THE COMPARATIVE ADVANTAGES OF STEAM AND WATER POWER.

By "Economy."

Now that the attention of the public is being closely directed to the possible utilization of the many valuable water powers which we have in Canada, it may be of interest and advantage to consider their value in comparison with the best known alternative method of generating energy, viz., by steam. The practical side of the question may almost be neglected, because modern science has so improved hydraulic machinery that the best classes of water wheels may be placed about on a par with steam engines as regards regularity of service and general satisfactoriness. The main interest will center in the commercial features of the comparison and might take the form of the question, "Under what circumstances is water power a more economical prime mover than a steam engine?" which leads to the next question, "Can there be conditions which will cause steam power to be more economical than water power?" Both steam and water power, in what may be called their "raw" state, must be rendered available for use by more or less expensive processes, including in many cases the transmission of the energy from the point of production to the point of utilization; and it will be evident that there may be many conditions, physical and commercial, which may have considerable effect in modifying the value of one form of energy in comparison with the other.

Our rivers and streams are most of them short, and the country through which they run being denuded rapidly of forests. Hence they are very sensitive to the precipitation and respond very rapidly to it, being swollen shortly after rains, and carrying off large volumes of water in a short space of time. Similarly, after a period of dry weather they shrink to sometimes a very small proportion of their maximum flow. Even those streams which rise in marshy localities which absorb and retain moisture better, largely depend on the character of the fall weather. Should there be a considerable snowfall before the severe cold sets in to freeze the ground, then the stream will keep a more steady, even flow during the winter than it will if the hard frost sets in before the snow. And if the somewhat exceptional condition be met with of a dry summer, with little precipitation, followed by an early and severe frost without snow until late in the fall, then it is probable that many streams would dry up almost completely for several weeks, if not months. Water, therefore, as a source of power, can not be considered always satisfactory in point of reliability, unless some means can be taken for averaging up the flow; storing up the excess in times of flood, and letting it go in times of low water. This expedient is well recognized and frequently adopted; but the expense of the storage reservoirs is likely to be so great that only peculiar commercial conditions would justify it. The cost of development of a water power also is an item that may become very serious. It is but seldom that the favorable condition is found of plenty water and a large direct fall. As a rule the large streams, particularly in Ontario, have a somewhat slow current, and a high head could be obtained only by carrying the water in a long canal, which would cost heavily.

It is therefore evident that, taking everything into consideration, the first cost of a water power plant to render available a certain definite, continuous horse power, depends on the cost of machinery, dams, and perhaps storage reservoirs. If the power required does not exceed the minimum flow, then the reservoirs are not required; but they will be if the average flow is necessary. Hence it is quite possible that the total first cost of a water power enterprise, including the wheels, may be even largely in excess of the total first cost of a steam plant of the same horse power capacity. In fact, unless the circumstances be altogether exceptional, it is not likely that water first cost will compare at all favorably with steam first cost. After the first cost of the two systems comes in a very important consideration purely commercial in its character. Manufacturing establishments using power require transporting facilities for their raw material, and for their finished product; and just in proportion as these are bulky or heavy, so does the cost of their transport become a more potent factor in deciding whether cheap power or low freight is of greater importance. More especially is this so in establishments that do a principally foreign trade, and hence require convenient access to a sea or lake port. It is a somewhat unfortunate circumstance, but in the nature of things, that the largest commercial and transporting centers are far from any considerable and swift streams. We all know of the observant traveller who remarked on the peculiar coincidence that there was always a navigable stream close to a large manufacturing city, and therein lies the answer to the question why cities are not near water powers; because navigable waters are very generally of greater importance than very inexpensive power. Hence the value of a water power largely depends on its position with regard to railways, canals, or navigable streams. Here, however, comes the very important fact that we have several distinct means of transmitting power over considerable distances; so that although the best place for generating hydraulic power may be distant from the most convenient shipping point, the intervening space may be bridged.

Power laid down in form convenient for use at any particular spot costs money to develop, and more money to operate; and whether steam or water power is the better for any particular case can only be arrived at after careful estimate of their respective total costs per year. These total costs may be divided into fixed and variable expenses. Among the former are interest on money invested, maintenance and depreciation, insurance, wages, and the like; among the latter are fuel, oil, and the like. Every enterprise is expected to pay a fair rate of interest on the investment; most have some bonded indebtedness which is a first charge on income, and therefore interest on investment is a fair charge in making the comparison. No machinery, building, construction, or apparatus of any kind can be expected to last forever, so that estimating its life at whatever length may be proper in the light of experience, it is only sound business to lay by every year out of the gross income a sum equal to the yearly deterioration in value, so that at the end of the plant's useful life it may be found to have paid back the money invested in it. This yearly sum may be expressed in terms of a percentage of the total cost, the actual percentage varying with the class of construction or apparatus. A sum must always be allowed for maintenance, repairs, &c., and for insurance, and the wage account is always a very considerable proportion of the expenses of operation. All the above items can be calculated very closely, and placed at a pretty accurate yearly sum. Variable expenses can also be estimated sufficiently close for purposes of estimate. This is an expense which is saved in water power enterprises for the most part, and as fuel is generally one of the larger expenses, the great advantage of water comes in here. To compare the above item by item: Whether steam or water power be used, the interest percentage will be the same, so that the respective charges on this account depend entirely and solely on the respective costs of the two methods. If the whole hydraulic construction be more expensive than the equivalent steam plant, then the hydraulic interest charge will be greater than steam interest charge, and similarly. This requires a mere comparison of estimates of investment. In the depreciation account this equality is not preserved. The hydraulic plant will probably be far more durable than the equivalent steam plant. The dams will last all the longer as they are more solidly built, and a small sum spent yearly in inspection and repairs will cause them to last indefinitely. Besides which a "second hand" dam and water privilege is just as valuable as one brand new, if it has been properly maintained, which cannot be said for a second hand steam plant. Probably a fair depreciation on the whole dam, gates, tail race, &c., can be placed at 2%. Of the hydraulic plant, wheels, regulators, shafting, &c., a reasonable life of 25 years may be expected, with the consequent depreciation percentage of 4%; building 2%, if of solid brick or masonry construction. The insurance charge will be considerably less in a hydraulic than in a steam plant, and will be smaller as the building is less fireproof. It must also be remembered that the first cost of the hydraulic building will very probably be quite appreciably less than that of the steam building.

The same items in a steam plant may be reasonably taken at: For boilers, a life of 10 to 15 years, depreciation percentage, 10%; engines, shafting, journals, piping, 20 years, percentage 5%; insurance probably 25 cents per $100 higher than with water. As to the wages charge, it is probable that a hydraulic plant can be operated just as efficiently as a steam plant, with fewer men, and consequently smaller wages expense. The larger the plants the better for the hydraulic, for while one man cannot properly attend to more than so many boilers and keep good steam, owing to the work increasing as the battery is large, the additional size or number of water wheels imposes no greater work on the operators. It may be fairly pointed out that there are labor-saving devices, such as automatic stokers, which increase the work efficiency of the firemen very greatly, enabling one man to keep good steam on a number of boilers, but at the same time it is wise to remember that all such devices increase the complexity of a steam plant, raise the probability of accident, and render advisable the employment of higher class engineers at greater expense. In plants of a certain capacity it is necessary to employ both engineer and fireman, one man not being sufficient. In a water power one man would be quite capable of looking after the entire plant, hence the other man's wages are saved; and one superior mechanic can do the work of two and save considerable. The great importance of this item will be evident when it is considered that the saving of $1 per day or $300 per year (about the usual wages of a fireman) will pay the interest at 5% on $6,000. This means that a water power plant may cost $6,000 more than a steam plant of equal size, and be an equally good investment, if thereby one fireman's wages can be saved.

The most important item among the variable expenses is undoubtedly the fuel, which will vary very greatly according to locality, kind of business, state of markets, etc. In coal mining localities refuse can be obtained for almost nothing—for the expense perhaps of carting it from the pile; in others good steam coal costs as high as $6, $7 or $8 per ton. Wood varies according to locality from 75 cents to $2.50 a cord. Oil or gas fuel can be obtained in certain favored localities. It is of course obvious that as fuel—whether coal, wood, oil or gas—is less expensive, so does the value of a water power become less in comparison with that of steam. Another very important commercial consideration—coal fields are always well supplied with railroad facilities, sometimes even with canals—so that the two most important manufacturing advantages are found together: easy transport and cheap power. Nature herself seems to place obstacles in the way of hydraulic power, for just as a large stream has a greater fall along its course, so does it become more difficult for railways to follow it, owing to the grades. Hence it is generally necessary to transmit hydraulic power for some considerable distance to a convenient shipping point, and this means larger fixed charges to offset the entire elimination of the fuel charge. It is obvious that assuming a sufficiently low cost of fuel at the shipping point, and an expensive water power plant, there may easily be conditions which will make a water power of no value whatever in comparison with steam. For instance, in a recent case, to develop and render available a certain water power for use 12 hours a day for 365 days a year, required the damming of some storage lakes, and the transmission electrically of about 150 h. p., in all about $20,000. The expenses in connection with this enterprise, for interest, depreciation, wages, etc., were estimated at $2,700 per year. The cost of a steam plant to do the same service was estimated at $8,000. Now, taking the above percentages and allowing two men for the steam at $800 wages, the same expenses without fuel would come to about $1,500. Thus $1,200 are allowable for fuel in order that steam and water (electrically transmitted) may be equally good investments. This allows $8 per horse power year for fuel. Or allowing 4 lbs. of coal per h.p.h. (condensing) comes to the equivalent of 1080 tons of coal per year. Coal, or equivalent, at $1.11 per ton would make either plant an equally good investment; at $1.12 would be more expensive than water power; at $1.10 would be more economical than water.

Now, if this water power had been situated about 100 miles from where it was, and placed as near a Nova Scotian coal mine as it was to its distributing point, then culm could have been obtained at 25 cents per ton, and allowing even 4 tons of culm to give as good effects as one ton of good steam coal, even then the steam plant would have been the better investment. At the distance of 32 miles from the above coal mine, culm cost $1 laid down, so that the fuel for the above plant would have greatly exceeded the $1,200 allowed. Here we have a very clear illustration of the way in which the comparative values of steam and water power vary. At one end of a 32 mile line the water power was worth nothing at all; at the other end it would have been a good investment for $25,000.

The kind of business to be done will also largely affect the comparison. There are many products that require heat in the various processes, for bleaching, cleaning, bending, drying, and what not. In the present state of