Determination of the thermal input power of an engine driven generator

It is not usual to find the thermal input power for an internal combustion engine or engine driven generator on the data-plate or from information supplied by the manufacturer. The following methods may be used to determine this.

Use the method in Annex A where fuel consumption data is available from the engine manufacturer and a fuel of known properties is used. This is the most accurate way of determining the thermal input. If both the Brake Specific Fuel Consumption (BSFC) and the rated mechanical power of the engine are known, these can be used to estimate the thermal input as also described in Annex A. If necessary, rated mechanical power can be estimated from the engine kVA rating, or the rated electrical power, as described below, if this is not given directly.

Where fuel consumption data is not available, or the fuel is of unknown properties (e.g. biogas) use the method in Annex B. This uses an estimate of engine and generator efficiency for both mechanical and electrical power ratings. The efficiency estimates given are conservative and should encourage efforts to determine the fuel consumption. The rated electrical power can be estimated from the engine kVA rating as described below if neither the mechanical or electrical rated power is given directly.

Engines or generator sets may have more than one rating, e.g. continuous power, prime power, and emergency stand-by power. The highest power rating applied in the application should always be used.

The rated power output of an engine in kilowatts (kW) or sometimes horse power (hp) is often provided on the data-plate of the engine or from information from the engine manufacturer and this should be first choice for determining rated power (conversion factors are provided in Annex A). If information on the engine is not available, then there should be information on the rating of the generator on the generator data-plate or information from the generator manufacturer that allows it to be determined.

Generator set ratings are often quoted in kVA at a 0.8 power factor. Where this is the case electrical power is determined by:

$$P_{e(r)} = kVA * 0.8 \qquad \text{(Equation 1)}$$

Where
$P_{e(r)}$ = Rated electrical power (kW)
kVA = kiloVoltAmps rating

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The electrical power must then be converted to mechanical power to take account of generator efficiency, when using the Annex A approach. There is also some power absorbed by ancillaries such as the cooling system, but this is highly variable and therefore ignored for this purpose.

$P_{m(r)} = P_{e(r)}*100/\eta_A$ (Equation 2)

Where
$P_{m(r)}$ = Rated mechanical power (kW)
$P_{e(r)}$ = Rated electrical power (kW)
η_A = Generator efficiency (%)

If the generator efficiency is not known it may be estimated from the following table:

Power Range (mechanical or electrical)		**Generator efficiency (%)**
<1	**MW**	**93**
1-5	**MW**	**94**
>5	**MW***	**95**

* Note that it is unlikely that a Medium Combustion Plant engine would be >than about 20 MW mechanical or electrical power, since at 40% efficiency that would take it to 50 MW thermal input and it would fall under Large Combustion Plant legislations.

Annex A – Determination of thermal input power from fuel consumption or specific fuel consumption, engine rated power and fuel properties

The fuel consumption of an engine is often published by the engine manufacturer. It may be given as a BSFC, gravimetric fuel rate or volumetric fuel rate. Use the fuel consumption at the power rating applied in the application in combination with the lower or net calorific value of the fuel to determine the thermal input.

Typical units would be:

g/kWh	(specific for liquid fuelled engines)
litres/h	(volumetric for liquid fuelled engines)
kg/h	(gravimetric for liquid fuelled engines)
m^3/h	(volumetric for gaseous engines)

This value, combined with the calorific value of the fuel, can be used to obtain the thermal input power. The calorific values of common fuels can be found in the Digest of UK Energy Statistics (DUKES):

https://www.gov.uk/government/statistics/dukes-calorific-values

These are given in the gravimetric parameter of GJ/tonne (same as MJ/kg) for liquid fuels or the volumetric parameter of MJ/m^3 for gaseous fuels. Net values should be used for this calculation. Common fuels would be Gas/diesel oil (42.6 GJ/tonne in 2016) or natural gas consumed (35.7 MJ/m^3 in 2016).

Liquid fuelled engines

When brake specific fuel consumption and rated power are known

$$P_{th} = b_{e(r)} * P_{m(r)} * H_u / 3.6 \quad \text{(Equation 3)}$$

Where

P_{th} = thermal input power (kW)
$b_{e(r)}$ = Brake specific fuel consumption at rated power (kg/kWh)
$P_{m(r)}$ = rated mechanical power (kW)
H_u = Lower heating value of fuel (MJ/kg)

When gravimetric fuel rate is known

$$P_{th} = \dot{m}_K * H_u / 3.6 \quad \text{(Equation 4)}$$

Where
P_{th} = thermal input power (kW)
$\dot{m}_K$ = gravimetric fuel rate (kg/h)
H_u = Lower heating value of fuel

Where volumetric fuel rate is known

The volumetric fuel rate must be converted to a gravimetric rate that can then be used in Equation 4. The density of the test fuel will often be given on the engine data sheet. If not the density of gas/diesel oil, that is usually used for a diesel engine test can be considered to be 0.84 kg/litre

$$\dot{m}_K = \dot{V} * \rho \qquad \text{(Equation 5)}$$

Where $\dot{m}_K$ = gravimetric fuel rate (kg/h)
$\dot{V}$ = Volumetric flow rate (litres/h)
ρ = Density of fuel (kg/litre)

Gaseous fuelled engines

Occasionally the energy input to a gas engine is given directly in kW or more often in Btu's (see conversion factors below).
Fuel consumption is usually measured in m^3/h of gas at standard conditions and this can be directly multiplied by the lower calorific value of the gas

$$P_{th} = \dot{V} * H_g / 3.6 \qquad \text{(Equation 6)}$$

Where

P_{th} = thermal input power (kW)
$\dot{V}$ = Fuel flow rate at rated load (m^3/h)
H_g = Lower heating value of gas (MJ/m^3)

Useful Conversion factors

1 m^3 = 35.31 ft^3

1 kW = 1.341 hp

1 MJ = 947.8 Btu

Annex B – Determination of thermal input power from engine rated power and estimated engine/generator efficiency

Where there is no fuel consumption data available it will be necessary to determine the thermal input power by using the rated power and estimating the effective efficiency of the engine or generating set.

Taking the effective efficiency from the table below, the thermal input power is calculated from the following equation:

$$P_{th} = P_{(r)} * 100 / \eta_e \quad \text{(Equation 7)}$$

Where:
P_{th} = thermal input power
$P_{(r)}$ = rated power (mechanical or electrical, whichever is available)
η_e = effective efficiency (relevant for mechanical or electrical power)

Fuel Type	Combustion type	Power range (mechanical or electrical)		Efficiency (η_e) (%)	
				Based on mechanical power	Based on electrical power
Gas oil or other liquid fuel	Compression ignition	<1	MW	36	33
		1-5	MW	38	35
		>5	MW*	40	38
Natural gas	Stoichiometric (rich) burn	<1	MW	30	28
		1-5	MW	32	30
		>5	MW*	34	32
	Lean Burn	<1	MW	35	33
		1-5	MW	36	34
		>5	MW*	38	36
Bio gas	Stoichiometric (rich) burn	<1	MW	29	27
		1-5	MW	31	29
		>5	MW*	33	31
		20-50	MW	34	33
	Lean Burn	<1	MW	34	32
		1-5	MW	35	33
		>5	MW*	37	35

* Note that it is unlikely that a Medium Combustion Plant engine would be >than about 20 MW mechanical or electrical power since at 40% efficiency that would take it to 50 MW thermal input and it would fall under Large Combustion Plant legislations.

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