Discussion.

The PRESIDENT, in moving the vote of thanks, remarked that the Paper described an interesting work which was unique in this country, and probably, as to its magnitude, in the world. The work of Civil Engineers was to adapt the sources of power in Nature to the use and convenience of man, and the Paper described how a source of energy hitherto wasted had been harnessed and made to do useful work. The President.

Mr. J. D. WATSON expressed his gratification that a description of the process had been presented to The Institution, especially as the Authors had formerly been his assistants. Mr. Donald Cameron, when he instituted the septic tank at Exeter about 30 years ago, demonstrated that the liquefaction and gasification of sewage was capable of producing a useful gas by lighting the sewage-works with it. The next work done in that direction was in 1907, when Mr. Carkeet James, M. Inst. C.E., put down a septic tank at the Matunga leper asylum near Bombay, from which he was successful in extracting enough gas to work a small engine. Mr. Watson had been able to inspect the site of that installation in 1919, and that had induced him to see whether it was practicable to obtain a reliable and useful quantity of gas from sludge. The Authors had explained how he had installed a 34-B.HP. engine at Birmingham and how his successor, Mr. Whitehead, had utilized it to make observations over a period of 4 years, which had justified him in building the large plant described by the Authors. The small portion of the digestion-tanks covered with gas-collectors, shown by *Fig. 2*, was enough to run a 150-B.HP. engine, clearly indicating that there was room for a much wider application of the process. The work at Colehall, however, had enabled Mr. Whitehead to make a careful estimate of what could be done with the huge sludge-digestion tanks installed. He was convinced that the estimate of the work that could be done, given in Table I, was not extravagant, and he had no doubt, therefore, that if further work was carried on as it had been begun, it would be possible to accomplish all that was foreshadowed in the Paper, and so utilize one of the waste products of sewage-treatment. Similar experiments had been made in Holland; and excellent work was also being done in Germany, where there were sewage-works producing sufficient gas to warrant its being sold to Mr. Watson.

Mr. Watson. coal-gas companies. The paramount reason for that was the calorific value of methane, which was considerably higher than that of ordinary coal gas. There was still much to be learned about the chemistry of the process. It was assumed at the moment that the methane came chiefly from the decomposition and fermentation of cellulose in the sewage. Whether it was possible to generate more gas by an ordinary sludge-digestion process without incurring disproportionate cost remained to be seen; he thought that would be possible in course of time. It would be useful to ascertain the difference between what could be done in Europe and what could be done, say, in India. The cellulose probably came chiefly from paper, which was sent to the sewage-works in a finely divided state. Indian sewage contained comparatively little paper. The industrial side of the question had been very carefully and moderately presented by the Authors, who showed that it had been possible to produce electricity from gas for about ½*d.* a unit. Even the best electricity supply stations could not do better than that at the present time. The Authors had drawn attention, however, to the fact that the work in question had been practicable very largely because the large digestion-tanks were near a building available for use as a generating-station. That was due to an interesting phase of procedure in modern sewage-purification which condemned the employment of coarse filters for the treatment of storm-water. In that case the site of those filters had been utilized for the construction of sludge-digestion tanks, which were employed primarily to deodorize sludge, and secondarily to reduce its bulk by gasification in digestion-tanks from which the gas was taken, and an existing pumping-station near them created a favourable opportunity for producing and utilizing gas of a high calorific value. It was interesting to compare the heat values and cost of gas-production at Birmingham with some German figures. For instance, at Essen gas was produced at three districts—Nord Essen, Frohnhausen, and Rellinghausen; the calorific value ranged from 780 to 1,000 B.Th.U., and for some reason it was produced for the very low price of 3·5 pfennigs per cubic metre. At Erfurt it was produced for the same price, at Stuttgart it was produced for 8 pfennigs, at Munich it was produced for 10 pfennigs, and there was a proposal to sell at Stuttgart for 25 pfennigs, which was equivalent to about 10*s.* per 1,000 cubic feet. Although German engineers began to produce gas from sewage about the same time as the Birmingham Board, the former appeared to have realized its commercial value first. He thought they would have to go far, however, before they improved upon the work described in the Paper.

Mr. H. C. WHITEHEAD observed that he found the Paper interesting from many aspects. The President had mentioned one of them, since the method described in the Paper was a somewhat novel way of bringing a little-known source of natural power to serve the convenience of man. In the second place, the economic recovery of methane gas was an added inducement to sewage-works engineers to resort to anaerobic fermentation of sludge as a method of treatment. The Birmingham Drainage Board was in no way entering into serious competition with the electricity-supply or gas departments. The total quantity of gas that it was possible to generate from sewage-works serving 1 million persons was probably sufficient to supply a town of between 40,000 and 50,000 population with all its gas requirements. The method described led him to speculate on the possibilities of using that source of power in portions of the Empire remote from coal, oil, or water-power, but possessed of a warm climate, vegetation, and a limited water-supply. Investigations on the production of methane by the fermentation of grasses and other forms of vegetation would appear to be worth while. He hoped one result of the Paper would be the stimulation of research work in parts of the Empire, and indeed of the world, more favourably situated than this country was so far as a warm climate was concerned. As was well known, a high temperature favoured rapid fermentation. The process was capable of being greatly improved. Experiments had been made in two directions. Firstly, a portion of the methane had been used to heat the contents of the digestion-tank. It was thought to be possible to double the rate of gas-production by utilizing about 25 per cent. of the total volume for heating purposes. He hoped to make that investigation on a large scale very shortly. The second direction of experiment lay in providing better means of mixing the incoming raw sludge with the contents of the digestion-tank. The Authors had thanked him for permission to present their Paper. Perhaps it would be correct to say that the permission amounted to leading them to the water and persuading them to drink. However, he felt that the excellence of the Paper justified any persuasion he had used, and he was very much indebted to them for their enthusiastic help in the design and construction of the scheme. Mr. Whitehead.

Mr. A. J. MARTIN remarked that for many years the disposal of sludge had been one of the greatest difficulties in connection with the treatment of sewage. The method Mr. Watson had adopted at Birmingham was very valuable. Not the least advantage of digestion was the large volume of gas to which it gave rise. The Authors stated that the sludge was pumped 4 miles. He would Mr. Martin.

Mr. Martin. like to know what type of pump was used, the size of the main, and what the friction amounted to. Had any difficulties been experienced in pumping owing to the nature of the material pumped? Each drying-bed was used on an average one-and-a-half times a year. The weather during the last 12 months had not been particularly favourable to the drying of sludge, but even so that seemed to be a very poor performance. He did not know whether that was due to the depth to which the sludge was applied to the beds, which was given as 18 inches. The general experience was that it was not desirable to run on more than about 9 inches of sludge at one time. An explanation which had been given was that with a shallow layer a good deal of water drained away during the first 2 days, but that the drying which took place later was due, not to drainage, but to evaporation; and the evaporation of water from a blanket of sludge 18 inches deep was very slow. The tank-capacities available for digestion at Birmingham were very large. Apparently there was 3 months' storage in the primary tanks and 2 months' in the secondary, making 5 months in all, the total sludge-digestion tank-capacity being 7½ cubic feet per head of population. He had adopted digestion in several plants, but he had not used such a large tank-capacity. He had aimed at 4 months' storage, or 1½ cubic foot per head of population, based on the Royal Commission's estimate for sedimentation-tanks (12 tons of sludge per million gallons), which he had worked on for lack of other data. The Authors mentioned the impossibility of covering the whole of a sludge-tank, owing to the difficulty of making a gas-tight connection between the roof and the sides. In gasworks practice it was not usual to make a rigid gastight connection between the roof of the tank and the sides, and he did not see why that should be necessary in the case of a sludge-digestion tank. Table I showed that at the Saltley works the yield of gas was ½ cubic foot per head of population per diem. At Manchester Dr. A. M. Fowler got 0·61 cubic foot, and at Exeter the yield was estimated at about 1 cubic foot. At Parramatta it was believed to be 3 cubic feet, and Mr. James said that at Matunga he reckoned on 3 to 4 cubic feet per head per diem. It was said that in a warm climate the evolution of gas was more rapid. That was easy to understand, but he would like to know whether, if the digestion were sufficiently prolonged, it would not be possible to get eventually as much gas per unit of sludge in a cold country as in a hot climate. During the last few months a good deal had been written with regard to the stimulation of gasification by the conditioning of the sludge, either by means of heat or by the adjustment of the *pH* value, as Messrs.

G. M. Fair and C. L. Carlson were doing at Boston.[1] It had been found that conditioning the sludge by means of lime greatly accelerated the evolution of gas. It would be interesting to get some data regarding the maximum yield possible. There was no doubt, as the Authors had pointed out, that the gas from sludge represented a very considerable value. Some years ago, in the case of Bristol, its value was estimated at £74,000 a year, but that estimate had been based on 3 cubic feet of gas per head per diem. Making all deductions, however, there was no doubt that the gas obtainable from sewage was very valuable and would furnish all the power required at any ordinary sewage-works. At the Parramatta sewage-works, which he visited 20 years ago, all the sewage had been pumped for years by the gas from the sludge, the saving effected by its use being estimated at £1,000 per annum. The activated-sludge process was a very useful one, but it had two drawbacks: it required a great deal of power, and it produced an immense, volume of sludge, with which it was difficult to deal. By digesting the sludge both those drawbacks might be overcome. The sludge would be reduced to a manageable volume and at the same time rendered inoffensive; and enough gas would be produced to furnish the whole of the power required at the works. It might be wise to give a word of warning about the danger from the gases. At Exeter there was a covered septic tank, in which there was an observation-shaft extending from the floor to the roof. At various heights in the walls of that shaft there were windows. It was necessary to light a match to see through them into the tank. On two occasions, when visitors were in that shaft, the gas in it had ignited, although there was no direct connection between the shaft and the tank. The wall was of 9-inch brickwork in cement, built by a very careful mason. Methane, however, diffused so readily that enough had reached the shaft to form an explosive mixture. There was no need to ventilate a tank to get rid of the gas; it would diffuse through a concrete roof. It was interesting, therefore, to learn that the gas-collectors described in the Paper were of concrete only 2½ inches thick. In the roof of the tank at Exeter there were a number of 3-inch sampling-pipes. Once, when he was inspecting the works, a man removed the plug from a pipe and applied a match. A blue flame shot up, followed by an explosion, which blew the covers off the tank. He had been responsible for some tanks at Cromer where an explosion took place, but without doing any Mr. Martin.

[1] *Engineering News-Record*, vol. 99 (1927), p. 1030. Recent numbers of "Engineering Abstracts" contain interesting data on the subject.—A.J.M.

Mr. Martin. damage. In a similar explosion at Sheringham two men had been killed. He was called in 20 years ago to investigate an interesting explosion at Ilford. There were five septic tanks, each ½ acre in extent, and although the tank-roofs were very massive, the explosion caused a great deal of damage. The tanks were side by side under precisely similar conditions, yet only one tank blew up. The tanks were ventilated by means of a fan which drew air through them. One tank was near the fan and the others were successively farther away. It appeared that the tank nearest the fan was so thoroughly ventilated that the gas was diluted to below the explosive strength. In the far tank there was very little air, so that the mixture was too rich to explode, but in the middle tank the gas and air were present in the proper ratio to form an explosive mixture.

Mr. O'Shaughnessy. Mr. F. R. O'Shaughnessy observed that for 60 years sludge had been a bugbear to both engineers and chemists who had had the misfortune during that period to have the problem to solve, but now, owing to work such as that described in the Paper, it was really becoming a rather attractive problem. In that connection it was interesting to recall that the Royal Commission on Sewage Disposal, which sat for 16 years, contented itself with recording existing methods of sludge-disposal. It investigated, through Dr. W. Somerville, Professor T. H. Middleton, and Dr. J. A. Voelcker, the manurial value of crude sludge, and that was almost the only contribution the Commission had made to what, until recently, had been a very difficult question. It was necessary above all things to maintain a correct sense of proportion in the matter, because there was much literature in existence dealing with a great deal of investigation that was going on in various parts of the world, and more particularly in Holland, Germany, and America. In America there was already almost a routine practice for putting down various appurtenances for sludge-disposal and gas-collection! The problem was essentially one of sludge-disposal, and the process described was primarily a sludge-dewatering process. Incidentally, gas was given off in the course of the operations, and the necessity or desirability of making use of that gas had been referred to. An interesting point in connection with sludge-digestion puzzled even chemists. Only a few weeks ago he was showing a party of chemists round the tanks described in the Paper: they were bio-chemists who were used to fermentation problems, and they were astounded to find that the intensive putrefaction of fermentable organic matter that was taking place could be carried on without offensive odour. All manner of statements had been made with

Mr. O'Shaughnessy.

regard to that absence of odour. For instance, it was generally inferred that in the putrefactive decomposition of such material sulphuretted hydrogen was always evolved. The amount of sulphuretted hydrogen evolved varied considerably. It was a maximum, as a rule, when a relatively large proportion of water was present; but when the sludge contained, say, as much as 10 per cent. of solid matter, the amount of sulphuretted hydrogen was almost negligible, being so small that it could not be detected by smell. The absence of smell was due to the peculiar character of the bio-chemical change, which resulted in practically inoffensive volatile end products when the correct fermentation prevailed, He laid special emphasis on that point, because there had been so many mis-statements with regard to it. The artificial modification of the reaction of the sludge to make it more alkaline or more acid, the question of the presence of interfering substances, and thirdly, what appeared to be the most important factor of all, temperature, were deserving of study. One of the most satisfactory investigations of that question had been made by Dr. G. J. Fowler in India.[1] There had been a good deal of literature on the subject since, but he had seen nothing which satisfied him so much as that investigation carried out by Dr. Fowler, who had not been concerned so much with sludge itself as with various kinds of cellulose. Dr. Fowler referred to the fact that the production of methane gas under conditions of the kind in question had first been pointed out by Mr. Omelianski as early as 1895. Methane was freely produced from the fermentation of particular kinds of cellulose, and Dr. Fowler had demonstrated that the biggest yield could be obtained from materials called hemi-cellulose—banana-skins and materials of that description. He had also shown that there were many substances which interfered with the production of methane, and there were even some forms of cellulose, especially resinous wood, which resisted the attack of the organisms, presumably by reason of the antiseptic character of the other materials present. There were several investigators in America, more particularly Professor A. M. Buswell, of Illinois, and Mr. W. Rudolfs, of Plainfield, New Jersey, who were working on the subject. Mr. Rudolfs, who had a very capable staff, was attacking the question from almost every point of view; but his results must be read in the light of the fact that, judging from his figures, he was experimenting with what was practically a purely domestic sewage. The organic matter corresponded almost exactly in some cases with pure faecal matter,

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[1] Journal Indian Inst. Science, vol. 3, part iv (1920), p. 39.

Mr. O'Shaughnessy. and therefore the yield was high and the conditions were exceptionally favourable. Mr. Rudolfs was rather inclined to generalize in the matter. It was no more possible to generalize in this new development of the sewage question than it had been in connection with other developments in the past. Each particular case needed investigation on its own merits. There had been some question as to where the methane came from. He believed cellulose material gave the biggest yield. Professor Buswell had indicated that the decomposition of fatty matter resulted also in an appreciable yield of methane, but there were also many other substances of a nitrogenous character which in the course of decomposition produced methane among other end products. The question had been raised at various times whether activated sludge, if fermented, would produce methane, and the answer was that unquestionably it would. The corollary of the fact that different substances affected the yield of the gas was, that a difference must be expected, if not in the total yield, at all events in the rate of yield, between a domestic sludge and an industrial sludge, because the latter would almost certainly contain materials that would tend to interfere with the free course of the reaction. Mr. Martin had referred to the question of the adjustment of the *pH* value, and also to the excellent article by Messrs. Fair and Carlson, whose conclusions showed that they thought the artificial adjustment of the *pH* value was of somewhat problematical benefit. In Birmingham that adjustment had been carried on by a proper admixture of fresh sludge with fermenting sludge. Fresh sludge was generally rather acid, but as the fermentation went on the *pH* value tended to change. At first the material became more acid, but later it became more alkaline. Messrs. Fair and Carlson emphasized the fact that the optimum *pH* value, about which other investigators were very dogmatic, was somewhat problematical, and he fully concurred with that. Caustic lime was an exceedingly dangerous thing to use in biological operations because it was a very powerful antiseptic—so powerful, in fact, that Sir Alexander Houston had told him that he had discovered the excess-lime method for water by examining sewage that had been submitted to lime precipitation and finding it absolutely sterile. Mr. O'Shaughnessy had made experiments on the lines suggested by Messrs. Fair and Carlson, and he had found that an appreciable amount of caustic lime would sterilize the sludge. It therefore had to be used with considerable care; adjustment was difficult, and considerable supervision had to be exercised. It was very doubtful whether its use was worth while. It had been demonstrated at Birmingham at all events that it was possible to carry on without that refinement, subject, of course, to further evidence which it was hoped would be produced in the course of time. He thought that the new development described in the Paper would follow very much the course of other developments. Very sanguine views indeed had been held with regard to land treatment and its economic results, to the application of septic tanks, and to the activated-sludge process, which was now, perhaps, viewed more soberly. It therefore seemed necessary to utter a word of caution. It did not do to be over-dogmatic or over-enthusiastic ; the question should be looked at in a common-sense way and further developments awaited. Speaking as a chemist, he could say there was every reason to hope that the economic prospects would be very good if the matter were followed up in a proper and sane manner. Mr. O'Shaughnessy.

Mr. A. P. I. COTTERELL observed that the Paper marked an epoch in the development of sewage-treatment so far as Great Britain was concerned. He concurred fully as to the need for caution in estimating the value of the process ; for there was no doubt that in the first stages of any development inventors were tempted to expect a great deal more from an invention than would prove to be possible in practice. At the same time, the method described was something that was already well known theoretically, but had simply not been applied on such a practical scale before ; and they seemed at Birmingham to have been rightly moderate in their estimates. He had had the privilege of watching the launching of the gas-collectors. It had been distinctly interesting to see what looked like a train of extraordinarily-shaped barges led by a plough working their way through the thick scum. On looking at *Figs. 4* it appeared to him that the collectors were shown to be remarkably buoyant—more than would be expected with reinforced-concrete—and they were floating so high in the sludge that apparently the upper buoyancy-chamber was not needed. The design of the collectors had clearly been conditioned by the shape of the existing sludge-tanks, and, were it not for that, the engineers might have chosen even better ways of collecting the gas. In a works where it was not required to utilize the existing open sludge-digestion tanks some more efficient method of collecting the gas might be evolved. Great advances had been made in gas-production since the septic-tank works at Exeter were lighted by gas produced in the tanks. He well recalled seeing the late Mr. W. J. Dibdin testing the gas there 30 or more years ago, and considerable progress had been made since then. Investigations in Holland and in Germany, more particularly in the Essen district, Mr. Cotterell.

Mr. Cotterell. had been referred to. He did not suppose there was any one works in Germany that at all compared with the plant at Birmingham, but with regard to gas-production in the Essen district he had been struck by three conditions that Dr. Imhoff had laid down, and which he thought were apposite to Mr. O'Shaughnessy's remarks. Dr. Imhoff insisted that the sludge should be properly inoculated, that was, that fresh sludge should be inoculated with the old ripe sludge. He insisted further that the time of treatment should be adjusted to suit the character of the sludge. Thirdly—and this was perhaps the most important condition—that the temperature should be maintained well above, say, 45° F. Dr. Imhoff stated—and Mr. Cotterell thought the experience at Birmingham bore it out—that, provided those conditions were maintained, the need for artificially altering the alkalinity of the sludge would be removed, and the optimum *pH* value would be maintained. In a paper by Dr. Imhoff in the *Engineering News-Record*,[1] translated from German by Professor Gordon M. Fair, there was a curve giving the variation of gas-production with temperature, prepared accordng to the investigations of Dr. Sierp. There it was shown that, by increasing the temperature from about 45° F. to 75° F., four times the quantity of gas could be evolved. The production of power-gas from sewage at Parramatta had been referred to, and it was of interest to note that the methane content in that case was said to be much the same as at Birmingham, and the calorific value was given as 600 B.Th.U. He had been lately brought into contact with an experimental plant that had been run in England with the object of showing that from sewage itself, not from sludge alone, sufficient methane could be collected to produce power. He thought it was possible that those who were promoting that method were expecting far too much, and that they would not in fact get what they claimed to be able to obtain from sewage. At the same time, the discussion that evening showed that in sewage itself there must be a certain amount of explosive gas that could be utilized if it were present in sufficient quantities. Mr. Martin's remarks had reminded him of an occasion when, being on a visit to Hereford in connection with the sewerage system, he had been asked as to the cause of an explosion that had occurred at the upper end of a siphon across the river, where a manhole-cover had blown out. Fortunately, no serious damage had been done, and the authorities had attributed the accident to an escape of coal-gas into the sewer. There was no apparent way for coal-gas to get into the sewer, and he had not known enough

[1] Vol. 99 (1927), p. 790.

about it then to be able to suggest a cause. It seemed now to be quite possible that methane gas was being generated, and that, in consequence of some alteration in the level of the sewer by flooding or otherwise, a large quantity had collected at the manhole and had been accidentally ignited. In a Paper on "The Destructive Distillation of Fæces," Mr. J. Menzies had shown[1] that by distillation it was possible to obtain oils and other products producing a gas giving results equal to those given by the best fuel-oil, and it was at the utilization of such a gas that such schemes as those described were aimed. The Paper suggested many possibilities applicable not only to large works like those at Birmingham, but to smaller works as well. The method captured for the service of man a source of power that had hitherto been allowed to escape into the atmosphere. Now, wherever efficient sludge-digestion tanks could be installed it was possible to contemplate the use of that power. Mr. Cotterell.

Mr. VOKES, in reply, remarked that the pumping-main, referred to by Mr. Martin, was 12 inches in diameter, and delivered at very nearly the same level as that at which the pump was situated. An average pressure of 50 lbs. per square inch was required to overcome friction. The velocity through the main was 1·2 foot per second. Very few difficulties were experienced, because an electrically-driven three-throw ram pump was used, driven by a motor which had practically infinitely variable speed. He thought that the thickness of sludge pumped on to drying-beds should vary with the different conditions in each neighbourhood, and he suggested it would largely depend upon the rainfall. Mr. Martin had also mentioned the large tank-capacity used for sludge-digestion at Birmingham, which he quoted as 7½ cubic feet per head of population. It would be seen from the Paper, however, that the capacity of the primary sludge-digestion tanks at the Saltley works amounted to 4½ cubic feet per head of population. This figure did not include the secondary digestion-tanks which were used for the purpose of securing the delivery of a uniform and completely digested sludge to the drying-beds. They also acted largely as storage-tanks. Mr. Martin had also raised the question of the fixed roof for collecting gas and the difficulty of maintaining a gas-tight connection between such a roof and the sides of a tank. He had proceeded to give examples which served excellently to illustrate one of the reasons for the adoption of the floating type of cover at Birmingham, namely, the necessity of making the plant "fool-proof" against such explosions as he had described. Gas-yields larger than those given in the Paper had been mentioned. Mr. Vokes confessed that Mr. Vokes.

[1] Journal Inst. San. Eng., vol. xix (1915), p. 145.

Mr. Vokes. he had been more pessimistic than ever about figures considerably higher than those given since seeing a report[1] that German investigators had succeeded in increasing the rate of yield of gas to as much as 11,000 cubic feet per head per annum, which was nearly 80 times the estimated figure in the Paper. Referring to Mr. Cotterell's remarks, the collectors in *Figs. 4* were shown in the position they took up when charged with gas. It had been suggested that this country was rather behind Germany with regard to the sludge-digestion problem. He ventured to differ from that opinion. The works at Essen-Rellinghausen that had been described by Dr. Imhoff, and the results that had been obtained there, pertained to the sewage from only 45,000 inhabitants, whereas the work Mr. Whitehead was doing at Birmingham was in connection with the sewage of over a million persons. That a very marked increase in the rate of yield of gas resulted if the temperature of the sludge was raised from 45° F. to 75° F., as shown by the curve which Dr. Sierp had published, had been well known in Birmingham for a number of years.

Mr. Townend. Mr. TOWNEND, in reply, remarked that up to the present time all efforts had been directed to collecting gas, which hitherto had been escaping into the atmosphere from the existing sludge-digestion plant. As the fact that this could be made a commercial success had been proved, attention might be directed to adapting existing plant for intensifying the process, in order to improve the rate of yield of gas and thus reduce the costs of production. It was in that direction that the whole scheme showed most promise. Temperature was the most important condition affecting the digestion process. Under natural conditions, the temperature of the sludge varied between the limits of about 45° F. and 60° F. For a rise in temperature of 10° from 50° F. to 60° F., the rate of gas-yield was increased by 300 to 400 per cent. Experiments had been conducted which showed that the increase was maintained up to a temperature of 75° F. or 80° F., above which the yield fell off again. It would seem probable, therefore, that if it were possible to maintain the process under control at that temperature of greatest efficiency, namely, 75° F. to 80° F., the rate of gas-yield would be many times—probably at least five times—the average rate of production under natural conditions, and it followed that the process of digestion would be similarly accelerated. On this assumption, the sludge-capacity necessary for the gas-collecting portion of the scheme would be reduced to one-fifth of that required

[1] *The Surveyor*, vol. lxxiii (1928), p. 89.

Mr. Townend.

under natural conditions, and that would considerably simplify any problem of applying artificial heat. Two sources of heat were available for this purpose, the first and most economical to utilize being the heat rejected by the generating-plant to the cooling-water and exhaust gases. The total of that waste heat amounted to about 65 per cent. of the initial heat available in the gas-supply, and it appeared to be practicable to transfer at least one-third of that waste heat to the sludge. On the basis of the total output of 150 million cubic feet of gas per annum, the heat transferred would be represented by the heat available from 30 million cubic feet of gas. It was estimated that this heat would be ample to maintain the reduced quantity of sludge at the desired temperature of 75° F. to 80° F., but should that not be possible during the coldest weather, additional heat could be obtained by using a portion of the gas itself for that purpose. A parallel case was to be found in the process of coal-distillation, where a portion of the coal was burnt in order to extract gas from the remainder at the cheapest possible rate. A primary consideration in any scheme of that nature would be the adaptation of sludge-tanks and gas-collectors to allow minimum heat-losses due to radiation. It was possible that development on the lines indicated would reduce the cost of gas-production to the negligible figure of 2*d.* or $2\frac{1}{2}$*d.* per thousand cubic feet, with a corresponding reduction in power-production costs. At the same time a more uniform supply of gas would be ensured throughout the year, which was an important factor in the utility of the scheme. There was no doubt that the income to be derived from that source would give an impetus to the more general adoption of the sludge-digestion process; and should the system of heat-control prove as valuable as was suggested, there was no doubt that it would be economical to install the system where tanks and other plant did not already exist. In this country, where the population was largely concentrated in urban areas, the greater part of the people was already served by the numerous sewage-disposal works. It would seem, therefore, that the total volume of gas available from that source must be about 5,000 million cubic feet per annum, at which figure the gas must be considered as a national asset.