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 transmitted direct, so to speak, from the pit's mouth to all or most of the large cities and towns by means of suitable plant and machinery with the necessary distributing mains. This was now daily coming to pass, as in the present Session Bills were before Joint Committees of both Houses of Parliament to carry out this and similar projects. In this connection, he was of opinion that it would be infinitely better for London—with its teeming millions and ever-increasing population, instead of trifling with the subject from time to time, and dividing the electrical supply of the metropolis between so many companies, vestries or district authorities, with the ever-increasing difficulties in the way of securing suitable sites for generating-stations, vibration, smoke and other nuisances, as well as the serious capital expenditure, coupled with the heavy management and maintenance charges inseparable from any undertaking established in or near London for the supply of electrical energy—to at once get rid of all such vexations and troubles by putting into practice the shrewd and far-seeing prophecy of the distinguished engineer he had mentioned. As the Author had already pointed out, the economical production of electricity was only possible with large works having a heavy load-factor. No doubt this was so, and in the wholesale supply of electrical current at high voltage, both for motive power as well as for lighting on a large scale, such as could only be carried out in practice to advantage by generation at the pit's mouth, and that chiefly with refuse coal or small siftings, now discarded at the collieries as too poor in quality to be conveyed by rail to any distance, all or most of the conditions needed to ensure success might be said to be present. For the present supply of electrical energy to the whole of the metropolis, on the Author's authority, some 80,000 HP. was necessary, whilst a further 40,000 HP. was now being installed for use next winter, or a total of 120,000 HP.; suppose this capacity be doubled, and, say, a generating power equal to not less than 250,000 HP. be taken as the probable demand for the near future for London alone; he would propose to divide this output between, say, not more than three or four generating stations, erected at as many different collieries. In calculations or estimates connected with a scheme of such magnitude, nothing must be left to chance, as, even supposing it were possible to obtain the whole of London's electrical supply on technical and practical grounds from one and the same centre, on other and far weightier grounds it would prove very undesirable to do so. A sudden colliery disaster, a labour dispute, strike or lock-out, any one of these or similar causes might at any unexpected moment intervene to

Mr. Hayes.

Mr. Hayes. overthrow the most elaborate scheme that could be devised for the electrical supply of a large city, and suddenly plunge it into total darkness. Again, in an installation of such magnitude the generating machinery should be divided into units not less than 2,500 HP. or 3,000 HP. each, as engines of this size and power, running at low speed, but with a long stroke and consequently high piston speed, would be likely to give much more satisfactory results on economical grounds, maintenance and repairs, than would be possible by any high-speed short-stroke engine yet introduced. Neither the utilization of a colliery as the site of a generating-station, with the close proximity of one to the other, nor the great saving in being able to burn under the boilers refuse coal, screenings or dust, should in any way be taken advantage of, or made an excuse for introducing any but the most economical type of engines and boilers. As up to the present no works of any magnitude, or such as had been suggested, had been yet carried out under similar conditions, elaborate experiments would seem to be desirable before many of the crucial parts of the subject could be ascertained with any degree of precision.

Mr. Head. Mr. JEREMIAH HEAD agreed with the Author as to the desirability of an efficient condensing apparatus as an adjunct to a power station, but he did not think the chief impediment was the difficulty of obtaining a sufficient supply of water for condensing purposes. The evaporative condensers at Hammersmith appeared to use 5 gallons (or 50 lbs.) of water per HP. per hour, or, say, three and a half times the feed-water used by an economical engine, and therewith only a comparatively poor vacuum was obtained. The make-up water needed in the condensing plant at Stanhope Street was not given; but, whatever it might be, the system described seemed a very crude one. Corrosion of the corrugated sheets must be very rapid, and the nuisance caused by the unconfined steam must be considerable. In engines running continuously with a good load-factor, the ratio between the feed- and condensing-water to produce a good vacuum (say, 24 inches to 28 inches of mercury) had been found to be 1 : 30 in jet condensers, and 1 : 50 in surface condensers. These ratios represented the total water-supply required in these cases, as compared with three and a half times the feed in the case of the evaporative condensers. Where a cooling-pond could be made sufficiently large to hold, say, 12 hours' supply of condensing water, the latter could be drawn from and returned to it; the boiler feed-water being abstracted on the way. In such case the only continuous supply needed was that necessary to balance any loss by evaporation from the pond. A cooling-pond would therefore be the ideal system of economical condensing were it not for the extravagant space needed, which precluded its adoption in London and most large cities. The cooling system referred to as having been tried in one solitary case was an attempt to substitute a compact apparatus for a large cooling-pond. If efficiently carried out, no water whatever would be needed to obtain the admitted benefits of condensation, except just enough to replace the loss by evaporation. And as the evaporation of 1 lb. of water at 212° absorbed the same number of thermal units as were given out by the condensation of 1 lb. of steam at 212° to water of the same temperature, it was clear that all the steam used could be condensed by the evaporation of an equivalent quantity of water. In other words, with an efficient cooler the total continuous water-supply should not be more than for a non-condensing engine. He was chiefly responsible for an electrical installation abroad of about 300 electric HP., in which such a system had been adopted. The principal engine was a compound one working with 100 lbs. per square inch steam pressure. The exhaust steam for it (and certain other engines) passed into a jet condenser, to which was attached a duplex air-pump. The heated water was delivered therefrom to the top of a cylindrical cooling-tower set on end on a brick well. The tower was filled with earthenware drain-pipes also set on end and crossing joint. It was 26 feet 6 inches high and 8 feet 6 inches in diameter. The heated water, on reaching the top of the tower, was distributed by a revolving sprinkler. It descended in drops to the well below, and thence passed again into the condenser as injection water. A blast of air from an electrically-driven fan passed from bottom to top of the cooling-tower, meeting the falling drops of water and assisting in partially evaporating them. This evaporation of a portion was the chief factor in cooling the remainder of the water. Some steam escaped at the top of the tower; but, should it prove a nuisance, it could be dealt with precisely as the exhaust from non-condensing engines. When once the well had been supplied and the apparatus was in steady operation no more condensing water was needed; indeed there was always an excess overflow from the well equal to about one-sixth of the feed-water. The only water consumed was therefore the equivalent of that fed into the boilers. The vacuum obtained averaged about 24 inches of mercury. The temperature of the hot water at the top of the tank was about 120° F.,

Mr. Head.

Mr. Head and of the cooled water in the well about 80° F. The arrangement had been designed and supplied by Messrs. Worthington of Brooklyn.

Mr. Scott. Mr. Ernest Kilburn Scott feared that oil-firing of electric lighting boilers would never find much scope in England on account of the expense of the oil. This was practically the reason why it had been abandoned at the Bankside Station. It would probably be found advantageous, if an arrangement could be made with those interested in gas manufacture, to utilize the waste heat from gas retorts for steam-raising purposes. He thought that, generally speaking, the heat developed in destructors was not more than enough to destroy sewage sludge, &c., as had been shown by the results obtained, for example, at Shoreditch. Single generating sets of greater output than 450 kilowatts were now often employed. At Manchester, for example, two of 1,700 kilowatts each were being erected. More competition was the only possible way of lowering the present absurdly high charges for electricity which were the rule in most of the lighting areas of London, and as there was always the possibility that the construction of large gas-engines would be improved and the generating costs brought down by their use, this was another argument in favour of allowing the gas companies to supply electricity as well. The present high prices could scarcely be due to the cost of fuel, as the gas companies were working under the same disadvantages so far as the coal supply was concerned, whilst the fluctuating demand was much the same for both illuminants. He thought that in the near future nearly all the present London electric-lighting stations would be merely sub-stations (probably owned by separate vestries) supplied with two-phase alternating current from a few very large generating stations situated well outside the London area, where fuel and water were plentiful, and where the vibration from the very large engine sets (which would be necessary) would not bring expensive litigation in its train. The Metropolitan Company was even now laying down a large two-phase Westinghouse plant at Willesden to supply the existing generating plants as sub-stations therefrom.[1] The enormous demand for power as well as lighting at Manchester was to be dealt with in the same way. The Midland Electric Corporation was another project which indicated the development in progress, and it was an excellent example as showing how necessary it was that

[1] This Company had already laid down continuous-current generators and mains with which to cater for a motor load.

companies and not municipalities should undertake the supply of electrical energy over large areas. If it had not been for the trouble at the Deptford Station caused by the switching in of the Electric Cab Company's synchronous motors, the Chelsea Station would have been turned into a sub-station of the London Electric Supply Company. The heroic attempt of the latter company to prevent vibration, as shown in *Fig. 7*, and the fact that the Metropolitan and other companies had had to lay down steam-turbines, were further arguments in favour of turning most of the existing stations into sub-stations even where there was land room for them to be extended. The results and curves which the Author had presented would appear to show that there was very little in the advantages which single-phase alternating current was supposed to have, and, it would, therefore, be interesting to know why the Author had recommended a single-phase alternating-current distribution for Wimbledon. Multiphase or continuous-current might be applicable, but surely not single-phase. Mr. Scott.

Mr. JOHN F. SNELL observed that the Paper embraced the four known methods of distribution in use in Great Britain, viz., the extra high-pressure alternating current, and the high-pressure alternating current, the high-pressure direct current, or Oxford system, and the three-wire direct-current distribution at 220 volts or 440 volts. The questions of vibration and smoke nuisance had been overcome, the first by the use of three-crank engines, and the second by careful stoking and selected coal, which, as was rightly remarked, was the cheapest that could be used in a city like London. Now that three-crank engines were being adopted it seemed unnecessary to lay down the elaborate type of engine-bed found in many London stations, *i.e.*, with a concave base, and, in some cases, with layers of felt. There, therefore, only seemed to be one disadvantage attendant upon the adoption of multiple central stations erected in the heart of London—that of atmospheric exhaust. Apart from the minor question of atmospheric vibration, which could be easily cured, the problem was that the reduced steam consumption of plant and saving of coal which was obtained with condensing engines, and also the softening of the water and extra cleaning of boilers necessitated with the atmospheric exhaust, made it desirable that sites by the river should be obtained if this advantage was not outweighed by others; but he thought, since a condensing plant necessitated the erection of the station by the river (because many London stations could not possibly adopt cooling towers), its value could be over-estimated, and that the erection of the station directly over Mr. Snell.

Mr. Snell. the centre of gravity, as it were, of the system which it was supplying was both better from an engineering and from a financial point of view. This being the case, it would seem that 440-volt direct-current stations, interconnected, formed the best solution to the difficulties of supply in large cities. It had been pointed out by Dr. Kennedy and by Mr. Ellington [1] that there was a critical limit of capacity in central stations beyond which it was as economical to build a second station as to enlarge the first one. This was an argument in favour of multiple stations. Another which Mr. Crompton had pointed out was the greater immunity from breakdown, and there was no doubt that now extra-mural stations were receiving so much attention, from which both the present and future supply of a city was to be derived, the question of sending such an enormous supply through a few trunk mains was one which must require the most serious attention of engineers. If this system must be adopted, it would seem that three-phase distribution to sub-stations, in which would be erected rotary transformers, and from which would be distributed direct-current, afforded the best solution; but a fair case might be put for multiple stations supplying direct current, which, from their simplicity, economy in running and distribution, and availability of the current for power purposes, would be very hard to improve upon. It was difficult to understand how it was that in such an ideal centre as that of the City of London proper, direct-current distribution had not been adopted. With respect to the generation of steam, water-tube boilers were undoubtedly most valuable in dealing with the exigencies of the lighting load in London, where fogs were by no means infrequent, and their quick-steaming properties and small ground-space rendered them almost invaluable. Marine boilers with induced draught were certainly being much adopted in practice, and no doubt would continue to be so in those stations where the condensed steam could be used over again as feed-water. It had been a matter of wonder to him that water-softeners and purifiers had not been more largely adopted in the London stations, and that the barbarous method of precipitating the salts in the boilers by means of fluids had not become a thing of the past. It was to be regretted that electrical pumps had not been more developed. The chief difficulty was in proportioning the speed to the duty of the pump. The speed could be reduced in certain proportions, but not with the same facility as in steam pumps. While he had acted as Resident Engineer at the King's

[1] Minutes of Proceedings Inst. C.E., vol. cxv. pp. 243, 244.

Road Station of St. Pancras Vestry, the refuse destructor, which adjoined the station, was of no help in the generation of steam in the lighting station, but he understood that developments had taken place recently by which the destructor had become more efficient. With reference to steam mains, he thought some equivalent of ring mains should be adopted, and certainly sluice-valves were infinitely preferable to the ordinary mitre-valve, necessitating a far less number of drain-pipes and offering much less resistance to the flow of steam. The difficulties experienced in laying electric-light cables in London had been mentioned. He had superintended, amongst other districts, the laying of the Crompton bare-copper system, the first system of mains in Notting Hill, and had experienced little trouble there, or at Kensington, in obtaining the necessary depth and straight runs which this system required; but both districts were suburban. The strained copper strip system had always appeared to him to be the most mechanical; the insulation could be kept up to a very much higher degree than had been stated, and the facility for connecting consumers was great. Although acting at St. Pancras during the explosions which occurred on that system (bare copper), he had never yet heard of any similar trouble on the strained bare-copper system, where every insulator could be inspected and renewed most easily if need be. His experience of armoured cables had been unhappy, and he could not recommend them, since the steel armour in many localities frequently oxidized and left the cable open to injury. The present tendency seemed to be to depreciate the value of rubber cables, and to adopt cables with hygroscopic insulation hermetically sealed by a continuous lead sheathing. No doubt rubber was injured by becoming alternately wet and dry, and unless carefully laid and its ends carefully prepared, portions of it would soon oxidize. In spite of this, where due precaution was taken, he had had, over many years' experience, the best results from rubber cables; the chief objection to the other types of cables in his opinion being that, given a pinhole in the lead sheathing, moisture quickly spread through the length of the cable, a leak set up, and the cable broke down. With reference to methods of charging, mentioned on p. 144, the maximum demand was the fairest to the consumer and supply station, inducing the consumer to adopt the light in places where, for alleged cheapness, he would frequently burn gas, a too-common error on the consumer's part. In Sunderland, the effect of this system had been to increase, during the last year, the units sold per lamp installed by 13 per cent. as against the previous Mr. Snell.

Mr. Snell. year. With reference to costs of supply, it was significant that in the London stations the direct-current stations were decidedly the cheaper, as the Author showed in his comparative figures from the Westminster and the City undertakings. He was glad to notice that the Author's opinion was that the direct-current system would be more used in future than the ordinary alternating current, even if in some cases it was to be conjoined with three-phase trunks from an extra-mural station.

Mr. Preece. Mr. A. H. PREECE, in reply to the Correspondence, observed that the question of the establishment of generating works at collieries was, at the present time, of great interest. There were, however, many points to be considered as well as the saving in the cost of fuel. There was the loss in transmission and the extra expenditure in conductors; the question of superintendence and labour and the accessibility of the works. In the expenses of generating electricity the cost of the coal was by no means the only important item. When reasonable interest on capital was provided and adequate amounts allowed for depreciation, it was found that coal formed only 10 per cent. of the total cost. Hence removal to a coal-field might only save 7½ per cent. of the total cost if it was assumed that the cost of the coal at the coal-field was 25 per cent. of the best Welsh coal obtained in London. The extra cost caused by the removal would be the additional loss of energy, which could hardly be less than 20 per cent., the interest upon the expenditure for the conductors and the maintenance of the line. His calculations tended to show that it was exceedingly doubtful whether it would be advantageous to go to a coal-field unless it was situated within 20 miles of London. At the same time, if the cost of transmission could be reduced and the demand for electricity spread over longer hours the question would present a more favourable aspect. The results given by Mr. Head of a cooling arrangement for condensing water were valuable. However, the same objection must always hold with this system, viz., the nuisance to the surroundings from the evaporation of the water. Multiphase currents were still comparatively untried except for transmission of power on a large scale and to long distances. It had been found abroad that 2-phase currents were unsuitable for use for ordinary town lighting unless changed into direct current at sub-stations. Such a system was only applicable to cases where the demand for electricity was confined to compact areas. The Author agreed with Mr. Snell in his remarks upon multiple stations, and their safety from general breakdown. Recently a bad fire had occurred in a London works which caused its absolute stoppage, and customers were supplied without any delay from the company's other stations and the help of another company working on the same system. The question of danger from fire was of the utmost importance, as it appeared almost impossible to erect absolutely fireproof works. London had been singularly unfortunate in having five stations wrecked by fire within the last 8 years. As regards cables he considered that rubber was as liable to manufacturing defects as other cables, and unless great expense was incurred in providing an extremely thick covering of rubber, the danger was greater with it than with fibre or paper cables. His experience showed that the safest system for high-pressure work was lead-covered fibre cables laid in iron or stoneware conduits. Mr. Preece.

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19 April, 1898.

Sir JOHN WOLFE BARRY, K.C.B., LL.D., F.R.S., President, in the Chair.

It was resolved—That Messrs. David Gravell, F. Hudleston, G. M. Lawford, C. S. T. Molecey, W. S. Rendel, T. Frame Thomson, and J. J. Webster be appointed to act as scrutineers, in accordance with the By-laws, of the ballot for the election of the Council for the year 1898–99.

The discussion upon the Paper on "The Electricity Supply of London," by Mr. A. H. Preece, occupied the evening.
