Student
Study
Section

Flue Sizing Options

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Conventional or Open Flues

Most boilers including some small commercial sizes have fanned flues and are sold with their own flue packs. But there are still many boilers, including some small commercial sizes that require a conventional flue, sometimes known as an open flue, and it is important that this type of flue arrangement is correctly sized.

To help understand the required procedure, lets take a look at the following example, that is based on a naturally aspirated boiler with an output of 99.6KW (340,000 btu/hr). The boiler is 80% efficient and therefore the heat input is 124.5KW. The boiler burns Natural Gas.

The first step is to calculate the gas rate and to do this we need to know the Calorific Value of Natural Gas. The C.V. is the number of heat units which can be obtained from a measured volume of gas and is expressed in joules per cubic metre. For this example we will use 38.7MJ/m3. We also need to know the number of seconds in one hour (3600) and the number of litres in a cubic metre (1000).

Therefore;

$$\frac{124.5}{38.7} = 3.217054264 \text{ litres/second}$$

$$\frac{3.217054264 \times 3600}{1000} = 11.58 \text{ m}^3\text{/hr (gas rate)}$$

The second step is to calculate the flue gas volume (products of combustion). The formula for this is as follows:

$$(\% \; CO_2 + 2) \times \text{gas rate} \times \frac{(\text{Absolute °C} + \text{Flue gas °C})}{(\text{Absolute °C} + \text{Ambient °C})}$$

This boiler is fitted with a draught divertor, so the CO_2 content measured in the flue will be 4.5%. The Absolute temperature is 273°C, the flue gas temperature is 100°C and the ambient is 15°C.

Therefore;

$$\left(\frac{100}{4.5} + 2\right) \times 11.58 \times \frac{(273 + 100)}{(273 + 15)} = 363.3 \text{ m}^3\text{/hr}$$

This calculation shows us that a naturally aspirated, conventional flued boiler that burns 11.58 m³/hr of Natural Gas will produce 363.3 m³/hr of flue gasses. It is therefore essential to correctly size the flue pipe to safely evacuate this large volume.

The third step is to calculate the diameter of the flue pipe. It is important to understand that wrongly directed airflow can, and often does, give us high CO readings. Air passing a gas injector at the wrong speed can alter the parameters of combustion. Therefore flue gas velocities (speed) must be limited to allow safe airflow around injectors/burners.
To avoid any problems it is recommended that the velocity of the flue products on a conventional flue should be kept below 3.5 m/second.

The formula is as follows:

$$\frac{\text{Flue gas volume (m}^3\text{/second)}}{\text{Velocity (m}^3\text{/second)}} = \text{m}^2 \text{ (area)}$$

Area x 1,000,000 (mm) divided by 3.142 = radius^2

Square root of radius^2 x 2 = diameter (mm)

Therefore;

$$\frac{0.1009166}{3.5} = 0.0288 \text{ m}^2$$

$$\frac{0.0288 \times 1{,}000{,}000}{3.142} = 9166$$

$$\sqrt{9166} \times 2 = 191\text{mm}$$

This size is not available and is between a 178mm (7") and 203mm (8"). We would therefore use a flue size of 203mm. We can check the velocity using this flue size and the formula is as follows:

$$\frac{\text{Flue gas volume}}{\text{m}^2} = \text{velocity}$$

Therefore;

$$\frac{0.1009166}{0.0324} = 3.11 \text{ m/second}$$

The velocity is acceptable, therefore the chosen flue is 203mm.

The fourth step is to determine the minimum height of the flue. Assume that the boiler is situated on a rooftop with no adjacent buildings and the flue is straight with no bends. The formula is as follows:

$6 \times MW^{0.6}$ (input) + bends + discharge loss

Therefore;

$$6 \times (0.1245)^{0.6} + 0 + 1$$

$$6 \times 0.2865 + 1 = 2.72 \text{ mtrs}$$

These simple calculations show us that a naturally aspirated/conventional flued boiler with an input of 124.5KW requires a flue size of 203mm and a minimum height of 2.72m.

Induced Draught

This is a conventional flue that is fitted with a fan (an air pressure switch is also fitted to check the fan). The recommended velocity should be between 6-7.5 m/second.

We will use the same boiler as above as most of the calculations have already been done.

Gas rate – 11.58m³/hr

Flue gas volume – 363.3 m³/hr

The flue size (diameter) formula is the same, but the velocity is different.

$$\text{Flue size} = \frac{\text{Flue gas volume (m}^3\text{/sec)}}{\text{Velocity}} = \text{Area m}^2$$

$$\text{Flue size} = \frac{0.1009166}{7.5} = 0.0135 \text{ m}^2$$

This flue size is between 127mm (5") and 152mm (6").

Using the 152mm (0.0182 m²) shows us that the velocity is as follows:

$$\frac{0.1009166}{0.0135} = 7.47\text{m/sec}$$

This flue size is therefore acceptable.

Fan diluted flue system

There are some situations were it is not acceptable to install a conventional flue system (usually architectural reasons). In these situations it is possible to exit the products at low level. To do this the products must be diluted so that they will not cause any harm to people or property. The products must exit at a temperature of 50°C (or lower) and the CO_2 must be diluted down to 1% of the total volume. The velocity for this type of system should be between 6-7m/sec.

It would be extraordinary to have a fan diluted system on an individual boiler (due to the cost) so we will calculate a flue system utilising four of the above boilers.

The formula is as follows:

$$(9.7 \times \text{KW/hr input}) \times \frac{(\text{Absolute °C} + \text{Flue gas °C})}{(\text{Absolute °C} + \text{Ambient °C})}$$

Therefore;

$$(9.7 \times 498) \times \frac{(273 + 50)}{(273 + 15)}$$

$$4830.6 \times 1.121527778 = 5417.65\ m^3/hr = 1.5049027\ m^3/second$$

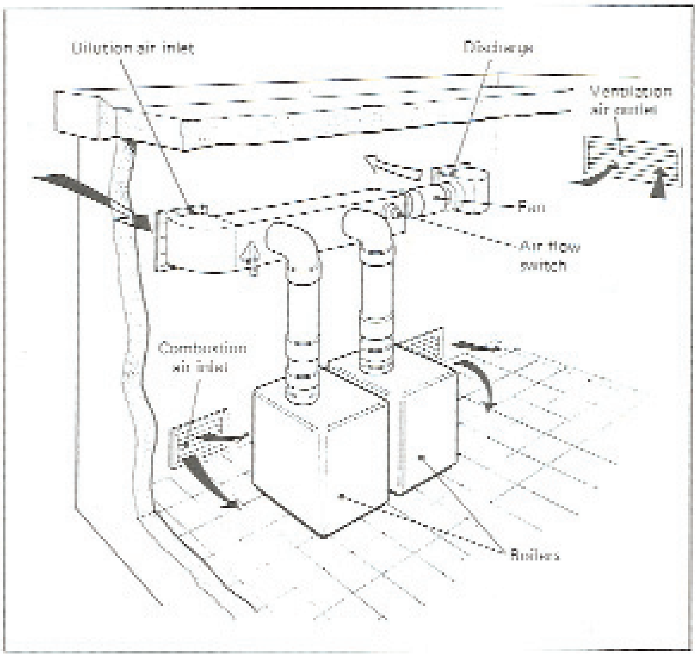
$$\frac{1.5049027}{6} = 0.25m^2$$

This would allow us to use a square duct of 495mm, or a round duct of 559mm. Using these sizes would give a velocity of 6.14m/second.

High Efficiency Boilers

High Efficiency boilers (condensing boilers) are becoming the norm in both the domestic and commercial/industrial sectors. It is important to recognise that these boilers have different flue gas characteristics. The CO_2 will generally be higher as the fan/burner arrangements do not permit excess air in the combustion process. The steam in the flue gasses will be at a lower temperature and therefore the flue gasses will be heavily saturated and will not be as buoyant, in fact most of the steam will have condensed into a liquid (dependant on boiler temperatures).

It is important that fan diluted systems are not utilised on condensing boilers as the calculation for this type of flue assumes that the flue gasses are 150°C. Diluting the products with cold fresh air will mean excessive pluming exiting the flue and excessive condense lying in the flue.



Ventilation

Correct ventilation is very important for complete combustion and dilution. Ventilation can be introduced via air vents or ductwork, the length of ductwork will determine if a fan requires fitting. Similair calculations are used to determine sizes/velocities.