PE Reference Guide (Mechanical HVAC & Refrigeration)

www.energy350.com ENERGY350

Properties of Water

Latent Heat of Vaporization = 970 Btu/lb

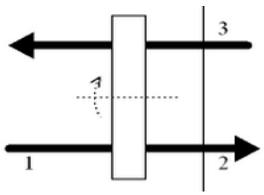
1 lb = 7,000 grains density = 62.4 lb/ft^3

1 gallon = 8.3 lb 1 ft^3 = 7.48 gallons

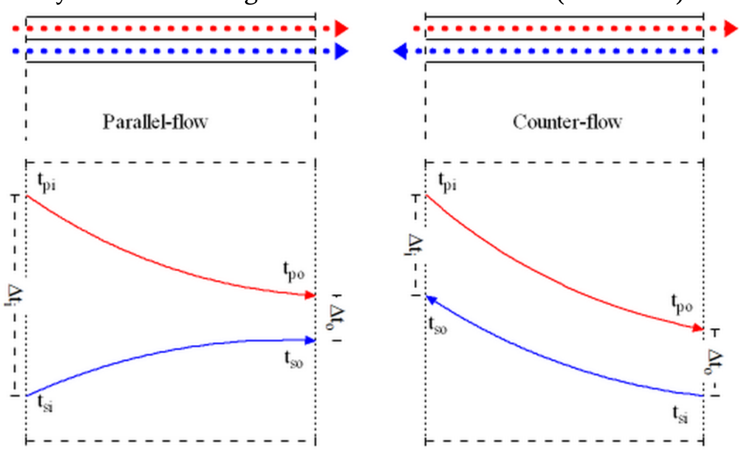
Heat Exchanger Calculations

Heat Wheel Effectiveness Calculation

Efficiency = $(T_2 - T_1) / (T_3 - T_1)$



LMTD – Log Mean Temperature Difference – Will be used in place of ΔT in nearly all heat exchanger calculations. LMTD = (ΔTo - ΔTi) / ln (ΔTo / ΔTi)



Steam

$P_{ABS} = P_{Gauge} + P_{ATM} = P_{Gauge} + 14.7$psi

Compressor COP = $(h_1 – h_4) / (h_2 – h_1)$, where h_1 = entering compressor, h_2 = leaving compressor, h_3 = sat liq leaving condenser, h_4 = entering evap
*If using temp to calculate efficieny, use absolute temp

Quality of Steam (x) = % vapor in saturated steam as a % of the total mass

Thermal Efficiency = $\frac{\text{Work Done (W)}}{\text{Energy In (Qin)}} = \frac{Qin - Qout}{Qin}$ Qin = Work + Wasted Energy

Partial Pressure = P_{SAT} (from steam tables) at given temp * % RH, or find dewpoint from psych chart, then lookup P_{SAT} of that dewpoint in steam tables

Isentropic – Constant Entropy (steam expansion across a PRV is isentropic)
Isentropic Efficiency = $(h_1-h_2')/(h_1-h_2)$
where h_1=entering h, h_2'=exiting h, h_2=ideal exiting h (constant entropy)
$S_{final} = S_f + (x)S_{fg}$ $h_{final} = h_f + (x)h_{fg}$ where x = quality of steam

Fluids

Kinematic Viscosity (ν) = $\mu g/\rho$, where μ=absolute viscosity, g=gravity (32.2 ft/sec^2), ρ=density (62.4 lb/ft^3)

Reynolds Number (R_e) = VD/ν = Dg/μ, where V=Velocity (ft/sec), D=Diameter (ft), ν=Kinematic Viscosity (ft^2/sec)

PV = nRT $\xrightarrow{yields}$ ρ = P/RT $\xrightarrow{yields}$ V = mRT/P $\xrightarrow{yields}$ P = $\rho R_{Specific}T$, where $R_{Specific}$ = specific gas constant and T is in absolute temperature (°R for US, °K for SI)

$$Mach\ \# = \frac{V}{\sqrt{kgRT/MW}}$$ where k=spec heat & T is in °R (k_{Air} = 1.4, R_{Air} = 1545)

Fluids / Pipe Friction / Darcy Equation

$hf = \frac{fLV^2}{2Dg}$ where hf=friction head loss, f=Darcy Friction Factor, L=Length of Pipe (ft), V=Velocity (ft/sec), D=inner Diameter (ft), g=gravity

$\Delta P = f\frac{L}{D}\rho\frac{V^2}{2g}$

Net Positive Suction Head (NPSH) Available = $h_p + h_z – h_{vpa} - h_f$, where h_p=atmospheric pressure, h_z=static pressure, h_{vpa}=vapor pressure, h_f=friction loss

Mechanics/Dynamics/Materials

AISI 1020 -The first digit indicates that this is plain carbon steel.
-the second digit indicates there are no alloying elements
-the last 2 digits indicate that the steel contains approximately 20% carbon

Kinetic Energy (E) = $mv^2/2g_c$ Potential Energy (E) = mgz/g_c where z = elevation

$$mz = \frac{mV^2}{2g} \rightarrow gz = \frac{V^2}{2}$$

Torque = KE/Radians (1 Revolution = 360° = 2π Radians)

Springs

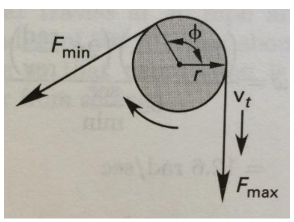
$$K = \frac{d^4 G}{8 D^3 N}$$

d = wire diameter
D = spring diameter
N = number of active coils
G = shear modulus
K = spring constant

F = kX where k=spring const. & X=compression

Stored Energy in a Spring (E_s) = ½ kX^2

If mass m is dropped from height z, $mg(z + x) = \frac{kX^2}{2}$



$$T = (F_{max} - F_{min})r$$

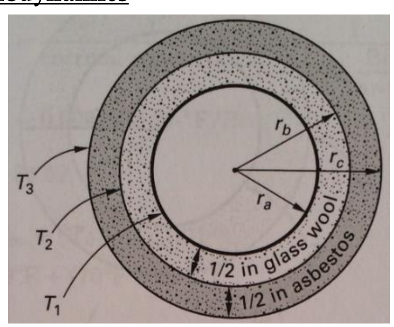
where
T = Torque &
ø is in Radians

$$\frac{F_{max}}{F_{min}} = e^{f\phi}$$

Thermodynamics

Heat Transfer through Pipe

$$\frac{Q}{L} = \frac{2\pi(T_1 - T_3)}{\frac{\ln\frac{r_b}{r_a}}{k_{glass\ wool}} + \frac{\ln\frac{r_c}{r_b}}{k_{asbestos}}}$$



Sensible Heat Ratio (SHR) = ratio of sensible load to total load = slope of the line on a psych chart = $q_s/q_t = q_s/(q_s+q_l)$

Conductive Heat Transfer (Btu/hr) = $UA\Delta T = \frac{A*\Delta T}{R} = \frac{k*A*\Delta T}{L}$

*cooling calcs should use CLTD in place of ΔT to account for solar gain.

Conductive R = L/k where k=conductivity

Convective R = 1/hk where h=convection coefficient $Q = \frac{\Delta T}{Rtotal}$

Thermal Resistance for series construction - $\frac{1}{Rtotal} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \cdots$

Solar Heat Gain = A * SC * SCL = A * SHGF where SC=Shading Coefficient, SCL=Solar Cooling Load Factor, SHGF=Solar Heat Gain Factor
Total heat gain through windows = UAΔT where ΔT is real, not CLTD

Cold Storage Heat Gain from People = 1295 – 11.5*T, where T is in °F

Engineering Economics

Multiply the given by the Formula on the right column.

Factor Name	Converts	Symbol	Formula
Single Payment Compound Amount	to *F* given *P*	(*F*/*P*, *i*%, *n*)	$(1+i)^n$
Single Payment Present Worth	to *P* given *F*	(*P*/*F*, *i*%, *n*)	$(1+i)^{-n}$
Uniform Series Sinking Fund	to *A* given *F*	(*A*/*F*, *i*%, *n*)	$\frac{i}{(1+i)^n - 1}$
Capital Recovery	to *A* given *P*	(*A*/*P*, *i*%, *n*)	$\frac{i(1+i)^n}{(1+i)^n - 1}$
Uniform Series Compound Amount	to *F* given *A*	(*F*/*A*, *i*%, *n*)	$\frac{(1+i)^n - 1}{i}$
Uniform Series Present Worth	to *P* given *A*	(*P*/*A*, *i*%, *n*)	$\frac{(1+i)^n - 1}{i(1+i)^n}$
Uniform Gradient ** Present Worth	to *P* given *G*	(*P*/*G*, *i*%, *n*)	$\frac{(1+i)^n - 1}{i^2(1+i)^n} - \frac{n}{i(1+i)^n}$
Uniform Gradient † Future Worth	to *F* given *G*	(*F*/*G*, *i*%, *n*)	$\frac{(1+i)^n - 1}{i^2} - \frac{n}{i}$
Uniform Gradient ‡ Uniform Series	to *A* given *G*	(*A*/*G*, *i*%, *n*)	$\frac{1}{i} - \frac{n}{(1+i)^n - 1}$

A=Annualized, P=Present Value, F=Final Value, G=Uniform Gradient amount, *i*=interest rate, *n*=time