jet and the gas burns with a large yellow flame. As the holes in such burners must be small, appliances using them cannot burn gas in large quantities. A luminous gas flame must not be permitted to touch any cold solid surface as this will result in arrested or incomplete combustion, the deposit of soot and the formation of carbon monoxide.

Blue flame or Bunsen type burners are provided with an external mixer in which a portion of the air (about 2 cu. ft. per cubic foot of gas) is mixed with the gas previous to ignition. This is called primary air. The flame issuing from the port of the burner has two distinct parts: a pale blue inner cone and a darker cone surrounding it. The heat of the flame issuing from the burner port draws currents of air past the flame and into it in sufficient quantity to cause complete combustion. This is known as secondary air. The flame should sit squarely on the port and should not have a yellow tip. A yellow tip indicates insufficient primary air, and is corrected by opening the adjustable air shutter.

It should be noted here that the proportions of the orifice at the entrance to the burner tube, and the proportions of the burner ports must suit the heat content of the gas being burned. A burner proportioned for natural gas is not suitable for water gas or coal gas, which are much bulkier in relation to their heat contents.

Table 83 shows the heat values of a cubic foot of gas and air mixture, the gas being mixed with the amount of air theoretically required to burn it. In practice excess air must be admitted to the fire in order to insure complete combustion.

TABLE 83. VOLUME OF AIR REQUIRED FOR COMBUSTION OF DIFFERENT GASES*

GAS	B.T.U. PER CUBIC FOOT	CU. FT. AIR TO BURN CU. FT. GAS	B.T.U. PER CU. FT. OF MIXTURE
Natural Gas	1084	10.27	96.2
Coal Gas—Rich	580	5.21	93.4
Coal Gas—Lean	510	4.43	93.9
Carburetted Water Gas	575	5.02	95.5

*Thomas King. *American Gas Journal*, October 22, 1921.

HEAT VALUE AND EFFICIENCY

A gas may be said to have two heat values; a gross or *higher* heat value and a net or *lower* heat value. The higher heat value is the entire heat that is liberated by the gas when it is burned completely. The complete combustion of a gas results in the formation of water vapor; the amount depending on the proportion of hydrogen or hydrocarbons in the gas. In order to utilize completely all of the heat of combustion of the gas it would be necessary to condense the water vapor in the products of combustion; thus reclaiming its latent heat of vaporization, and then to cool down the water to the starting temperature.

To condense any of the water vapor in the products of combustion it is necessary to cool them down to the dewpoint, which will always be below 212 deg. This is what is done in a calorimeter, but it is obviously impossible to do it in any commercial gas-burning appliance. Since it is not

possible to utilize all of the heat liberated by the gas in burning, the heat value is sometimes expressed in terms of the lower value; obtained by deducting from the higher value, the total heat of the water vapor down to the starting temperature. The lower heat value is always about 10 per cent less than the higher heat value.

Although it is practically impossible to utilize the higher heat value in any house heating appliance, it is nevertheless customary to express boiler and furnace efficiencies in terms of this higher value. This gives a lower efficiency than one calculated from the lower heat value and is of course based on an unattainable standard, but it is a more accurate and consistent way of expressing efficiencies. An appliance may reclaim a little bit of the latent heat of the water vapor. If the test efficiency of such an appliance is calculated from the lower heat value, one is placed in the position of crediting the appliance with some heat that was not charged against it. Although quoted efficiencies are usually based on the higher heat value, care should always be taken to understand which standard guaranteed efficiencies are based on.

For example.—Take an hypothetical gas having a gross heat value of 550 B.t.u. per cu. ft. and a net heat value of 500 B.t.u. per cu. ft., burned in a steam boiler giving an evaporation of 465 lb. of water (from and at 212 deg.) per 1000 cu. ft. of gas burned:

$$\text{Efficiency} = \frac{\text{B.t.u. in steam}}{\text{B.t.u. in gas}} \times 100 = \frac{465 \times 970.4}{\text{cu. ft.} \times \text{heat value}} \times 100$$

$$\text{With Gross Value Efficiency} = \frac{451{,}235}{550{,}000} \times 100 = 82.04 \text{ per cent}$$

$$\text{With Net Value Efficiency} = \frac{451{,}235}{500{,}000} \times 100 = 90.25 \text{ per cent}$$

It will be noted from the example cited that when the efficiency is based on the net or lower heat value, the appliance apparently absorbs 8.21 per cent more of the heat supplied to it than when the efficiency is based on the gross heat value.

The following Table 84 shows the maximum possible efficiencies obtainable when burning a typical manufactured gas with various stack temperatures. These are based on the gross heat value and do not include any correction for radiation from the boiler covering. Radiation would reduce these efficiencies from 2 to 10 per cent depending on the insulating

TABLE 84. PRODUCTS OF COMBUSTION AND EFFICIENCIES WITH TYPICAL MANUFACTURED GAS

Stack Temperature (deg. fahr.)	220	235	250	265	280
Heat in Dry Flue Gas above 60° (%)	3.25	3.57	3.90	4.14	4.28
Heat in Water Vapor above 60° (%)	9.95	10.03	10.10	10.16	10.22
Heat absorbed by Boiler or Efficiency (%)	86.80	86.40	86.00	85.70	85.50
	100.00	100.00	100.00	100.00	100.00

Flue Gas Analysis

CO_2 8.04% O_2 5.86% N_2 86.10%