Discussion.

The President. The PRESIDENT moved a vote of thanks to the Author for his admirable Paper, and recalled the fact that this was not the first Paper Mr. Jones had been good enough to present to the Institution, for 26 years ago he had contributed one which had led to a discussion extending over three evenings. So much time was not available on this occasion, the next ordinary meeting being the last of the Session, but he trusted, as there were many well-known gas-engineers present, that the discussion would be heartily sustained throughout the time at disposal.

The Author. The AUTHOR feared that, in his effort to make the Paper acceptable to members of the Institution generally, he had dealt rather with the lines of general interest, showing how the main requirement of the consumer of gas, viz., a cheap supply, could be met. Lest that might lead the members to think there was in the Paper a little too much of the general manager looking for a dividend, he would point out that in it he had urged very strongly the claims of the engineer, as responsible for the capital expenditure, to be recognised as the most potent factor in insuring a cheap supply of gas.

Mr. Brackenbury. Mr. C. E. BRACKENBURY remarked that it might perhaps be doubted whether the Author had succeeded altogether in giving an impression of what was generally accepted as the modern practice in the manufacture of gas. The arrangement of the Paper had resulted in some lack of clearness, and in overlapping and repetition. He only mentioned that small point to show that, in his opinion, although the Paper was of considerable interest, it might have gained in interest and conciseness had it been cast in a different mould. More important, however, were the omissions. It struck him as somewhat curious that a Paper on the modern practice of gas-manufacture made no mention, except incidentally, of those gasworks where all the operations, from receiving coal to the selling of the residual coke, were performed entirely by mechanical means. There were several works in existence where coal was received from either railway trucks or barges, placed in coal-stores, taken away automatically and carbonised, and the coke was discharged, quenched, and conveyed to overhead bunkers, and thence into consumers' carts, railway wagons,

or barges, entirely by mechanical operations. The difficult question of successfully conveying hot coke from the retorts might have been mentioned, particularly as it was one to which gas-engineers had given considerable attention within the last year or two; and there were now some successful hot-coke conveyors which also quenched the coke without causing trouble to the working-staff in the retort-house. There was no mention of the tendency of modern practice to replace high and bulky plant by low and compact apparatus. For instance, large atmospheric condensers were being replaced by the more compact water-tube condensers. Again, no reference was made to gas-exhausters; within the last 10 years Mr. Donkin had greatly improved their capacity by utilizing the drum, and had thereby increased the efficiency of the machine and confined it within smaller space. No mention was made of what were known as washer-scrubbers, very compact machines which were replacing rapidly the old-fashioned cumbrous and unmanageable tower-scrubbers. In the interesting account given of carburetted water-gas, space might have been found to mention the Dellwik process and its possible developments; and in the department of gasholder-construction it was curious to find no mention of the radical changes made in recent times by the Gadd and Mason spiral holders, which did away with the exterior guide-framing, and the well-known Pease system of guiding the lifts of the holder by wire-ropes. With regard to spiral holders, the company with which he was connected had erected what he believed to be the largest gasholder on that system. It was not a very large one as gasholders went, but it had a capacity of something approaching a million cubic feet, and was nearly 150 feet in diameter, with three lifts. That holder had proved so successful that it was to be duplicated in the near future. He thought the Author had claimed rather too much for the sliding-scale legislation, and the Paper might give the impression that all improvements were due more to that legislation than probably was the case. Labour troubles had played a far greater part in making gas-companies adopt mechanical appliances. The increased cost of labour and the competition with electric light had also instigated gas-engineers to find the best means of handling their material, and of producing illuminating-gas at as low a price as possible. With regard to carbonising, the Author mentioned charging- and drawing-machines driven by hydraulic power, compressed air, and direct-acting steam. Mention of direct-acting steam might lead some to suppose that it was still to be found in general use in gasworks, but such was not the case.

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Steam had been naturally used in the first place for stoking-machinery, but there were many objections to it, and it was found now only in isolated instances for drawing the retorts, as shown in Fig. 4, Plate 2: stoking-machines of the present day were actuated almost exclusively by hydraulic power or compressed air. It would have added completeness to the Paper had an illustration been given of the compressed-air machine, which had been brought to a high state of perfection by Mr. John West, M. Inst. C.E. The Author stated that the coke from machine-retorts was not worth so much as that drawn by manual labour, by as much as 1s. 6d. to 2s. 6d. per ton. If that was the case, it was a very serious drawback to the introduction of stoking-machinery for the arduous work of retort-houses; but with the machines which he had been privileged to manage for some time in works abroad, that had not been his experience. There no complaint had been made of the coke, nor had the price of it been reduced. Turning to inclined retorts, which the Author treated rather summarily perhaps, having regard to the importance of the system, it was interesting to note that the father of the gas-industry, Murdock—whose name figured on the walls of the Institution—had started with a vertical retort and had then adopted an inclined retort, and finally the horizontal retort. It appeared that gas-engineers were now going from the horizontal retort to the inclined, and, it might be in the future, to the original vertical retort, in the shape of water-gas plant or in producing gas from coke-ovens. The idea of inclined retorts had been resuscitated by Mr. Coze, of Rheims, in 1885, and in 1889 the system had been introduced into this country by Mr. Frank Morris, M. Inst. C.E. Within 10 years very nearly 100,000 lineal feet of inclined retort had been put up in this country alone, representing an expenditure of £750,000, or an average yearly expenditure of £75,000. New works for the municipality of Birmingham were in course of construction, or had been just completed, in which there were 416 inclined retorts; and at the new works at Granton, for Edinburgh, under Mr. Herring, 504 inclined retorts were being put up. Other municipalities, such as Leeds, and gas-companies, such as the Brentford gas-company and others, had used them very largely. On the Continent it might be said that practically all new works were on that system. Yet notwithstanding this extensive adoption of the system, it was stated that the drawback of the slipping of the coal must be absolutely overcome before the system could make much headway. The keynote of the Paper seemed to be cheapness, and although

that was no doubt a very estimable thing in these days, Mr. Brackenbury.
yet it might be carried too far. He did not understand that the whole duty of the gas-engineer was merely to produce gas as cheaply as possible. He took it that it was part of the engineer's duty to maintain the efficiency of his plant and to adopt modern apparatus. There was a humanitarian account as well as a capital account, and the former necessitated the introduction of mechanical appliances to relieve the human machine wherever possible. Even if this resulted in increased cost of working, which it did not, it would be a thing to be recommended for the very severe and trying work of the retort-house. The Author evidently had a preference for manual labour, and remarked that "many of the machines have hitherto failed to attain the speed and efficiency of zealous and well-directed hand labour." But an inclined retort could be emptied of its coke and charged with 7 cwt. of coal within 30 seconds, and the average speed of stoking-machinery was sixty to eighty retorts per hour. Coal and coke could also be much more expeditiously conveyed by mechanical means than by hand. Again, the Author stated that such apparatus could be introduced with safety and real economy only in works of adequate size, yet it had been shown by actual practice that gas-works making a minimum of 100,000 cubic feet per day could successfully adopt coal- and coke-conveying plant, and even smaller works could profitably use many forms of stoking-machinery. Turning to the purifying-plant, it was not generally considered advisable to introduce steam-boilers into purifier-houses, as shown in Fig. 6, Plate 2. Several methods adopted by the Author were not generally accepted by gas-engineers. Thus, he used water-sealed valves, which in the majority of gas-works were now replaced by dry centre-valves: he cooled the gas in contact with its tar and ammoniacal liquor, while the general practice was to separate them: and he still preferred the original coke-scrubber, and stated in the Paper that coke was almost universally used for scrubbing or washing the gas with water. This latter was a somewhat startling statement, since in this connection coke had long been generally superseded by the use of thin boards, which gave far greater wetted surface than was possible with coke, in addition to many other advantages. In modern practice, however, washer-scrubbers were adopted, which could be easily regulated to the work to be done. It was no proof of the correctness of the Author's practice that, after severe testing by the authorities, very favourable reports had been given as to immunity from impurities;

Mr. Brackenbury. for what had to be shown was that equally good or better returns would not have been obtained—and in an easier, more mechanical and more scientific way—by the adoption of methods recognised as those of modern practice. The Author's liberal and sound views on distribution would be heartily welcomed and endorsed by all. Particularly should the thanks of engineers be accorded to him for having so admirably drawn attention to the importance of appointing thoroughly trained men at proper remuneration to fill the responsible technical posts in British gas-works, as was done on the Continent.

Mr. Jones. Mr. C. E. JONES congratulated the Author on having given a synopsis of the Metropolitan system. He did not intend to criticise omissions from the Paper, for it was evident to engineers that the Paper was not intended to be a complete history of the gas-undertakings in the kingdom. He agreed with the Author that reduction of capital expenditure was a very important matter. There was no doubt whatever that the gas-capital of this country stood very high, and one reason for this was indicated by the account of the eight mains found to occupy one street. That was a case in which the need for economy in capital expenditure was apparent, as one large main would do the work of all eight. Another source of economy was to be found in working gas at higher pressure than had been the practice hitherto. "Keep down your pressure" was a maxim frequently heard amongst gas-engineers; but he did not believe that the practice was in all cases economical, and if a gas-engineer could not lay gas-mains to work at higher pressures than a few inches of water it was time he employed a water-engineer to put down the mains for him. It was possible to work with pressures attaining even to scores of pounds, with the greatest ease. The increase of pressure in gas-mains would lead to a reduction of capital, because as much gas could be driven through the small main as through the large one. This practically increased the delivering-capacity of the mains without enlargement of the pipe. He would like the Author to give his views upon that point. It had been truly remarked that gasholders could be built without guide-framing, which cost between a quarter and one-third of the total cost of the structure, and that was another source of economy. He had put up the largest gasholder of the kind in Nottinghamshire many years ago, which had worked satisfactorily up to the present time. A great deal of the capital expenditure in gasworks could be saved by abolishing the guide-framing, which was not necessary, and certainly was not ornamental. The Author had given the cost of gas of

14 to 20 candle-power, and had also expatiated upon the improved Mr. Jones. burners and the supply of gas to burners under high pressure. Did the Author consider 20-candle-power gas at all economical from the public point of view? He himself did not. About 22 years ago he had submitted a Paper¹ on "Public Lighting with special reference to Streets" to a kindred Institution, in which he had expressed the opinion that gas of more than 20 candle-power was of no advantage to the general public; but now he would go farther, and would say that gas of over 14 candle-power was a waste to the ordinary consumer; if only he would burn the gas in incandescent-mantle burners he would get more light with low-pressure gas. Gas-engineering was in a state of progressive transition; formerly gas had been used for lighting only, now it was used for a variety of purposes, such as heating and motive power, for which it was in ever-increasing demand. That showed that gas of 14 candle-power was more useful for all-round purposes than gas of 16 candle-power or 20 candle-power, or even 30 candle-power. With regard to water-gas, he did not think it was likely to take the place of coal-gas. It was only an auxiliary, a help-mate; and as long as it took a subsidiary position in supplementing coal-gas, so long would it be useful.

Mr. A. G. GLASGOW considered that the very broad character of Mr. Glasgow. the Paper invited such abundant collateral discussion, that it would be advisable to limit his observations to that portion with which he was most concerned, viz., carburetted water-gas. He had listened with great pleasure to the Author's able and appreciative statement of the distinguishing features of that process, but he felt bound to say that the satisfaction which the Author rightly felt in the process was not eloquently reflected in the statement of cost of manufacturing carburetted water-gas given in the Paper. Practically all the items in that statement indicated arithmetical error, or, perhaps he might say, a conservatism which approached inaccuracy; probably due to the fact that arrangements had not been completed for measuring the volume of the carburetted water-gas produced. If normal quantities were substituted in the items of "oil," "coke," and "purification," the estimate would be reduced by about 3*d.* per cubic foot for 20-candle-power gas, or if the whole quantity of the oil were used, the illuminating power would be increased to about 25 candle-power. Such amended figures would accord with the

¹ Read at Birmingham on 1st May, 1879, before the "Midland Association of Gas Managers."

Mr. Glasgow. working of the Author's installations upon numerous occasions when they had been under special study, but in no case would a comparison of the manufacturing accounts of the two gases, when manufactured concurrently, represent the financial benefit accruing from carburetted water-gas. The auxiliary production of carburetted water-gas, as had been pointed out by the Author, enhanced the price of coke, obviated the use of cannel enrichment, took care of the "peak" load in winter and of emergency variations and burdens otherwise borne by the retort-house, and enabled the retorts to be operated under practically constant load. All the advantages thus obtained went to the credit of coal-gas in the accounts. The means whereby these economies were obtained, being a burden on the water-gas plant, was charged against that gas in the accounts, and very rightly, so far as accounts went. But this was a question where common sense was called for rather than strict book-keeping, and he might remark in passing that no one was better able to exercise this common sense than the Author. By an odd coincidence he had received that morning, quite unexpectedly, a statement of the results, for the 6 months ending 31st December, of a large gas-undertaking, not in London, where the manager for his own information had made an estimate of what his gas would have cost him for that 6 months had it been all coal-gas, as against what it had cost when a certain portion had been carburetted water-gas. His figures were worked out in total sums. £88,000 odd was what the gas would have cost if it had been all coal-gas; the actual cost had been £68,000 odd, a difference of £20,000 in 6 months. That difference in the year would have paid for the entire carburetted water-gas works. The percentage of water-gas used was not stated, but he thought it would be about 30 per cent.

Mr. Carpenter. Mr. CHARLES CARPENTER thought the Author was to be congratulated on his very able Paper, especially considering the fact that at the outset he had been confronted with the difficulty of making it interesting to the many while valuable to the few. With regard to the water-gas question, he was not a maker of water-gas, but he would make a few remarks from the point of view of the user. He objected strongly to the use of water-gas as a means of getting over what had been called the peak of the load. Every now and then, as a consumer, he had a dose of water-gas sent into the mains for the purpose of getting over the peak difficulty, and it was not at all pleasant. It upset the working of the gas-fires in the winter-time, and was not satisfactory in the incandescent-mantle burners. Care should be exercised in seeing

that in all alterations of methods due regard was paid to the Mr. Carpenter. interests of the consumer. He had no objection to water-gas itself, but if it was used care should be taken in mixing it with the coal-gas, and the mixture should be, as nearly as possible, uniform. The Author had given a great deal of information with regard to stoking-machinery, but he had not said very much on the use of inclined retorts, and the Paper had been adversely criticised on that score. It was becoming more and more admitted that the use of inclined retorts entailed the use of suitable coal; and when that was admitted it put the use of inclined retorts on a very different basis from that on which it had been originally advocated. It was said that with many kinds of coal it was absolutely impossible to use inclined retorts, owing to the fact that in the process of carbonising the coal slipped down to the lower end of the retort. Within the last four or five weeks he had had the opportunity of trying a well-known north-country coal, which gave very good results in horizontal retorts, and when that coal had been used in inclined retorts which, with suitable coal, produced between 10,200 cubic feet and 10,300 cubic feet per ton, the yield had fallen to 8,760 cubic feet. It was a striking fact that, with the carbonising-plant in admirable order, with regular heats, and with every advantage for obtaining a high yield of gas, 10,200 cubic feet to 10,300 cubic feet of gas, and perhaps even more, per ton, could be obtained from a suitable coal, yet with certain kinds of coal unsuited for such work, owing to the fact that the coal did not rest in the position in which it was charged, the make fell to 8,760 cubic feet per ton. That was a fact which those who had any thought of using inclined retorts should bear in mind. With regard to stoking-machinery, he had had some experience in using that which had been described by the Author, and he had no doubt most engineers would prefer it in cases where the method of charging by gravitation was suitable. The disadvantages of machinery were not so serious as at first sight might be imagined. He did not consider that it should be a drawback to a system of charging retorts that it entailed the use of machinery. It was within the province of engineers to design machinery to work in a dusty retort-house as well as in the more cleanly engine-rooms, such as those of a water-pumping plant. It was only a question of finding the most suitable method of actuating the various parts and of adapting them to the work they had to do. It was the engineer's business to fit the machinery to its work, and if that was done very good results should be obtained. Another interesting point raised by

Mr. Carpenter. the Author was the use of high-pressure mains. Perhaps, without knowing it, the South Metropolitan Gas Company had taken a leaf out of the electrician's book. In South London, having an area of 50 or 60 square miles, instead of supplying gas at a pressure about equal to that at which it was sent out of the works, high-pressure "feeders" had been used, on Mr. Livesey's suggestion. The mains from the works carried gas at high pressure into the hearts of the respective districts, where the smaller mains were supplied at lower pressure, and the result had been enormous reduction of the capital outlay in expenditure on gas-mains. Instead of an initial pressure of 3 inches or 4 inches head of water, a pressure of several times that amount was used, and the system had worked admirably. When the large amount of capital invested in gas-mains was considered, it was very important that the greatest possible duty should be obtained from them, and that object was attained by working them under the considerably higher pressures which Mr. Livesey had advocated. The maximum pressure on the high-pressure mains under this system was at present about 12 inches to 15 inches head of water.

Mr. Cross. Mr. F. W. CROSS remarked that it had been his privilege to design and erect some inclined retorts during the past year. He had started with a rooted prejudice against coal-elevators and conveyors, and the question had arisen, what method should be adopted with inclined retorts for dealing with the coal. After much consideration it had been proposed to use hydraulic power. The design of the works was a modification of that shown in Fig. 5, Plate 2. On the right-hand side there was a coal-store running the whole length of the retort-house, 30 feet in width, and the side wall of the retort-house formed the wall of the charging-floor, of the hopper-floor, and also of the floor level with the top of the hoppers; there was a semi-circular roof rising from the wall on the left-hand side and extending to the wall of the coal-store. That roof, instead of springing from a height of 50 feet, as shown in the diagram, sprang from a height of 35 feet, and gave ample head-room over the hoppers and the hopper-floor. Outside that building, quite apart from the retort-house and the dust and dirt of the coal and coke, was the power-house, whence power was transmitted underground to a lift placed in the coal-store against the middle wall, the lift having a direct-acting ram and rising to the height of the hopper-floor. The coal-store had several lines of tram-rails, and tip-wagons were used in which the coal was conveyed to the lift. On the lift was a turn-table. The lift was raised to the hopper-floor, and the tip-wagon was taken off

on to the hopper-floor and run alongside the hoppers, into which the coal was tipped. The greatest difficulty had arisen in dealing with the larger lumps of coal, and it had puzzled him for a long time how to put the coal into the hoppers in such a state that it would be suitable for inclined retorts, without using a mechanical coal-breaker. At the top of the hopper was a specially designed screen. The coal was tipped on to the screen, the bulk of it fell through, and the large lumps were easily broken upon the screen by the man working the tip-wagons. He thought this was the first time such an application of hydraulic power had been made to a gasworks for inclined retorts. The power provided was in excess of the present requirements, but the works were new and he purposed to apply hydraulic power to many other uses in the works, such as hoisting the trucks of coal into the retort-house, moving the coal by grabs, and running from the power-house to the lift in the water-gas plant. If in the course of time it were found undesirable to extend the inclined retorts—he was not a believer in the present absolute perfection of the system, but he believed that inclined retorts would be the retorts of the future—and the next house built were one having horizontal retorts, there was already available power for working the stoking-machinery. There was also power for an installation of stoking-machinery in the present houses. In many works where there were inclined retorts there would be a house of horizontal retorts and probably no machinery; but with hydraulic power machinery could be installed in the works. The many uses to which hydraulic power could be put in gasworks were apparent.

Mr. J. CASH considered the Paper a worthy addition to the Papers previously presented to the Institution by the Author. It was so wide in scope that it was somewhat difficult to deal with in its entirety, and he would therefore confine himself to certain points. The Author stated that when an illuminating-power was required beyond that afforded by the coal from the neighbourhood of the gasworks, the cost of enrichment inevitably exceeded its relative value to the consumer. No truer words had ever been written. There was no doubt that the product of the cheapest description of coal obtainable at a gasworks should determine the illuminating-power of the gas with which the district was to be supplied. Any excess of enrichment beyond that which the coal would naturally give was an expense to the consumer, and he was glad that a recent enactment of Parliament—he referred to the South Metropolitan Company—had dealt with that point.

Mr. Cash. and had reduced the 16-candle standard for the illuminating-power of the gas; and he thought that was one of the wisest steps ever taken. The Author had set forth very fully the advantages claimed for the use of water-gas. He was rather an advocate of water-gas; he had used it very largely in his own works for a number of years, and he was bound to say he had not found the little difficulty to which Mr. Carpenter had alluded. Probably that was because his gas was always maintained uniform in composition, the relative quantities of water-gas and of coal-gas being constant. An advantage due to water-gas which had been overlooked was the great saving of labour. No plant in gasworks was more useful to the manager in dealing with that awkward question which all had to deal with from time to time, namely, labour, and there could be no more adequate testimony to its merits than the figures given by the Author, viz., 4·59*d.* for coal-gas, and 1·91*d.* for carburetted water-gas. It was also stated in the Paper that the coke from machine-worked retorts was not worth as much as that obtained by the manual system; but he had tried machine-retorts, and had found no difference whatever in the quality of the coke produced.

Mr. Fowler. Mr. HENRY FOWLER differed somewhat from the previous speakers in that, being the gas-engineer of a large railway company, he represented to a large extent the consumer. He thought that, in discussions at the Institution, it was sometimes as well that the consumer should be a little more in evidence. With regard to the question of lighting, the Author had stated that the incandescent burner effected a saving in the ratio of 5 to 1, but he would be pleased if the Author could give any definite data with regard to the cost, with a large system, of repairs, renewals, chimneys, etc. The incandescent mantle was so rapidly coming forward at the present time that, by-and-by, gas-engineers would go about, not with a portable photometer, but with a calorimeter. Another point which not only gas-engineers but electrical engineers so frequently lost sight of was the varying intensity of light over a given area. Doubtless most members could call to mind places which were lit with lamps of high intensity placed near to the ground, the result being that in the immediate neighbourhood of the lamp itself there was intense illumination, in comparison with which the space between the lamps appeared to be almost dark. In these days of high-pressure gas-lighting that was a point which should be specially borne in mind, and the drawback could only be overcome by placing the standards at a height sufficient to give good diffusion of the light. In connection with

water-gas, one matter which appealed to him strongly was the freedom from naphthalene failures. These were a constant source of trouble, particularly on a railway, where it was essential that the light should be reliable. He had recently left a railway company to which he had been gas-engineer for about 5 years. Steps had been taken to have the failures reported and recorded, and he had no recollection of a single naphthalene failure having been reported where water-gas was used. The Author referred to the question of laying service-pipes and coating them with tar, and he would like to ask whether the Author had experienced any difficulty in getting the tar thoroughly over the pipe after it was laid. He had found that, by knocking together a rough creosoted box, in which the pipe was laid, filling the box with shavings, and then pouring hot tar over it so as to thoroughly cover the pipe, the service could be relied upon to last for many years. He had seen pipes which had been laid under these conditions lifted after being down 8 or 9 years, and the scale from the mill had still been on them. Perhaps on a railway pipes suffered more than the pipes of an ordinary gas-company, because they so often had to be laid through ashes, which was the worst material to deal with. The Author stated that the effect of the use of gas for cooking and heating was illustrated by the experience of a Metropolitan company, in whose district the daily consumption between 6 A.M. and 6 P.M. during the month of July had been quadrupled in 12 years. If the Author could give the percentage of the total daily output used for these purposes it would add considerably to the interest of that matter. Also, if the figures which were given in the Table of the sale of residuals could be brought up to date, so as to include the year which all would look back upon as the worst experienced in regard to coal, it would be more valuable. There were many small gasworks to which the various systems of charging referred to by the Author were not applicable. He believed that in England and Wales alone considerably over one-eighth of the total output of gas was from works which did not make more than 100 million cubic feet per annum. If some figures could be added, bearing on the utility of machinery in small works, to compare with those already given, they would be of great use. He was sure that all who were connected with gasworks were much indebted to the Author for his instructive Paper, and for figures which would be found very useful for many years to come.

Mr. W. J. A. BUTTERFIELD emphasized the great economy resulting from the manufacture of carburetted water-gas, as shown

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Mr. Butterfield.

Mr. Butterfield.

by the figures in the Table. It appeared that in June, 1900, when both coal and oil had been dear, 20 candle-power carburetted water-gas cost about $1\frac{1}{4}d.$ per 1000 cubic feet more than $14\frac{1}{2}$ candle-power coal-gas. The superficial critic might ask why the manufacture of coal-gas was continued, seeing that carburetted water-gas would give an advantage of over 35 per cent. in the value of the gas for lighting-purposes, and that analyses of those gases of the qualities named showed an increased value for the carburetted water-gas of about 16 per cent. for heating-purposes, while the extra $1\frac{1}{4}d.$ on a selling price of 3s. per 1,000 cubic feet meant an increase of only 4 per cent. in cost. Therefore it would appear that the carburetted water-gas would be the better supply for the consumer, for all uses, at that slightly enhanced cost. But it had to be borne in mind that the low cost of the carburetted water-gas was due to a large extent to the fact that it was produced by the combustion of coke which was a by-product of coal-gas manufacture. If the plant were worked independently, its cost would probably be much greater; nevertheless, he believed there was an inherent economy in the process. Some 10 years ago, when the process had been first introduced into this country, figures as good as those mentioned had not been obtainable. Formerly, gas-engineers had attempted to make as good producer-gas as possible by raising the temperature of the fuel in the generator. Thirty per cent., theoretically, of the heating-value of the coke consumed during the blows was spent in raising the temperature of the fuel in the generator. The Dellwik process for making simple water-gas now aimed at utilizing something like 100 per cent. of the heating-value of the fuel consumed during the blow. Some analyses which he had made quite recently of the products from carburetted water-gas plant tended to show that, unconsciously perhaps, the Dellwik principle had been more or less embodied in the carburetted water-gas plant of the present day. Much higher duty for the oil and the coke than was shown by the Table had been claimed by Mr. Glasgow, and the plant of which he was speaking, according to the returns from the works—the Southall Works of the Brentford Gas Company—also showed a much higher efficiency in both respects. That plant had been manufactured by Messrs. Samuel Cutler & Co., while the Author's plant had been manufactured by Messrs. Humphreys and Glasgow. Instead of 30 per cent., fully 55 per cent. of the heating-value of the fuel consumed during the blows was utilized in the generator, and the surplus heat carried forward was quite adequate to gasify the oil. It was evident that the Dellwik principle in its entirety

could not be embodied in a carburetted water-gas plant so long Mr. Butterfield.
as carburetting was done by oil. There must be a certain amount of producer-gas carried forward to effect the gasification of the oil. He believed that the greatly increased efficiency of modern carburetted water-gas plants was due to the embodiment of the Dellwik principle, perhaps more or less unconsciously, which his investigation of the plant at the Southall Works had shown. The Author had spoken of the increased cost of purification of carburetted water-gas over coal-gas. He doubted whether there ought to be a greatly increased cost. At the time he had investigated the plant to which he had referred, the impurities had not amounted to more than 1,200 grains per 1,000 cubic feet, which was the figure given by the Author for the amount of impurities in coal-gas. Therefore he contended that, even with lime purification, entailing the removal of the whole of the carbonic acid from the gas, the cost of purification of carburetted water-gas ought not to exceed that of the purification of coal-gas. Another point to which the Author had not referred was the superior enriching-value of the carburetted water-gas. If the 20-candle-power water-gas was mixed with coal-gas of 14 candle-power in equal volumes, the illuminating power of the mixture would be higher than 17 candles; it would be more nearly $18\frac{1}{2}$ candles. That property of carburetted water-gas had been first pointed out clearly by the late Mr. John Methven. It was said to be due to what was the inherent defect of carburetted water-gas, viz. that the diluents of that gas were not so well fitted to bring out the full illuminating-duty of the hydro-carbons present, as were the diluents of coal-gas. Whether that explanation was correct or not, the fact remained that carburetted water-gas had a higher enriching-value than the illuminating-power of the gas undiluted with coal-gas would indicate. Having regard to that fact, and to the low cost of the carburetted water-gas—he took the Author's figure, although Mr. Glasgow and others claimed that it should be reduced—it appeared that the enrichment of coal-gas to $16\frac{1}{2}$ candle-power would cost only about one-third of a penny per 1,000 cubic feet. That was a trifling figure in comparison with the high capital charges which were shown in the Paper, and it was hard to say why there should be any demand for the reduction of the illuminating-power of gas from $16\frac{1}{2}$ candle-power when gas of that quality could be had at such a low increased cost over 14-candle-power coal-gas. With regard to the removal of naphthalene from coal-gas, the Author stated that it could be fully accomplished by means of the tar. A process had recently been proposed for the removal of

Mr. Butterfield. naphthalene by washing the gas with the green oils of tar. In that process $\frac{1}{4}$ pint of the oils was said to suffice for the removal of the naphthalene from 1,000 cubic feet of coal-gas. The tar from 1,000 cubic feet of coal-gas contained something like ten times that amount of tar-oils, and therefore it would appear there was an ample supply of those oils in the tar to remove the naphthalene. It was open to question, however, whether the large and expensive condensation-plant necessary to apply the tar for that purpose was cheaper and more easily supervised than the comparatively simple and compact washing-plant by which the oils might be applied directly.

Mr. Livesey. Mr. GEORGE LIVESEY remarked that the Author had gone into the subject very thoroughly, and the Paper might be taken as an up-to-date record of what was known and practised in gas-manufacture. In the Table of gas-undertakings, the Author gave the percentage of increase under various headings, and amongst others there was an increase of capital in the last 4 years of £28,227,880 or 39·8 per cent. As the Author mentioned, that was not the real increase, because in a number of cases the capital had been nominally increased. In addition to the two London companies referred to, he believed there had been certain purchases of gas-undertakings by local authorities where the nominal capital had been largely increased. At any rate those figures showed a great discrepancy—an increase of 39 per cent. in the capital and of 21 per cent. in the quantity of gas sold. He was sure the Author would never agree that such figures could be taken as illustrating what gas-engineers wished to see. He had no doubt the fact was that, with an increase of 21 per cent. in the quantity of gas sold, the increase of capital would probably be about 10 per cent., and it was to reduction of the capital charge per thousand cubic feet sold that gas-companies looked for economy in supplying gas. The Author, in dealing with labour-saving machinery, said that many of the machines as yet failed to attain the speed and efficiency of zealous and well-directed hand-labour, and he quite agreed with that remark. A man with a shovel and a barrow took a great deal of beating if he would work properly, and he believed that in many cases very little advantage had been derived from the introduction of stoking-machinery, because the work of the machine had been limited by the action of the trade unions. The South Metropolitan Gas Company was perhaps in a unique position in that matter. It had been forced into the adoption of labour-saving machines against its will—certainly against his will; it had been with the greatest regret that he had

seen labour-saving machines introduced, because he had not wished to displace labour. The work had been done by hand in a thoroughly satisfactory manner, but the saving from the use of machinery was so great that the company had been obliged to introduce it. In many cases the machinery had been introduced to get rid of the labour difficulty. With regard to the question of enrichment, the Author had expressed what was the present general opinion, and Mr. Cash had emphatically endorsed it. One of the most mischievous ideas with regard to gas-supply was that relating to enrichment. Tens of thousands—perhaps hundreds of thousands—of pounds were wasted yearly for the purpose of so-called enrichment, and that had been brought about by the local authorities. Whenever a gas-company came to Parliament, the local authorities thought it was fair game for attack, and for years past they had been pressing for an increase in illuminating-power, thinking thereby to get something out of the gas-company, and not seeing that they were taxing their own constituents; that whatever expense of enrichment might be imposed on the gas-company was repaid by the consumer; and that the latter was not a halfpenny the better for enrichment and the thousands of pounds spent in accomplishing it. A turn in the tide had taken place, and he thought the first step would be to get the best quality of gas obtainable from the available supply of coal. Another step, as Mr. Fowler had remarked, would be to consider the calorific value of the gas and not its illuminating-power. Turning to the item of wear and tear in the comparison between carburetted water-gas and coal-gas, he pointed out that wear and tear with coal-gas was put down at 4·36*d.* per thousand cubic feet sold. He believed that was the total wear and tear. There was an item in gas-companies' accounts headed "Repair and Maintenance of Works and Plant," which was the total amount expended on the repair and maintenance of the whole of the works and plant inside the station. But he thought that, for the purpose of comparison, it ought only to include the wear and tear of retorts, and he would reduce the 4·36*d.* by 3*d.*, and obtain an advantage to the coal-gas to the extent of that 3*d.*, which would make the coal-gas cost 1*s.* 2*d.* instead of 1*s.* 5*d.* per 1,000 cubic feet. Again, the tar of the oil-gas was estimated to be worth 1·82*d.* per gallon, but that was the price obtained for the whole of the tar, whereas the tar from the oil-gas was certainly not as valuable as tar from coal-gas. He was only speaking from theory, because he knew nothing of water-gas, and was rather glad he did not; but he wished the advocates of water-gas would set forth in plain figures

Mr. Livesey. the actual cost of the system. For many years he had been trying to find out, from the public accounts, the cost of water-gas, but without success. The Crystal Palace District Gas Company had put up water-gas plant 2 years ago, and had an engineer there who had been very ready to carry out any views that might tend to accuracy and perfection of working. The total cost of the water-gas there had been given in exact figures, and had been found to exceed greatly that of coal-gas. With regard to the use of high pressures, he could say that the South Metropolitan Gas Company had done with the laying of further large mains for many years to come. The Company had large trunk mains leading from the works, and he was of opinion that they would be adequate for many years. He owed an acknowledgment to Mr. Carpenter for the able way in which he had carried out the idea of supplying gas by means of high-pressure distribution. There had been considerable difficulty, for instance, in supplying Clapham Junction. There had been an 18-inch main leading nearly to the district, with no connections; a Sturtevant blower had been put on, and the gas had been sent under high pressure through the 18-inch main right into the district. He would conclude with a few general remarks on what was often spoken of as a "dying industry." The gas-industry had never been so much alive as it was at the present day, and, he thought, had never had such good prospects. He had taken the trouble to ascertain what had been the increase in the consumption of gas in South London, and he was able to make a rough estimate, which, however, was not far from the truth. In the year 1840 the total consumption of coal for the manufacture of gas in South London had not exceeded 20,000 tons; in 1870 it had been 200,000 tons; in 1890, 700,000 tons; and in 1900 over 1,200,000 tons. In the first 30 years there had been an advance in the coal-consumption of not quite 200,000 tons, in the next 20 years an advance of 500,000 tons, and in the last 10 years an advance of another $\frac{1}{2}$ million tons. The consumption of coal in 1900 by the gas-companies in South London, mentioned as exceeding 1,200,000 tons, did not include the large southern suburban companies, which added a further 250,000 tons. In another respect there had been great advances in the use of gas. In looking over a drawer in his workshop he had come across some of the original burners, which had reminded him that originally gas had been burnt in the worst manner possible. The first burner had been a single jet, and not content with making it a single jet, the designer had made the aperture in the burner as

small as possible—a needle would hardly pass into it. To increase the light the number of jets had been increased. One of his early experiences as a school-boy had been the stock-taking during his holidays at Midsummer, when his father had given him 6d. a day to assist, and part of his work had been counting the burners—so many one-hole, so many three-hole, so many seven-hole burners, and so on. He did not think one candle-power per foot per hour had been obtained from those jets. Then about 1860 Mr. Sugg had made the discovery that the gas ought to pass through larger apertures, and had introduced the London Argand burner, and thus obtained a duty of 3 candle-power per cubic foot of gas burned per hour. There had also been the old inferior fishtail burners and batwing burners, improved by Mr. Bray, as well as by Mr. Sugg. Then had come, about 1880, the Siemens regenerator burner, which had given 6 candle-power per cubic foot per hour; and that had been followed by the Welsbach burner, which had doubled the illuminating-power again, making it 12 candle-power per cubic foot per hour, or 60 candles for 5 cubic feet per hour from so-called 16-candle-power gas. The improved Welsbach burner had doubled it again, making it 20 candle-power to 24 candle-power per cubic foot of gas per hour. Now, by the high-pressure Welsbach system, 30 candle-power per cubic foot per hour could be obtained. So that under the most favourable conditions a consumption of 5 cubic feet of gas per hour would give as much as 150 candle-power, whereas 70 years ago it had only given 5 candle-power. Taking that into consideration, as well as the vast increase in the output of gas, some idea might be formed of the enormous increase in the amount of light derived from gas. He could assure Mr. Fowler that the gas-companies regarded the consumer as their best friend, and were anxious to do everything possible to meet his wishes. The difficulty with regard to the Welsbach mantle was that the ordinary consumer could not be troubled with it, and the South Metropolitan Company were undertaking to supply and maintain mantles at a charge of 1s. per quarter per light if the lights did not exceed six in number, and of 9d. per quarter per light if the lights exceeded six. Some large consumers, such as shop-keepers using, say, 150 Welsbach burners, were having them maintained by the Company on those terms. The gas-industry had been in existence for 100 years, and he saw no reason why it should not go on progressing at a rapid rate. It had captured the working man and had brought about the use of gas in working-class houses to a wonderful extent. What was required was that young men of ability should enter this

Mr. Livesey.

Mr. Livesey. branch of the profession. He was afraid they rather looked down upon it. Recently he had had the great privilege of going over the magnificent works which the President was carrying out in Mid-Wales, and he could not help a feeling of envy and a wish that he had been a waterworks engineer. But there was wide scope for the gas-engineer, and his occupation was a most interesting one. There were many things in it which required the attention of the ablest men, and one of them was to produce gas as cheaply as possible. He looked back to his early days, when he had nothing to do but to look after the working part of the business, with the greatest pleasure and satisfaction. He pleaded for the entrance of young men of ability into the profession of gas-engineering, and predicted a good future for them.

Mr. Woodall. Mr. CORBET WOODALL always listened to the remarks of Mr. Livesey with pleasure, especially when he was speaking on matters with which he was so fully cognisant. He had no doubt whatever that a few years hence Mr. Livesey would have an equally interesting story to tell about carburetted water-gas and its relations to the general supply, but with a very different conclusion. He concurred in what Mr. Livesey had said with regard to the development of the light from gas by means of improved burners; but he deprecated the emphatic condemnation of those who had in times past advocated an improved illuminating-value for the ordinary gas supplied. It was rather a case of being wise after the event. Mr. Livesey's observations were correct, but it was not necessary to condemn those who, before the incandescence burner had been introduced, had been willing to improve the value of gas, and had performed a public service by so doing. He emphatically supported the suggestion that there was still in the field of gas-lighting an opening for young men of education and energy. He believed, and the belief was supported by the experience of many years, that there was still in gas-supply possibly as wide a field for development as there was in the great field of electricity. The last few years had seen developments of a very remarkable character, not simply those affecting the amount of light to be obtained from a given quantity of gas, but also in the recovery of unexpected products from the distillation of coal, which had conduced materially to the reduction of the cost of the original fuel. The Paper dealt with a wide subject, and he was surprised that it had been founded upon observations over a very limited field. In speaking of the improvements which had taken place in the modern practice of gas-manufacture and distribution, it was surprising

that attention had not been given to what had been done in other Mr. Woodall. countries. Continental engineers were sometimes more logical and careful in their scientific and exact investigation than were gas-engineers at home, and the development that had taken place on the Continent was very striking. Incidentally he would like to put in a plea for a little more combination between the chemist and the engineer than had been customary. Apart from the Continent, he thought there was as much evidence of development in the provinces as in London. He doubted very much if the majority of gas-engineers in the country would say that in coming to London they were coming to the ultimate evidence of progress in that particular direction. The observations of the Author with regard to economy in the expenditure of capital would appeal to everybody; they were, so to speak, accepted gospel. At the same time, where capital expenditure was productive he would be very sorry to see it spared. He did not think the utmost had been done when an appliance had been bought at the minimum cost and had been housed as cheaply as possible in a gasworks. Something was due to the neighbourhood in which the gasworks was placed and the engineer's feeling of pride in the work done. He felt that when the modern Edile, for whom the souls of many people longed, was found and appointed, he might take under his wing not only some bridges of less pretentious character than those referred to in a recent discussion at the Institution, but also bridges which crossed the streets of towns, and the lamp-posts with which the streets were adorned. When that day came, Mr. Woodall would be willing and glad to hand over to him some of the structures with which gas-engineers had disfigured the towns which they served; and with regard to some structures the censor would certainly be disposed to remark, "You say it was very cheap, but I am quite sure, whatever it cost, it is dear at the price." The late Mr. Thomas Hawksley had built many gasworks in England, at considerable cost, but those works were standing now very much as Mr. Hawksley had built them, and the people of the towns which they served were proud of their works, and considered them rather an ornament. The Author had referred to the great advantage which resulted from the introduction of the sliding scale as a means of governing the price of gas and the profit of the gas-shareholder. He was of opinion that the sliding scale had been an advantage on both sides, particularly because it had satisfied the general public that there was a community of interest between the makers and users of gas. But it was certainly a mistake to credit the sliding scale

Mr. Woodall. system, as had been done, with all the economies which had resulted since its introduction. Comparing the prices charged to the consumer at the present day with the prices charged, say, in the year 1876, it would be found that practically the whole reduction in price that had taken place in the interval had been due to the reduced net value of coal, and to the reduction in the charge for capital which had resulted from the compulsory sale of stock by auction. That was a point worthy of notice. The Paper had not dealt to any large extent with recent construction, but he was surprised at the uncertainty that appeared to affect the Author's mind with regard to inclined retorts. There was hardly a retort being built in Continental works which was not upon that plan, and he knew of several works in England where coal was now being distilled in no other retorts but those on the inclined system. He had the greatest respect for Mr. Carpenter's opinion, but he thought the difficulty that he had found with regard to the creeping or sliding of the coal in the retorts could be met, and was met, comparatively easily by blending the coals, so that those which had a tendency to creep down were held by those which had a less tendency, or none at all. The system itself was a very charming one, and was distinctly economical in use. If he were to place in order of importance the improvements in gas-manufacture which had taken place in modern times, they would be the introduction of labour-saving machines, the introduction of carburetted water-gas, the improvement in the firing of retorts by the introduction of gaseous firing, and the regenerative principle. There were works now where the coal was picked from the ship or from the truck, carried to the retort and passed through it; and where the coke was taken out and carried away, lifted into hoppers and loaded into trucks or barges, without being handled at all except by machinery. That, combined with the introduction of water-gas, had improved the conditions of labour, and had made the conduct of the business of a gas-company much more pleasant, both to the men themselves and to their chiefs, than it had been in days gone by.

Mr. Hawksley. Mr. CHARLES HAWKSLEY, Vice-President, thanked Mr. Woodall for his appreciation of the designs of his late father, who had always endeavoured to make gasworks not only such as would last, but such as would disfigure the neighbourhood as little as possible. With regard to the supply of gas during the day, perhaps sufficient attention was not paid to the overlapping of the day and evening consumption, say, between 4 o'clock and 6 o'clock on a winter evening. Warming went on in the evening as well as

during the day, and the consumption of gas was the same. The Mr. Hawksley. consumption for cooking depended largely on the kind of district which was being supplied, viz., whether it was the habit of the people to dine in the middle of the day or in the evening. With regard to inclined retorts he was not able to speak from actual experience, but he had had occasion recently to visit a gasworks in the North of England where north-country coal was employed, and there the inclined system of retorts was giving complete satisfaction, as he had been informed by the engineer. The only way, he thought, of employing lattice framing for gasholders would be with lattice-work similar to that of a waste-paper basket, within which the gasholder was placed. He was glad to say that the subject of electrolysis had now received recognition by Parliament, which within the last few weeks had given protection to a gas-company in regard to any injury which might be done to its pipes and apparatus by electrolysis or by fusion. Now that Parliament had begun to recognise that principle it was very likely that it would be applied in future to nearly all cases in which public bodies or companies sought to introduce electrical power into a town. On the question of carrying pipes through subways, he did not know whether the Author had forgotten that it had given rise in more than one case to considerable damage, and to some loss of life, by reason of explosion.

The PRESIDENT remarked that Mr. Livesey had referred to the gas-industry as not being a dying one; at all events Mr. Livesey was a very "live" man himself, and would not allow gas to die for want of a powerful advocate, and the President hoped that his predictions as to the future of the gas-industry would be verified. The President. Mr. Livesey's depreciatory remarks about carburetted water-gas were hardly justifiable after his confession of only partial acquaintance with the subject. He heartily congratulated the Author on the animated discussion which his Paper had evoked.

The AUTHOR, in reply, was glad his Paper had produced so good a discussion, but he almost wished his statements had been handled more vigorously. The Author. The explosions mentioned by Mr. Hawksley had been confined to Paris, none, in his recollection, having taken place in London. Those who knew what the pulling up of the streets in London meant to the undertakers, as well as to the users of the streets, would agree that some accommodation for mains, such as subways, should be provided. Mr. Woodall favoured gasworks in which the whole of the work was performed by machinery; such works were shown in Fig. 3, A and B, Plate 2. The coal was grabbed out of the ships, taken away

The Author. in railway trucks, shot into the stores, turned into coke, shot into the cellars below, taken away by wagons and put into the barges without handling at all. With regard to hand labour, he cordially endorsed all Mr. Livesey had said. Anything more delightful to witness than the smartness, the neatness, and the efficiency of a gang of men charging retorts in the old-fashioned way he could not conceive. He found considerable difficulty in making managers see that for works below a certain size the best possible machine was the human machine, because a man directed his energy with judgment. With regard to the blending of coal, he would leave the question of inclined retorts in the hands of Mr. Carpenter, than whom no abler critic could be found. But in handling, as was done in London works, hundreds of thousands of tons of coal a day, blending was difficult. He had seen a splendid installation of inclined retorts in Mr. Carpenter's works, the retorts being fed and discharged admirably; but Mr. Carpenter had shown him records taken a fortnight previously, in which, owing to the use of another variety of coal, the good return had disappeared, because the coal had slipped down and had not been perfectly carbonized. Works must be made to suit the vicissitudes of trade; therefore they should not be limited to the coal of one particular colliery. He valued especially the crisp and vigorous remarks of his old friend, Mr. George Livesey, and felt flattered that he had lent the weight of his authority to the discussion. He had turned up recently an interesting record of coal-contracts. Coal which at the present time was put on board ship in the north at 9s., and which had been in the past year 16s., the year before 8s., and the year before that 7s. per ton, had been contracted for in 1852 at 4s. 3d. per ton. With regard to tar, petroleum tar was more valuable than other tar, but the manufacturers had not yet paid the value of it. Mr. Livesey was quite right about the wear and tear. He had put in the whole of the wear and tear of the gasworks, and had loaded the coal-gas in that way. With regard to the capital, there was a footnote warning readers of the fact that much of the increase was nominal. In preparing the Table, he had felt it necessary to state absolute facts, and those were the facts from the Board of Trade returns; but the Secretary, whom nothing escaped, had pointed out that much of the increase was purely nominal, due to conversion, and had given the footnote, correcting the Table by £13,000,000, and probably the amount was more than that. With regard to Mr. Butterfield's remarks, it was quite true that carburetted water-gas which measured, say, 20 candle-power by

itself, when mixed with other gas developed a higher illuminating-value, and the fact was deserving of the attention of scientific investigators like Mr. Butterfield. He endorsed what had been said as to the desirability of young men of good education and professional training not scorning the gas-industry. Although occasionally, as he had said in the Paper, councillors or directors did not quite see the advisability of paying proper salaries to competent men, on the whole he believed there was a great future for young men of ability who entered the profession. The greatest development of inclined retorts which had taken place in this country he believed had been at the Brentford Gasworks under his old friend and his father's pupil Mr. Morris. Mr. Van Restraat, who had been Mr. Morris's assistant at one time, had also done much to develop them. The reason why he had warned gas-engineers not to rush to water-gas unless it was required for enrichment—for which it was especially valuable—was that he had found, during the past year, great difficulty in getting oil at a reasonable price. Oil in America was a by-product, and there was not an unlimited quantity of it. He could not congratulate Mr. Brackenbury upon either the substance or the manner of his criticism. That speaker wanted to know why the Author did not describe all the washers, scrubbers, and other things with which Mr. Brackenbury was acquainted. His answer was, simply because the Paper had been limited to the appliances which he had found, from the practical experience of 30 years, enabled him to conform to the rather exacting requirements of the London gas-referees. In the case of the Metropolitan companies, the gas was tested with a rigour and microscopical research which occurred nowhere else in the kingdom. Gas-engineers outside London had not the faintest idea how, from day to day and from hour to hour, the gas was searchingly investigated on points which in other parts of the country were ignored. The companies were subjected to "forfeitures," which were very much like fines, and to which a certain amount of disgrace attached. Therefore London gas-engineers were unduly busying themselves in meeting this microscopic investigation instead of applying their time to more important matters.

The Author.