Discussion.

The PRESIDENT, in proposing the vote of thanks to the Author, observed that the Paper was of interest to all who had to pay for gas. It indicated that the public utility undertakings were waking up to the fact that it was necessary to use the most economical methods of production. The Paper showed that it was possible to supply electric power for the working of the various items of gasworks plant from steam generated by waste-heat boilers, and he could visualize an era of cheap gas, which appealed to him strongly, as it would to all gas-consumers. The President.

Mr. THOMAS HARDIE congratulated the Author both upon the thorough and clear manner in which he had dealt with the power requirements of gasworks, and upon his courage in presenting a statement of affairs which, to those unfamiliar with the evolution of gasworks and their *modus operandi*, might seem to be lacking in efficiency as judged by present-day standards. His description of the steam power-units—scattered, non-condensing, and, he might have added, low-speed—was, in the main, an accurate representation not only of his own works but of many others, and especially of the older gasworks of the country. The significance of his remark that those units had been in use for a considerable number of years should be noticed as indicating the reliability in operation which had been secured, and which it was so essential that any new methods should possess. That economy in steam could be obtained by the substitution, for those admittedly inefficient machines, of high-speed, condensing steam power-plant in large units, using electricity as a convenient means of transmission, was obvious, and was a point in works economy that had been recognized by all progressive gas undertakings during the past decade or more. The suggestion in the Paper that electricity should be adopted in new works for all power purposes would necessitate the laying of both electric cables and steam mains throughout the whole works, as steam would always be required for many purposes other than power, and possibly the duplication of mains might result even in further transmission losses. Gas-making, of course, was a continuous process, and reliability and safety in operation of all plant employed must always be the first consideration. Breakdowns in gas-supply were practically unknown, and for essential manufacturing processes at gasworks it would be foolish to adopt any system of power that might damage the high standard of reliability reached by gas under- Mr. Hardie.

Mr. Hardie. takings. Coke-dust was very prone to find out the weak points in the design of electric motors and starters, while the presence of ammonia gas was not conducive to long life in copper. There were also instances in which explosive mixtures were present, and special precautions were necessary to avoid explosions. All those difficulties, of course, could be overcome by makers of electrical plant, but it was advisable to specify clearly the requirements of electrical plant which was to be used in gasworks, and very often that entailed an increase in cost of 50 to 100 per cent. over normal types. The Author did not mention the question of cost of electrical plant but he had given an indication of the low cost of steam arising from ability to use cheap fuel and from waste-heat recovery. A balance-sheet of costs, including capital expenditure, would have been a valuable addition to the Paper. The Author assumed that the test-bed results of electrical generating-plant with a 75-per-cent. load would represent the average performance throughout the year, and upon that fact he had based his estimate of the savings from an extended use of electricity. Mr. Hardie's experience was that, with generating plants of the type and capacity mentioned, an average efficiency of conversion of 7 per cent. was as much as was realized. That would give an overall figure of 4·2 per cent. instead of the 6·1 per cent. given in the Paper—an advantage of only 19 per cent. over the existing system in the Author's works, instead of the 74 per cent. claimed. With units of 1,000 kilowatts and more, an average conversion efficiency of 13 per cent. was possible in gasworks, but units of that size were only suitable in the very largest gasworks. On the question of the quantity of steam that could be obtained from waste heat, the Author gave figures of 950 lbs. of steam per ton of coal carbonized, and 30 lbs. per 1,000 cubic feet of water-gas made. Other works were regularly obtaining 1,200 lbs. per ton and 75 lbs. per 1,000 cubic feet of water-gas. The percentage of waste-heat steam could therefore be raised from the 32·5 per cent. made in the Author's works to 70 per cent. That again, of course, reduced very considerably the average cost of steam-raising and the value of the steam-economies which were to be effected from the electrical installation. The Author had arrived at his conclusions by comparison of his existing old-type steam plant with electrical plant whose efficiency was assumed to be maintained at test-bed figures for a high load-factor. He had mentioned, but not taken into account, the installation of a further system of waste-heat recovery utilized by other undertakings. Mr. Hardie was satisfied that, while for many purposes electricity could be adopted with economy on gasworks, its general adoption for the vital power requirements with a prospect of securing a small saving in the consumption of cheaply produced steam was a question requiring very careful consideration and analysis in each individual instance. He appreciated the amount of work carried out by the Author in the preparation of the detailed figures, which would prove of great value to other undertakings by way of comparison, and also by way of example. Mr. Hardie.

Mr. R. C. MACDONALD complimented the Author on his having resisted the temptation to take advantage of the opportunity to advertise the wares of the industry which he represented. At the same time, it was difficult to understand why he should have gone out of his way to advertise the wares of his competitor. The engineer had several sources of power at his disposal, which he could use individually or collectively. A few days ago a friend of his had made the following remark: "The value of a man depends not so much on his store of knowledge as on his ability to sort things out." In the use of the various forms of power it was the man with that ability who would achieve the best results. The Author stated (p. 4) that pneumatic and hydraulic power were not likely to be installed to any considerable extent in new gasworks. And yet the large gasworks, including those described in the Paper, which had largely adopted the use of electrical power and had dispensed with forms of power evidently despised by the Author, had not been able, before the present abnormal times, sell gas as cheaply as some of those undertakings which had not adopted electrical power for a single operation. He would be very loth to be responsible for the maintenance of power in a large undertaking without the assistance of pneumatic and hydraulic plant. Hydraulic plant was particularly suitable for retort-house machinery, and for coaling and other cranes. Where the load was fairly uniform there was nothing more reliable, speedy, or economical, than a hydraulic crane. Of course, the electrical drum was one that was being beaten by politicians, pressmen, financial adventurers, and others, who fondly imagined that they had found in it a panacea for all their troubles; but it was disappointing to find the Author being distracted by their noise. Mr. Macdonald was not suggesting that instances did not exist where electrical power would prove to be a great advantage, but he submitted that greater efforts should be made to obtain the best from sources of power which did not come into serious competition with one's own business. The Author disposed of gas power in one short paragraph (p. 4), and even there seemed to suggest that it could best be used for the generation of electricity. Mr. Macdonald maintained that in many cases he would find it Mr.Macdonald.

Mr. Macdonald. much more economical to use a gas-engine in place of a number of small, troublesome motors. Probably the most interesting part of the Paper was that devoted to the generation of steam. He could conceive that it might be practicable to generate all the steam required on a gasworks by means of waste-heat boilers, even although it entailed the use of more fuel in the producers; but carbonizing should be credited with its share in the saving. The Author's ideal appeared to be to utilize all the steam required for power purposes in generating electricity by means of condensing engines. Having regard, however, to the amount of steam required for process work, the use of non-condensing engines discharging into a low-pressure system, providing steam for heating and process work, was well worth serious consideration, and would, he believed, result in higher efficiency than the method suggested by the Author. He regretted that he could not compliment the Author on his method of applying electrical power to his plant. The fifty-seven motors in use (Table VII, pp. 19 and 20), included twenty-three different sizes. That must entail the stocking of a large number of spare parts. Considerable economy in maintenance could doubtless be effected by merely reducing the variety, and also by grouping in the place of a number of small individual drives.

Mr. Leather. Mr. J. P. Leather observed that the Author referred to the fact that in many cases present-day gasworks, having developed by successive additions to meet increasing demands for gas, necessarily contained very varied types of plant. That often rendered it difficult to arrange for the application of power in the most economical way. It had been his fortune a little more than 3 years ago to have to design an entirely new gasworks, the first unit of which was to have a capacity of 4 million cubic feet of gas per diem. He had had, therefore, to consider carefully the quantity of steam required and the means of supplying it. That was the ideal condition to which the Author referred as being a possible opportunity to make very considerable reductions in his figures. The figure given by the Author for steam raised was equivalent to 137 lbs. of steam per 1,000 cubic feet of gas. The Author admitted that that was exceedingly high, and assumed that in a newly-designed works only 69·8 lbs. of steam would be required per 1,000 cubic feet of gas. In the design of the works he had mentioned, Mr. Leather had made provision for only 56·6 lbs. per 1,000 cubic feet. Practically the whole of the power requirements—not quite all, as the Author suggested should be the case—were to be supplied by electricity. No boosting plant (which seemed to be one rather large item in the Author's figures) was needed, as that work was otherwise

Mr. Leather.

provided for. The Author estimated that it would be possible to supply 83 per cent. of the steam required by waste-heat boilers. He did not give any details showing how those estimated quantities of waste heat had been derived, but he stated that 950 lbs. of steam from and at 212° F. could be raised by waste-heat boilers per ton of coal carbonized. Mr. Leather had allowed for a possible 425 lbs. of steam. Mr. Hardie seemed to think that even 950 lbs. was a low figure, but to his own mind it was really a high figure, because it was impossible, according to his calculations, to obtain so much steam, except on one of two assumptions—that the waste gases left the retort bench at a very high temperature, say 1,300° F., or that there was a large consumption of fuel in the furnaces. In other words, as Mr. Macdonald had suggested, an unduly large quantity of fuel was used in the producers in order to get more waste heat, which was not economical. Secondly, the figure was apparently based on the supposition that it was possible efficiently to cool the waste gases down to atmospheric temperature. He did not think that that was really economically possible. The high figures which had been given—such as those Mr. Hardie had mentioned—of steam-production per ton of coal really must mean that there was want of economy in the furnaces or in the regenerators first, before sufficient waste heat could be got to produce that quantity of steam. While the waste heat from the carbonizing-plant seemed to be estimated on the high side, on the other hand the heat from the carburetted water-gas plant appeared to be low. The Author allowed 30 lbs. of steam per 1,000 cubic feet of carburetted water-gas made. In the test made by the Gas Investigation Committee of the Institution of Gas Engineers at Birmingham,[1] the lowest test result was more than 60 lbs. under the conditions of the test, equivalent to 69 lbs. from and at 212° F. Analysis of the gas leaving the boiler showed that, with a correctly-proportioned supply of air it might have been possible to obtain better results—probably 110 lbs. of steam per 1,000 cubic feet of carburetted water-gas; and that was, of course, much more than was necessary to supply the whole of the requirements of the carburetted water-gas plant, including blowers and exhausters. The quantity of steam given in the Paper as being made from the carburetted water-gas waste-heat boilers appeared, assuming that the quantity of carburetted water-gas was 20 per cent. of the total production of gas on the days of the test, to work out to considerably more than 30 lbs.—in fact to between 50 and 60 lbs.—

[1] Trans. Inst. Gas. E., 1921–22, p. 63.

Mr. Leather. per 1,000 cubic feet of carburetted water-gas; but even that was not as much as it was possible to get. If his criticisms were just, the Author's estimate that 83 per cent. of the required steam would be available from waste heat would require modification. A further source of heat at present was wasted at many gasworks. In the works referred to by the Author much of the gas was manufactured in horizontal retorts. In that case the sensible heat of the coke, which was withdrawn from the retorts at a temperature approximating to 1,900° F., was entirely lost in the water used for quenching the coke. At a number of works on the Continent and in America that heat was utilized for the production of steam by the Sulzer process. At the gasworks at Utrecht a 4-day test in which he had taken part the previous year had shown an average of more than 950 lbs. of superheated steam per ton of coke. In other gasworks on the Continent similar and even better results had been obtained over long periods of working. Taking the quantity of coke cooled at 50 per cent. of the coal carbonized, the steam from this source would be approximately 600 lbs. from and at 212° F. per ton of coal carbonized. When that was added to the other figures, the steam available from surplus heat sources would considerably exceed that required by the whole works; in fact, there were gasworks on the Continent where the surplus steam obtained in that way was used to generate electricity, which was then supplied at a low price to the municipal electricity department.

Mr. Lacey. Mr. L. LACEY observed that he was particularly interested in the question of the allocation of steam on a gasworks, and he was rather sorry, for that reason, that that matter had not been dealt with more fully in the Paper. There was much information in it, if it could be sorted out; but the process of sorting was laborious. He was rather mystified by the figures given on p. 12, of the subdivision of the heat used. How much water-gas had been made on the day of the test? Presumably the 3,458 lbs. of steam used for carburetted water-gas making was process steam, and that, according to his calculations—assuming 25 per cent. of the gas made, or about 1·9 million cubic feet per day, to be water-gas—worked out at 43 lbs. of steam per 1,000 cubic feet of water-gas, which to his mind was rather high. He noticed that the quantity of oil used was very high in relation to the quantity of gas made, and that might have something to do with his question. In Table IV (p. 13) it was stated that there was 2,350 brake horsepower-hours per 24 hours in the steam used for carburetted water-gas blowers. That worked out at about 100 HP. He had had experience of a plant making in the neighbourhood of 3 million cubic feet per diem, and he had found no difficulty in getting sufficient blast with half that amount of power. Table IV would have been still more interesting if, in addition to the horse-power developed, the steam supplied in each case had been shown. According to the Author's figures, it appeared that 137 lbs. of steam from and at 212° F. were used per 1,000 cubic feet of mixed gas made. In using such a basis of comparison it should be laid down, of course, what the steam-consumption should include. For instance, boosting gas on to the district, or anything connected with by-product works, should not be included; and if power was derived from gas-engines it should be converted into an equivalent weight of steam. In connection with the Author's observations as to the economies that might be effected by making greater use of electricity for power purposes on gasworks, and with his advocacy of the maximum use of waste-heat boilers, Mr. Lacey was able to give figures relating to the works of the Gas Light and Coke Company with which he was associated. Those results had very largely been achieved without the highly efficient electrical plant which the Author favoured. Over a period of 6 months, about 75 per cent. of the steam required for the works—not including pumping gas, but including process steam and steam for generating electricity—was derived from waste heat. About 15 per cent. was used for producing electricity and 10 per cent. was process steam. The efficiency of electrical generation was, roughly, about 7 per cent. He thought Mr. Hardie had given that figure as one applicable to small gasworks. The works in question made about 2,000 million cubic feet a year, being about two-thirds of the size of the Author's works. Mr. Lacey.

Sir William Ellis. Sir WILLIAM ELLIS, Past-President, thought that the Author had suggested a very roundabout way of using gas power, and the result was that he arrived at a figure which was not at all inviting. The cost for gas per brake horse-power-hour was given (p. 4) as "only 0·75*d*." Sir William Ellis knew from experience that gas, properly and directly applied, would still produce power more cheaply than even the most modern electrical installation. For years, when he was in the position of manager of a works, the cost of power, with a small gas-plant supplying an engine directly, was no more than 0·25*d*. per brake horse-power-hour, including depreciation. If gas was used to generate electricity which was then used as power, it was not given a reasonable opportunity. If the Author considered the use of gas for power purposes direct from gas-producer to gas-engine, he would obtain a cost totally different from that given in the Paper.

Mr. Bullmore. Mr. A. W. E. BULLMORE observed that the Author's company appeared to be using the unusually high figure of about 40 per

Mr. Bullmore. cent. of the residual product in coke and breeze for generating steam in the works. At the works with which he was associated—which produced only about 150 million cubic feet of gas per annum—a corresponding figure of 20 per cent. was considered to be very high. The Paper would be particularly interesting to engineers concerned with smaller works, because it was not unusual even at the present day to find a small works where boilers were being used with hard water; and when it was realized that $\frac{1}{8}$ inch of scale increased the fuel-consumption by 15 per cent., $\frac{1}{4}$ inch by 50 per cent., and $\frac{1}{2}$ inch by 150 per cent., the Author's figures would provide food for thought on the part of those in charge of such works. In the majority of smaller works the feed-water was not heated. He had ventured to write a short article for one of the technical journals, and he had been surprised to learn of the interest aroused by the suggestion that feed-water could be heated very simply by passing the steam leaving the exhausters through a small shell through which the softened feed-water was passed. As the result of the adoption of such a device in his own works the water was now fed at a temperature of about 110° F. With regard to electricity, he had used it to some extent, and he had found what had already been mentioned, namely, that the electrical fittings soon went to pieces. That was especially noticeable in the case of the switchboard terminals in the exhauster-house (where one exhauster had been fitted with electric drive for a particular reason) owing to the effects of ammonia. He therefore did not think that electricity could be applied to gasworks as widely as the Author imagined. A particular difficulty was that coal-dust got into the motors, and it was impossible to keep the commutators clean—even in the blowing-house for the water-gas plant, although precautions were taken to keep the dust out. At what figure did the Author value the fuel used for steam-raising? The figure of 4·7 cwt. for coke sold out of the yard seemed rather small for a works of the size described. On a small works it would not be so bad at the present time, considering the quality of coal that had been available. The Paper would certainly encourage gas-engineers to consider the problem of power-economies in dealing with steam. Reliability was essential in the gas industry, and steam power was reliable, which could not always be said for electricity.

The Author. The AUTHOR, in reply, remarked that he had heard with pleasure the discussion which the Paper had evoked, and if any member had learned half as much from the Paper as he had learned from the discussion, he was amply repaid for any little trouble writing the Paper had meant to him. As mentioned in the Paper, he had not dealt with the capital costs of the electrification scheme, which, of course, must be taken into consideration for every case. It would undoubtedly be necessary to carry process steam to certain portions of the works, as mentioned by Mr. Hardie, and it was possible that examination of a concrete case might cause him to modify his ideas considerably, owing to the capital costs involved in laying both steam and electric mains. Mr. Hardie had said that reliability must be a first essential. Those in charge of gasworks did pride themselves on maintaining a supply of gas under any conditions, and they could not afford to put in any form of power which was not reliable. He thought that most gas-engineers had now had sufficient experience of using electrical power to know under what conditions it might be considered reliable, and he thought, too, that they could get electrical apparatus and appliances which would work satisfactorily under any of the conditions which were likely to be met with. The difficulty of working electrical motors in coal- and coke-dust and in ammonia fumes had been mentioned, but there were plenty of motors working in this country in gasworks under conditions which he ventured to think the average electrical engineer would say were impossible. It was only necessary to examine a few cases of these conditions; for instance, a retort-charging machine was operated immediately in front of a retort-bench at a high atmospheric temperature and generally in a cloud of coal-dust; a motor driving a coal-conveyor at the top of a retort-house got all the heat and smoke thrown up from the retort-bench, particularly when the retorts were being charged and discharged, and was also working in an atmosphere of coal-dust; a motor driving a coke-conveyor or a coke-screening plant also worked under difficult conditions, where again there was plenty of dust, but in this case it was coke- instead of coal-dust. If motors would work satisfactorily under those conditions—and hundreds of them were doing so—he ventured to suggest that they would work under any conditions likely to be met with in gasworks. Mr. Hardie considered that too high an efficiency of electrical generation had been taken by the Author when he assumed that the test-bed results for steam-consumption were likely to be maintained with an average load of 75 per cent. The Author agreed that the test-bed steam-consumption might be a little lower than the average actual consumption, but at the same time the actual average load-factor was nearer 80 per cent. than 75 per cent. Mr. Hardie seemed to think that he had underestimated the quantity of waste heat which should be obtained per ton of coal, whereas Mr. Leather thought he had overestimated it. That question depended very largely on the temperature at which the waste gases left the retort-settings before waste-heat boilers were installed. In the case of his own works, before waste-heat boilers were put The Author

The Author. in, the temperature of the gases discharged into the base of the chimney had been about 1,000° F. It was found that the retort-settings worked most economically when the waste gases were discharged at that temperature. After the waste-heat boilers had been put to work the temperature of the waste gases at the outlet of the boiler was reduced to 486° F., while the temperature of the waste gas entering the boiler was 1,032° F. With inlet and outlet temperatures such as these, he found that he could generate 950 lbs. of steam per ton of coal carbonized. This steam was raised from genuine waste heat, but he had found that by using a little more fuel in the producers on the retort-settings additional steam could be made at the waste-heat boilers, raising the figure to far more than 950 lbs. per ton of coal carbonized. It might be economical and expedient to raise steam in this way by using a little more fuel in the producers on the retort-settings, rather than by carting fuel to the screening-plant, screening it, and then conveying it to a boiler-house for use there; but it was not fair to say that this additional steam was from waste heat. Before it could be claimed that any steam was being raised from waste heat, the temperature at the inlet to the waste-heat boiler should not be any higher than was previously necessary for the economical working of the retort-setting before the waste-heat boiler was installed. It had been said that his figure of 30 lbs. of steam per 1,000 cubic feet of water-gas made was low. Actually in the tests made on the Humphreys-Glasgow waste-heat boiler at his works about 60 lbs. per 1,000 cubic feet of gas were made, but since that waste-heat boiler had been installed there had been considerable improvements in the design of water-gas plants. On some of the latest plants a portion of the waste heat was used in the gas-making process itself, by means of what was known as the "back-run" process. If that process were used it would not be of any use putting in a waste-heat boiler such as the Author had described in the Paper, but the most modern water-gas plant would probably have a boiler-generator in which steam would be raised from water contained in a jacket surrounding the generator, and in that case 30 lbs. of steam per 1,000 cubic feet of gas made was a reasonable figure to take. He had been very interested to hear Mr. Leather's remarks with reference to his experience in designing an entirely new gasworks more than 3 years ago, particularly as in the design of that works Mr. Leather had made provision for 56·6 lbs. of steam per 1,000 cubic feet of gas to be made, which compared very closely with the Author's estimate of the requirements. Mr. Leather's figure was lower than the Author's, but no boosting plant was needed. In the Author's works a large quantity of steam was used for boosting. Mr. Leather had said that details

The Author.

had not been given showing that it would be possible to supply 83 per cent. of the steam required by waste-heat boilers. The argument for this would be found on p. 23, and the figure of 950 lbs. of steam per ton of coal carbonized had been obtained from actual tests. The question of utilizing the heat which at present was lost when water was used for quenching coke in the horizontal retort-house was very interesting, and of the plants which had been designed for this purpose, the Sulzer appeared to be as satisfactory as any. The objection at the moment to this process seemed to be the high capital cost, but the possibility of generating 600 lbs. of steam per ton of coal carbonized from the heat to be recovered during coke-quenching was very attractive. He appreciated Mr. Macdonald's strong partisanship of the gas industry. The Author's object, however, was not to advertise the wares of the industry which he represented, but to try to indicate the manner in which those wares might be produced at a lower cost. It seemed to him that it was the duty of an engineer to make the most efficient and economical use he could of any source of power which was available. In any case, the Author's company supplied electricity as well as gas! Mr. Macdonald had remarked that before the abnormal times which had just been experienced gas was not sold so cheaply by some undertakings that were using electricity for power purposes as it was by some of those that had not adopted electrical power for a single operation. It was always unsatisfactory to try to compare the price of gas as sold by the different companies on one factor alone. The geographical position had a great bearing on the costs of manufacture. At the present time, however, certain companies whose works used electricity for power were selling gas at a lower price than the works which the Author thought Mr. Macdonald had in mind and which made no use of electricity, and he thought it was a moot point whether the works which used no electricity at all might not have been able to sell cheaper gas if at some time or other reasonable use had been made of electricity for power purposes. He had not been distracted in any way by the electrical drum. His suggestions were that electricity required for power should be generated on the gasworks from the waste heat of the gas-making processes. As reliability was one of the first essentials in a power-supply in gasworks, it would be necessary to install duplicate generating-plants. If it were made compulsory to purchase any electricity required from the capital power-stations of the large authorized power-suppliers, the position would be entirely altered, and on many points he would agree with Mr. Macdonald. Unfortunately a wide variety of motors were in

The Author. use on the works, but an endeavour was being made to standardize these. He quite agreed that standardization within reasonable limits made the maintenance question much simpler. It had been suggested by Mr. Lacey that the quantity of coke used for the manufacture of water-gas appeared to be rather high. The figures in the Paper had been prepared from 24-hour tests, and although the steam which was being used and the gas which was being made were practically the same as on an average day, it was hardly safe to say that multiplication by 365 would give the quantities per annum. At the same time, the tests had been made during the period of the coal-stoppage, when the quality of the coal carbonized, and therefore the quality of the coke used in the carburetted water-gas plant, was not up to the usual standard, and during 1926 more coke had been used in the water-gas plant than was usual. Sir William Ellis's figure of 0·25*d.* per brake horse-power-hour appeared to be a pre-war cost for a suction gas plant; the Author's figure was a post-war cost for town's gas, so that the two were hardly comparable. It was almost impossible to make any fair comparison between the quantity of steam used on a large works, where practically every process was carried out by mechanical means, and the quantity used on a very much smaller works, where a large amount of hand labour was used. That would explain why in Mr. Bullmore's case to use 20 per cent. of residual coke and breeze for generating steam would be considered high, whereas in the Author's case about 40 per cent. of these by-products was used. The whole of the water used in the boilers was softened, and the feed-water was heated. In some cases the feed-water was heated by being passed through the cooling tubes of gas-condensers, thereby serving two objects. The fuel used for steam-raising had been valued at 10*s.* per ton, as was shown in Table VI. It appeared that Mr. Bullmore, in arriving at a figure of 4·7 cwt. of coke sold out of the yard per ton of coal carbonized, had left out of consideration the quantity of coke used in the water-gas plant, which should be credited as a sale. Table VIII showed the estimated cost of generating steam on waste-heat boilers, including the capital costs of the boiler and the installation; and also the estimated cost of generating electricity from steam generated in waste-heat boilers under the conditions outlined in the Paper. The capital costs of the waste-heat boiler and auxiliaries, including installation costs, were £2,712, and were the actual costs incurred in installing a boiler which generated a net quantity of 4,800 lbs. per hour of steam at 120 lbs. per square inch pressure, after the quantity of steam required for driving the induced-draught fan had been deducted.

The Author.

TABLE VIII.—COST OF STEAM GENERATED BY WASTE-HEAT BOILER.

CAPITAL COST.

Boiler	£1,712
Installation and Auxiliaries	1,000
	£2,712

Interest on Capital at $6\frac{1}{2}$ per cent.	£175	15	7
Depreciation at 10 per cent.	271	4	0
Repairs at 5 per cent.	135	12	0
	£582	11	7

Interest, depreciation, and repairs—Cost per diem = £1 11 11

COST OF STEAM-GENERATION.

Boiler generates 4,800 lbs. per hour at 120 lbs. per sq. in. = 115,200 lbs. per diem.

Interest, depreciation, and repairs	£1	11	11
Labour, 1/3rd man, 3 shifts	0	10	6
Softened water, 11,520 galls. at 1*s.* 1*d.* per 1,000 galls.	0	12	6
	£2	14	11

Cost per 1,000 lbs. = 5·72 pence.
Cost per ton = 12·8 pence.

COST OF GENERATING ELECTRICITY BY STEAM PRODUCED BY WASTE-HEAT BOILER.

Output = 610 kilowatts, or 14,640 units per diem.
Load-factor 85 per cent. Maximum demand = 610 × 100/85 = 718 kilowatts.

CAPITAL COST

of two 750-kilowatt sets, including condensing and water-cooling plant, at £15 per kilowatt = £22,500.

Interest on capital at $6\frac{1}{2}$ per cent.	£1,462	10	0	
Depreciation at 5 per cent.	1,125	0	0	
Repairs at 5 per cent.	1,125	0	0	
	£3,712	10	0	per annum.
	= £10	3	5	per diem.

COST OF GENERATING PER DIEM.

Interest, depreciation, and repairs	£10	3	5
Labour, 1 man per shift.	1	15	3
314,000 lbs. of steam at 5·72*d.* per 1,000 lbs. .	7	10	0
Cost of 14,640 units =	£19	8	8

= 0·318*d.* per unit.

Correspondence.

Mr. J. N. REESON complimented the Author on dealing with a subject that had, perhaps, had too little attention; for the modern gasworks, as the Author pointed out, was necessarily equipped with power for performing practically every operation. Mr. Reeson considered, however, that hydraulic and pneumatic power, useful as they had been in the past, were fast giving way to electrical

Mr. Reeson.