Discussion.

Mr. W. H. PREECE, C.B., Vice-President, said it was his duty as Chairman to propose a vote of thanks to the Author for the labour, the patience and the care with which he had collated the materials placed so unreservedly at his disposal, and the clear way in which he had enabled the members to follow the conclusions at which he had arrived. Mr. W. H. Preece.

Mr. A. H. PREECE desired to thank the Secretary of the Gas Light and Coke Company for the figures to enable him to draw *Fig. 9*. He thought the questions of greatest importance were the reduction in the costs of the production of electricity, and the question of the utilization of the day load. The ordinary load in an electric-light station came on practically in the evening only, and the whole of the machinery was out of use for 20 hours of the day. If suggestions could be made as to some utilization of the enormous amount of plant standing idle it would be of advantage. The establishment of very large generating stations in the suburbs for the purpose of supplying London itself, was now becoming more important than ever. London was not conveniently situated for the erection of large stations in the centre, and the time had now arrived when it was necessary to establish stations outside London and to consider the most economical means of transmitting the electricity into the areas where it was required. Mr. A. H. Preece.

Dr. A. B. W. KENNEDY said that the matter dealt with in the Paper was one in which he took great interest. He was glad the Author had been able to give so much information in such a very dispassionate, temperate and quiet manner. It was not many years ago since matters of that kind apparently could not be discussed without an amount of disturbance which might almost be considered characteristic of electricity at somewhat high pressure. The Author had dealt with such a variety of points that he was afraid any discussion on his Paper must be necessarily more or less discursive. In reference to the water-softening question, although he had done a great deal with regard to the use of London water, he had never found that such a process was essential. Whether he had spent more in boiler maintenance than he would have spent in water-softening he did not know, Dr. Kennedy.

Dr. Kennedy. but exact information on the point would be of great value. It was very justly said by the Author that the somewhat elaborate arrangements of steam-pipes which had to be more or less necessarily used in electric-lighting stations caused considerable loss through condensation in the pipes. The matter was of great importance, and the losses that were so caused, more or less unavoidably, were no doubt comparable in magnitude with the difference between an ordinarily good engine and a very economical one, as he had pointed out on previous occasions. He would like to emphasize, in connection with the steam-pipe arrangements, that it was necessary really to cover the valve-boxes, and particularly also to cover the flanges thoroughly, in order to avoid a very undesirable amount of loss through radiation from the pipes. He would like to know on what the Author based his opinion that the banding of chimneys had been necessitated in many cases on account of the practice of carrying the exhaust-pipes inside the chimneys. It was an important practical question in London, where condensation could not be used. The steam must be discharged at least 150 feet above the ground; and even then he had known cases where people had found steam-rain in various parts of London. A separate exhaust-pipe 150 feet high could not be made, and for this reason it seemed to be necessary to take the exhaust-pipes up the chimney. He had not found any trouble from that source, and he doubted if a properly-fixed exhaust-pipe in the centre of a chimney would cause trouble, but it was possible that the Author had grounds for a different opinion. The type and size of units was a very vexed question. He would only say that he was brought up to the use of marine engines and reasonably low-speed machines, in which all the parts could be seen; but since he had had an opportunity of using engines running fast and entirely shut up he would never dream of going back to anything else. The saving of trouble and attention, and, above all, the saving in maintenance and in lubrication, was so great that he would not hesitate to continue using them for any size of machine, and certainly would not take another type of engine when dealing with a larger size. He thought that had been the experience of many members. This was a question on which there was great room for difference of opinion and room for difference of action. As to the size of units he did not think a 3,000-HP. engine was more economical than a good 300-HP. engine, and the question was clearly not one of economy. But a 3,000-HP. engine took up much less than ten times the room of ten 300-HP. engines. On the other hand, when

Dr. Kennedy.

running the plant at its full load always (and he would point out later that that was a very important matter indeed) it was desirable to have the plant so subdivided that an engine would never be required to run at half load for more than a few minutes at a time. On that account it was often necessary to make the units very much smaller than would otherwise be desirable. As to the use of batteries, the Author noted that some years ago the use of batteries was expected to help generating plant during the time of heavy load. That, as the Author quite rightly said, had not been found practicable in general, at least in England. The amount of help to be so obtained must be so enormously large, if it were to be worth anything, that the batteries to provide it would have to be of very much greater capacity than any which had been used hitherto, and, in fact, they would have to be used more or less on the gigantic scale adopted on the Continent in some places. He did not suggest that the English way of working was necessarily the best, but the change would require so large a departure from English practice that, as the Author had rightly said, the use of batteries at times of heavy load had such practical difficulties that it was not adopted. In reference to the use of different pressures in one station, since the beginning of his own electrical work in London and other places he had always arranged that the feeders could be run at different pressures; in other words, there was always an alternative omnibus-bar on which a feeder or feeders could be arranged to run at a higher pressure than the others. That method had been used occasionally in the winter when the load was very heavy and badly balanced over different parts of the district, but it had been so seldom that it had practically only been adopted in cases of emergency and for particular reasons for a few days at a time. He believed that had also been the experience of other engineers. If two or more sets of feeders were run, the plant must also be subdivided into two or more sets, with all the accompanying drawbacks. Instead of having all the plant running up to its full load, two, three, or four sets of the units at least had to be run very much under their full load, and that had been found troublesome. It was stated by the Author that "the regulation of the pressure is not so simple with the direct-current systems as with the alternating-current systems." He did not know whether that was the case or not, but he should hardly think so from the diagrams which the Author had given. Both the best and the worst of the diagrams were "alternating current." He did not believe in practice there was much to choose between the systems in this matter. It was a simple

Dr. Kennedy. matter in any case if it were only reasonably well attended to, except in the case of fogs and serious trouble of that kind. He believed that a very great deal of the vibration which had caused trouble and annoyance to various people had been more due to ineffective and inefficient foundations than to anything connected with the plant. Both in practice and theory a three-crank engine would cause less vibration than a two-crank engine, but he had tested a row of six or eight two-crank engines running together, separately, and in pairs, and had been unable to find any vibration beyond a most minute quantity coming from any of them. He believed that the difficulty, in all ordinary cases at any rate, depended much more on the matter of foundations than on that of plant. If the foundation was a long narrow block of concrete like a brick set on edge, whether carrying one or many machines, and especially if the subsoil were not good, very troublesome vibrations might occur elsewhere than in the engine-room. On the other hand, if the foundation were a large flat block approximately square in plan it seemed more difficult to make a vibration than to prevent it, supposing always that the subsoil was reasonably good and that proper means had been taken to prevent the block from rocking on either of its two corners across itself. That was very easily prevented. It might not be generally known how extremely sensitive the inhabitants of any city were to vibrations of the air caused by the escape of exhaust steam. That caused infinitely worse trouble, and was much more easily found out, than vibrations caused by the actual development of thousands of HP. Not once, but two or three times, to his personal knowledge, complaints had come into a station that there was a very bad and intolerable vibration, and suggestions had been made by the persons complaining that more plant was being erected, and so on. He suggested to his friend at the station that probably there was a drain-cock left open, or something of that kind, in the exhaust-pipe, and on examination that had been found to be practically the whole cause of the trouble. Perhaps his exhaust-pipes were somewhat peculiar, but if air got into any of them there were complaints from the neighbours; while as long as air was not allowed to get in by leaks or by open cocks vibration was non-existent. But the amount of vibration which came from the periodic motions of the column of steam in a long pipe, if there were any access of air, was certainly very annoying and irritating. From the interesting details of costs of repairs given in the Paper, the Author showed that different types of engines and boilers did not give very different results. The Westminster

Dr. Kennedy.

Corporation had both marine boilers and Babcock-Wilcox boilers in use. He did not know that any very definite difference had been found in the matter of repairs between the two types. As to the question of total cost the Author had stated "the average total cost per unit delivered varies between $2\frac{1}{2}d.$ and $3d.$ per unit with large works, and is slightly higher with smaller works. This result is not good." He could hardly forgive the Author for stating that. It was a bold way of expressing the matter which was apt to hurt one's feelings. Then the Author went on to say, "but it is principally due to the small load-factor in London." In his opinion there were other reasons; in fact, he very much doubted whether that particular reason had very much to do with it. First of all, in London the Author was dealing with companies in which, no doubt quite rightly, the general capital and management charges were much heavier than in most country stations, especially those managed by municipalities. In London coal was expensive and wages were high, and he did not think that it was to be expected that in London the rates would be got down to the point at which things could be worked in the country. The question with regard to small load-factor was one with regard to which he should like to say a few words. He really thought that the load-factor question had been somewhat run to death, and that the small load-factor had been made a scapegoat for all the sins of the engineers who had to run stations. He did not think it was nearly responsible for all that it was supposed to be responsible for. He would not stop to give any details, but he had compared very many stations with widely different load-factors and he had found, rather to his surprise, that its effect was absolutely masked by a great many other things. He did not say that the load-factor question was not an important one, but it was hidden by so many other things that it was very difficult indeed to find out its true effect. The load-factor was taken, as the Author had pointed out, and as he believed Mr. Crompton had originally intended it to be taken, as the proportion borne by the work done by a station to the total work that would be done by the plant in that station if the whole of it were running day and night all the year round, a quantity which varied between 5 per cent. and 15 per cent. No doubt that was very important, but if a very high load-factor, in this sense, was ever to be obtained, the plant must be run all day and all night. That was as yet impossible in electric-lighting stations, and he thought it would continue to be impossible in the lifetime of any of the members present.

Dr. Kennedy. He would, therefore, not compare electric-lighting stations with works in which electricity was produced for industrial purposes continuously, but would consider the subject on its own basis and under its own conditions. Of course, there were reasons which made the costs in London higher than in other places, but Edinburgh was just as subject to a high peak as any of the other places; in fact, it was worse than most places in certain senses, because in the summer there was daylight really all night, so that there was practically no light at all wanted. Notwithstanding this, the total cost had been reduced to 1·13*d.* per unit. He did not think that could be said to be "not good"; indeed it was admitted to be extremely good. But the point which he wished to make was that the load-factor in Edinburgh was not very different from that in other places; therefore he thought that the effect of the load-factor, large as it might be, might be quite concealed by other matters which might overpower it or strengthen it, as the case might be. He thought, however, that for economical running one matter about load-factors was essential, viz., that the plant run at any particular time should be run at its full power; he believed that was a more important matter in reference to economy than the proportion indicated by the load-factor, as he had described it. In other words, if on a summer evening 500 HP. was being generated, and on a winter evening 5,000 HP., both the 5,000 and the 500 could be run economically if the engines were respectively of 500 HP. and 5,000 HP.; but if a 10,000 HP. engine, or 10,000 HP. of engines had to be run for the 5,000 HP., and 1,000 HP. of engines for the 500 HP., they would never work economically, no matter what the load-factor might be. No doubt the point was to run the plant at the heaviest load at which it would run. Those engines and dynamos suited electric lighting best which could be always run at full load and often 10 per cent. over. The Author had given interesting financial particulars, including the percentages of costs to revenue. He would like to point out, what no one knew better than the Author, that the ratio of percentage of costs to revenue was not one which told very much, because the different undertakers charged different prices per unit. For instance, the first half-a-dozen companies mentioned in the Paper charged 5½*d.* per unit; the second three companies charged an average of 6½*d.* per unit, so that any proportion based upon revenue came out very differently in those two cases. With regard to load-factor, he did not think that either a very heavy load-factor (in the original sense of the word) nor a very large

station was necessary to economy. If anyone would take the trouble to look through the published results of working electric-lighting stations—not comparing London with other places, which would not be fair, but comparing places, differing in size but otherwise similar—they would be astonished to find how very economically a small plant could be run. That indicated that size, either of station or of unit, was not necessarily in any way connected with economy of production. Dr. Kennedy.

Mr. R. E. CROMPTON thought it a matter of congratulation to all that such a fair and temperate statement of the present condition of electric-lighting plants in London should have been brought forward at that time. One of the great causes, as Dr. Kennedy had pointed out, of the heavy stand-by losses in London supply-stations had been condensation in the double set of steam-pipes used. One method of overcoming that had been the use of superheated steam, not so much for the direct advantage which it undoubtedly had when taken absolutely to the engine-cylinders, but as a means of counteracting the condensation losses. He had tested one form of superheater made by the Babcock and Wilcox Company, and could give it unqualified praise in this respect, that whenever it had been in use, not only had condensation in the steam-pipes been entirely prevented, but some economy in addition had been observed in the use of steam by the engines. The main advantage was the very excellent condition in which the steam-pipes were always found. The joints were better kept, no doubt, from absence of water in the pipes. He believed great advantage would be found from its extended use. Part of the same subject had been the gradual extension of the use of condensing plant all over London. That had been attempted largely on the evaporative-surface principle, that was, a certain small supply of water had been allowed to trickle over the outside of tubes, the exhaust-steam being within the tubes. That had been a qualified success, qualified because of the nuisance produced by the steam evaporating from the trickling water. It produced what had been called a "washing-day" effect, he thought by Sir Frederick Bramwell, very annoying to neighbours; so much so that in the stations under his charge he had decided where it was possible to so largely increase the surfaces of the condensers that they could be used without water as plain air-surface condensers. In that direction, and the use of the air-fan draught to make the surface more effective, would lie the future improvements of such stations as had already existed in the metropolitan area, where it was so necessary to prevent the steam nuisance. The experience of the last Mr. Crompton.

Mr. Crompton. few years had shown very strongly one thing that certainly had not occurred to anyone a few years ago, namely, the enormous advantage of having very tall and powerful chimneys. Wherever the recent stations had adopted chimneys of nearly 200 feet in height, such a draught had been afforded that cheaper qualities of coal could be burnt, and with very great economy. He alluded to the Pall Mall and St. James's Company, where splendid results had been obtained, mainly due to the excellent chimney draught. Ten years ago, when very much attention had not been paid to that, it had been thought that a stack of large external diameter, 100 feet to 120 feet high, provided all that was necessary. He was now convinced that that was a wrong conclusion. The question now arose whether, in carrying the system further, by means of forced draught produced by power, even better results could not be obtained than with the chimneys. He believed that a great deal could be done in that direction, and that the required temperature could be produced in the furnaces of the boilers at a less expenditure of power, which evidently came from the coal itself, by actually driving fans and obtaining the draught artificially. In that case the products of combustion would be delivered at a height of 120 feet above ground, and all the draught required could be obtained. Very inferior fuel, also, could be burnt to that which must be burnt with the present shafts. The substitution of oil for coal had been tried by himself and by the engineers at Kensington with considerable success. It was found useful because a boiler could be pressed if a sudden demand came on which was so sudden that time could not be given to light up additional boilers. In order to obtain full advantage from the use of oil-fuel a special form of furnace was required. The bridges at the back of the furnaces must be curved and made of very refractory material, curved so that the impinging jets of incandescent oil were deflected up in the proper direction. If the usual bridge were used it was rapidly burnt away and deteriorated. The use of those properly-formed bridges in no way took away from the good working of the furnace when ordinary coal-fuel was used. The Author had been rather severe upon the practice of carrying the exhaust-pipes inside the chimneys. He believed he was himself the introducer of the practice, so that he rather felt the Author's remark. As a matter of fact, however, it had never produced any bad results where the work had been carried out properly. It was a fact, as the Author had stated, that if the pipes were not properly placed they were liable to unequal expansion; but where they were placed symmetrically up the

Mr. Crompton.

centre of the chimneys, and where the means of support were such that they could expand without buckling, no trouble had been experienced. He had placed exhaust-pipes in that position in the Victoria Station of the London, Chatham, and Dover Railway Company about 14 years ago, and they had never been repaired. Now that condensation could be carried on to a certain extent there was not the same necessity for the pipes inside the chimney, but, as Dr. Kennedy had pointed out, the steam which had to be exhausted into the air must be delivered at a height of not less than 150 feet above the pavement. It would be very unsightly to have the exhaust-pipe stacked outside away from the chimney. With regard to the highly important question of storage, he did not think that either the Author or Dr. Kennedy had been quite fair; in fact, storage had never had a fair chance in England. The subject had never been attacked with the same pluck as it had in Germany. He himself had been one of the first to use it on a large scale, but he had been very soon surpassed by Mr. Müller and other gentlemen who had built up the great accumulator works at Hagen. They were the only men who had had the pluck to install large batteries of accumulators of a suitable type to help the generating machinery at the time of heavy load. If the Germans had been successful with their heavy loads, which went on for three or four hours, whereas in England the heavy load peak only went on for about an hour, how much more should an Englishman be successful with that class of plant? He did not think that the question of batteries had been at all well worked out in England; in fact, he was quite certain that the use of batteries in many cases might be extended with advantage. Batteries still played a very important part in the stations, as they enabled the load to be worked easily at light periods, periods when it was much more difficult to keep the pressure constant than at the heavy load periods. During the periods of light load, if any consumer suddenly turned on a number of lamps, or some device or other such as a large photographic lamp or large motor, he disturbed the pressure very much indeed, as at that time, there was probably only one small set running in the station, but if batteries of considerable size were connected with the system those ill effects were minimized. Those who worked the stations where there were batteries of accumulators had every reason to bless them; they were not called out of bed and worried as were those who had not any such storage at their backs. Then came the question of the regulation of pressure, which was a very important one. He did

Mr. Crompton. not think any of the diagrams given were specially good. Most London stations were now in a state of transition, hoping to go over to the double voltage very shortly, and they were not making the connections and not putting down the copper at all in the way in which they were doing a year or two ago because of these projected changes. If the Author had taken a series of those diagrams two or three years ago Mr. Crompton could have shown him many which were almost perfect lines without any of the variations shown. He agreed with Dr. Kennedy that it was quite an easy matter, when the proper amount of copper for a district had been settled and the network was completely connected up, to keep the pressure sufficiently constant for all purposes, but so many companies had not sufficiently connected up their network. The demands had increased and increased, and they had spread out long branches which had been not connected up at their extremities, and the result had been that towards the end of the branches considerable variations of pressure had been observed which almost entirely disappeared directly those few connections were made.

Mr. Raworth. Mr. J. S. RAWORTH remarked that the question of vibration had been a very vexed one in London, and had given rise to an enormous amount of trouble. When the Chelsea station was started 10 years ago the plant suffered very badly from vibration. The foundation which was provided by the Imperial Continental Gas Association of Vienna was exactly similar to the one shown in *Fig.* 7, which he understood Dr. Kennedy to say was a cure for vibration troubles.

Dr. Kennedy. Dr. KENNEDY had said exactly the opposite. He had the Imperial Continental foundation in mind as being one of the very worst kind.

Mr. Raworth. Mr. RAWORTH thought Dr. Kennedy had said that if a narrow perpendicular shaft of a foundation were built and an engine were planted upon it, there was a liability to vibration, but with a large square solid block that liability to vibration disappeared.

Dr. Kennedy. Dr. KENNEDY had stated that if a long block like a brick on edge were put in, a block very long in proportion to its breadth, and at the same time comparatively thick or high, much longer in one direction than the other (say 100 feet long, 20 feet wide and 15 feet deep), that would cause vibration. The block in Vienna was of some such proportions. If a foundation block were made square in plan and sufficiently thick, the difficulty would disappear.

Mr. RAWORTH observed that at Vienna a foundation block was constructed the whole length of the engine-house, and was separated from the engine-house wall by about 18 inches. The vibration was so intense with three or four Willans engines running that it was not a question of any effect upon the drums of the ears of people in the vicinity, but it shook off the arms of the gas chandelier in adjacent offices. He wished to bring out the fact clearly that that particular form of foundation did not overcome vibration. It appeared to be the opinion of Dr. Kennedy that no advantage was obtained from a greater expansion of steam, for he had said that it was uneconomical to run electric plant at half load. Mr. Raworth thought that, with every greater expansion of steam down to a certain point, which was about half load, there was an advantage, inasmuch as more indicated HP. was obtained from a given weight of steam than was obtained previously. The Willans law showed distinctly that the maximum economy was obtained at full load with an engine with constant expansion. It was never stated by Mr. Willans that it was obtained with an engine with automatic expansion, and as a matter of experimental fact it was found that, taking into account the fact that if, starting at 42 lbs. per square inch mean pressure, the load was reduced by expansion to a point something like 25 lbs. or 26 lbs. per square inch mean pressure, the steam was used more economically all the way down to that point. But the fixed losses in the engine from friction and the fixed losses in the dynamo about counterbalanced that advantage, and in the end this result was obtained—that from full load down to half load the unit was produced with almost exactly the same steam consumption. He had tried that repeatedly, and the fact had become so clearly recognized now, that the Brush Electric Engineering Company undertook to make the test of any dynamo and steam engine together for steam consumption at any point between full load and half load which the purchaser liked to choose. That result could be obtained in an automatic-expansion engine, in which the automatic-expansion valve was applied to the high-pressure inlet only. With an engine in which one valve was made to fulfil the functions of all the valves—to act as a cut-off valve for the high pressure and low pressure, and as an exhaust-valve for the high pressure and the low pressure—that result could not be obtained; but if the valve-gear of an engine were constructed on the Corliss principle the result was that the half load was obtained with the same consumption of steam per unit as with full load. Mr. Raworth.

Mr. W. E. GRAY noticed that the Author pointed to the Mr. Gray.

Mr. Gray. possibility of all the London supply companies being united in one great scheme. The difference of treatment in the various districts offered many difficulties to such a union, but the different treatments would give valuable information as to what ultimately should be the system chosen for the great whole. With regard to coal the Author had stated that in view of the heavy cost of transport it was economical to use only the best. The best coal merely meant the coal from which the most power was obtained, and no doubt the price of Welsh coal had been so forced up owing to the great demand, that there was now a great number of coals, and he might specify as one Durham coal, which could be obtained, and compete very favourably in steam-raising power with any Welsh coal, considering the difference in price. The question of a choice of a boiler in London was hardly comparable with a choice of a boiler in the Navy. In the latter case not only had the available floor-space to be considered, but also the weight to be carried. In London it was mainly a question of the floor-space and the cost of maintenance. That naturally was a different problem, and he thought that perhaps a little too much stress had been laid upon the value of what might be called the newer type of boiler. Certainly, with a battery working in conjunction with a continuous-current distribution the quick steam-raising properties of a boiler were not in such requisition, inasmuch as the battery would assist the dynamos in the event of a sudden increase in load. He thought with Mr. Crompton that a great deal too much stress was laid on the behaviour of small batteries, and that the opinions arrived at with regard to them would not be the same if the batteries used were very much greater in comparison with the generating plant. It was very interesting to note from the Paper that low-speed machines were now largely used for the larger units in preference to engines of the high-speed type, although some of these had given very good results, though not such good results as would justify the older type of engine being overlooked. The marine type of engine had been referred to by Dr. Kennedy, who had dwelt also on the consumption of oil with this type. There was, however, the low-speed engine of horizontal type which did not present the same disadvantage, and he had had it on very good authority that horizontal engines could be made probably more economical even than some of the enclosed vertical engines. He did not quite agree with the statement that only a comparatively small amount of rubber-covered mains were used at the present time. From the Paper it would be inferred that in the past rubber was used and had now been discarded for

Mr. Gray. something better. He did not know what that improvement was, but he knew that in such modern stations as Wandsworth rubber was exclusively used for both extra-high and high-tension distribution; in Camberwell the same types were adopted; Islington also used them; St. Luke's, St. Pancras, Woolwich, and Richmond all used them, and the Metropolitan Company, which had some 500 miles already laid, still continued to use them. Therefore he thought it was inaccurate to assume that rubber no longer continued to be used. It was true the material was costly, but its cost was justified.

Mr. Robinson. Mr. MARK ROBINSON noticed that the Author referred to the comparative liability to vibration in three-crank and two-crank engines, but it seemed that he scarcely gave the right reason for the superiority of the three-crank engine. Dr. Kennedy had spoken admirably upon the many other causes which might produce vibration in a station; but still the main source of mischief was in the engines themselves. Experience showed that there was one kind of vibration which could not be eliminated by any arrangement of foundations, however good, if the engine were of a type to give rise to it. One set of vibrations was due to the couple of the forces acting on the lines of parts, and tending to rock the engine endwise. These were independent of the number of cranks, and were practically incurable, without great complications; but fortunately they were easily controlled by good foundations, and they were not likely to be transmitted. A far worse action, giving rise (in a vertical engine) to vertical vibrations, easily transmissible through a bad subsoil, resulted from the obliquity of the connecting-rods, but happily, if the engine had three cranks and equally-weighted parts, the vibrations from this cause wholly neutralized each other. In a two-crank engine, however, the results of the obliquity of the cranks resembled the other and less serious cause of vibration mentioned before, in that they were practically incurable. It was rightly said by Dr. Kennedy that if the subsoil were suitable there was very little to fear, but it often happened that the subsoil was bad. Many of the London stations were built upon alluvial deposit, and in other parts of the country stations were built near rivers for the sake of condensing water, and the wet subsoil transmitted the vertical vibrations as a kind of up-and-down pumping action. That had occurred at Manchester Square and in some other places. The evenness of turning moment of a two-crank engine left nothing to be desired for most purposes, and the vibration found in such engines had nothing to do with uneven turning moment.

The President. The PRESIDENT asked what Mr. Robinson meant by a bad subsoil?

Mr. Robinson. Mr. ROBINSON: A water-charged subsoil.

The President. The PRESIDENT: Whether gravel or peat?

Mr. Robinson. Mr. ROBINSON believed that peat would be much the worse. It was only recently that sound ideas as to the true causes of vibration had gained general acceptance, thanks, largely, to the work of his colleague, Captain Sankey; and he was anxious that ideas now deservedly obsolete should not be revived through a misunderstanding of the Author's meaning. Mr. Raworth had said that engines might work with equal economy from full load to half load. But what was full load? Surely an engine should be so designed that its ordinary full load should be its most economical load. No doubt an engine might be overloaded considerably without much loss of economy; but it seemed to him that what Mr. Raworth called full load was really an over-load.

Mr. Raworth. Mr. RAWORTH had stated 42 lbs. per square inch mean pressure, which was he thought the ordinary full-load pressure used by Messrs. Willans and Robinson.

Mr. Robinson. Mr. ROBINSON regarded that as a considerable over-load for a condensing-engine. It was stated by the Author that the tendency was to return to low-speed engines of the marine type, for large units of power, and the assumed hesitation among engineers to adopt high-speed engines for large powers was also remarked upon. Surely the only reason for this hesitation was that high-speed engines were as yet comparatively unknown for large powers. It was elsewhere indicated in the Paper that 750 HP. was the limit of high-speed engine practice, but the size of high-speed single-acting engines had often been limited before. He could remember when it was fixed at 100 HP.; it was said to be reasonable to go so far, but not farther. In the same way he could remember how it used to be said that high-speed engines would break up after 3 years' running; that was said about the time when they had been 2 years in use. The next year they were given another year's life, and so it went on from year to year. He could not help thinking that it would be the same in the present instance. As the high-speed engine made its way to higher powers, it would have to be reckoned with and accepted. It was a fact, however, that the Author himself had placed an order for one high-speed engine with the dangerously high power of 800 HP.

Mr. A. H. Preece. Mr. A. H. PREECE said it was 750 HP. That was the limit he had given in the Paper.

Mr. Robinson. Mr. ROBINSON said that it certainly stood at 800 HP. in its makers' published lists, and it had about a dozen fellows to keep it company in their shops. The same firm were building high-speed engines of 1,500 HP., and they had patterns in hand for engines very much larger.

Mr. Lawson. Mr. A. J. LAWSON thought that in Plate 3 the Author had omitted three of the districts which had been given to the County of London and Brush Provincial Electric Lighting Company. With regard to the pipes and chimneys, he had adopted, at the two stations of Wandsworth and St. Luke's, the principle which Mr. Crompton stated he had adopted years ago, namely, placing the pipes in the centre of the chimneys and carrying them to the top. He found no difficulty with that, and did not think that any would be experienced. With regard to vibration he had gone much further than was shown in *Fig. 7*, and had laid a complete block of concrete at both places on to the London clay under the footings of the walls, and carried the foundations of the engines on to it. He had found no particular vibration at any points of the station. If there were any tendency to vibration it was at the extreme top of the wall, and that was very slight. He also agreed with Dr. Kennedy as to vibration due to the emission of steam from the exhaust-pipe, especially if air were emitted. At Dover complaints had been made when the power-plant was started there. The engines were exhausting to atmosphere for about a fortnight, the condensers not being ready. The bottom of the steam-pipe was drained by a small pipe, and the complaints were that the vibration set up by the new plant was so great that it was cutting the cords of pictures in a house about 100 yards away. That was rather an extreme complaint, but it was found that a certain amount of vibration was set up which was very unpleasant. But there was no vibration at all communicated from the machinery through the foundations. With regard to the size of stations and the size of the plant, he agreed with Dr. Kennedy that there was a limit to the units to be used. In many of the stations with which he was connected a high load-factor had been obtained. A few sets of moderate size could be used at light load at their maximum efficiency. In winter time larger units were required. He did not agree that it was an economical method to have a number of stations, because the plant must be increased, and the expenditure on buildings and land must be increased. It was unfortunate that in London so many stations had already been erected. He thought that four or five well-designed stations on suitably

Mr. Lawson. chosen sites would have been far more economical in the end, and would have given a lower price to consumers in the very near future than the great number—some thirty-six to forty-three—of stations now erected or projected. He had been fortunate enough to obtain sites for his company's stations where water was obtainable for condensing, and where coal was conveyed alongside in barges. None of the troubles which he believed had been caused in the centre of London from condensation of steam during winter would be encountered. He had seen in one or two places on a clear night an apparently heavy shower of rain falling, due to not having a suitable position for the station and not being able to condense. With regard to load-factors he had prepared the following Table, showing the values at various stations for 1896.

LOAD-FACTORS, 1896.

CORPORATIONS.			COMPANIES.		
Station.	Output × 100.		Station.	Output × 100.	
	Plant in Station × 8,760.	Maximum Demand × 8,760.		Plant in Station × 8,760.	Maximum Demand × 8,760.
Hampstead Vestry	10·01	14·21	Charing Cross	12·33	20·84
Islington Vestry	6·80	8·95	Chelsea	7·09	9·48
St. Pancras Vestry	8·94	11·98	House-to-House	5·55	11·17
			Kensington	9·27	12·33
Aberdeen	5·58	5·92	Notting Hill	6·06	11·21
Blackpool	6·13	8·17	St. James's	10·04	13·36
Bradford	4·33	8·93	Westminster	10·66	13·33
Brighton	9·61	12·24			
Bristol	6·11	9·70			
Cardiff	8·00	9·92	Bournemouth	4·94	8·10
Dublin	5·46	10·58	Cambridge	4·30	8·35
Dundee	4·54	8·60	Coatbridge	2·67	5·91
Edinburgh	7·36	12·12	Dover	5·41	11·43
Glasgow	7·95	9·63	Eastbourne	7·68	10·37
Huddersfield	4·34	8·07	Hastings	9·60	12·63
Hull	5·88	7·17	Hove	5·06	8·84
Liverpool	3·09	4·78	Leeds	8·89	10·21
Manchester	7·95	10·64	Newcastle District	6·37	13·31
Nottingham	3·55	7·71	Newcastle-on-Tyne	7·28	10·15
Oldham	6·02	8·67	Oxford	5·55	12·29
Portsmouth	11·98	14·52	Preston	6·07	10·33
Wolverhampton	5·32	10·69	Richmond	3·82	8·21
Worcester	7·61	12·29	Scarborough	3·79	8·16
Yarmouth	3·99	10·09	Sheffield	6·90	8·59

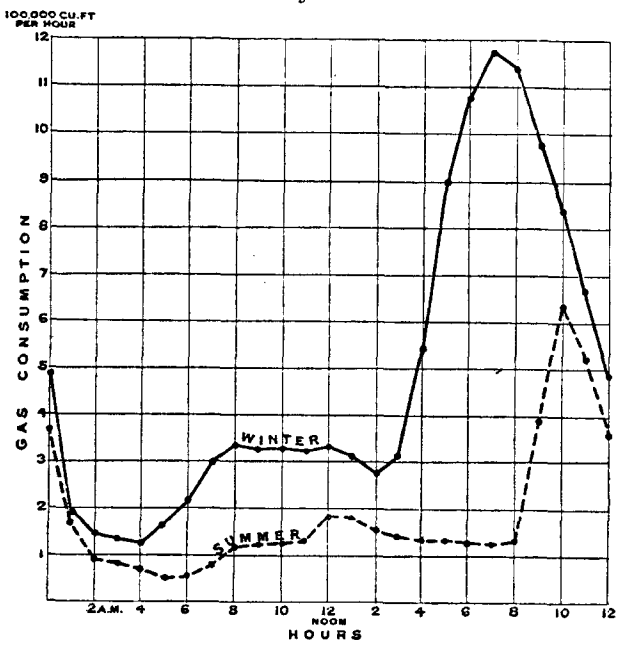
He had taken that year because the 1897 statistics dealing with London stations were not yet complete. Those stations which

were owned by vestries had the advantage that they obtained a fairly good load-factor by giving themselves public lighting, which kept up a fair demand for 12 hours of the day on the average throughout the year, and in London on foggy days a little over. It was evident, if it were now possible to reduce the number of stations, getting a better load-factor, a much more economical result would be obtained, and there would be a cheaper rate to the consumers generally. Mr. Lawson.

Mr. H. E. JONES observed that when 12 years ago he had spoken on this subject, Mr. Crompton had stated that his observations reminded him of the song of the dying swan. The swan was not dead yet, and he hoped it would live a little longer. He wished to thank the Author for the enormous mass of information which he had collected. He had never read a Paper which had given him more information, which was more plain, direct, and intelligible, or which gave such reliable statistics upon such an extensive basis. With regard to the question of the area basis, he noticed that the Author had selected the metropolitan area, that of the London County Council. In that area there were the three large companies supplying gas, and there were besides the Wandsworth and Brentford. He was happy to see that those portions of Plate 3 which were uncoloured were precisely those which Mr. Livesey and he had endeavoured to supply with cheap gas. At Wandsworth they were supplying it cheaper still, and he hoped those portions of the map would remain uncoloured. The deepest colours would be noticed in "Clubland" and Pall Mall and in the neighbourhood of the hotels and restaurants. He did not think there was much to tempt the suppliers of electricity at Whitechapel and Bermondsey. At any rate, if they went there, the gas companies would endeavour to make the competition as keen as possible. For comparison with Table 6 giving the total amount of electricity supplied, the capital expended in gas in the case of the five companies he had mentioned which covered the area of the map was, as compared with £6,000,000 in electricity, only £18,800,000. The number of consumers supplied with gas as against the 35,000 was, in 1896, 475,500, and it had since greatly increased. It would be seen that the capital was only threefold, while the number supplied was thirteen-fold. The revenue was £5,440,000 as against £800,000, so that there was about seven times the amount of business. The profit was only £1,500,000 against £350,000, which was the difference between the revenue and the cost of electricity. That figure was not stated, but it had to be deduced from those stated, so that the Mr. Jones.

Mr. Jones. profit was about a fourth. It would be at once observed that the capital spent per consumer for electricity was about £171 while for gas it was £39. The profit at £350,000 was exactly £10 per head, whilst the profit on the gas was something like £3 per head. It would be seen that the gas companies were able to supply the consumer at a very much lower cost to himself in the shape of profit. With regard to the load-factor, which now gave concern to some gas companies as well as electric-supply companies, he had prepared a diagram, *Fig. 11*, which showed that the gas companies

Fig. 11.



had their peaks of maximum lighting which were approximately the same as those mentioned by the Author, *Fig. 10*. As a matter of fact, the gas companies did not sustain their maximum supply for much more than two hours on a winter's evening. For the summer, the corresponding figures were given as they were in the Paper in dotted lines. It was well known that the great demand must be expected between sunset and the closing of houses of business and shops, after which time it fell away very rapidly. He did not think the electrical companies would improve their position in that respect by supplying power for traction for tramways, because

it would be inevitably found that people would want to go home in large numbers by the tram-cars just about the hours of darkness on a winter's night, when there was a maximum demand for the lighting. With regard to the pressure, he was a little struck by what had been observed in regard to electricity, of which he himself was comparatively ignorant. The Author had stated that, by doubling the pressure, the volume of power transmitted would be quadrupled. With gas- and water-mains it was found that so far from being as the square of the extra pressure it was only the square root of the extra pressure, and very little advantage was obtained by giving extra pressure. He contended that the same physical laws governed all those matters of transmission of volume. He might say that he had himself endeavoured to get two gas Bills through Parliament with clauses for supplying electricity. He thought every one in the room would see that a company which had an installation involving administration, collection, inspection, by a complete staff, and everything of that sort, would be able, if Parliament only saw fit, to conduct electrical business at a lower price to the consumer than an independent company; but Parliament appeared to be very much against it. Mr. Jones.

Mr. W. H. PATCHELL thought the Author had misread the 1882 Act in his statement in the opening of the Paper. There was certainly no allowance made for goodwill, but allowance was distinctly made for the business being sold as a going concern, which was a very different matter from selling for the value of the old material. With regard to the regulation of pressure, Dr. Kennedy had said that he could bank the whole of his dynamos, but he did not state that he banked them in three different stations. Mr. Patchell had sometimes to run seven different pressures in a station, and by that means he kept a good deal better line than was shown on pressure-curve *Figs. 6*. If the pressure were regulated to give only such a rough line as some of those shown, fewer pressures would suffice, and a better load-factor would be obtained. It would have been interesting had the Author given the temperature of the steam in the test given at page 142. It was a very good test, but he did not think it was taken with saturated steam. It appeared much more like a superheated-steam trial. It was stated by the Author that "All draw-pits have to be either carefully ventilated or absolutely sealed, and all pipes must be plugged in the draw-pits." He differed with the Author on this point; he had had considerable experience in Callendar casings laid in large banks, Mr. Patchell.

Mr. Patchell. many of them with sixty holes, and his practice had invariably been to keep them open and coax the draught through them wherever he could. He thought by bottling them up gas might be confined to one section and accumulate in sufficient quantity to give such troubles as some companies had experienced. The Charing Cross Company had ventilated their casings all through and tried to induce a draught from one section to another. The result was that they had never experienced trouble from the accumulation of gas. With regard to the ratio of cost to revenue, it was not fair to quote those costs without quoting other figures with them. His company had the proud position of being at the top of the percentage of cost to revenue column for the direct-current companies. But alongside that it was only fair to state that their selling price was about 20 per cent. lower than any other. It was under $4\frac{1}{2}d.$, and the next, the St. James's, was $5{\cdot}3d.$, whilst the Westminster was $5\frac{1}{2}d.$ It would be seen that if the revenue was one-fifth less than any other their costs unfortunately were not one-fifth less, and the percentage of costs to revenue therefore increased considerably. The Author had stated "A large expenditure is also generally incurred in lighting the principal streets." The Author did not state that it was generally a sprat to catch a mackerel. He wished he could coax his Vestry to do it. With regard to forced or assisted draught, Mr. Crompton had strongly advocated high chimneys, or at any rate strong draught. It was rather more than 2 years since he had stated the results he had obtained with fans in the chimney.[1] Much better results had since been obtained, and he thought it was well worth the consideration of every engineer who had steam to raise. One need not go far into it to see that if he took the proper means to catch the heat he could catch a good deal more heat than was necessary to work the motor to make the draught, and it was far more economical to have mechanical draught than to have "natural" draught up a chimney caused by the heat itself.

Mr. A. H. Preece. Mr. A. H. PREECE, in reply to the Discussion, remarked that his statement as to the banding of chimneys was based on observations at many of the stations in London, at which not only were the chimneys being at present banded, but, in some cases, they had already been banded for 3 years or 4 years, and he had been informed in two cases that it was undoubtedly due to the exhaust-pipe. He thought it would be agreed that, to place an important

[1] Proceedings of the Institution of Mechanical Engineers, 1896, p. 153.

pipe like an exhaust-pipe in the middle of a chimney, which could practically never be got at from year's end to year's end, was fraught with danger, and therefore it should, if possible, be avoided. It was easy to erect a separate chimney, and he did not think the expense would be very great. If a chimney of 8 feet or 10 feet in diameter were built and an exhaust-pipe of 2 feet or 3 feet diameter was placed inside that, its effective area was reduced very considerably. With regard to the load-factor, most of the speakers had been somewhat mistaken in referring to the point which he had raised; they were inclined to discuss whether the load-factor was 10 per cent., 15 per cent. or 20 per cent. What he had especially called attention to was the necessity to increase that load-factor to 50 per cent. and not to trouble about what it was below 20 per cent. The plant should be employed more in the daytime, and he was sorry that no reference had been made to the use of power from electricity. He was afraid that was almost a confession that there was not much being done, but at the same time it was a matter which all station engineers should endeavour to foster by giving electricity almost for nothing during the hours of daylight. He thought the remarks of Mr. Crompton upon superheated steam were perfectly correct. In the near future there would be a greatly extended use of superheated steam in order simply to prevent the loss in condensation. With regard to the chimney draught, there were objections to tall chimneys which might be mentioned—one was their unsightliness. He thought Dr. Kennedy would bear him out in saying that the ground landlord, in his district, for example, was very strict on the chimney question. There might be a very strong objection raised to chimneys of 200 feet and over. Mr. Crompton also entered a protest with regard to his remarks on batteries. In England experience was very unfortunate with batteries; perhaps it was better in Germany. He noticed that a good many German batteries were being ordered in England, and he thought that showed that the troubles might have been due to the battery makers rather than to any other cause. In all cases where batteries had been used there had been difficulties from the excessive up-keep. As regards Mr. Gray's remarks, he did not state in the Paper that rubber had been given up, but he said it was not so much used now as it had been, and that was a fact which could not be disputed. As to the question of vibration, in many places it was found that the subsoil was of such a nature that it very easily transmitted vibration. Gravel was very often far worse than anything else because it ran in veins

Mr. A. H. Preece.

Mr. A. H. Preece.

and cropped up at unexpected points and caused endless difficulties. With regard to the hesitation to adopt high speeds for very large powers, he thought that was a fact. The difficulty which he foresaw with high-speed engines was that the friction losses were likely to be greater than with any low-speed engine through the necessity for a large number of cylinders, and the efficiency was somewhat reduced. It was very curious that all the large stations in London charged the largest prices, and it would be found that those large stations in London produced worse results than any other. It was very interesting to see the great difference between the cost from the figures which Mr. Jones had given for connecting customers with gas- and electric-light. He thought he was correct in saying that with gas companies the connection of consumers and certain works of that kind were very often charged to revenue, and, not as in other companies, direct to capital. It would be generally agreed in London that the regulation with direct current was generally a little worse than with alternating current. He feared that Dr. Kennedy and Mr. Crompton had based their remarks rather upon the measurements taken in the electric-lighting station. The curves given in *Figs. 6* had been taken on consumers' premises unknown to the company, and they were affected a great deal by the want of balance; in fact, the two top lines, which he did not think were very good, belonged to the Westminster Corporation. It would be seen that the variation at times was larger than it should be. With regard to lighting of streets, that was purely a question of cost and an administrative matter, and he did not think he need refer to that. With regard to the plugging of the pipes, which had been referred to by Mr. Patchell, he submitted that it was far better to prevent any gas from entering the pipe-system by plugging the pipes, and that any gas should be confined to the spots where it gained an entrance.

Correspondence.

Mr. Hayes.

Mr. JOHN HAYES considered that, as only some 15 years had elapsed since electricity had first been supplied on a commercial scale, much cause for congratulation should exist for the rapid strides already made. The late Sir William Siemens, some years ago, was the first to point out that at no distant date it was highly probable that electricity would be generated at the collieries and