

THE RELATION OF FLUE GAS ANALYSIS TO  
THE EFFICIENCY OF THE OIL BURNERGEORGE T. PARKER AND H. A. GEAUQUE, LOMBARD COLLEGE,  
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## INTRODUCTION

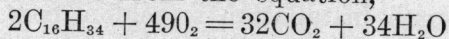
The extensive use of fuel oil in all types of furnaces gives economic importance to standards of furnace control. The small installation is seldom controlled from the measurements of a testing engineer as the variations in the efficiency of the installation seldom amount to enough to warrant the employment of an engineer. The large installations, however, are being controlled by the modern methods which have been developed for coal fired furnaces. These methods are tests of the intensity and quantity of combustion and, when applied to the combustion of fuel oil, indicate the efficiency of the furnace, provided, of course, they are interpreted in the right way.

Because of the rapid development of the oil burner industry, the discussion of the efficiency of the oil combustion has been left largely to the salesmen or promoters, while the factory engineers have been busy developing the production efficiency of the plants. Efficiency standards have been set by argumentation rather than being based upon information gained in the industrial laboratory. As a result many exaggerated claims have been made regarding the efficiency of the furnace, including claims of more than 17 per cent carbon dioxide in the flue gas. Of the many claims of advantage of the oil burned over the coal fired furnace the flue gas analysis should show the relation in efficiency of starting, change in load, and complete combustion.

## COMBUSTION EFFICIENCY

The type of fuel used varies considerably, but with the lighter fuel oils, the average hydrocarbon indicated by the properties of the oil is probably represented by the formula  $C_{10}H_{34}$ . The quantity of this oil, or the percentage, cracked during vaporization, probably varies considerably, but the ease with which it is distilled would indi-

cate that it is stable at the moderate temperatures. The vaporization in the burner is at a point where a large quantity of air is being admitted to the fire pot. The cool air keeps the temperature of this part of the fire pot very much lower than that of the flame. On the assumption that only a very small per cent of the hydrocarbon is cracked, the maximum percentage of carbon dioxide in the cooled flue gas can be calculated by calculating the combining volumes from the equation,



If we assume that the ratio of oxygen to air is 1 to 5, the reaction will be expressed by volume as follows:

2 volumes Distillate + 245 volumes Air =

32 volumes CO<sub>2</sub> + 196 volumes N<sub>2</sub> and inert gases

This gives us a ratio of 32 volumes of CO<sub>2</sub> in a total of 228 volumes of flue gas, which gives a percentage of 14.03% carbon dioxide as the maximum percent possible in the cooled flue gases. The maximum carbon dioxide from oil combustion is calculated by F. D. Harger<sup>1</sup> as 15.395% from the analyses of the oil given as C = 84.0; H = 14.0; O = 1.2; S = 0.4; N = 1.7. The calculation of the maximum percent of carbon dioxide possible from the combustion of the above oil is 12.52%.

The cracking and dissociation at the high temperature of the flame give the combustion a process of oxidation of carbon and hydrogen as dissociated in the flame rather than a molecular reaction. This change in the condition of these elements would not, however, change the resultant compounds found in the flue gases.

#### EXPERIMENTAL

Two types of burners were studied—the vaporization and the spray types. The temperatures were measured by means of a thermo-couple and potentiometer. A modified form of the Orsat gas analysis apparatus was used in analyzing the flue gases.

In the spray type found in the market at present, the oil being sprayed by air pressure, the quantity of air seems to be governed by the necessity of spraying the oil rather than by the amount necessary for combustion

<sup>1</sup> F. D. Harger, Fuel Oil, Vol. 11, No. 6, p. 9.

and by attempts to lower the air supply. The study of the effect of the air supply upon the efficiency resulted in the stopping of the spray and the burner, of course, was extinguished. The maximum carbon dioxide from this type of burner was found to vary between 4 and 5 per cent, 4.6 being the average. These conditions can probably be made more favorable by several adjustments, but it was found impossible by the author to keep the oil supply constant and change the amount of air supplied to the burner. In this type of burner, the oil supply, of course, depends upon the velocity of the air current.

In the studying of the vaporization type of burner, the air could be controlled and the relationship of the temperature to the quantity of air necessary for the maximum efficiency was easily found. Figure 1 shows the relationship between the temperature and the percentage of carbon dioxide in the flue gas. The oil supply was held constant during these readings and the air supply was diminished. The maximum air supply that the burner could possibly use was used as a starting point and the readings were taken as the air supply was diminished. As is indicated on the curve, both the percentages of carbon dioxide and the temperature were found to increase to approximately 8.3% carbon dioxide. After that a quick break in the curve, indicating a lower temperature, shows that above this point, at least, the efficiency was quickly lowered on the carbon dioxide curve between 6.6 and 8.3%. There was only a comparatively small change in temperature, and this would indicate that an average in this range would be perhaps the most efficient in this condition. The conclusion from a study of the flue gases of the ordinary marketed types of oil burners can be summed up as follows:

1. A control of the air supply is very advantageous.
2. The air supply should be such that the carbon dioxide in the gas should come between 6.6 and 8.3%.
3. The construction of the burner should be such that a change in regulation would not affect the mechanical action of the burner.

4. An excess of forced air should be avoided because of the serious cooling effect it has upon the flue gas.

