8) Correctly complete the following sentence with the appropriate word provided:
The result of squaring the radius and multiplying it by π, is the _____ of a circle.
   a) Diameter
   b) Area
   c) Widest
   d) Circumference

9) What type of tool is used to ensure correct clearance between parts?
   a) Drill gauge
   b) Pocket tape
   c) Feeler gauge
   d) Square

10) What type of tool is used to measure an orifice size?
   a) Drill bit blank
   b) Callipers sizing drill
   c) Feeler Gauge
   d) Pocket tape

# 5. Combustion testing instruments

## Overview

### Purpose

The gas technician/fitter uses many instruments to check air quality in the working environment and to ensure safe and efficient operation of gas fired equipment. This Chapter identifies some of the important instruments used. Unit *3 Properties, Characteristics, and Safe Handling of Fuel Gases* describes them in more detail.

### Objectives

At the end of this Chapter you will be able to:

- identify types of combustion testing instruments.

## Terminology

| Term | Abbreviation (symbol) | Definition |
|---|---|---|
| Combustion | | The rapid oxidation of any material classified as a combustible matter. |
| Ignition temperature | | Temperature at which combustion can take place. |
| Pound per square inch | PSI | Measure of pressure in a vessel. |

# Types of combustion testing instruments

Gas appliances are designed for many different applications. The required operating characteristics vary from appliance to appliance and from installation to installation. Ensuring that gas-fired equipment is operating safely and efficiently is the responsibility of gas technicians/ fitters.

It is an important part of the gas technician's/fitter's job to understand:

- the combustion process; and
- the available testing instrumentation used to test the combustion process.

This section gives an overview of these topics that later Units cover in greater detail.

## Principles of combustion

Combustion is the rapid oxidation of any material classified as a combustible matter. It is a rapid chemical reaction. Familiar combustion processes include the burning of gasoline in an automobile engine and the burning of natural gas as a fuel.

### Combustion elements

During combustion, oxygen from air combines with the combustible elements of a fuel—normally carbon and hydrogen—to release heat energy. However, fuel and oxygen alone do not produce combustion. Raising the temperature to the ignition temperature at which combustion can take place also requires *heat*, i.e., there are three combustion elements: fuel, oxygen, and heat,

Removal of any one of the three elements stops combustion. For efficient combustion to take place, you must present each in the right quantity. It is important to have the right flow of air containing oxygen. There can be too much or little air to support combustion.

### Flue gases

The combustion process forms products which are usually exhausted through a flue, vent, or chimney. In the gas industry, these are called flue gases. Altering the air–gas mixture to the combustion process affects the volume of and percentage of flue gas components.

You must analyze flue gas to check:

- the efficiency of combustion; and

- the level of toxic gases.

A combustion analysis determines the completeness of combustion and what percentages of the total volume of dry flue gas are carbon dioxide ($CO_2$), oxygen ($O_2$), and carbon monoxide (CO). In certain cases, you may also measure hydrogen ($H_2$), nitric oxides (NO and $NO_2$), and hydrocarbons (HC).

# Flue gas analyzers

Flue gas analyzers provide the gas technician/fitter and client with accurate information that they may use in adjusting appliances for optimum combustion efficiency or to verify safe operation. The analyzers fall into three types:

- continuous sampling (electrochemical, non-dispersive infrared tube, selective chemical reaction);
- tube (such as *Draeger* and *Gastec*); and
- liquid (selective chemical absorption).

Incorrect handling of flue gas analyzers can easily damage these instruments and give inaccurate readings, which can be very dangerous. To prevent these, always follow the manufacturers' recommendations for storage, handling, calibration, and use of these instruments.

## Continuous sampling electronic analyzers

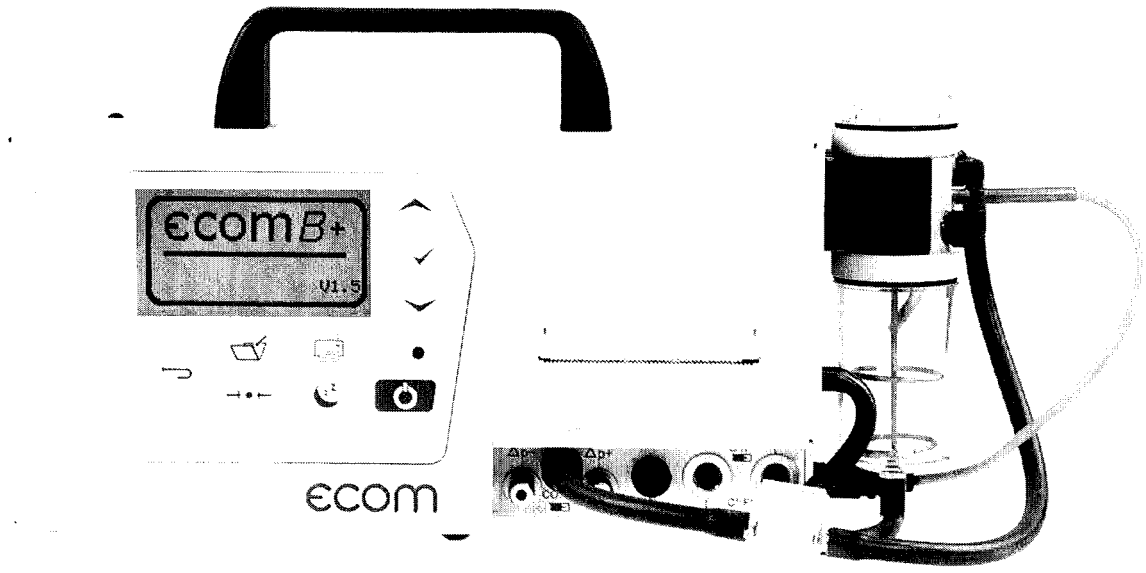
The most commonly used flue gas analyzers are electronic, and they come in many different makes and models. The field technician/fitter usually uses a hand-held portable device, which is versatile and not difficult to operate. The most up-to-date analyzers measure all the products of combustion. Most analyzers have temperature probes and pressure sensors built in.

With a continuous sampling device, sensors in the Unit continuously analyzes a measured flow of flue gas sample for the device's duration of being connected to the appliance, unlike its predecessors which only manually spot sample at user-determined intervals.

Modern flue gas analyzers can store information, download the data to a computer, and transmit the information to a printer to produce hard copy reports for the client.

Figure 5-1 shows a typical hand-held combustion gas analyzer.

**Figure 5-1**
**Multi-gas emission analyzer**
**Image courtesy of ECOM**




## Tube analyzers

The least expensive flue gas analyzer uses pencil-shaped glass tubes filled with dry chemicals. Each tube contains a different chemical, and each one's function is to test for a specific type of gas. Usually, the tubes are single-use.

Each detector tube contains precise amounts of detecting reagents in a glass tube with a fixed inner diameter. The tube is hermetically sealed at both ends to protect the contents until they are exposed to the flue gas during testing. *Draeger* and *Gastec* are two well-known manufacturers of this type of equipment.

## Gastec detector tube

The Gastec detector tube (Figure 5-2) is a good example of how a tube analyzer works.

**Figure 5-2**
**Gastec tube type flue gas analyzer system**
**Image courtesy of Terry Bell**

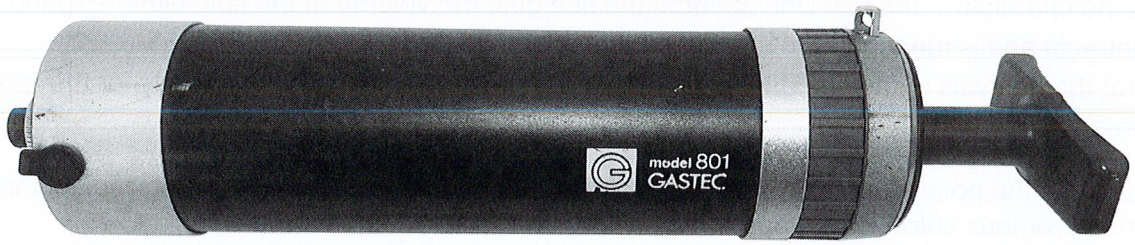



**Figure 5-3**
**Gastec $CO_2$ analyzer tube**
**Image courtesy of Terry Bell**

1) To start the test, break off the tapered tube ends and connect one opened end of the tube to the Gastec sampling pump.
2) Pull the hand operated vacuum pump handle to draw the flue gas sample through the tube. (The pump, which may draw a fixed amount or be adjusted for different tests, measures the volume of gas drawn.)
3) As the sample moves through the tube, the test gas reacts immediately with the dry chemical and causes it to discolour, beginning at the entry end of the detector tube. The higher the concentration of test gas present, the greater the length of dry chemical discoloration (Figure 5-3).
4) Measure the gas concentration at the point where the coloration stops. (Graduated markings on the side of the tube make it easy to read the precise percentage of the test gas found in the sample.)

## Liquid analyzers (selective chemical absorption)

The advantage of liquid over tube analyzers is that they enable you to test many flue gas samples without the need to change the chemicals. This is particularly useful when you must analyze several samples during the set up of a burner system.

The two most common gases measured with liquid flue gas analyzers are $CO_2$ and $O_2$. The reagent (reacting chemical) for measuring $CO_2$ is potassium hydroxide (dyed red) and for measuring $O_2$ is chromous chloride (blue).

The liquid analyzer works as follows:

- Each individual test Unit is partially filled with the specific reagent to test a particular component of the fuel gas, $CO_2$ or $O_2$.
- As the chemical in the test Unit absorbs the flue gas, the volume of the fluid either expands or contracts and is measured on a scale on the side of the tube.
- After the analysis of the flue gas sample, the test Unit is vented, leaving it ready for the next sample.

You can use the potassium hydroxide for approximately 400 tests before requiring replacement. and the chromous chloride for approximately 200 tests prior to replacement.

A common liquid test Unit is the *Fyrite* system which uses the "Orsat Method".

## Combustible gas indicators

Gas technicians/fitters use combustible gas indicators (Figure 5-4 and Figure 5-5) to test for combustible gases in surroundings. Attaching a sampling probe can be useful for difficult-to-access areas. Digital or analogue types are available.

Unit *3 Properties, Characteristics, and Safe Handling of Fuel Gases* covers this instrument in greater detail.

**Figure 5-4**
**Combustible gas indicator (solid-state)**

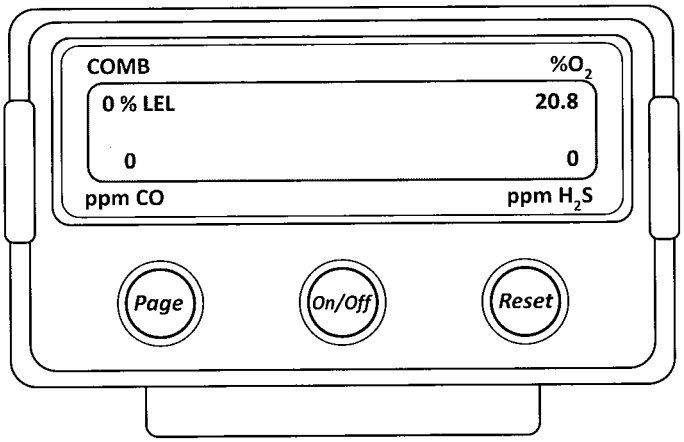
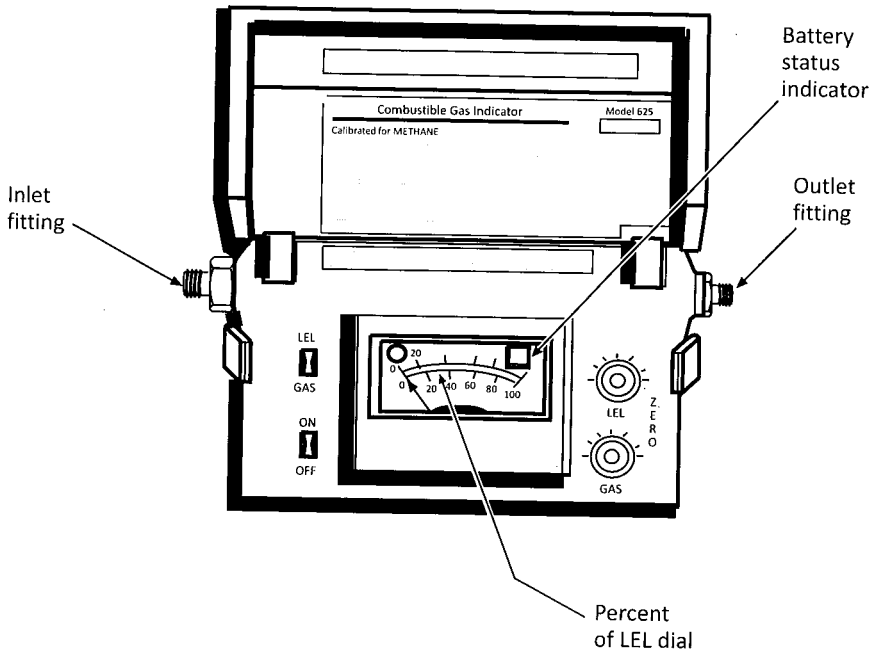


**Figure 5-5**
**Filament-type combustible indicator**




# Pressure and temperature gauges

Gas technicians/fitters use various other instruments in testing. These measure gas pressure and temperature:

- When an object exerts a force over an area of another object, it exerts pressure. Pressure is the force exerted per Unit area.
- Temperature (i.e., the degree of heat) is measured using various scales such as Fahrenheit and Celsius. These scales have fixed points used for comparison and are based on such things as the boiling and freezing points of water at a particular pressure.

Gas technician/fitter use various gauges to measure gas pressure and temperature:

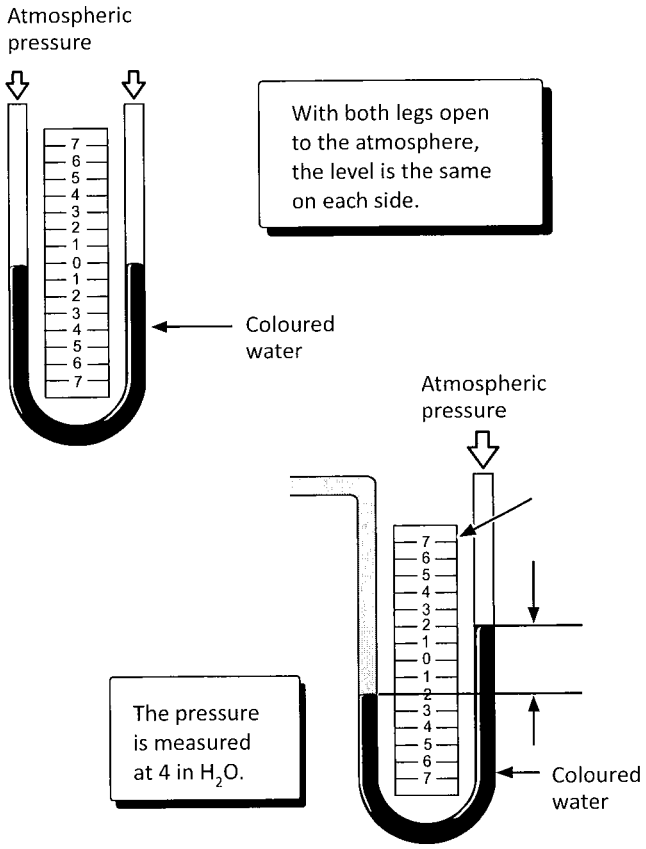
| Type | Description |
|---|---|
| Pressure gauges | Measure the force per Unit area exerted by a confined gas. They measure pressures above atmospheric. |
| Vacuum gauges | Measure pressures below atmospheric. |
| Compound gauges | Measure pressures both above and below atmospheric. |
| Draft gauges | Measure the gas density of low gas heads or small differential gas pressures. |

| Type | Description |
|---|---|
| Temperature gauges | Measure sensible heat changes. Sensible heat is a change in temperature which you can feel. Latent heat causes a change in state without changing temperature. |
| Digital temperature gauges | Are the most common for technicians/fitters to use. |

## Manometers

The manometer (Figure 5-6) is a U-shaped tube that helps measure the difference in pressure between the tops of the liquid in the two sides of the tube. The liquid is water or coloured gauge oil. Small positive or negative pressures are expressed in inches of water column; 1 PSI is equal to 27.7 inches of water column. Gas technicians/fitters most often use the water column measurement.

**Figure 5-6**
**A U-tube manometer**




The water-filled U-tube manometer works as follows:

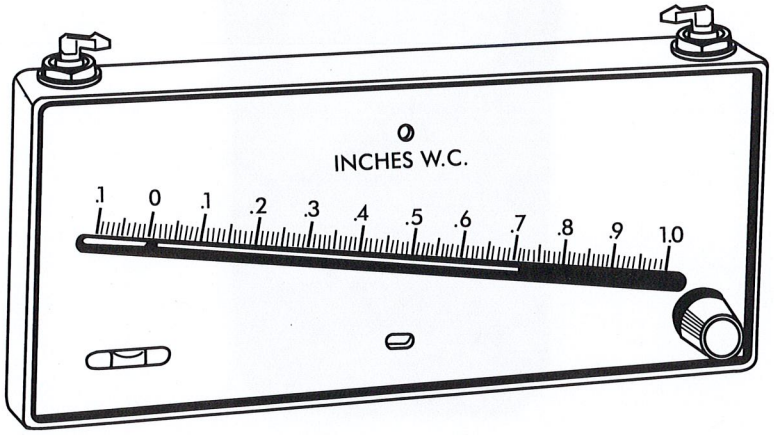
- When both legs of the tube are open, only atmospheric pressure acts on the surface of the liquid. This gives the same liquid level in each leg. The gauge pressure then reads zero.

- When one leg is connected to a source with pressure higher (or lower) than atmospheric, the additional (reduced) pressure causes the liquid to move, lifting (displacing) the column in the leg that is open to the atmosphere. The difference between the liquid heights in the two legs determines the gauge pressure of the pressurized source. [In Figure 5-6, it is (2 plus 2) +4 in of water.]

## Slope manometers

Slope manometers are also called inclined-vertical manometers (Figure 5-7). In this type, the arm of the manometer in which liquid level varies is gradually sloped rather than vertical. Typically, a slope manometer is about 20 in (500 mm) long. This enables the accurate observation of extremely small incremental changes. Normally, these devices are permanently mounted on equipment.

**Figure 5-7**
**Slope manometer**




## Digital manometers

Electronic manometers are the most common field service tool that measures positive and negative pressures. They are available in a variety of models showing different ranges and may have many other features.

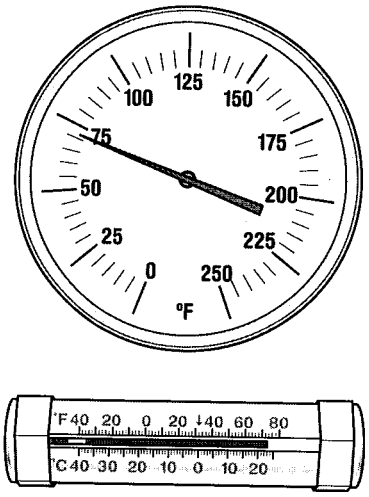
You can use digital manometers as draft gauges, if equipped with the correct range, and to measure differential pressures.

**Figure 5-8**
**Hand-held digital manometer**
**Image courtesy of TPI**

## Temperature gauges

Sometimes referred to as thermometers, temperature gauges come in many different styles and types. In their traditional form, thermometers are a scale (Figure 5-9) displaying temperature Units of measurement, (i.e., degrees Fahrenheit). As with most other instruments, many electronic options are now available. Digital thermometers are the most popular temperature measuring tool used today. Their only disadvantage is the need for battery power (Figure 5-10).

**Figure 5-9**
**(top) Bimetal dial thermometer, (bottom) Spirit-filled thermometer**




The type of hand-held thermometer shown in Figure 5-10 uses plug-in sensors in a variety of types, sizes, and styles.

**Figure 5-10**
**Digital hand-held thermometer**

# Assignment Questions – Chapter 5

1) What is the purpose of flue gas analysis?
   a) To determine proper supply pressure
   b) Safety (check for toxic gases) and efficiency of operation
   c) To ensure the vent is working

2) Which of the following is not a type of flue gas analyzer?
   a) Pressure
   b) Tube
   c) Liquid
   d) Continuous sampling

3) How many different gases is each detector tube designed to test for?
   a) Two
   b) Three
   c) Multiple
   d) One

4) What is the advantage of using a liquid-type flue gas analyzer compared to the tube type?
   a) Liquid types can be used to take many samples without changing the chemicals
   b) Tubes are more expensive
   c) Tubes are more dangerous because of glass ends

5) Which type of flue gas analyzer allows you to adjust the burner while watching the results on a monitor?
   a) The liquid type analyzer
   b) The continuous sampling type
   c) The tube type analyzer

6) Which type of liquid manometer does the gas technician/fitter normally use?
   a) The oil manometer
   b) The glass tube manometer
   c) The water column manometer