## COMBUSTION OF GASEOUS FUELS

Gas burners employed in domestic heating appliances are generally of the non-luminous flame or Bunsen type. Part of the air required for combustion is inspirated as *primary air* into the burner mixing tube where it mixes with gas, and then takes part in combustion at the burner ports. As the amount of primary air is seldom sufficient to support complete combustion, additional air is supplied to the burner flames around the periphery of its ports. This *secondary air* is induced into the appliance and around the base of each separate burner flame by force of the issuing mixture of gas and primary air and by draft inspiration inherent in the heat of the flames. If a Bunsen type burner is properly adjusted, its flames will generally have a clear, blue appearance. Yellow flames are indicative of insufficient primary air supply, and possibly of incomplete combustion. An appreciable updraft is seldom, if ever, present even in flue-connected gas heating appliances, because most appliances of this kind are equipped with a draft hood which reduces the chimney draft at the appliance. It is important to note that gas furnaces and boilers, as well as most other classes of heating equipment, are designed to create their own draft.

The air-to-gas ratio in a Bunsen burner head has a decided effect on the rate of flame propagation. The gas-air mixture must flow from the burner ports faster than the flame burns, otherwise flashback will occur. The flashback condition normally results either from an excess amount of primary air or insufficient gas or both. Conversely, the velocity of the issuing mixture must not be so high that the flame will be blown from the ports, a condition known as *lifting*. Fortunately, contemporary types of such burners have a rather wide range of flexibility in capacity and adjustment. In addition to this characteristic, gas supply is normally so uniform that if a gas heating appliance is properly adjusted when it is installed, its burners, with occasional cleaning, should provide trouble-free service for years.

To insure proper combustion in gas appliances it is necessary that the burners, mixing tubes, and gas orifices be correct for the gas being burned. These parts are generally labeled or tagged to assure the installers that they are correct.

The next consideration is to make certain that the gas pressure in the burner manifold (which is usually measured by a water U-gage) is that used as a basis for determining the orifice size. From a reading of the gas meter the gas input can be obtained as a product of the gas volume and the heat value of the gas. This input should not exceed the AGA rating shown on the appliance nameplate.

If the input requires only a small change to equal rating it can be made by adjusting the gas pressure regulator to change the manifold pressure. A large correction of input, however, will require a change in orifice size. When the input is right the air shutters should be given final adjustment and locked in place.

Luminous flame burners are occasionally used in central heating gas appliances. With these devices all air required for complete combustion is supplied to the flames as secondary air. If there is any appreciable amount of flame impingement on any portion of the heating surface, or if secondary air is not effectively supplied to the flames, soot may be formed and also combustion may be incomplete.

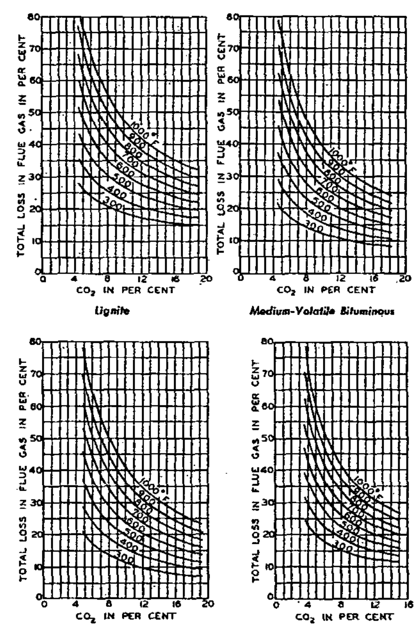
In some types of gas burners radiant baffles are used to convert part of the energy formed during the process of combustion to radiant heat. These baffles may also serve to direct the flow of products of combustion along the heat-absorbing surface.

Gas-designed furnaces and boilers approved by the American Gas Association are certified for operation at the rating shown on the nameplate. Appliances are available that have a wide range of allowable input. In the case of some forced warm air furnaces, this may be down to 50 percent of full input. For installations above 2000 ft elevation the maximum ratings must be reduced by 4 percent for each 1000 ft of elevation above sea level. Considerations relating to safety, performance, and service life, require that such appliances be adjusted at inputs that do not exceed the nameplate input rating. These appliances normally draw in from 20 to 50 percent excess air, depending on the type and general design. As has been indicated, some excess air is necessary to insure complete combustion at all times and also to provide a reasonable degree of flexibility in performance.

Various types of appliances used for gas space heating purposes are described in Chapter 34.

## FUNDAMENTAL PRINCIPLES OF COMBUSTION

Regardless of the type of fuel under consideration, its combustion results in the production of gaseous products. Many kinds of solid fuels contain minerals which cannot be burned and are therefore left as a residue commonly called




*Flue Gas Temperature Shown. Loss is Based on 65 F Room Temperature*

Fig. 4 . . . . Flue-Gas Losses with Various Fuels[2]

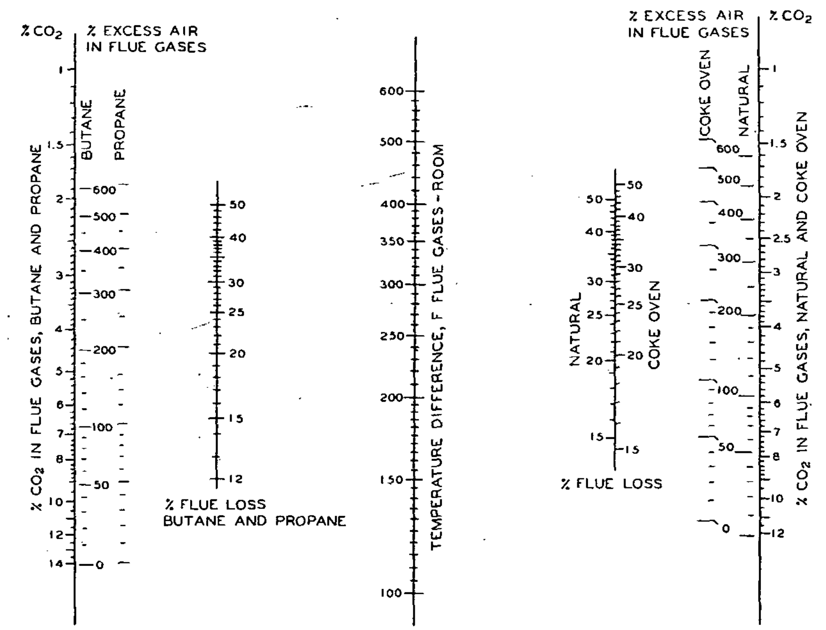


ash. Moreover, unless sufficiently high temperatures are employed and an ample supply of oxygen properly distributed is present, the combustible constituents of solid, liquid, and even gaseous fuels cannot be completely burned. Incomplete or partial combustion of all fuels produces toxic gases, such as carbon monoxide, with smaller quantities of aldehydes, ketones, and other hydroxylated hydrocarbon compounds. This fact indicates that, while combustion processes involving common types of fuel may be regulated by experienced operators to produce the most efficient results, normal combustion processes can be so unbalanced as to create hazards unless both design and operation are planned with a knowledge of the fundamental principles of combustion.

*Combustion* may be defined as the chemical combination of a substance with oxygen resulting in the evolution of heat, and usually some light. The rate of combustion depends upon the rate of reaction of the substance with oxygen, upon the rate at which oxygen is supplied, and upon the temperature obtained due to surrounding conditions. This is combustion in its simplest form. All solid, as well as liquid and even gaseous fuels generally contain several combustible elements in combination with others which, depending on their nature, affect oxygen requirements and thus govern the combustion process. For a continuous reaction, as in heating processes, it is necessary to establish an effective balance between rates of removing heat and of supplying fuel and air or oxygen to keep the reaction going. In establishing such a balance, consideration must be given to the removal or venting of products of combustion, so that the entire process is one of flow wherein draft conditions in the combustion space are important.

*Complete combustion* is obtained when all combustible elements in a fuel are oxidized by all of the oxygen with which they will combine. All oxygen or air supplied is generally not utilized, and this excess portion is commonly called *excess oxygen* or *excess air* and expressed as a percentage of the air required for perfect combustion.

*Perfect combustion* results when the exact amount of oxygen required for complete combustion of all elements of a fuel is supplied and utilized. The percentage of carbon dioxide contained in the products of combustion from such a reaction is obviously the maximum attainable and is referred to as the ultimate $CO_2$ or *maximum theoretical percentage of carbon dioxide*. This condition of perfect combustion, without having excess air or oxygen left from the reaction, is seldom, if ever, realized in practice. Most types




Adapted from American Gas Association Laboratories Flue Loss Charts.

Fig. 5 . . . . Alignment Chart for Calculation of Flue Losses for Butane, Propane, Coke Oven, and Natural Gases