to 12 in. water. A portion of the air or primary air required for combustion is entrained from the atmosphere by the stream of gas issuing from an orifice, and the air-gas mixture is delivered through a venturi mixing tube to the burner head and parts. About 40 to 60 percent of the air required for combustion is in the form of primary air and the remainder, known as secondary air, is supplied from the air surrounding the flame.

Each system embodies characteristics essential for certain applications. It is important that proper and qualified engineering authorities be consulted prior to the purchase, installation, or operation of industrial gas equipment.

FUEL BURNING RATES

The burning rate for automatic fuel-burning devices is determined by the gross heat output required of the boiler, or furnace, to carry the net heating load, plus allowances for system losses and pickup. General values for these allowances have been given in preceding text. Detailed information for piping and pickup allowances for steam and hot water systems, is given in Chapter 35, and for warm air systems, in Chapter 18.

When the gross output, operating efficiency, and heat value of the fuel are known, the required rate of burning can be determined by means of Figs. 17, 18, and 19 for the several fuels. As the rate of fuel-burning is directly proportional to the load for a given efficiency, these charts can be extended by moving the decimal points the same number of digits in both vertical and horizontal scales.

The correct fuel-burning rate can be determined directly from the several charts for oil or gas burning installations, as these customarily operate on a strictly intermittent basis. These fuel burning devices usually introduce the fuel at a single fixed rate during the *on* periods, and this rate should be sufficient to carry the gross load. In the case of coal stokers, which are usually capable of variable rates of firing, it is desirable to operate at as low a rate as weather conditions will permit, but the maximum firing rate of the stoker should be sufficient to carry the gross load. This rate may be determined by the same method as used for oil or gas.

CONTROLS FOR AUTOMATIC FUEL-BURNING EQUIPMENT

Controls for the automatic fuel-burning equipment described in this chapter are outlined here. The basic requirements for oil burners, gas burners and coal burners (stokers) are included and the term *burner* refers to all three types of fuel-burning equipment. Controls for these burners can be classified as *operating controls*, *limit controls* and *primary controls*. The schematic diagrams shown in Fig. 20 indicate the relationships of the basic components. The *power supply* may be line voltage for each type of burner. In control systems for domestic burners the line voltage may be reduced by means of a transformer for those portions of the circuits indicated by dotted lines. Such transformers are usually built into the stoker and oil burner *primary controls*. Control systems for domestic gas burners frequently contain a separate transformer as shown. There are domestic gas burner control systems which obtain their electrical power supply from the conversion of heat to low-voltage electrical energy, in which case no transformer would be required. As the burner sizes increase, the tendency to use all line voltage controls increases in each of these general categories.

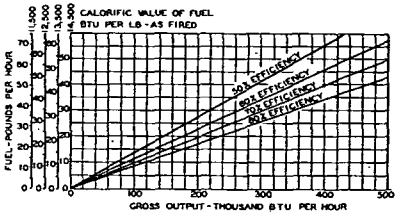
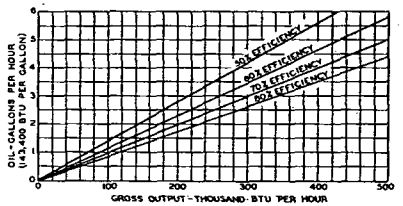


Fig. 17 .... Coal Fuel-Burning Rate Chart



[a] This chart is based upon No. 2 oil having a heat content of 143,400 Btu per gallon. If other grades of oil are used multiply the value obtained from this chart by the following factors: No. 1 oil (139,000 Btu per gallon) 1.032; No. 4 oil (144,500 Btu per gallon) 0.992; No. 5 oil (148,000 Btu per gallon) 0.982; and No. 6 oil (150,000 Btu per gallon) 0.956.

Fig. 18 .... Oil Fuel-Burning Rate Chart[a]

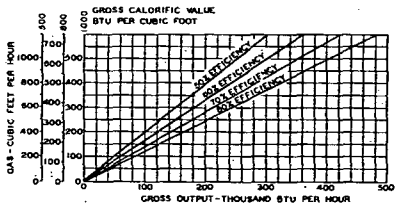
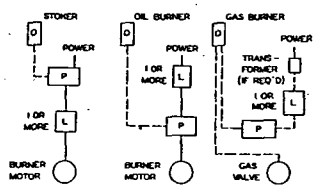


Fig. 19 .... Gas Fuel-Burning Rate Chart



(O = *Operating Control*; P = *Primary Control*; L = *Limit Control*)

Fig. 20 .... Schematic Diagrams of Some Typical Burner Control Systems

Operating Controls

Operating controls initiate the starting and stopping of the burner and on larger burners they usually vary the fuel and air input to the combustion chamber in response to varying load demands. For residential and small commercial heating plants with fuel inputs up to aproximately 500,000 Btuh, the *operating controller* is usually some form of room thermostat which automatically starts and stops the burner through the *primary control* as the *limit controls* permit. As the size of the heating system increases, the use of a room thermostat as the *operating controller* for the burner becomes less common. An insertion thermostat (for furnaces), immersion thermostat (for hot water boilers) or pressure controller (for steam boilers) may be applied as an *operating controller*. Also, such devices as submaster and compensated controllers (which are reset from outdoor temperature for governing the bonnet temperature in large furnaces or the water temperature in a boiler) come into more frequent use on the larger installations. The still larger burners are usually equipped to vary the rate of fuel and air input in response to varying load demands.

Limit Controls

Limit controls guard against unsafe temperature, pressure or water level to assure that safe conditions prevail for the operation of the burner. Regardless of the type of fuel burned, draft controls increase combustion efficiencies and reduce flue gas loss by maintaining proper draft conditions at all times. For fuel input requirements above approximately 1,000,000 Btuh, some additional factors become common to all types of burners. For example, the draft in the firebox is controlled at a suitable constant for all firing rates, including the *off* period, by measuring the draft conditions in the firebox and actuating a *damper operator* to position the damper at the boiler outlet. Where necessary, provision may be made to open the boiler outlet damper wide before permitting the burner to start and then to return this damper to automatic control after the burner has been started. Also, the firing rate of these larger burners is frequently automatically adjustable. Provisions are made for always starting the burner on its low firing rate, with facilities for increasing the firing rate slowly after the burner has been started. It is not recommended and codes seldom permit the use of one and the same instrument as both an *operating controller* and a *high limit control*. In such cases an *operating controller* will be adjusted to control at the desired set point while the *high limit control* will be adjusted to stop the burner at some higher point in the event that the *operating controller* fails to stop the burner before the higher shut-off point is reached. For example, to maintain a constant water temperature in a hot water boiler, the operating controller may be set to stop the burner when the boiler water temperature reaches 180 F. The *high limit control* should then be set to stop the burner at about 200 F.

Various interlocks or limit controls are usually included to assure safe operation of these larger burners. A latch-switch interlock prevents burner operation if the burner is not in its proper firing position. Another interlock must prove that the burner is in its low-fire position before the burner can be started. Safe draft conditions should be proved before the burner can be started or allowed to run, especially where induced draft fans are involved. A smoke detecting device may sound an alarm and stop the burner if excessive smoke is produced. Also, protection against electrical overloads must be provided.

Primary Controls

Primary controls provide for the safe start and operating procedure of the burner. They are somewhat different for each of the three types of fuel burners.

1. *Stokers.* Stokers are equipped with refueling, or *hold-fire*, controls. These *primary controls* cause the stoker to intermittently feed a predetermined amount of coal during the long *off* periods of the *operating controller* to maintain ignition and to reduce the possibility of having idle fuel beds damage stoker castings. In some cases the *primary control* system includes an *out-fire* feature which stops the feeding of coal into the firebox if the fire goes out.

2. *Oil Burners. Primary controls* required for oil burners depend on the size and type of burner. Some of the more common *primary controls* are discussed in following paragraphs a to d.

a. Domestic oil burners of the vaporizing type usually require a *primary control* that will (1) meter the correct amount of oil into the burner to maintain the pilot flame; (2) regulate the required amount of oil into the burner for its high flame operation; and (3) completely shut off the flow of oil in the event of a flame failure.

b. Domestic oil burners of the pressure-atomizing type require a *primary control* that will (1) energize the burner motor and electric ignition; (2) test for the establishment of main burner flame and stop the burner and ignition if flame has not been established; (3) cut off the ignition after a safe burner flame has been established (does not apply to constant ignition type burners); (4) monitor the flame continuously during burner operation and stop the burner in the event of flame failure (manual reset is necessary following a flame failure lock-out); and (5) stop the burner when either the *operating controller* or *limit control* requires it.

c. Commercial and industrial oil burners of the pressure atomizing type have *primary controls* that are essentially the same as those outlined for domestic oil burners of the pressure atomizing type. In addition, some models are equipped with a solenoid oil-shut-off valve to provide a pre-purge period, if desired, and a quick shut-off of the oil flow when the burner is stopped.

d. Commercial and industrial oil burners of the horizontal rotary-cup type are usually equipped with a more elaborate *primary control* system. The primary control is often described as a programming combustion safety control. Its most important operations include (1) starting the burner upon a call for heat; (2) providing a pre-purge period before activating the gas-electric ignition; (3) proving the presence of proper ignition before permitting the flow of oil to the main burner; (4) proving the presence of a stable main burner flame within a predetermined period of time; (5) shutting off the gas-electric ignition after a predetermined length of time has elapsed; (6) monitoring the main burner flame during its entire *on* period and stopping the burner quickly in the event of a flame failure (it is usually required that the flow of oil through the burner be stopped within four seconds following a flame failure); (7) stopping the flow of oil through the burner when either the *operating controller* or a *limit control* requires it; (8) operating the burner for a predetermined length of time after the main fuel valve has been closed; and (9) locking out on a flame failure shutdown (the programming control then must be manually reset prior to a restart).

When steam-, air-, or mechanical-atomizing burners are