The heat that is reclaimed by the condensation of the water vapor amounts to about 10 per cent of the total heat value. It is practically impossible to utilize the entire higher heat value of the gas in any house heating appliance, because to do so it would be necessary to cool the products of combustion down below their dew-point, which is ordinarily in the neighborhood of 130 deg.

The heat balance of a gas-burning heating boiler or furnace, therefore, includes the following items:

Heat in the dry flue gas.
Heat in the water vapor.
Heat loss due to incomplete combustion.
Heat loss through radiation.
Heat absorbed by the water or air in the boiler or furnace.

THEORETICAL EFFICIENCIES

Table 1 shows the maximum theoretical efficiencies when burning a typical manufactured gas with various stack temperatures. These are based on the higher heat value of the gas, and do not include any correction for radiation from the boiler covering. Radiation will reduce these efficiencies as much as 5 per cent, depending on the insulating properties of the covering. The gas is assumed to be burned with 35 per cent excess air and has the following composition:

CO	8.6 per cent	
H_2	52.5 " "	
CH_4	31.6 " "	
C_2H_4	1.1 " "	Heat value per cubic foot at 60 deg. fahr.
C_6H_6	1.1 " "	and 30 in. hg., 535 B.t.u.
O_2	0.1 " "	Specific gravity 0.58 (air = 1)
CO_2	1.5 " "	Air Temperature 60 deg. fahr.
N_2	3.5 " "	Atmospheric moisture neglected.
	100.0 per cent	

It will be seen from Table 1 that the maximum attainable efficiency under practical operating conditions, which include the necessity of having a stack temperature sufficiently high to insure a good draft, and with a normal radiation loss, is approximately 80 per cent.

AIR FOR COMBUSTION

Most gas appliances consume the gas with a blue or Bunsen flame, although some room heaters use a luminous or yellow flame. Bunsen flames and luminous flames differ in the way in which the air necessary for combustion is supplied. Bunsen type burners are provided with an external mixer, in which a portion of the air is mixed with the gas previous to ignition. This is called *primary air*. The aspirating effect of the jet of the mixture issuing from the burner ports, and the chimney effect of the gas passages above, draw currents of air past the flame and into it, in sufficient quantity to cause complete combustion. This is known as *secondary air*. In order for combustion to be complete and for the products to be free of carbon monoxide, it is necessary that heating surfaces be

sufficiently high above the burner to prevent the pale blue inner cone, which is a characteristic part of a Bunsen flame, from striking any cold heating surfaces. A yellow tip on the flame indicates insufficient primary air and is corrected by opening the adjustable air shutters.

Some room heaters which consume gas in very small amounts use the luminous flame. A luminous flame is limited in its application to appliances burning small amounts of gas. No part of a luminous flame can be allowed to touch any cold surface, as this will result in incomplete combustion with the formation of soot and carbon monoxide.

Table 2 shows the heat values of a cubic foot of each of three common varieties of gas, together with the theoretical air requirements and the air requirements with 50 per cent excess. In practice excess air must be admitted to the fire in order to insure complete combustion.

TABLE 1. PRODUCTS OF COMBUSTION AND THEORETICAL EFFICIENCIES WITH A TYPICAL MANUFACTURED GAS

Stack Temperature (deg. fahr.)	250	275	300	350
Heat in Dry Flue Gas above 60 deg. (%)	3.57	4.05	4.52	5.48
Heat in Water Vapor above 60 deg. (%)	9.13	9.22	9.30	9.47
Heat absorbed by boiler, or efficiency (%)	87.30	86.73	86.18	85.05
Radiation (not calculated)	0	0	0	0
	100.00	100.00	100.00	100.00

Flue Gas Analysis CO_2 11.18% O_2 5.63% N_2 83.19%

TABLE 2. VOLUME OF AIR REQUIRED FOR COMBUSTION OF DIFFERENT GASES

Gas	B.T.U. per Cubic Foot	Theoretical Air per Foot of Gas Cu. Ft.	Actual Air with 50 Per Cent Excess Cu. Ft.
Natural Gas	1131	10.70	16.05
Coke Oven Gas	560	4.78	7.17
Mixed Coke Oven and Water Gas	537	5.03	7.55

In designing and installing gas-burning equipment, particularly where large amounts of gas are to be consumed, it is important that provision be made for the easy access of sufficient air to support combustion and to provide boiler room ventilation. Very little motive force exists to draw air into the boiler room. Therefore, the opening through which it enters must be large enough to keep the velocity to a very low value.

FUEL COSTS WITH GAS

In comparing the cost of gas with that of other fuels, a common basis should be used. This is usually taken as the cost per 1,000,000 B.t.u. and for gas involves consideration of the calorific value of the fuel, the overall efficiency and the average gas rate, which should include the demand rate as well as the commodity rate.

The chart (Fig. 1) can be used for estimating the cost per 1,000,000 B.t.u. for both manufactured and natural gas for various efficiencies and average gas rates. This chart is based on a heat content of 535 B.t.u. per cubic foot for manufactured gas and 1,000 B.t.u. for natural gas.