12 Gas

Learning objectives

Study of this chapter will enable the reader to:

1. calculate the flow of gas required by an appliance;
2. identify gas pressures;
3. know how to measure gas pressure;
4. calculate gas pressures;
5. calculate gas pressure drops in pipelines;
6. calculate the equivalent length of a gas distribution pipe system;
7. use gas-pipe-sizing tables;
8. choose suitable gas pipe sizes;
9. describe gas service entry;
10. understand the working of a gas meter;
11. identify the space requirement for gas meters;
12. explain the flue requirements for gas appliances;
13. describe gas flue systems;
14. understand fan-assisted flue systems;
15. apply appropriate gas flue systems to designs;
16. understand how gas combustion is controlled and regulated;
17. know how gas systems are operated safely.

Key terms and concepts

density 281; efficiency 281; equivalent length 284; flue systems 286; gas burner controls 289; gas flow rate 281; gas meter 285; gas service entry 285; gross calorific value 281; ignition and safety controls 289; manufactured gas 281; natural gas 281; pipe size 285; pressure 282; pressure drop 283; pressure governor 289; specific gravity 281; U-tube manometer 282; ventilation 285.

Introduction

Gas services are provided to most buildings, and safety is of paramount importance. Economy is also important, and the versatility and controllability of gas are appreciated. It is used for heating, hot-water production, refrigeration for small and large cooling loads, electrical power generation, cooking and decorative heating.

Gas is converted from its primary fuel state into useful energy at the point of use. Its distribution energy loss is accounted for in the standing charge to the final consumer and, although it is charged for, does not appear to be related to the load as for water pipes or electricity cables. Gas is conveyed in a one-way pipe system and is not returned to the supplier as are electricity and water.

The use of natural gas and, ultimately, an artificially produced substitute from coal and oil is a highly efficient use of primary resources, and all efforts are directed at continuing this trend.

This chapter introduces the calculation of gas flow rate into a load and the gas pressure measurement that is used to monitor the flow rate and condition. The sizing of pipework depends on the gas pressure of the incoming service and that required by the final gas-burning appliance in order to maintain the correct combustion rate. Incoming gas service provisions, metering and particular flue systems are explained. Gas is more suitable than any other fuel for low-level flue gas discharge provided that sufficient dilution with fresh air is available. Typical methods of gas burner control and pressure reduction are explained.

Gas pipe sizing

The gas flow rate required for an appliance can be found from the manufacturer's literature or calculated from its heat output and efficiency:

$$\text{appliance efficiency } \eta = \frac{\text{heat output into water or air}}{\text{heat input from combustion of gas}} \times 100\%$$

Most gas appliances have an efficiency of 75%.

The gross calorific value (GCV) of natural gas (methane) is 39 MJ/m^3. If the appliance heat output is SH kW, then the gas flow rate Q required is

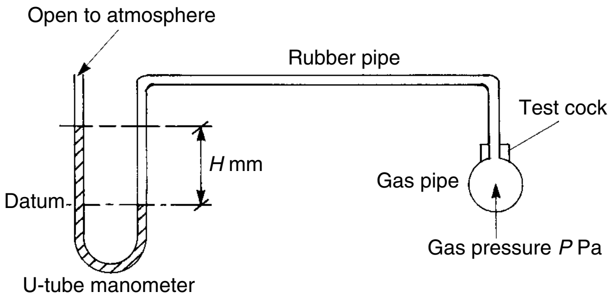
$$Q = \frac{SH\text{ kW}}{\eta} \times \frac{1\text{ kJ}}{1\text{ kWs}} \times \frac{1\text{ MJ}}{10^3\text{ kJ}} \times \frac{1}{GCV}\,\frac{\text{m}^3}{\text{MJ}} \times \frac{10^3\text{ l}}{1\text{ m}^3}$$

$$= \frac{SH}{\eta \times GCV}\text{ l/s}$$

The maximum allowable gas pressure drop due to pipe friction between the gas meter outlet and the appliance will normally be 75 Pa. Gas pressure in a pipe is measured with a U-tube water manometer as shown in Fig. 12.1. The water in the U-tube manometer is displaced by the gas pressure until the gas and water pressures in the two limbs are balanced. The atmosphere acts equally on both limbs under normal circumstances and all pressures are measured above atmospheric. These are called gauge pressures.

Methane has a specific gravity (SG) of 0.55 and so its density ρ is:

$$\rho_{\text{gas}} = SG \times \rho_{\text{air}}$$



12.1 Measurement of gas pressure.

The standard density of air at 20°C d.b. and 1013.25 mb barometric pressure is 1.2 kg/m^3. Thus

$$\rho_{gas} = 0.55 \times 1.2 \text{ kg/m}^3$$
$$= 0.66 \text{ kg/m}^3$$

The water column H in the manometer shows the net effect of the gas pressure P and the different density of the column H of gas in the right-hand limb. At the datum, the pressure exerted by the left-hand column equals the pressure exerted by the right-hand column.

$$P_{water} = P - \text{pressure of column } H \text{ of gas}$$

The pressure at the base of a column of fluid is $\rho g H$ where $g = 9.807$ m/s^2. The density of water ρ_W is 10^3 kg/m^3. Therefore

$$\rho_W gH = P - \rho_{gas} gH$$
$$P = \rho_W gH - \rho_{gas} gH$$
$$= gH(\rho_W - \rho_{gas})$$

Thus

$$P = 9.807 \, \frac{\text{m}}{\text{s}^2} \times H \text{ mm} \times \frac{1 \text{ m}}{10^3 \text{ mm}} \times (1000 - 0.66) \, \frac{\text{kg}}{\text{m}^3}$$
$$= \frac{9.807 \times 999.34}{1000} - H \, \frac{\text{kg}}{\text{ms}^2} \times \frac{1 \text{ Ns}^2}{1 \text{ kgm}} \times \frac{1 \text{ Pa m}^2}{1 \text{ N}}$$
$$= 9.801H \text{ Pa}$$

A sufficiently good approximation is $P = gH$ Pa, where H is in millimetres of water gauge.

EXAMPLE 12.1

A gas-fired boiler has a heat output of 280 kW and an efficiency of 82%. Calculate the flow rate of gas required.

$$Q = \frac{SH}{\eta \times GCV} = \frac{280}{0.82 \times 39} = 8.76 \text{ l/s}$$

EXAMPLE 12.2

Calculate the gas pressure if a water manometer shows a level difference of 148 mm.

$$P = 9.807 \times 148 \text{ Pa}$$
$$= 1450 \text{ Pa} \times \frac{1 \text{ kPa}}{10^3 \text{ Pa}}$$
$$= 1.45 \text{ kPa}$$

EXAMPLE 12.3

A gas-fired warm-air unit requires a gas pressure of 475 Pa at the burner test cock. What reading will be found on a water manometer?

$$P = gH \text{ Pa}$$

and so

$$H = \frac{P}{g} = \frac{475}{9.807} = 48.5 \text{ mm}$$

Gas pressure may be expressed in millibars (mb) as

$$1 \text{ bar} = 100\,000 \text{ Pa}$$
$$1 \text{ bar} = 100 \text{ kPa}$$
$$1 \text{ mb} = \frac{100 \text{ kPa}}{1000} = 0.1 \text{ kPa}$$
$$1 \text{ mb} = 100 \text{ Pa}$$

The gas pressure loss rate $\Delta p/EL$ along a pipeline is needed to find the pipe diameter. EL is the equivalent length of the measured straight pipe, bends and fittings. An initial estimate can be made for the flow resistance of pipe fittings by adding 25% to the straight lengths L m of pipe.

EXAMPLE 12.4

Calculate the pressure loss rate in a gas pipeline from the meter to a water heater. The pipe has a measured length of 34 m.

$$EL = (1.25 \times 34)\ \text{m} = 42.5\ \text{m}$$

The allowable pressure loss Δp is 75 Pa. Thus

$$\frac{\Delta p}{EL} = \frac{75\ \text{Pa}}{42.5\ \text{m}} = 1.76\ \text{Pa/m}$$

EXAMPLE 12.5

A pressure loss rate of 4.2 Pa/m is to be used for sizing a gas pipeline in a house. Calculate the maximum length of pipe that can be used if the resistance of the pipe fittings amounts to 20% of the installed pipe run.

$$\frac{\Delta p}{EL} = \frac{75\ \text{Pa}}{EL\ \text{m}} = 4.2\ \text{Pa/m}$$

Thus

$$EL = \frac{75}{4.2} = 17.9\ \text{m}$$

and

$$EL = 1.2\ l$$

Hence

$$l = \frac{17.9}{1.2} = 14.9\ \text{m}$$

This is the maximum length of run.

The gas pressure of the incoming service will be up to 5 kPa and this is reduced by a governor at the meter inlet to give 2 kPa in the installation within the building. For large gas-burning equipment the gas pressure may have to be increased with a booster. A boosting system comprises an electrically driven reciprocating compressor, a high-pressure storage tank and automatic pressure and safety controls. Pipe diameters can be found from Table 12.1.

EXAMPLE 12.6

Find the pipe size required for a gas service carrying 1.75 l/s and having an allowable pressure loss rate of 5.1 Pa/m.

Table 12.1 Flow of methane (natural gas) in copper pipes.

Δp/EL (Pa/m)	*Gas flow rate Q (l/s) for pipe diameters of*			
	15 mm	*22 mm*	*28 mm*	*32 mm*
1	0.08	0.31	0.69	1.22
2	0.16	0.47	1.05	1.84
3	0.21	0.59	1.33	2.34
5	0.29	0.81	1.8	3.15
7	0.35	0.98	2.2	3.83
10	0.44	1.21	2.7	4.71

Source: Reproduced from *IHVE Guide* (CIBSE, 1986 [IHVE, 1970]) by permission of the Chartered Institution of Building Services Engineers.

From Table 12.1, using the nearest pressure drop below 5.1 Pa/m, in this case 5 Pa/m, a 28 mm copper pipe can carry 1.8 l/s and would be suitable.

Gas service entry into a building

The gas service pipe from the road main should slope up to the entry point to the building, at right angles to the road main and entering the building at the nearest convenient place. Ground cover of 375 mm is maintained and new pipework is made of plastic. When old steel services are renewed, the plastic pipe can be run inside the steel.

A meter compartment can be built into the external wall in housing installations and the service clipped to the wall under a cover. This facilitates meter reading without entry to the property. Computer monitoring of energy meters using a telephone link to the supply authority will eventually replace manual reading.

Where the meter compartment is inside the building, the service should pass through the foundations in a pipe sleeve, plugged to stop the ingress of moisture and insects but allowing for some movement. A 300 mm^2 pit is provided in a concrete floor to allow the service to rise vertically to the meter. The pit can subsequently be filled with concrete.

The meter compartment must not be under the only means of escape in the event of a fire in a building where there are two or more storeys above the ground floor unless it is located in an enclosure having a minimum fire resistance of half an hour.

Gas service pipes, meters and appliances should always be in naturally ventilated spaces, as dilution with outside air is the best safety precaution against the accumulation of an explosive mixture with air. Early detection of leaks is essential, but ventilation assists the dilution of leaks. Gas detectors can be provided as an additional precaution.

Domestic credit meters pass up to 10 l/min, 0.17 l/s, and are 212 mm wide, 270 mm high and 155 mm deep. Their overall space requirement is approximately double the width and height measurements for pipework, valve and filter. Industrial meters have flanged steel pipework up to 100 mm in diameter and a bypass to allow uninterrupted gas flow in the event of meter breakdown. A 500 l/s meter is 2 m wide, 2.25 m high and 1.6 m deep. Due allowance must be made for doorways and access for replacing the meter during the building's use. A separate meter room is recommended, which should be secure, accessible, illuminated and weatherproof with no hot pipes or surfaces.

Manufactured town gas came from the conversion of coal or oil. It had a high hydrogen content and flame speed but its cross-calorific value was half that of methane. In future, substitute natural gas (SNG) may be manufactured from hydrocarbons as indigenous reserves become exhausted. SNG will come from the chemical conversion of coal, tar sand or crude oil and will have characteristics similar to those of methane.

Gas pipes or meters should usually be spaced 50 mm from electrical cables, conduits, telecommunications cables or other conductors. Electric and gas meters may be accommodated in a single compartment if a fire-resistant partition separates them.

Positive displacement mechanically operated meters are used as the billing meter. These meters have three compartments with a horizontal valve plate near the top of the casing and a vertical division plate in the lower section. Bellows formed by a metal disc surrounded by a leather diaphragm are located on each side of the division plate to measure the gas flow. Rotary meters may be used for downstream gas flow metering for energy management purposes and these may be logged by a BMS.

Flue systems for gas appliances

Gas appliances can be flued by a wide variety of methods, as the products of combustion are mainly water vapour, carbon dioxide, nitrogen and oxygen, at a temperature of about 95°C after the draught diverter. The function of the draught diverter is to discharge flue products into the boiler room during a down-draught through the chimney. Such reverse flows occur infrequently for a few seconds during adverse wind conditions. Diversion ensures that the correct combustion process is not interrupted. It stops the pilot flame from being blown out, with consequential shutdown of the appliance until manual ignition is arranged. The draught diverter also dilutes the products of combustion by entrainment of room air into the flue. A carbon dioxide concentration of 4% by volume is found in the secondary flue after the diverter. The primary flue pipes are those before the diverter. Flue systems are described below.

Brick chimney

New masonry chimneys must be lined with vitrified clay or stainless steel pipe. Existing chimneys may incorporate a stainless steel flexible flue liner, which can be pulled through an existing chimney with a rope and rounded plug. The liner has the same diameter as the appliance flue outlet, often 125 mm for domestic appliances, and is built into the top of the chimney with a plate to form a sealed air space between the liner and the brickwork. This acts as thermal insulation to maintain flue gas temperature. If the flue gases were allowed to cool to below about 25°C condensation of the water vapour would occur and deterioration of the metal and brickwork would reduce serviceability. Asbestos cement or glazed earthenware pipes can be built into new chimneys for protection of the brickwork. A cowl is fitted to the flue to reduce the ingress of rain and the possibility of down-draughts.

Free-standing pipe

Figure 4.22 shows a typical free-standing pipe flue, which can be used for a gas appliance. The pipe will be either asbestos cement or double-walled stainless steel with thermal insulation between the inner and outer pipes. A flue pipe taken through a roof is fitted with a lead slate to weatherproof the junction. The terminal should be 600 mm from the roof surface and clear of windows or roof-lights. An internal flue from a small domestic appliance can be connected to a ridge terminal. An externally run asbestos cement flue pipe has a branch tee junction at its emergence through the wall. A 25 mm copper drain pipe takes condensation to a drain gulley.

Balanced flue

Figure 12.2 shows the balanced-flue system used for boilers, warm-air units, convectors and water heaters. It is used for appliance ratings up to around 30 kW. External wind pressure is applied equally to the combustion air inlet and the flue gas outlet parts of the combined terminal. The only pressure difference causing air flow through the appliance is that caused by combustion. The flue terminal should not be underneath a window or within 0.5 m of a doorway or openable window. It should not be located in a confined corner where external air flow might be restricted. Fan-assisted balanced flues have been used and these allow more flexibility in siting the appliance further away from the terminal. Balanced-flue appliances are also called room-sealed appliances.

Se-ducts and U-ducts

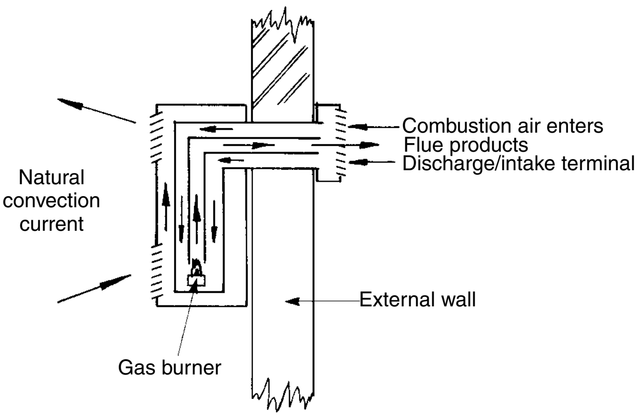
Room-sealed appliances in multi-storey flats are connected to a vertical precast concrete shaft extending from the fresh air inlet grille at ground level to a terminal on the roof. Combustion air is taken from the duct by each heater and its flue products are passed into the shaft. The duct is sized so that sufficient ventilation is provided for the whole installation. With a U-duct a separate combustion air inlet duct takes air from the roof downwards to the lowest appliance, and then the upward duct acts in the same manner as the Se-duct.

Shunt duct

Precast concrete wall blocks, 100 mm wide, with a rectangular flue passage are built into partition walls or the inner leaf of a cavity wall. A continuous flueway is formed for each heater, often a gas fire, to ceiling level. An asbestos pipe then connects to a ridge terminal. Several flues built into a wall side by side are called a shunt duct system.

Fan-diluted flue

Fan-diluted flues are mainly used in commercial buildings where a conventional flue pipe and terminal could not be used or would be unsightly: for example, in a shopping precinct. Fresh air enters a galvanized sheet metal duct, which passes through the boiler plant room and discharges back into the atmosphere. A centrifugal or axial flow fan in the duct is started before the boilers



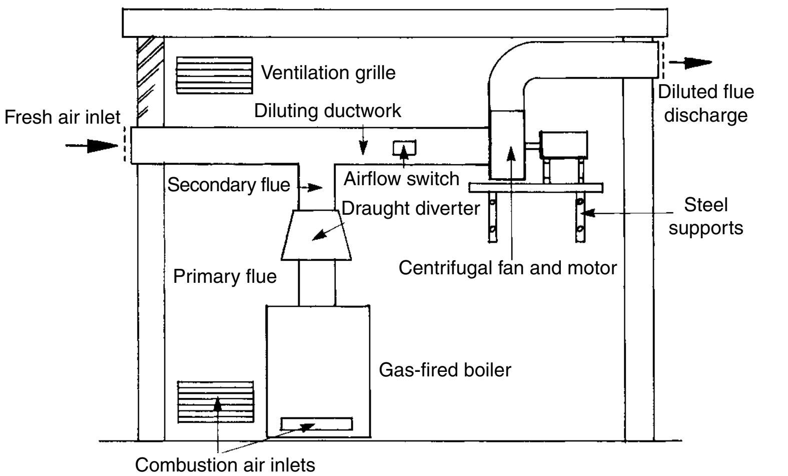
12.2 Balanced-flue gas appliance.

are ignited and an air flow switch cuts the burners off in the event of fan failure. Secondary flue pipes from the boilers are connected into the duct on the suction side of the fan. Dilution of the combustion products takes place and the discharge air from the system may contain as little as 0.5% carbon dioxide and be down to 30°C. Any condensing moisture is carried by the high-velocity air stream and is dispersed as steam into the atmosphere.

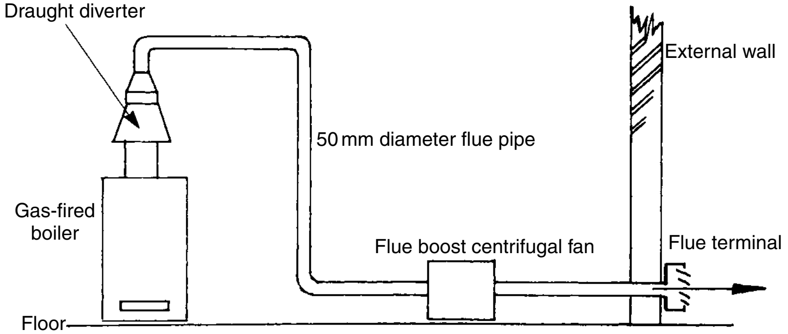
The air inlet and discharge louvres should be positioned on the same external wall to balance wind pressures on each. The discharge can be made into a shopping arcade or covered walkway to make use of the available heat. Careful fan selection is essential to avoid creating a noise nuisance. Figure 12.3 shows a fan-diluted flue installation for one boiler.

Boosted flue

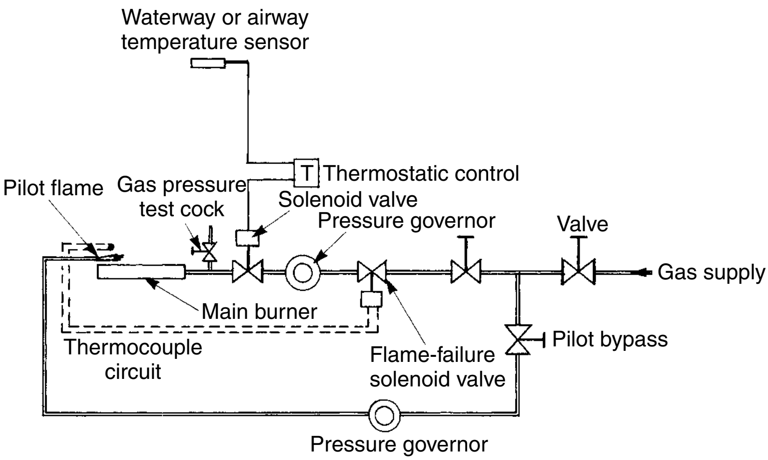
A domestic boiler may have a booster centrifugal fan fitted into its flue pipe to allow a long horizontal run or even a downwards run. The pipe diameter can be smaller than the boiler flue outlet diameter and the fan pressure rise is used to overcome the frictional resistance. A typical installation is shown in Fig. 12.4.



12.3 Fan-diluted flue (reproduced by courtesy of Airdelle Products, High Wycombe).



12.4 Boosted flue (reproduced by courtesy of Airdelle Products, High Wycombe).



12.5 Gas burner controls.

Ignition and safety controls

Natural gas is burnt in an aerated burner in which half the air needed for combustion is entrained into the gas pipeline by a nozzle and venturi throat. This premixed gas and air goes to the burner, which is often a perforated plate through which the mixture passes. Further mixing occurs above the plate and the flame is ignited by a permanently lit pilot jet. A sheet of clear blue flame is established over the top of the burner plate or matrix. Large gas boilers, over 45 kW, use forced-draught burners in which gas and air are blown under pressure into a swirl chamber where the flame is established, with a fair amount of noise.

Gas burner control of appliances under 45 kW is achieved as follows. The pilot flame, which is ignited manually or with a piezoelectric spark, heats a thermocouple circuit whose electrical voltage and current holds open the flame-failure solenoid valve. In the event that the pilot flame is extinguished, the flame-failure solenoid becomes de-energized because the thermocouple is no longer heated, and the main gas supply is stopped. As long as the pilot is alight, the control thermostat in the boiler waterway or warm-air unit outlet duct is able to ignite the burner by opening its own solenoid valve. Figure 12.5 shows the diagrammatic arrangement of the control system for a gas burner of less than 45 kW. A combination gas valve is used to incorporate some of these functions into one unit.

The governor maintains a constant gas pressure to the burner by means of a synthetic nitrile rubber diaphragm which rises when the inlet pressure is increased. The diaphragm is connected to a valve, which closes when the diaphragm rises. This action increases the resistance to gas flow and maintains the outlet gas pressure at the set value. An adjustable spring is used to set the downstream pressure appropriate to the gas flow rate required by the burner.

Questions

1. A gas-fired water heater has a heat output of 30 kW at an efficiency of 75% and a gas pressure of 1225 Pa. Calculate the gas flow rate required at the burner and the reading on a U-tube manometer in millimetres water gauge at the outlet from the pressure governor.
2. Express gas pressures of 55 mm H_2O, 350 N/m^2, 75 Pa, 1.5 kPa and 1.05 bar in millibars.

3. The pipe from a gas meter to a boiler is 18 m long and has elbows that cause a resistance equivalent to 25% of the measured length. Calculate the maximum allowable pressure loss rate for the pipeline.
4. If the maximum allowable pressure loss rate in a pipeline can be 2.3 Pa/m and the resistance of the pipe fittings amounts to 20% of straight pipe, what is the maximum length of pipe that can be used?
5. A gas boiler of 43 kW heat output and 75% efficiency is supplied from a meter by a pipe 23 m long. The resistance of the fittings amounts to 25% of the pipe length. Find the gas supply pipe size needed.
6. Calculate the actual gas pressure drop through a 22 mm pipe carrying 0.81 l/s when the pipe length is 12 m and the fittings resistance amounts to 20% of its length.
7. Sketch and describe the gas service entry and meter compartment arrangements for housing.
8. Explain how a gas meter measures gas flow rate and total quantity passed during a year.
9. List the methods of flueing gas appliances and compare them in relation to their application, complexity and expected cost.
10. Explain, with the aid of sketches, the sequence of operation of safety and efficiency controls on gas-fired appliances.
11. Around what pressures do natural gas and liquefied petroleum gas run at in pipe distribution systems in buildings? More than one correct answer.

    1. Up to 40 atmospheres.
    2. Usually above 200 kPa.
    3. Up to 3000 mm water gauge.
    4. 20–200 mm water gauge.
    5. Less than 100 kPa.

12. Natural gas metering for billing is carried out with:

    1. Rotary gas meter monitored by the BMS.
    2. Flow rate measured from the pressure drop through an orifice plate in the pipeline.
    3. Positive displacement gas consumption meter.
    4. Pitot-static tube in pipeline and a data logger.
    5. Rotary vane anemometer in pipeline and an integrating revolution-counter meter.

13. What happens to water vapour in flue gas?

    1. Condenses when flue gas cools to water vapour dew-point temperature.
    2. Remains as vapour at all times.
    3. Cools and appears as steam discharging into atmosphere.
    4. Becomes absorbed into flue system materials and drains.
    5. Combines with other flue gases.