between domestic grades and between commercial and industrial grades. The relation between the *API* gravity of fuel oils and their calorific value is shown in Table 5. Grades No. 1 and No. 2 are used predominantly in domestic heating equipment whereas grades 5 and 6 are used in commercial and industrial burners. Grade 6 usually requires preheating to increase its fluidity and to permit atomization, whereas grade 5 is used in some burners without preheating. Grade 4 fuel oil does not require preheating and can be burned satisfactorily in a limited number of domestic burners.

COMBUSTION OF FUEL OILS

Many theories have been advanced during the past century to explain the mechanism of combustion of hydrocarbons in oil burners and other devices used for producing heat or light. These theories have been modified from time to time to agree with new experimental evidence. Much still remains unknown about the process of decomposition and combustion of hydrocarbons.

Table 5. Approximate Gravity and Calorific Value of Standard Grades of Fuel Oil

Commercial Standard No.	Approximate Gravity *A.P.I.*	Weight lb per gallon	Calorific Value Btu Per Gallon
1	35–45	7.076–6.675	138,800–132,900
2	26–40	7.481–6.870	144,300–135,800
4	12–25	8.212–7.529	153,000–145,000
5	10–23	8.328–7.627	154,600–146,200
6	8–17.5	8.448–7.909	156,000–149,700

Only three theories will be discussed here: (1) the carbonic combustion theory, (2) the aldehydeous combustion theory, and (3) the chain reaction theory.

The carbonic combustion theory postulates that thermal destruction of hydrocarbon molecules is likely to occur if (1) the oil is suddenly exposed to intense heat without allowing time for previous evaporation, (2) the oil and air are inadequately mixed, and (3) there is no preheating of the air or mixture. According to this theory the hydrocarbons would be thermally decomposed into hydrocarbons of lower molecular weight along with some free carbon atoms released under the conditions just described. The free carbon atoms may produce smoky combustion while those carbon atoms that are oxidized to carbon dioxide will produce a yellow luminous flame.

The aldehydeous combustion theory is based on the evidence that aldehydes, alcohols, and possibly peroxides are formed as intermediate products when hydrocarbons are decomposed and oxidized to the final products of combustion. The formation of formaldehyde is certain since it can be identified in the flue gases from blue flame oil burners when insufficient combustion air is provided. Alcohols have been identified by certain investigators during the oxidation of methane and ethane. Aldehydeous combustion is illustrated by the blue flame oil burner and the conditions conducive to this type of hydrocarbon decomposition consist of (1) allowing the oil time and opportunity to evaporate completely prior to combustion, (2) mixing the air and oil vapor thoroughly before combustion, and (3) preheating the air or the mixture.

Blue and yellow flame combustion can be demonstrated by the apparatus

illustrated in Fig. 3. If methane is burned in an atmosphere of air, as in burner A, a yellow flame will result, whereas the introduction of the air for combustion in the center of a stream of methane, as in burner B, will result in blue flame combustion. As the center of the flame in burner A is exposed to intense radiation the methane is thermally decomposed and liberates carbon particles which emit a yellow luminous flame during oxidation. In burner B the center of the flame cone is filled with air which cannot decompose under heat, the methane gas at the zone of contact with the air is only moderately heated because of outward radiation, and the air is preheated in the center as it approaches the flame; each of these conditions tend to produce aldehydeous combustion.

It is probable that the chain reaction theory is an extension of the aldehydeous combustion theory since most investigators who have studied the former have observed that the formation of aldehydes is one of the steps in the combustion process. It has been well established that fuel oils must be gasified before combustion can occur, and that molecules of a hydrocarbon and oxygen do not combine directly with each other to form carbon dioxide and water vapor, but pass through intermediate reactions in the process.

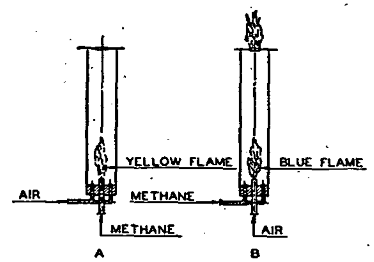

Fig. 3. Illustration of Blue and Yellow Flame Combustion

Lewis and von Elbe,[5] Pease, and others[6] have advanced the theory that the reactions between hydrocarbons and oxygen are probably chain reactions. This theory postulates that a great many different reactions take place simultaneously or progressively between molecules, atoms, and radicals in a mixture of hydrocarbons and oxygen. Some of these reactions produce particles or substances that tend to accelerate the reactions while others tend to slow down the process. Also, temperature, pressure, light and certain catalytic agents all may affect the speed and nature of these processes. The kind of intermediate products formed before combustion is complete depends on the physical conditions mentioned, as well as the molecular structure of the particular hydrocarbon participating in the reaction. Aldehydes, methyl and ethyl alcohols, formic acid, and other substances, have all been identified as intermediate products in certain reactions. The chain reaction theory, in reality embraces and elaborates on the aldehydeous combustion theory.

Oil Burning Indexes

A number of indexes have been used, or proposed, as an indication of the burning qualities of fuel oils based on one or more physical measurements made on the oil. These may be summarized as follows: