Mr. Ellington. square inch. As a general rule the higher the pressure the greater economy in working. In Glasgow there was a very large use of power rom the Corporation waterworks mains already. Some 600 machines were at work, and there was very great disturbance of pressure in the mains in consequence. The idea was to get rid of the very uncomfortable demand that existed upon the mains in the City by introducing the high-pressure supply for power purposes. The charge for power supplied on the Kensington Court Estate was on a special scale. In reply to Sir Frederick Bramwell's question whether experiments had been made with regard to the flow of water in pipes at high pressures, he was sorry to say he had made no such experiments. It was a matter often in his mind, and he would take seriously into consideration the question of conducting such experiments. He had hitherto used the ordinary formulas for flow which applied to lower pressures.

Correspondence.

Mr. Anderson. Mr. E. W. Anderson, referring to the Author's remarks as to the generation of electricity by means of the Pelton wheel, desired to know the efficiency of that machine, or rather, of a combination of Pelton wheel and dynamo, at loads ranging from a light load up to full load; also what regulating arrangements, if any, there were for keeping the efficiency as constant as possible, in other words, regulating the use of the water. He presumed the calculation of 6*d.* per unit was based upon full power. Now, in ordinary electric lighting, it was obvious that the full load would rarely be attained, and it seemed, therefore, that the calculations of cost should have been based upon the efficiency at the average load, and not at the full load. He would also like to know how far the fluctuations of pressure which occurred in hydraulic mains would affect such a plant working incandescent lamps. He imagined that a variation of pressure which was of little moment in working lifts, cranes, etc., might be of considerable importance in working dynamos for electric lighting, unless some automatic pressure-regulator was adopted, either for the water or for the dynamo. One other point was, the cost of 6*d.* per unit appeared to have been calculated at the terminals of the dynamo. There was, however, loss in the mains, and interest and depreciation on the capital expenditure, both in the mains and in the wheel and dynamo, which he thought ought to be allowed for. It might not amount to much, but still there must be something, which the consumer

Mr. Anderson. had to pay for. He inferred from the low rate quoted (2*s.* per 1,000 gallons) that the Author had calculated upon a considerable consumption of water; or was it a special rate proposed for that particular work, irrespective of the quantity used by each consumer?

He would be glad to know whether the Author had experienced any trouble with the joints of the cast-iron mains. He understood that in the hydraulic installation at the Royal Arsenal some trouble had been experienced from corrosion on the inside of the joints, owing, apparently, to the use of the somewhat brackish Thames water. It appeared as if the machined ends of the pipes, where not protected by the gutta-percha joints, had frequently corroded very much.

Mr. Wingfield. Mr. C. HUMPHREY WINGFIELD would like to know what arrangements the Author had found best for drawing water from the river direct, without choking the suction-pipes and pumps with sand or floating weeds, &c. That was a difficulty which always presented itself when it was necessary to provide circulating water for the condensers of steam-engines near a river. He observed that the diameter of the intermediate cylinder given on page 223 was 22 inches, whereas it should have been $23\frac{1}{4}$ inches, if taken as a mean proportional between the two other cylinders. The point of cut-off was not given, but if it was nearly the same in each cylinder he should expect the effect of that proportion would be to prevent the HP. cylinder from doing its fair share of work. He would be glad to know if that was so in the case referred to, as although recommended in a standard work on marine engineering, it was not, in his opinion, based on correct reasoning.

Referring to *Fig. 6*, the uppermost point in each curve agreed with column 3 of the Table on p. 230, with the exception of curve "E," and he would be glad of an explanation of that point. Roughly, all the curves in *Fig. 6* were similar, but drawn to different scales. Probably the average curve for one day would present the same general form. In the latter case, the ratio of the maximum height to the mean height of the average curve would give the load-factor, and the fact of the curves in *Fig. 6* being so nearly similar, showed why the load-factor was so slightly affected by the total output. *Fig. 7* showed, as might have been foreseen, that in a district where the demands for both electric and hydraulic power were limited to almost the same hours of the day, viz., from 10 or 11 A.M. to about 6 P.M., a combination of the two would not perceptibly improve the load-factor. If, however, Mr. Wingfield. the hydraulic power could be limited to a district in which offices and warehouses required it between those hours and the same engines could be employed to deliver electric energy to the West End, where those who had been using hydraulic energy in town during the day would employ electric light in their houses at night, the case might be different. Those who used the hydraulic energy at present provided during the day left their places of business at night, and to reduce the combined load-factor shown in *Fig. 7* the energy should follow them in another form. He supposed it was out of the question to attempt to store half a day's supply of water at the pressure or the equivalent head required in the service-pipes; but any step in that direction would tend to equalize the power required from the engine, and would materially reduce the working cost, if the interest on the outlay did not overbalance the gain.

The plan of breaking up the central-station plant into sections was a very necessary one for any works in which the power varied greatly. He was glad to see that the Pelton wheel had given such satisfactory results. Had any experiments been made to determine the probable total energy per pound of water issuing from an orifice of known size at the end of a pipe of known length and diameter? For instance, if it were desired to erect a 15-HP. wheel 50 feet from the main, what data were available for determining the necessary diameter of supply-pipe and nozzle?

Mr. Wingfield had never seen a trustworthy method of measuring the pressure in a moving column of water, although some experiments with fire-hoses had been lately published in "Engineering" which bore on that point. Many years ago it was proposed to measure the speed of ships by means of two vertical glass tubes passing through the bottom of the vessel. Their lower ends were bent at right angles, the one pointing forward, the other aft. The inventor expected the water in the former tube to rise and the latter to fall, when a suitable scale would give the speed of the vessel. It was afterwards found that in an unbent tube passing through the bottom of a vessel, the water fell even lower than in the one bent backwards, none of the three pipes giving the same head as that outside, and that was what happened whenever a current of water or air flowed nearly across the opening to a pressure gauge—the gauge indicated too low a pressure. The pressure inside the nozzle being unknown, how was the theoretical power computed, from which the 80 per cent. efficiency given on p. 238 was reduced? The pressure, when the jet was closed, was of course useless for the purpose.

He suggested the following method of testing the energy in a jet without risking the error due to incorrect readings of pressure. Mr. Wingfield.

If the temperature was 53·3° F., 1 lb. of water was equivalent to a prism 3·3077 feet long and one square inch in section.

Hence $$V = 2 \cdot 3077 \frac{W}{A},$$

where V denotes feet per second; W, lbs. per second; A, area of section of stream in square inches.

Then $$\text{foot-lbs. per second} = \frac{V^2}{64 \cdot 4} \times W = 0 \cdot 082697 \frac{W^3}{A^2};$$

or $$\text{foot-lbs. per minute} = 4 \cdot 96172 \frac{W^3}{A^2}.$$

Therefore the HP. of jet was nearly $\frac{W^3}{665\ A^2}$.

It was only necessary therefore to catch and weigh the water which issued in 5 or 10 minutes from a suitable nozzle and estimate the rate of discharge. That and the area of the jet were all the data required. If the nozzle was properly formed, there should be no perceptible contraction after the jet left it. Where there was a *vena contracta*, the nozzle might be considered as not completely filled by the jet, and the formula would give too low a result unless the section of the stream was measured at its narrowest part.

If desired, the constants could readily be corrected for temperature, supposing that to differ materially from 52·3° F. He was rather surprised to see no mention of the Rigg hydraulic engine, having been under the impression that it was specially adapted for hydraulic-power supply.

Mr. ELLINGTON, in reply to the Correspondence, stated that experiments wlth the Pelton wheel and dynamo were in progress; therefore at present he was unable to give results. So far as they had gone, they indicated that an efficiency of 66 per cent. could be obtained at full load. The efficiency of the Pelton wheel varied only slightly at different loads and constant speed, and, therefore, the combined efficiency at varying loads depended principally on the construction of the dynamo. Interest and depreciation on the special capital expenditure would have to be added to the hydraulic power cost, but if the dynamo were used to supply single blocks of buildings there would be no additional cost for mains. The rate mentioned of 2*s*. per 1,000 gallons was the usual charge of the Hydraulic Power Company for con- Mr. Ellington.

Mr. Ellington. sumptions of 500,000 gallons per quarter; and for very large consumptions, 1*s.* 6*d.* per 1,000 gallons was the usual charge. No special rate had as yet been fixed for hydraulic power used for driving dynamos. At 1*s.* 6*d.* per 1,000 gallons, 6*d.* per Board of Trade unit would be about the total cost of electricity obtained in this way, including maintenance and interest. As regarded maintenance of the hydraulic mains, no trouble had been experienced. Many of the mains had been in use for ten years, and from various causes single pipes in those mains had from time to time been renewed, but no corrosion had been observed. The principal cause of leaks had been settlement in the roadways; and a leak once set up quickly enlarged the aperture with very curious results, at first sight suggestive of corrosion, but which on examination were found to be due to mechanical and not to chemical action.

In answer to Mr. Wingfield, the arrangements for drawing water from the river direct were described in the previous Paper.[1] The I.HP. of three cylinders in the engine-trial marked No. 1 (Appendix) were respectively, high-pressure, 58·18; intermediate, 64·47; and low-pressure, 57·15.

During the trial marked No. 3, the horse-powers were 70·47, 72·07, and 64·01 respectively. The cut-off was adjustable only in the high-pressure cylinder.

The maximum output during one hour given for 1891, viz., 90,000 gallons, was quite correct. The maximum hour's work in that year did not occur on the same day as the maximum supply during any twenty-four hours between 6 A.M. and 6 A.M.; though, as a rule, the maximum hour's work occurred during the maximum day's work.

[1] Minutes of Proceedings Inst. C.E., vol. xciv. p. 1.