The question now arises what becomes of the initial pressure when the fly-wheel is sufficiently heavy to insure perfect rotary motion; surely it cannot be averaged with the diminishing pressure, and counted as thrust, as is the practice (per indicator). For this would necessitate the fly-wheel slowing down and starting up in speed twice during each revolution, and as the resistance is assumed to be constant, and the periphery speed absolutely uniform, the answer is that "no other than the terminal pressure can be counted in estimating the power delivered." This would be unquestionably true if the piston were thrusting a plunge into a chamber of constant resistance; or against a loaded platform, and when fully understood the conditions will be accepted as being precisely the same. Duly considering the foregoing, it cannot but be admitted that where the resistance is constant, the pressure on the steam piston must be constant. And that where the fly-wheel is sufficient in weight and velocity to maintain a perfectly uniform periphery speed, operated by an engine cutting off at any fraction of the stroke, the resistance becomes practically constant, and only the terminal pressure can be estimated as passing into useful work.

—The paper by James Milne, of Toronto, on the "Steam End of an Electric Plant," was read before the Canadian Electrical Association by C Lord Weeks, of Toronto. Press of matter has obliged us to omit this paper from the present number of THE CANADIAN ENGINEER.

IMPULSE WATER WHEELS.*

By J. T FARMER, MA.E.

(Continued from May Issue).

In all these particulars there are some modifications which can be more or less exactly stated: (a) The velocity of the impinging jet is reduced in the ratio of a coefficient of velocity depending on the pipe line and nozzle. (b) Instead of striking the vane tangentially, the jet generally, as in the case particularly alluded to, strikes at a point nearer to the nozzle. (c) The force of impact is reduced owing to the velocity lost by the water in passing over the surface of the vane. Some previous experiments on this subject afford data which will be used in approximating to the loss due to this cause. (d) It is impossible, practically, to turn the water completely back on itself on account of the reaction which would take effect on the back of the succeeding vane.

In practice there will be a reduction of velocity, due to two causes: (1) Resistance of pipe line. (2) Loss in discharge from the nozzle. In the trials under discussion the heads given are those measured close to the point of discharge, so that no loss due to the pipe line need be considered. The only loss of velocity is that which occurs in the discharge from the nozzle. In the nozzles used in the experiments the stream issued from a parallel throat, and consequently there would be no appreciable contraction of the jet. The co-efficients of discharge were determined for these nozzles for heads up to 20 feet, above which point the variation becomes very slight. The results obtained therefore give an approximation to the true velocity of the jet. In addition to these determinations the co-efficient of discharge was calculated from the data afforded by each of the trials. These co-efficients agreed very closely with those obtained directly in the case of the ¾-in. nozzle. The mean values were .972 and .980 respectively. The discrepancy is not surprising when it is considered that in the former case the outflow was from the end of a long pipe, while in the latter it was from a large body of water at rest.

The discrepancy is more marked in the case of the nozzle ½-in. diameter, where the two values are .909 and .976. It is suggested that this difference is due to the fact that the interior of this nozzle was covered with rust at the time of its being used in the water wheel, as it had been in place for some time. The coating of oxide on the interior would diminish the actual area of outlet, so that the co-efficient would appear to be smaller than it actually was. In addition to this there can be no doubt that the rough surface of the oxide would diminish the velocity of the outflowing water; this may be partly the reason why the trials with the ½-in. nozzle show a smaller efficiency than those made with the ¾-in. nozzle. If this explanation is correct, it would point to the desirability of having the interior surfaces of the nozzle tips clean and free from rust. To accomplish this, it would probably be worth while to have detachable nozzle tips made of brass or some other metal not so liable to be acted upon as iron in the presence of moisture. It would also be advisable for the user to periodically take out and clean the nozzle tip, especially if made of cast or wrought iron. With a dirty nozzle there is a direct loss of efficiency corresponding to whatever loss of velocity is caused by the rough surface of the nozzle. More than this, there is a diminution in the area of the outlet, and therefore in the discharge, with the result that the power developed by the motor falls off. This may become a serious consideration if the motor is not much more than equal to the demands usually made upon it.

From calculations made it was apparent that there is still a waste of from 15 to 25 per cent. of the original energy of the water which has not been accounted for. The loss due to friction of bearings would be small in a simple machine of this sort, and the greater part of the 15 to 25 per cent. loss must be due to some departure in practice of the phenomena of action from those assumed. It is suggested that the loss arises wholly or in part from the imperfect action of the vanes or buckets in turning back the water. It will be remembered that one of the functions of the wedge was described to be to cause the water to be discharged to the side of the wheel. A little consideration, however, will show that during a part of the period of action the wedge does not perform this function. When the vane begins to intercept the jet, it is the outer lip or scoop which first comes in contact with the jet. The small amount of water which strikes the blunt edge of this outer lip is scattered, and thus only gives up a proportion of its energy to the wheel. More than this, it probably causes considerable disturbance and consequent loss of energy in the rest of the stream. As the vane passes further into the path of the jet, the water strikes on the interior curved surface of the outside scoop portion of the bucket on each side of the outer end of the wedge. The curve of the bucket at this point is such that the water is mainly deflected in an inward and backward curve in the plane of the wheel, so that it emerges from the vane surface in a plane tangential to the wheel rim: it proceeds in the same direction until it strikes the back of the following vane, producing upon it a force of impact opposite to the direction of motion of the wheel. As the wheel moves into such position that the jet plays upon the central portion of the wedge, the stream is deflected to each side in a plane parallel to the axis of the wheel, and it is then and only then, that the conditions of action assumed are approximately fulfilled. It may be estimated that the action of the water is not what it is assumed to be while the vane moves over from 1-5 to 1-3 of the total arc of action. During this interval the action of the water is more or less inefficient.

It was noticed that the deficit of the actual from the calculated efficiency increases steadily as the speed is increased. It is suggested that this may be attributed to two causes. (1) The best effect of the impact occurs when the sharp edge of the wedge is perpendicular to the line of the impinging jet. This condition only occurs at one point in the arc of action. At all other points the position of the edge of the wedge departs more or less from the perpendicular position, and the deflection does not take place in the manner assumed, with the consequence that the efficiency of the impact is more or less impaired. The higher the speed of the wheel the greater is the arc of action, and consequently the greater will be the departure of the cutting edge of the wedge from perpendicularity to the line of the jet. This would mean that the loss of efficiency of the impact is less when the arc of action is smaller, or the speed small, and that the loss of efficiency increases as the arc of action increases, or as the speed is increased. (2) It was pointed out how the action of the outer lip or scoop at the beginning of the arc of action tended to impair the efficiency of the wheel. It will be seen that if the arc of action is large enough the same effect will take place at the end of the arc of action, as well as at the beginning. If, therefore, the speed is increased to such an extent as to allow this to occur, there will be a further cause of loss of efficiency at high speeds.

It is estimated that the efficiency would not suffer diminution from this latter cause until the velocity reaches a value of 800 revolutions per minute with the 175 foot head, or a value of 900 revolutions per minute with the 235-ft. head.

I.—Nozzle .5277 in. Diameter. (a) Pressure 50 lbs. per sq. inch. Equivalent head = 115 feet. Discharge = 45 gallons per second:

*From a Paper read before the Canadian Society of Civil Engineers.