HVAC ENGINEERING FORMULAS

FORMULAS

AIR FLOW:

CFM = BTUH (SENSIBLE) ÷ (ΔT X 1.08)

CFM = VELOCITY X AREA IN SQ'

MIXED AIR DB = ID DB + [% FA X (OD DB – ID DB)]

COOLING CAPACITY:

BTUH (SENSIBLE) = CFM X ΔT X 1.08 (Also works for HEATING capacity)

BTUH TOTAL = CFM X 4.5 X ΔH (H = Enthalpy)

BTUH LATENT = CFM X .68 X Δ GRAINS PER LB.

BTUH LATENT = OZ. Water X 4101 ÷ 10 Minutes (10 minutes is a minimum sample time)

BTUH = REFRIGERATION EFFECT X LBS OF REFRIGERANT PER MIN X 60

ΔT DB = BTUH (SENSIBLE) ÷ (CFM X 1.08) (Also works for HEATING)

COOLING EFFICIENCY:

EER = BTUH ÷ TOTAL WATTS

TOTAL WATTS = CLOCK METER (SEE ELECTRIC METER)

ELECTRICAL:

COMPRESSOR PHASE BALANCE = AVERAGE VOLTAGE LEG TO LEG COMPARED TO THE HIGHEST LEG MUST NOT EXCEED 2.5%.

COMPRESSOR VOLTAGE TOLERANCE + - 10% (SEE EQUIP. SPECS)

ELECTRIC HEATERS 1Ø

VOLTS X AMPS = WATTS

WATTS X 3.413 = BTUH

ENGINEERING DATA SHEET

AIR HANDLING UNITS

BTU/HR = CFM X ΔT + 10%

$$\text{STEAM: LBS/HR} = \frac{\text{BTU/HR}}{1{,}000}$$

$$\text{WATER: GPM} = \frac{\text{BTU/HR}}{60 \times 8.3 \times \Delta T\ H_2O}$$

FOR ΔT = 20°

$$\text{GPM} = \frac{\text{MBH}}{10}$$

FOR ΔT = 40°

$$\text{GPM} = \frac{\text{MBH}}{20}$$

WATER (COOLING):
1 GPM = APPROX. 5,000
BTU/HR. AT ΔT OF 10°

CONVERTERS

$$\text{LBS/HR} = \frac{\text{GPM X 60 X 8.3 X } \Delta T + 10\%}{1{,}000}$$

$$\text{LBS/HR} = \frac{\text{GPM X } \Delta T + 10\%}{2}$$

VALVE PRESSURE DROPS - ΔP

STEAM: PROPORTIONING
15 PSI OR LESS - 80%
OVER 15 PSI - ABSOLUTE
PRESSURE X .42
TWO POSITION
MINIMUM OF 10%

WATER (TWO WAY): ΔP
ΔT = 60° - 50%
ΔT = 20° - 75%
(SMALL BOOSTER PUMPS - 50%)

TWO POSITION ΔP
LINE SIZE OR 10%

MISCELLANEOUS

STEAM	WATER
1 LB/HR = 4 EDR	1 FT = .43 PSI
1 # EDR = 24O BTU/HR	1 PSI = 2.31 FT

Chapter 3 – Basic HVAC Calculations

- Single-Path Systems – equations for supply air

Supply Air for Cooling:

$$(Q_{sRS1})^S = \frac{(q_{SR1})^S}{C_1(t_R - t_s)} \quad (3\text{-}32)$$

Supply Air for Dehumidification:

$$(Q_{sRL1})^S = \frac{(q_{LR1})^S}{C_2(W_R - W_s)} \quad (3\text{-}33)$$

Supply Air for Heating:

$$(Q_{sRS1})^W = \frac{(q_{SR1})^W}{C_1(t_s - t_R)} \quad (3\text{-}34)$$

FAN LAWS:

Remember RPM is interchangeable for CFM

Note: *new* is the same as **1** and *old* is the same as **2**

Fan Law #1

$$\left(\frac{CFM_{new}}{CFM_{old}}\right) = \left(\frac{RPM_{new}}{RPM_{old}}\right)$$

Formulas for problem solving

$$\textbf{CFM}_{new} = \text{CFM}_{old} \times \left(\frac{RPM_{new}}{RPM_{old}}\right) \qquad \textbf{RPM}_{new} = \text{RPM}_{old} \times \left(\frac{CFM_{new}}{CFM_{old}}\right)$$

Fan Law #2

$$\left(\frac{CFM_{new}}{CFM_{old}}\right)^2 = \frac{SP_{new}}{SP_{old}} \text{ Or } \left(\frac{CFM_{new}}{CFM_{old}}\right) = \sqrt{\frac{SP_{new}}{SP_{old}}}$$

Formulas for problem solving

$$\textbf{CFM}_{new} = \text{CFM}_{old} \times \sqrt{\frac{SP_{new}}{SP_{old}}} \qquad \textbf{SP}_{new} = \left(\frac{CFM_{new}}{CFM_{old}}\right)^2$$

Fan Law #3

$$\left(\frac{CFM_{new}}{CFM_{old}}\right)^3 = \frac{BHP_{new}}{BHP_{old}} \text{ or } \frac{CFM_{new}}{CFM_{old}} = \sqrt[3]{\frac{BHP_{new}}{BHP_{old}}}$$

Formulas for problem solving

$$\textbf{CFM}_{new} = \text{CFM}_{old} \times \sqrt[3]{\frac{BHP_{new}}{BHP_{old}}} \qquad \textbf{BHP}_{new} = \text{BHP}_{old} \times \left(\frac{CFM_{new}}{CFM_{old}}\right)^3$$

ROOM NAME	Design Temp. (Dry Bulb) ° C (° F) ± 2 °C (3.5 ° F)	% Relative Humidity	Pressure Relative to Atmosphere	Air Quality
Offices/Administration/ Mosque building	24 °C (75 °F) summer 22 °C (72 °F) winter	50% ± 5%	+0.05" (12.5 Pa)	ASHRAE 62.1
Conference Rooms or Auditorium	24 °C (75 °F) summer 22 °C (72 °F) winter	50% ± 5%	+0.05" (12.5 Pa)	ASHRAE 62.1
Training/ Waiting Rooms	24 °C (75 °F) summer 22 °C (72 °F) winter	50% ± 5%	+0.05" (12.5 Pa)	ASHRAE 62.1
Lobbies and Corridors	24 °C (75 °F) summer 22 °C (72 °F) winter	50% ± 5%	+0.05" (12.5 Pa)	ASHRAE 62.1
Libraries and Reading Areas	24 °C (75 °F) summer 22 °C (72 °F) winter	50% ± 5%	+0.05" (12.5 Pa)	ASHRAE 62.1
Restrooms and toilets	24 °C (75 °F) summer 22 °C (72 °F) winter	50% ± 5%	Negative pressure to the rest of the building	ASHRAE 62.1
Janitor's Room	26 °C (80 °F) summer 22 °C (72 °F) winter	50% ± 5%	Negative pressure to the rest of the building	Secondary air may be utilized

NATURAL GAS COMBUSTION:

Excess Air = 50%

15 ft.^{3} of air to burn 1 ft.^{3} of methane produces:

16 ft.^{3} of flue gases:

- 1 ft.^{3} of oxygen
- 12 ft.^{3} of nitrogen
- 1 ft.^{3} of carbon dioxide
- 2 ft.^{3} of water vapor

Another 15 ft.^{3} of air is added at the draft hood

GAS PIPING (Sizing - CF/hr.) = $\dfrac{\text{Input BTU's}}{\text{Heating Value}}$

Example: $\dfrac{\text{80,000 Input BTU's}}{\text{1000 (Heating Value per CF of Natural Gas)}}$

Example: $\dfrac{\text{80,000 Input BTU's}}{\text{2550 (Heating Value per CF of Propane)}}$

= 31 CF/hr.

FLAMMABILITY LIMITS	Propane	Butane	Natural Gas
	2.4-9.5	1.9-8.5	4-14

COMBUSTION AIR NEEDED	Propane	Natural Gas
(PC=Perfect Combustion)	23.5 ft.^{3} (PC)	10 ft.^{3} (PC)
(RC=Real Combustion)	36 ft.^{3} (RC)	15 ft.^{3} (RC)
ULTIMATE CO_2	13.7%	11.8%

CALCULATING OIL NOZZLE SIZE (GPH):

$\dfrac{\text{BTU Input}}{\text{140,000 BTU's}}$ = Nozzle Size (GPH)

OR

$\dfrac{\text{BTU Output}}{\text{140,000 X Efficiency of Furnace}}$

FURNACE EFFICIENCY:

% Efficiency = $\dfrac{\text{energy output}}{\text{energy input}}$

OIL BURNER STACK TEMPERATURE (Net) = Highest Stack Temperature minus Room Temperature

Example: 520° Stack Temp. - 70° Room Temp. = Net Stack Temperature of 450°

KELVIN TO CELSIUS: C = K - 273

CELSIUS TO KELVIN: K = C + 273

Typical Air Changes Per Hour Table

Residential	
Basements	3-4
Bedrooms	5-6
Bathrooms	6-7
Family Living Rooms	6-8
Kitchens	7-8
Laundry	8-9
Light Commercial	
Offices	
Business Offices	6-8
Lunch Break Rooms	7-8
Conference Rooms	8-12
Medical Procedure Offices	9-10
Copy Rooms	10-12
Main Computer Rooms	10-14
Smoking Area	13-15
Restaurants	
Dining Area	8-10
Food Staging	10-12
Kitchens	14-18
Bars	15-20
Public Buildings	
Hallways	6-8
Retail Stores	6-10
Foyers	8-10
Churches	8-12
Restrooms	10-12
Auditoriums	12-14
Smoking Rooms	15-20

ELECTRIC HEATER 3Ø

TOTAL WATTS = AVERAGE LEG VOLTAGE X EACH LEG AMPS = WATTS
TOTAL OF EACH LEG WATTS ÷ 1.73

EXAMPLE: AVERAGE VOLTS X AMPS = WATTS
AVERAGE VOLTS X AMPS = WATTS
AVERAGE VOLTS X AMPS = WATTS

WATTS ÷1.73 = TOTAL WATTS

BTUH = TOTAL WATTS X 3.413

ELECTRIC METER:

KW FROM ELECTRIC METER = 20 (DISC REVOLUTIONS) X KH FACTOR X 3.6 ÷ SECONDS

METER TEST = TURN OFF ALL BREAKERS. PLUG 100-WATT LIGHT BULB INTO ONE KNOWN CIRCUIT AND APPLY ABOVE CALCULATION.

GAS:

THERM = 100,000 BTU

- NATURAL GAS IS APROX 1030 BTU PER CUBIC FOOT
- PROPANE IS APROX 2500 BTU PER CUBIC FOOT
- PROPANE HAS APROX 91,500 BTU PER GAL.

INPUT = METER REVOLUTIONS X CU' PER REVOLUTION X 3600 ÷ SECONDS OF REVOLUTIONS X BTU CONTENT PER CU'OF GAS. (AVERAGE BTU CONTENT IS 1000. PIEDMONT NATURAL GAS IN GREENVILLE IS 1038 BTU PER CU')

BTU OUTPUT OF AN APPLIANCE = BTU INPUT X EFF.

REFRIGERANT:

BTUH = (VAPOR ENTHALPY - LIQUID ENTHALPY) X *POUNDS OF REFRIGERANT PER MIN X 60 (*3 lbs. per minute per ton is normal flow rate)

WATER:

BTUH (WATER) = GPM X 500 X ΔT

HP = GPM X HEAD FT ÷ 2800 (THIS IS FOR WATER AND A PUMP EFF. OF 70%)

GPM ON WATER SOURCE UNIT = PRESSURE DROP ACROSS HEAT EXCHANGER COMPARED TO EQUIPMENT DATA (SIMILAR TO STATIC CFM DATA). USE THIS AND ABOVE CALCULATION TO DETERMINE BTU EXCHANGE.

HVAC FORMULAS

TON OF REFRIGERATION - The amount of heat required to melt a ton (2000 lbs.) of ice at 32°F

288,000 BTU/24 hr.
12,000 BTU/hr.

APPROXIMATELY 2 inches in Hg. (mercury) = **1 psi**

WORK = Force (energy exerted) X Distance
Example: A 150 lb. man climbs a flight of stairs 100 ft. high

Work = 150 lb. X 100 ft.
Work = 15,000 ft.-lb.

ONE HORSEPOWER = 33,000 ft.-lb. of work in 1 minute

ONE HORSEPOWER = 746 Watts

CONVERTING KW to BTU:

1 KW = 3413 BTU's
Example: A 20 KW heater (20 KW X 3413 BTU/KW = 68,260 BTU's

CONVERTING BTU to KW:

3413 BTU's = 1 KW
Example: A 100,000 BTU/hr. oil or gas furnace
(100,000 ÷ 3413 = 29.3 KW)

COULOMB = 6.24×10^{18} (1 Coulomb = 1 Amp)

E = voltage (emf)
I = Amperage (current)
R = Resistance (load)

WATTS (POWER) = volts x amps or P = E x I

$$P(\text{in KW}) = \frac{E \times I}{1{,}000}$$

U FACTOR = reciprocal of R factor
Example:

$$\frac{1}{19} R = .05U$$

= BTU's transferred / 1 Sq.Ft. / 1°F / 1 Hour

B HVAC EQUATIONS—U. S. UNITS

TABLE 16-14 Air Equations (U.S.)

a) $V = 1096\sqrt{\frac{V_p}{d}}$

or for standard air (d = 0.075 lb/cu ft):

$V = 4005\sqrt{V_p}$

To solve for "d":

$d = 1.325\frac{P_b}{T}$

V = Velocity (fpm)
V_p = Velocity Pressure (in.w.g.)
d = Density (lb/cu ft)
P_b = Absolute Static Presure (in. Hg) (Barometric pressure + static pressure)
T = Absolute Tempeerature (460° + °F)

b) Q (sens.) = 60 x C_p x d x cfm x Δt

or for standard air (C_p = 0.24 Btu/lb • °F):

Q (sens.) = 1.08 x cfm x Δt

c) Q (lat.) = 4840 x cfm x ΔW (lb.)

Q (lat.) = 0.69 x cfm x ΔW (gr.)

d) Q (total) = 4.5 x cfm x Δh

e) Q = A x U x Δt

f) $R = \frac{1}{U}$

g) $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} = RM$

Q = Heat Flow (Btu/hr)
C_p = Specific Heat (Btu/lb • °F)
d = Density (lb/cu ft)
Δt = Temperature Difference (°F)
ΔW = Humidity Ratio (lb or gr H_2O/lb dry air)
Δh = Enthalp Diff. (Btu/lb dry air)
A = Area of Surface (sq ft)
U = Heat Transfer Coefficient (Btu/sq ft • hr • °F)
R = Sum of Thermal Resistances (sq ft•hr•°F/Btu)
P = Absolute Pressure (lb/sq ft)
V = Total Volume (cu ft)
T = Absolute Temp. (460° + °F = °R)
R = Gas Constant
M = Mass (lb)

h) TP = V_p + SP

i) $V_p = \left(\frac{V}{4005}\right)^2$

j) $V = V_m\left[\frac{d\text{ (other than standard)}}{0.075\text{ (d = std. air)}}\right]$

k) cfm = A x V

l) TP = C x V_p

TP = Total Pressure (in.w.g.)
V_p = Velocity Pressure (in.w.g.)
SP = Static Pressure (in.w.g.)
V = Velocity (fpm)
V_m = Measured Velocity (fpm)
d = Density (lb/cu ft)
A = Area of duct cross section (sq ft)
C = Duct Fitting Loss Coefficient

SENSIBLE HEAT FORMULA (Furnaces):

BTU/hr. - Specific Heat X Specific Density X 60 min./hr. = X CFM X ΔT

.24 X .075 X 60 X CFM X ΔT = 1.08 X CFM X ΔT

ENTHALPHY = Sensible heat and Latent heat

TOTAL HEAT FORMULA
(for cooling, humidifying or dehumidifying)

BTU/hr. = Specific Density X 60 min./hr. X CFM X ΔH

= 0.75 x 60 x CFM x ΔH

= 4.5 x CFM x ΔH

RELATIVE HUMIDITY = $\frac{\text{Moisture present}}{\text{Moisture air can hold}}$

SPECIFIC HUMIDITY = grains of moisture per dry air

7000 GRAINS in 1 lb. of water

DEW POINT = when wet bulb equals dry bulb

TOTAL PRESSURE (Ductwork) = Static Pressure plus Velocity Pressure

CFM = Area (sq. ft.) X Velocity (ft. min.)

HOW TO CALCULATE AREA

Rectangular Duct	Round Duct
A = L x W	$A = \frac{\pi D^2}{4}$ OR πr^2

RETURN AIR GRILLES - Net free area = about 75%

3 PHASE VOLTAGE UNBALANCE =

$$\frac{100 \times \text{maximum deg. from average volts}}{\text{Average Volts}}$$

NET OIL PRESSURE = Gross Oil Pressure - Suction Pressure