CHAPTER 11 HEATING - HYDRONIC SYSTEM SIZING

11.3 Chimney System Design

Chimney System Sizing

A chimney must be designed properly to control draft and remove the gases produced by combustion in a boiler, furnace or fireplace. Draft is negative gauge pressure measured relative to atmospheric pressure. Chimney design balances buoyancy forces against friction losses.

Draft is produced by natural convection of hot flue gas through the chimney; this may be enhanced in some cases with draft chimney fans.

An appliance may require draft applied at the flue gas outlet to draw air into the combustion chamber. Another type of appliance with a draft hood does not require a draft at the combustion chamber outlet and the combustion process is isolated from chimney draft variations. A third type of appliance may produce a positive pressure at its outlet.

Theoretical draft D_t is the draft due to buoyancy of the hot flue gases. This is a function of chimney height and mean gas temperature difference. **Available draft Da** is the draft needed at the appliance outlet. If the height of the chimney is too high or the flue gas temperature is greater than anticipated there will be surplus available draft and **draft control** may be required.

The draft required to overcome chimney flow resistance is equal to the difference between theoretical draft and available draft.

$$\Delta p = D_t - Da$$

Flue gas velocity in a chimney is usually in the range 1.5 to 15 m/s. A cone is required at the top to increase velocity and achieve effluent dispersal.

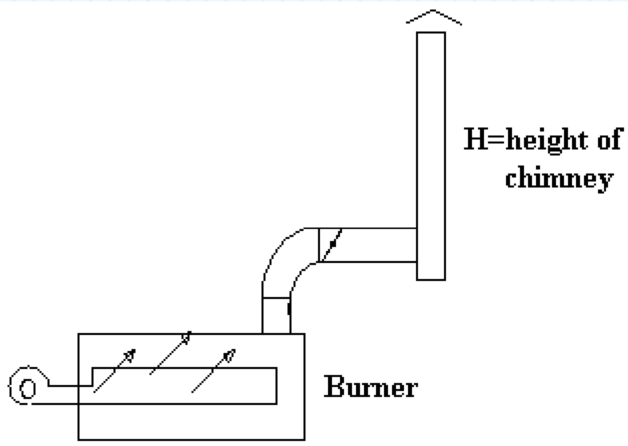
During analysis of a chimney system one must first determine the mass flow ratio of flue gases per kg of fuel burned. Then, the theoretical draft should be determined (depends on buoyancy force) which is a function of chimney height and flue gas temperature. Based on an assumed diameter, the flow velocity is then determined as well as the flow pressure drop. The difference between theoretical draft and flow pressure drop is the available draft.

Example: Chimney Design

Consider the analysis of a chimney system for an oil-fired 30 kW boiler (using No. 2 oil). Assume mean chimney gas temperature equal to 220 degC and an ambient temperature of 0 degC.

(For properties and theory see ASHRAE 1996)

$CO2 := 9$ %CO2 in flue gases for no. 2 oil



First determine the mass flow ratio (kg flue gases/ MJ fuel burned) M which depends on fuel type and % CO2:

$M := 0.31 \cdot \left(.12 + \frac{14.4}{CO2}\right)$ $M = 0.5332$ kg/MJ

$I := 30$ kW input of boiler/furnace

$w := I \cdot \frac{M}{1000}$ g/s mass flow rate of fuel $w = 0.015996$

$B := 101000$ atmospheric pressure, Pa

$T_m := 273 + 220$ mean chimney gas temperature (K) $To := 273$ ambient T

First, we may assume a chimney height and then check it:

$H := 6$ assumed chimney flue height, meters

The following equation for theoretical draft does not consider cooling of flue gases during flow through the chimney; this process will reduce Tm and Dt. The theoretical draft is the difference in weight between the warm light air in the chimney and an equal column of ambient air (buoyancy):

$D_t := 0.03413 \cdot B \cdot H \cdot \left(\frac{1}{To} - \frac{1}{T_m}\right)$ $D_t = 33.808198$ theoretical draft

$\rho := 0.00348 \cdot \frac{B}{T_m}$ density of flue gases kg/m³ $\rho = 0.712941$

Assume a flue diameter and then check velocity:

$d_i := 120$ chimney diameter (mm)

Assuming one 90 degree elbow (k=0.75) , one Tee (1.25) and an exit cone (k=1), we determine the total k-value (dimensionless system resistance coefficient) as follows:

$k := 0.75 + 1.25 + 1.0 + 0.033 \cdot H \cdot \frac{1000}{d_i}$

$k = 4.65$ dimensionless system resistance coefficient of chimney

(the last term above is the coefficient accounting for friction losses in the straight duct)

$V := \frac{I \cdot M \cdot 4 \cdot 1000}{{d_i}^2 \cdot \rho \cdot \pi}$ $V = 1.983834$ velocity of flue gases m/s (1.5-15 recommended range)

$\Delta p := \frac{k \cdot \rho \cdot V^2}{2}$ $\Delta p = 6.5236$ pressure drop in chimney & fittings (Pa)

$Da := D_t - \Delta p$ $Da = 27.284599$ available draft (Pa)

Most boilers require about 20 Pa draft at their outlet. Therefore, the above design is acceptable.

References

ASHRAE, 1996, Handbook- Systems and Equipment, Atlanta, GA.