Boiler Draft Equipment

Learning Outcome

When you complete this module you will be able to:

Discuss, sketch and describe the basic equipment used to supply combustion air to a boiler furnace.

Learning Objectives

Here is what you will be able to do when you complete each objective:

1. Define "draft" and describe natural draft.

2. Describe the forced, induced, and balanced methods of mechanical draft.

3. Discuss the common methods of controlling combustion air flow.

4. Discuss the common methods of measuring furnace pressures.

INTRODUCTION

The term ‘draft’ refers to the process of supplying combustion air to the boiler furnace. It can be defined as “a differential in pressure, which will produce a flow of air”. This continuous air flow is necessary to provide the oxygen required for the combustion of the boiler fuel. The movement of air into the furnace, and the subsequent flow of combustion flue gases through the boiler, conducts heat to the convection sections of the boiler and conveys exhaust gases out of the stack.

Air is supplied to the burner so that its oxygen can combine with fuel. Burners are therefore essentially mixing devices. The air going to the burner is often separated into different streams to facilitate mixing, especially on oil-and coal-fired systems. These different air streams are referred to as primary air and secondary air.

Primary air refers to the air which may be pre-mixed with the fuel before being admitted to the furnace, or to the air admitted close to the burner tip or fuel bed.

Secondary air is the remaining air necessary for complete combustion, and is supplied close to the burner in the combustion zone.

In order to promote thorough mixing of fuel and air the primary air is often given a clockwise rotation and the secondary air a counter-clockwise rotation or vice-versa.

DRAFT EQUIPMENT

Equipment used to supply combustion air to the furnace can be classified into two groups, namely: natural draft equipment and mechanical draft equipment.

Natural Draft Equipment

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When a gas is heated it tends to expand so that each cubic metre has less mass than it did before heating. Therefore the hot gases in the stack or chimney, see Fig. 1, will have less mass than an exactly equal column of the outside colder air.

The pressure due to the column of colder air at the base of the imaginary stack entering the furnace will be greater than the pressure due to the mass of the column of lighter, heated gases at the base of the chimney. The heavier, colder air displaces the lighter gas and as more is heated in the furnace the process becomes continuous.

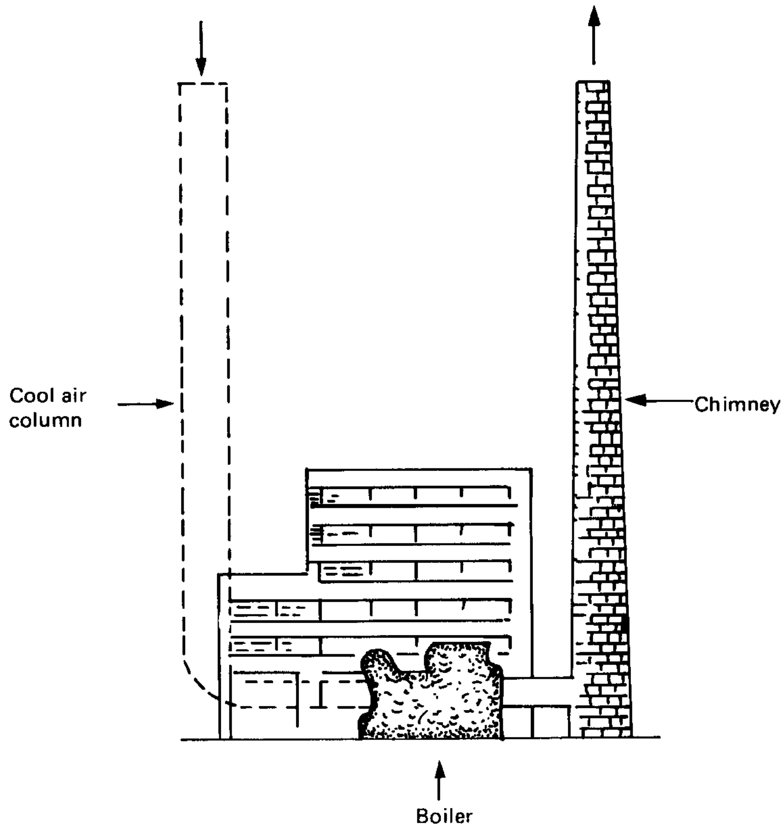

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Figure 1
Chimney Producing Natural Draft

Fig. 2 illustrates a firetube boiler that obtains combustion air by natural draft. The hot gases pass through a nest of firetubes and leave the tubes at the front of the boiler, collect in the smoke box and from there are discharged into the chimney.

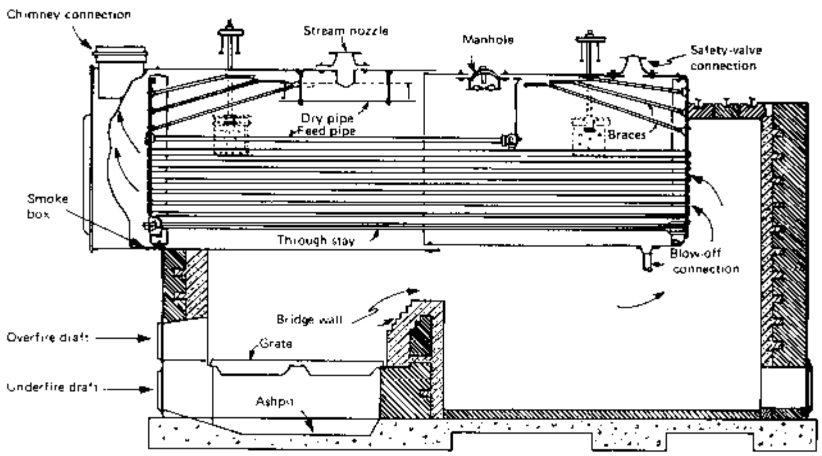

Figure 2
Natural Draft Horizontal Return Tubular

From the previous discussion it may be concluded that in order to increase the pressure differential between the pressure at the furnace inlet and the pressure at the furnace exit there are three alternatives:

1. Chill the outside air.

2. Increase the temperature of the gases leaving the furnace.

3. Increase the height of the chimney.

The first method is obviously next to impossible to attain. However, during the cold weather, better draft conditions can be expected compared to those during the summer months.

The second method, increasing the stack (chimney) temperature, is easily accomplished but it should be kept in mind that the higher the stack temperature, the greater the heat loss through the chimney.

The third method seems to be the only sensible solution, however, economically there are limitations to this solution. In addition, increasing the height of the stack produces a proportional increase in frictional resistance when the gases travel through the stack.

Another function of the stack, besides creating draft, is to disperse dust particles, and occasionally smoke, over a large area. In the interest of public health, various government bodies, in order to reduce air pollution to a minimum, have established rules pertaining to the quantity and size of dust particles emitted from a stack.

A taller stack will disperse the pollutants over a larger area and thus reduce the pollution problem. For coal-fired furnaces, dust collectors are installed in the flue gas ductwork before the flue gas enters the stack. Efficient dust collectors may remove as much as 95 percent of the dust from the flue gases emitted from the furnace.

The chimney or stack is the only means of providing draft in natural draft systems, therefore its design and construction are important considerations.

Chimneys are commonly constructed of reinforced concrete, brick or steel. The **reinforced concrete chimney** is the more durable type and Fig. 3 shows the arrangement and details of this design. The **brick chimney** gives a nice finished appearance and is shown in Fig. 4. Common brick is not heat resistant and the chimney for this reason requires a firebrick or clay lining. The mortar tends to disintegrate with time and is subjected to air infiltration, which reduces the available draft.

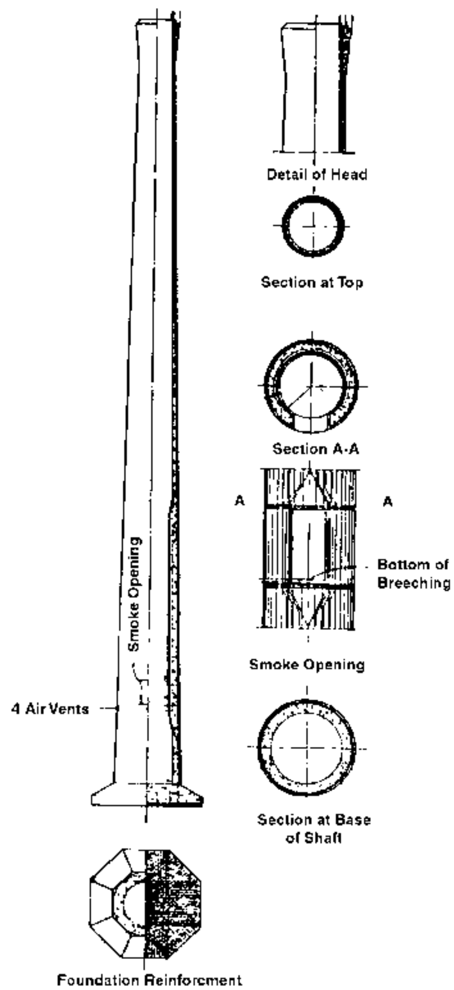

Figure 3
Concrete Chimney Details

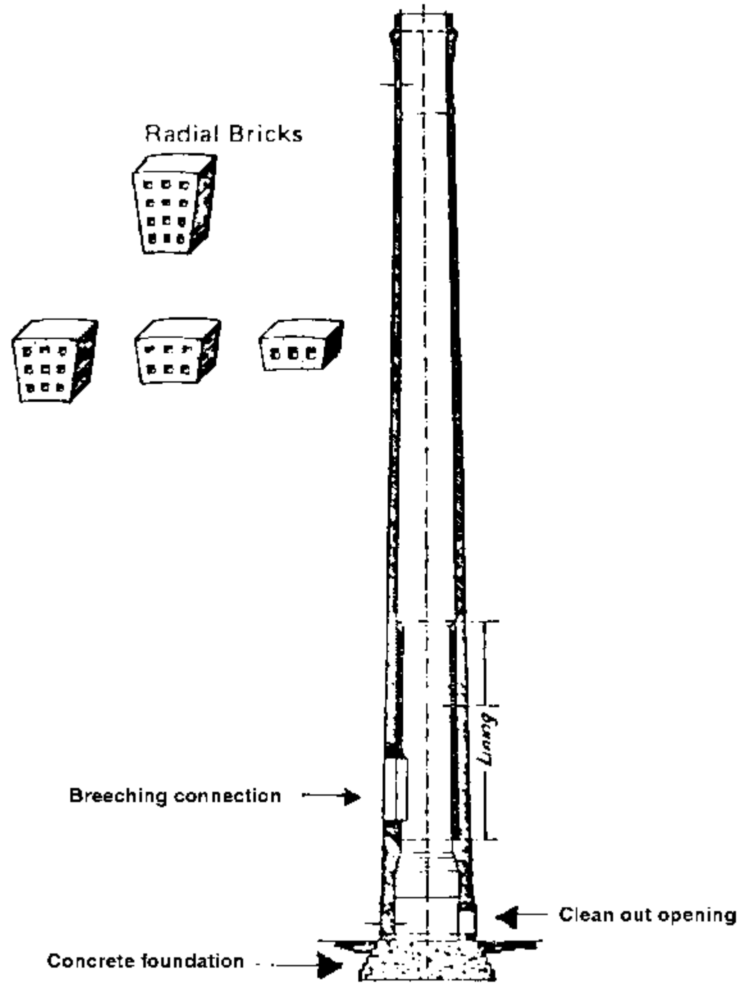

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Figure 4
Masonry Chimney Details

Steel chimneys, as shown in Fig. 5, are the most popular type,.

They are low in first cost, of light construction and may be erected on the same structure that carries the weight of the boiler. The disadvantages of the steel chimney are that it requires considerable maintenance and it also requires a refractory lining. In order to reduce cost and weight, the lining may extend to only one third of the total length.

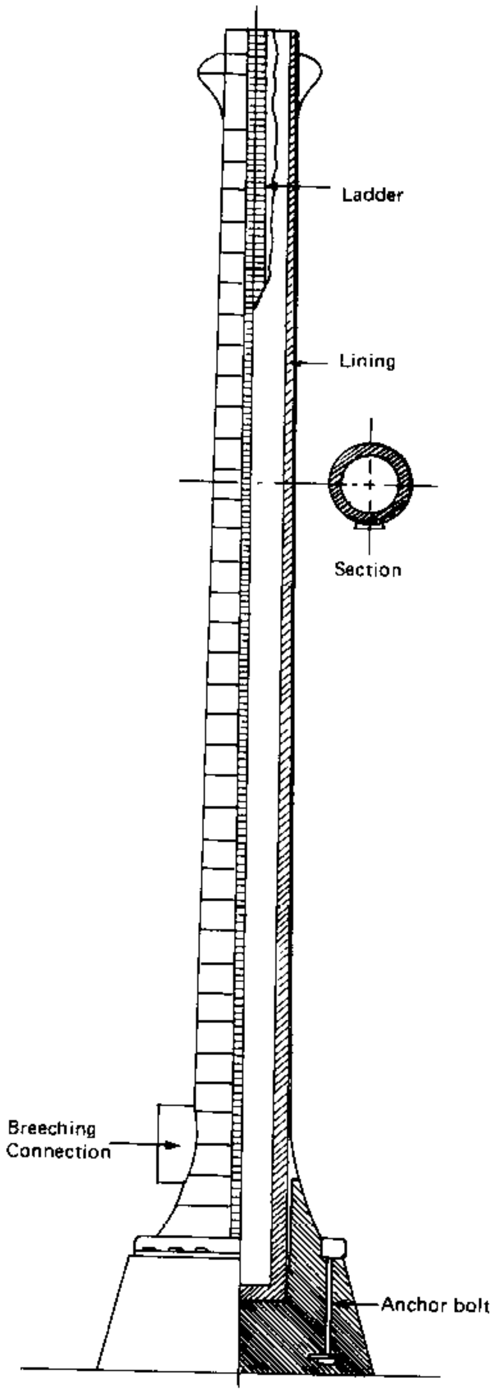

Figure 5
Self-Supporting Steel Chimney

Mechanical Draft Equipment

The amount of draft that can be created by chimney action alone is limited, which means that the amount of fuel burnt per unit of time is also limited. For this reason some additional means must be provided to increase the amount of draft to that necessary for high output boilers. There are three methods available to solve this problem:

1. **Induced draft**, where the velocity of the gases in the chimney is increased. This creates a partial vacuum in the furnace, thereby increasing the air flow into the furnace.

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2. **Forced draft** which means forcing air into the furnace.

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3. **Balanced draft** - this system forces air into the furnace and the combustion gases are removed from the furnace by natural or mechanical means.

1. Induced Draft

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This may be accomplished in two ways: by steam jet and by fan.

(a) Steam Jet

A partial vacuum in the furnace is created by a steam jet. This method was used on the older steam driven locomotives where the exhaust steam from the engine was utilized for supplying steam to a venturi tube placed in the chimney. The high velocity steam escaping from the venturi imparted velocity to the surrounding flue gases. Consequently the increased gas flow through the chimney induced a greater draft across the furnace.

(b) Fan

A fan consists of a rotating wheel or impeller, which sets up a centrifugal action on the air or gas to be moved, and a fan casing, usually a spiral type, to convert a part of the velocity created by the impeller into pressure energy.

Fig. 6 shows a double suction induced draft fan. The gases from the boiler are drawn into the inner core or eye of the impeller from both sides. The gases are then accelerated by the rapidly rotating wheel and leave the tip of the impeller blades at a high velocity and are then discharged into the surrounding casing.

A part of the casing has been removed to give access for cleaning, inspection or repair. The chimney connection is at the upper section of the casing. The impeller shaft is supported by two end bearings. When used as an induced draft fan this unit is located at or near the furnace outlet and may be motor or steam turbine driven. It draws the gases through the furnace and forces them up into the stack.

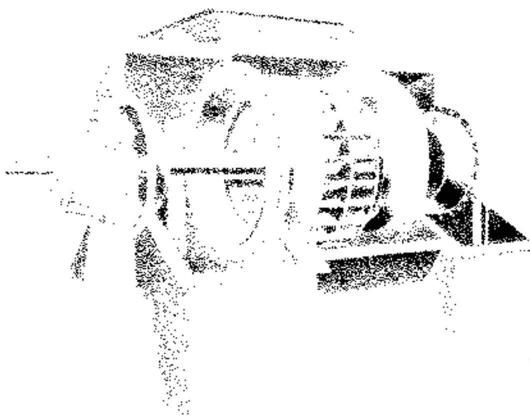

Figure 6
Inducted Draft Fan

Fig. 7 shows the position of the induced draft fan at the lower section of the stack. For this particular arrangement, the fan and drive are supported by overhead steel work.

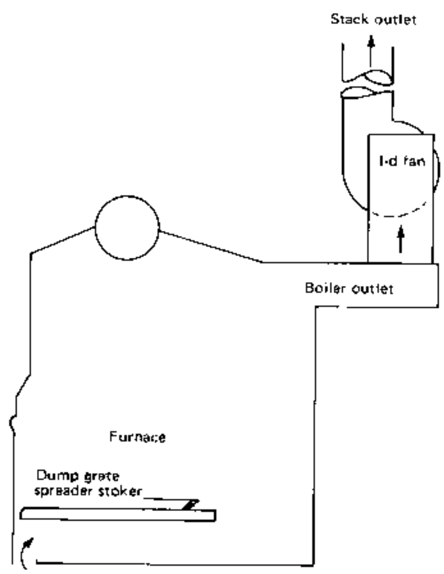

Figure 7
Induced Draft Arrangement

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2. Forced Draft

The fan in this case delivers air to the furnace by means of ductwork. The quantity of air admitted is usually regulated by a damper. Fig. 8 shows a typical forced draft fan suitable for a large industrial boiler. The atmospheric air is drawn into the side of the casing via a set of dampers which control the amount of air handled by the fan.

When using a forced draft system, the entire furnace casing is under positive pressure. To prevent the escape of gases, the furnace and all furnace openings must be carefully sealed against outward leakage and the casing must be strong enough to withstand the internal pressure. This type of furnace construction is called a pressurized furnace.

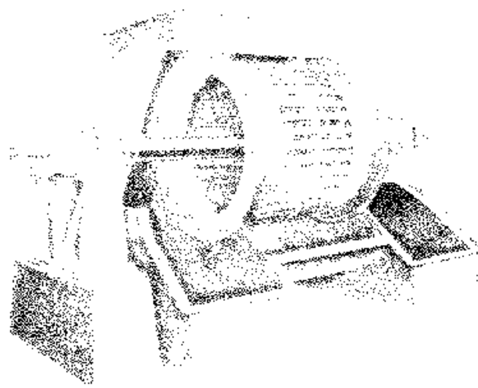

Figure 8
Forced Draft Fan

Fig. 9 illustrates a reinforced furnace casing suitable for a pressurized furnace.

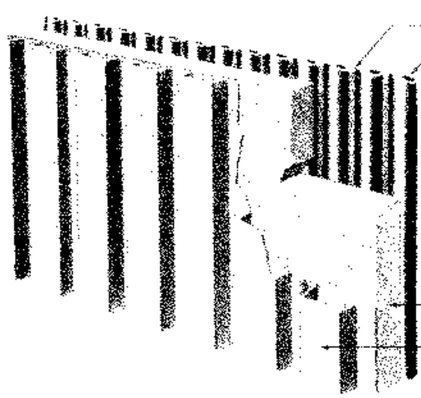

Figure 9
Reinforced Outer Casing (Courtesy of Babcock & Wilcox)

Fig. 10 shows a cross section of a water-cooled pressure sealed access door.

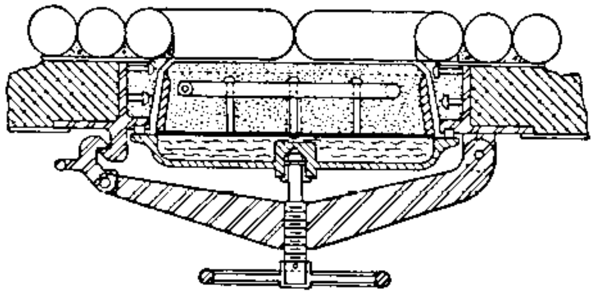

Figure 10
Water-Cooled Access Door

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Fig. 11 shows a combination gas-oil burner. The gas burner is attached to the boiler front and a packing box maintains a seal between the windbox and gas burner barrel. The gas burner is of double walled construction. The gas flows through the annular ring formed by the two tubes and issues from the gas burner ports.

The oil burner is inserted in the inner gas burner tube and can be removed when gas firing or oil burner servicing is desired. Sealing air (aspirating air) is supplied from the forced draft fan or other source at a sufficiently high pressure to allow for safe removal of the oil burner or automatic gas lighter while the boiler is in service.

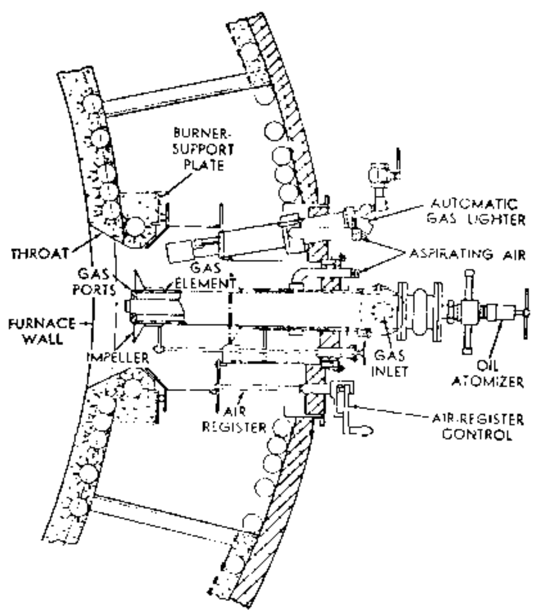

Figure 11
Gas-Oil Firing Equipment with Aspirating Air

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A duct system is shown in Fig. 12. The forced draft fan is connected to the lower duct, which conveys the air through an air heater to preheat the air before it is admitted to the burners. The duct passes underneath the boiler floor and is connected at the front to a windbox, which distributes the air to a number of burners. The upper duct discharges the flue gas from the boiler via the air heater into the stack. It is common to have a set of adjustable louvres (dampers) in the windbox at the point where the air is admitted to the burner.

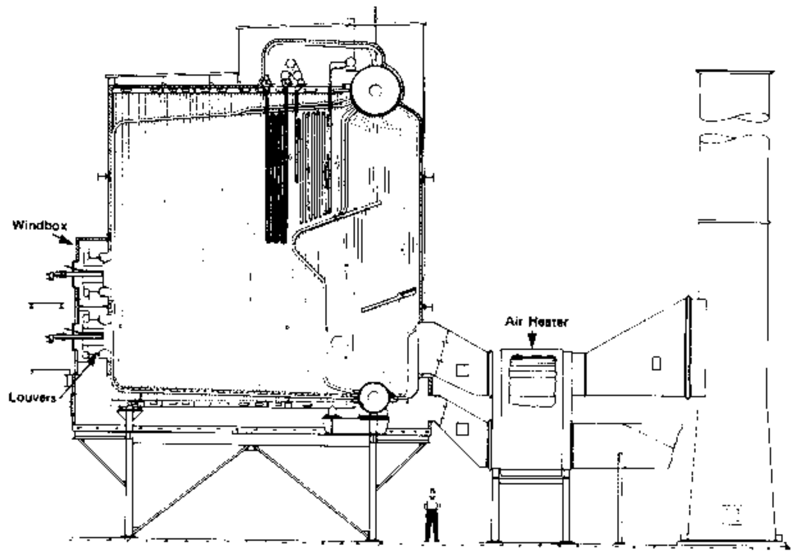

Figure 12
Duct System - Forced Draft

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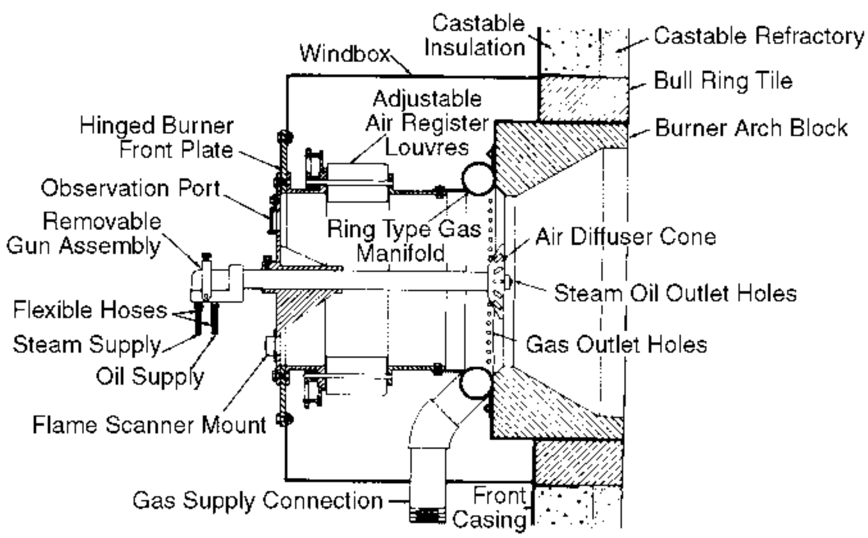

Figure 13
Boiler Front - Windbox and Louvres

These louvres, as illustrated in Fig. 13, perform two functions; first of all they give the air a swirling motion in order to obtain better mixing of fuel and air, and secondly they shut off the air supply when the burner has been taken out of service and in this way prevent the other burners from being starved for air.

When the boiler is taken off the line all the louvres are shut allowing the boiler to cool at a slow controlled rate avoiding undue stress on the tube joints and other parts.

Fig. 14 shows a forced draft fan, including all the necessary firing equipment, mounted directly on the boiler front of a packaged boiler.

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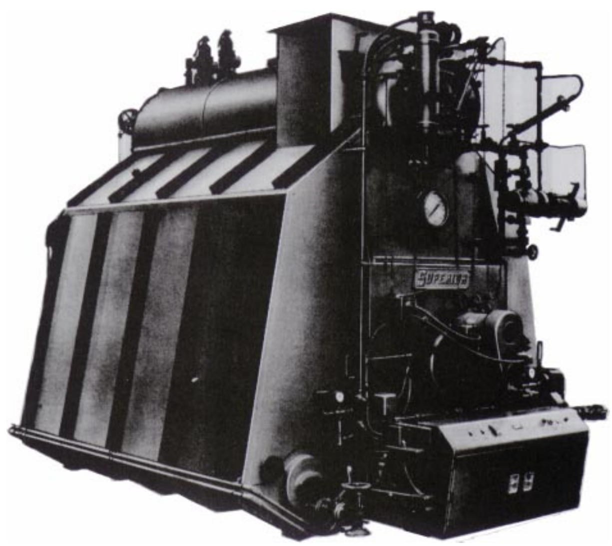

Figure 14
Three-Drum "A" Type Packaged Boiler

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Fig. 15 shows a fan of simple design suitable for smaller sized boilers. The air flows parallel to the motor and the propeller type fan forces the air into the boiler furnace.

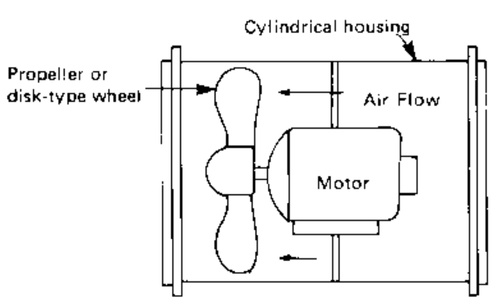

Figure 15
Axial Flow Fan

3. Balanced Draft

The term, balanced draft, is usually applied to a combination of forced and induced draft. These are regulated so that the forced draft fan supplies a sufficient amount of air necessary for complete combustion of the fuel and the induced draft fan removes the flue gases, keeping the furnace pressure slightly below atmospheric. This system is commonly employed for large steam boilers where the gases travel a long distance through a number of boiler passes with a proportional increase in resistance to flow.

The induced draft fan works in conjunction with the forced draft fan allowing the furnace pressure to be maintained slightly below atmospheric.

Fig. 16 shows a balanced draft system. The forced draft fan forces air into the windbox while the induced draft fan creates a partial vacuum at the fan suction inducing the gas to flow through the various boiler passes.

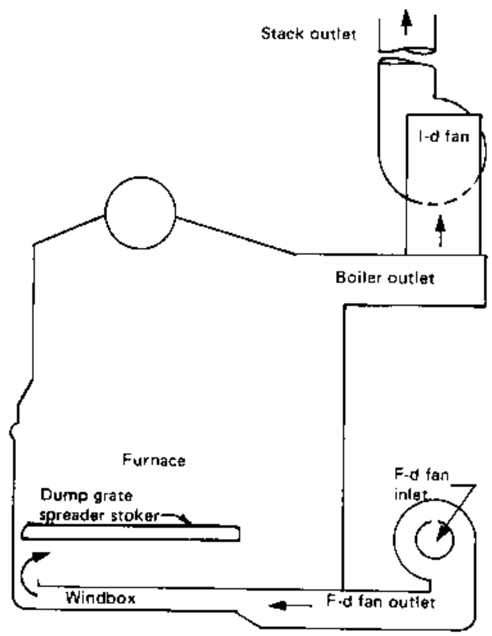

Figure 16
Balanced Draft System

Fig. 17 shows a typical balanced draft system used on large boilers (steam generators). Both fans are positioned for easy access at ground level.

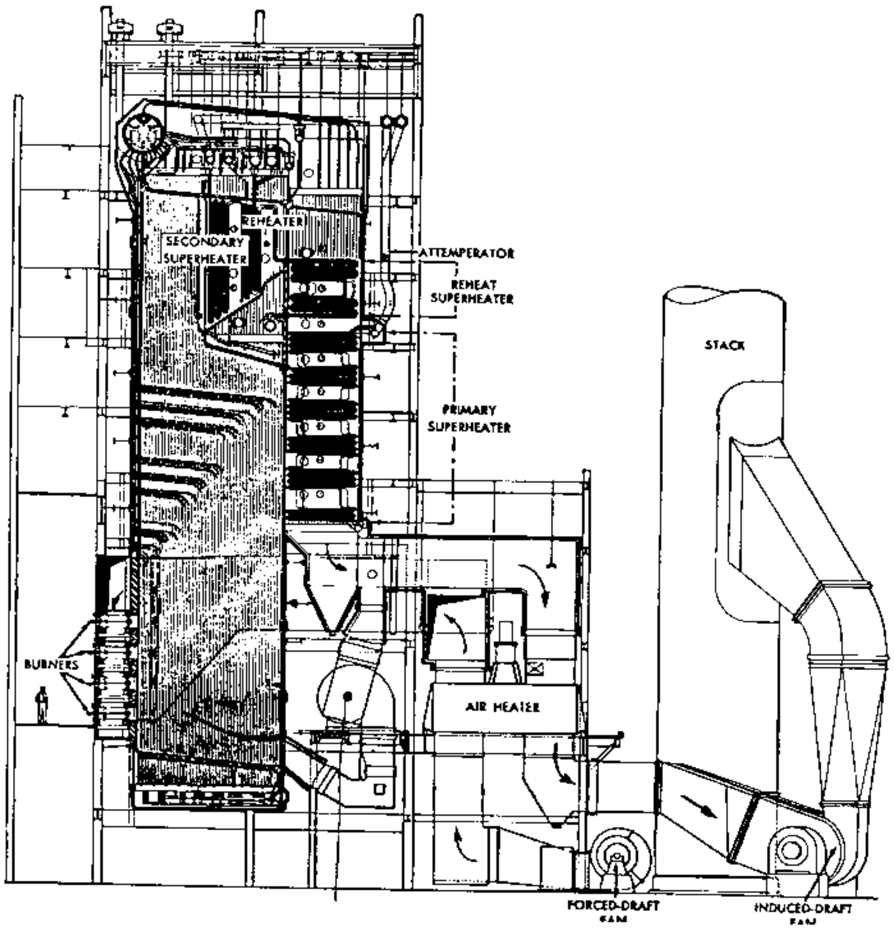

Figure 17
Gas or Oil-Fired Steam Generator

Advantages of Mechanical Draft

1. It is independent of atmospheric air temperatures.

2. It is independent of the chimney temperature, whereas for natural draft this is an important factor.

3. Mechanical draft can be regulated more accurately than can natural draft, hence steam production can be varied to suit a fluctuating demand.

4. Better draft regulation increases the efficiency of combustion.

5. The chimney needs only to be sufficiently tall to adequately disperse the flue gases.

Comparison of Forced Draft and Induced Draft

The forced draft fan handles clean cool air, which means longer fan life as well as a smaller size fan and fan drive requirement. On the other hand, the induced draft fan maintains the furnace pressure below atmospheric preventing any toxic gases from entering the boiler room. Also furnace inspection and burner openings do not require pressure sealing as is the case with a pressurized furnace. The induced draft fan impeller may be subjected to corrosive action of the flue gases and erosion due to flyash when coal is used as a fuel.

DRAFT CONTROL

The combustion process in the boiler furnace must be regulated in accordance to the demand of steam from the boiler. Combustion is regulated by controlling fuel flow and air flow into the furnace. In addition to making sure that sufficient fuel and air are admitted, the control system must maintain the proper ratio of air to fuel in order to achieve safe and efficient combustion.

When balanced draft is employed, the control system must also ensure the correct flue gas flow from the furnace in order to maintain the correct furnace pressure.

Control of Air and Flue Gas Flow

The following sections of this module will discuss the methods used for controlling the combustion air to the furnace and the flue gas flow from the furnace.

1. Register or Damper Control

When draft is produced by natural means the flow is controlled by means of an air register, see Fig. 18, at the point where the air enters the furnace or a damper at the chimney inlet.

Usually the chimney damper is perforated so that when the damper is in the closed position and the boiler shut down, a slight flow of air is maintained through the furnace thereby preventing the possibility of an explosive gas mixture build up in the furnace.

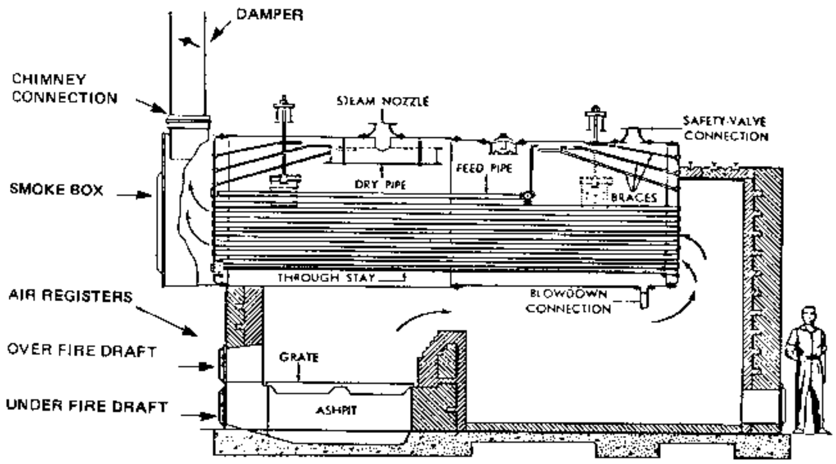

Figure 18
Natural Draft Control

2. Fan Speed Control

The most efficient operation of a fan demands that the speed be only sufficient to supply the required amount of air. This can easily be accomplished when a steam turbine drives the fan and an automatic control system is used to regulate the steam flow to the turbine by means of a throttle valve.

However, with constant speed electric motors it is necessary to find other methods to control the flow of gases. A simple method is to place a set of dampers at the fan outlet or at the fan inlet.

3. Outlet Damper Control

A damper is a simple device. It acts as a throttle valve and restricts the fan output to any desired quantity. For a fan outlet damper control, the damper is placed in the fan outlet duct. The fan output can in this case be easily controlled from minimum to maximum output.

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Fig. 19 shows a schematic diagram of an outlet damper control and Fig. 20 shows the damper control linkage.

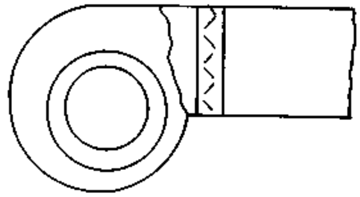

Figure 19
Outlet Damper Location

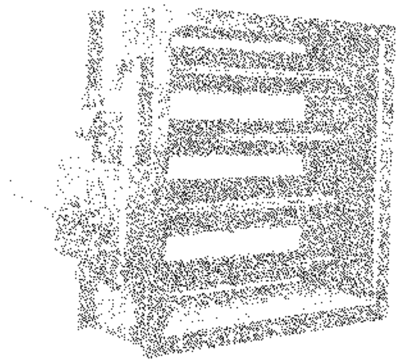

Figure 20
Damper Control Linkage

This system can be used for a forced or induced draft system. If the boiler is fitted with an air heater, a simple fan outlet damper control can be used.

Cold atmospheric air supplied by the forced draft fan is forced into the air heater as illustrated in Fig. 21. The air is passed over a nest of tubes, heated and the hot air forced into the boiler. The hot flue gases from the boiler flow through the tubes and are discharged into the stack.

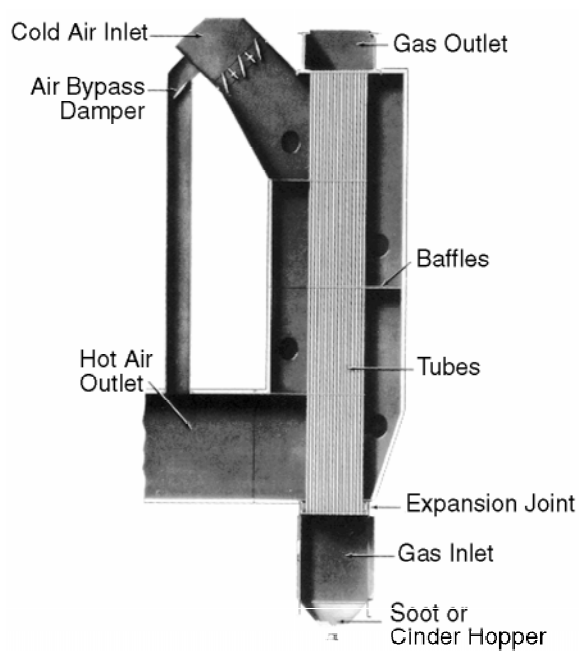

Figure 21
Air Heater with Outlet Damper Control
(Courtesy of Babcock & Wilcox)

This type of air heater, due to the increase in frictional resistance to the flow of gases, is generally used in conjunction with balanced draft systems.

Air heaters provide for more efficient and economical boiler operation. These units recover some heat, which otherwise would go to waste, from the flue gases. They add heat to the air necessary for combustion. Heated air will improve the combustion process, especially for coal-fired furnaces, and will require less fuel to generate a given quantity of steam.

4. Inlet Damper Control

Fig. 22 illustrates an induced draft fan with dual fan inlet damper control.

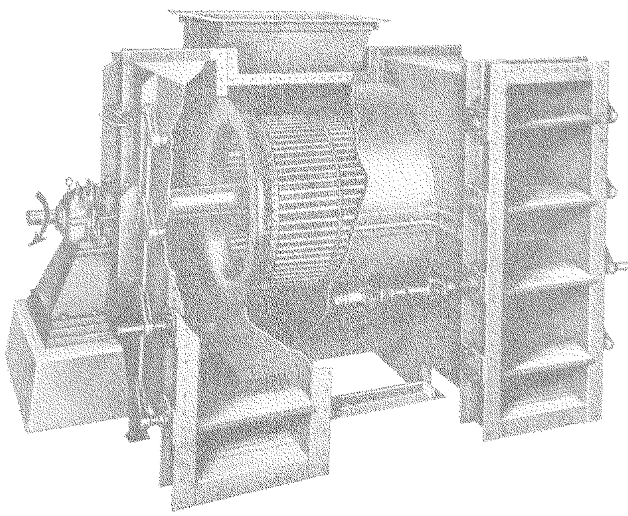

Figure 22
I.D. Fan Inlet Damper Control

The damper for controlling the combustion air flow may be located directly at the forced draft fan inlet. Fig. 23 shows this arrangement. This type of a damper is of somewhat more complicated design. However, by employing this type of design less power is required to drive the fan at reduced loads.

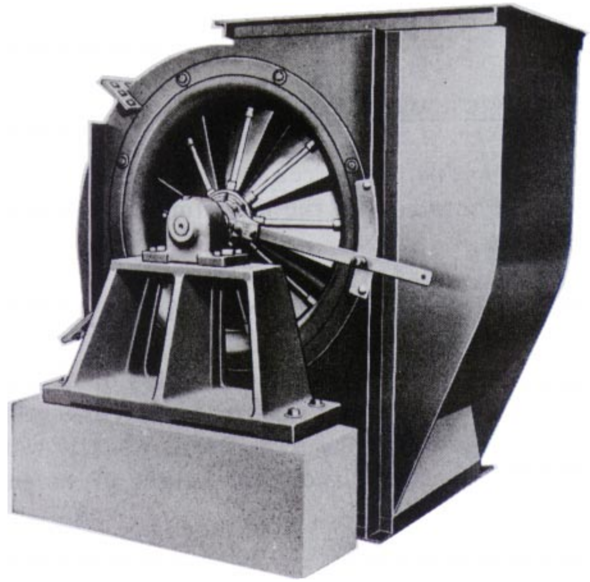

Figure 23
Forced Draft Fan with Inlet Damper Control

5. Variable Speed Coupling

The speed of a fan driven by a constant speed motor can be varied by means of a variable speed coupling. Fig. 24 shows one of these units. The initial cost for this system is high. It gives excellent fan speed control as well as requiring the least amount of energy to drive the fan at varying speeds compared to any other type of control.

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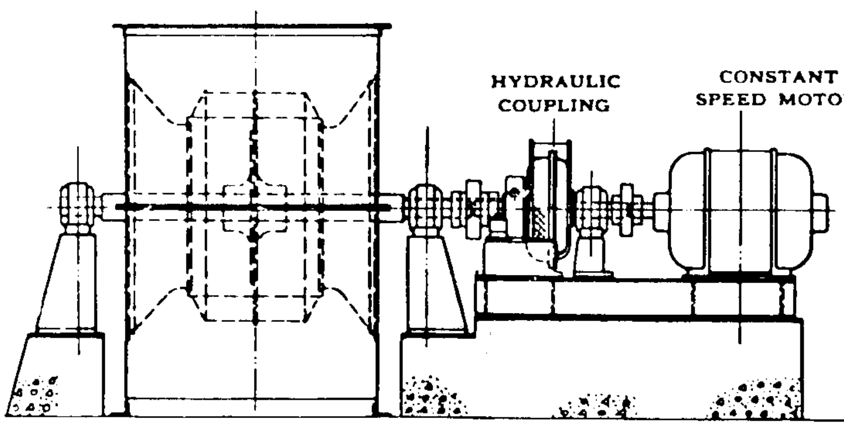

Figure 24
Variable Speed Coupling

Draft Measuring Instruments

The pressures experienced in combustion air systems are relatively low and for this reason the instruments used should be sensitive to small pressure changes. The simplest device is the **“U” tube manometer** as shown in Fig. 25.

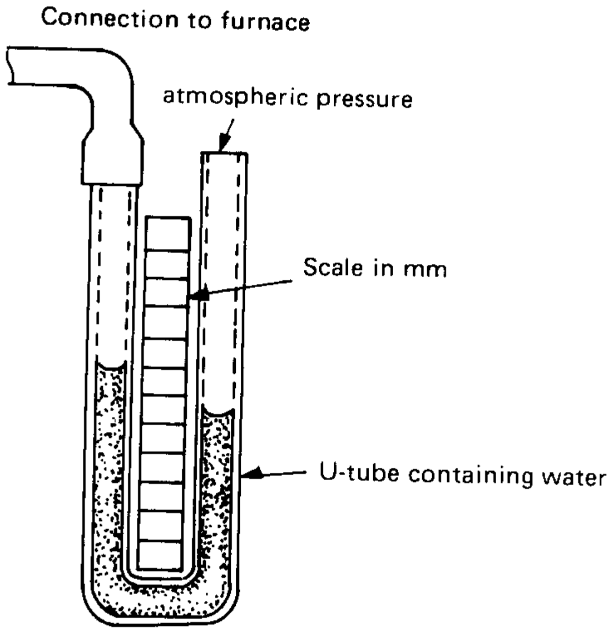

Figure 25
“U” Tube Draft Gage (Manometer)

The tube is made of glass or any other transparent material bent in the form of a “U”. With no pressure connection and both legs open to the atmosphere, the tube is filled about half full, usually with water. The surface of the liquid in one leg will then be at the same height as the surface in the other leg and the scale may be raised or lowered so that the zero line coincides with the liquid surfaces. If pressure is applied to one leg of the manometer, the liquid in that leg will be forced down and the liquid level in the other will rise. When the liquid comes to rest, the pressures in the two legs, measured above some common datum point, will be equal. That is, the force caused by the mass of the liquid in the one column will just balance the total force caused by the applied pressure and the mass of liquid in the other column.

The inclined tube manometer operates on the same principle as the “U” tube manometer and one of these is shown in Fig. 26.

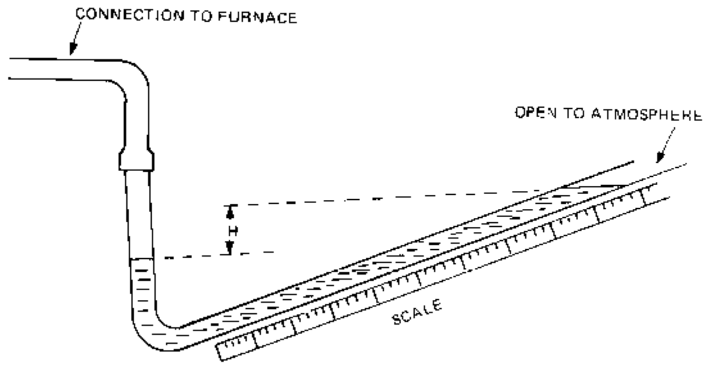

Figure 26
Inclined "U" Tube Manometer

The pressure to be measured is connected to the vertical leg while the read out is taken from the slanted or inclined leg.

Any given pressure differential between the applied and atmospheric will always create the same differential in vertical level for a given manometer liquid. By using an inclined scale, the liquid will have a greater movement over the inclined scale for the same vertical travel of the liquid. This type facilitates reading as there is only one scale to be read. Also it gives a more accurate reading for small pressure changes.

Another type of sensing element used for pressure measurements is the diaphragm gage. Referring to Fig. 27, the pressure to be measured is applied to the housing surrounding the diaphragm and this causes the diaphragm, which is made of a limp material such as rubber, to be moved. This movement is transmitted through a push rod to a cantilever spring which is linked to a pointer. This movement is used to indicate the applied pressure or to vary a control signal for transmission.

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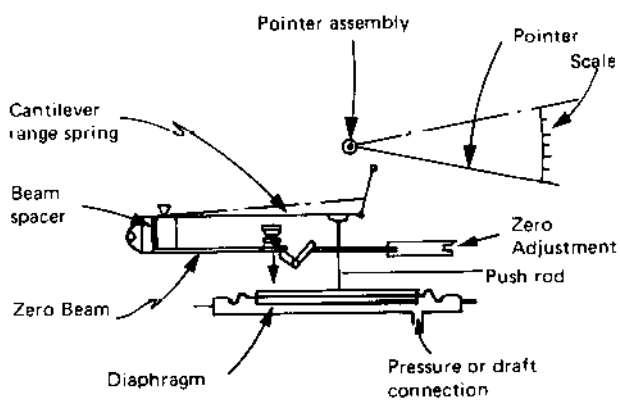

Figure 27
Diaphragm Draft Gage (Bailey Meter Co. Ltd.)

Size of Air Openings

The student should be aware of the importance of having adequate openings for the admission of combustion air in buildings containing boilers. For an enclosed boiler room it is important that adequate openings for combustion air be provided into the boiler room from the outside. These must be in addition to the boiler room doors and windows which are usually kept shut in cold weather.

The CSA code B-51 specifies the size of openings required when burning a number of heat units in a given time.

Notes: