

Quick reference Formulae

Temperature – °C or °K

$$^{\circ}\text{C} = \frac{5}{9} (^{\circ}\text{F} - 32)$$

Pressure SI unit – Pascal

1 Pa = 1 N/m², too small a unit

Common unit = Bar

$$1 \text{ Bar} = 10^5 \text{ N/m}^2 = 0.1 \text{ Mpa}$$

Atmospheric Pressure = 1 Bar abs at MSL

Vacuum = 0 Bar abs

Gauge pressure + Atmospheric pressure = Absolute pressure

$$\text{barg} = \text{kg/cm}^2\text{g}$$

Density in kg/m³

Specific Volume = 1 / Density in m³/kg

Specific Gravity = Density ratio to water

Energy SI unit = 1 Joule = 1 Nm = 4.186 cal

Common unit = kilocalorie

1 kcal = heat reqd to raise 1 kg water by 1°C

1 kcal = 4186.8 Joules

Cp = sp. heat capacity in kcal/kg °C

Conversions between SI and other units

mWC = meters water column

1 Bar = 10 mWC

1 Bar = 14.23 PSI (Lbs/in²)

150 psi = 10.54 Kg/cm²g

50 psi = 3.5 Kg/cm²g

$$10 \text{ bar g} = 11 \text{ bar a} = 10.2 \text{ kg/cm}^2\text{g} = 11.2 \text{ kg/cm}^2\text{a} = 145 \text{ psig} = 1 \text{ MPa} = 10^6 \text{ N/m}^2$$

$$\rho = \frac{m}{V} = \frac{1}{V_g}$$

Where

ρ = Density (kg/m³)

m = Mass (kg)

V = Volume (m³)

V_g = Specific volume (m³/kg)

$$\text{Specific gravity} = \frac{\text{Density of substance } \rho_s}{\text{Density of water } \rho_w}$$

Enthalpy of saturated steam:

$$hg = hf + hfg$$

Where:

hg = Total enthalpy or total heat of saturated steam (kJ/kg)

hf = Liquid enthalpy (Sensible heat) (kJ/kg)

hfg = Enthalpy of evaporation (Latent heat) (kJ/kg)

Heat Balance in Process:

$$\text{Primary Q} = m \times h_{fg}$$

Where,

Primary Q = Quantity of heat energy released (in kcals)

m = Mass of steam releasing the heat (in kgs)

h_{fg} = Specific enthalpy of evaporation of steam (in kcals/kg)

$$\text{Secondary Q} = m \times c_p \times \Delta T$$

Where,

Secondary Q = Quantity of heat energy absorbed (in kcals)

m = Mass of the substance absorbing the heat (in kgs)

c_p = Specific heat capacity of the substance (in kcals / kg °C)

ΔT = Temperature rise of the substance (in °C)

$$\text{Primary Q} = \text{Secondary Q}$$

Heat transfer equation:

$$Q = U \times A \times \Delta T$$

Where:

Q = Heat transferred per unit time (kcals/hr)

U = Overall heat transfer coefficient (kcals/hr / m²°C)

A = Heat transfer area (m²)

ΔT = Temperature difference between the primary and secondary fluid (°C)

Steam line sizing:

$$D = 1000 \times \sqrt{\frac{4 \times m \times V}{3600 \times \pi \times c}}$$

Where,

D = Line size in mm

m = Mass flowrate of steam in kg/h

V = Specific volume in m³/kg

π = a constant 3.14

c = velocity m/s

Calculating Savings:

$$\text{Boiler Heat Input} = Q_f \times \text{GCV}$$

where,

Q_f = Quantity of fuel (in kg/hr)

GCV (Gross Calorific Value) = Energy contained in fuel in kcal/kg

$$\text{Boiler Heat Output} = Q_s \times (H_s - H_w)$$

where,

Q_s = Quantity of steam (in kg/hr)

H_s = Heat contained in steam (Enthalpy of Saturated steam hg)

H_w = Heat already present in the water from which steam is raised

$$\text{Boiler } \eta = \frac{Q_s \times (H_s - H_w)}{Q_f \times \text{GCV of fuel}}$$

$$Q_f = \frac{Q_s \times (H_s - H_w)}{\text{GCV} \times \eta} \quad \frac{\text{kg/hr} \times \text{kcal/kg}}{\text{kcal/kg}}$$

$$\text{Cost of solid fuel} = \frac{Q_s \times (H_s - H_w) \times \text{Cost of fuel}}{\text{GCV} \times \eta} \quad \text{kg/hr} \times \text{Rs/kg}$$

$$\text{Cost of FO / gas} = \frac{Q_s \times (H_s - H_w) \times \text{Cost of fuel}}{\text{GCV} \times \eta \times \rho} \quad \text{litres/hr} \times \text{Rs/litre}$$

where,

Q_c = Quantity of condensate (in kg/hr)

H_c = Heat contained in condensate (in kcal/kg)

H_w = Heat already present in the water at ambient temperature (in kcal/kg)

GCV (Gross Calorific Value) = Energy contained in fuel in kcal/kg

η = Boiler efficiency

ρ = Specific gravity of liquid/gas fuel

% Flash steam calculation:

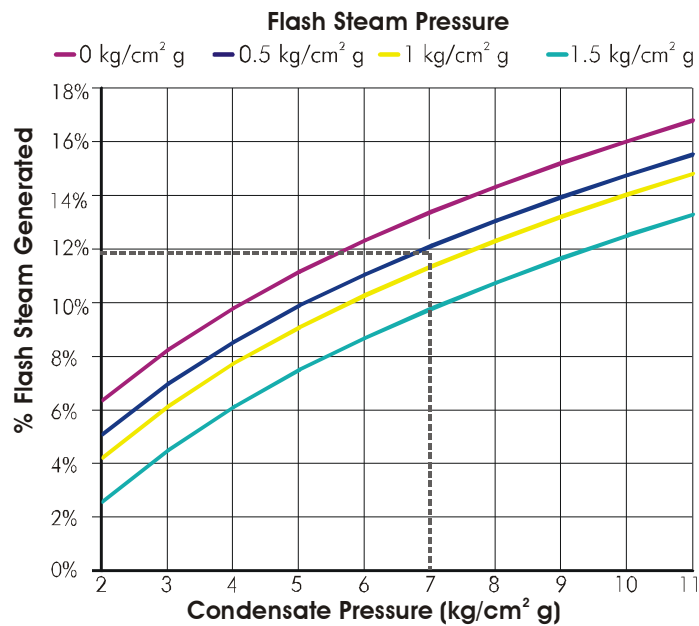
$$\% \text{ Flash steam generated} = \frac{(h_{f1} - h_{f2}) \times 100}{h_{fg2}}$$

Where,

h_{f1} = Enthalpy of water at the higher pressure kcal/kg

h_{f2} = Enthalpy of water at the flashing pressure kcal/kg

h_{fg2} = Enthalpy of evaporation at the flash steam pressure



Actual rating of a Boiler:

$$\text{Actual Rating} = \text{F\&A Rating} \times 540 / (h_g - h_{f_{FW}})$$

where,

h_g = enthalpy of steam at generation pressure

$h_{f_{FW}}$ = Feed water enthalpy

Blowdown:

$$\text{Blowdown (in kgs)} = \frac{F}{B - F} \times S$$

Where,

F = Feedwater TDS in ppm

B = Boiler water set point in ppm

S = Steam generation in kg/hr.

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