Mr. Foster. way of getting nitrogen in a valuable form out of coke was to turn it into gaseous fuel. In that way the sulphur could be eliminated and the nitrogen recovered as ammonia while producing a gaseous fuel which was smokeless. Little reference had been made to the question of the use of coke with coal-gas. The late Sir William Siemens had introduced a small apparatus (a kind of grate) in which he burned a small amount of coal-gas and coke, but that appeared to have taken very little hold upon the community. There could be no doubt that gaseous fuel of any description for domestic purposes ought to be used with solid fuel. With coke in a fire-place without bars, a slow combustion and a certain amount of genial effect could be secured by the presence of a small amount of coal-gas. Whatever might be done in the direction indicated, experimenters should never, as Sir William Siemens had said, lose sight of possibilities, but should try to attain to a certain maximum, although they might not at present be able to reach it. That was the spirit which had actuated him in working out the action of steam on coke, hoping thereby to obtain a fuel which he did not propose to distribute right and left indiscriminately, but which might first be used for great industrial operations, and afterwards for other purposes. He had lately had a letter from Bradford stating that a very important experiment would be commenced there with a view of supplying gaseous fuel to certain industries, and he hoped that the rival claims of patentees would not seriously jeopardize the undertaking.

## Correspondence.

Mr. Beilby. Mr. G. BEILBY observed, in respect to those divisions of the Paper in which the Author treated of the nitrogen of minerals, that this subject first engaged his attention twelve or thirteen years ago in the laboratory and works of the Oakbank Oil Company at Midcalder. The legitimate work of the company, as distillers of shales, &c., for the production of paraffin oils and ammonia, supplied a strong incentive to such researches, as well as exceptional facilities for their prosecution. He had elsewhere published some of the results of these researches.[1] When a person

---

[1] "On the production of Ammonia from the Nitrogen of Minerals." The Chemical News, 1883, vol. xlvii., p. 221. "Young and Beilby's process for the treatment of Coal." Transactions of the Mining Institute of Scotland, 1883, vol. v., p. 158.

Mr. Beilby.

had been interested in, and worked so long at a subject like this, and especially when the interest and work had by so long a time preceded any general recognition of it by scientific and technical men, the feeling of proprietorship in it was apt to grow very strong. While pleading guilty to such a feeling, he was most anxious to recognise whatever was original and excellent in the work of others. It was, therefore, with all respect for the good work done by the Author, and recounted in the Paper, that he had most distinctly to challenge his claims of priority in this field of research. Twice in the Paper was this priority asserted; in the second case, at the conclusion of the Paper, the Author mentioned the names of Mr. Young and Mr. Beilby as among those who had, "since the publication of the Author's discovery," worked at the subject. For the present purpose it was sufficient to compare dates of publication, and their chronological order was as followed:—

12th April, 1881. Mr. William Young lodged a provisional specification, in which the following occurred:—

"The first part of this invention has for its object improvements in the system of distilling shale or other similar substances for the production of oil and ammonia, and consists in distilling the shale in such a manner that the oil shall be liberated and distilled from the shale at a low, uniform temperature, the remaining nitrogen being liberated at a much higher temperature as ammonia . . . . steam being employed for liberating the ammonia at the hot end."

18th May, 1881. Mr. Beilby applied for a patent, in the specification of which the following words occurred:—

"In working, however, according to any of the systems in common use, or publicly known prior to the date of the hereinbefore in part recited letters patent, the ammonia actually obtained is not nearly all that is obtainable from the shale subjected to distillation, as the shale, after all or most of the oil has been extracted from it, and when it is in the condition ordinarily known as that of 'spent shale,' is capable of yielding a considerable further quantity of ammonia if subjected to the joint action of a sufficiently high temperature and of superheated steam."

21st March, 1882. Mr. William Young and Mr. Beilby applied for a patent, in the provisional specification of which the following occurred:—

"The second part of our invention has for its object the obtaining from coal, shale, or other bituminous minerals when used for the production of illuminating and heating gases, of a largely

Mr. Beilby. increased yield of ammonia, and this is effected by subjecting the coke or residue of the coal or other substances, after it has parted with all or most of its hydrocarbon gases, to the action of sufficient heat and of steam, thereby obtaining a quantity of ammonia, which has hitherto been wasted, together with poor gases suitable for heating purposes."

4th July, 1882. Professor Foster made some statements as to his experiments on the nitrogen of minerals.[1]

December 1882. Professor Foster read a Paper on the same subject before the Chemical Society.[2]

The Papers read by Mr. Young and himself before various societies could necessarily only follow the applications for patents. The patents of Dr. Grouven of Leipzig, which dated from 1878, anticipated theirs as far as the general process of burning nitrogenous substances in an atmosphere of steam for the production of ammonia was concerned. They therefore worked certain of their processes under license from him.

The Author seemed to have paid very little attention to the proportion of the nitrogen of minerals, which was ultimately found in the condensed tars as alkaloidal substances. The tar or oil from bituminous shales and cannels sometimes contained 20 to 25 per cent. of the nitrogen of the original mineral, while from ordinary coals 5 to 7 per cent. of the nitrogen appeared in this form.[3] Mr. Watson Smith of Owens' College had recently published some independent observations on this point. In the Author's calculations relative to the production of ammonia and "water gas," a serious oversight had occurred; it was assumed that it was possible to obtain the largely increased yield of ammonia (90 lbs. of sulphate per ton) by consuming the coke according to the equation—

$$C + H_2O = CO + H_2.$$

But this could never be accomplished; the temperature at which this reaction took place was far above the dissociation point of ammonia, and only as the temperature of the reaction was reduced by the free use of excess of steam or other neutral gas, could any of the ammonia be saved. Such a reduction of temperature was always attended with the production of carbonic acid. In practice

---

[1] The Journal of Gas Lighting, 1882, vol. xl., p. 1081.

[2] Journal of the Chemical Society, No. ccxliii., p. 105.

[3] Chemical News, vol. xlvii., p. 221.

it was found that the reaction was more nearly expressed by the equation Mr. Beilby.

$$3C + 9H_2O = CO + 2CO_2 + 5H_2 + 4H_2O \text{ (excess).}$$

The true excess of steam employed, as indicated by the water condensed from the gas, amounted to from 400 to 500 gallons of water for every ton of coal gasified. This very large excess might be reduced considerably by the use of a neutral gas such as nitrogen, so that the employment of air along with steam effected a most decided economy, and at once brought the process within reach for many purposes for which it would otherwise be inadmissible economically. In a Paper read before the Glasgow section of the Society of Chemical Industry on the 11th of March, he had so fully entered into all of these questions that it would be out of place to do so here; but, as bearing directly on the Paper under discussion, the results of working the process on a manufacturing scale at Oakbank were here quoted. From a dross or slack containing (by analysis) nitrogen equal to 165 lbs. of sulphate of ammonia per ton, there had been regularly obtained for some months a yield of ammonia varying from 90 to 134 lbs. of sulphate per ton, or over 60 per cent. of the total nitrogen, and, after deducting the fuel used in the process itself, heating gas equal to at least 60 per cent. of the theoretical heating value of the coal had been available for other purposes.

Mr. Brunton. Mr. R. H. **Brunton** remarked that, in his Paper on "The Production of Paraffin and Paraffin Oils,"[1] he pointed out that the increased yield of ammonia obtained by the Henderson retort was due to the exposure of the shale to a current of highly superheated steam. The Author's experiments bore this out in a rather remarkable way, as he showed that not only did steam evolve the nitrogenous vapours, but it exercised an elective influence by acting on those which were specially of value for the production of ammonia. The general impression amongst practical men, up to within the last few years, had been that an increased temperature in the retort was the means by which an increased yield of ammonia could be obtained; but the amenability of the nitrogen to highly superheated steam was not fully appreciated. The Author's experiments also seemed to open up a large field for the Scotch oil companies, the working of which might possibly lead to highly remunerative results. He showed that from 1 ton of a certain quality of coke it was easy to obtain 140 lbs. of sulphate

---

[1] Minutes of Proceedings Inst. C.E., vol. lxvi., p. 180.

Mr. Brunton. of ammonia. It might be assumed that a quantity something similar could be obtained from the spent shale of the Scotch oil companies. From shale, during its distillation in the old form of retort, 14 lbs. of sulphate per ton used to be obtained; by the Henderson retort an amount of 18 lbs. per ton was now obtained; and these figures, agreeing so nearly with the ammonia got from coal, gave an indication that the nitrogen in shale was somewhat similar to that in coal. But assuming that only half the above quantity, or say 70 lbs. per ton, was to be obtained from the spent shale, there were quantities of this material heaped up in mountains sufficiently large to form important features in the character of the country, quantities which might be estimated at from 10,000,000 to 15,000,000 tons, and which, at the above figure, would produce from 300,000 to 400,000 tons of sulphate of ammonia, this representing at the present market price from £5,000,000 to £7,000,000 sterling. These figures might offer some inducement to the Author to extend his experiments to spent shale, as, if there were any grounds for his assumption, a lucrative industry might be inaugurated.

Mr. Carr. Mr. W. Carr thought it likely that firms requiring a large expenditure of fuel for the production of power would become gas-makers on their own account; they would first convert their fuel into gas, and apply it in that form for raising steam, as being the more scientific and economical method of application. His reason for this opinion was, that gasworks would inevitably tend to cheapen ordinary gas, which would be used for both heating and lighting, and by small consumers for the production of power. Now to convert the coke into gas would require duplicate mains, and mains of very large dimensions, as it came to be used to any large extent. Take, for instance, a concern which consumed 30,000 tons of coal per annum for heating purposes. In the case of the adoption of gas, there would be required about 4,000,000 cubic feet per working day of ten hours delivered into the concern. Such an establishment existed within a mile of the Halifax Corporation Gasworks. The enormous outlay of capital in mains and gasholders to meet an extended consumption in that direction might be imagined. This one firm would require 30,000 tons of coke to satisfy their demands. The Halifax Corporation had for disposal about 20,000 tons. Gasworks could not go far in that direction, but could supply a cheap gas for all purposes requiring heat and light. On the other hand, private firms consuming much fuel would find it to their advantage to convert their fuel into gas first. Whether it would pay private firms to

Mr. Carr.

recover the ammonia or not remained to be seen. He was rather afraid that it would interfere with another important consideration, that of regeneration. One reason why private firms were more likely to convert fuel into gas for themselves was, that they could adopt the regenerative principle, without which gaseous fuel would be a questionable advantage. Now whether it was possible to do this and still recover the ammonia was doubtful. He thought the gases must be cooled before the ammonia could be recovered, and, if so, much heating effect would be lost from the gaseous fuel, and the relative value of the heat lost and the ammonia gained would require to be determined.

Mr. Davis.

Mr. George E. Davis remarked that the all-important question for the consideration of ammonia-manufacturers was whether by any process it was possible to eliminate the whole of the nitrogen in coal, as ammonia. He felt bound to say that the Author had shown how this could be accomplished. In Table IV. the Author had demonstrated that coal yielded amounts of sulphate of ammonia varying from 20·27 lbs. to 26·4 lbs. per ton of coal. He was inclined to think these amounts low, but even taking the highest there was great loss, as theory indicated that about 150 lbs. was possible, and he knew of no subject which offered so many inducements to the practical chemist as this one. True, about one-sixteenth of the total nitrogen of the coal was found in the tar, but, as the Author had shown, the bulk of it remained in the coke. The object of these remarks, however, was to point out how, from a sanitary point of view, the Author's idea of producing a water-gas would benefit mankind. He had no doubt that so-called fogs would never disappear until all cooking was done by gas, and heating by the combustion of coke; and he was convinced that if the public generally knew how economical this system was, even with gas at the present price, they would not hesitate to adopt it. Several of his friends in Manchester, after seeing the system, had adopted the use of gas-coke. In his own house not a particle of coal had entered for over twelve months; a very accurate account had been kept of the gas used for cooking and lighting, and the coke used for heating. The system of heating and cooking with coal he would call the "old system," while that of cooking and lighting with gas, and heating with coke, he would call the "new system." The comparison was as followed:—

Mr. Davis.

| — | | Old System, per Annum. | New System, per Annum. |
|---|---|---|---|
| | | Cubic Feet. | Cubic Feet. |
| Lighting-gas . . . | 3*s.* 2*d.* per 1,000 cubic feet | 51,000 | 53,500 |
| Cooking-gas . . . | ,, ,, | None | 34,500 |
| | | Tons. | |
| Coal . . . . . . . . . . . | 9*d.* per cwt. | 22 | None |
| | | | Tons. |
| Coke . . . . . . . . . . . | 7*s.* 6*d.* per ton | None | 8 |
| | | £. *s.* *d.* | £. *s.* *d.* |
| Money value . . . . . . . . . . . . . | | 24 11 6 | 16 18 3 |

So that it was much cheaper not to produce smoke, and it would be of incalculable benefit to the country if the Government would step in and compel householders to use gas for cooking, and coke for heating. Looking at it again from another point of view, that of the vitiation of the atmosphere by smoke and sulphur-acids, the basis of 20 grains of sulphur per 100 cubic feet having been taken for the sulphur impurity of coal-gas, and 1 per cent. of volatile sulphur to exist in coal and coke. Of course some specimens contained much more than this, and would make the comparison more odious:—

| — | Old System. | New System. |
|---|---|---|
| | Lbs. | Lbs. |
| Smoke . . . . . . . . . . . . . . . . | the maximum | the minimum |
| Sulphur from lighting . . . . . . . . . | 1·4 | 1·5 |
| ,, cooking . . . . . . . . . | 0·0 | 1·0 |
| ,, coal . . . . . . . . . . . | 493·0 | 0·0 |
| ,, coke . . . . . . . . . . . | 0·0 | 179·2 |
| Lbs. per annum of sulphur evolved calculated as oil of vitriol . . . . . . . . approximate | 1,482 | 546 |

Even with the old system of gas-making without special mains or fittings in a house, the use of gas for cooking was more economical and advantageous than the use of coal; and he had strong doubts whether water-gas made from coke could be distributed to consumers, as a special gas, at less money per unit of heating power than the existing coal-gas. It was in summer time that the use of gas for cooking offered the greatest advantages, and it was in the summer also that one-half of the ordinary gas-plant of the country was lying idle. His opinion was therefore this, that gas companies, instead of running after schemes for producing residuals, should make the most of the plant they already possessed, and offer more favourable terms to consumers to induce them to burn gas for cooking all the year round. There was no difficulty in the employment of coke for heating in ordinary fireplaces. There was no need for burning gas simultaneously with the coke; all that was necessary was a grate with a clay back, and to make sure that in lighting the fire the grate was well filled with coke, and a sheet-iron blower used to advance the combustion. If a water-gas could be supplied at about double the price per heat-unit now paid for coal, he was sure it would be universally and quickly adopted, and at the same time an immense benefit would be conferred on mankind by the reduction of sulphur acids in the atmosphere. If heating could be done with a fairly pure water-gas, it might be assumed that the quantity of oil of vitriol sent out into the air would be reduced from 1,482 lbs. annually to about 10 lbs., and no smoke would be produced in the latter case. He thought such a probability should be treated with all the importance it deserved, especially in or near large towns. If water-gas was to be made, the existing companies might be able to manufacture and distribute it at a profit; but, in his opinion, more attention should be paid to the distribution of coal-gas at cheaper rates for heating and cooking purposes. Mr. Davis.

Mr. C. GANDON remarked, with respect to the statement in the Paper, that coal-analyses did not usually give the nitrogen separately; that Tables would be found in King's Treatise on Coal-gas, in which the nitrogen, as well as all the other elements, were given for a number of different coals, and these Tables possessed the advantage over those in the Paper, that the names of the different coals were also given. A reference to the Tables in King's treatise would show the importance of this, as it would be seen that the nitrogen in Newcastle coal varied from 0·72 to 1·69 per cent. Also in Table I., accompanying the Paper, No. 3, described as a Yorkshire coal, contained only 0·55 per cent. of sulphur; while No. 5, also a Yorkshire coal, gave 2·00 per cent. of sulphur. Again in Table IV., No. 4, a Durham coal, produced 26·4 lbs. of ammonium sulphate per ton of coal, while Yorkshire coal, No. 5, yielded only 20·5 lbs. per ton, although there were some kinds of Yorkshire coal which in practice yielded more ammonium sulphate than the Durham coals. The Author's Tables were, however, interesting and useful, as they showed the distribution of the elements between the coke and the gas in a manner Mr. Gandon.

Mr. Gandon. which had not before been done. The conclusion arrived at—that coke was preferable to coal as fuel because it contained less sulphur—seemed scarcely evident in all cases. It was true that a portion of the sulphur in the coal was taken up by the gas, and therefore the remaining coke contained less, but the coke from a ton of coal weighed only 12 to 13 cwt., and if a ton of this was required to do the same work as a ton of coal, it would in some cases contain more sulphur than the same weight of coal. As the Author observed, it was much to be regretted that the question of temperature of distillation had not received more attention, as it undoubtedly had considerable influence upon the results. It would also be interesting to know the quantities of the various products passing off at different periods of the distillation; no complete experiments seemed to have been made upon these points. When a charge of coal was put into a retort, it passed through all degrees from its normal temperature up to a dull or bright red heat, and different gases, or combinations of gases in varying quantities, must be evolved at the different temperatures; such variations were practically unavoidable, but a knowledge of what did take place might enable some evil results to be obviated: for instance, it was generally assumed that the proportion of sulphur compounds, other than sulphuretted hydrogen, was increased with high heats, and that the greater quantity passed off towards the end of the distillation, or when the retort was at its hottest. Referring to coal No. 1, the Author remarked that, "The coke which is produced is also considerably "richer in nitrogen than the parent coal;" but this seemed to require some explanation, as in Table IV. the nitrogen in the coal is given at 1·28, while in the coke it is only 0·661 per cent. The details of the production of ammonia from coke by means of steam were interesting and instructive, but it seemed doubtful whether it could in all cases be done at a profit. The coke from Scotch Cannel which had been experimented upon was of little value; but, assuming that similar quantities of ammonia would be obtained from the coke produced in and around London, and taking the Author's estimate that £40 worth of sulphate would result from the treatment of 100 tons of coke, the advantage of the operation appeared questionable; coke to the amount of 100 tons, at present London prices, would realise £75; but to obtain the ammonia all the coke was supposed to be consumed either for gasification or for fuel to produce the result, and it remained a question whether the fuel gases obtained would be equal to the difference between the values of the sulphate and the coke. It seemed also probable that the ammonia would be obtained

Mr. Gandon.

in such a dilute state that the cost of converting it into sulphate would be much increased.

The desirability of extending the use of gaseous fuel for manufacturing and domestic purposes would be generally admitted; but although it might be advantageously used on the spot where it was produced without requiring to be cooled, stored and distributed, yet it was doubtful whether this could be economically done by distributing it from a manufactory in the same manner as illuminating-gas; such gaseous fuel might be produced at a cheaper rate than ordinary coal-gas, but its heating-power per cubic foot was greatly inferior to the latter, and in consequence of the enormously increased size of the storing and distributing plant that would be needed, it was doubtful whether coal-gas would not be the cheapest for most purposes: such water or producer-gas was also largely composed of carbonic oxide, the poisonous nature of which was a strong argument against its use in dwelling-houses. If coal-gas were more generally adopted for heating-purposes, the increased consumption would reduce its cost, and probably render it in most cases cheaper than a dual supply of lighting and heating gases, requiring duplicate storing and distributing plant, and duplicate fittings where the two were used. The question raised by the Author as to the difficulty of disposing of the increased quantity of coke that would be the outcome of an extended use of coal-gas for heating purposes was worthy of attention, as its value might thereby be reduced; but it should be possible to find means of increasing the demand of a smokeless solid fuel like coke, either by itself, or, as suggested by the Author, in combination with gas. Much had been done in this direction by breaking the coke sold for domestic purposes, and if this plan were more generally adopted, it would form one means of extending its use.

Mr. Hunt.

Mr. C. Hunt remarked that in his Presidential address to the British Association of Gas Managers (now the Gas Institute) in 1881, he had referred to recent experiments, showing the influence of temperature and period of distillation upon the production of ammonia in gas manufacture, and suggested the desirability of further investigation of the subject. Since then the enquiry had been pursued with considerable success by the Author of the Paper, although the primary object of it appeared to have been to a considerable extent lost sight of. The Paper was mainly occupied with a statement of the results of experiments confirmatory of previous investigations. It had long been known that the nitrogen obtained as ammonia formed a very small proportion of the total quantity existing in the coal operated upon, and some

Mr. Hunt. years ago Dr. Grouven of Leipzig, demonstrated the practicability of its recovery in the form of ammonia from peat and other substances by the use of steam. More recently, Messrs. Young and Beilby had devised, and put into practice on a working scale, a process for the recovery of ammonia from gas-coke in combination with the manufacture of water-gas, identical with that experimented upon by the Author of the Paper. It might be admitted that the practicability of such a process as that of Messrs. Young and Beilby ought greatly to facilitate the introduction of gaseous fuel, if its economy were at the same time made clear; but the great cost of providing the necessary amount of steam appeared to be an obstacle to its success. This was acknowledged by Messrs. Young and Beilby, who, from motives of economy, utilized for the purpose the heat given off in the cooling of the resultant gases. He was somewhat surprised at the results obtained by the Author from his examinations of Durham and Yorkshire coals—the former according to him, yielding the largest quantity of ammonia, whereas in actual practice the reverse was invariably the case. Where Yorkshire or Derbyshire coals were used, from 30 to 35 gallons of liquor was no uncommon yield, while the yield from Durham coal seldom, if ever, exceeded 25 to 26 gallons of equal strength per ton. Could this disparity of results be accounted for by the temperature employed by the Author in his experiments? With respect to the employment of gaseous fuel in gasworks, the Author was scarcely accurate. The introduction of the Siemens system in the Paris gasworks dated, no doubt, as far back as twenty years ago; but it had also been tried almost simultaneously in two English works, namely, the Brick Lane Station of the Chartered Gas Co., and the Windsor Street works of the late Birmingham Gas Co. Mr. Hunt was responsible for its final abandonment at the latter works in 1875. A protracted trial, extending over several years, had proved its general unsuitableness for the purpose. Gas-makers had therefore held aloof from a system which, however successful in other industries, proved upon trial to be inapplicable to their own. At the same time they had not been slow to recognize the advantages of the regenerative system when presented in a sufficiently practicable form. It was the introduction, primarily by German gas-engineers, of continuous recuperation, as distinguished from the alternating system, which was identified with the name of the late Sir William Siemens, that more than anything else had rendered gas-firing both practicable and advantageous when applied to gas-retorts; while at the same time the most successful methods at present in

Mr. Hunt.

use would be found, on examination and enquiry, to follow strictly upon the lines of a system known, as proved by the records of the Patent Office, nearly forty years ago. That in all this they had followed a safe course, was quite true, although not in the sense suggested by the Author of the Paper. The advocates of water-gas need not be apprehensive of indifference on the part of gas-makers to any properly matured scheme they might bring forward, and the possibility of the recovery of so large a quantity of ammonia in conjunction with the manufacture of gaseous fuel added greatly to the desirability of giving the subject the fullest consideration. He had already stated his opinion that there were no insuperable difficulties in the way of gasifying within the walls of the retort-house, for distribution if need be in the ordinary way, the whole of the coke produced in the manufacture of illuminating gas, and at an almost inappreciable cost for labour; but would the difficulties of the enterprise end here? Would there not then be a still more formidable one to encounter, namely the uncertain utility of the resultant gases for heating purposes? The Author had scarcely touched upon this all-important question, but the consideration of it could not be ignored—the fact being that there were few industrial purposes, and certainly none requiring a very high degree of heat, to which cold carbonic oxide or even water-gas could be successfully applied without recourse being had to recuperation, or some special means of concentration. Consequently new apparatuses in all directions would be needed before it could be successfully applied as a substitute for the open fire: and it was not to be anticipated that the change which this indicated could be otherwise than very gradual.

Mr. Jones.

Mr. H. E. Jones said he should like to acknowledge the obligation which in his view the industry of gas-making owed to the Author for bringing forward the important fact which he had discovered of the valuable residuum of nitrogen contained in gas-coke, and further of his interesting experiments in the direction of developing that value in a commercial shape. It was well known that gas-coke did not bring its full fuel-value in the market owing to its being produced, not at the will of the gas-maker but by force of the demand for gas, so that it was not possible to suit the production to the demand. Any means, therefore, of realising the value of the product in a new manner must be of the greatest importance to gas-producers. He could not, however, quite follow the sanguine anticipations of the Author with regard to the means that he indicated for obtaining this end. He noticed in the first place that while submitting to a current

Mr. Jones. of steam coke maintained at a high temperature the rate of production of nitrogen rapidly fell off as the experiment continued. Thus, in the experiments recorded, about one half of the amount of ammonia was produced in ninety minutes at the end of the experiment which was produced in the first forty-five minutes, being in round figures reduced to a quarter the rate. This would mean, in pushing the process farther, an enormous expenditure of heat both upon the coke and upon the steam in proportion to the amount of ammonia obtained towards the end of the process.

And while it might be true that the coke would yield ultimately 140 lbs. of ammonium sulphate per ton, he feared it would not be easy in the later stages, and very far from economical. Passing to the estimate of the return of 4 tons of ammonium salts per 100 tons of coke, it would be obvious to those acquainted with the enormous discrepancy between the theoretical equivalent of fuel and the practical result obtained in steam-boilers, gas- and iron-furnaces, and other commercial applications of fuel, that the ratio of 14 parts of coke as fuel to 12 parts of coke converted would be very far from the commercial result. Judging from the loss in such furnaces as he had alluded to, and especially bearing in mind the great loss of gas furnaces owing to the high temperature that all parts of the retorts had to be maintained at, it would be safe to increase the ratios to 10 or 12 to 1 instead of 14 to 12. In this way the return from ammonia would be so small as to offer little encouragement of the process beyond what would be realised by the value of the water-gas. And in dealing with this part of the Author's suggestion he was bound to say that, apart from the objection of the danger to animal life accompanying the supply and the combustion of gas of this kind, there were serious difficulties of a commercial character in the way, the chief of which would be the necessity for providing a separate system of distributing pipes. Allowing for this gas not being universally used, and for the difference in its specific gravity as compared with coal-gas, he estimated that the interest upon the capital so employed would not be less than 8*d.* per 1,000 cubic feet of gas. To explain this he would point out that the average dividend charge of gas companies might fairly be stated, and had been stated by Mr. George Livesey, at 15*d.* per 1,000 cubic feet of gas sold upon an area. Allotting the proportion of this to the capital employed in distribution as distinguished from manufacture and storage, gave 5*d.* per 1,000 cubic feet upon ordinary gas. As water-gas had a specific gravity roughly 25 per cent. higher than that of coal-gas, it followed that pipes would have to be of a relatively larger calibre. Allowing for this and for the longer distances between the points of consumption, the total interest would come to 8*d.* as above stated. Adding for wear and tear of this plant 2*d.*, and for the interest and wear and tear upon the plant for producing, together with labour, which by analogy with that for producing ordinary gas could not well be taken at less than 7*d.* per 1,000 cubic feet of gas, and allowing nothing for storage plant, which might nevertheless be required, the result was 1*s.* 5*d.* per 1,000 cubic feet of gas. Probably other charges for establishment expenses would have to be added, but without regard to these a cost would have been reached which, when it was borne in mind, as stated by Dr. Bunte, that the thermo value of this gas was only half that of ordinary illuminating gas, would admit of no gain to the consumer in substituting this gas for ordinary coal-gas at 2*s.* 10*d.* or 3*s.* per 1,000 cubic feet. He had endeavoured here to show the difficulties that lay in the path of any attempt to distribute a heating gas independently of and concurrently with a system of supply of illuminating gas, in reference to which last he should like to refer to the important statements of Dr. Bunte, which had been published within the last few days, of the comparative value for fuel purposes of the various kinds of gases which had been before the public and coal-gas. Mr. Jones.

The figures were as followed:—

| | Units. |
|---|---|
| Heating-power per cubic metre of coal-gas . . . | 5511·0 |
| ,, ,, water-gas . . . | 2813·0 |
| ,, generator- and water-gas mixed . . | 1470·0 |
| ,, ,, gas (Dowson) . . . . | 1048·0 |

Coal-gas was, therefore, 5·3 times the value of generator-gas, and as nearly as possible double the value of water-gas. It would have been of interest if the Author had pursued his experiments up to the point of the exhaustion of the coke in developing ammonia, and had taken observations of the amount of coke consumed as fuel in converting a definite weight of coke to water-gas and ammonia.

Dr. G. Lunge, of Zurich, expressed his appreciation of the painstaking and useful work which the Author had bestowed on the analyses of coal and coke, and upon the behaviour of the nitrogen contained in the same. Although he differed from the Author in some essential points, this only referred to his conclusions, whilst he saw no reason to doubt the accuracy of the facts which he had brought to light. Dr. Lunge.

It was true, as the Author had stated, that most of the former

Dr. Lunge. analyses of coal and coke were incomplete, and he welcomed with pleasure his fuller analyses as a beginning in the right direction. But he did not consider six analyses, one from each coal-bearing district, as entitling to anything beyond provisional and conditional inferences. Much more material ought to be collected before coming to a firm conclusion in that respect. The very small quantity of ash found in all those six samples went far, in his opinion, to prove that they could not be accepted as representative of the average composition of their respective kinds. Much larger quantities of ash had been found by Mr. Pattinson and others;[1] but even apart from that it stood to reason that no single sample of coal could be said to fulfil that condition.

As to the results obtained by the Author on the behaviour of the sulphur in the coking process, he could not approve the statement that "it is generally accepted as an axiom that coke contains more sulphur than coal." Unless the Author referred to a vague popular impression, which he considered unnecessary to notice, he must demur to the above, and state his opinion that both among scientists and practical manufacturers the direct contrary was generally accepted, if not as an "axiom," at any rate as a fact. It was all the better that the Author's work strengthened the latter view. Among the most valuable results of the Author's inquiry were those obtained with reference to the disposition of the nitrogen of coal during destructive distillation. Hitherto it had been generally assumed that, apart from ammonia, most of the nitrogen was evolved in the free state, but little remaining behind in the coke. Whether this free nitrogen was evolved directly, according to the common opinion, or was formed subsequently by decomposition of ammonia, as assumed by the Author, was a minor question; but he thought the results as to the large quantity of nitrogen remaining behind in the coke must be granted, and in this instance he believed that the number of analyses sufficed for establishing that important fact. No doubt the experiments upon the evolution of ammonia from coke by the action of steam were highly interesting, and proved that there existed a possible reserve store of ammonia in a source hitherto overlooked. But it was another question whether this source was practically available, and this had not been decided by the experiments. Apart from the immense difference existing in every way between the conditions on the small and on the large scale, the Author had failed to show what entitled him to assume that the same quantity of ammonia as was

---

[1] Transactions of the Newcastle Chemical Society, vol. iv., pp. 135 and 140.

Dr. Lunge. obtained with 16 times the theoretical amount of steam should be got on the large scale when employing steam "not unduly in excess of the theory." The most serious criticism he had to exercise was that on the Author's calculations referring to the heating value of water-gas. He believed that both the amount of heat absorbed in producing it, and that evolved in burning it, had been wrongly calculated. He could not understand how the Author had not been startled by his own conclusion, that the theoretical value of water-gas as a heating agent, produced from 26 parts of carbon, of which 7 parts were assumed to be wasted "in conducting the operation on a commercial scale," should not be equal to 26 − 7 = 19 parts of carbon, namely, 73 per cent. of the quantity of coke consumed; but should be within 4 per cent. of the theoretical value of the whole of the coke used in its manufacture, including the 27 per cent. assumed to be wasted. This would upset the fundamental law of nature, that of the conservation of energy, which of course, was not set aside by the intervening process of water being decomposed and again recomposed from its elements! To simplify matters he should assume all the fundamental data as the Author had given them, although it might be doubted whether 600° Centigrade sufficed for effecting the complete reaction, and whether twice the theoretical amount of carbon was sufficient for carrying out the operation on a practical scale. In the first instance the calculation of the heat absorbed in producing the water-gas was wrong; for it contained the heat required for converting water to steam twice over, once directly in the item 18 × 626 = 11,268, another time in the "heat-units to effect the decomposition," which started from the datum 68,068 heat-units for separating a gram-molecule of water into hydrogen and oxygen. But this datum was only true when starting from liquid water, and hence already contained the above 11,268 heat-units. Consequently the total was not 55,679, but 44,411 heat-units, and corresponded not to 7, but to 5·5 parts of carbon for each 12 parts of carbon to be gasified. Doubling this, for practical purposes, as did the Author, 11 parts of carbon would be required to gasify 12 parts. These 23 parts, burned to carbonic acid in the ordinary way, would yield 23 × 8,080 = 185,840 heat-units. Now the Author stated 202,636 as the total heat-units developed by the combination of the hydrogen and carbon monoxide, resulting from gasifying 12 parts of carbon, that was, 9 per cent. above the theoretical value of the 23 parts of carbon consumed; but as 5·5 parts of this were wasted, really only 17·5 × 8,080 = 141,400 heat-units must be taken in comparison, and hence there would be a gain of 43 per cent. on the

Dr. Lunge. theoretical value indicated by the hitherto undisputed laws of nature. How the Author arrived at 202,636 he did not know; in reality the theoretical value of water-gas produced from 12 parts of carbon was:—

| | Heat-units. |
|---|---|
| $CO + O = CO_2$ yielded . . . . . . . | 67,284 |
| $H_2 + O = H_2O$ „ . . . . . . . | 68,068 |
| | 135,352 |

From this must be deducted the latent heat of aqueous vapour at the ordinary temperature, which might be put at 600 without any great error, as the water produced in the combination always remained in the state of vapour; this must be multiplied with the molecular weight of water, and there would be obtained thus as the final result: $135,352 - 18 \times 600 = 124,552$ heat-units. This was just 67 per cent. of the heat-units produced by the direct combustion of the 23 parts of carbon; consequently the theoretical value of water-gas as a heating agent, according to the Author's own data, but calculated properly, was 33 per cent. below that of the coke used in its manufacture, not 4 per cent. as stated by the Author. How materially this difference must modify the practical conclusions and suggestions, based by the Author on his erroneous calculations, it was needless te follow out.

Mr. Smith. Mr. Watson Smith desired to refer firstly to the question of nitrogen unaccounted for, which was undoubtedly expelled from the coal in some form or other during destructive distillation. At a recent meeting of the Chemical Society he communicated a paper bearing upon this very subject, so far as the nitrogen existing in the tar was concerned.[1] He had made a series of determinations (1) of the amount of nitrogen in the crude tar itself, and had found 1·667 per cent. in the sample examined. Reckoning an average of 10 per cent. of tar to be obtained from coal in gas-making, this would mean 0·167 per cent. of nitrogen in the coal. Of course this nitrogen included that of some ammonia, existing as ammonia water suspended in the tar. (2) Of the amounts of nitrogen in the various fractions of the coal-tar, and in the pitch. It was found that in the various products of the coal-tar distiller, the nitrogen was pretty evenly distributed. It was further found that even hard pitch contained 1·595 per cent. of nitrogen, which

---

[1] "Note on (I.) the behaviour of the Nitrogen of Coal during Destructive Distillation, and (II.) a Comparison of the amounts of Nitrogen left in cokes of various origin." Journal of the Chemical Society, 1884, No. cclvii., p. 144.

Mr. Smith.

on coking the pitch and allowing it to cool partially, at the same time allowing damp air to enter the still, was partly evolved as ammonia. Of course pitch contained a considerable amount of its nitrogen in the form of the substance which had been recently attracting much attention amongst organic chemists in Germany, namely, acridine. It was to the presence of this body that coal-tar pitch owed its acrid, stinging character, a property only too well known to the workmen who had to excavate it on a hot summer's day. Another extremely stable and high-boiling nitrogenous constituent of pitch was the imidophenylnaphthyl: (3) He had moreover determined the amounts of nitrogen in three kinds of coke prepared under different conditions. (*a*) Gas-retort coke (total exclusion of air, and high temperature for about six hours). (*b*) Beehive metallurgical coke (tolerably high temperature, admission of air to limited extent and lengthened duration of coking). (*c*) Simon-Carvès' oven coke (very high temperature, exclusion of air, and lengthened duration of coking). Amounts of nitrogen found—(*a*) 1·375 per cent.; (*b*) 0·511 per cent.; and (*c*) 0·384 per cent. Though different coals were of course employed, yet some comparison could be made, because the variation of the amounts of nitrogen left in coke when using one and the same process of distillation was not at all great. Taking this as granted then, it was seen that the effect of a strong heat of long duration, as in *c*, did act upon the very stable nitrogen compounds in coke, gradually dissipating the nitrogen. In the Simon-Carvès' ovens the four-ton charge lay in a vertically disposed and proportionately thin layer for about forty-eight hours, and exposed to a temperature of about 2400°. As regarded the dissipation of much of the ammonia first formed as nitrogen, and also of nitrogen in other forms, at the highest temperatures, he quite agreed with the Author. He desired, however, to call attention to a communication recently made to the Chemical Society by Professor William Ramsay and Dr. Sidney Young, on "The decomposition of ammonia by heat."[1] Thus, when ammonia was passed through an iron or porcelain tube, or a glass tube containing asbestos, the temperature at which it began to decompose was found to be a little under 500° Centigrade. In contact with a glass surface, the temperature at which decomposition began was much higher. Again, the influence of rate of passage of the ammonia gas, or in other words, of the time of exposure, was very great. Further, the nature of the surface of the containing vessel exerted an enormous influence on

---

[1] Journal of the Chemical Society, 1884, No. cclvi., p. 88.

Mr. Smith. the amount of decomposition. By increasing the surface, the decomposition was greater. Whereas, on passing the ammonia through a plain iron tube at 780° Centigrade, total decomposition ensued, only 2 per cent. of decomposition ensued at 760° Centigrade, when the gas was passed through a glass tube containing copper wire, and only 1·72 per cent. of ammonia was destroyed on passing the gas through a hard glass tube filled with bits of broken small glass tubing, the temperature being 780°. From these experiments at all events it might be concluded that until the walls became covered and coated with finely divided carbon or gas coke, it might be expected that the red-hot walls of the old iron gas-retorts would decompose far more ammonia than those of the present fire-clay retorts employed in gasworks. It had occurred to him that this strongly decomposing action of iron at high temperatures on ammonia might be accounted for to a great extent by the fact of the ready permeability of red hot iron to hydrogen gas, the decomposing action being aided and stimulated by the rapid removal by diffusion of the hydrogen gas as soon as set free by decomposition of the ammonia, thus a new atmosphere being continually created. As regarded the use of steam to obtain the nitrogen from coke as ammonia, it seemed to him that if the treatment were to take place in the gas retorts, and the action of the steaming process neither proved deleterious as regarded the gas produced, nor the tar, that the matter was one of pounds, shillings, and pence, as the Author reasoned, and that a middle course would possibly be advisable, in which to gain the more valuable ammonia : a certain weight of coke might be sacrificed. Of course a process like that of Mr. Tervet, in which the coke treated with hydrogen gas would not suffer diminution, other things being equal, would be still more valuable. It seemed to him that good coke was more likely in the future to be preferred for general household use than gas. It must be remembered that the present household grates and fireplaces were most clumsy, ineffective, and wasteful arrangements, in comparison with properly constructed stoves, which might be used, and so as to combine economy with a cheerful appearance.

Dr. Spiegel. Dr. A. SPIEGEL concluded that some of the Author's experiments had been undertaken with a view of showing that the manufacture of water-gas might be made to pay better by the simultaneous production of sulphate of ammonia. It was interesting to learn the extent to which he had been successful. He wished to point out however that greater expense in the production of water-gas had to be incurred than the Author assumed. Owing to his overrating the heating power of coke, when made to furnish the

Dr. Spiegel.

temperature requisite for the formation of water-gas, he arrived at too low an estimate of the percentage of coke taken away as fuel. In assuming the combustion of 12 parts of carbon in oxygen to carbonic acid to be attended with the production of 96,960 heat-units, the Author had forgotten that 1 part of carbon produced 8,080 heat-units, provided the gaseous products of the combustion gave up all their heat, that was, cooled down to the initial temperature of the oxygen used. But since it was well known that the gaseous products of the combustion left the furnace at a temperature about 300° higher than that of the retort they were heating, none of the heat carried off by these gases was available. In addition to this, carbonic acid did not form the only part of these gases when the combustion was carried on in air instead of oxygen. Neglecting the fact that far more oxygen in the shape of air passed into the furnace than was actually employed to bring about combustion, four times the amount of the oxygen used up had to be heated in nitrogen to the temperature at which the gases left the furnace. The Author assumed that the formation of water-gas at a red heat presumed a temperature of 600°. Taking this for granted, the gaseous products of the combustion, together with the nitrogen from the air, left the furnace at a temperature of 900°. 12 parts of carbon required 32 parts of oxygen in the shape of 128 parts of air. They yielded carbonic acid 44 parts, and there were left, nitrogen 128 parts; so that the result was, heating gases 172 parts, which left the furnace at a temperature of 900°. Neglecting the difference in the specific heat of the various components of these heating gases, and assuming them to be equal to that of air:—$172 \times 0{\cdot}2375 \times 1{\cdot}41 \times 890 = 51{,}262$ heat-units which left the furnace for every 12 parts of carbon burnt. Deducting this number of units from that which 12 parts of carbon yielded when the products of its combustion were made to give up the whole of their heat, the heating value of the 12 parts of carbon which remained = 45,698 units. This was the theoretical number. When introduced into the Author's calculations the amount of fuel used up theoretically in making water-gas was found to be about equal to what the Author had allowed in practice. In practice the requisite amount of fuel would be found to exceed what theory demanded by 100 per cent., consequently to convert 12 parts of carbon into water-gas, 30 parts, instead of the Author's 14 parts, would have to be burnt as fuel. It was easy to see how this altered the case. It was useless to apply the results in order to effect a comparison between the heat produced by coke *per se*, and the heat produced by the same amount when consumed in making

Dr. Spiegel. water-gas. Means had to be found to utilize the heat carried off by the gases leaving the furnace at a high temperature. It might prove practicable to employ it for heating the coal retorts at the gasworks manufacturing both coal-gas and water-gas.

Mr. Tervet. Mr. R. Tervet said that, the constituents of coal, when subjected to the action of heat in closed vessels, yielded to its influence; while at the same time other causes acted upon them and tended to change the place or position which they originally occupied. This movement and distribution of the constituent elements was partly the result of the heat upon the coal, and partly due to chemical affinity. With regard to the production of ammonia, the Author was careful to say that it was in some degree dependent upon the amount of nitrogen in the coal. Now, in the case of some coals, which contained a large proportion of nitrogen, their sterility in ammonia was due to their not possessing sufficient hydrogen for its formation, or to the fact that the hydrogen, although sufficient in quantity, was evolved under such conditions, and at such a time and temperature, as to preclude the formation of ammonia. It had been shown by Mr. Tervet, that the yield of ammonia could be increased to a very large extent by means of an artificial supply of hydrogen, either during the process of distillation or after its completion. It was essential, therefore, where the full advantage of the nitrogen was desired as ammonia, that such means should be employed as should enable it to take that form. The action of an artificial supply of hydrogen as an ammonia-producer, although very considerable, was limited to a gain in point of time; and in a process such as this, where all the changes were effected by contact, it was obviously necessary, for the exercise of the acting power, that to accelerate the formation, some endeavour must be made to render every particle accessible to the action of the hydrogen. It was well known that steam, when employed in sufficient quantity, had the power of eliminating from coal, &c., all the nitrogen in the form of ammonia; and that the elements of the coal were disunited by reason of the powerful attraction of the carbon for the oxygen of the water. New surfaces of the coal were thereby exposed to the action of the hydrogen, and the elimination of the ammonia was thus accelerated. Mr. Edmund Hunt, of Glasgow, had suggested the introduction of air into the retort, and this, which had now been extensively carried into practice, had the same effect but in a greater degree. Seeing, then, that hydrogen was so important a factor in the formation of ammonia, it was evident that the proportion of hydrogen which a coal was capable of

Mr. Tervet.

yielding, was as important a consideration as its yield of nitrogen, and this was the more forcibly manifested on considering that a difference of 0·1 per cent. more or less hydrogen increased or diminished the volume of hydrogen to the extent of no less than 400 cubic feet per ton of coal; that was assuming the hydrogen to be evolved in the free state. Hence a difference of hydrogen in a coal, which might amount to from five to ten times the above quantity, must manifestly have a very considerable influence upon the reactions going on in the retort. Taking into consideration merely the ultimate composition of the coals employed by the Author, as tabulated in the Appendix to the Paper, it must be admitted that the results of his analyses conformed entirely to his opinion, namely, that the proportion of volatile matter had some influence upon the yield of ammonia; but he added, "clearly this of itself does not appear to be the full explanation." Without venturing any theory of his own, Mr. Tervet might be permitted to say, that there could scarcely be any doubt with regard to this point, taking into account the information furnished by the analyses in conjunction with that derived from practice.

If the analysis of No. 1 coal was examined, it would be seen that that coal contained 8·70 per cent. of oxygen, and yielded 23·96 lbs. of sulphate per ton; while No. 5 coal contained only 3·66 per cent. of oxygen, and yielded 20·5 lbs. of sulphate per ton. He cited Nos. 1 and 5 because their analyses showed them to be so dissimilar; but he should prove farther on that they were almost identical. The same might be said of Nos. 2, 3, and 4. Further, the Author said, "Had the maximum results only been taken, No. 1 coal would have shown almost as high a yield of ammonia as No. 4." It was safe, therefore, to assume that by some slight modification of treatment, a still higher average result might have been obtained. Suppose, for the moment, that the greater proportion of the oxygen combined with the hydrogen to form water, it would then appear that there was present in No. 1 coal a condition which might be expected to favour in a very high degree the formation of ammonia; but it was known from experience that the production of ammonia was effected at three different stages, the conditions of which were different. The first took place when the coal might be said to be in the moist condition; the second occurred when the moisture had been expelled, and when the hydro-carbonaceous matter was undergoing decomposition; and the third was brought about by artificial means. At the be-

Mr. Tervet. ginning of the distillation of coal, &c., the quantity of matter in the act of undergoing transformation was naturally the greatest, and all the phenomena which accompanied the process, such as the evolution of gas, were most distinct at that time; but the yield of ammonia was much less than at the subsequent stages of the process, although relatively it was greatest in those coals which contained the largest proportion of volatile matter. As the distillation proceeded, the nature of the changes going on in the coal diminished; and when the greater part of the coal had undergone decomposition, the evolution of ammonia was produced in greatest abundance. Finally, the distillation and production of ammonia might be said to cease entirely long before the process could be regarded as anything like complete. So far, then, as the production of ammonia was influenced by the volatile matter, the point had been completely solved by the Author's analyses, which were so much the more valuable, as they had been made with a totally distinct object in view. But, on the other hand, coals possessed an unequal capacity in offering resistance to the disturbing influence of heat; or in other words, the permanency of a coal seemed to depend on a certain order and arrangement of its elementary composition. Now, if the several analyses of coal given in the Appendix were minutely compared, it would be found that, so far as the elementary composition was concerned, there existed a relationship between certain of them which might at first sight escape observation. To show this, he deducted the ash, moisture, oxygen, and the equivalent of hydrogen necessary to combine with the oxygen to form water. The analyses then stood thus:—

| | 1. | 2. | 3. | 4. | 5. |
|---|---|---|---|---|---|
| Carbon . . . | 89·81 | 92·09 | 92·83 | 92·06 | 89·68 |
| Hydrogen . . . | 6·07 | 4·93 | 4·72 | 5·21 | 6·34 |
| Nitrogen . . . | 1·52 | 1·90 | 1·84 | 1·88 | 1·91 |
| Sulphur . . . | 2·60 | 1·08 | 0·61 | 0·85 | 2·07 |
| | 100·00 | 100·00 | 100·00 | 100·00 | 100 00 |

Thus it would be seen that Nos. 1 and 5 coals had the same elements united in the same numerical proportions; but in the two cases the nitrogen appeared to exert a most unequal power of offering or overcoming resistance. In No. 5 coal, it would certainly seem to be impeded by other forces, whose activity looked as if they gave preponderance either to its fixity or volatility. This was still farther shown by the fact that No. 1 coal, besides

Mr. Tervet.

yielding considerably more sulphate of ammonia per ton, also indicated a large proportion of its nitrogen as unaccounted for, and which had passed either into the gas or the tar; and further, the nitrogen remaining in the coke of No. 5 was 11·5 per cent. greater than that of No. 1. The foregoing observations were equally applicable, as an explanation of the deposition of the sulphur in coals. It was only by an exact estimation of the total sulphur, and an analysis of the ashes, that it could be learned what proportion might be expected to be variable, and what would remain constant. It was worthy of note that several of the coals, notably No. 1 and 5, did not contain sufficient mineral matter to combine with the equivalent of sulphur, and that they yielded the largest proportion of volatile sulphur. It might therefore be inferred, that the sulphur must be united with the carbon and hydrogen in some way at present unknown. He had carefully examined the figures tabulated in the Appendix, and had discovered many other points of analogy, both interesting and suggestive. The production of cyanogen was undoubtedly due to high heats, and its presence could only be accounted for on the assumption that there was an insufficient supply of hydrogen at the moment of formation, since it would otherwise have been resolved into ammonia. He had shown that all cyanogen compounds immediately yield ammonia in an atmosphere of hydrogen. He fully concurred with the Author that the nitrogen found in the free state was not evolved as such from the coal, but as ammonia, which latter was dissociated by the influence of heat and contact. The method of analysis adopted by the Author, although yielding strictly comparable results, would certainly have shown very different figures had the several coals been projected into a red-hot retort, especially in the case of Cannel coals. His own experience of Cannel coals and shales was, that the nitrogen had not the same degree of stability as in other coals, the least elevation of temperature beyond a certain limit being fatal to the formation of ammonia. He was strongly of the Author's opinion, that the deportment of the nitrogen in coals and shales generally, was to be found in the nature of the nitrogen itself, which might assume some allotropic modification not yet known. A preliminary notice of some experiments and observations made by Mr. Tervet on this point would be found in "The Journal of Gas-Lighting."[1] The imperfection of the present method of analysing coals for technical purposes had hitherto rendered it impossible to ascertain

---

[1] Vol. xliii., 1884, p. 403.

Mr. Tervet. the true theory of destructive distillation. No new fact in regard to a more intimate knowledge of the functions of the constituent elements could be hoped to be attained from the results of the existing mode of analyzing; and technologists were thus deprived of what would otherwise be their best guide to their economical treatment. Any improvement was inconceivable without a deeper and better knowledge of the various decompositions which the coal underwent within the retort. With regard to the point of priority in the method of treating coals for the complete elimination of their ammonia, he might be permitted to state that, anterior to any precise steps being taken in the matter, he had completed a series of investigations, the results of which had been submitted to several scientific men, who advised that the subject should be pursued. Although the expression "incineration" was not his, the definition which he had given at the time was to "maintain the substance in a state of glowing combustion in an atmosphere of steam."

The Author's investigation and analyses cited all the conditions and observations essential to trustworthy experiment; and it was not too much to hope that, by means of such researches, and by the united diligence of chemists and technologists, we may ultimately arrive at a more advantageous method of employing our coal, and avoiding the present lavish and unnecessary expenditure of capital and power.

Mr. Townsend. Mr. H. TOWNSEND observed that it was in contemplation at Bradford to make an experiment, on a sufficiently large scale, to demonstrate the value of water-gas made from coke, for application to various industrial purposes. In a series of letters recently contributed to "The Journal of Gas Lighting,"[1] he had endeavoured to prove that if all the coke at present made in the gasworks at Bradford were to be converted into water-gas, and distributed through a separate service of mains, &c., and sold at 6*d.* per 1,000 cubic feet, an additional profit of nearly £20,000 per annum would be added to the Corporation exchequer, provided a market could be found for all the gas so produced, due allowance being made for the present value of the coke, the interest on the capital expended, and the working expenses so far as could be at present ascertained. He had also entered pretty fully into the sanitary aspect of the question, and had endeavoured to show that the poisonous properties of carbonic oxide had been greatly exaggerated, and that whereas water-gas, carburetted with petro-

---

[1] Vol. xliii.

Mr. Townsend. leum, had been adopted for lighting purposes by no less than fifty towns in the United States, yet no increase in the death-rate had taken place in any of them; neither, so far as he had been able to ascertain, had any fatality occurred from its use, except in sleeping apartments. Accidents of a similar nature had also occurred with coal-gas, owing to defective fittings, and the carelessness of people who allowed gas to be escaping in their bedrooms all night. Should the experiment before alluded to be carried out, it was intended to adopt a simple method by which a strong odour would be given to the water-gas, and the proportion of carbonic oxide considerably reduced. Among the advantages which he had tried to prove would, in the course of a few years, be gained by the adoption of this policy, might be mentioned the following:—(1) The suppression of the smoke-nuisance; (2) the encouragement of industry by the supply of cheap gaseous fuel free from sulphur; (3) the gain to the agriculture of the country, by the production of cheap sulphate of ammonia; (4) the ultimate abolition of factory chimneys; (5) reduction in the consumption of coal; (6) reduction in the traffic on streets and roads; (7) substitution of cleanliness and economy for dirt and drudgery in domestic occupations; and (8) relief of rates from this new source of revenue. It remained to be seen whether these advantages were sufficient to outweigh the prejudice existing on the subject.

Mr. Foster. Mr. W. Foster, in reply to the correspondence, remarked that, owing to its great length, and the fact that many of the points raised had already been dealt with in the verbal discussion, he would limit himself to what appeared to be the most important matters. His observations in the Paper on the publication of his earlier results respecting the amount of nitrogen of coal which remained behind in the coke had called forth some quotations from specifications of processes having for their object the increase of ammonia in destructive distillation. The date of the specifications could not be disputed. Nor had he desired to imply by anything that he might have said or written that there were not chemists and manufacturers who, prior to June 1882, had great practical acquaintance with the subject. Yet the very specifications quoted, if discussed impartially, furnished more powerful evidence in favour of the Author's statements than anything that he had personally advanced. He believed that he was the first to disclose the scientific facts relating to the whole question of ammonia-production, and to make such knowledge available for public use. The publication of his earlier labours had thrown a new light on the subject, thereby giving it an interest which it

Mr. Foster. had not previously possessed. It would only have been fair if quotations from specifications bearing dates subsequent to June 1882 had also been given. It would then have been interesting to note how the latter had been altered in accordance with an advance of public knowledge.

The amount of ash in the samples of coal examined by the Author was small, as it should be, seeing that the samples were nearly all gas-coals of high repute. He was informed by the analyst referred to in the correspondence that the analyses in question were those of small coal used in manufacturing operations, and were known to contain more ash than the lump coal from the pits. The names of the pits from whence the Author's samples came had not been mentioned, for obvious reasons.

There was a blunder in his calculations of the thermal value of water-gas. The quantity 68,068 had been doubled. In taking 68,068 as the heat-units produced by the combustion of two parts of hydrogen in sixteen parts of oxygen, he was wrong in the way in which they were applied in the calculations. It was therefore his duty to acknowledge the correction made in the correspondence, while it was no less important that he should point out that the calculations given in the correspondence were still incorrect. He had therefore prepared a short addendum giving the data assumed, with the calculations, in tabular form.

In answer to the numerous criticisms respecting the amount of fuel needed to convert coke into a form of gaseous fuel, he would point to the experience recorded at Oakbank. He attached great importance to these data, and desired to give them all the prominence which they deserved. His calculations of the heat-values of gaseous fuel were purely incidental to the Paper.

The general results expressed in the Paper afforded material for considerable speculation, as was evidenced by the correspondence. On many of the points raised he wishes, for the present, to reserve his judgment, as he had pursued his inquiries since the Paper was written; and he hoped at some future time to give an account of his further investigations.

## ADDENDUM.

The Author in the Paper calculated the theoretical amount of heat necessary to convert coke at a given temperature into gaseous fuel, allowing 100 per cent. more fuel for the purposes of "gasification" than was theoretically needed. Owing to errors referred to elsewhere he submitted the following figures, with the data employed.

Mr. Foster.

The following data were assumed:—

That the initial temperature was 10° Centigrade.
,, ,, temperature of decomposition was 600° Centigrade.
,, ,, water-gas was finally brought down to the initial temperature.

| | |
|---|---|
| Specific heat of carbon | 0·240 |
| ,, ,, steam | 0·480 |
| ,, ,, carbonic oxide | 0·245 |
| ,, ,, hydrogen | 3·409 |

| | Heat-units. |
|---|---|
| Latent heat of steam | 536 |
| True heat of chemical combination of 2 parts of hydrogen with 16 parts of oxygen in producing vapour of water | 57,924 |
| Heat of combustion of 12 parts of carbon in oxygen to carbonic oxide | 29,676 |
| Heat of combustion of carbonic oxide (28 parts) in oxygen to carbonic acid | 67,284 |
| Heat of combustion of 12 parts of carbon in oxygen to carbonic acid | 96,960 |

In considering the decompositions, 12 parts of carbon were acting on 18 parts of steam, and producing 28 parts of carbonic oxide and 2 parts of hydrogen. Thus—

$$C + H_2O = CO + H_2.$$

Taking the left side of the equation first, and regarding the total heat-units, there were:—

| | |
|---|---|
| Carbon 12 × 0·24 × 590 | = 1,699 |
| Water to steam 18 × 626 | = 11,268 |
| Steam to 600° Centigrade 18 × 0·48 × 500 | = 4,320 |
| True heat of chemical combination of components of 18 parts of water | = 57,924 |
| Total | 75,211 |

Taking the right side of the equation, there were:—

| | |
|---|---|
| Carbon to carbonic oxide | = 29,676 |
| Carbonic oxide cooling down from 600° Centigrade to 10° Centigrade = 28 × 0·245 × 590 | = 4,047 |
| Hydrogen in cooling from 600° to 10° Centigrade = 2 × 3·409 × 590 | = 4,022 |
| Total | 37,745 |

The difference between these two totals was 37,466, and represented the net amount of heat needed to effect the changes. Suppose this amount, which was theoretically necessary, to be doubled. It then became 74,932. To obtain this amount of heat, by the combustion of carbon to carbonic acid direct, required 9·3 parts of carbon nearly. Hence the "gasification" of 12 parts of carbon was attended with the use of 21·3 parts of carbon.

To compare now the thermal value of the water-gas with that of the whole coke used in its production, the latter being supposed to be burnt direct to carbonic acid.

Mr. Foster. The thermal value of the water-gas was :—

| | |
|---|---|
| 28 parts carbonic oxide to carbonic acid . . . . . . | = 67,284 |
| 2 parts hydrogen to vapour of water . . . . . . . | = 57,924 |
| Total . . . . . . . . . . . . . | 125,208 |

The thermal value of 21·3 parts of carbon was :—

$$21 \cdot 3 \times 8{,}080 = 172{,}104.$$

The ratio of this latter quantity to the former was that of 100 to 72. That was to say, if carbon was converted into water-gas and double the amount of fuel was used which was theoretically necessary, the gas obtained had a heating value of 72 per cent. of the whole carbon used in the process, supposing the latter to be burnt direct to carbonic acid.

---

## 8 April, 1884.

Sir J. W. BAZALGETTE, C.B., President,
in the Chair.

The discussion upon the Paper by Mr. W. Foster, "Experiments on the Composition and Destructive Distillation of Coal," occupied the whole evening.

In pursuance of the notice on the card of the meetings it was resolved to adjourn for a fortnight, in order to avoid holding a meeting on the Tuesday in Easter week.