Mr. Humphrey

down for a fortnight, with the fire in it, without requiring attention during that time. The method was as follows: The producer was cooled by a good charge of fresh slack, then the blast was reduced as the first regenerator pipe was being luted with water, the gas blowing away through the ball-valve on the producer. Finally, as the gas generated diminished to a very small quantity, provision for its escape was made by placing the hole in the ball-valve in a vertical position, so that the pressure inside and outside the producer was maintained uniform. A producer stopped in this manner retained enough fire in its mass of fuel to be started at short notice any time within a fortnight.

Correspondence.

Mr. Deboutteville.

Mr. E. DELAMARE DEBOUTTEVILLE, of Rouen, was gratified to find that the difficult problem of the utilization of rich coal was about to be at length solved, and that the progress of the gas-engine would no longer be hindered by the unfortunate consideration of the choice of fuel. The new gas-producers, with their very complex apparatus, would be but little applicable to small powers, but with such powers as 150 HP. or 200 HP., it was possible to realize greater economy than had hitherto been possible. As the Author had justly pointed out, electrical transmission to a distance, with the establishment of large central power-stations to distribute the energy to a spreading district would involve economy superior to the best which could otherwise be realized in practice. Such cheap power could not be obtained with steam, for the results now realized nearly approached the possible limit, and could certainly not be greatly improved upon. But in the case of gas, however great the advance during the last few years, a large margin still remained for increased economy. Steam-engines, in the present state of knowledge, had, with the exception of perfection in details, achieved almost the highest efficiency that could be expected from them; but gas-producers were still imperfect, in the sense that they had not been able to utilize rich coal for the production of power-gas. When this barrier had disappeared, and cheap coal from whatever field could be utilized for the production of power-gas, large installations of gas-power plant would arise on all sides, and the great progress which had been shown to be possible would be an accomplished fact. Having made many experiments with various apparatus, and with rich coals from numerous districts, he

Mr. Debontteville.

appreciated the difficulties of their utilization, and he viewed with gratification the fact that the new producer took them into account and successfully overcame them.

Messrs. The Gasmotoren Fabrik Deutz.

Messrs. THE GASMOTOREN FABRIK DEUTZ, noticed that the Mond gas-producer was principally adapted for production on a large scale; for generation on a small scale the apparatus was too cumbersome and expensive, and had the disadvantage of requiring careful supervision, in particular in those parts in which the gas was purified and the ammonia extracted. It was therefore probable that the simple apparatus would retain its old position for the treatment of anthracite and coke. So long as one gas-engine unit did not exceed, say, 200 HP., they could not but regard one simple generating apparatus, working with either coke or anthracite, as the most advantageous generator, owing to its extremely simple arrangement and low cost. Anthracite and coke were obtainable in abundance, and thus obviated the necessity of a large compound cleansing apparatus, which, as shown by the working of the Mond apparatus, was inseparable in the case of other kinds of coal. In small plants the price of the fuel was a matter of secondary importance; in large plants, on the contrary, the question of procuring and utilizing the cheapest fuel was of the foremost moment. In a plant installed at Basel,[1] the coke was supplied by the municipal gasworks and showed very satisfactory results, so much so that an additional engine of about 200 HP. was now being erected. They had recently tested a 16-HP. gas-generating plant and found the consumption of fuel to be 0·62 kilogram per brake HP. per hour; and, in the case of a plant for 100 HP., 0·49 kilogram. Of this 85 per cent. was anthracite consumed in the generator and 15 per cent. coke consumed in the steam boiler.

Mr. Holgate.

Mr. THOMAS HOLGATE remarked that the problem of how to obtain in the form of ammonia the nitrogen of coal or coke, without loss of heating-value of the fuel, had occupied many experimenters, notably, with successful results, by Messrs. Beilby and Young,[2] in dealing with shale in the oil-works of Scotland. He was impressed with the results obtained by those gentlemen (who had improved on the method of Dr. Hubert Grouven, of Bürgerhof), and had in 1891 investigated the system to discover its suitability for the Halifax Corporation Gasworks. The material available was the coke from an inferior Cannel to the extent of 10,000 tons per annum, and

[1] Sonderabdruck von Vortrag Meyer, Wasserwerk Basel; Sonderabdruck von Schöttler, Heizgas.

[2] Journal of the Society of Chemical Industry, vol. iii. p. 216.

containing 50 per cent. of ash. It was tested and found to be a material that could thus be utilized, but the estimated cost of the necessary plant for so small a yearly output, and the low price of sulphate of ammonia, left no prospect of profit sufficient to justify the expenditure. From Table V, in Appendix I, it appeared that the net cost of 1 ton of fuel, in the form of gas, was 80 per cent. of the cost in the solid form; but this was exclusive of interest on the capital. Further, the charge made for sulphuric acid would apply only inside a works where that substance was manufactured; in other works the charge would be 50 per cent. higher than that adopted by the Author. Adding the necessary items thus indicated, it appeared that the total net cost would not be much less than the raw fuel. There would remain the advantage which pertained to facility of regulation of a gas for heating purposes, which might be described as a minimum when employed for boiler-heating, and a maximum when employed for heating the cast-iron pans referred to. The greatest advantage appeared, however, to be due to the use of the fuel-gas in the newest type of gas-engine, instead of in the wasteful cycle of a steam-engine. The Author's proposal to distribute this gas from a gasworks or other central station, would thus be most suitable for users of motive power, and that within a reasonable distance from the generating station. No information was given as to the capacity or cost of gasholders for storing, and of mains for distributing this gas, but it was evident that these expenses must be considerable in comparison with coal-gas. The fuel-gas contained but 40 per cent. of combustibles, having a calorific value of 85·9 against coal-gas containing 98·8 per cent. of combustibles, and having a calorific value of 381. The heat wasted in raising the temperature of the 60 per cent. of incombustibles, would make the useful effect of coal-gas fully five times that of the other. It was eminently desirable that a gas to be distributed should not be burdened with useless and wasteful constituents such as CO_2 and nitrogen. It was evident that Dr. Mond's arrangements for the utilization of heat had been carefully devised, and with the proposal to utilize the jacket-water from the gas-engine still better results would be accomplished. In one respect, however, the method appeared capable of a substantial improvement by means that were readily applicable to the plant as now working, and which, whilst saving a large proportion of the steam used for evaporating the sulphate of ammonia liquor, would enable the percentage of CO_2 in the fuel-gas to be very materially reduced. At the Halifax gasworks there was in operation a plant for the re- Mr. Holgate.

Mr. Holgate. moval of CO_2 from crude gas by washing with purified ammoniacal liquor, and this could be applied so as to form sulphate of ammonia in an ordinary saturator, or to give nearly pure gaseous NH_3 and CO_2 separately, as might be desired.

Professor Robinson. Professor HENRY ROBINSON thought particulars of a gas-producing plant he had recently erected for the Leyton Urban District Council might be of interest. The plant was for the purpose of an electricity station, and consisted of Dowson gas-producers to supply gas to four Wells gas-engines, each of 55 brake HP. These drove (by belting) four dynamos of 35 kilowatts capacity each. The works represented the ordinary condition of an electricity-supply station, where the current had to be available throughout the twenty-four hours. It was a 150-volt continuous-current supply, on the three-wire system, with 300 volts between the outer wires. On the completion of the first half of the work, in October, 1896, he had had a trial run with one Dowson gas-producer serving two engines. The result showed that 280 Board of Trade units were generated in 5 hours 35 minutes, with a fuel consumption as follows:—

	Lbs.
Anthracite	448
Coke	52
Total . . .	500

equal to 1·783 lb. per Board of Trade unit.

The cost was thus only $\frac{1}{4}d.$ per unit for fuel. The engines were running at about five-eighths their full power, at 160 revolutions per minute, having fifty-two explosions per minute out of a possible eighty. This quantity of fuel did not include anything beyond what was put into the producer and boiler during the test, finishing with the fuel at the same level as at the start. In ordinary working the amount used in raising gas to the proper quality had to be allowed for. The plant was now in regular work, supplying electricity to the Leyton district, and the Resident Engineer, Mr. H. Collings Bishop, had supplied him with the coal-consumption as follows:—During February the current sold amounted to 5,660 Board of Trade units. The fuel-consumption was 3·92 lbs. per unit sold, costing 0·506*d.*; so that the fuel-cost was only $\frac{1}{2}d.$ per unit sold. The price of the anthracite coal was 24*s.* per ton. In March, 1897, a third engine had been finished and set to work at full load, when about 90 kilowatts were generated, using only 2·01 lbs. of coal per unit generated, and this was a fair sample of the permanent conditions of running. This led him to the opinion that the fuel consumed per unit sold would be less than 3½ lbs., and therefore less than ½*d.* This compared very favourably with the published figures of fuel-cost at other electricity stations throughout the country, and was better than any stations in or near London. The Westminster Electric Supply Company was the nearest to it, with 0·57*d.* for coal per unit sold. The provincial stations in the coal districts obtained their fuel at low prices, but out of forty-eight only ten had a lower coal-cost than that at Leyton. Professor Robinson.

Mr. F. J. ROWAN observed that the large majority of the users of gas-producers had not space for, even if they had the means otherwise of using, the extensive plant which the Author had described. In the future a large development of the central supply-station plan might be applied to the distribution of gas or of electric energy for power purposes; and in such works, as in large chemical works, such as those at Northwich, elaborate gas-producing and treating plant would find a fitting home. Such works must, however, be necessarily few as compared with the bulk of users of power—at any rate, for a long time, and the many would not be greatly helped by the interesting details of plant for the recovery of sulphate of ammonia from producer-gas. The apparatus described in the Paper had undoubtedly shown itself economical in working, but it did not present any features of novelty which called for special remark; in fact, the tube-regenerator described seemed to have been anticipated by Mr. Fichet in the Muller-Fichet plans, judging from his remarks in the discussion [1] of the Paper on gas-producers which he had had the honour to present to the Institution in January, 1886. That the combustion of fuel for the production of gas with recovery of the nitrogen as ammonia should be carried on at a low temperature, with the use of abundance of steam, was plainly stated in the discussion referred to, although Messrs. Young and Beilby, following Dr. Grouven, of Leipzig, had for some time strenuously worked at and continued to advocate the high-temperature method. The low-temperature method had since been verified in the later shale retorts of Mr. Norman Henderson, of the Broxburn Oil Company, and in the Mond producers described by the Author; but where condensation and washing of the gas were inconvenient or impossible, and the maximum quantity of hot gas was wanted for heating purposes, producers would in all probability still continue to be worked at higher temperatures with air or steam Mr. Rowan.

[1] Minutes of Proceedings Inst. C.E., vol. lxxxiv. p. 83.

Mr. Rowan. blast. As there seemed to be three systems of gas-supply from producers used for gas-engines or central-station work and in competition with one another, viz., the Dowson, the Lencauchez and the Mond systems, it would be interesting and useful to have a close comparison of the three as to first cost and working expenses for an installation of a given size.

Mr. Tapscott. Mr. R. LETHBRIDGE TAPSCOTT thought that having regard to the economy of using fuel gas made from the cheapest coal, and the ease and convenience in conveying and utilizing it at a distance from the producing plant, it was gratifying to find that a waste-product had been recovered during the process, which of itself had a commercial value. Owing to the large scale on which the gas could be produced, its low temperature and absence from tar recommended it for use in place of coal, besides being free from some of the objections inherent in conveying steam about extensive works. He presumed that the storage in large quantities under pressure would require gasometers.

Mr. Thwaite. Mr. B. H. THWAITE took exception to the suggestion that the producer bearing his name was similar to the others mentioned. The effective principles of his system, both in structure and operation, were distinct, more so than in the process described by the Author, from other systems in daily use. On p. 192 it was implied that no gas-producers had been made to give good results with the cheapest bituminous coal. One of his systems had for many years permitted the worst fuel refuse, even common peat, with or without hydro-carbons in its constitution, to be used for driving gas-engines, and with excellent results.[1] There was no proof that the difficulties referred to at the Britannia Works were intrinsically associated with the use of coke. Generators had been designed, and were in daily use, that successfully dealt with this fuel. He could not reconcile the reference on p. 193 to the advantages of the low-temperature working conditions of the Mond plant with the statement on the following page that the products of distillation had to pass downwards through the hot zone, by which the tar was destroyed and converted into a fixed gas. To volatilize hydro-carbons and afterwards to convert such products of volatilization into a permanent gas, involved the establishment of the following conditions:—The volatile gases from the distillation of the hydro-carbons must be compelled to flow through and in intimate contact with 2 feet to 3 feet of fuel, in a condition of

[1] *The Times*, December 25, 1894, and March 30, 1895. *The Journal of Gas Lighting*, vol. lxv. p. 1191. *The Engineer*, vol. lxxx. p. 3 *et seq.*

bright incandescence, otherwise the products of tar volatilization would recondense. As far back as 1885 attempts had been made to compel the volatile hydro-carbons to pass downwards through the fuel in a single-vessel generator. All such attempts had proved failures, because the fuel above the lower edge of the drop-curtain wall was at a comparatively low temperature, and also because the heated gases were diverted from, and did not pass through the fuel above the lowest edges of the drop-curtain wall, the volatile gases only passed through this comparatively cold fuel and escaped under the edge of the drop-curtain wall into the outlet flue, so that the volatile products were not exposed to contact with incandescent fuel in such a way as to effect the fixation of the volatile gases. The drop-curtain of the Mond producer was identical with the original arrangements introduced with this object, but working under higher temperatures than were maintained in the Mond plant, so that the Mond apparatus was even less capable of dealing with a highly hydro-carbonaceous fuel. If an average character of hydro-carbonaceous, or so-called bituminous fuel, were utilized (containing say 20 per cent. to 25 per cent. of volatile hydro-carbons) in the Mond apparatus, working with the low-temperature conditions resulting from the use of such large volumes of steam, the tar would perhaps be vaporized, but the vapour would certainly not be fixed but would recondense. The arrangement of utilizing the generator-shell radiant heat was satisfactory, but it was one of the features that characterized his own generators, and had been used in his plant for many years. The method of treating the gases on their emission from the gas generator constituted whatever novelty there existed in the Mond arrangement, and where agricultural fertilizers were in great demand, and water was pure, abundant, or cheap, the question of adding such an expensive auxiliary to the plant might be worthy of serious consideration. With regard to the report of the trials, the test giving the critical figure of fuel expenditure to produce 1 I.HP. of energy was unreliable, extending as it did over a period of only some 120 minutes. The test should have extended over eight hours at least. There was a considerable difference in the two figures of volume consumption per I.HP. hour—in one instance 76·18 cubic feet was given, and in the other 69·70 cubic feet, as the factor of expenditure. His own best results with bituminous coals showed 1 E.HP. hour for an expenditure of $1\frac{1}{3}$ lb. of fuel[2] burnt in an Otto-cycle engine; with the commonest bituminous Mr. Thwaite.

Report by George Cawley, *The Engineer*, vol. lxxxii. p. 320 *et seq.*

Mr. Thwaite. slack coal, unfit for steam raising, the expenditure had been equal to 2 lbs. per E.HP. In the Thwaite system neither the generation of gas nor the recovery of ammonia involved the employment of a steam-boiler. The statement at the foot of page 200, that the engine there referred to was the first instance in Great Britain of a large gas-engine driving a dynamo direct, was incorrect. He had tested an engine of the vertical inverted type, made by the Acme Gas Engine Company, Limited, Glasgow, in 1895, which engine was providing the light and power of an installation that involved an output at the rate of 108 E.HP. Gas plant on his system for using the cheapest kind of steam coal was either being constructed or was in operation in England, the Colonies, and in various parts of the Continent. A single unit plant, on the Thwaite system, both of engine and gas plant, of 500 E.HP., was being constructed in England; this was the largest single unit of gas-power station that had yet been constructed. The result of a long and varied experience on the generation and employment of gaseous fuels had brought him to the conclusion that for power and heat-producing purposes generally, and, except where high local temperature effects were required, carbon monoxide was to be preferred to hydrogen. A $\frac{\text{volume}}{\text{weight}}$ calorific comparison, and extended to calorific and the sequence of power possibilities, and using Berthelot's specific heat at high-temperature factors, showed there was little to choose between the two gases. There was no latent heat absorption to be taken into account in calculating with the CO factor, and there was no trouble with the water resulting from the oxidation of hydrogen—both advantages favouring the use of carbon monoxide. The Table of comparative efficiencies, at p. 210, was ingenious, but it is misleading. The figure of merit should be multiplied by the proportion of the incombustible in the fuel used; this would correct the variation in the calorific value of the solid fuel used in the generator. The same gas generator, working with two different kinds of anthracite, would give a greater difference of thermal value than was shown between one kind of generator and another. A simple measure of efficiency of a gas was the percentage of the carbon dioxide constituent. Whatever the quality of the fuel, the volume of the CO_2 should not exceed 6 per cent. Reference had been made to his project of generating power on the coalfields and transmitting it electrically to the Metropolis and to the industrial centres of Lancashire, Yorkshire and the Midlands, which had formed the subject of a Paper read before the Manchester Association of Engineers on the 12th November, 1892.[1] The first

[1] Minutes of Proceedings of the Manchester Association of Engineers, 1896.

Mond producer, as described, had commenced work in September, 1893. The scheme had been described more recently in his article in the *Nineteenth Century*.[1] In the preparation of the report associated with that scheme he had Mr. James Swinburne as a collaborator, and the assistance of reports from Mr. Huber, of Oerlikon, and Mr. C. E. L. Brown, of Baden. The project embodied all that was described in the Paper, and long before the Mond plant described by the Author was erected. In regard to the estimate of a plant to supply gas-engines of 10,000 I.HP., the structural simplicity of the Thwaite Power Gas Plant would enable a plant of that power to be erected for at least 50 per cent. less than the Mond plant. It was stated in the Paper that by using the Mond apparatus the recovery of the sulphate would be sufficient to cover the cost of the coal entirely. He was glad to hear this was the case; but if so, why did Messrs. Brunner, Mond and Company continue to employ ordinary coal for raising steam in their main battery of boilers? Great credit was due to Dr. Mond for having doubled the weight of sulphate of ammonia obtainable from 1 ton of coal, but the cost of evaporating the immense proportion of water made this excess a decided drawback to the application of the system, independently of the great complication and extent of the combination of the plant. Mr. Thwaite.

Mr. C. HUMPHREY WINGFIELD thought that the intersection of the curves of temperature in *Fig. 4*, would convey the idea that at some part of the tower the temperatures of the gas and water, for instance, were equal, while to the right of this point the water appeared hotter than the gas from which its heat was derived. In Table III this was clearly shown not to be the case, and he thought that by reversing the direction of the lower lines the relative temperatures of the respective media would be better indicated. It would then be seen that the difference in temperature between the gas and the acid was nearly constant throughout. The near approach of the water- to the gas-line in the second column would show that the water was not in excess—a desirable feature, since its temperature should be high in order to heat the air efficiently in the third column. In the latter the air-line kept well away from the water-line, showing, again, that the ratio of water to air was not too large to allow of a large part of its heat being taken up. Mr. Wingfield.

Mr. H. A. HUMPHREY, in reply to the Correspondence, was glad to find his opinions supported by so eminent an authority as Mr. Mr. Humphrey.

[1] "Electricity from the Coalfields," *Nineteenth Century*, December, 1894.

Mr. Humphrey. Delamare Deboutteville, whose long experience and great success constituted him one of the first authorities on all matters relating to gas-producers and gas-engines. He thought the Gasmotoren Fabrik Deutz might be congratulated on the excellent results achieved; but it should be mentioned that where anthracite and coke were used the quantity of ammonia present was not considered worth recovering, and this source of revenue was therefore lost; also common bituminous slack must always be the cheapest of the three fuels. The charge for sulphuric acid given in Table V, Appendix I, was correct, the chamber acid being delivered to the works in tank steamers at the price stated. No gasholders were used, or considered necessary, even when the output exceeded a million cubic feet of gas per hour. The presence of CO_2 and nitrogen seemed to be a stumbling-block to many who had not had experience with a gas of low calorific value. That the presence of these gases in a gas used for heating purposes was not to be commended might be granted, unless great uniformity of temperature and absence of local heat was the chief desideratum when they might be of actual advantage. But the point requiring emphasis was that they exercised no such serious detrimental effect as was often believed, for although the heat absorbed by the incombustible gases during combustion of the other portion tended to limit the temperature attainable, yet this heat was not lost if the products were properly cooled. In spite of the CO_2 and N present in Mond producer-gas, the available heat from 1 ton of coal gasified was greater for Dr. Mond's system than for others, and in these days when the principle of regeneration was so well understood, the gas in question was in every way suitable for very high temperature work. What was really required by those who used gas for heating, was that the final cost of a million available heat-units should be the minimum, and that was exactly where Dr. Mond's system had proved the most successful. Mr. Holgate's suggestion to remove the CO_2 by washing the gas in ammoniacal liquor could not, he believed, be recommended as an addition to Dr. Mond's plant, chiefly because the bicarbonate of ammonia which would be formed was volatile and unstable, even at comparatively low temperatures, and this would lead to a loss of ammonia; also a calculation of the quantities involved showed a discouraging result. Such figures as those given by Professor Robinson proved the advance in economy where gas-engines were employed, under suitable conditions, instead of steam-engines. In the present communication an endeavour had been made to satisfy such a want as that expressed by Mr Rowan by giving a full and detailed statement of the cost of the producer plant at Northwich. He thought Mr. Thwaite had construed the opening statements of the Paper to mean more than was stated, and that recognised authorities would have to plead the same ignorance of the system which permitted "the worst fuel refuse, even common peat, with or without hydrocarbons in its constituents, to be used for driving gas-engines, and with excellent results." Mr. Dowson's and Mr. Delamare Deboutteville's statements in 1893 and 1894 respectively, showing the contrary, had already been referred to. Even so late as 1896, before the results contained in the Paper were published, Mr. D. Clerk[1] had written:—"Mr. J. E. Dowson's producer is the only one at present in existence giving suitable gas, and it requires the special fuel anthracite. The use of ordinary fuel has not yet succeeded." He regarded Mr. Thwaite's experiments as inconclusive, but hoped to see his efforts rewarded with a well-deserved success. The dust, carried over by the gas from the producer, of which a sample drawn from the bottom of the regenerator tubes had been placed on the table, consisted of fine particles of slack, and was so free from tar that it would run through an open cock in the same manner as fine dry sand. No better evidence, perhaps, could be given to satisfy Mr. Thwaite's doubts of the solution of the tar difficulty. The difference between the volumes per I.HP. given in Tables I and II, Appendix III, would be expected, when it was considered that one was a trial figure and the other was obtained by ordinary running during one month and in charge of unskilled hands. In Mr. C. F. Jenkins' Paper[2] proof would be found that the "figure of merit" was calculated on a sound scientific basis, and took due account of the incombustible in the fuel used. He had elsewhere corrected the impression that the first Mond producer was started in 1893. Dr. Mond's square producers utilizing the same principles were much older; his numerous producer patents dated back to 1883, and his experimental installation was older still. The reply to Mr. Thwaite's question, as to why Messrs. Brunner, Mond and Co. still employed ordinary slack in raising steam in their main batteries of boilers, had been anticipated by Mr. Holgate, when he deduced the cases for maximum and minimum advantages of gas-firing. The boilers in question were not specially suitable for use with gas, and were at present working with mechanical Mr. Humphrey.

[1] "The Gas and Oil Engine," 6th edition, p. 267.

[2] Minutes of Proceedings Inst. C.E., vol. cxxiii. p. 328.

Mr. Humphrey. stokers, also as fast as the producer plant at Northwich was extended the extra capacity was appropriated for work where the advantages of gas-firing are more keenly felt. The meaning of the curves, *Fig. 4*, became clear when it was stated that for any of the three towers the temperatures on the left of a vertical column were those of the liquid or gas entering, while those on the right were for the liquid and gas leaving.

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23 March, 1897.

JOHN WOLFE BARRY, C.B., F.R.S., President, in the Chair.

The discussion upon the Paper "The Mond Gas-Producer and its Application" was continued and concluded.