar. This affects all hydrocarbons (C_x, H_yR_z) with 6 or more carbon atoms and a molar mass (M)≥ benzene (78.11 g/mol) with every possible substitution group (R_z).

When condensing out, tars can cause problems in the gas or mixture-side intake tract.

If tars condense or sublimate in components that are in contact with the gas or mixture, some of the problems that may arise are as follows:

- Clogging of fittings (filters, pressure regulators, solenoid valves, etc.) in the gas train

- Clogging of the gas mixer and compressor impeller on the exhaust gas turbocharger
- Clogging of the intercooler

When gases containing tar are mixed with cold combustion air, the mixture temperature must not fall below the tar dew point. In such situations, the tar dew point of the fuel gas must be correspondingly lower in order to prevent the tar condensing and/or sublimating in components that are in contact with the gas or mixture!

⚠ ATTENTION

Condensed and/or sublimated tars

Condensed and/or sublimated tars can result in a reduced service life for components, increased maintenance costs and limited engine operation as well as compromising the safety of the gas train!

[8)] Condensate or sublimate in the area where gas/air is added to the mixture (gas mixer) can sometimes also be caused by combustion air which is too cold. In this case, the problem can be remedied if the customer takes measures to preheat the combustion air, such as recirculating the room ventilation!

The absolute quantity of elements which have entered the engine is decisive when analysing the trace element content. The limit levels will be valid, assuming that the combustion air is free from impurities.

By accepting a service life reduction of all engine and system components that come into contact with the fuel gas, engine oil or exhaust gas and an increase in maintenance activities, the limits can be increased in consultation with Jenbacher. Moreover, additional measures, such as the design and attachment by Jenbacher of a supplementary lubricating oil reservoir, can help increase the minimum service life of the oil.

Additional requirements when Jenbacher fuel gas or exhaust gas treatment systems are used

Jenbacher supplies a range of designs of bespoke treatment systems which it has developed for fuel gas and exhaust gas in engine systems. In the case of engine systems that use this type of treatment system, the additional requirements for the system as a whole are as shown in the table below.

Designation	Additional	Limitation	Unit	Note
Total sulphur	S	≤ 500	mg/10 kWh	When Jenbacher active carbon system is used
		≤ 200	mg/10 kWh	When Jenbacher CO catalytic converter is used [9)]
		≤ 20	mg/10 kWh	When Jenbacher formaldehyde catalytic converter is used [9)]
Halogen compounds	Total Cl + 2 x F	≤ 200	mg/10 kWh	When Jenbacher active carbon system is used
		≤ 200	mg/10 kWh	When Jenbacher ClAir system is used
		≤ 20	mg/10 kWh	When Jenbacher CO catalytic converter or Jenbacher formaldehyde catalytic converter used
VOSC as total silicon	Total silicon as Si_{BG}	≤ 0.0005		When Jenbacher CO catalytic converter or Jenbacher formaldehyde catalytic converter used

Designation	Additional	Limitation	Unit	Note
Total trace elements when catalytic converter is used	The metals and heavy metals listed as examples have the effect of deactivating the catalytic converter. This reduces its service life accordingly.			
	▪ Sulphur, phosphorus, lead, mercury, arsenic, antimony, zinc, copper, tin, iron, nickel, chromium, etc.			
	▪ The warranty will cease to apply if the cumulative volume of these elements exceeds 350g/Nm^3 honeycomb catalytic converter. The evidence will be provided by quantitative analysis of a used sample. The exhaust gas must, in all cases, be free of silicon compounds, such as siloxanes.			

[9] SO_2 is converted to SO_3 in the catalytic converter. As condensate forms, sulphurous or sulphuric acid is produced. Consequently, heat recovery boilers, catalytic converters and exhaust gas systems for exhaust gas temperatures < 180°C are covered by a limited warranty in the event of damage.

Additional requirements for engines with a pre-chamber gas system

The following additional limit values for the fuel gas apply to engines with a prechamber gas system.

Designation	Additional	Limitation	Unit	Note
Total sulphur	S	≤ 200	mg/10 kWh	

Engines equipped with a pre-chamber gas system require fuel gas at a higher pressure. Changes in pressure level could result in the condensation and sublimation of trace substances in the fuel gas. If a compressor is used to increase the pressure level, the additional requirements for the compressor will apply as follows:

Additional requirements on the fuel gas when using a prechamber gas compressor for the prechamber system

Designation	Additional	Limitation	Unit	Note
Gas temperature at the prechamber gas compressor inlet	Min.	10	°C	Higher temperatures should be checked in all cases! If the engine room temperature is below 30°C, trace heating and insulation of the entire gas train can be carried out to reliably avoid condensation and sublimation.
	Max.	40	°C	
Relative gas humidity at the prechamber gas compressor intake	Max.	15	% rel.	No condensate in the gas train up to the pre-chamber gas valve!

Additional requirements on the fuel gas for applications using mine gas in tropical zone countries

Special requirements exist for mine gas applications in tropical zone countries located between latitudes 30° north and 30° south. Areas affected include Central America (including Mexico), South America (with the exception of Uruguay, Argentina and Chile), Africa, the Arabian Peninsula (including Israel), the Indian subcontinent (Pakistan, Bangladesh, India, Sri Lanka), the whole of South-East Asia (including China), Australia (north of 30° latitude) and Oceania. To prevent condensation in the components carrying fuel gas and mixture, the following requirements apply in these countries to the operation of Jenbacher engine systems with mine gas.

Additional requirements in tropical zone countries located between latitudes 30° north and 30° south

Designation	Additional	Limitation	Unit	Note
Relative gas humidity of coal mine gas	Max.	50	% rel.	No condensate in the gas train up to the gas mixer!

Requirements on the freedom from condensate of the fuel gas - air - mixture.

In addition to water vapour, many types of gas also contain other condensable substances that demand special attention. Condensation processes can adversely affect engine operation. This is particularly true in the case of gases from gasification processes, which, depending on the process and the gas treatment system, may contain condensable organic components such as tar and water-soluble naphthalene, not to mention many others. This can have potentially negative consequences, especially for the components conveying the fuel gas.

NOTE

Danger of engine damage

Experience shows that an insufficiently dry gas initially mostly causes malfunctions in the valves, devices and piping outside the engine itself. If the cause is not rectified, however, damage to the engine cannot be ruled out.

Malfunctions that occur because the fuel gases supplied are insufficiently free from condensate are not covered by our warranty. This warranty exclusion does not apply if the contractual scope of supply of Jenbacher expressly includes a specific fuel gas drier.

Additional information relating to freedom from condensate can be found in the Appendix.

6 Appendix

6.1 Overview of the fuel gas requirements and limits

Physical characteristics, main components and thermodynamic requirements

Designation	Additional	Limitation	Unit	Note
Gas pressure	Fluctuation	≤ 10	mbar/s	
Gas temperature	Min.	10	°C	Higher temperatures should be checked in all cases!
	Max.	40	°C	
Relative gas humidity	Max.	80	%	Must be guaranteed at any temperature and supply pressure!
Lower calorific value	Fluctuation	≤ 4	%/min	Lower calorific value in KJ/Nm^3
Methane number	Speed of change	≤ 10	MN/min	According to standard calculation method (AVL)
Hydrogen H_2	Speed of change	≤ 4	vol%/min	Especially in the case of process gases
Ignitability		The gas must not be ignitable. Take note of statutory regulations and limit levels!		

Hydrogen (H2) in pipeline natural gas (EG)

If hydrogen is added to the natural gas in the pipeline, a maximum H2 content of 5% (vol.) is permitted. In these cases, it is strongly recommended to use the LEANOX^{plus} NOx control (measurement of NOx emissions and correction of the LEANOX controller). Please note that it may be necessary to readjust the LEANOX controller and the ignition timing. If large fluctuations (approx. +/-40 % rel. or +/-2% by volume) of the hydrogen content are to be expected, INNIO Jenbacher GmbH & Co OG must be consulted.

6.2 Overview of the requirements and limits for the combustion air

Designation	Additional	Limitation	Unit	Note
temperature				See TA 1100-0110
Particles Total particle content		≤ 0.1	mg/Nm³	Purity class G3 as per EN779 A filter in the combustion air intake protects the system against particles. The value specified is the design basis for the air filter
Highly flammable components				Safety limits must not be exceeded. If the combustion air is not free of highly-flammable components, its usability must be agreed with INNIO Jenbacher GmbH & Co OG.
Acid-forming and base-forming constituents				Must not enter the engine

The table shown only represents an extract. Details can be found in the individual sections.

6.3 Overview of the requirements and limits for the mixture

Designation	Additional	Limitation	Unit	Note
Limit levels for trace substances and impurities				
Total sulphur	S	≤ 700	mg/10 kWh	Note effect on oil service life
		≤ 1200	mg/10 kWh	With limited warranty
Halogen compounds	Total Cl + 2 x F	≤ 100	mg/10 kWh	Note partial load operation
		≤ 400	mg/10 kWh	With limited warranty
Ammonia	NH_3	≤ 50	mg/10 kWh	Higher NH_3 values in the fuel gas may result in the NOx values for the engine exhaust gas stated in the specification being exceeded.
VOSC as total silicon	Total silicon as Si_{BG} (silicon operational limit value)	≤ 0.02		Silicon SiO value in operation to be determined exactly by means of oil $analysis_B$
Highly flammable components	Acetylene (C_2H_2) carbonyl sulphide (COS)	≤ 0.02	% vol.	These substances can cause uncontrolled spontaneous combustion in the system!
Limit levels for oil, condensate and particles				
Particles		-		A filter in the gas train protects the system against particles The filter in the gas train is not used as a work filter
Total oil content		≤ 0.2	mg/10 kWh	
Tar	CxHyRz	No tar in components that are in contact with the gas or mixture		Where gases (particularly wood gas) contain tar, the gas train must be fitted with a trace heating system and thermal insulation!
Condensate or sublimate		-		No condensate and no sublimation of water or tars in components that come into contact with gas and/or mixture.
Additional requirements when Jenbacher fuel gas or exhaust gas treatment systems are used				
Total sulphur	S	≤ 500	mg/10 kWh	When Jenbacher active carbon system is used
		≤ 200	mg/10 kWh	When Jenbacher CO catalytic converter is used
		≤ 20	mg/10 kWh	When Jenbacher formaldehyde catalytic converter is used
Halogen compounds	Total Cl + 2 x F	≤ 200	mg/10 kWh	When Jenbacher active carbon system is used
		≤ 200	mg/10 kWh	When Jenbacher ClAir system is used
		≤ 20	mg/10 kWh	When Jenbacher CO catalytic converter or Jenbacher formaldehyde catalytic converter is used

Designation	Additional	Limitation	Unit	Note
VOSC as total silicon	Total silicon as Si_{BG}	≤ 0.0005		When Jenbacher CO catalytic converter or Jenbacher formaldehyde catalytic converter used
Total trace elements when catalytic converter is used	The metals and heavy metals listed as examples have the effect of deactivating the catalytic converter. This reduces its service life accordingly. • Sulphur, phosphorus, lead, mercury, arsenic, antimony, zinc, copper, tin, iron, nickel, chromium, etc. • The warranty will cease to apply if the cumulative volume of these elements exceeds 350g/m³ of catalytic converter honeycomb. The evidence will be provided by quantitative analysis of a used sample. The exhaust gas must, in all cases, be free of silicon compounds, such as siloxanes.			
Additional requirements on the fuel gas for engines with a prechamber system				
Total sulphur	S	≤ 200	mg/10 kWh	
Additional requirements on the fuel gas when using a prechamber gas compressor for the prechamber system				
Gas temperature at the prechamber gas compressor	Min.	10	°C	Higher temperatures should be checked in all cases! If the engine room temperature is below 30°C, trace heating and insulation of the entire gas train can be carried out to reliably avoid condensation and sublimation.
	Max.	40	°C	
Relative gas humidity at the prechamber gas compressor intake	Max.	15	% rel.	No condensate in the gas train up to the prechamber gas valve!
Additional fuel gas requirements for mine gas in tropical zone countries between latitudes 30° north and 30° south This additional requirement for mine gas applications typically applies to the countries of Central America (incl. Mexico), South America (with the exception of Uruguay, Argentina and Chile), Africa, the Arabian peninsula (incl. Israel), the Indian subcontinent (Pakistan, Bangladesh, India, Sri Lanka), the whole of South-East Asia (incl. China), Australia (north of 30° latitude) and Oceania.				
Relative gas humidity of coal mine gas	Max.	50	% rel.	No condensate in the gas train up to the gas mixer!

The table shown only represents an extract. Details can be found in the individual sections.

6.4 Explanation of freedom from condensate

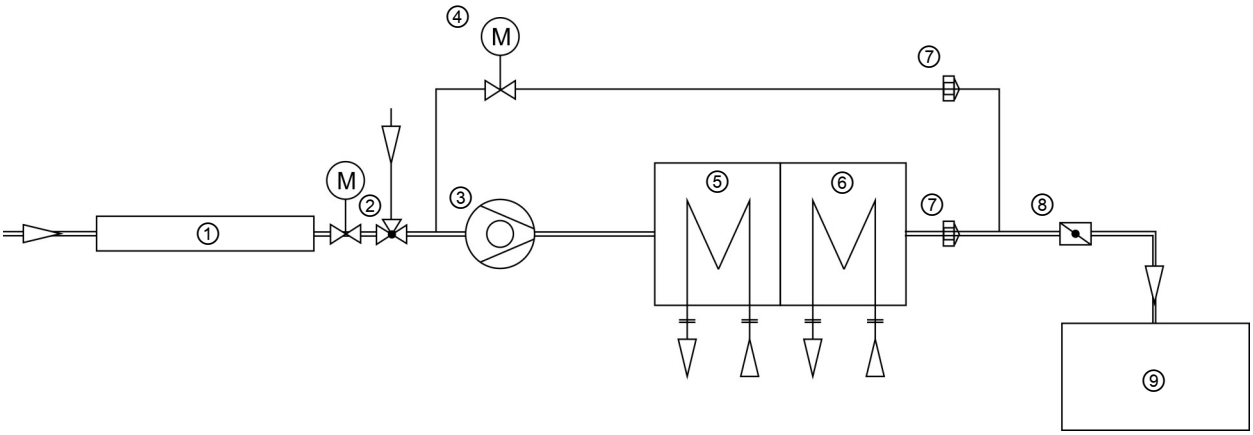
If this Technical Instruction is adhered to, no condensate should form at any point on components carrying fuel gas and mixtures. Should condensation nevertheless occur, the following explanations may prove helpful.

The most common types of condensate formation

Gas	Condensate texture	Most common consequences for engines
Biogas, sludge gas and landfill gas	Acidic water, also as an emulsion with the lubricating oil in the gas compressor	Corrosion (→ wear)
		TAN concentration or pH reduction in lubricating oil

Gas	Condensate texture	Most common consequences for engines
		Carbon deposited on valves, piston ring grooves and slots
Associated petroleum gas	Higher hydrocarbon compounds in liquid form	Film of lubricating oil washed off (seizing)
		Knocking combustion
		Edges burnt off
	Higher hydrocarbon compounds in liquid form and/or crude oil	Carbon deposits on: valves, piston ring grooves and slots
Liquid gas, propane gas	Liquid propane/butane	Film of lubricating oil washed off (seizing)
		Knocking combustion
		Edges burnt off
Gas from gasification process, process gases	Same as all other gases	Same as all other gases

Influence on engine operation



Component	Effect	Solution	Detection
No. ① Gas train	Clogging of gas filter, sources of membranes, deposits from condensate or sublimate	Clean or replace affected parts as described in Maintenance Instruction	Visual inspection at 10,000 operating hours (Oh) or in the event of a malfunction
Nr. ② Gas mixer	No known consequences		
Nr. ③ Turbo charger	Deposits on compressor wheel or diffuser	Clean at 10,000 Oh as described in Maintenance Plan or as required	Problems in reaching full load/power reduction
No. ④ Turbo charger bypass valve	Clogged with tar deposits; valve failure in the worst-case scenario	Clean with solvent. Can be cleaned at the same time as intercooler (10,000 Oh)	Visual inspection at 10,000 Oh or in the event of a malfunction

Component	Effect	Solution	Detection
No. ⑤ Intercooler 1. stage	No known consequences		
No. ⑥ Intercooler 2. stage	Clogged with tar deposits and condensate; possible power reduction as a result of increasing pressure loss	Clean with intercooler cleaning device	Large fall in pressure can be equalised to a certain extent using turbocharger reserves; indication: increase in boost pressure
No. ⑦ Flame barrier	Clogged by tar deposits; possible power reduction	Mechanical cleaning. Can be cleaned at the same time as the intercooler (10,000 Oh)	Large fall in pressure can be equalised to a certain extent using turbocharger reserves; indication: increase in boost pressure Component temperature greater than e.g. intercooler temperature (~80-90°C)
No. ⑧ Throttle valve	Clogged by tar deposits; in worst case, failure of the throttle valve	Clean with solvent. Can be cleaned at the same time as intercooler (10,000 Oh)	Visual inspection at 10,000 Oh or in the event of a malfunction
No. ⑨ Engine	-	-	-

How to avoid malfunctions resulting from condensate in the fuel gas

- In general, the technical project execution department at Jenbacher should be contacted if condensation occurs.
- Condense the vapour by cooling and/or expansion.
- Mechanical separation (e.g. cyclone or separation filter) and by gas-tight discharge of the condensate.
- The fuel gas line leading to the engine must be designed not to allow the gas to continue to cool down (and also not to be expanded by resistance or downstream pressure reducers). If necessary, the fuel gas line must be insulated or provided with a trace heating system.
- In spite of the freedom from condensate found at the condensate test points, a certain amount of condensate can find its way into the engine. It is therefore very important to ensure that the condensate is as free from acid-forming components as possible. To verify this, the pH-value of the aqueous extract taken from the condensate separators must be checked. The stronger the acid, the more powerful the adverse effect is, even with condensate quantities that can hardly be verified.

⚠ ATTENTION

Skin hazards from chemical substances! Corrosive condensate

The safety instructions must be observed when draining condensate from the gas system. Wear acid-resistant gloves when handling condensate.

6.5 Check list for fuel gas quality information

General information

Name of the project or the plant	
Location (country and/or city) of the plant	
Name of the contact person	
Telephone number	
Origin of the gas	
Gas type classification: Natural gas (**NG**) Associated gas (**APG**) Biogas, sludge gas, landfill gas (**BG**) Mine gas (**CMG**) Gases from gasification processes (**GG**) Process gases (**PG**) Liquid gas, propane gas (**LG**)	

Physical properties

Gas pressure (from – to)	-	mbar(o)
Gas temperature (from – to)	-	°C
Gas relative humidity (from – to)	-	%
Atmospheric pressure (from – to)	-	mbar

Main components	**Relevant for the following gas types ***							**% by vol.**	**Measurement method**
	NG	**APG**	**BG**	**CMG**	**GG**	**PG**	**LG**		
Methan $CH4_4$	X	X	X	X	X	X	X		
Ethane $C_2H₆$	X	X					X		
Propane $C_3H₈$	X	X			X		X		
Butane $C_4H₁₀$	X	X					X		
Pentane $C_5H₁₂$	X	X					X		
Hexane $C_6H₁₄$	X	X					X		
Carbon monoxide CO			X		X	X			
Hydrogen $H2_2$					X	X			
Carbon dioxide $CO2_2$		X	X	X	X	X			
Nitrogen $N2_2$		X	X	X	X	X			
Oxygen $O2_2$			X	X	X	X			
Miscellaneous	X	X	X	X	X	X	X		

Trace substances and impurities		Relevant for the following gas types *							Qty.	mg/10 kWh	Measurement method
		NG	APG	BG	CMG	GG	PG	LG			
Ammonia $NH3_3$				X		X	X				
Total chlorine				X		X	X				
Total fluoride				X		X	X				
Prussic acid HCN						X					
Hydrogen sulphide H_2S			X	X		X	X				
Total organosilicon compounds				X							
Total sulphur			X	X		X	X				
Acetylene C_2H_{22}						X	X				
Carbonyl sulphide COS						X	X				
Tar	Benzene					X	X				
	Naphthalene					X	X				
	Tar dew point					X	X		temperature	°C	
Miscellaneous		X	X	X	X	X	X	X			

Particles										
< 3 µm				X	X	X				
> 3 µm				X	X	X				
Miscellaneous	X	X	X	X	X	X	X			

* The individual positions are relevant if this component is (or can be) present in the gas. Positions allocated to a gas type are marked "X" and are required in each case.

Other information:

Analysis institutes known to Jenbacher can be recommended.

6.6 Organosilicon compounds in biogas, sludge gas and landfill gas

Organosilicon compounds

Organosilicon compounds are found in fuel gases from landfills, water purification plants and biogas installations (depending on the source of the biomass). When using these fuel gases in combustion engines, silicon oxide is produced (quartz particles), which may result in increased maintenance of the machinery and, in certain cases, in the deactivation of an exhaust gas catalytic converter.

Siloxanes, silanes and silanoles all belong to the organosilicon compound group. Siloxanes are increasingly used in cosmetics, detergents and as anti-foaming agents in industry. The other substances enter the fuel gas primarily as siloxane decomposition products. These are combustible and very volatile substances that originate from watery systems (sludge, fermenters, landfill leach water).

An assessment of the levels of organosilicon compounds in fuel gas should be carried out in the following applications:

- Gases from landfills
- Gases from sewage plants that mainly process domestic waste water
- Gases from biogas installations, depending on the origin of the biomass
- Gases from landfills where intermediate products from silicon chemical processes or other silicon-containing products are dumped, and gases from sewage plants into which silicon-containing effluent is discharged

While the tried and tested Jenbacher renewable active carbon system effectively removes these organosilicon compounds from sludge gas and biogas, any decision to use this cleaning technique for landfill gas should be taken on a case-by-case basis.

Determining levels of organosilicon compounds

The total of the organosilicon compounds contained in the fuel gas is used to calculate the total silicon atoms contained in the fuel gas in [mg/Nm³]. Given the methane value, this value can be converted into the content of silicon atoms from organosilicon compounds in [mg/10 kWh].

Particularly in the case of fuel gases from landfill sites, Jenbacher's advice is to analyse the organosilicon compounds in the preparatory project phase in order to estimate the expected level of maintenance operations. The analysis results also provide Jenbacher with a framework on which to base its advice for the best gas-cleaning method, taking into account feasibility and efficiency aspects.

The sampling and analysis of organosilicon compounds in the typically occurring concentrations do not reflect the generally accepted state-of-the-art. Jenbacher offers its customers a tried and tested analysis technique which the company has developed itself. The sampling should only be performed by trained specialist Jenbacher staff.

During operation, the silicon load is determined from the silicon content of the oil. Strict maintenance of this limiting value forms the basis for the validity of a service contract. This limit value does not indicate the current silicon load value, but shows the amount of silicon accumulated during the period between two oil analyses.

Requirements for sampling and the selection of the sampling location

Identifying the organosilicon compounds in fuel gas is always a reflection of the current situation at the time the sample was taken. Sample taking can only yield suitable results if the fuel gas source to be sampled meets the following criteria:

1. The sample location must be a part of the gas line with a constant gas flow and must be **free of condensate**. Up or downward pipe sections are well suited for this purpose. In case of horizontal pipe sections, the sample location must branch off upward, otherwise condensate will collect in the branches. This also falsifies the sample if the condensate has been drained off and the gas is visually dry.

2. The fuel gas supply must have been up and running without interruption for at least three (3) hours. The gas volume flow must be at least 75 % of the operational gas flow that would be needed at full-load condition of the projected gas engine installation. With gas lines having a reduced flow during sample there is the risk of a faulty measurement when trace components condens on cold surfaces and/or when silicon-organic compounds are absorbed in other condensed trace components.
3. The sampling location should preferably be in the pressurised part of the fuel gas line upstream of the projected engine is reached. However, sample taking in negative pressure lines is also possible.
4. During this period, landfill gas installations require the suction pressure to be approximately the same as the suction pressure during the projected full-load operation. Landfills which produce no gas flows in the volumes required for the projected engine operation cannot be sampled satisfactorily. In the case of landfills, suitable samples can only be taken in a gas collecting line. Sample taking from individual sources will not yield results that can be used as described in this Technical Instruction.
5. In order to achieve a fuel gas trace element load that is as constant as possible, none of the settings of the operational gas installation should be modified during sample taking.

6.7 Note about the mixture

Polluted combustion air may be used in individual cases provided that the pollutants it contains are not already present in the fuel gas in the maximum permitted concentration. Note here that the mixture ratio is dependent on the fuel gas composition and determines the specific combustion air requirement. The mixture ratio is roughly 4 for gases originating from gasification processes, and this means that the fuel gas must be mixed with approximately 4 times its volume of combustion air. The figure for this ratio for natural gas or propane is more than 20. The Table below shows approximate mixture ratios for individual gas types.

Fuel gas	**Mixture ratio of combustion air to fuel gas (approximate, depends on the project)**
Natural gas (NG)	22
Associated petroleum gas (APG)	13
Biogas, sludge gas, landfill gas (BG)	8
Coal mine gas (CMG)	10
Gases from gasification processes (GG)	4
Process gases (PG)	8
Liquid gas, propane gas (LG)	24

This shows that the ingress of harmful substances via the combustion air (with the same concentrations as in the fuel gas) can lead to significantly more severe damage to the engine.

This means that the sulphur limit of 700 mg/10 kWh applicable to fuel gas can be converted to the combustion air using the mixture ratio. For example, a sulphur limit of 88 mg/Nm³ for the combustion air can be calculated for an engine running on biogas, provided that the fuel gas is totally free of sulphur! The mixture ratio contains the conversion of [mg/10 kWh] in [mg/Nm³].

The following Appendix shows a calculation example for a plant with polluted fuel gas and polluted combustion air.

6.8 Sample calculations

Sample calculation trace substance concentration SC

Measured concentration [mg/Nm^3]

$$SC = \frac{}{\text{Calorific value [kWh/Nm}^3\text{]}} \text{ X } 10$$

Concentrations are frequently indicated in volume-related quantities e.g. ppm (parts per million), which must be converted in an intermediate step to mg/Nm3 using the density under normal conditions: i.e.

$$SC' \text{ [mg/Nm}^3\text{]} = \text{Measured concentration [ppm] x element density [kg/Nm}^3\text{]}$$

Remark: Expressing the quantity as ppm ($=10^{-6}$) and converting from kg to mg (10^{+6}) cancel each other out.

Calculation example for biogas

CO_2	40%
CH_4	60%
H_2S	260 ppm (at normal density condition = 1.52 kg/Nm^3)
Lower calorific value	6 kWh/Nm3 (= 60% of 100% CH4 = 10 kWh/Nm^3)

Step 1: Conversion of measured value in ppm to mg/Nm^3, referred to H_2S

SC'_1 [mg/Nm^3]= 260 [ppm] x 1.52 [kg/Nm^3] $\qquad$ SC'_1= 395 mg/Nm^3

Step 2: Conversion of the value in relation to H_2S to the limited sulphur value in mg/Nm^3

$$SC' \text{ [mg/Nm}^3\text{]} = \frac{\text{Sulphur molar mass}}{\text{Molar mass of } H_2S} \text{ x } SC'_1 \qquad SC' \text{ [mg/Nm}^3\text{]} = \frac{32}{34} \text{ x } 395 \text{ [mg/Nm}^3\text{]}$$

SC'= 372 mg/Nm^3

Step 3: Conversion of measured value in mg/Nm^3 to comparison value (mg/10 kWh).

$$SC = \frac{372 \text{ [mg/Nm}^3\text{]}}{6 \text{ [kWh/Nm}^3\text{]}} \text{ x10} \Rightarrow SC = 620 \text{ mg/10 kWh} \quad \text{actual value}$$

Without catalytic converter ⇨ SC_G= 700 mg/10 kWh $\qquad$ SC < SC_G ⇨ OK

In principle, this sample calculation also applies to all limit values expressed as mg/10 kWh.

Calculation example for a plant with polluted fuel gas and polluted combustion air

The combustion air for the biogas plant in the above example contains sulphur dioxide (SO_2) in a concentration of 12 mg/Nm³.

Step 1: Conversion of the value referred to SO_2 to the limited sulphur value in mg/Nm^3

$$SC'' \text{ [mg/Nm}^3\text{]} = \frac{\text{Sulphur molar mass}}{\text{SO molar mass}_2} \text{ x } SC''_1 \qquad SC'' \text{ [mg/Nm}^3\text{]} = \frac{32}{64} \text{ x } 12 \text{ [mg/Nm}^3\text{]}$$

SC''= 6 mg/Nm^3

Step 2: calculation of the additional sulphur ingress via the combustion air

For biogas, the mixture ratio of combustion air to fuel gas is 8. The mixture ratio contains the conversion of [mg/Nm³] in [mg/10 kWh].

SC_{Luft} [mg/Nm³] = SC'' x mixture ratio SC_{Luft} = 6 [mg/Nm³] x 8 [mg/10 kWh]/[mg/Nm³]

SC_{Luft} = 48 mg/10 kWh

Step 3: calculation of the total sulphur ingress

$SC_{tot} = SC + SC_{Luft}$ SC_{tot} = 620 [mg/10 kWh] + 48 [mg/10 kWh]

SC_{tot} = 668 mg/10 kWh

$SC_{tot} < SC_G$ ⇨ OK

Sample calculation for converter gas

Main gas components	Value	Unit
Acetylene C_2H_{22}	< 0.1	% vol.
Higher-value HC (> C_5H_{12})	< 0.2	% vol.
CO	67.75	% vol.
N_2	13.21	% vol.
CO_2	16.22	% vol.
H_2O	2.52	% vol.
Trace substances and impurities	**Value**	**Unit**
H_2S	80	ppm
HF	7.1	mg/10 kWh
HCl	4.0	mg/10 kWh
Gas characteristics	**Value**	**Unit**
Lower calorific value	2.38	kWh/Nm³

Hydrofluoric and hydrochloric acid

Step 1: calculation of the total quantity of chlorine

$$Cl\ [mg/10\ kWh] = \frac{\text{Chlorine molar mass}}{\text{HCl molar mass}} \times Cl'$$

$$Cl\ [mg/10\ kWh] = \frac{35.4}{36.4} \times 4\ [10\ mg/kWh]$$

Cl= 3.9 [mg/10 kWh]

Step 2: calculation of the total quantity of fluoride

$$F\ [mg/10\ kWh] = \frac{\text{Fluorine molar mass}}{\text{HF molar mass}} \times F'$$

$$F\ [mg/10\ kWh] = \frac{19}{20} \times 7.1\ [10\ mg/kWh]$$

F = 6.7 [mg/10 kWh]

Step 3: calculation of the total quantity of halogens

Hal [mg/10 kWh] Cl + 2 x F = Hal [mg/10 kWh] 3.9 [mg/10 kWh] + 2 x 6.7 [mg/10 kWh] =

Hal = 17.3 [mg/10 kWh]

Step 4: comparison of actual and setpoint value

Without catalytic converter ➔ Hal_G = 100 mg/10kWh Hal < Hal_G ➔ OK

In principle, these sample calculations apply to all limit values indicated in mg/10 kWh.

Sample calculation of silicon operational value Si_B

Determined using two oil analyses:

Δ Si $_{\text{Gehalt im Motoröl}}$: the increase of the Si content in the lubricating oil in ppm between two analyses, and

Δ oil service life: the operating time in hours between the two oil analyses.

$$\text{Si}_{\text{Betriebskennwert}}\ [Si_B] = \frac{\Delta \text{ Si}_{\text{Gehalt im Motoröl}}\ [\text{ppm}] \times \text{total operating oil volume (l)}}{\text{Average engine power output [kW]} \times \Delta \text{ oil service life (h)}} \times 1.1$$

The total operating oil volume equals the oil volume in the oil pan plus the oil volume of any additional oil tanks, if installed.

Refilling volume is definitely excluded.

Sample calculation

Increase in the Si content of the engine oil between two oil samples	40 ppm
Total operating oil volume	500 l
Engine power output	2000 kW
Operational oil life between the analyses	600 h

$$Si_B = \frac{40 \text{ ppm} \times 500 \text{ l}}{2000 \text{ kW} \times 600 \text{ h}} \times 1.1$$

Si_B= 0.018 actual value

Si_{BG}= 0.02 $Si_B < Si_{BG}$ ⇨ OK

7 Revision code

Revision history

Index	Date	Description/Revision summary	Expert *Verifier*
11	25.02.2021	Überschrift „Wasserstoff (H2) im Leitungserdgas (EG)“ in Kapitel 6.1 ergänzt / Heading "Hydrogen (H2) in pipeline natural gas (EG)" added to Chapter 6.1 Text in Überschrift „Flüssiggas, Propangas“ unter Kapitel 4 aktualisiert / Text in heading "Liquefied petroleum gas, propane gas" under Chapter 4 updated	**Fuchs J.** *Boewing R.*
10	28.02.2020	Ergänzung von Kapitel “Anforderungen und Grenzwerte an das Treibgas“ / Addition of chapter „Fuel gas requirements and limits“	**Birgel A.** *Boewing R.*
9	30.04.2019	GE durch INNIO ersetzt / GE replaced by INNIO	**Opoku** *Pichler R.*
8	30.11.2015	Ergänzung „Klassifizierung – Potenzieller Kunde“ / Additional „Classification - Prospective Customers“	**Bilek** *Kelly*
		Geringfügige Änderungen (Formatierung, Terminologie, Übersetzung)/ Minor Changes (formatting, terminology, translation)	**Provin** *Nübling*
		Ergänzung Verbrennungsluft und Gemisch / Extension for intake air and mixture	**Provin** *Nübling,Wall*
7	30.04.2015	Implementierung TA 1000-0301, TA 1000-0302, TA 1400-0091 und Umbenennung Treibgasanforderungen/ Implementation TA 1000-0301, TA 1000-0302, TA 1400-0091 and renaming Fuel gas requirements	**Provin** *Nübling, Wall*