

Discussion.

The Author, in introducing his Paper, showed a number of lantern slides.

He observed that one criticism which had been made of the Paper was that he had devoted twice as much space to the percolating filter as to the activated-sludge process. The only reply he could give was that he had known the percolating filter for 40 years, and the activated-sludge process for only half that time.

Mr. R. G. Hetherington observed that the Author had referred to progress in the design of sewage-purification works having been made empirically, especially in connexion with the percolating filter. That recalled to mind the fact that the late Mr. Santo Crimp, who he believed put up the first contact-bed, told him when he was a pupil the origin of that contact-bed. He had had a filter which was intended purely as a straining filter, but he could not induce the sewage to flow evenly over it; he therefore put a valve on the outlet and filled the filter, so that every part of the filter-material had to do some straining; and from that came the contact-bed.

Mr. Hetherington supported the Author in emphasizing the necessity of finding out what it was that one had to deal with before starting to deal with it. Many people were inclined to think that all sewage was the same. Therefore works were sometimes designed which were not the best for dealing with a particular sewage, although they might be excellent for dealing with another type of sewage somewhere else. It had been suggested by some that among the factors which might affect the consideration of sewage-treatment was the nature of the water-supply in the area—whether it was a hard or a soft water. He did not think that that point had been satisfactorily settled, and he would be glad to have the Author's views upon it.

Throughout the Paper, and in many other discussions on sewage purification, reference had been made to three-times dry-weather flow and six-times dry-weather flow, as if those figures were fixed as the limits of the purification which should take place. That was quite true with regard to three-times dry-weather flow, but he did not think that it was true with regard to six-times dry-weather flow. He thought that, if the Report of the Royal Commission on Sewage-Disposal were read carefully, it would be found to bear him out in saying that the six-times limit came entirely from the sewer end, and not from the sewage-disposal end, that was to say, the six-times rate was fixed as a reasonable figure at which overflow discharge from the sewer might be allowed, and that allowance was made for

the purpose of preventing the sewers becoming too large and expensive, as would be the case if, say, twenty times the dry-weather flow had to be carried, which might happen even in a partially separate system. His department would object to the installation of a six-times dry-weather overflow at the entrance to the works in order to cut down the amount to be treated as storm-water. If something more than six times had been taken down to the works, as was generally the case (it was more likely to be ten times), then the balance over three times should be treated as storm-water.

The Author had referred to disintegration as a part of screening, but he had not touched upon one rather important point—disintegration as applied to sea-outfalls. The Ministry of Health took the view that, in such cases, disintegration should not be substituted for screening, if screening were feasible, because one process removed the screenings entirely, whilst the other merely chopped them up and sent them out; but at some places screening was not feasible, and disintegration had a beneficial effect in such a case. The most marked case he knew of was at a town on the south coast of England, where formerly sea gulls had congregated around the sea outfall, but after a disintegrator had been installed not a single gull appeared.

The Author had referred to detritus-tanks and grit-removal, and had rather suggested that they were not necessary in an entirely separate system; but he would like to ask whether the Author knew of any system which was so entirely separate that it could afford to do without a detritus-tank. He was not referring to the sewage works of an institution, where one had complete control, but to the case of public systems. In the one with the most rigid separation that he knew of, the flow rose to two-and-a-half times in rain. There were so many back-yards and grit-delivering areas that it was doubtful whether any public system could afford to dispense with detritus-tanks.

He thought that there was still a great deal of scope for research into the design of tanks. He did not think that sufficient was known about their operation and the most efficient form having regard to the type of sewage with which they had to deal.

During recent years one or two installations on a very large scale had introduced a rather new factor which should be borne in mind. They covered such a wide area that the standard storm-water tank had, in effect, become much larger, in proportion to the flow arriving at the works at any one time, than in the smaller works. This was due to the fact that storms might occur on only part of the area, and a heavy rainfall might by no means cover the whole area. The flows coming down were delayed, and it seemed to him that there was a balancing of the flow which made the storm-water tank of the normal size more in proportion than it was in the smaller works. Possibility of trouble also arose because the sewage might become septic owing to the length of travel before reaching the works. Those were

two problems which had occurred to him in connexion with large works, and he thought that they needed consideration.

Dr. H. T. Calvert observed that he had had the pleasure of participating in the Discussion on the earlier Paper¹ presented by the Author and the late Mr. O'Shaughnessy. He considered that the two Papers could definitely be regarded as a *multum in parvo* edition of the Fifth Report of the Royal Commission on Sewage-Disposal, brought up to date. The Author had had exceptional opportunities of continuing the work of that Commission, and had used those opportunities to the full. The secret of the success of the work of the Author and of the Royal Commission lay in the fact that their conclusions had been based upon experimental research in which the numerous factors concerned had been varied one at a time for the purpose of examining the effects produced. That opened up a very wide field of research, which naturally formed part of the program of the Water Pollution Research Board, of which the Author had been a member since it was set up in 1927.

From what he had said it might be gathered that the Paper was a textbook on sewage treatment. If one glanced at the textbooks which had been published on the subject during last century, it would be found that in the latter half of that period most of them were descriptions of sewage-purification works carried out by their authors, and contained little discussion on the principles underlying the design of those works. It was with the advent of Professor Dunbar's textbook² on the principles of sewage treatment that that aspect of the subject had been opened up; and the translation of that book, which Dr. Calvert had undertaken in the early years of the present century, had inspired his education on the subject of sewage treatment. Probably no aspect of the civil engineer's art of "directing the great sources of power in nature for the use and convenience of man" had given rise to more controversy than had the theories underlying the design of sewage-purification works, and finality had not yet been reached.

The Author had begun by assessing the polluting-character of a sewage by the weight of polluting matter it contained. It was natural for a mechanically-minded man to think first of all in terms of weight, but the nature and the character of the polluting matter must not be lost sight of, and were definitely of great importance. Those interested in the subject were still groping for an accurate measure of the polluting character of the matters contained in sewage. As the Author had stated, it was only by applying several tests that a proper assessment of polluting character could be made. Each new test, when introduced, had been hailed as a satisfactory single test, but no single test had yet fulfilled that requirement.

¹ "The Treatment of Sewage Sludge by Bacterial Digestion."

² "Principles of Sewage Treatment." (Translated from the German by H. T. Calvert, M.Sc., Ph.D.) London. 1908.

The Author had made the rather sweeping statement that, "Some sewages, especially those containing trade-wastes, are much more amenable to sedimentation-tank treatment than are others." That depended very largely upon the nature of the trade-wastes. The Author had also suggested that chemical treatment of sewage was indicated when trade-wastes were present; but that again depended upon the nature of the trade-wastes, and Dr. Calvert would be loth to prophesy that the day of chemical treatment—especially for domestic sewage containing large amounts of matter in a colloidal state—was past; he did not think that that was the case.

The Author had justified his plea for more adequate purification of sewage-flows in excess of three times the average dry-weather flow. In his reference to detritus and grit-removal the Author had not referred to the possibility of utilizing the grit; but it could be readily cleaned by blowing air through it.

With regard to the design of the sedimentation tanks, to which Mr. Hetherington had also referred, the Author had illustrated a method which had been applied to even out the "flow", by which the head of sewage in the tank was raised or lowered. That was only a partial method of evening out the "strength" of the sewage. Dr. Calvert was acquainted with works where the strength of the sewage was evened out without losing any head, by the provision of a series of multiple inlets along the length of the tank; for instance, an inlet by which the strong sewage could be introduced half-way through the tank, so that it overtook the weak sewage which had entered the tank a considerable time before, and vice versa.

The subject of activated-sludge treatment had not come within the purview of the Royal Commission on Sewage-Disposal. Nobody had done more than the Author in contributing to the development of that method of sewage-purification, and his views deserved the closest study.

Mr. George Watson observed, with regard to the question of the utilization of sludge on the land, that he was old enough to remember the efforts made to defeat water-carriage by men who said that the land was being robbed of its rights by the sewage system. He considered that the Author was preserving nearly all of the valuable manurial constituents of the sewage in a more readily available and complete form than could ever have been achieved by any pail system. That system never dealt fully with the liquids, and those who recommended its use, because they could thus get manure back on to the land, would have lost much of the value. Digested sludge contained nearly the whole of the original manurial value and was free from grease, formerly the bugbear of farmers, which was now converted into valuable gas. The sludge was reduced on the Birmingham drying-beds to a content of only 35 per cent. of water. The Author had stated, that, at most towns, as a rule, farmers would not carry the sludge more than 2 or 3 miles, would pay very little or nothing for it, and would take it during only 6 or 8 weeks in the year, so that it

had to be stored. The reason appeared to be that the sewage works were at the mercy of a very small ring of customers, who simply took the sludge to suit themselves, and at their own price. If de-watering of the sludge were carried a little farther, which could easily be done by the available heat from the gas, and the sludge were reduced to powder, the manure could be carried long distances, so that one could get outside the ring. The question of soil fertility was of such importance that the treatment ought to be pursued to its logical conclusion by reducing the sludge to powder, so that it could be transported and distributed more widely. Sir Albert Howard, in his book, "An Agricultural Testament," had shown that, by having a really fertile soil on a farm controlled by him in India, he had obtained not only a double crop but also a very much better crop, from the point of view of quality, with the result that his animals were immune from disease. His cattle had actually come into contact with cases of foot-and-mouth disease without catching it.

Mr. David M. Watson observed that his only criticism of the Paper was that it was too short. Although true to its title, it did not cover all the ground implied thereby.

The most recent development dealt with was the theory of double or alternate filtration, with which was naturally associated partial treatment by one of the activated-sludge processes as a preliminary to filtration, and he inferred from the way in which the Author had treated the whole subject that the Author regarded that development as the main point to be emphasized in the Paper. The need for a complete understanding of the composition of the sewage and its preliminary treatment was of paramount importance if development were to continue. If those concerned with the problem were on the verge of finding that one of their old tools could be made to do more efficient service, they should study the theory of the use of that tool, and that was exactly what the Author was encouraging them to do.

Clogging of surface filters by colloidal and suspended matters in sewage was such a common complaint that it was doubtful whether the Author had emphasized it sufficiently. Probably it was no exaggeration to say that most filters suffered from that malady to some extent, but the trouble was not always discovered—certainly it was not diagnosed—until some visible ponding had appeared on the filter. It was, therefore, to be expected that treatment which eliminated the cause of the trouble would result in more efficient work by the filter. The Author's work in Birmingham, and also that of the Water Pollution Research Board, indicated that the enhanced efficiency would be well worth the trouble, and also the possible additional expense.

It had certainly been recognized for a number of years that the flocculation of colloids was the more efficient part of the duty of an activated-sludge plant, and that the less efficient part was the purification of the polluting matter in solution, whereas in the filter the reverse was the case.

Obviously, therefore, there was much to be said for a combination of the two processes, but it was a newer line of thought that the alternate filters might do the preliminary work for one another, and results which had so far come to Mr. Watson's notice clearly indicated that a great deal more had yet to be heard on that subject.

Reference had been made in the Paper to the responsibility of the high initial avidity of some sewages for oxygen for certain features of design in the activated-sludge plant. In the summer of 1939, when he had had the privilege of visiting some of the large sewage plants in the United States, he had seen two ingenious attempts to counter that initial avidity. The first was the Tallman's Island plant in the Borough of Queens, New York City, where there were two aeration units, each consisting of four channels traversed in series by the sewage. Each channel was 373 feet long by 20 feet wide. The flow was about 20 million gallons per day to each of the units, which had therefore a detention-period of $3\frac{1}{2}$ hours with a sludge-return of about 20 per cent., but the sludge was admitted at one point only, namely, the inlet to the first channel. The sewage was admitted at the inlet to the first channel, at the inlet to the second channel, and at the inlet to the third channel, so that the load on the sludge was applied very gradually. Unfortunately the results of that plant were not then available, but it was claimed that a shorter detention-period was the result. The other attempt to solve the problem was made at the Southerly works of the city of Cleveland, Ohio, where the system of diffused air was referred to as tapered. In the first of the channels the diffusers were eight abreast, and at the far end four. Both the sewage and the sludge could be introduced either at the inlet end of the channel or at its far end. He believed that there were four channels in series. The result was, of course, that the first channel could be used solely for regeneration of the sludge, solely for pre-aeration of the sewage, or for a combination of the two in any proportions.

Mr. Harry Jackson observed that engineers in Birmingham were proud of the work of the Birmingham Tame and Rea District Drainage Board; in particular of their investigations, on scientific lines, of the conditions under which the various stages of purification worked themselves out. Those conditions known and reproduced in a plant, its success was assured.

In the experimental work upon the double-filtration plant it had been shown clearly that the control of the particular appliances in the various stages of purification—the detritus tank, the sedimentation tank, the percolating filter, and so on—so as to produce the conditions best suited for economical work, represented the best possible kind of design.

The Paper was valuable from another standpoint. Government Departments might be led by it to give attention to schemes of sewage purification designed to fulfil the conditions required for satisfactory working, rather than mere duplication of plants already in operation elsewhere.

If expressions in the Paper, such as "self-purification" and "the purifi-

cation-capacity of a percolating filter" could be clarified by the Author, its value would be enhanced.

Mr. L. F. Mountfort observed that for the bulk of the Paper he had nothing but praise, but there were a few points in connexion with percolating filters that he would like to raise.

The Author had illustrated the concept of "liquor-facility of treatment" by two examples, in the first of which he had compared the results of what might be called a synthetic sewage, containing all its impurities in the dissolved state and being treated on a laboratory filter, with the results of what Mr. Mountfort presumed was intended to be an ordinary sedimented sewage treated at an ordinary rate on the type of filter in use at Birmingham. He could not help thinking that the conclusions which the Author had drawn from that first experiment were to a certain extent obscured by the fact that his laboratory filter consisted of an exceptionally fine medium, whilst the other filter consisted of a medium about $1\frac{1}{2}$ inch in size. In that experiment the Author had endeavoured to ascertain the effect of the removal of colloidal matter and of having all the impurities in solution. If one factor were varied in order to study its effect upon a result which depended on a number of factors, endeavour should be made, of course, to maintain all the other factors constant. In the case in question one filter contained a very fine medium indeed, whilst the other presumably contained a fairly large medium. Mr. Mountfort considered that, if the Author had been able to manufacture a synthetic sewage, in which the impurities were all in solution, and which was of the same strength as his ordinary sedimented sewage, and had then treated it on a filter of the same size, he would have been able to draw a much more satisfactory conclusion. Mr. Mountfort could not help thinking that the conclusion at which the Author had apparently arrived, namely, that if one had a filter dealing with ordinary sedimented sewage and could by some process substitute for that sewage a sewage of the same strength in which all the impurities were in solution, one could therefore treat the latter at three times the rate on the same filter, was hardly the conclusion to which the experiment would lead. He was much more impressed with the result of the second experiment, which definitely proved that on the same filter a greater liquor-facility of treatment could be obtained by the removal of some of the colloidal matter. If account were taken of the fact that the sewage had only about 70 per cent. of its previous strength, an improvement of at least 60 per cent. was still effected by the removal of the colloidal matter.

The Author had asserted that the size of the medium selected should depend upon the character of the liquid to be treated, but Mr. Mountfort considered that the method of distribution should also be taken into account. There was a vast difference between the kind of intermittent distribution produced by a continuous rotary sprinkler with dosing tank and a rectangular travelling distributor. The Author had stated that

filters filled with flints, unbroken quartzite, and other gravels, should have a cubic capacity 25 per cent. higher than that of filters filled with broken material. Mr. Mountfort had found that with gravel plus a rectangular travelling distributor, twice as much gravel as clinker was required to produce the same result.

He was very interested in the Author's statement in the introduction to the Paper, that the results of experiments with alternate filtration had already indicated a considerable improvement upon the original results obtained with single filtration.

He would like to point out, however, that the economic value of any method of improving the operation of a filter could not be judged entirely by confining consideration to the filter itself. If the improvement were obtained by altering the kind, as distinct from the quantity, of work which the filter was called upon to perform and by relieving it of work with which it was not well suited to deal, such work would have to be undertaken by some other portion of the plant, and any additional cost thus involved would need to be set against the improved economy of the filter.

Dr. A. Parker observed that when the Water Pollution Research Board began an investigation of methods for the treatment and disposal of milk effluents it was soon found that the settled waste-water from dairies and creameries could not be satisfactorily treated in single percolating filters by the method ordinarily used by sewage-disposal works. Effluents of good quality were obtained for a time, but the filter gradually became clogged and inoperative. Long before that the Author and the late Mr. O'Shaughnessy had observed that filters which had been overloaded with sewage and were becoming clogged could be restored to a satisfactory condition by the application of a treated or partially-treated sewage liquor, and they had suggested that the Board should try treating milk effluents by using two filters in series and changing the order of those filters, the underlying idea being that any excessive quantity of solid matter deposited in the primary filter would be removed when that filter occupied the secondary position. Experiments were carried out on a large scale at a cheese factory over a period of several years, and were eminently successful. In the Paper the Author had given a load of 160 gallons per day per cubic yard of filtering medium for milk effluent with a B.O.D. of the order of 25 parts per 100,000. That figure allowed a margin of safety. In actual fact, during the summer months, when the load on the factories was greatest, 240 gallons of the liquid was treated per cubic yard of filtering medium. Dr. Parker would not suggest, however, that plants should be designed on that basis, because the experiments were very carefully controlled: such accurate control could not be expected under factory conditions, and he considered that the figure given by the Author should not be exceeded.

More recently, in the Board's laboratory at Watford, similar experiments had been carried out on a smaller scale with a mixture of sewage

and waste water of a kind discharged from factories recently erected in various parts of the country. Equal success had been achieved in dealing with those waste waters, and twice the load per cubic yard of filtering medium had been treated with the double-filtration system in comparison with single filters. The process was being applied on a large scale, and the result would be that a considerable amount of expense and material would be saved to the country. It was obvious that attempts should be made to ascertain whether the double-filtration method could be used with advantage in treating sewage at sewage-disposal works. The Author and his Board, with characteristic generosity and public spirit, had at once offered four percolating filters, and had provided all the additional equipment, such as settling-tanks and pumps. They had even built a laboratory, and the Water Pollution Research Board had been working at the Minworth works for more than 2 years. There was no doubt that at sewage works more than twice the load could be treated by the double-filtration system, and there was a possibility that even better results might be obtained by the use of, say, two filters as primary filters and one as a secondary filter, and by running those in a different order. The question of the cycle of change had also to be considered. A change once per week had been adopted, but there were indications from the biological work that some improvement might be effected by altering that period, possibly to once a day in the summer and once in 3 or 4 days in the winter. In order to assist in that work, the Author and his Board had erected eight smaller filters, each of which could hold up to 16 cubic yards, so that double or treble filtration could be used, or two could be run in parallel and one in series, or any other arrangement could be made, the size of the filtering medium and even the size of the filters being changed. It was hoped thereby to obtain useful information, and to supplement that with biological observations.

It appeared that sewage sludge ought to be used as a fertilizer. One difficulty was in drying it, distributing it, and applying it on the land, whilst another difficulty lay in ascertaining its real value. However, more interest was being taken in the matter. Through the Agricultural Research Council, experiments on the real fertilizing value of sewage sludge for different soils and different crops were being undertaken.

* * **Dr. S. H. Jenkins** believed that the time was opportune for reconsidering the principles underlying the design of sewage-disposal works, and the means for applying them. Many schemes for improving existing works were under consideration at the outbreak of the war, but with the altered conditions of a post-war period and the growing demand for improved town planning, such schemes might have to undergo drastic revision. Among the problems the future might bring to some works, the effect of admitting trade-effluent to the sewage might rank high in importance. Numerous commissions had urged the need for passing trade-

* * This contribution, and also the following, were submitted in writing.

effluents into the public sewers as an important step in preventing river pollution. The Public Health (Drainage of Trade Premises) Act, 1937, allowed occupiers of trade premises to make application for the reception of trade-effluents into public sewers and, subject to certain safeguards, imposed an obligation upon local authorities to accept and treat the liquors. That measure, in spite of certain defects, was an important advance, which should help to mitigate pollution by industrial effluents, since the treatment of such effluents alone often failed to be effective through lack of adequate technical control or inherent difficulty in treatment. During recent years several trade-wastes formerly believed to be incapable of purification had been successfully treated in well-designed plants, but those plants were exceptional.

The presence of considerable quantities of some trade-wastes in sewage might affect the design of the works required to a far greater extent than might be foreseen from an examination of the usual figures of chemical analysis, and extreme caution was required in the interpretation of such data. For example, a waste which nearly neutralized the reserve of alkali in the sewage or added an appreciable quantity of chromium salts, would certainly limit, and perhaps stop, the formation of nitrate from the ammoniacal substances present in the sewage. Another instance, taken from actual practice, would aptly illustrate the burden sometimes imposed upon sewage-treatment plants by industrial wastes. A fairly weak domestic sewage required treatment in primary sedimentation tanks, followed by filtration in bacteria-beds at the rate of 100–200 gallons per 24 hours per cubic yard of medium, in order to produce an excellent, well-nitrated effluent. On the other hand, a highly industrial sewage, with a biochemical oxygen demand of similar order, but with a much higher figure for oxygen absorbed from permanganate, was treated by primary and secondary sedimentation, partial treatment with activated sludge, and filtration at the rate of 90–100 gallons per cubic yard, but yielded only partly-nitrated effluents of moderate quality.

The Author had referred to the method of partial activated-sludge treatment as one means of increasing the capacity of a bacteria-bed. Mr. S. J. Roberts and Dr. Jenkins¹ had recently demonstrated that about 15 per cent. of the impurity removed from sewage by activated sludge in 1 hour was removed by oxidation, whilst 85 per cent. was removed by coagulation, the coagulated solid matter becoming part of the sludge. Clearly it was the removal of solid matter by flocculation which permitted higher rates of filtration of partially-treated sewage. At the Minworth works, Birmingham, partial treatment with activated sludge for 1 hour had removed an average of 1,050 lb. of dry solid matter per million gallons of sewage treated during the year 1940. Under the most favourable con-

¹ "Studies on Activated Sludge: I, Flocculation and Oxidation of Sewage Solids." *Journal Soc. Chem. Ind.*, vol. lviii (1939), pp. 225–29.

ditions of quiescent sedimentation it would be possible to remove from that sewage no more than 390 lb. of dry matter per million gallons.

With regard to the use of sewage sludge as a manure, the general opinion of users appeared to be that it was a slow-acting fertilizer, although its value varied from one works to another, and also according to the type of land to which it was applied. It seemed to be especially suitable for light soils deficient in organic matter, and that view had been confirmed by the results of field experiments carried out by the Midland Agriculture College with air-dried sludge which had undergone decomposition in lagoons. Those trials showed that the yields of market-garden crops were increased by the application of sludge fortified with artificial fertilizers. No serious efforts had yet been made in England to dry activated sludge without the loss of its fertilizing constituents. A product like activated sludge, containing 5-8 per cent. of nitrogen and 75-85 per cent. of organic matter, would find as ready a market in England as in the United States, where commercial dryers were being installed in many works.

Mr. Edward Halliwell agreed with the principles advocated by the Author for the design of sewage works. He wished specially to emphasize the importance and necessity of balancing the volume and equalizing the strength of the day- and night-flow of sewage, which gave rise to many of the difficulties in sewage treatment. He agreed also as to the advisability of removing, as far as possible, the suspended impurities before passing the effluent on to the percolating filters or into the aeration tanks of the activated-sludge plant. He considered that bacteria and organisms had enough work to do in purifying the dissolved organic impurities without expending time and energy in the purification of suspended organic solids, which ought to be settled as sludge, in the tanks.

The Author, in reply, remarked that, bearing in mind the crude methods of distribution adopted in the early filter experiments, Mr. Hetherington's account of the origin of the first contact-bed was probably historically accurate.

The nature of the water-supply in the drainage-area had a bearing upon sewage treatment, a hard water being preferable to a soft water in assisting flocculation in the sedimentation tanks, and in providing some of the alkali reserve which, as mentioned in the Paper, served a useful purpose in the subsequent biochemical oxidation of the nitrogenous substances present in sewage.

The alkalinity in domestic sewage from an area using soft water might amount to 30 parts per 100,000, and that quantity was sufficient for all demands made to neutralize the nitric acid produced during biochemical oxidation of the settled sewage. From that it would be seen that the additional alkalinity which would be available when a hard water was used for supply purposes was of more service in a sewage containing trade-wastes of an acid character, than if the sewage were solely of domestic origin.

The Author agreed with Mr. Hetherington that all storm-water sewage delivered to the sewage works in excess of three times the average daily dry-weather-rate of flow should receive some form of treatment.

In the Author's view, serious river pollution at the present time came from storm-water sewage overflows in large urban areas, and an examination of some of the sewerage systems would disclose that many of the older storm-water overflows came into action at rates of flow much lower than the six-times limit.

A large sewerage system offered better safeguard against the too-frequent operation of storm overflows if the branch intercepting-sewers and their storm overflows were designed on a more generous scale, in terms of their dry-weather flow, than the main sewer into which they discharged.

The Author advocated disintegration of screenings as a part of the usual equipment of the larger inland works, in order to ensure that the screenings should be returned to the sewage and subsequently dealt with as part of the sludge in a less objectionable manner than by disposal separately.

Disintegration of screenings as part of a sea-outfall scheme in no way reduced pollution, although it did reduce the food-supply of seagulls.

With regard to detritus tanks, the Author was of opinion that the general tendency was to make them too large, and to provide them with needlessly elaborate grit-removal apparatus. He agreed with Mr. Hetherington that only on very rare occasions in the larger installations could the detritus tank be dispensed with.

The remarks of Mr. Hetherington regarding the capacity of storm-water tanks for very large drainage-areas illustrated one of the advantages of regional drainage-control as exemplified in the West Middlesex works, and to a smaller degree in Birmingham, where the main sewers had less margin for storage and the balancing of sudden storm-water discharges.

The Author was in agreement with Dr. Calvert as to the value of research in matters affecting sewage purification, and was thankful that the work of the Water Pollution Research Board, unlike that of the Royal Commission on Sewage Disposal, had been allowed to continue in wartime.

Even now Dr. Dunbar's textbook on the Principles of Sewage Treatment (to which Dr. Calvert had referred) was of outstanding value. It should not be forgotten, however, that the Proceedings of The Institution contained valuable Papers and discussions upon that subject. A study of some of the earlier Papers disclosed how near to modern discoveries were some of the engineers and chemists of 50 or 60 years ago.

In making the statement that "Some sewages, especially those containing trade-wastes, are much more amenable to sedimentation-tank treatment than are others," the Author had had in mind cases in which certain trade-wastes, by themselves or in combination with others, provided excellent sewage precipitants, and thus counterbalanced their ill

effect by improving purification action in the sedimentation-tanks, instead of merely increasing the strength of the sewage into which they discharged.

Dr. Calvert had referred to a method of evening the strength of the sewage, without loss of head, by the provision of multiple inlets in the length of the sedimentation-tank. That method was of value in averaging the strength of the daily flow, but did not possess the two-fold advantage of averaging strength and rate of flow as illustrated in the Paper (*Fig. 6*).

The Author was interested in Mr. George Watson's views regarding the treatment and disposal of sewage sludge. He would not, however, ascribe the farmers' reluctance to take delivery of sewage sludge at all times of the year to purely selfish motives, but rather to the fact that their business of farming was strictly controlled by its seasonal variety of operations and weather conditions. The farmer naturally desired to have the sewage sludge when he had the labour and transport available, and could get the material on to the land.

In reply to Mr. David Watson's criticism that the Paper was too short, the Author took refuge behind the general desire of members for Papers of moderate length, and his own opinion that such Papers were more likely to succeed in their object, by promoting an exchange of views, than were those of greater length. Mr. Watson was correct in surmising that the Author regarded the improvement in efficiency of the percolating filter by the use of double or alternate filtration as the main point of emphasis in the Paper.

The research work at Minworth, Birmingham, which was being carried out by the Water Pollution Research Board, had advanced sufficiently far to enable it to be said that by a simple modification in the method of operating percolating filters, their efficiency, as measured by their ability to purify settled sewage per cubic yard of medium by single filtration, might be doubled; and that that might be done cheaply was obvious from the facts that the only additional items of capital expenditure related to larger humus-tanks, supply-pipes, distributors, and a pumping-plant.

The quantity of energy for pumping to obtain the double filtration was, in most cases, likely to be moderate, and was about one-half of the energy consumed in a bio-flocculation plant carrying out a corresponding amount of work, namely, flocculating sedimented sewage to such a degree that it might be purified by single filtration at double the rate of plain sedimented sewage.

The reasons for the enhanced efficiency of a percolating filter when used alternately as a primary and secondary filter, in comparison with the original method of single filtration, had yet to be established, but two facts relating to the retention and discharge of humus might have important bearings upon the differences in performance under the two methods.

Graphs illustrating the yearly discharge of humus from single percolating filters and from corresponding filters working in series with alternate

charges in their order, showed that in the first instance the discharge might be indicated by a smooth curve with two large humps in the spring and the autumn respectively, when the discharge of humus was at its maximum, whilst the discharge from the alternating filters was represented by a regular zig-zag line corresponding to the alternating periods of the filters.

It was thus obvious that whilst the single filter cleansed itself twice annually, the alternating filters working in a fortnightly cycle discharged their excess humus twenty-six times.

Most filters suffered from the malady of surface clogging, which in itself imposed a mechanical check upon the quantity of liquid which could be applied to the surface, and produced other ill-effects, such as lack of aeration and unequal distribution of the liquid.

It was probable that the higher efficiency of the alternating filters over single filters was due largely to the better control of surface clogging afforded by that method.

The Author was interested to hear of the means adopted at New York and at Cleveland, Ohio, to counter the ill-effects of the high initial avidity of some sewages for oxygen, and looked forward to reading an account of the experiments on their conclusion.

The Author regretted that Mr. Jackson regarded such expressions as "self-purification" and "the purification-capacity of a percolating filter" as insufficiently clear. "Self-purification" of a polluted liquid or river might be defined as the ability of the liquid or river to purify, or partly purify, itself by natural means without outside assistance. "The purification-capacity of a percolating filter" was usually expressed in terms of gallons of liquid purified per cubic yard of filter medium per 24 hours, and might vary in amount in inverse ratio to the strength of the liquid, and to the degree of purification achieved. It was also affected, as described in the Paper, by several factors connected with the construction of the percolating filter, the method of distribution, and the temperature in the filter.

The Author had studied Mr. Mountfort's criticism of the experiment illustrating the "liquor facility of treatment" of a synthetic sewage containing all its impurities in a dissolved state, as compared with a liquid containing an equal load in a mixture of suspended and dissolved impurity, and could not agree that a difference in the size of medium employed in the two experiments affected the permissible inference. Each size of medium was the most favourable for the respective liquids treated, and to have employed a small medium for the liquid containing suspended impurity would have been just as unfair to that liquid as the employment of a $1\frac{1}{2}$ -inch medium for the liquid containing only dissolved impurity.

The Author agreed with Mr. Mountfort that the method of distribution to be employed should be taken into account in assessing the capacity of a percolating filter, and had stated that in the Paper.

The Author's experience with continuous rotary sprinklers and rect-

angular travelling distributors had left him with the conviction that there was no perceptible difference between the results obtained from the best of both types, although there was wide variation in the results obtained from various patterns of rotary sprinklers.

Mr. Mountfort's remarks regarding the reduced efficiency of gravel and flint medium, in comparison with clinker, tended to confirm the Author's views; the difference in degree of the respective results obtained by Mr. Mountfort and the Author were probably due to dissimilar types of distribution and size of medium employed.

The Author was indebted to Dr. Parker for placing on record a clear account of the circumstances which led to the development of the double-filtration system. Considerable scientific work still remained to be done to round off the investigation; but the results so far obtained had been upon a sufficiently large scale and covered a period sufficient, in the Author's view, to justify further development of the new system, not only in the extension of old works already using single filtration, but also for the design of new works.

The remarks of Dr. Jenkins regarding the influence of certain trades wastes upon sewage treatment tended to emphasize the views expressed in the Paper, and by Mr. Hetherington, as to the necessity of "finding out what it was one had to deal with before starting to deal with it."

The interesting comparison made by Dr. Jenkins of the removal of dry solid matter from sedimented sewage by flocculation with activated sludge, as compared with the results obtained by quiescent sedimentation, confirmed similar findings by the late Mr. F. R. O'Shaughnessy, who might be said to have been one of the pioneers of the bio-flocculation process.

The Author agreed with Dr. Jenkins regarding the desirability of a more general use of sewage sludge as a manure; but he would point out that the conversion of wet activated sludge into a dry form at a reasonable cost, and without materially reducing its fertilizing value, formed a very difficult problem, and one that could not yet be said to have been solved in an economical manner. Surplus activated sludge formed a comparatively small proportion (about one-fifth) of the total sludge-production of a sewage purification works employing that method of treatment, and it was only in a very large works that a separate method of conversion into a dry manure would appear to deserve consideration.

The Author was indebted to Mr. Halliwell for underlining some of the more important views expressed in the Paper.