Duct Calculations

To Determine Approximate Cross Sectional Area

To determine the approximate cross section area of a hidden or inaccessible rectangular duct first determines cfm airflow and air velocity through the duct. Then substitute in the following equation to determine approximate area in square feet.

$$\text{Area, sq. ft.} = \frac{\text{Cfm}}{\text{Velocity}}$$

(Equation No. 11)

Multiply the answer by 144 to reduce to square inches of area. To find approximate dimension determine the square root of the area in inches, or compare with known dimensions on a duct size table of slide chart. The equivalent round duct size may also be determined by the same process.

To Determine Air Velocity In a Duct

Velocity in a duct may be found by solving:

$$\text{Velocity} = \frac{\text{Cfm}}{\text{Area in feet}}$$

(Equation No. 12)

Example: cfm = 1200, area = 1.33 sq. ft.

$$\text{then: Velocity} = \frac{1200}{1.33} = 902 \text{ fpm}$$

To Determine Approximate CFM

If velocity and area in feet are known, approximate cfm may be determined by:
Cfm = Velocity x area in square feet
Thus: Velocity = 902 fpm; area = 1.33 sq. ft.
Cfm = 902 x 1.33 = 1197

To Determine Friction in a Duct Section

When cfm, velocity, and duct cross section area are known, duct friction per 100 feet may be found by referring to duct friction tables (Guide) or other charts.
Friction per 100 ft of duct length may be reduced to the friction of the actual length of duct section by the following equation:

$$\text{Duct friction} = \frac{\text{Length of duct section in feet}}{100} \times \text{(Friction loss per 100 ft. of duct)}$$

(Equation No. 13)

Example: 12 ft. of 12 x 24 in. duct at 0.1 inch friction per 100 ft.

$$\text{Friction in inches} = \frac{12}{100} \times 0.1 = 0.12 \times 0.1 = 0.012$$ inches of water gage for a 12 ft. length.

To Determine Air Changes

To determine number of air changes per hour within a given space and at a fixed air quantity, use the equation:

$$\text{Number of air changes (N)} = \frac{60 \times \text{cfm}}{\text{Space volume in cu. ft.}}$$

(Equation No. 14)

Example: 9600 cu. ft. ,1200 cfm

$$N = \frac{60 \times 1200}{9600} = 7.5 \text{ changes per hour}$$

Air quantity may be determined by equation (15) when space volume in cu. ft. and desired air changes per hour are known:

$$\text{Cfm} = \frac{\text{Number of air changes x cubic volume}}{60}$$

(Equation No. 15)

Example:

$$\text{Cfm} = \frac{7.5 \times 9600}{60} = \frac{72{,}000}{60} = 1200$$

Fan Laws

There are several laws or rules, which govern the overall operation of a fan or blower used in heating and cooling units.

One of these, the first, is more important than the others. Therefore, due to space limitations only that one will be explained. It is:

For constant air density operation:
(a) Air quantity (cfm) varies as the speed of the fan varies.
(b) Static pressure varies as square $(\ )^2$ of fan speed.
(c) Power varies as cube $(\ )^3$ of fan speed.
Given as Example:
A certain fan delivers 1200 cfm at a static pressure of 0.5 inch of water when operating at a speed of 725 rpm and requires a 1/3 hp motor. If the fan speed is to be increased to deliver 1500 cfm what will be the speed, static pressure, and horsepower?

To Determine Fan Speed

$$\text{Speed} = 725 \times \frac{1500}{1200} = 725 \times 1.25 = 906 \text{ rpm}$$

(Equation No. 16)

To Determine Static Pressure

$$\text{Static pressure} = 0.5 \times \left\{\frac{906}{725}\right\}^2 = 0.5 \times (1.25 \times 1.25) = 0.78 \text{ inch water gage.}$$

(Equation No. 17)

To Determine Motor Horsepower

$$\text{Horsepower} - 0.33 \times \left\{\frac{906}{725}\right\}^3 = 0.33\,(1.25 \times 1.25 \times 1.25) = 0.64 \text{ hp or a 2/3 hp motor}$$

(Equation No. 18)

Example – Requirement Changed
Now, suppose the speed of the same fan is to be decreased to deliver 1000 cfm. What will be the overall operating conditions?

To Determine New Fan Speed

$$\text{Speed} = 725 \times \frac{1000}{1200} = 725 \times 0.833 = 604 \text{ rpm}$$

To Determine New Static Pressure

$$\text{Static pressure} = 0.5 \times \left\{\frac{604}{725}\right\}^2 = 0.5\,(0.833 \times 0.833) = 0.35 \text{ inch water gage.}$$

To Determine New Motor Horsepower

$$\text{Horse Power} = 0.33 \times \left\{\frac{604}{725}\right\}^3 = 0.33\,(0.833 \times 0.833 \times 0.833) = 0.19 \text{ hp or a 1/4 hp motor.}$$

To Determine True Electric Heat at other than Nominal Voltages:

$$W_2 = W_1 \left\{\frac{V_2}{V_1}\right\}^2$$

where: W_2 = kw @ actual voltage
V_2 = actual voltage
V_1 = nominal voltage
W_1 = nominal kw

Example:

$$W_2 = 40 \left\{\frac{208}{240}\right\}^2 = 40\,(.752) = 30 \text{ kw}$$

(Equation No. 19)

SIMPLIFIED HEATING-COOLING FORMULAS

To Determine Cooling Air CFM

The approximate total cfm of air required to do a specific cooling job may be calculated by:

$$\text{Total cfm} = \frac{\text{Space total sensible heat gain}}{1.08 \times (tl - t2)}$$

or: *(Equation No. 1)*

$$Qt = \frac{Hs}{1.08 \times (tl - t2)}$$

(Note: Qt = total cfm; Hs = total sensible heat gain)

Do not use total sensible and latent heat gain. The factor 1.08 is derived in a formula shortening process and is accurate within 1% for all cooling and heating calculation.

For cooling *tl – t2* is commonly called the temperature difference or the temperature drop across the coil, *t1* being the temperature of the air entering the coil and *t2* the temperature of the air leaving the coil. For heating, this becomes *t2 – t1* and is called the temperature rise.

To Determine Sensible Heat

To determine sensible heat when cfm and temperature difference are known; simply re-arrange equation (1) as follows:

$$Hs = Cfm \times 1.08\ (tl - t2)$$ *(Equation No. 2)*

To Determine Approximate Temperature Difference

To determine approximate temperature difference (t1 – t2) when heat sensible and total cfm are known, re-arrange equation (1), thus:

$$(t1 - t2) = \frac{Hs}{1.08 \times qt}$$

(Equation No. 3)

To Determine Room CFM Required

Room cfm may be determined by one of several different methods. If unit air delivery is loosely fixed, as is usually the case with packaged units, you may use equation (4a) or (4b):

$$\text{(a) Room cfm} = \frac{\text{Room vol cu. ft.}}{\text{total vol cu. ft.}} \times \text{total cfm}$$

(Equation No. 4a)

Example: Room volume = 1100 cu ft.; total volume = 9600 cu ft.; total cfm – 1200:

$$\text{Room cfm} = \frac{1100}{9600} \times 1200 = 0.114 \times 1200 = 137$$

$$\text{(b) Room cfm} = \frac{\text{Room sensible gain}}{\text{Total sensible gain}} \times \text{total cfm}$$

(Equation No. 4b)

Example: Room sensible gain = 3250 Btuh, total sensible gain = 28,000 Btuh; total cfm = 1200:

$$\text{Room cfm} = \frac{3250}{28{,}000} \times 1200 = 139$$

When unit cfm delivery may be varied as desired, the following equation may be used:

$$\text{Room cfm} = \frac{\text{Room sensible gain}}{1.08 \times (tl - t2)}$$

(Equation No. 5)

Example: Room sensible 3250; (t1 – t2) = 80 – 58 = 22)

$$\text{Room cfm} = \frac{3250}{1.08 \times 22} = \frac{3250}{23.70} = 137$$

It is apparent that either equation may be used since the difference between results is negligible.

To Determine Heating Air CFM

To determine total cfm for heating, equation (1) is changed to:

$$\text{Heating cfm} = \frac{\text{Total heat loss}}{1.08 \times (t2 - t1)}$$

(Equation No. 6)

For heating *t2* is the desired furnace leaving air temperature and *t1* may be the design indoor temperature. Thus: Desired leaving air temperature = 165 deg.; design indoor temperature = 75 deg. Then: (t2 – t1 = 165 – 75 = 90 deg. House heat loss = 96,000 Btuh. Then:

$$\text{CFM} = \frac{96{,}000}{1.08 \times 90} = \frac{96{,}000}{97.2} = 988$$

To Determine Total Furnace Capacity

If cfm and temperature rise (t2 – t1) is measured or otherwise known, the approximate Btuh capacity of a furnace may be determined by:

Btuh capacity = cfm x 1.08 x temperature rise.

Thus, as in example (6): *(Equation No. 7)*

Btuh capacity = 987.7 x 1.08 x 90 = 96004 or 96,000.

When measuring furnace leaving air temperature insert the thermometer far enough down stream to prevent a false or excessively high reading due to heat exchanger radiation. Measure the actual temperature of the air as it enters the supply trunk duct. Measure entering air temperature at the return inlet at the furnace.

To Determine Approximate Temperature Rise

Required approximate temperature rise may be determined if cfm and total heat loss are know:

$$\text{Temp rise } (t2 - t1) = \frac{\text{Total heat loss}}{1.08 \times \text{cfm}}$$

(Equation No. 8)

Example: Heat loss = 96,000 Btuh; cfm – 986.

$$\text{Temp rise } (t2 - t1) = \frac{96{,}000}{1.08 \times 986} = 90.3$$

To Determine Room CFM Required

The total cfm for heating may be apportioned to individual spaces by use of equation (4a) as is, or in (4b) by substituting Loss for Gain above and below the division line. By re-arrangement of equation (6) a third proportioning equation is available. Thus:

$$\text{Room cfm} = \frac{\text{Room heat loss}}{1.08 \times (t2 - t1)}$$

(Equation No. 9)

$$\text{Example: Room cfm} = \frac{8150}{1.08 \times (165-75)} = \frac{8150}{97.2} = 84$$

Heating Load Estimate Variations

If, after the heat loss or gain estimate has been made, it becomes necessary to determine the load at any other set of design temperatures the following equations may be used instead of a complete re-calculation.

Rule: To determine the heat loss or gain at a smaller or greater design temperature difference, multiply the known heat load by the ratio of the know to desired or new temperature difference.

For *decreasing* or *increasing* temperature difference:

$$\text{New heat load} = \text{Known heat load} \times \frac{\text{New temp difference}}{\text{Known temp difference}}$$

(Equation No. 10)

Example: (a) Known heat loss = 96,000 Btuh; known temperature difference 75° indoor, 0° outdoor = 75°; new difference 75° indoor, 15° outdoor = 60° *decreasing* difference:

$$\text{New heat loss} = 96{,}000 \times \frac{60}{75} = 96{,}000 \times 0.80 = 76{,}800 \text{ Btuh}$$

(b) As above but new temperature difference is 75° indoor, minus 5° outdoor = 80° *increasing* difference:

$$\text{New heat loss} = 96{,}000 \times \frac{80}{75} = 96{,}000 \times 1.066 = 102{,}336 \text{ Btuh}$$

(Any temperature design point below zero must be added to the indoor design temperature to obtain total temperature difference.)

PRACTICAL FORMULA FOR HEATING AND COOLING CALCULATIONS		
EQUATION NO.		USE
1	Total cfm = $\frac{\text{Space sensible heat gain}}{1.08 \times (tl - t2)}$	Cooling only
2	Hs = cfm x 1.08 x (t1 – t2)	Cooling only Hs = Heat Sensible
3	(t1 – t2) = $\frac{\text{Hs}}{1.08 \times \text{qt}}$	Cooling only Qt = total air quantity
4a	Room cfm = $\frac{\text{Room volume in cu. ft.}}{\text{Total volume in cu. ft.}}$ x total cfm	Heating or cooling
4b	Room cfm = $\frac{\text{Room sensible gain}}{\text{Total sensible gain}}$ x total cfm	Cooling only
5	Room cfm = $\frac{\text{Room sensible gain}}{1.08 \times (t1 - t2)}$	Cooling only
6	Heating cfm = $\frac{\text{Total heat loss}}{1.08 \times (t2 - t1)}$	Heating
7	Btuh capacity = cfm x 1.08 x (t2 – t1)	Heating and cooling Substitute (t1 – t2) for cooling
8	Temp rise (t2 – t1) = $\frac{\text{Total heat loss}}{1.08 \times \text{cfm}}$	Heating
9	Room cfm = $\frac{\text{Room heat loss}}{1.08 \times (t2 - t1)}$ (or equation 4a or 4b)	Heating
10	New heat load = Known heat load x $\frac{\text{new temperature difference}}{\text{known temp difference}}$	Heating or cooling
11	Duct area, sq. ft.= $\frac{\text{cfm}}{\text{velocity}}$	Heating, cooling, ventilation
12	Duct area velocity = $\frac{\text{cfm}}{\text{duct area in feet}}$	Heating, cooling, ventilation
13	Duct friction = $\frac{\text{Length of duct section in feet}}{100}$ x (friction loss per 100 ft. of duct)	Heating, cooling, ventilation
14	Number of air changes per hour (N) = $\frac{60 \times \text{cfm}}{\text{Space volume in cu. ft.}}$	Ventilation
15	Ventilation cfm = $\frac{\text{Number of air changes per hour}}{60 \times \text{cubic volume}}$	Ventilation
16	Fan Speed = Old Speed x $\frac{\text{new air quantity}}{\text{old air quantity}}$	Heating, cooling, ventilation
17	Static pressure = Existing static x $\left(\frac{\text{new speed}}{\text{old speed}}\right)^2$	Heating, cooling, ventilation
18	Horsepower = Present horsepower x $\left(\frac{\text{new speed}}{\text{old speed}}\right)^3$	Heating, cooling, ventilation
19	True electric heat = nominal kw x $\left(\frac{\text{actual voltage}}{\text{nominal voltage}}\right)^2$	Heating

carrier says @ 400 cfm
ΔWB S/B 9°

cfm = velocity x area

velocity = $\frac{cfm}{Area}$

TOTAL HEAT

$H_t = 4.5 \times CFM \times \Delta h$ (CHANGE IN HEAT CONTENT)

$CFM = \frac{H_t}{4.5 \times \Delta h}$

$\Delta h = \frac{H_t}{4.5 \times CFM}$

SENSIBLE HEAT

$H_s = 1.08 \times CFM \times \Delta t$ (CHANGE IN DB TEMPERATURE)

$CFM = \frac{H_s}{1.08 \times \Delta t}$

$\Delta t = \frac{H_s}{1.08 \times CFM}$

LATENT HEAT

$H_L = .68 \times CFM \times \Delta w$ (CHANGE IN GRAINS OF WATER)

$CFM = \frac{H_L}{.68 \times \Delta w}$

$\Delta w = \frac{H_L}{.68 \times CFM}$

MIXED AIR DB = INDOOR DB + (% FRESH AIR) x (OUTDOOR DB MINUS INDOOR DB)

% FRESH AIR = $\frac{\text{MIXED AIR DB — INDOOR DB}}{\text{OUTDOOR DB — INDOOR DB}}$

$\frac{\text{Rated volts} \times \text{Rated amps}}{\text{Actual volts}}$ = ampdraw (s/B)

$\Delta_T = \frac{BTUH}{GPM \times 500}$

$GPM = \frac{BTUH}{\Delta_T \times 500}$

$BTUH = GPM \times \Delta_T \times 500$

% of FRESH AIR

% of Fresh Air = $\frac{\Delta t \text{ between mixed air D.B. \& return air D.B.}}{(\Delta t \text{ between fresh air D.B. \& return air D.B.})}$

example: 50° Fresh air, 75 return air, 70 mixed air
5 / 25 = 20%

Mix Air Dry Bulb

Cooling

Mixed air D.B. = Return air D.B. + [% of Fresh Air X (Δt between fresh air D.B. & return air D.B.)]

example: 100° Fresh air, 75° return air, 15% fresh air <u>desired</u>
100° - 75° = 25°; .15 X 25° = 3.75 75 + 3.75 = 79° Mixed air temp

Heating

Mixed air D.B. = Return air D.B. - [% of Fresh Air X (Δt between fresh air D.B. & return air D.B.)]

example: 50° Fresh air, 75° return air, 15% fresh air <u>desired</u>
50° - 75° = 25°; .15 X 25° = 3.75 75 - 3.75 = 71° Mixed air temp

$BTUH = \Delta_H \times 4.5 \times cfm$