DISCUSSION.

Mr. A. D. Nelson, in opening the discussion, expressed his satisfaction at the author having decided to read this very interesting paper, but regretted that the subject of the application of the Hydraulic Power Company's water to the driving of motors had been omitted. This, he thought, was a very important matter, and he would like to know whether anything of the kind had been done in Sydney; and if so, with what result as to cost per horse-power, the type of motor used, and what efficiency was obtained. In Melbourne, hydraulic cranes had been very extensively introduced, the largest being of 25 tons capacity; and it was a proof that we in Sydney were behind the times, that only very little of a similar nature had been done here. This was probably in a measure due to the general public not yet having grasped the advantages they would derive from using the Hydraulic Power Company's water. In going over the power station he was struck with the type of engine that was used, and he would like to know why a more modern class had not been adopted. It would also be interesting to know what the cost per day for water for a passenger lift with, say, a 4-in. diameter ram would be.

Mr. Norman Selfe considered that the paper before them contained some very valuable information, for which the best thanks of the members were due to Mr. Dickinson. The absence of hydraulic cranes from our wharves was, he thought, due to the ships here being discharged by stevedores, who had small donkey engines, that could be moved from place to place as required. In England this kind of work was done by large corporations, who provided themselves with the best appliances for the purpose; and if Sydney had a Harbour Trust to take charge of the whole of the water frontages used for shipping, there was no doubt that they would introduce a large quantity of modern hydraulic lifting machinery. Speaking of the processes to which the power water might be applied here, an important one was forging, as there was no doubt that the hydraulic forging press turned out the best work. He would like the author, if possible, to give some information concerning the Greathead ejector. He (the speaker) might mention in connection with this that he devised an ejector some years ago in which there was no waste of power, the quantity of water being adjusted to the load. It would be interesting to know whether any Pelton wheels had been introduced into Sydney for use with the high pressure water, and if so, with what result.

Mr. Hector Kidd mentioned the application of the Greathead ejector to fire hydrants, and considered that the adoption of something of the kind in Sydney, in view of the height of our buildings, would be an advantage to the community.

Mr. T. H. Houghton (visitor) referred to the cost of the Hydraulic Power Company's plant, and said that it came out to almost the same figure as that of the London Company when it was distributing the same quantity of water. The capital cost of the London installation was £112,000, and that of Sydney £114,000.

Mr. A. M. Howarth said he was particularly impressed by the interesting statistics which the author had furnished for the purpose of showing how a really first-class service of high pressure water-power was being appreciated in Sydney; but it appeared that, with the exception of lifting and pressing machinery, the hydraulic service was but little used. In view of the author's statement that he had only been called upon three times to supply water to motors, and coupled with the pertinent inquiry of a previous speaker for information regarding the cost of working, and other details of water-pressure machinery, confirmed him (the speaker) in the belief that a large number of small hydraulic machine installations would be added to the list of those now at work, if it could be satisfactorily shown that it was profitable to do so. Probably the reason that more water motors were not used might be due to a commonly prevalent idea amongst engineers—and those who have tried and believed—that high pressure water-power was not economical when compared with other systems, unless those systems were handicapped by special intermittent duties or other conditions which might preclude their use, such as organ-blowing, operation of draw-bridges or railway crossing-gates, driving machinery for the manufacture of explosives, mining in gaseous atmospheres, or for the working of submarine machinery. This discussion would not permit him to examine the relative costs of work done by direct heat engines *versus* water-pressure motors further than that of a few sample examples. The 25 gas engines displaced by the Hydraulic Power Company aggregated 175 h.p., and averaged 7 h.p. for each engine. Taking a modern gas engine of 7 h.p., with a common gas consumption of 34 cube feet per b.h.p. hour, the cost for 238 cube feet at 4s. 9d. per 1,000 = 13½d., and this sum added to 3⅛d. for cooling water, electric or jet ignition costs, and lubricants = 16⅝d., or 2⅜d. per b.h.p. hour. When Dowson or other specially made gas was available in lieu of common gas, it was found that 1·6lbs. of fuel per b.h.p. was amply sufficient for a 7 b.h.p. engine on continuous duty. Presuming that the engine was engaged upon intermittent work, and that we doubled its fuel allowance, we would find that 1·6 × 2 × 7 b.h.p. = 22·4 lbs. per hour, or ·01 tons. The one-hundredth of a ton at 13s. 4d. per ton = 1·6d., and this amount added to 3·3d. for water, lubricants, and ignition charges, = 4·9d., or seven-tenths of a penny per b h.p. hour. With a steam-engine of 7 b.h.p., and one whose coal consumption was considered to be 14 lbs. per b.h.p. hour, the cost of running would be 98 lbs. of coal at 13s. 4d. per ton, = 7d., and this sum added to 2⅝d. for feed water and engine oil = 9⅝d., or 1⅜d. per b.h.p. hour. The work done per hour by each of the three preceding example engines would be 6,187·5 foot tons. The energy stored up in 1,000 gallons of water at a pressure of 700 lbs. per square inch = 7,200 foot tons. This energy exerted through the medium of a water-pressure motor of 78 per cent. theoretical efficiency = 5,616 foot tons; therefore the quantity of water required for 7 b.h.p. hours = $1{,}000\frac{6187.5}{5616}$, or 1,100 gallons. This quantity, at 4s. 2d. per 1,000 gallons. = 55d., and if an extra penny be added for oil and stores, the total working cost of the hydraulic motor will be 56d., or 8d. per b.h.p. hour. Attention had been called to the similarity in the first costs of the London and Sydney Power Companies' plants, and also to the quantities of water supplied by each company. London supplies 7,000,000 gallons per week, at an average cost of 3s. per 1,000; Sydney supplies 740,000 gallons per week, at an average of 4s. 2d. per 1,000. London had 1,800 machines, as against 200 in Sydney. The ordinary rate for 500,000 gallons per quarter by the London Company was 2s. per 1,000, and in special instances a minimum rate of 1s. 6d. per 1,000 gallons was quoted. At these rates the Company paid 5¾ per cent. dividends for the capital outlay in 1891, and in the face of formidable competition from various electrical supply associations, one of which was securing a large business at 4d. per b.h.p. hour. Electric energy at 4d. per electric unit, or 3¾d. per b.h.p. hour, meant that pressure water must be supplied at 2s. per 1,000 gallons, at 700 lbs. per square inch, so as to be equally cheap. When we compare the relative costs of working of gas engines, steam engines, and water motors, we observed striking differences; and probably it was safe to say that Lord Armstrong, the pioneer of hydraulic power distribution, must have been contemplating similar tabular results when he and his co-directors decided to use *gas engines* in preference to any other power for the driving of the plant in their extensive new machine shops at Elswick. In taking out the relative costs of working for gas and other engines, he had made liberal allowances for fuel, &c., such as 34 cubic feet of gas for gas engines, and 14 lbs. of coal for the steam engine, per b.h.p. hour. Recently conducted brake tests with gas and steam engines gave 19·4 cube feet of gas and 4·6 lbs. of coal per h.p. respectively for engines of 7 b.h.p. To show that his allowance of 1·6 lbs. of fuel per b.h.p. hour was amply sufficient for the gas engine using Dowson gas, he wished to submit a few figures taken from actual results. For years past Messrs. Crossley Bros., the English makers of gas engines, had driven all the engines at their works with Dowson gas instead of steam power; and in a recent trial, lasting 35 weeks, they found that the total fuel consumed was barely 1·3 lbs. per h.p. hour during the whole of that period. The gas was only made in the daytime, and the fuel consumption included the waste during 244 nights and 34 Sundays; the aggregate daily use being 200 h.p. One man made all the gas that was required, and, in addition, he had charge of two engines, and did other odd jobs. Careful tests recently applied to a gas engine of 100 h.p. showed a fuel consumption of rather less than 1 lb. per horse-power when driven by Dowson gas. Messrs. Andrews, the well-known gas engine makers, were building an engine to indicate 400 h.p., and it was confidently believed that the fuel consumption would be well under 1 lb. per horse-power. According to scientific investigations, 1 horse-power was the theoretical equivalent of 3¾ cubic feet of ordinary illuminant gas; therefore it was evident that there was room for considerable improvement upon our present champion records of 19 cubic feet per horse-power. Tresca's experiments upon gas engines (Paris, 1866) gave as a best result 92 cubic feet per horse-power, for the Hugon engine. It would be seen, therefore, that the present gas engine was nearly five times as economical as the best one of 28 years ago. In conclusion, he would ask the author to kindly furnish such information he might possess, that would serve to dispel the doubtful impressions referred to in his (the speaker's) opening remarks.

The President (Mr. R. Pollock) said his visit to the Hydraulic Power Company's works had given him great pleasure; the completeness of the design appeared to provide for any contingency that was likely to arise. The mechanical stokers were as near perfection as it was possible to be, and in these days of labour troubles it was surprising that they were not more generally adopted. Last year a paper was read before this Association on the low efficiency of the compound engine for electric lighting purposes, owing to the great variation of load, and pointing out that it was not an economical type to adopt for that purpose. The designers of the Hydraulic Power Company's plant were evidently of the same opinion; hence the adoption of the high-pressure type of engine at their works. It was very gratifying to know that this Company was on the road to financial success.

Mr. Dickinson, in reply, said the discussion had raised some interesting questions in regard to the application of hydraulic power, and to the relative cost as compared with steam, gas engines, compressed air, &c. Mr. Nelson had expressed his regret that the question of application of hydraulic power to lifts, motors, and machinery generally had not been entered into more fully. For obvious reasons, hydraulic power had never been advocated for continuous driven motors or engines; in the first place, water could not in itself be worked expansively, so that unless the engine or motor was worked up to its full power the efficiency would be very low, the cylinders having to be filled with water at each stroke, regardless of load or duty. Several attempts have been made to perfect an engine with an automatic regulation of consumption of water according to the various demands on the engine, but, so far as he knew, without success; and until some marked improvement was made in the economy of hydraulic engines for small powers, the demand for power in this direction must be very limited. Even in London, where hydraulic power is being supplied as low as 1s. 6d. per 1,000 gallons, the number of engines or motors driven direct from the mains is very small as compared with the number of lifts, hoists, cranes, presses, and machines where only intermittent power is required. Mr. Nelson desired information as to the cost of running the ordinary type of suspended hydraulic passenger elevator from the power supply. Assuming the car travels to be 60ft., and the load to be raised 8cwt., exclusive of weight of car and attachments, which were counterpoised by balance weights attached to the ram crosshead, the lift machine, if geared 4 to 1, would require a ram $3\frac{1}{2}$in. diameter, with a stroke of 15ft., consuming ·41 gallons for each full trip of 60ft. of the lift car, and allowing 150 full trips, equal to, say, 300 average trips, per day of nine hours, which allows less than two minutes to admit passengers, make the ascent, land them on their respective floors, and return to the ground floor for the next journey. The consumption for this duty, allowing 70 full working days per quarter, would be: $\cdot 41 \times 15 \times 150 \times 70 = 64{,}575$ gallons per quarter; say, 65,000 gallons, at 6s. per 1,000, would be £19 10s., or an annual cost of £78 for the power supply. Add to this for maintenance, renewal of lifting cables, oiling, repacking, &c., the sum of £20, we have a total cost of £98 per annum, a sum which, in a great number of cases where gas engine plants have been in use in this city, would not cover the attendant's wages, leaving out the cost of gas, repairs, stores, value of room occupied, interest and depreciation on machinery, and, not least, the nuisance of having a gas engine on the premises. Mr. Nelson referred to the class of pumping engine in use at the Power Company's station. The engines are of the "Armstrong" horizontal high-pressure type. While the author was not responsible for this type of engine being adopted, yet he maintains that there is much to be said in favour of this class of engine under certain conditions. Considering the extra first cost of compound engines, the difficulty of obtaining a supply of water for condensing purposes, the increased complication and consequent extra cost of maintenance, and the fact of having in Sydney very cheap coal, the economy claimed for compound engines under these conditions is open to question. Mr. Kidd and Mr. Selfe had referred to the application of

Greathead's ejector to fire hydrants. In Melbourne high-pressure hydrants of the class referred to had been adopted and fixed for the protection of many of the Government buildings, including the Houses of Parliament, Treasury Buildings, Queen's Warehouse, and others; also many of the large warehouses in Flinders Lane are protected by the hydrants in a similar manner. It is surprising that in Sydney the insurance companies have not at least advocated a trial of Greathead's ejector hydrants, to demonstrate practically what can be accomplished in that direction. Mr. Norman Selfe mentions having devised an appliance for using water in proportion to the load to be raised by introducing the principle of the ejector. It may be of interest to Mr. Selfe to know that in 1881 the author erected in London, at Irongate Wharf, a 30cwt. hydraulic whip hoist, for raising or lowering goods, having a travel of over 70 feet. The hoist in question was fitted with a device patented by Martindale and Greathead, introducing the ejector, which effected a saving of the pressure water, especially when lowering goods from the upper floors. In lowering a load the water was exhausted from the cylinder into a small tank, in which was fixed an ejector. The pressure being admitted to the cylinder through the ejector, carried with it a quantity of the water from the tank again to the cylinder, making up the volume and reducing the pressure to a point sufficient to overhaul the chain, ball, and hook. In raising light loads, a proportion of exhaust water was also used, but when the pressure in the cylinder had increased to a certain limit due to a heavier load, the increased pressure closed automatically the supply from the exhaust tank; then only high-pressure water was used. This invention is apparently on parallel lines with the device described by Mr. Selfe. Mr. Selfe referred to the absence of hydraulic cranes and other hydraulic appliances on the Sydney wharves, and he is quite correct in his explanation as to the cause of this being divided interests and ownership; and until we have a Harbour Trust or Board, as in Melbourne or Wellington, little improvement will be effected in this direction.