centages of dilution, respectively, were determined. These tests were made on a gasoline engine with a considerably lower degree of compression than that found best for 94 per cent alcohol. No attempts to use higher degrees of compression for the more dilute alcohol were made. The results are conclusive as far as they go. They probably would not be different had a higher degree of compression been used; but, be that as it may, the commercial significance of the results as obtained lies in the fact that if 80 per cent alcohol can be manufactured for 15 per cent less per gallon than 90 per cent alcohol it becomes a commercial advantage to use the lower grade, provided the difference in cost of handling the greater bulk does not offset the gain in cost of manufacture. It is even possible that the use of 70 per cent alcohol or lower grades will prove to be cheaper; but the use of these more dilute alcohols is limited to a certain extent by the difficulty of starting an engine using them and by the increased uncertainty of operation, especially under conditions of variable speed. Adaptability must be taken into account when comparing fuels.

Relative Adaptability of Gasoline and Alcohol.—Different properties limit the availability or determine the adaptability of liquid gasoline and alcohol and their combinations for use in internal-combustion engines of existing types. Gasoline is more volatile than alcohol, and the heat of combustion of a pound of gasoline is considerably greater than that of a pound of alcohol. The weight of air theoretically necessary for complete combustion of a pound of gasoline is different from that for alcohol, but the theoretical heating values of a cubic foot of gasoline vapor and air and a cubic foot of alcohol vapor and air, with just sufficient air for complete combustion in each case, is very nearly the same—about 80 British thermal units. Further than this but little is positively known about the properties of the working mixtures of alcohol or gasoline vapors and air, except that the pressure to which differently proportioned explosive mixtures of air and vapors of either fuel can be compressed without preigniting in the engine varies, and that an explosive mixture of alcohol vapor and air can be compressed to over twice as high a pressure as an explosive mixture of gasoline and air before self-igniting (preigniting in the engine).

Mixtures of air and fuel vapors, or sprayed fuel, are delivered to the cylinder of an engine, mixed with the remaining hot products of combustion, and subsequently burned. Differences in the homogeneity and intimacy of this ultimate mixture, in the limit of ex-

cess of air that can be used without the mixture becoming too dilute to fire and in the rate of flame propagation, may each affect the completeness of combustion, and though the mixture quality be relatively the same, alcohol may burn more completely than gasoline, or *vice versa*. The specific heat of the burned or burning charge may also be different for alcohol and for gasoline mixtures, thus changing the theoretical basis of comparison, and may also affect the rate of heat loss to the cylinder walls. But be all these things as they may, the ultimate effect is such that alcohol can be used a little more efficiently than gasoline, even in the same engine with the same degree of compression—that is, more efficiently with respect to the percentage of available heat that is transformed into useful work, but with equal efficiency with respect to the quantity of fuel consumed when the best degree of compression for each is used.

Considering only the heating values of gasoline and alcohol, it is obvious that, if other factors are equal, the relative consumption of alcohol and gasoline will be inversely proportional to their respective heating values. The low heating value of denatured alcohol, which corresponds very closely to 94 per cent by volume ethyl alcohol, will average about 10,500 British thermal units per pound, while the low heating value of 0.71 to 0.73 specific gravity gasoline will average about 19,100 British thermal units per pound. The comparison gives a consumption-rate ratio of 1.8 to 1 by weight for a thermal efficiency ratio of 1 to 1. In actual operation, however, where gasoline and alcohol were each used in the same medium-sized (10 to 15 horse-power) stationary gasoline engines without change of compression or speed, and the operating conditions, including load, were limited to the best possible for each fuel, a ratio of alcohol consumption to gasoline consumption in pounds per brake horse-power per hour was obtained as low as 0.98 to 0.59, equivalent to 1.66 to 1 by weight, or 1.45 to 1 by volume, with a thermal efficiency ratio of 28 to 26 per cent (based on the low heating value and indicated horse-power), or 1.1 to 1. By raising the degree of compression from that best for gasoline (about 70 pounds per square inch above atmospheric) to that best for alcohol (about 180 pounds per square inch above atmospheric) the consumption-rate ratio was further reduced and a ratio of 0.7 to 0.59 pound per brake horse-power per hour, equivalent to 1.2 to 1 by weight, or 1 to 1 by volume, was obtained with a thermal efficiency ratio of 39 to 26 per cent, or 1.5 to 1.

These figures are not the results of single tests, but

are the average values obtained for a number of tests under identical conditions; furthermore, these values were duplicated on different engines and at different times on the same engine. They represent the best practical values that were obtained for each fuel and stated degree of compression with the equipment at hand. They were obtained under special test conditions, however, and are not commercial values; nor were they obtained offhand, even by skilled operators.

Likewise, a consumption rate was obtained as low as 0.58 pound per brake horse-power per hour for gasoline with a corresponding thermal efficiency of 28 per cent, but the compression pressure used was 90 pounds per square inch above atmospheric. With this degree of compression it is necessary to use the weakest mixtures that will explode, in order to prevent preignition, and the load had to be reduced accordingly. Heavy loads could not be carried without excessive preigniting. Similarly, a fuel consumption rate of 0.68 pound per brake horse-power per hour, with a corresponding thermal efficiency of 40 per cent, was obtained for alcohol, with a compression pressure of 200 pounds per square inch above atmospheric, but preignitions were prevented only with difficulty and by a method similar to that used with gasoline, so that the conditions under which these results were obtained were not considered practical and the values have not been used in the discussion. They do not, however, change the ratios given.

The thermal efficiencies given in this discussion were calculated from the indicated horse-power and the lower heating value of the fuel. The method employed in determining the average indicated horse-power for each load was carefully worked out and the results were very satisfactory. They are consistent throughout with the brake horse-power determinations. It is not at all impossible to obtain the average indicated horse-power with sufficient accuracy for all practical purposes, if the load is kept reasonably constant; but the indicator diagrams must be taken in a careful, systematic, and understanding manner.

The difference between the brake and the indicated horse-power, or the friction loss of engines used, was practically the same and constant. For 484 tests on the five engines the average difference was 2.3. A full description of the methods used in determining the average indicated horse-power from the indicator diagrams, with tables giving details of the tests from which the mechanical efficiency of each engine at various loads was obtained, will be given in the final report. These tables substantiate the above statements.

(To be continued.)

TRANSMISSION OF HEAT IN BOILERS.

PROFESSOR DALBY'S RESEARCHES.

PROF. W. E. DALBY placed before the Institution of Mechanical Engineers the results of a research on the transmission of heat across boiler heating surfaces. The paper is a most elaborate one, and is the most complete and up-to-date information on this most important problem. He gives a list of over 500 papers bearing on the subject which have been read and which he has carefully indexed.

The general nature of the problem is that the combustion of fuel may be regarded as originating heat energy in the furnace at a temperature so much above the temperature surrounding the firebox, that a rapid flow of heat is determined to its boundaries and across the boundaries into the water on the other side. The transmission of heat to the boundaries of the furnace takes place in two fundamentally different ways: First, by direct radiation from the incandescent fuel and the flame and the hot gases; and second, by the agency of the matter in the path of the flow; that is, the hot gases, the metal boundary, and the water on the other side of the boundary. In the first case, transmission is effected by the vibration of the ether in the same way that the heat of the sun is transmitted to the earth across space and is instantaneous. The quantity of heat radiated in this way to a first approximation may be regarded as uninfluenced by the presence of the furnace gases, although actually the quantity is modified by their presence to a certain extent. In the second case, the matter in the path of the flow transmits by convection and by conduction. Thus, in a furnace there are in general three methods of heat transmission acting simultaneously from the flame to the water, namely, transmission by radiation, transmission by convection, and transmission by conduction. It is extremely difficult to analyze the results of experiments, so that the heat transmitted by each of the three methods may be separately stated. These problems are all elaborately discussed.

In conclusion, Prof. Dalby points out that it must be confessed that notwithstanding the large number of researches and papers bearing on the subject of heat

transmission there is a general absence of complete data regarding the actual phenomena occurring in a steam boiler when working under the ordinary conditions of practice. No data exist, for instance, which give the temperature gradients at different parts of a boiler flue with accuracy; isolated experiments furnish incomplete data from which the gradient may be roughly imagined, but researches and papers alike have had very little influence in modifying the general design of steam boilers. The Cornish boiler is still of the same design as it was a century ago. The Lancashire boiler has been scarcely modified in any essential particular. The locomotive boiler of to-day is a magnified type of the Rocket boiler. The most important development of recent years has been in the gradual introduction and perfecting of the water-tube type, but even in this modern product the essential features of the old types persist. This general absence of complete data is in no way due to the lack of endeavor or to the dearth of able and distinguished men in this field of research, but rather to the inherent difficulties of the problem and to the enormous cost of carrying out complete experiments upon a large boiler under the ordinary working conditions. The effect of varying the initial temperature and the flue dimensions was studied, together with the relation between the velocity of the air passing over the heating surface and the rate of heat transmission. The results show: (1) That the heat absorbed by the boiler varies almost directly as the calculated velocity of the air; (2) that the rate of heat absorption does not rise as fast as the increase in initial temperature. The curves given show that as the velocity of the air increases the true boiler efficiency of the boiler drops at first very rapidly, but after a certain velocity is reached it becomes nearly constant with a low initial temperature, and varies little with a higher initial temperature. The velocity at which, for any initial temperature, the true boiler efficiency curve becomes nearly horizontal is called the critical velocity, and the critical velocity varies with the initial temperature.

Considering the mass of work which has already been done, the century of accumulated practical experience in the design, construction, and working of steam boilers, the numbers of able engineers who have devoted their attention to boiler construction and design, and the distinguished men who to-day control and influence the industry, it would almost seem that present practice represents the survival of the fittest, and that there is hardly a necessity for further research. But recent years have been fruitful in researches in other directions, and Prof. Callendar, by his brilliant work in platinum thermometry, has placed at the disposal of engineers a practical way of measuring temperatures unknown to early experimenters. We have now a means of accurately measuring the temperatures at different parts of a boiler directly. The author ventures to suggest, therefore, that a research might be undertaken by the Institution, in which steam boilers of different types working under practical conditions may be made the subject of experiments in which all the elements of their working are measured, together with temperature measurements for the purpose of establishing the temperature gradients at different parts of the heating surface.—The Steamship.

The construction of the new war signal station at Blackhead, off the entrance to Belfast Lough, is now completed. From the station, which occupies the lofty eminence at Muddersleigh Hill, a lookout can be kept on the channel on a clear day extending from the Isle of Man and Welsh coast on the south almost to the Clyde on the north. Adjoining the station there has been erected a semaphore about 70 feet high from which signals can be made directly to the Whitehead Coastguard Station, which is at present manned by an expert signaling staff, under Station Officer W. J. Collins. As one of the cross-channel cables is laid from Whitehead, the Blackhead Signal Station, when the telephonic installation is completed, will be in direct communication with the Admiralty offices in London.