The air gas ratio has a decided effect upon flame propagation. It is necessary that the gas will flow out of the burner ports fast enough so that the flame cannot travel back into the burner head, i.e. *flash back*, but the velocity must not be so high that it blows the flame away from the port.

The maximum and minimum flow speeds from burner ports which may be permitted are known to be very close together when air-gas mixtures in theoretical proportions are being supplied to the burner. As the air-gas ratio is lowered, and the mixture becomes more *gas rich*, the limiting speeds become farther apart, until with 100 per cent gas, in an all-yellow flame, flash back cannot occur and a much higher velocity is needed to blow off the flames.

## SOOT

The deposit of soot on the flue surfaces of a boiler or heater acts as an insulating layer over the surface and reduces the heat transmission to the water or air. The *Bureau of Mines Report of Investigations* No. 3272[5] shows that the loss of seasonal efficiency is not so great as has been believed, and usually is not over 6 per cent because the greater part of the heat is transmitted through the combustion chamber surfaces. The *Bureau of Standards Report* BMS 54[6] points out that, although the decrease in efficiency of an oil fired boiler due to soot deposits is relatively small, the attendant increase in stack temperature may be considerable.

Table 10. Average Flue Gas Dew-Point for Various Fuels[8]

| Type of Fuel | Average Dew-Point Temperature, F |
|---|---|
| Anthracite | 68 |
| Semi-Bituminous Coal | 84 |
| Bituminous Coal | 93 |
| Oil | 111 |
| Natural Gas | 127 |
| Manufactured Gas | 137 |

The soot accumulation clogs the flues, reduces the draft, and may prevent proper combustion. Soot can probably be most effectively removed by a jet of compressed air or by means of a brush. However, it has been found that copper chloride, lead chloride, tin chloride, zinc chloride, common salt and some other salts are partially effective in removing soot from furnaces and boilers when properly used.[7]

## CONDENSATION AND CORROSION

Sulfur dioxide or sulfur trioxide formed by the combustion of sulfur in fuels is the principal corroding element in flue gases, and becomes active whenever moisture is present for the formation of sulfurous or sulfuric acid. It is necessary, therefore, to maintain a flue gas temperature in excess of the dew-point temperature of the flue gases in all parts of appliances unless they are made of materials that will resist these corrosive influences. It is usually desirable to maintain a flue gas temperature above the dew-point temperature throughout the heating appliance and the chimney or smokestack because of these same corrosive effects. The average dew-point temperatures of the flue gases from the several fuels, when burned with the amount of excess air usually supplied to insure complete combustion, are shown in Table 10.



## LETTER SYMBOLS USED

$h_1$ = heat loss in the dry chimney gases, Btu per pound of fuel.

$h_2$ = heat loss in water vapor from combustion of hydrogen, Btu per pound of fuel.

$h_3$ = heat loss in water vapor in combustion air, Btu per pound of fuel.

$h_4$ = heat loss from incomplete combustion of carbon, Btu per pound of fuel.

$h_5$ = heat loss from unburned carbon in the ash, Btu per pound of fuel.

$w_g$ = weight of dry flue gas per pound of fuel (from Equation 6), pounds.

$c_p$ = mean specific heat of flue gases at constant pressure.

$t_g$ = temperature of flue gases at exit of heating device, Fahrenheit degrees.

$t_a$ = temperature of combustion air, Fahrenheit degrees.

$H_2$ = percentage of hydrogen in the fuel by weight from ultimate analysis of fuel as fired.

$M$ = humidity ratio of combustion air, pounds of water vapor per pound of dry air.

$w_a$ = weight of combustion air per pound of fuel used, pounds.

$C$ = weight of carbon burned per pound of fuel corrected for carbon in ash, pounds.

$C_u$ = percentage of carbon in the fuel by weight from the ultimate analysis.

$CO$, $CO_2$ = percentages of $CO$, $CO_2$ in the flue gases by volume.

$W_a$ = weight of ash and refuse, pounds.

$C_a$ = per cent of combustibles in ash and refuse by weight.

$W$ = weight of fuel used, pounds.

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[3] Quality of Anthracite as Prepared at Breakers, 1935 (*U. S. Bureau of Mines Report of Investigation*, R. I. 3283).

[4] Hand Firing Soft Coal Under Power Plant Boilers (*U. S. Bureau of Mines Technical Paper* No. 80).

[5] Effect of Soot on Heat Transmission in Boilers (*U. S. Bureau of Mines Report of Investigation* No. 3272).

[6] Effect of Soot on the Rating of an Oil-Fired Heating Boiler (*National Bureau of Standards Report* BMS 54).

[7] Removal of Soot from Furnaces and Flues by the Use of Salts and Compounds, by P. Nicholls and C. W. Staples (*U. S. Bureau of Mines Bulletin* No. 360).

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