soiled filter paper. A high reflectance, relative to a clean filter paper, indicates low smoking tendency. CO_2/U is the observed CO_2 divided by the ultimate or maximum theoretical CO_2 expressed as a percentage. Reid and Hersberger[12] have related burning qualities and burning index for various oils in a wall-flame burner. Cauley and Delgass[13] cite test results on combustion indexes obtained with vaporizing burners. The present experimental data are probably too meager as yet to correlate adequately any one of these indexes with burning qualities of oil fuel for all types of burners. Few attempts have been made to suggest limits for any of these fuel oil indexes for particular applications, even though correlations between them and burning qualities have been observed. In other words,

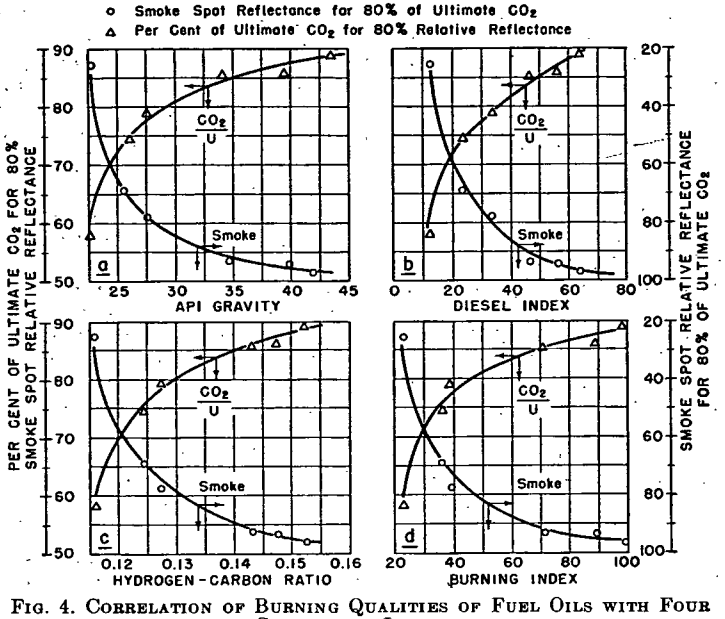

FIG. 4. CORRELATION OF BURNING QUALITIES OF FUEL OILS WITH FOUR COMBUSTION INDEXES

none of the above mentioned indexes has yet gained sufficiently wide usage to replace the grading of oils by *Commercial Standard* CS12-48.

Experiments have shown that thermal decomposition or cracking of hydrocarbons begins at a temperature of approximately 680 F at atmospheric pressure, although the temperature of cracking varies somewhat above and below this value. Thus pure distillate fuel oils, whose end point does not exceed this temperature, can usually be completely evaporated in vaporizing-type oil burners at atmospheric pressure without leaving a residue or without cracking of the hydrocarbons. Fuel oils that cannot be completely evaporated below 680 F are likely to undergo cracking in vaporizing type burners, with the resulting possibilities of smoky combustion and residues in the oil burner. A complete distillation curve cannot usually be determined for fuel oils containing fractions that evaporate above 680 F.

Since No. 1 grade fuel oil in *Commercial Standard* CS12-48 has a maximum end point of 625 F, it can in most cases be completely evaporated in atmospheric vaporizing burners without cracking, although occasionally an oil is found that undergoes cracking at temperatures below 625 F. By the same criterion, No. 2 grade fuel oil in the *Commercial Standard*, which can have a maximum distillation temperature of 675 F at the 90 percent point, would frequently be cracked in a vaporizing burner. However some No. 2 fuel oils do not crack before complete evaporation takes place. Vaporizing-type burners can generally use only No. 1 fuel oil with assurance that thermal decomposition will not occur during combustion. On the other hand either No. 1 or No. 2 fuel oils may be employed in high or low pressure atomizing burners when the temperatures developed in the combustion chamber are high enough to assure complete combustion, even if the fuel oil is thermally decomposed.

In vaporizing burners, preheating of the combustion air and fuel, complete evaporation of fuel before it is exposed to intense heat, and thorough mixing of the air and gasified fuel promote complete combustion without smoke and with a minimum of excess air. In pressure-type burners preheating of the combustion air, a maximum of air turbulence, good atomization of the fuel, and high combustion chamber temperatures (preferably red hot) promote smokeless combustion with a minimum of excess air.

Natural draft burners depend on the motivating force of a chimney to induce enough air into the burner for complete combustion. Forced draft burners are supplied with combustion air by means of a blower or fan; the chimney merely conducts the flue gases outdoors and prevents leakage of flue gases inside the building. More details on the operation of the different kinds of oil burners and on chimneys and draft will be found in Chapters 15 and 17 respectively.

FUEL GASES

Fuel gases employed for various heating and air conditioning processes throughout the United States fall into three broad classifications: natural, manufactured, and liquefied petroleum. Natural gas is a mixture of several combustible gases and, usually, a small percentage of inert gases obtained from geologic formations. Natural gas is produced in significant amounts in 20 states. Texas is by far the largest producer, followed by Louisiana, Oklahoma, California, Kansas, and West Virginia. Manufactured gas is made by the distillation or cracking of oil or coal, by the steam carbon reaction, or by combinations of these processes. Liquefied petroleum gases (propane and butane) are higher hydrocarbon gases normally obtained as a by-product of oil refineries or by stripping natural gas. These two compounds are generally gaseous under usual atmospheric conditions although they can be liquefied by the application of moderate pressures at normal temperatures.

The demand for gaseous fuels has increased so tremendously during the past 25 years that few cities now can be said to depend solely on one source of supply. During peak load periods, heating demands on natural gas distribution systems may necessitate augmenting the base supply with supplemental fuels such as high Btu oil gas or liquefied petroleum gas-air mixtures. The supply of manufactured gases may be similarly increased by adding natural gas, reformed refinery gases, or relatively low heating value mixtures of liquefied petroleum gas and air.

In American gas practice the heating value of a gas and appliance efficiencies are based on the gross heating value. This value is the number of Btu liberated by complete combustion, at constant pressure, of one cubic