FUEL GAS SPECIFICATIONS - SYNTHESIS GAS (SYNGAS)

1. ANALYSIS OF FUEL GAS

It will be necessary to carry out a chemical analysis of the gas to be used as a fuel. Such an analysis will be made first in order to select the type of engine required and to check the gas conformity with the specifications for its use as an engine fuel. Additionally, gas analysis shall be conducted whenever harmful constituents are suspected to be present in the gas as well as from time to time as part of the installation monitoring.

The basic parameters of the fuel gas which need be checked, based on the gas origin, are outlined below.

1.1. GASES RESULTING FROM THERMOCHEMICAL PROCESSES. GASIFICATION AND PYROLISIS

This category includes gases resulting from the gasification or pyrolysis of biomass, waste tyres and sundry solid materials. They develop under the heating of the initial organic matter in the presence or absence of air. Their composition will be determined by analyzing at least the following parameters:

1. Description of the site where the analysis is conducted
2. Date/time of sampling
3. Date/time of analysis
4. Analysis procedures employed
5. Gas temperature and pressure
6. CH_4 concentration (Vol %)
7. CO concentration (Vol %)
8. H_2 concentration (Vol %)
9. CO_2 concentration (Vol %)
10. N_2 concentration (Vol %)
11. O_2 concentration (Vol %)
12. C_2H_6 concentration (Vol %)
13. C_2H_4 concentration (Vol %)
14. C_2H_2 concentration (Vol %)
15. C_3H_8 concentration (Vol %)
16. C_3H_6 concentration (Vol %)
17. C_4H_{10} concentration (Vol %)
18. C_5H_{12} concentration (Vol %)
19. Gas relative humidity at engine intake (%)
20. Concentration of oils and tar (mg/m_n^3)
21. Concentration of solid particles (mg/m_n^3)
22. H_2S concentration (ppm or mg/m_n^3)
23. Concentration of other sulphur compounds (ppm or mg/m_n^3)
24. NH_3 concentration (ppm or mg/m_n^3)
25. Concentration of halides (ppm or mg/m_n^3)
26. Concentration of halogenated organic compounds (ppm or mg/m_n^3)
27. Concentration of BTEX (mg/m_n^3)
28. Concentration of siloxanes (mg/m_n^3) at least TMOH, TMS, L2, L3, L4, D3, D4, D5

2. SPECIFICATIONS FOR FUEL GASES

2.1. LOWER HEAT VALUE

Lower heat values of gases from thermochemical processes may be within the following range:

- 4.6 / 7.0 MJ / m_n^3 equal to 1100 / 1670 Kcal / m_n^3: lean syngas
- 7.0 / 14.0 MJ / m_n^3 equal to 1670 / 3,350 Kcal / m_n^3: rich syngas

For engines with a mechanical carburetion system, the maximum permissible variation in the gas LHV is ±5% in respect of the carburetion point. Greater variations would mean that carburetion must be readjusted.

Engines with an electronic carburetion system must be used where LHV variations can be as high as ±10%; above this limit, the gas composition has to be continually monitored with an analyser. It require send a signal from the LHV analyser to the gas carburation system, as show in the product information "IC-G-D-30-051e "Signal of LHV for the carburation system - Syngas with variable quality

LHV variation in excess of 1%/min. absolute value shall not be allowed over time.

2.2. METHANE NUMBER

The methane number is not considered in this type of gases.

2.3. SUPPLIED GAS CONDITIONS

In this respect, the following applies:

2.3.1. SUPPLIED GAS PRESSURE AND TEMPERATURE

Since the acceptable gas pressure and temperature at the inlet to the engine depend on the carburetion system the engine is equipped with, refer to the following Product Information documents for the applicable ranges.

- IC-G-D-30-012e: Engines with a TECJET 110 type electronic carburetion system
- IC-G-D-30-040e: Engines with a TECJET 52 type electronic carburetion system
- IT-G-A-00-011e: Minimum room temperature for operating gas engines

2.3.2. GAS HUMIDITY

The gas relative humidity at the inlet to the gas train shall always be less than 60% and by no means shall water be allowed to condense over the engine components. The minimum temperature of the gas at the engine intake has to be 15°C above the dew point. The maximum water dew point in the gas cannot exceed 30ºC.

2.3.3. OXYGEN IN GAS

For engines with a mechanical carburetion system, the maximum permissible quantity of oxygen (O_2) in the gas is 2% vol. For higher values or fluctuations greater than ±1% in respect of the carburetion point, it will be necessary to use engines with an electronic carburetion system and continuous monitoring of the gas composition by an analyzer.

An oxygen content in the gas greater than specified indicates that the thermochemical process is not performing adequately or this may indicate abnormal operation.

2.3.4. HYDROGEN IN GAS

The allowed quantity of hydrogen (H_2) in fuel must contribute a lower value of 40% of the fuel LHV. To contributions between the 30% and 40% of the LHV, the rated power of the engines has a derating of 10%. For higher percentages consult Siemens.
Calculation for % LHV of H_2:

LHV total = %vol $_{CH4}$ * LHV_{CH4} (MJ/mn3) + %vol $_{CO}$ * LHV_{CO} (MJ/mn3) + %vol $_{H2}$ * LHV_{H2} (MJ/mn3) + %vol $_{C2H4}$ * LHV_{C2H4} (MJ/mn3) + %vol $_{C2H6}$ * LHV_{C2H6} (MJ/mn3) + other hydrocarbons.

An example of calculation is shown below:

Component	% Volumen (1)
Methane	10
Carbon Monoxide	30
Hydrogen	45
Ethene (ethylene)	1
Ethane	1
Nitrogen	3
Carbon Dioxide	11

Component	Chemical formula	LHV (MJ/m_n^3)(2)
Methane	CH_4	35.818
Carbon Monoxide	CO	12.62
Hydrogen	H_2	10.777
Ethyne (acetylene)	C_2H_2	56.07
Ethene (ethylene)	C_2H_4	59.04
Ethane	C_2H_6	63.76
Propane	C_3H_8	91.18
Propene (propylene)	C_3H_6	85.94

(1) Dry gas
(2) LHV according to ISO 6976-E 1996, at 0ºC.

LHV example = 0.10*35.818 + 0.3*12.62 + 0.45*10.777 + 0.01*63.76 + 0.01*59.04 = 13.445 MJ/m_n^3

H_2 LHV example = 0.45*10.777 = 4.85 MJ/m_n^3

% LHV H_2 (against LHV total) = (LHV H_2/ LHV Total) *100 = (4.85/13.445) *100 = 36%

This gas complies with the specification, since the % LHV (MJ/m_n^3) from hydrogen is lower than 40% of total LHV, but the % LHV from hydrogen is higher than 30% so the power must be derated 10%.

2.3.5. HYDROCARBONS IN GAS

The maximum permissible quantity of ethylene must be according to a maximum contribution of 12% to the LHV of the gas

The maximum permissible quantity of acetylene must be according to a maximum contribution of 5% to the LHV of the gas

In any case, the total maximum contribution to the LHV of the gas from all the alkenes (linear hydrocarbons with carbon-carbon double bond, as ethylene or propylene) and all the alkynes (linear hydrocarbons with carbon-carbon triple bond, as acetylene) must be lower than 15%.

The maximum permissible quantity of lineal C_4+ hydrocarbons (butane and higher) and BTEX components (Benzene, Toluene, Ethylbencene and Xylene) must be according to a maximum contribution of 10% to the LHV of the gas.
For greater percentages, contact Siemens.

2.4. CONTAMINANTS OF FUEL GAS

Listed below are the maximum permissible values of the contaminants that are normally found in natural gas used as fuel in Siemens engines. The stated limits may not be exceeded; neither are contaminants - other than those listed below - allowed in the fuel gas.

2.4.1. SULFUR COMPOUNDS STATED AS H2S

The maximum permissible limit of H_2S equivalent* is set at:

- 70 mg / MJ ENGINES WITHOUT CATALYTIC CONVERTER

*: In order to calculate the H_2S equivalent in other sulphur compounds, the mass of S present in the sulphur compound may be taken as a basis for the mass of H_2S, considering organic and inorganic compounds.

For the calculation of the H_2S concentration in the indicated units, (mg / MJ), it is necessary to know the gas LHV in MJ / m_n^3. The following formula will be used:

Conc. (mg / MJ) = conc. (ppm) x 1.52 / LHV (MJ / m_n^3)
Or Conc. (mg / MJ) = conc. (mg / m_n^3) / LHV (MJ / m_n^3)

Example:

Measured concentration of sulphur compounds: 300 ppm

For a 7 MJ / m_n^3 LHV gas, the concentration in mg / MJ is:
Conc. (mg / MJ) = 300 (ppm) x 1.52 / 7 (MJ / m_n^3) = 65 < limit

For a 5 MJ / m_n^3 LHV gas, the concentration in mg / MJ is:
Conc. (mg / MJ) = 300 (ppm) x 1.52 / 5 (MJ / m_n^3) = 91 < limit

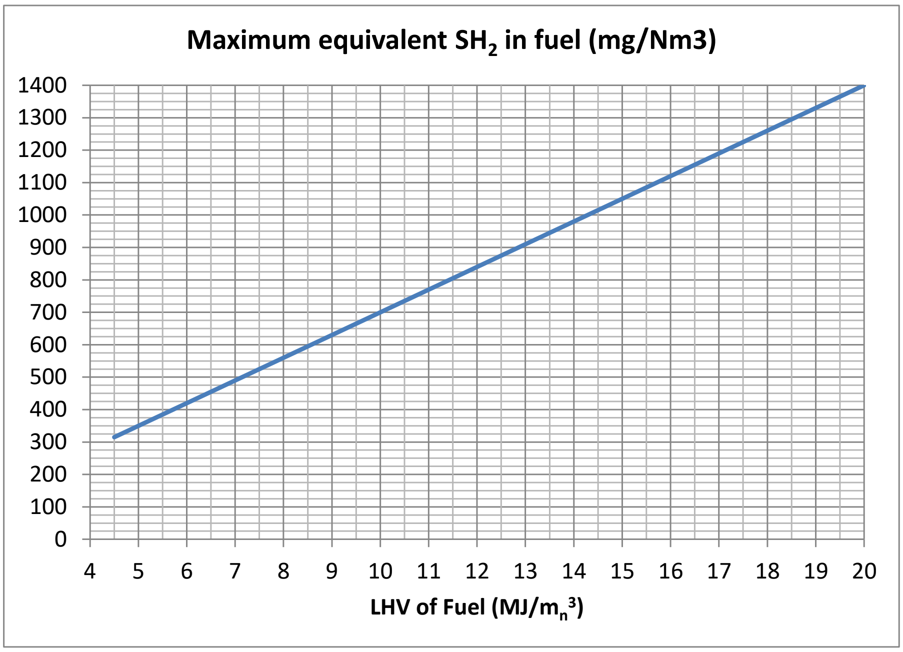

Fig. 1 - Maximum Value of equivalent SH_2 in fuel

2.4.2. HALOGENATED COMPOUNDS (F, Cl, Br, I) STATED AS Cl-

HF and HCl are the most harmful acids; therefore, their concentration is specified in mg of Cl^- equivalent / MJ and the remaining constituents are considered as if they were chlorine, using the following equations:

Fluor = 2 Chlorine   Bromine = 0.5 Chlorine   Iodine = 0.25 Chlorine

The maximum permissible level of halides, expressed as chloride equivalent, is set at:

- 3.5 mg de Cl^- equivalent* / MJ   ENGINES WITHOUT CATALYTIC CONVERTER

*: Organic and inorganic halides must be taken into consideration.

For the calculation of the Cl- concentration in the indicated units, (mg / MJ), it is necessary to know the gas LHV in MJ / m_n^3. The following formula will be used:

Conc. (mg / MJ) = conc. (ppm) x 1.63 / LHV (MJ / m_n^3)
Or Conc. (mg / MJ) = conc. (mg / m_n^3) / LHV (MJ / m_n^3)

Example:

Measured concentration of halogenated compounds: HCl 4 ppm and HF 4 ppm
Concentration of Cl- equivalent: 4 $ppm_{(HCl)}$ + 2 x 4 $ppm_{(HF)}$ = 12 $ppm_{(Cl-)}$

For a 7 MJ / m_n^3 LHV gas, the concentration in mg / MJ is:
Conc. (mg / MJ) = 12 ($ppm_{(Cl-)}$) x 1.63 / 7 (MJ / m_n^3) = 2.8 < limit

For a 5 MJ / m_n^3 LHV gas, the concentration in mg / MJ is:
Conc. (mg / MJ) = 12 ($ppm_{(Cl-)}$) x 1.63 / 5 (MJ / m_n^3) = 3.9 > limit

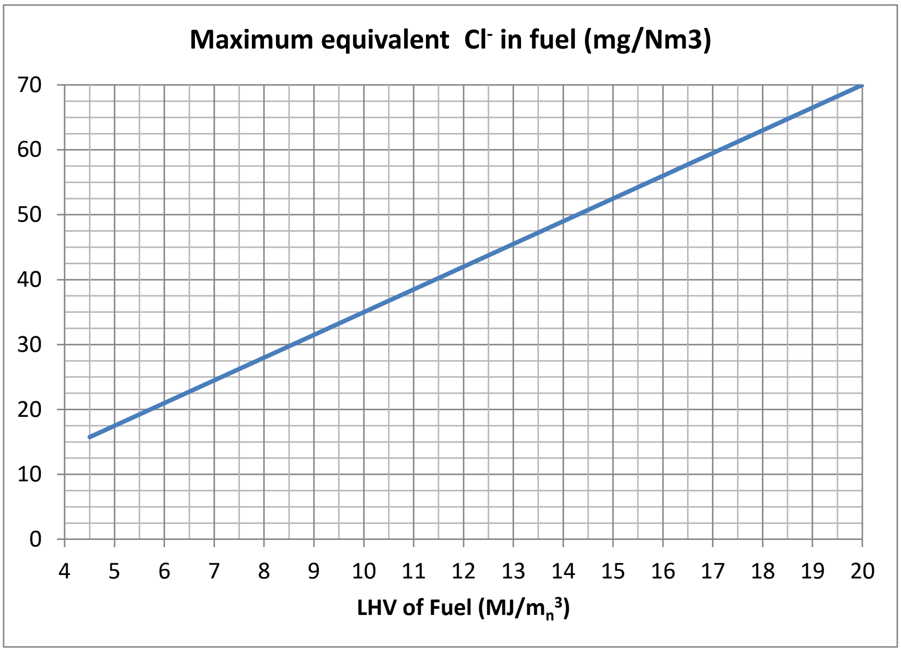

Fig. 2 - Maximum Value of equivalent Cl^- in fuel

2.4.3. SILICON COMPOUNDS

The maximum permissible content of silicon in a fuel gas is set at:

- 0.2 mg / MJ * ENGINES WITHOUT CATALYTIC CONVERTER

In calculating the proportion of silicon in siloxanes, it is reasonable to take an average of 37% of silicon per total siloxanes.

For the calculation of the siloxane concentrations in the indicated units, (mg / MJ), it is necessary to know the gas LHV in MJ / m_n^3. The following formula will be used:

Conc. (mg / MJ) = conc. (mg / m_n^3) / LHV (MJ / m_n^3)

*: Given the difficulties in analyzing and quantifying the silicon compounds in a fuel gas (Contact Siemens for information on reference laboratories), it is generally agreed that the silicon content in the oil of the engine should not exceed 75 ppm during the contracted maintenance period of the engine concerned. Accordingly, this value of Si in oil may also be deemed to be the maximum relative limit of silicon in the fuel.

Example:

Measured silicon compounds: 1.2 mg / m_n^3

For a 7 MJ / m_n^3 LHV gas, the concentration in mg / MJ is:
Conc. (mg / MJ) = 1.2 (mg / m_n^3) / 7 (MJ / m_n^3) = 0.17 < limit

For a 5 MJ / m_n^3 LHV gas, the concentration in mg / MJ is:
Conc. (mg / MJ) = 1.2 (mg / m_n^3) / 5 (MJ / m_n^3) = 0.24 > limit

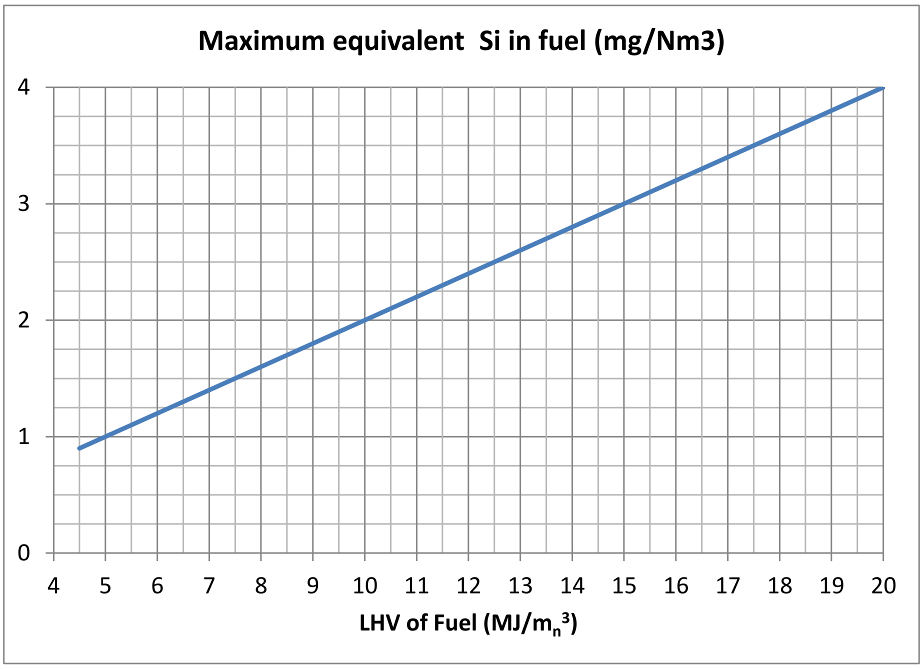

Fig. 3 - Maximum Value of equivalent Si in fuel

2.4.4. AMMONIA (NH3)

The maximum permissible content of ammonia in the fuel gas is set at:

- 1.5 mg / MJ

For the calculation of the ammonia concentration in the indicated units, (mg / MJ), it is necessary to know the gas LHV in MJ / m_n^3. The following formula will be used:

Conc. (mg / MJ) = conc. (ppm) x 0.76 / LHV (MJ / m_n^3)
Or Conc. (mg / MJ) = conc. (mg / m_n^3) / LHV (MJ / m_n^3)

Example:

Measured ammonia concentration: 12 ppm

For a 7 MJ / m_n^3 LHV gas, the concentration in mg / MJ is:
Conc. (mg / MJ) = 12 (ppm) x 0.76 / 7 (MJ / m_n^3) = 1.3 < limit

For a 5 MJ / m_n^3 LHV gas, the concentration in mg / MJ is:
Conc. (mg / MJ) = 12 (ppm) x 0.76 / 5 (MJ / m_n^3) = 1.8 > limit

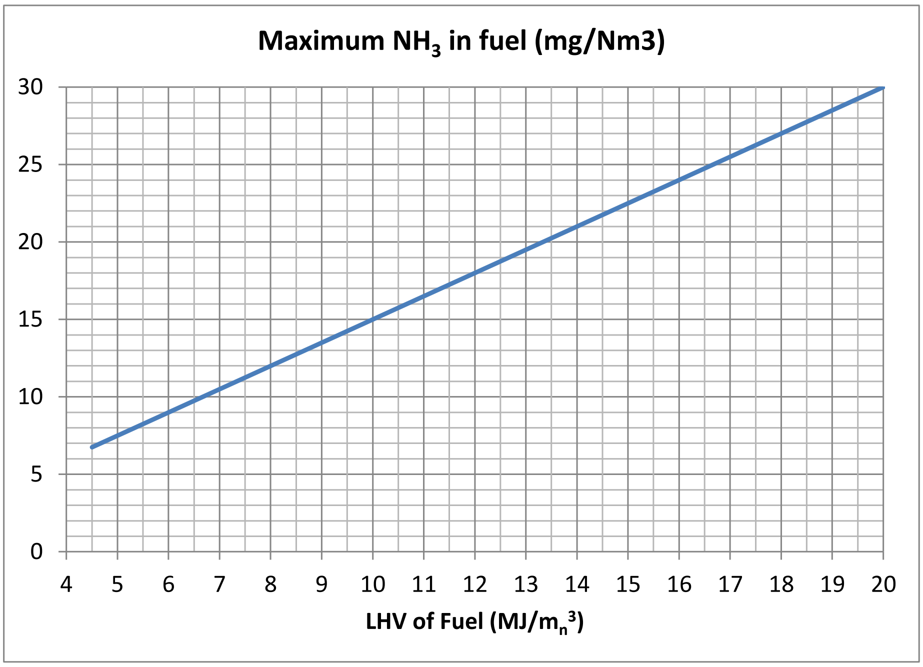

Fig. Maximum Value of ammonia in fuel

2.4.5. RESIDUAL OILS AND TAR

Condensates are inadmissible. Therefore, fuel gas must enter the engine at a temperature over its dew point (Siemens recommends a gas temperature of between 35 ºC and 50ºC at engine intake), however always meeting the inlet gas temperature specifications stated in the Product Information Sheets mentioned under 2.3.1.

Siemens proposes the European standard technical specification CEN/BT/TF 143 as a methodology for determining the tar content in the gas and limits tar concentration in gas to values below those set in the next table. The tar composition known, the gas dew point can be calculated.

Tars according to carbon ring no.	Limit concentration (mg/MJ)
1-ring (Pm < 110 g/mol)	1.500
2-ring (110< Pm< 152 g/mol)	200
3-ring (152< Pm< 200 g/mol)	3
4-ring (200< Pm< 250 g/mol)	Not allowed
5-ring (250< Pm< 273 g/mol)	Not allowed
6-ring (273< Pm< 295 g/mol)	Not allowed
7-ring or more (Pm > 295g/mol)	Not allowed

Refer to Siemens about the use of other tar and dew point analysis methods.

2.4.6. SOLID PARTICLES

the following limits in respect of the presence of solid particles in fuel gas have been established:

Maximum permissible particle size: 10 microns

Maximum concentration of particles 1 to 10 microns in size:

- 0.3 mg / MJ ENGINES WITHOUT CATALYTIC CONVERTER

For the calculation of the solid particle concentration in the indicated units, (mg / MJ), it is necessary to know the gas LHV in MJ / m_n^3. The following formula will be used:

Conc. (mg / MJ) = conc. (mg / m_n^3) / LHV (MJ / m_n^3)

Example:

Measured solid particle concentration: 2 mg / m_n^3

For a 7 MJ / m_n^3 LHV gas, the concentration in mg / MJ is:
Conc. (mg / MJ) = 2 (mg / m_n^3) / 7 (MJ / m_n^3) = 0.29 < limit

For a 5 MJ / m_n^3 LHV gas, the concentration in mg / MJ is:
Conc. (mg / MJ) = 2 (mg / m_n^3) / 5 (MJ / m_n^3) = 0.4 > limit

It is imperative to ensure that the limit concentration of particles <5 microns is not exceeded at any time of the engine operation, so an adequate filter element should always be mounted as part of the gas train engine.

2.5 TEMPERATURE IN UNIT

The temperature in the engine room or industrial plant where the engine is installed should be in accordance to IT-G-A-00-011e: Minimum temperature in engine room for operating gas engine

Contact Siemens in the event said temperature cannot be reached.

3. SUMMARY TABLE

Symbol	Parameter	Limit Value	Engine/application	Comments
LHV	Lower heat value	7.0 - 14.0 MJ/m_n^3	All syngas engines	rich syngas
		4.6 - 7.0 MJ/m_n^3	All syngas engines	lean syngas
ΔLHV	LHV variation	<±5%	Mechanical carburetion	Readjust carburetion
		<±10%	Electronic carburetion	
		>±10%	Electronic carburetion Continuous gas analyzer	Continuous gas analyzer required for LHV signal
∇LHV	LHV gradient	<1%LHV/min	All syngas engines	
MN	Methane number	---------------------	All syngas engines	
P & T	Supplied gas pressure and temperature	IC-G-D-30-012e	Electronic carburetion	TECJET 110
		IC-G-D-30-040e	Electronic carburetion	TECJET 52
		IT-G-A-00-011e	Mechan./Electronic. carb.	Engine room temperature
φ	Gas humidity	<60% -Dewpoint < 30ºC	All syngas engines	No condensation
WetDewT	Wet gas dew point	>15º less than Tgas		Recommended
WetDewT	Wet gas dew point	<278K		Recommended
O_2	Oxygen in gas	<2% vol.	Mechanical carburetion	Readjust carburetion. Problems with thermochemical process
		>±1% vol. carb. point	Electronic carburetion	Continuous methane meter for automatic setting of carburetion
H_2	Hydrogen in gas	<30% of total LHV	All syngas engines	Without rated power
		<40% of total LHV		10% rated power
Ethylene	Double bond hydrocarb.	<12% of total LHV	All syngas engines	Alkenes + alkynes <15% of total LHV
Acetylene	Triple bond hydrocarbons	<5% of total LHV	All syngas engines	Alkenes + alkynes <15% of total LHV
C4+ BTEX	Higher HC +BTEX	<10%of total LHV.	All syngas engines	
H_2S	Hydrogen sulphide equiv.	<70 mg / MJ	W/o catalytic converter	Total sulphur: H_2S equivalent
Cl^-	Chlorine equivalent	<3.5 mg / MJ	W/o catalytic converter	F, Cl, Br, I organic and inorganic
Si	Silicon and siloxanes	<0.2 mg / MJ	W/o catalytic converter	Analyze: TMOH, TMS, L2,L3,L4,D3, D4,D5 In addition <75ppm of Si in engine oil
NH_3	Ammonia	<1.5 mg / MJ	All syngas engines	
Tar	Oils and tar 1 ring 2 rings 3 rings >3 rings	Condensates not allowed <1.500 mg / MJ < 200 mg / MJ < 3 mg / MJ 0 mg / MJ	W/o catalytic converter	Condensable oil vapours CEN/BT/TF143 Standard
Dust	Solid particles	<10 μm	All syngas engines	Larger size not allowed
		<0.3 mg / MJ (1-10 μm)	W/o catalytic converter	

Summary table of syngas specifications