

Engines Exercise : Emissions

Exercise V: Selection of a cogeneration engine

Data:

Consider the following list of engines for integrating a 145 kW cogeneration engine into an industrial process:

Engine model	Cylinder geometry	Engine displacement	Type of fuel	Nominal speed	Effective power	Air mass flow rate	Fuel mass flow rate	NO _x emissions	CO emissions	HC emissions	O ₂ concentration
				1/min	kW	kg/h	kg/h	ppm	ppm	ppm	%
E1-D	4L	6.6 L	Diesel	1500	145.0	698	28.17	965	49	92	9.20
E2-D	4L	7 L	Diesel	1500	145.0	664.3	30.3	487	82	58	7.92
E3-NG	6L	12 L	Natural gas	1500	145.0	839	29.49	66	320	835	9.47
E4-BG	6L	12 L	BIOGAS 22% CO ₂	1500	145.0	810	28.52	71	410	651	9.38
E5-BG	6L	12 L	BIOGAS 35% CO ₂	1500	145.0	757	28.09	75	481	730	8.57

Table 1: Technical data of 5 cogeneration engines of 145 kW effective power.

Remarks:

⇒ We consider the Biogas Fuel as a mix of Natural gas and CO₂. Therefore, the “fuel mass flow rate” value is related only to the Natural gas mass flow rate.

For the computations, you can consider the following values:

Lower heating value of Diesel:	42'915 kJ/kg
Lower heating value of Natural gas:	47'120 kJ/kg
Air / Fuel ratio of Diesel:	14.5
Air / Fuel ratio of Natural gas:	16.2
Natural gas molar mass:	17.53 kg/kmol
Burned gas molar mass:	30.2 kg/kmol
CO ₂ molar mass:	44.0 kg/kmol
CO molar mass:	28.0 kg/kmol
HC molar mass:	13.87 kg/kmol
NO _x molar mass:	46.0 kg/kmol
Universal gas constant:	8314 J/kmolK

Questions:

1. Calculate for each engine the following specific emissions:

- a) NO_x, HC and CO \Rightarrow [g/kWh]
- b) NO_x and CO \Rightarrow [mg/Nm³] at reference conditions = 5% O₂

Remark: For the reference conditions, use the following relation:

$$\bar{c}_i \left(\frac{mg_i}{m_N^3}, O_2 = 5\% \right) = \bar{c}_i \left(\frac{mg_i}{m_N^3}, O_2 = \dot{c}_{O2} \right) \cdot f_{O2} \quad \text{with} \quad f_{O2} = \frac{21-5}{21-\dot{c}_{O2}}$$

2. Explain / comment the results obtained in question (1)

3. Select an engine which satisfies the emission standards for three industrial plants

- a) Industrial plant is located in Switzerland
- b) Industrial plant is located in France
- c) Industrial plant is located in Italy

The emission standards for stationary engines are listed on page 3.

4. In which application field the manufacturer of the two Diesel engines is working?

Emission standards for stationary engines:

Switzerland

Power range	Fuel	NO _x	CO
kW	-	mg/Nm ³ (@ 5% O ₂)	mg/Nm ³ (@ 5% O ₂)
> 100	Biogas WWTP gas (*)	400	650
> 100	other (**)	250	650

(*) WWTP = Waste water treatment plant

(**) Gaseous or liquid fuel

France

Delivered Power	Fuel	NO _x	CO
MWh	-	mg/Nm ³ (@ 5% O ₂)	mg/Nm ³ (@ 5% O ₂)
20 - 100	Liquid	1000	650
	Gaseous	350	650
> 100	Liquid	600	650
	Gaseous	250	650

Italy

Power range	Fuel	NO _x	CO
MW	-	mg/Nm ³ (@ 5% O ₂)	mg/Nm ³ (@ 5% O ₂)
< 3	Diesel engines	4000	650
> 3	Diesel engines	2000	650
all	Gas engines	500	650