Discussion.

Mr. Wolfe Barry. Mr. J. WOLFE BARRY, C.B., President, in moving a hearty vote of thanks to the Author for his interesting and suggestive Paper, said that it opened up a subject which might have a great and important future, and he hoped it would be discussed in all its bearings.

Mr. Humphrey. Mr. H. A. HUMPHREY remarked that since the experiments tabulated in the Paper certain changes had been made, and the working of the producers had been improved in several respects. A typical gas from Mond circular producers now contained 40·6 per cent. of combustible gases; the analysis in volumes per cent. being:—hydrogen, 28·0; carbonic oxide, 10·8; marsh gas, 1·8; C_nH_{2n} gases, traces; carbonic acid, 16·6; and nitrogen, 42·8. From daily samples of the gas taken during the month of February, 1897, the average calorific value, as determined by the Junker calorimeter, was 1,352 kilocalories per cubic metre. To show the regularity in the heating properties of the gas, it might be mentioned that the highest calorific value during that month was 1,403 and the lowest 1,322 kilocalories, giving the maximum variation between 3·77 per cent. above, and 2·2 per cent. below the average. The average analysis of dried samples of slack used in the producers showed, during February, 10·82 per cent. of ash, 69·60 per cent. of total carbon, 1·30 per cent. of nitrogen, and 18·28 per cent. of volatile matter, other than carbon, driven off at a temperature above 100° C. The calorific value of the fuel now employed was always below 7,000 Centigrade heat-units per unit weight, as determined by the Berthelot bomb calorimeter, in which the fuel was burned in oxygen compressed to 24 atmospheres. The remarks in the Paper regarding the immunity from repairs of the first circular producer erected still held good. The Mond gas-producer and recovery plant was not, at any rate for the present, applicable to installations where less than about 20 tons of fuel were used per day. On any smaller scale the recovery plant would be expensive in proportion to the output.

Mr. Dowson. Mr. J. E. DOWSON congratulated Dr. Mond upon the thorough manner in which he had attempted to grapple with a difficult subject. He might not agree with all Dr. Mond's conclusions, but he could at least admire the skill and care with which he had designed the plant. It was well known how much engineers were indebted to the late Sir William Siemens, for his work in connection with gaseous fuel, and it was gratifying to know that a distinguished countryman of his was following in his steps and was giving the matter close attention. He gathered from the Paper that Dr. Mond's first generator was made in 1893; and it was striking that that gentleman should have there and then built a generator capable of converting as much as 1 ton of fuel in the hour. He remembered that many years ago, when he had first dealt with the subject, his little generator was capable of converting only 20 lbs. or 30 lbs. of coal per hour; and even if he had then had the means at his disposal, he did not think he should have had the boldness to attempt such a size as 1 ton per hour. In Appendix I, Table I, he observed that the average amount of carbonic acid in the Mond gas was 16 per cent. In another Table it was given as 12·9 per cent.; he need hardly say that both were exceptionally high for producer-gas. Yet in Table VIII a figure of merit was adopted for the Mond producer which placed it at the top of a list of various other producers. He thought the basis of calculating that figure of merit—taken from a Paper[1] by Mr. C. F. Jenkin—misleading for producers which were worked by steam. He had determined the efficiency of a producer from the heat value of the gas in relation to the carbon in the fuel gasified, and that, doubtless, was right where the gas was produced with an air-blast without steam; but where both steam and air were sent through the fire, hydrogen was added to the gas produced, and the steam consumed for that purpose, which represented an additional coal-consumption, should be taken account of. In Dr. Mond's process an exceptionally large quantity of steam was used; and he thought it was wrong to give a supposed efficiency to the gas-producer alone without taking into account the steam required to carry on the complete process of making the gas—apart from the recovery of the ammonium sulphate. He thought the Author would probably find that Table VIII needed correction on that account. In Appendix III, Table I, it was stated that the gas consumed by the engine was measured by meter, and that the slack used at the producer was 1·03 lb. per I.HP. hour. Seeing that the producer was gasifying nearly 1 ton of coal per hour, that the engine consumed only 3,051 cubic feet an hour, and that the engine trial lasted only 2 hours, he would ask how the fuel consumption for the engine alone was arrived at, even to two places of decimals. Would the Mr. Dowson.

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

Mr. Dowson. Author also state whether this allowance included the fuel equivalent for producing the steam used in the production of the gas? In Table III the Author appeared to have included in the cost of the gas 60 lbs. of water per brake HP. per hour; but actually that water was used for the cooling of the engine only and had nothing to do with the cost of the gas. He was surprised to find that Table V supposed the recovery plant was not used, while the whole of the Paper seemed to deal with the recovery of the sulphate of ammonium as an integral part of the process. It seemed that the cost of Mond gas made on the scale of some 2,000 I.HP. should hardly be compared with that of a small plant of 150 HP. only, working for only 8 hours or 10 hours per day, and charged with the usual stand-by losses. In the large plant, the work was going on continuously night and day, naturally under certain advantages in that respect. It seemed that it would be as correct to compare the working-cost of large steam-engines and boilers on board a vessel running continuously night and day, with a small stationary engine on land, the boiler fire of which was banked 14 hours or 16 hours per day. In some districts the use of bituminous coal would no doubt be cheaper than working with anthracite or coke; but in many places the prices were practically the same. The generators he had designed were now made to work with small anthracite costing between 6*s.* and 7*s.* a ton at the pit in South Wales, or at pits near Glasgow, when bought in single truck-loads. Bituminous coal cost about the same in those districts; so that for the South and West of England, and for many parts of Scotland, the cost of the coal delivered would be practically the same in each case. For those districts, therefore, if there were no recovery of the ammonium sulphate, which was the case in the particular Table he was referring to, there did not appear to be any gain in the Mond process. For the Midlands and the Northern Counties the case was different, and there it would be advantageous to use bituminous local coal where it cost appreciably less than coke, provided that the first cost of the plant was not excessive. With regard to furnace work with Mond gas, he was disappointed at the statement in the Paper to the effect that more coal was used for the gas-firing than by the ordinary system. That loss, he supposed, was partly due to the fact that the gas contained such a high percentage of carbonic acid, and that some of the hydrocarbons had been washed out. He wished to know more precisely if that loss were compensated by the recovery of the ammonium sulphate, and also what was the initial cost of the plant required to carry out that process. Some years ago he had had occasion to design a furnace, for the Projectile Company at Wandsworth, for heating billets of steel before they were compressed into shells. When the furnace was fairly at work, the Company had made an independent 12 hours' trial with the gas furnace, in comparison with another furnace of exactly the same size and doing similar work, but heated with a fire in the ordinary way, each furnace having its own gang of men and its own machine. The result showed that the new gas generator consumed 765 lbs. and the old system 1,276 lbs. of coal, or a saving of 40 per cent. in weight of coal in favour of the gas-fired furnace. It appeared that the Mond producer was not intended to work on such a small scale. On the supposition that there were several such furnaces to be heated, requiring 5 cwt. or 6 cwt. each per hour, or any other figure that the Author considered fair, he would ask whether it was cheaper to work such furnaces with producers of well-known types or with the Mond recovery plant, with its 16 per cent. of carbonic acid and with all the hydrocarbon vapours removed. Mr. Dowson.

Mr. G. L. ADDENBROOKE noticed from the Paper that the amount of ash was taken at 7·3 per cent., but the Author now appeared to be using coal with 10 per cent. to 11 per cent. of ash. From a Table giving the moisture, ash, and combustible matter in Welsh, Scotch, Staffordshire and other slacks, or coal dusts, he found such percentages of ash as 17, 12 and 18, though one was as low as 6·4. Some Staffordshire dust gave as much as 28 per cent. Breeze-dust had 16 per cent., coke-breeze 24 per cent., and so on, so that apparently the majority of the fine slacks referred to by the Author had a larger percentage of ash than the particular fuel used by Dr. Mond, though the word slack was used in a very elastic sense. He would ask whether the Author thought that an additional quantity of ash would affect the work of the furnaces. The question of long-distance transmission, say from the Midland Counties to London, was a point to which he had given a good deal of attention three or four years ago, when power had been transmitted from Schaffhausen to Frankfort. In that case the distance of transmission was 112 miles, or about the same as from the Midland coalfields to London; consequently if it could be done in the one case it could be done in the other. The first conclusion at which he had arrived was that the only gain would be the difference in the cost of carriage of the coal from the pits. The cost of the conveyance of coal from the Midlands by the London and North Western Railway Company was about 5*s.* 10*d.* Mr. Addenbrooke.

Mr. Addenbrooke. per ton, including truck hire. If a central station were erected near the collieries on such a large scale as mentioned in the Paper, it would not be possible to depend on one colliery, and therefore something would have to be paid for transmission even in this case. Subtracting 10*d.* on this account, 5*s.* a ton was left of difference between taking the coal and turning it into an electric current in the Midlands and employing it in London. He had no doubt that the figures given by the Author were correct if current could be sold at $2\frac{1}{2}$*d.* a unit to supply companies in London. But the supply companies in London were already making current for themselves for less than $2\frac{1}{2}$*d.* per unit, so if they wanted a supply from the outside of current at all they wanted to get it at about 1*d.* a unit. Under those circumstances he was doubtful if such a scheme would be successful. Further, although he thought the other difficulties would be conquered in time, there were still important points, such as the power of insulators to resist high pressures, which were by no means satisfactorily settled at present. The problem had been dealt with some years ago by Messrs. Swinburne and Thwaite who intended to use gas-engines, and the Author referred to it now as one which could be carried out still better by Mond or producer gas; it appeared, however, that the Author's argument was much more against it. He observed that 1 lb. of slack produced 77 cubic feet of gas, and that was about what was required per HP. in a gas-engine; but from Appendix II, the results of using gas under the Babcock-Willcox boilers, 1 lb. of slack would evaporate between 7 lbs. and 7·36 lbs. of water; therefore 10 cubic feet of gas would evaporate 1 lb. of water, which needed about 1,000 British thermal units. Consequently, taking 14 lbs. of steam per I.HP. as the best that could be obtained in practice with a steam-engine, nearly 160 cubic feet of gas fired under the boiler were required; but the tests in the Paper showed 1 brake HP. hour with a gas-engine for about 73 cubic feet or 80 cubic feet; therefore by using a gas-engine only half the amount of coal used for a steam-engine would be required. So that if in the first case there was an advantage in sending current from the coalfields it was very much reduced by using gas, only half the coal being required, and therefore only half the carriage. Supposing, notwithstanding that a central station were erected in the Midlands to supply power, the railway companies charging 5*s.* 10*d.* per ton, and another rival station was erected just off one of the main lines outside London, if they could get cheap carriage; it would not be likely that the railway company would allow all that carriage to pass out of its hands. The coal would be probably delivered a train-load at a time collected from a single colliery; it would be cheaply managed, and would go straight into the central station sidings; under these circumstances was it not likely that the railway companies might be induced to reduce their rates to about one half? Looking at these uncertainties he thought it would have been better to have omitted the point of transmitting power to a great distance from the Paper; on the other hand, he thought there was a great opening for the transmission of power over moderate distances. He had considered the question carefully, and his idea of the economical limit of electrical transmission, unless there was a waterfall in one part and a town in another, under ordinary circumstances was between 8 miles and 10 miles at the outside. Certainly if Dr. Mond could make gas-engines work on anything like the basis stated in the Paper, there was a wide field for their use, but he was afraid the opening did not lie in the direction of long-distance transmission. Mr. Addenbrooke.

Mr. T. Parker had, four or five years ago, investigated the subject under discussion with the then means of producing gas for gas-engines for the purposes of applying power, and again in another case for a large electro-chemical application. In those cases he found that the gas and the gas-engines available at the time were not so cheap and handy as steam, and he was therefore compelled to recommend steam-engines. He was glad to see from the Paper that the application of bituminous coal for producing power in gas-engines was within reach. He observed that Dr. Mond was able to produce 1 HP. of work with 1·03 lb. of bituminous slack, and at the same time produce a product which would be very valuable in the shape of sulphate of ammonia. He thought it would be better to apply the figures to some means by which they could be continuously worked, such as an electrolytic or electro-chemical application. With regard to producing power for transmission on a large scale, there was also great scope for its application. He thought the figures assumed by the Author with regard to the capital outlay of a plant capable of yielding 10,000 HP. excessive, and would not do justice to the possibilities of the case. It might be reasonably expected to run such a plant of 10,000 HP. for 8,000 hours per annum; that would give a margin of 760 hours per annum for any attention that might be required upon the plant; and, comparing that with water-power, the time would be reasonable. That number of hours would yield about 80,000,000 HP. hours per annum, and give 1 HP. year for the cost of 16*s*. with 7 per cent. for depreciation. Any smaller number of hours would proportionally affect that figure. There was an unlimited amount Mr. Parker.

Mr. Parker. of slack coal, as suggested in the Paper, to be obtained at the rate of 500 tons per day at 2*s.* 6*d.* per ton, and this could be used in the neighbourhood of the colliery. Allowing $1\frac{1}{4}$ lb. per HP., brought it out at 10*s.* per HP. year, making a total cost per HP. year of 26*s.* for coal and depreciation of plant, or about $\frac{1}{25}d.$ per HP. hour. Those were results which he expected to see realized, and which he had long ago thought possible and probable. He hoped they would soon be put into practice, because the field of electrical application would then be unlimited. He had a number of applications for plant that could be put to work at such a price, to say nothing of the ammonia products, which should balance the whole 26*s.*, and would give power for practically nothing, except attendance, oil, and the like. The figures he had referred to placed the prospect of electrical industry in a very hopeful light, and he expected real results to follow the Paper. With regard to sulphate of ammonia, it would need special attention, but he felt that that could be left to Dr. Mond.

Mr. Preece. Mr. W. H. Preece, C.B., Vice-President, called attention to the marvellous and rapid growth of electrical industry, and to the advantage which that industry must experience by the introduction of such processes as that which Dr. Mond had brought forward. To illustrate that growth he might mention that only that day he had been inspecting an installation which two years ago was thought to be gigantic, when he suggested that a plant of 375 kilowatts should be installed. In the short space of two years the question had to be considered of exactly doubling that plant. If it progressed at that pace, and there was no reason why it should not, in another two years it would double itself again. It seemed almost a rule in most of the electric-light installations that were started under good conditions, that they doubled themselves at a marvellous rate. There was one striking fact coming out in all those additions and enlargements of electrical industries, to whatever purpose they were applied, viz., that the cost of production was diminishing with the magnitude of the output. If, in addition to that natural reduction in the cost of output, there was introduced, with the assistance of able chemists, such as Dr. Mond, a process also of reducing the cost of production, the result would be, as the electrical industry grew, that the cost of production would diminish almost as the square of the output. If there were any truth in that deduction, it was certainly something that should make not only those who were interested in gas manufacture think seriously, but it was one of those things that applied to all, whatever their occupation might be and in whatever direction power was applied. In the case, for example, of the Post Office, wherever large new post-offices were being built electrical plant was being applied to all kinds of purposes. It was not alone used for electric lighting, it was used for lifts, for air-pumping engines, for pneumatic tubes, for working folding machines in the savings bank, and even for melting wax, an enormous quantity of wax being used for sealing registered packets and parcels generally. The more the cost of production was reduced, the more the use of that form of energy was applied to the useful purposes of mankind, and therefore engineers should hail with satisfaction the introduction of any processes, whether Mr. Dowson's or Dr. Mond's, which reduced still further the cost of production. The main feature of Dr. Mond's process—the process by which bituminous coal could be applied to gas production—was a feature distinctly in the right direction. He had heard even of a better case than the cost of 2*s.* 6*d.* a ton referred to by Mr. Parker, that of a large coal-owner, who said he could supply 500 tons a day at the pit mouth, of slack, at 1*s.* per ton, which could be converted into gas. It was all very well to supply coal at 2*s.* 6*d.* or 1*s.* per ton, but it had to be taken away from the mouth of the pit. The questions were (1) whether it was more economical to transport the coal in bulk from the pit's mouth to the place where it was to be consumed, (2) to conduct the results of distillation, namely, the gas in pipes, to the point of usage, or (3) to transport the energy produced at the pit-mouth by the combination of coal converted into gas and there and then utilized for the production of electrical energy, and thus transported to great distances. He did not go so far as Mr. Addenbrooke, who had limited the distance to a very short one. But from calculations he had made, he had found it was much cheaper to transport fuel in bulk from the colliery districts to London than to attempt to transport it in the form of electrical energy. How far, with coal at 1*s.* a ton, it would be remunerative to transport gas to London was another question. The whole of the Chicago Exhibition in 1893 was lighted, and power distributed, by gas brought about 130 miles, from Pennsylvania. The results were very satisfactory and certainly economical. He had said that the larger the output the cheaper the cost of production. There was another and most important point in connection with the cost of production; the output must not only be large but must be continuous. He had already mentioned in that room that, even with present knowledge, with the use of coal, with economical high-pressure engines, it was possible with a large output, used continuously, as, for instance, in the case mentioned by Mr. Parker Mr. Preece.

Mr. Preece. of electrolytic depositions of copper and the electro-chemical deposition of phosphorus, to produce energy continuously and *easily in great magnitude for less than $\frac{1}{4}d.$ a unit.* The great hope inspired by the Paper was that that could be even reduced. It was pointed out that by taking 10,000 HP. it could be produced at practically $\frac{1}{6}d.$ per unit. When it was possible to develop a kilowatt-hour of electricity, viz., $1\frac{1}{3}$ HP., continuously for an hour, at $\frac{1}{6}d.$, there was no other available form of energy which could compete with it. All workshops would utilize that form of energy, and it would be possible to remove those noisy and uncomfortable shaftings that were so disfiguring. The force could be applied, too, where it was wanted and when it was wanted, and, to a certain extent, many of those industries could return to the home instead of being concentrated under the tyrannous rule of Trades Unions in large workshops. Then there were possible combinations in the towns of electric lighting and tramway working. The experience of America and the Continent, and, on a smaller scale, in England, as in Bristol, Dublin, Leeds, and other places, showed that of all the systems of working tramways there was none so comfortable or so promising, and none so economical, as that of the application of electricity; however much or little the tramway working might cost during the day, it would cost less when the power was utilized for a longer period during the night for lighting. Looking at the growth of the industry, therefore, from all points of view, with its innumerable applications, such a process as had been invented by Dr. Mond and brought forward by Mr. Humphrey, led engineers to expect that in the very near future electrical energy was going to walk away with all other forms of power, and that the production of electricity for every purpose—many other than those to which he had alluded—was certain to become, not only practical, but economical.

Mr. Jenkins. Mr. H. C. JENKINS thought Dr. Mond had demonstrated the possibilities of regenerating at low temperatures. He had been able to pass an enormous quantity of steam through producers and thus keep the temperature down without losing the heat he otherwise would. He had also overcome the difficulty of clinkering, and recovered the ammonia. This was accomplished at the expense of having a larger amount of carbon than usual in the ash, and the hydro-carbons of the C_nH_{2n} series were lost; but apart from that, Dr. Mond obtained a good gas. Although, as Mr. Dowson had pointed out, an enormous quantity of carbonic acid was present in the product, he should look also at the very large amount of hydrogen. In the present case, Dr. Mond had obtained a large amount of hydrogen at the expense of some carbon monoxide. It was obvious the plant could not be used on a small scale on account of the capital cost and the trouble the apparatus involved. With regard to the proposals for obtaining energy in an electrical form in the Midlands and bringing it to London, he would ask were not still risks being run from strikes. In the distribution he would also suggest that shafting could not be eliminated. The cost of motors to each and every machine would be prohibitive, and it would be necessary to have a certain amount of shafting and belting, although factories were supplied with electrical power. The Author appeared to have chosen good general conditions under which to burn the gas when he adopted the firebrick combustion-chamber to his boilers. He would suggest, however, that its use had not been highly successful. There was an enormous quantity of carbonic oxide in the flue gases, and no free oxygen. Was not that a reversal of the usual order? Air was cheaper than producer-gas, and would it not be better to use more air and have a slight excess of oxygen? It was true the carbon monoxide could not be completely burned; still it could be reduced certainly to some much smaller figure than 3½ per cent. The combustion-chamber appeared to be too small, and the maximum amount of gas had been put through it in order to raise sufficient steam in the boilers. The temperature of the flue gases was very low, a result due to the clean state in which the boilers could be kept when using the gas, rather than to any efficiency of the gas-firing. The efficiency of the gas itself did not seem to be quite what it might be made. The gas-engine was by far the most important motor now to be considered, and some of the benefits might be expected in it that must be derived from using a thoroughly washed gas. He would ask the Author whether the use of the sawdust-filter was compulsory or whether it could not be altogether dispensed with by having more washing-towers? He should be glad to know, too, what kind of meters were used in the tests of the gas-engines, and whether they were standardized before use. The Author had referred to the economy that would result if gas-engines could be run in conjunction with the plant, because of the increased heat efficiency of the whole plant. It would be interesting to see how far economy could be carried by such means. For metallurgical purposes the gas seemed to be very good, in spite of the large amount of carbon dioxide and the small amount of water vapour. That small amount of water vapour could of itself be of no harm, provided the regenerators for the furnaces were large enough. The thorough washing of the gas would enable use to be made of certain kinds of slack that would be otherwise objec- Mr. Jenkins.

Mr. Jenkins. tionable on account of sulphur, the plant offering special facilities for the elimination of this element. Some account of the capital and interest charges would be of interest to show the minimum limits of size and the output per day.

Mr. Head. Mr. JEREMIAH HEAD thought the process described in the Paper was of the greatest importance to all engineers. He felt especial interest in it in connection with the iron and steel industries, which were becoming more and more dependent on gaseous fuel. It was only recently that English steel manufacturers had been alarmed by the competition of the United States. The steel sent to England came from Pittsburg, where one of the advantages in making it cheaply was the use of natural gas. It would be seen from Table VI, p. 208, that Pittsburg gas contained nearly double the amount of combustibles that producer-gas contained. There were enormous advantages to the steel-melter and the steel-heater in having a gas of that kind which contained heat in so concentrated and easily-dealt-with a form. In meeting that competition in future, it was of the greatest importance that the methods of making gas for application to metallurgical processes should be improved. Better and cheaper gas was required, if for no other reason than that of helping to meet foreign competition. The process described in the Paper was extremely interesting, as it appeared to enable more power to be obtained out of the coal burnt than by any other way, something like one half as much again as was obtainable in the very best engines and boilers of which he had any experience. The question had been asked whether the apparatus could not be worked without the recovery process. It had been shown distinctly that the apparatus could be perfectly well worked in that way, and if that was done, the saving of the coal over gas produced in any other way was reckoned at 25 per cent. Another advantage of using this system, even without the recovery plant, was that clean gases were obtained—gases that could be conveyed to almost any distance without risk of deposition in the pipes or flues. It also diminished the sulphur and the cost of labour. He wished to point out what he thought had not been sufficiently dwelt upon, namely, the extreme regularity of the process. With self-acting conveyors and elevators the fuel passed into the producers, and the ashes were withdrawn at the bottom with the utmost regularity, so that it became a continuous process resulting in the gases being of an exceedingly equable and reliable kind. That was of great importance, indeed some of the more delicate processes could not be carried on without gas of that kind. He understood from the Paper that Dr. Mond considered that the value of the ammonium sulphate was equal to the cost of the coal; so that either the gas or the ammonium sulphate was obtained for nothing. That was really one of the great advantages and compensations obtained from that somewhat costly apparatus. He agreed to the desirability of knowing the cost of the apparatus. He was somewhat disappointed to find that the slack used was estimated to cost 6*s.* 2*d.* when delivered to the producers. It certainly must have been slack of a very superior kind, or it must have had a very high cost of carriage upon it. He agreed that slack could be obtained in quantity in certain colliery districts in England at 2*s.* per ton at the pit. Very large quantities had been shipped at the Tyne in times past for 1*s.* a ton; indeed, thousands, if not millions of tons had been put in heaps at the collieries and allowed to go to waste altogether. Anything that turned slack into useful gas must be a national advantage. One of the great advantages of Dr. Mond's system was that, by previously lowering the temperature, a great deal of the moisture which would otherwise go forward was condensed and taken away. Those wet gases were very bad for metallurgical purposes, but the gas when cooled and therefore dried, as in the present case, was perfectly good for melting steel. Nothing had been said in the Paper about the by-products other than ammonium sulphate. He supposed that as the tar was retained they were retained with it; therefore the only by-product was the ammonium sulphate. In carrying the system out to the almost unlimited extent contemplated by the Author, it had occurred to him whether the demand for ammonium sulphate was unlimited. He hoped it was, in order that the system might thrive in that way, and also that the depressed agriculture might derive benefit from an unlimited supply of almost the best manurial substance that existed. He understood that it was of special importance because it was so good for grass, and it was well known that latterly more and more agricultural land had been laid down in pasture. Mr. Head.

Dr. H. E. Armstrong considered the Paper gave an account of the first moral process which had been put forward for producing gas —the first attempt to recover a by-product that should not be sacrificed. He thought ammonia was one of those things that it was not right to throw away, considering its great value from an agricultural point of view, and one of the important features in the Paper was the necessity of taking care not to waste any of the ingredients in fuel which were commonly wasted. Hitherto an enormous proportion of valuable material had been sacrificed, but Dr. Mond had explained how to do the work in a moral way. Dr. Armstrong.

Dr. Armstrong. The percentage of carbon dioxide in the gas was extraordinary in comparison with that present in most producer-gases, and he could not help thinking that considerable improvement might be effected in the quality of the gas in that direction. If a diminution in the percentage of carbon dioxide could be brought about, the fuel would undoubtedly be a more valuable one. He asked whether the experiments on the use of the gas for firing, not boilers or evaporating vessels, but high-temperature furnaces, had been sufficiently numerous to bring out the value of the gas? The point which had been brought into special prominence by Mr. Frederick Siemens—the great value of carbonaceous matter in fuel used in high-temperature furnaces—was one to which attention had to be directed in considering the value of the Mond gas; the gas in question appeared to be particularly free from hydro-carbon constituents. It might be thought that the gas would not lend itself so well to steelmakers' use, not only on account of the presence of a large amount of carbon dioxide, to which Mr. Dowson had referred, but also on account of its freedom from constituents which would give rise to the separation of carbon in a condition to promote radiation at high temperatures.

Mr. Bauerman. Mr. BAUERMAN thought Dr. Armstrong, in his remarks about carbonic acid in the gas, had rather missed the point—that in gasification at a low heat (which appeared to be the essence of the whole matter) the production of carbonic acid in quantity was a necessary consequence, with a large development of sensible heat which was taken up by the most effective regenerator—a large quantity of water. With regard to the use of Mond gas in regenerative furnaces, it appeared from the data given by Mr. Darby,[1] that in the preliminary heating in the regenerator reconstitution of the gas took place, though the mutual reaction of carbonic acid and hydrogen gave rise to water and carbonic oxide with some increase in the thermal value per unit volume of the gas before it was burnt in the Siemens furnace. Although it was a "poor" gas as compared with water-gas made by the intermittent process, it proved perfectly efficacious for steel-melting, and, apart from the ammonia recovery, another advantage was to be found in the freedom from dust of the fuel-gas obtained. He thought the Paper showed a most remarkable example of what might be called low-temperature regeneration. The four up-and-down pipes, and the towers, contained the essence of the whole thing. It was a remarkably beautiful process, and he was ex-

[1] Journal of the Iron and Steel Institute, vol. xlix. p. 144.

ceedingly glad that it had been so fully and completely brought before the Institution. Mr. Bauerman.

Mr. HUMPHREY, in reply, said that Dr. Mond's experiments dated from 1879; and when, ten years later, he described his system to the Society of Chemical Industry, a large plant of square producers was at work. It was from the experience gained with these producers that he was enabled to at once build a circular producer of the capacity stated. In Appendix III, Table I, given simply in connection with a gas-engine trial made a year previous to the other experiments, the gas was not a pure circular-producer gas, but was mixed with that from square producers, the supply being drawn from a main common to both. The higher figure for CO_2 was the correct one for the producer described. The reason the gas, containing as it did so much carbonic acid, headed the list with the best "figure of merit," was to be found in the large quantity of hydrogen present, which had been chiefly raised at the expense of that portion of the carbon burnt to form CO_2. To introduce into Table VIII such a correction as that proposed by Mr. Dowson would make the Table misleading, for in the Mond plant the steam used was partly that recovered by the regenerators, and the remainder was exhaust steam which would otherwise be wasted. On the other hand, the Dowson plant used steam which had to be generated purposely and supplied under pressure. Suppose, however, that no exhaust steam was available, and that the producers were worked for the sake of the gas only, then the Dowson and Mond plants both required about the same proportion of additional fuel for steam-raising, as might be clearly seen from Appendix III, Tables III and V. The 1·03 lb. of bituminous slack per I.HP., as recorded in the gas-engine trial, was obviously not measured directly, but the point was important because great accuracy was required in determining such figures. From a large amount of experience the exact volume of gas obtainable from a given quantity of coal was known, and the most reliable means of verification were to be obtained from a balance-sheet of carbon quantities, taking account of the carbon in the coal, the carbon in a measured quantity of gas, and that lost in the ashes. This meant systematic and careful analyses, and at Winnington a special laboratory was devoted to the work. In the engine trials the gas was measured by an ordinary type of rotary wet meter of ample capacity, and then calculated back to slack actually fed into the producer, no allowance being made for extra fuel for steam-raising, because in a large gas-engine plant such extra fuel would be replaced by the hot exhaust gases. A Mr. Humphrey.

Mr. Humphrey. large Crossley-Otto engine, of the two-cylinder end-to-end type, capable of developing 150 I.HP., had been recently erected at Winnington to work with Mond gas, and, as might be expected from a larger and more modern engine, better results had been realized than those given in Appendix III. As complete experiments were to be carried out on this engine, it would suffice to say that on the official trial the fuel consumption was 0·92 lb. of slack per I.HP. hour, and the thermal efficiency 26·85 per cent. To insure accuracy, a meter with a capacity of 20,000 cubic feet per hour was used to measure the gas. In Appendix III, Table V, it was intended to place the case of the Dowson plant in as favourable a light as possible, for in no instance he had investigated had he found a plant regularly making 1,000 cubic feet of gas for the sum mentioned; also the cost of the extra fuel at the boiler had been purposely omitted. In the corresponding figures for the Mond plant, this extra fuel had been included. If the locality of suitable pits was to be chosen, the cost of bituminous fuel for the Mond process would be considerably lower than that given in the Paper. As regarded furnace work with gas-firing, it was true that this method required a larger consumption of coal when compared with careful hand-firing carried out under favourable circumstances. Nor did it appear possible that it should be otherwise, for, although the balance of advantages remained in favour of gas-firing, some heat must be lost in converting the fuel to the gaseous state, no matter what producer was adopted. The comparison instituted by Mr. Dowson, in which a saving of 40 per cent. was shown in favour of gas-firing, would indicate that the particular example was either not suited for direct-firing, or that the hand-firing was badly carried out. In any case where gas-firing was adopted, and when leaving out of account the recovery of ammonia, that producer was the best which yielded the greatest number of heat units in the total gas made from 1 ton of coal. Table VIII provided a clear answer to Mr. Dowson's question on the subject. As to the suitability of slacks for use in the Mond producer when they contained a large percentage of ash, his experience showed that a heavy ash did not involve difficulties in working; but he had no experience of such percentages as 28 and 34, which must be regarded as exceptional. When generating power by gas-engines using Mond gas, a given HP. could be obtained for a given time with an expenditure of half the fuel required by the best steam-engine, and at a still greater reduction in cost, whether the central station was in the Midlands or in London. The costs

Mr. Humphrey.

quoted by Mr. Parker might be possible, but those in the Paper were given with a margin on the safe side. The large sulphate-of-ammonia plant at Winnington, with its regular supply to the market, was a standing proof that the ammonia question was no longer in the problematic stage, as Mr. Parker's remarks would almost indicate. With regard to the valuable remarks of Mr. Preece, and his important suggestion to transmit energy by distributing Mond gas through pipes, Professor W. C. Unwin had made [1] calculations which showed that large powers could be transmitted in this manner by comparatively small pipes and with very little loss of energy, due to the pumping power required to put the producer-gas under sufficient pressure for distribution. He had the best authority for stating that the cost of motors was not prohibitive, as stated by Mr. Jenkins, at any rate for new factories, for in such cases the saving in first cost had been conclusively proved. In the performance of Mond gas burnt under a Babcock-Willcox boiler, and showing, in Appendix II, a proportion of unburnt CO, some of the flames had been extinguished by the comparatively cold tubes before combustion was complete, so that it would have been possible to have an excess of oxygen, and yet some unburnt gas. The difficulty had been overcome by shielding the portion of the tubes closest to the perforated arch, and by enlarging the combustion-chamber. It was quite possible to burn all the combustible gases under proper conditions. When Mond gas was applied to a gas-engine, the sawdust filter might be desirable, but was not necessary, as was shown by such a filter running for more than a year without being disturbed. The total cost of a plant in connection with the 10,000 HP. central station was £20,000. This sum included the fuel handling plant, the producers, towers, regenerators, sulphate plant, and all blowers, engines, pumps, tanks, and machinery erected and in working order. In reference to the cost of slack, viz., 6*s.* 2*d.* per ton, Winnington, which was close to Northwich, in Cheshire, had been chosen for Messrs. Brunner, Mond and Company's works because cheap salt and brine were obtained there, and not on account of cheap fuel. All the important coal districts were at a distance, and the cost of carriage was a considerable item. The demand for sulphate of ammonia could not be called unlimited; but it may be regarded as nearly so. In a recently published work,[2] Mr. Legrand estimated that England consumed

[1] "Development and Transmission of Power," 1894 ed. p. 262.

[2] "L'Ammoniaque, ses nouveaux procédés de fabrication et ses applications," by P. Truchot. Paris, 1896.

Mr. Humphrey. $\frac{1}{66}$th of the quantity of nitrogenous manures which could be advantageously and economically used for agricultural purposes. Also the amount of nitrogen in sulphate of ammonia was 21·21 per cent., against 16·47 per cent. contained in nitrate of soda, and as the unit of nitrogen was of equal value in both forms, there was good reason to believe that sulphate of ammonia would replace nitrate of soda for mixed manures, in spite of the splendid organization of the nitrate trade. Dr. Armstrong's inference that Mond gas would not be so useful where very high temperatures were needed was found to be contradicted by practical results. Without going into the curious change which took place when the gas passed through a high temperature regenerator, and which had been dealt with in Mr. Darby's Paper, another interesting fact might be recorded, namely, that this clean washed gas, which burned at lower temperatures with a pure transparent blue flame, became intensely luminous at high temperatures, and apparently the radiant effect valued for steel furnace work was fully realized. The steel furnace at Winnington was carried on as long as there was anything to learn from the experiments, and the results proved beyond all doubt that the gas was in every way suitable and economical for making the best qualities of steel. He thought the presence of so much CO_2 could not be regarded as detrimental while the equivalent in hydrogen was present. It did not in any way limit the useful application of the gas, and if this gas contained more heating value than could be obtained by using any other producer, this seemed, after all, to be the most important point. As to starting, stopping, and working a producer at different speeds, if the circular producer was to be started for the first time, a preliminary drying of two or three days was necessary. In any case, if the producer had been emptied, and was starting cold, it was advisable to proceed to heat slowly, the fire being lighted with shavings and wood, and fed with coke, the bottom and top of the producer being open, and the combustion regulated to prevent too high a temperature. When the wood was all burnt, the bottom lute was filled with water, and only a very small amount of blast was used. Coke was employed until there was a depth of 6 feet in the producer, then the attendant began to add slack. The gas formed was wasted until it tested 30 per cent. of combustible gases, when the conditions could be quickly brought to the normal state. This process should not be necessary more than once a year, because when once started, there was no need to entirely stop a Mond producer. Its output could be regulated by the blast within wide limits, and, if desirable, it could be shut

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