the system peak, gains a load factor of 75% and at the same time generates 90.6% of the total energy. The steam station carries 40% of the peak, has a daily load factor of 11.75%, and generates 9.4% of the total energy.

In such a system as this, if the hydro-electric plant has an average capacity of 15,000 kw., the peak load on a load factor of 75% is 20,000 kw.; but if the load factor is reduced to 50%, as given for the entire system, the peak load becomes 30,000 kw. This would require, in the latter case, an addition of 10,000 kw. of installation more than that necessary for a load factor of 75%. As this addition of installation affects the design and size of pipe lines, water-wheels, generators, transformers, and transmission lines, a large difference in cost is represented by the difference of 10,000 kw. At $100 per kw., this would amount to a difference of $1,000,000, which would build, under modern conditions, a steam plant of 20,000 kw., or as large as would be necessary in such an installation, as an emergency plant. The additional cost of operation, over the standby charges, would be slight, and is represented practically by the fuel. For this there is compensation in the sale of the steam-generated energy.

These statements would be varied by every different kind of load curve, but in general they remain true. Depending on the form of the curve, and with present fuel prices, it can be shown that when a hydro-electric plant, with an ordinary length of transmission line requires (for continued operation) to be supplemented by a steam plant, it is the best practice to operate the steam plant over the peak and raise the load factor on the hydro-electric plant up to the neighborhood of from 60 to 75%.

A further requirement for raising the load factor at the hydro-electric plant is derived from the operation of the transmission line. The energy transmitted varies directly as the current, and the electrical losses vary as the square of the current. On a load factor of 50%, the energy transmitted at peak load is twice that at average load, at which time the losses would be approximately four times that of average load. On a 75% load factor, the losses at peak would be less than twice those at the average.

This entire subject becomes one where the conditions surrounding each particular case must govern. It is mentioned here as a major point affecting the design of hydro-electric plants.

The Rules of Economy.—The first rule of economy is that, in any given installation, the design should be governed by the consideration that the amount of the investment should be the least possible within the limits of good construction, other things being equal. In some cases where there is an abundance of water, it is not necessary to strive for the highest efficiency of the various parts, as the losses are not vital. This statement is true during a large part of the year in most plants, but, as a general rule, the power developed is measured by the minimum flow of water, and hence the economy of design holds true.

The second rule of economical design can be stated as follows: Any conduit carrying energy satisfies the requirement of minimum cost when the sum of the annual cost of conduit plus the value of the energy annually lost is a minimum. This rule governs all the conduits of the energy: ditches, flumes, tunnels, pipes, and transmission lines. Considerable latitude is possible in any design, without departing far from the rule, and here the governing factor is to reduce the cost of the investment to a minimum.

The Value of Power.—In applying the rule of economy, the value is not that for which it is sold. It is the cost alone that measures the value as far as design of parts is concerned. If the design is made on this basis, it will be properly proportioned to the actual sale value of the energy.

The value of the energy at any place is a variable, depending on the position it then occupies in the course of its transmission from the source to the place of use. Judged by cost, the energy in water as it falls has no value. At the intake of the conduit it has a value depending on the value of water rights, cost of storage dams, and the diverting dam. At the end of the conduit the value of the contained energy has been increased by the cost of the conduit and regulating reservoir. At the high-tension bus-bars the value has been further increased by the cost of penstocks and power-station equipment, and, at the delivery end, there has been added the cost of the transmission line and the sub-station. A corollary of this proposition is: If money is to be spent to save energy by reducing losses, it should be apportioned, not along the

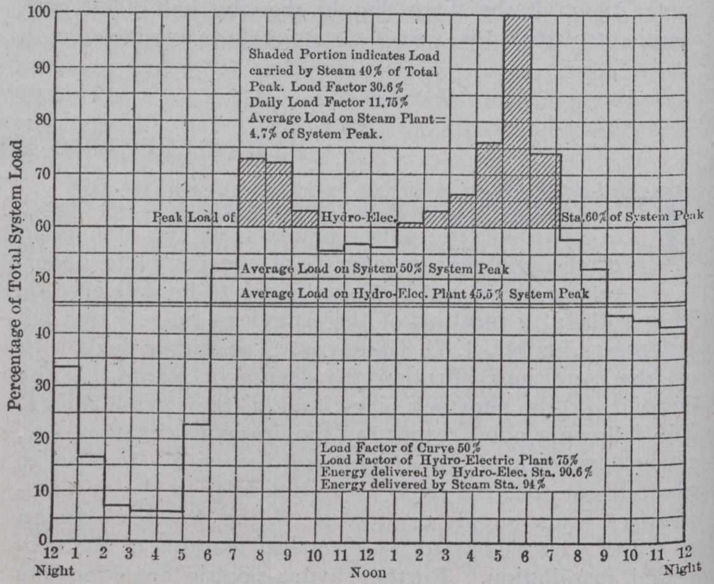

Fig. 1.—Load Curve Illustrating Load Factors and Influence of the Operation of an Auxiliary Steam Plant.

course, but near the receiving end. If a given sum of money will save a given amount of energy otherwise lost, it is much better to apply it at the receiving end. If applied near the origin, say, on the conduit, the energy saved must be transmitted through all the other parts of the system along the entire course. It must also be borne in mind that the amount of energy conveyed grows constantly less by losses, and is decreased to about 60% of the original amount at the receiving end.

In practice it is impossible to know the cost before the design is prepared, and assumptions must be made. If the cost of an installation is such that the resulting cost of energy amounts to 0.5 cent per kw.-hour, the values may be apportioned at 0.2 cent for the conduit calculations, 0.3 cent for the penstocks, and 0.4 cent for the transmission line. Such values will give results of sufficient accuracy.

FAIR WAGE CLAUSE IN ONTARIO GOVERNMENT CONTRACTS.

The Minister of Public Works of the Province of Ontario has announced that the government will in future place the fair wage clause in all contracts arranged under that department.