In the above table the evaporation is per pound of combustible. We might notice the small difference in efficiency between the different kinds of boiler. Economy depends vastly more on careful firing and proper proportioning of the grate and heating surface than on the kind of boiler used. Shell boilers, of course, fall below all others in matters of economy; and of the other two classes the water-tube are generally more compact and stand forcing better, but, on the other hand, are more expensive and perhaps harder to keep in condition, more particularly if the water supply is of inferior quality. In the statement of evaporation we were, of course, dealing with firing under tests, which is usually more carefully handled, and were not allowing for ash and banking and general waste, so that, considering these last, we see that actual evaporation is from 15 to 20 per cent. lower, running about 9 or 10 pounds, or even as low as 8 pounds, in cases of varying load, such as we might expect in electrical plants of moderate size.

Most furnaces are constructed to meet the requirements of high-grade fuel, and serious losses result with the use of inferior grades, unless allowances are made for this in grate surfaces, draught, etc.

(12) At the present time there is a demand for larger boiler units, caused by the introduction of the steam turbine, whose relatively small floor space makes a compact boiler of great desirability. It must not be forgotten that the smaller the number of boiler units the less attention they require, and the cheaper their cost of installation, piping and maintenance becomes.

To-day, mechanical stokers are in very extensive use in some parts of the country, and the reports from these, though varying in their nature, would seem to indicate that they are advantageous in the handling of medium and low-grade coals only. Firing large quantities at a fairly uniform rate, they are found to work satisfactorily, while with irregular loads and high-grade coal careful hand-firing is, perhaps, more economical. It must also be noted that automatic stoking saves no labor in small plants. A saving of from 20 to 30 per cent. in labor can be effected by their use in plants using from one hundred to one hundred and fifty tons per week, and this can be increased to 30 or 40 per cent. in plants burning over two hundred tons per week. Coal-handling machinery is not, as a rule, an economical investment in plants of less than one thousand b.h.p.

Primarily, the condition of firing must be taken into account. This is very often overlooked, and any laborer who can handle a shovel is accepted. A poor fireman is dear at any price, and quite as disadvantageous to the station as a poor engineer. Very often poor firing is evidenced by a poor and non-uniform spreading of the coal, and by not admitting just the correct amount of air. With not enough air combustion is incomplete and gases are smoky, while with too much air gases are cooled, and we have a serious loss in efficiency. As boilers are ordinarily set the temperature of the flue gases is greater than is conducive to best economy, and for this reason economisers are introduced.

We have noted the several consumptions for different engines, but the amount of coal consumed per horse-power hour is an indication of the economy of the plant. The cost of fuel varies considerably, and its price on the market is by no means proportionate to its thermal value. As a rule, the coals giving the best economic results are not those of the greatest intrinsic heating power, as the best results are frequently from cheap coal, or a mixture of the two. Here the boilers of a model plant may show an evaporation of only seven or eight pounds of water per pound of coal. For electric power stations operated by steam power the vital, economical question is the cost of fuel per kw. hour rather than the performance of engines or boilers alone. The final result involves the performance under varying loads and the skill of the operator in keeping his apparatus running as near its point of maximum efficiency as possible in spite of changes in the electrical output. This personal element forbids a reduction of the facts to generalities.

Steam.

An electric light plant run by steam of a capacity of one hundred to one hundred and fifty horse-power will use from five pounds of coal per horse-power hour to six pounds of coal per electrical horse-power hour.

(13) Steam should be admitted at the highest pressure feasible and exhausted at the lowest pressure possible. This indicates that high boiler pressure should be used, and that it is better to condense the steam than to expel it into the air, as by condensing most of the atmospheric pressure can be added to the working range of the pressure in an engine.

Waste of heat in the engine should be stopped as much as possible. This means checking losses from the cylinder by radiation and conduction and internal losses from cylinder condensation. The first principle laid down has for its object the increase of the possible efficiency, while the second principle bears on the recurring of as large a proportion as possible of this possible efficiency. The work of an engine should be maximum practically for its dimensions and use. To fulfil this condition high pressure and high piston speed are necessary. Compound engines involve the principle of lessening thermal losses in a cylinder by avoiding extremes of temperature between initial and final temperatures. The simple engine may be used where the size is small and coal is very cheap.

Condensing engines always furnish power more economically than non-condensing ones. This is particularly true at less than full load, since the loss at the atmospheric pressure may be taken as a constant source of inefficiency, which is very serious at low loads. For example, a triple expansion engine working at one-quarter load in one horse-power will be likely to have its consumption of steam per one horse-power increased 15 to 25 per cent. above that per one horse-power at full load, while working non-condensing the increase would be from 50 to 100 per cent. per one horsepower. Hence, for elctrical working, where light loads are frequent, condensing engines are an enormous advantage. With simple or compound engines the same general rule holds good as for triple expansion engines, with the additional point that light loads effect their economy even more when working non-condensing. It must be borne in mind that if an engine is to do its best work under varying loads its valve gear and working pressure must be arranged with this in mind, else the advantage may be thrown away. Among engines having the same class of valve gear, compound engines give better economy than simple ones and triple-expansion better than compound ones.

As regards speed of engines, there is always advantages in high piston speed, both as respects first cost and mechanical efficiency. So far as economical use of steam goes, speed makes little difference, except that it sometimes involves a change in valve gear. Most high-speed engines have valve gear of the dependent sort, which puts them at a disadvantage, except in so far as lessened cylinder condensation may offset the losses due to less efficient distribution of the steam, but the best dependent valve engine is less economical than the best independent valve engine of the same class.

With respect to actual economy in the steam consumption, the size of the engine has a powerful, though somewhat indeterminate influence. Even at full load, non-condensing dependent valve engines of moderate size require 30 to 40 pounds of steam per indicated horse-power hour, and only in very large engines does this steam consumption fall below 30. Working condensing, the same machines used from 20 pounds in very favorable cases to 25 to 30 pounds more commonly.

Passing to compound non-condensing engines, the effect of compounding on the efficiency is about the same as that of condensing. Independent valve compound engines, which are seldom worked non-condensing, perhaps use from 18 to 20 pounds of steam per horse-power hour.

When condensation is employed the dependent valve engines are in rather infrequent use. The steam consumption

(12) W. E. Moore, A.I.E.E., February, 1906.

(13) "Electric Power Transmission." Bell. Page 311.