Quick reference Formulae

Temperature – °C or °K

°C = $\frac{5}{9}$ (°F - 32)

Pressure SI unit – Pascal

1 Pa = 1 N/m^2, too small a unit
Common unit = Bar
1 Bar =10^5 N/m^2= 0.1 Mpa

Atmospheric Pressure = 1 Bar abs at MSL
Vacuum = 0 Bar abs

Gauge pressure + Atmospheric pressure = Absolute pressure

barg = kg/cm^2g

Density in kg/m^3

Specific Volume = 1 / Density in m^3/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/in^2)
150 psi = 10.54 Kg/cm^2g
50 psi = 3.5 Kg/cm^2g

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

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

Where
ρ= Density(kg/m^3)
m = Mass (kg)
V= Volume (m^3)
v_g= Specific volume (m^3/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)
hfg = Specific enthalpy of evaporation of steam (in kcals/kg)

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

Where,
Secondary Q = Quantity of heat energy absorbed (in kcals)
m = Mass of the substance absorbing the heat (in kgs)
cp = 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 m^3/kg
π = a constant 3.14
c = velocity m/s

Calculating Savings:

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

where,
Qf = Quantity of fuel (in kg/hr)
GCV (Gross Calorific Value) =Energy contained in fuel in kcal/kg

$$\text{Boiler Heat Output} = Qs \times (Hs - Hw)$$

where,
Qs = Quantity of steam (in kg/hr)
Hs = Heat contained in steam (Enthalpy of Saturated steam hg)
Hw = Heat already present in the water from which steam is raised

$$\text{Boiler } \eta = \frac{Qs \times (Hs - Hw)}{Qf \times GCV \text{ of fuel}}$$

$$Qf = \frac{Qs \times (Hs - Hw)}{GCV \times \eta} \qquad \frac{kg/hr \times kcal/kg}{kcal/kg}$$

$$\text{Cost of solid fuel} = \frac{Qs \times (Hs - Hw) \times \text{Cost of fuel}}{GCV \times \eta} \text{ kg/hr x Rs/kg}$$

$$\text{Cost of FO / gas} = \frac{Qs \times (Hs - Hw) \times \text{Cost of fuel}}{GCV \times \eta \times \rho} \text{ litres/hr x Rs/litre}$$

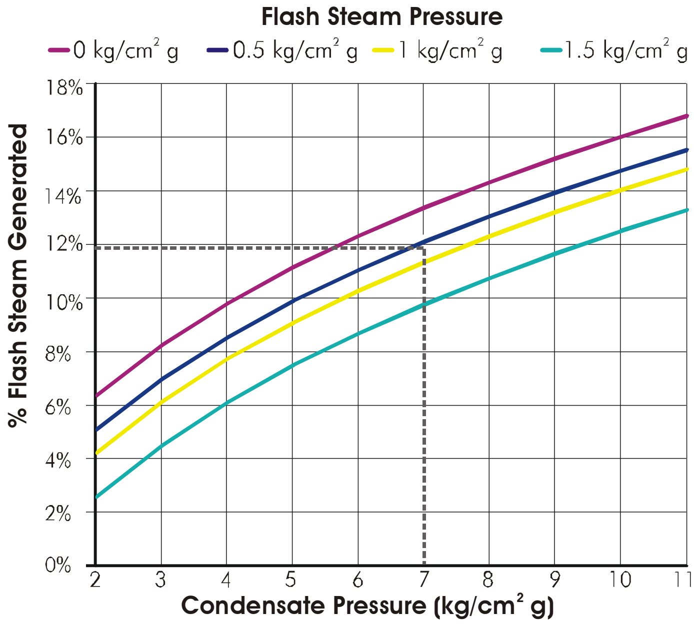
where,
Qc = Quantity of condensate (in kg/hr)
Hc = Heat contained in condensate (in kcal/kg)
Hw = Heat already present in the water at ambient tenmperature (in kcal/kg)

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,
hf1 = Enthalpy of water at the higher pressure kcal/kg
hf2 = Enthalpy of water at the flashing pressure kcal/kg
hfg2 = Enthalpy of evaporation at the flash steam pressure



Actual rating of a Boiler:

$$\text{Actual Rating} = \text{F\&A Rating} \times 540 / (hg - hf_{FW})$$

where,
hg = enthalpy of steam at generation pressure
hf_{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.