Design of extensions to the Beckton sewage treatment works of the Greater London Council

S. H. DAINTY, R. A. R. DRAKE, J. E. JAMES & T. D. SHEPHARD

Mr Dainty

In 1930 there were some 70 sewage works contained within the Greater London area, as it is now defined. Today there are 15, and we look forward hopefully to reducing that number still further to 8 major works by 1980. Concurrent with this progressive reduction of plants there has taken place the long term investigation into the pollution of the tidal estuary of the Thames, the publication in the early 1960s of the Pippard Report, and later, Technical Research Paper No. 11[6], by the Water Pollution Research Laboratory (WPRL).

117. In spite of all the improvements effected, it became immediately apparent that these would not be sufficient if the conditions set out in that Research Paper and the Pippard Report were to be met. It was equally apparent that improvement of the Beckton Works would make the greatest contribution to reducing the pollution load on the River Thames.

118. Many will know that of the total load discharged to the tidal Thames, over 50% comes from Beckton Works, and large scale reduction alone of that load, which is implied by giving full treatment to all flow reaching the Beckton Works, would bring conditions close to the range of the recommendations of Report No. 11. This is the background of the extensions which are now proposed.

119. We have not stopped at providing just an improved effluent. Sludge digestion plant has been extended, to ensure that all sludge is now fully digested before it is shipped to the outer estuary. There is, of course, a need to consider storm sewage discharges, and to this end we propose to provide vast stormwater treatment at Abbey Mills which will reduce still further the overall pollution load to the estuary.

120. The measurement at the top of Fig. 9 in the Paper should have been 6·10 m.

Mr Drake

Construction of the digestion plant and powerhouse extension began in October 1967, and of the sewage treatment plant in March 1968. It is hoped that the scheme will be complete by the end of 1973.

122. Figure 13 shows a model of the works as they will be when completed. Briefly, the flow arrives in five 9 ft × 9 ft horseshoe-shaped outfall sewers, goes through detritus channels and to the screen house. This was constructed, in 1955, large enough to cope with future flows, and has therefore not needed amendment. Pre-aeration channels follow, and the flow is divided between two virtually identical sets of sedimentation tanks. The first set was constructed in 1955 also, and the duplication now being constructed is almost identical.

123. The new aeration tanks and final tanks with electrically operated blowers in the houses between will treat approximately two-thirds of the flow, and the 1959 aeration plant, upgraded, the remaining third. A new effluent channel takes the treated flow to the Thames. Room was left in the powerhouse in 1959 for two additional gas turbines, and these have been provided to drive 3000 kW generators.

124. The digestion plant, built in 1959, comprised four dewatering tanks and 16

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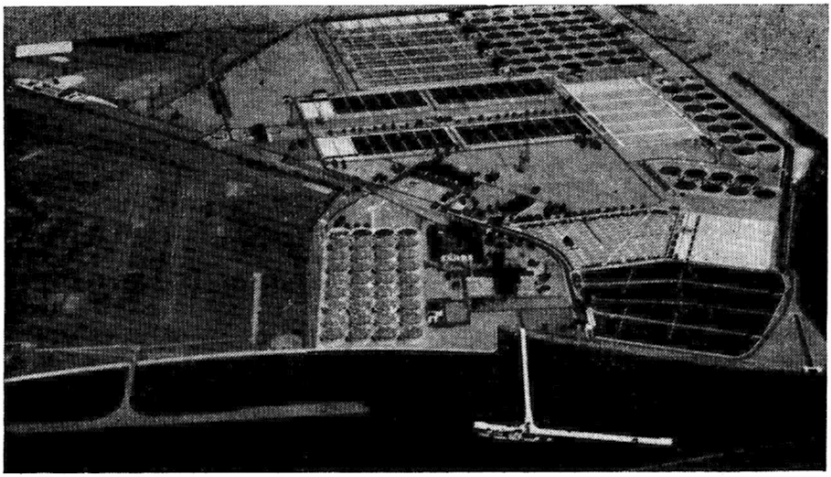

Fig. 13

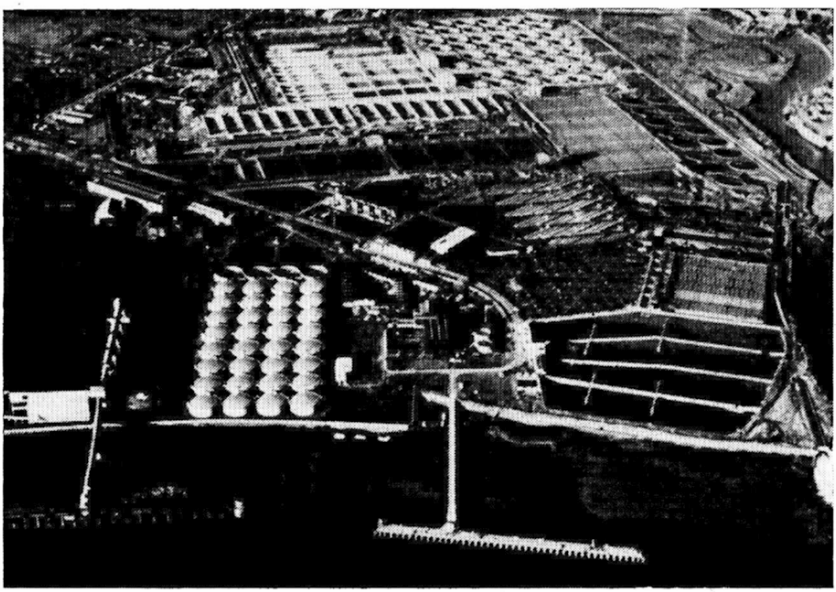

Fig. 14

floating roof heated primary digesters. To duplicate the primary tanks, several acres were reclaimed from the river and 16 more tanks built.

125. Figure 14 shows progress to date. Of the new sewage treatment plant, 50% is virtually complete, together with a good deal of the civil construction of the remaining 50%.

126. Figure 15 shows an aeration tank with, in the distance, two of the blower houses. Feed to the tank is normally to a forebay to which return sludge is also admitted, but it can be incremental via the central channel. The cross walkways carry anti-foam oil distributors. The small diameter diffuser pipework on the floor

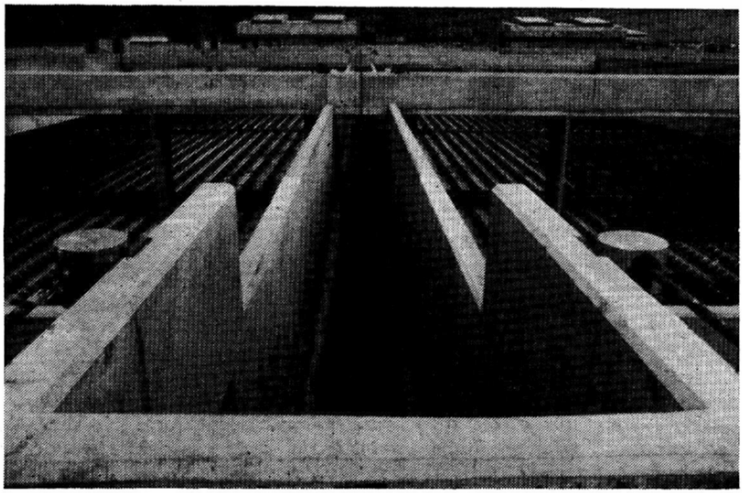

Fig. 15

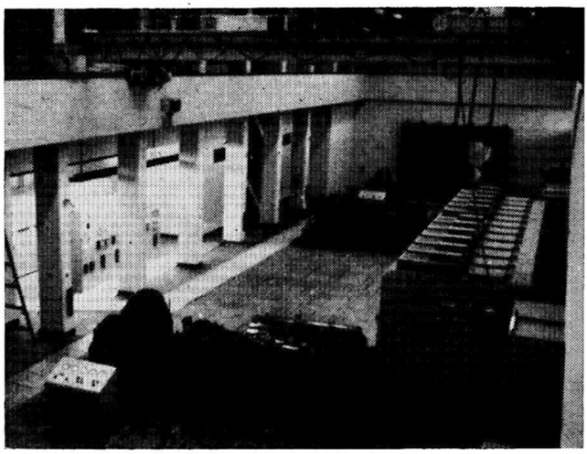

Fig. 16

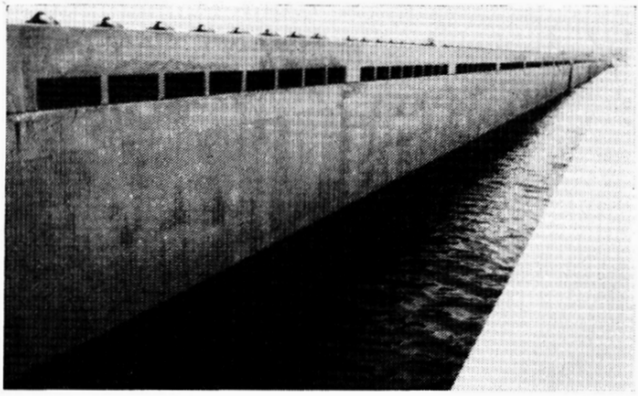

Fig. 17

of the tank is plastic, the dome bases being integral with the pipes. Each tank contains about 40 000 7 in. domes.

127. The inside of one of the four new blower houses is shown in Fig. 16. Each blower can produce 20 000 cu. ft/min and is driven by a 750 hp motor. Return sludge is piped through the basement and measured and surplussed. Each house is a sub-station on the 6600 volt ring main, and also contains automatically washed electro-static air cleaning precipitators.

128. It has been necessary to provide a new main effluent channel of which part is shown in Fig. 17. The ports at high level will be noted. These are the outlets from one of the batteries of air lifts provided to lift effluent over the higher tides.

129. Work is in progress on the completion of the new works and amendment of older plant, in particular the upgrading of the 1959 diffused air plant from 60 mgd to 80 mgd.

Mr H. S. Tricker, Director of Water Engineering, Department of the Environment

The scheme is quite typical of several schemes which have been carried out in large cities in the UK since the Second World War. Good civil engineering principles have been adopted, namely, to scrap what is outworn, to retain what is good, and to complement what is good with the new, incorporating lessons learned by experience.

131. With a need to serve a 3 million population the existing works were only half man enough to do the job, and of that half, only half the aeration plant was worth keeping. The remaining half of the aeration plant was retained, having been boosted to about one-third of the required capacity, and the remaining two-thirds was provided by new plant. On the primary treatment side, the existing plant was made to deal with half the load, and was duplicated, again introducing modifications and improvements which had been learned from experience. Sludge digestion tank capacity was doubled.

132. The most outstanding feature of the design, and the major constraint, was the limited area of land in which to work. I suggest that severely limited the layout of the plant and possibly the basis of design.

133. The Authors state that they chose the diffused air method of oxidation because it was more flexible. I am not sure what is meant by 'flexible', and I would appreciate some elaboration on that point. Similarly, with regard to aeration tanks, is there any more information concerning the considerations which led them to adopt single pass tanks? I should also be interested to hear about the distribution of diffusers on the floor. If I have understood the Paper correctly, the floor is covered

evenly with diffusers: I have no doubt the Authors took into account a number of factors before they chose such a layout. Although it appears that the air is uniformly distributed over the floor, I gather that provision is being made for incremental feed.

134. Again reverting to changes in design: what has experience taught us? I would appreciate a comprehensive list of the main innovations which have been introduced into the £21 million scheme as a result of previous experience on the existing plant.

135. At the opening of the Minworth Works extension at Birmingham recently, I noted a number of similarities between those works and the design of the GLC works at Beckton. I should be interested to hear whether there has been any consultation or collaboration between the two design teams. In recent months I have heard a certain amount of criticism of civil engineers working in the public health field. Some of the criticisms made are that civil engineers get their income from digging holes and building massive structures and that this factor is reflected in their designs. Other people, it is said, can produce similar results at less cost and with less massive structures. An analysis shows that of the £21 million total cost of certain large sewage treatment works, about 74% represented structural works. I do not find that at all surprising, because they are indeed civil engineering works predominantly; however, I would appreciate the Authors' comments on the possibility of reducing costs without at the same time reducing effectiveness by using less massive means of construction.

136. From the little that has been said about digestion plant, it appears that the extension is largely a duplication of what went before. I should be interested in two aspects of that. One is the differences, if any, as a result of the improvements which have been learned by experience, and second, I would ask the question—why digestion? The sludge has to be carried out to sea. Is digestion intended to reduce the volume, or the smell, or to satisfy the appetite of the gas turbines?

Mr R. W. Horner, Greater London Council

With regard to the hydraulic diagram in Fig. 2, I recall a long discussion in the LCC days about the desirability of pumping flow to Beckton, and I wonder whether it was wise to let slip an opportunity to improve the position and particularly the velocity in the sewers. Overnight, at periods of minimum flow, the velocity falls lower than 1 ft/s, becoming in effect a sedimentation tank for several hours a day.

138. Turning to the primary sedimentation plant, in § 22 the assumption is made that only 15% of the sludge will stay in the sludge troughs. This seems to be rather pessimistic, because I recall experiments at Beckton in about 1959 when we found that about 50% by weight of sludge was removed from the sludge troughs of the original primary sedimentation tanks, if the Mieder scrapers were not operated. I wonder whether 15% is the volume figure because it is feasible that the sludge from the further parts of the tank would be lighter than the sludge which was settled out in the sludge trough area.

139. Turning to the aeration plant, I am a little worried over the maximum air capacity which comes to only a little over 2 cu. ft/gal. Looking at plant which we hope will not be obsolescent by the year 2000, it seems it is a little meagre; I visualize that much higher standards will be required of flows to the river in the future.

140. The use of the air lifts in this particular case seems most reasonable. There was some trouble with air lifts on the original plant due to the migration of sludge from one end of the plant to the other. It was found that discharge from the air lifts varied with the density of the sludge coming to them, so if there was a tank delivering thicker sludge than another tank, the flow at that particular air lift was reduced, but in this case I see no difficulty over this.

141. Turning to the final tanks, looking at the layout, the question arises why not use rectangular tanks? It is necessary to have a large number of circular tanks,

and it seems that rectangular tanks would have made better use of the area. I appreciate the problem over scrapers, but rectangular tanks have been used on the continent, and it seems that this problem could be overcome.

142. I was pleased to see that the design of the old primary digestion tanks was adopted for the extension, and on the subject of the site, I would suggest to Mr Drake that he was fortunate that neither of the original sites was adopted, because it seems it was much easier to extend the plant where it was finally sited by a small reclamation from the river than it would have been to extend the plant at either of the original sites.

143. I should like some more details on the question of charging the tanks. I consider that the ideal set-up would be to have an electromagnetic flow meter connected to each individual tank with an integrator which could be pre-set with the charge appropriate to the tank. When charging started, the meter would click up the total, and when the right total was reached it would shut off.

144. I feel the structural design does not reflect quite the same advanced thinking as the sewage treatment side. We are probably being over-conservative on the number of expansion joints. The builders of overhead motorways are building sections of motorway over supports a thousand metres in length without expansion joints. Looking at the tanks on piles, it seems to be that the transverse joint across the primary sedimentation tanks, for example, could have been dispensed with.

Mr J. H. Potter, Port of London Authority

Improvement of the Beckton Works has been long overdue, due to many complicated reasons, including difficulty in getting money to invest in sewage treatment works immediately after the war. The involvement and co-operation of the GLC and the PLA in recognizing the danger at that time, and impressing the Ministry and the public of the need for improvements, set about the creation of new pollution control powers for the Port of London Authority, and I hope played no small part in persuading the general public of London that the expenditure of some £21 million was justified. This in itself was a vital part in setting the stage for the colossal design project such as has been described.

146. The value obtained from previous works has been considerable. The sedimentation channels were built in 1889, and the paddle sets and re-aeration channels were built in 1931. I wonder whether the present works will serve so long and so well. I agree that the life of materials need not be long if design techniques are likely to change.

147. The oxygen requirement of the effluent from the Beckton Works between 1966 and 1970 was an average of 265 t/day. That was three times as much as the next biggest discharge. In 1972 the polluting load was reduced to the equivalent of 200 t of oxygen, but the extended works described can cut this load by more than a half, we hope in the PLA, to a level of between 60 and 70 t of oxygen per day. The effect on the Thames will indeed be significant. At last we might reach a state where we are within sight of a situation where total polluting loads require slightly less oxygen than the atmosphere is capable of introducing through the air–water interface. So for the first time in 50 years we may have an oxygen credit balance.

148. However, the management level at which the works will be operated is equally important. A good operator can halve the design load or a poor one double it, and his conscientiousness and desire to achieve good results are as important as good design. I think in this particular design the GLC and its officers have involved everybody who will have an interest in the future operation of the works, and this will do a great deal to ensure its effectiveness.

149. The Pippard Report in 1961 suggested that the tidal flow of the Thames was such that the polluting significance of a particular load was halved for every 10 miles by which it was moved down river. It produced in my mind a very interesting point which I would put to the Authors. How much has the GLC been constrained by its

territorial limits in deciding where the works shall be built, and at what standard of treatment? London is paying a premium for being situated where it is on the Thames. In 1864 when the sewers were laid, it was in a desperate attempt to intercept drainage and remove it from the habitable area of the City of London. Since then, London has overtaken its outfall, and I wonder whether a suitable solution might not have been found to take the load further away from the doorstep of London economically.

Mr D. B. Sheppard, W. & C. French, Ltd

My company has had the privilege of being associated with the LCC and the GLC in a number of sewage treatment works projects apart from the one described in the Paper. It has also been responsible for the sludge digestion contract. The Paper and discussions are about the design of the works, and I hope that at a later date we shall have a Paper on the construction.

151. In § 7 of the Paper, the Authors refer to their intention to prepare working drawings prior to letting the contract. This they did, and the excellent detailed coverage which these original drawings have given to the constructional requirements has helped considerably. In my experience it is seldom one gets so much useful information so early on and both the contractors and the client have benefited.

152. However, I feel that savings in cost could have been achieved by the substitution of prefabricated standard units in lieu of some in situ work. Both Fig. 3 which shows the inlet works, and Fig. 5 showing the air lift arrangements, contain fairly complicated detail. I believe this could have been simplified, but it would have had to have been done at the design stage. Alterations during construction involve the question of responsibility. I favour a system by which more collaboration between the design office and the constructor at an early stage takes place.

153. In §§ 9 and 16, reference is made to the trial borings on which it was hoped to be able accurately to assess the length of piles. In the event, the data available was insufficient, and a certain amount of in situ lengthening and off-cutting were necessary. When one realizes that some 30 000 piles have been driven, I suggest an even more extensive pre-contract site investigation, including a number of test piles, would have been worth while. Perhaps 100 such piles could have been driven and many could have been of permanent use.

154. The Paper mentions in § 110 the part played in design by the Director of Mechanical and Electrical Services and the Architect. We have found on site that the system adopted has tended to produce varying standards of such things as tolerances, access requirements, finishes, quality of materials, etc. Divided responsibility for design inevitably produces site management problems. Would it not have been possible for design in all its aspects to be the responsbility of one department and of one engineer?

155. The contract called for part of the works to be put into operation before the whole was completed. This posed problems which would have been eliminated if the early commissioning work had been made a separate contract. This would have produced advantages, but undoubtedly there are good reasons why this was not done, and I should be interested to hear more of this. A long contract such as this, namely 66 months, is not really advantageous to either the client or the contractor.

Mr P. A. Banks, John Taylor & Sons

I should like to comment on the overall cost of the scheme. If we assume Mr Tricker's rough and ready division of the capacity as being enough plant for about two-thirds of the population, it brings the cost per head to about £10, which, even for a works of this size, is a commendably low figure.

157. I should like to ask whether rectangular final tanks were considered. The cogent arguments in favour of circular tanks are well known, but here tanks with

steeply sloping floors were not possible, and rectangular tanks might have been a possibility.

158. Mr Drake said there was no provision for dissolved oxygen control, although there was metering installed. I would be interested to hear why they decided that dissolved oxygen control was not to be installed initially, and whether it could be put in at a later date.

159. In § 48 there is a reference to the head loss from distribution through the works which implies that head loss has been kept down in order to equalize flow to individual tanks. I had always believed that it was desirable for head loss to be maximized for equal distribution, and so I would be glad if the Authors would elaborate on that.

160. The overflow weirs on the final tanks are similar to those used at Crossness, and no doubt experience there was taken into account in using these relatively complicated structures which have to be built into the tanks separately. I wonder whether the Authors would enlarge upon the experience that led them to stick to this type of weir?

161. One final point on piling; it is implied that a decision was made before the job started to use precast piles and not to provide an opportunity for tendering on any other basis. I wonder whether the GLC feel that their decision was right, and that their assessment of the cost was borne out in the tenders which came in?

Mr D. A. D. Reeve, Upper Tame Authority

Mr Tricker has commented upon the similarity of these primary tanks with some that were built at Minworth and put into operation two years ago. However, I do not think he is quite right. They are similar, although the Minworth tanks are slightly more shallow. Each unit on both plants is subdivided by a wall which seems to give a great deal of trouble. But at this point the design diverges considerably. For example, the Beckton tanks are fed over a rather shallow submerged weir. The Minworth tanks are fed through something like 24 vertical slots extending from above water level to the tank floor level in each half tank. This was done because it was thought that this approach would make the best possible use of the length of the tank for settlement, and it would allow heavier sludges to fall directly into the hoppers. I know that the extensions at Beckton are based largely upon the original ones, but it would be interesting to know whether the designers of the plant ever considered the use of these slotted inlets.

163. There is also a similarity in approach with respect to sludge storage capacity. I confess that this worries me. It arises in part only from the decision as to the frequency of discharge of the sludge from the hoppers. The adoption of de-sludging with the use of a narrow channel and very small sludge hopper suggests to me the acceptance of thinner sludge for withdrawal, but it is not so because the design implies a 4% solids content. At Minworth the withdrawal of sludge is carried out once daily, and the corresponding percentage is between 4 and 5. It contains humus and surplus activated sludge, although at Minworth humus sludge predominates and a degree of consolidation is achieved by having six hoppers per tank, with a hopper capacity of 775m^3. Such a design at Beckton would have produced quite serious structural problems.

164. The other important point on which I wish to comment concerns the use of closed circuit television for monitoring sludge withdrawal. I have no doubt that this will be just as successful at Beckton as it has proved to be at Minworth. However, the original installation was not a complete success and certain modifications have been made.

165. We have, for example, abandoned a system by which the camera was mounted on arms, and travelled up and down at the bell mouth. It is now fixed in position on the wall of the chamber. The reason was that the camera became splashed with

sludge, and the use of washing and wiping merely served to smear the sludge over the screen rather than clearing it, and there was a serious deterioration in monitor picture quality as a result. This splashing arose not so much from the discharge of the sludge over the bell mouth, but from the entrainment of air in the bell mouth discharge main. These conditions may not arise at Beckton, but in case they do, it might be of interest. It is not an insuperable problem to move the camera well away, and keep it fixed. The orginal lenses fitted were 25 mm lenses, and these have now been replaced by 15 mm f2·8 which are sufficient to give good definition over the whole range of bell mouth travel which is 7·5 m.

Mr E. A. Drew, Middle Lee Regional Drainage Scheme

I was interested to read that the PLA had agreed that the quality of the effluents from Beckton and Crossness Works should be assessed together, and should give a combined effluent complying with the Royal Commission standard. I should like to hear how this kind of formula works in practice.

167. It is probable that Beckton could now, without difficulty, produce a 10/20 effluent, and I feel that the design should have included provision for re-use of that effluent. If the Water Resources Board fail to notice that possibility, and I doubt it, is it not probable that Regional Water Authority No. 6 will have to consider it?

168. Provided there is no inhibition in the sewage, something of the order of 10% increase in air provision for the new secondary treatment would be adequate to produce full nitrification of the final effluent. This improvement in effluent quality will have far reaching effects not only on Works stability, but also on the dewatering characteristics of the digested sludge which in turn eases the disposal problem. In the latter case, I was pleased to learn that the GLC are now considering the use of sludge from Beckton in agriculture.

169. The next question concerns air supply for secondary treatment. What prompted the decision to operate activated sludge plants on the same works at different air pressures? Surely this must lead to inflexibility of operation? What effect will there be on the distribution of air throughout the new system when the air lifts for effluent disposal are in operation? We have already heard that some deterioration would be expected in air distribution to the plant. I would suggest that this is a grave design weakness. Why not have separate compressors for air lift duties? There is a statement in § 39 to the effect that local valves and meters for balancing and adjusting air distribution will be provided. From my experience, it is most desirable that the air system for a diffused air plant should, as far as practicable, have hydraulic symmetry. Attempting to adjust air distribution by valving is extremely difficult, if the object is to balance flows.

170. I should like to hear the Authors' comments on the means of controlling and/or dispersing any build-up of matted scum on the surface of the digesting sludge. Again, what prompted the choice of spiral heat exchangers for the digesters? There is extreme difficulty in clearing scale deposits on the sludge side in spiral tube exchangers, whereas with straight tube heat exchangers it is simple.

171. What means are there of achieving hydraulic symmetry on the gas side of the 32 digesters in order to prevent gas blowing from the skirt of the dome which has the least resistance?

Mr M. G. Healey, Department of the Environment

Two years ago I had the opportunity of having a look round Beckton while it was under construction. I was impressed by the standard of workmanship that was being achieved on this big and involved job. On that day there seemed to be two contractors working in parallel. One was doing one half of the works and the other was doing the other half, and they appeared to be competing with each other as to who could produce the best job. If that thesis can be substantiated, then it seems an

excellent arrangement to be adopted elsewhere. I would like to hear more about quality control on the job.

173. Nowhere in the Paper did I find a reference to dry weather flow. There are several references to average flow. I am aware of the limitations of dry weather flow as a parameter, but I am not convinced that average flow is any more informative. I should be grateful if the Authors would comment upon this, and they may reflect upon the Storm Overflow Committee who do not talk about average flow or dry weather flow but average dry weather flow!

174. Perhaps they will then explain why they decided to give full treatment to 2·4× average flow. It seems a curious figure to me. Looking at the Paper I noted that minimum flow is stated to be 0·4× average. It is not unusual on big works for the minimum flow to be half the dry weather flow. This might suggest that dry weather flow is 0·8 of the average. If this is the case at Beckton and they decide to treat 3× dry weather flow, it might suggest that they would give full treatment to 2·4× average flow.

175. I calculate from the Paper that there were 32 000 domes in a tank. The suggestion is that they have to be cleaned at intervals of from three to ten years. I was surprised to see the figure of 3, and I wonder where it came from? When it comes to the ten yearly cleaning time, it will be quite an undertaking. I wonder whether the designers were tempted to divide the tanks by extending incremental feed channels to make the operation that much easier? Could we hear more about the arrangements being planned for cleaning the domes?

176. Is it expected in the ten yearly operation to adjust the level of the domes? I noticed there was some 37 mm of adjustment on the domes, and I wonder whether any part of that 37 mm adjustment had been left to take account of differential settlement? Presumably when we talk about flexibility of the aeration system, we are not thinking in terms of differential settlement.

Mr K. J. Flemons, Sir Frederick Snow & Partners

The spacing of expansion joints in the rectangular tanks has been referred to in the Paper but could the Authors say what specification was issued for the spacing of the construction joints? In CP 2007, 0·15% of the steel is required in each face of the walls, although it is maintained by some bodies that experience has shown this to be inadequate unless the panels are very short, with contraction joints spaced about 2·5–3·0 m apart. The alternative suggestion is that the percentage of reinforcement should be increased to about 0·6% whereby the joints could be spaced at 4–5 m apart, which would lead to a reduction in cracking.

178. Mention was made, in respect of the circular tanks, that precautions were taken to avoid shinkage cracks which had occurred in the earlier structures. Could the authors say whether these precautions have been effective? Could they give some indication of the shrinkage which was encountered in the circular tanks?

179. On reading the Paper, I formed the impression that the sludge density meters referred to in § 23 had not been used because there was some degree of unreliability in the instrument. If this is the case, what range of variation was encountered, or is it correct to say that this was a problem related to the manual operation or reading of the meters? From their experience do the Authors feel that these meters could be successfully developed for determining the density of the sludge?

Mr C. Davis, Upper Tame Main Drainage Authority

One of the most difficult tasks which befalls the designer when drawing up proposals for new or extensions to existing sewage treatment works is the estimation of future trends in water consumption within the proposed drainage area in respect of increased usage by existing consumers, of new demands as a result of new development and changes resulting from major redevelopment. I note, from § 5, that in the design of

Beckton an increase of 1400 l/s or 12% has been allowed over the 1969–70 figures for sewage flow. Could the Authors explain the basis for this forecast?

181. The assessment of final effluent standards, as agreed for Crossness and Beckton, on the basis of the overall effects of several closely situated outfalls on a stretch of river, appears to be a more realistic approach to the problem than the more normal assessment of such outfalls in isolation. Could the Authors explain how this effluent standard is assessed; is it for instance based on individual samples of the two effluents or on average figures over a period of time?

182. With a retention time of 7·1 h in the aeration tanks, stated in § 33, do the Authors expect to achieve any nitrification?

183. It has been suggested that where nitrification occurs, problems of rising sludge in final separating tanks can be attributed in part to the practice of returning surplus activated sludge to the sedimentation tanks. Has there been any experience of this on the existing plant and was consideration given to methods of thickening the surplus activated sludge separately and then feeding direct to the digestion plant?

Mr James

Mr Tricker asked about the flexibility of the diffused air system in relation to alternatives. Decisions on the main treatment processes were taken in 1964 and there have been many developments in most forms of secondary treatment since then. We felt that changing conditions could best be catered for by the direct application of air with provision for metering and regulation both to individual tanks and to parts of tanks. We adopted the concept that Beckton was to be run as one works and not as a series of separate plants, and the existence of a large and successful diffused air plant weighed heavily. Even so, it is undoubtedly true that the limited area available severely restricted its design, e.g. had there been room we might well have used screw pumps for lifting returned sludge.

185. Much thought preceded the decision to use single pass aeration tanks. The saving on internal walls was considerable but initial mixing and distribution over the full width of the tanks became very important. We were reassured by the performance of the British Hydromechanics Research Association's scale model, but modifications were made to the mixing forebay design as a result of their experiments.

186. Concerning the layout of diffusers, we concluded that the simple uniform spread of diffusers over the whole floor could not be improved upon. The diffusers in each tank are in six blocks, each separately metered and controlled. Incremental feed of the settled sewage has been allowed for, although normally the plant would be operated with all settled sewage entering the mixing forebay with the returned activated sludge.

187. The design team had close co-operation and liaison with works managers at Beckton and Crossness and the experience gained has been invaluable. The performance of the existing primary sedimentation tanks has been excellent and they are a credit to their designer Mr D. H. Cassidy. No apology is made for making so few changes in the design of the new tanks.

188. Innovations made as a result of experience include better provision for scum removal on the primary tanks, scraper bridge rail fixing direct into concrete tank walls, monitoring and remote control of de-sludging using closed circuit television, single pass aeration and the use of uPVC for diffuser pipework, improved air lift design for both returned sludge and final effluent, separate streams in secondary treatment with final tanks associated with specific aeration tanks, full provision for metering and automatic sampling linked to rate of flow, remotely controlled compressors adjacent to the aeration tanks, and a water tower with twin tanks for town water and final effluent.

189. To some extent the Upper Tame MDA designers and those of the GLC have been working on parallel lines with contact at intervals but I think this is a case of great minds coming to similar conclusions!

190. The criticism sometimes levelled about building massive structures rather than shorter life units can be answered at Beckton; relatively expensive piled foundations are necessary for all structures on this site. Furthermore, if maintenance and the need for good safety standards are taken into account, temporary structures may well be no cheaper than permanent ones. The costs of temporary works associated with commissioning, and any subsequent change in the flow path, can also be high since the incoming sewage cannot be turned off, nor can it be diverted untreated to the river, save in the gravest emergency.

191. The approximate breakdown of costs is as follows:

	%	%
Earthworks	6	
Piling	13	
Riverwork	1	
Roadwork	1	
Pipework	7	
Structures	46	
Total civil engineering		74
Buildings		2
Mechanical and electrical		19
Diffused air equipment		5
		100

192. The new digestion plant is an extension of the existing plant but a new control station to serve all 32 digesters and the 4 dewatering tanks has been included. In general, the extension is a duplication but as a result of experience with the original plant, feed of raw sludge to all tanks is now metered and controlled in sets of four tanks whereas the original design relied on hydraulic symmetry. Automatic feed of a pre-selected volume of raw sludge to any four tanks is now a push-button operation. The original tanks cannot be completely scoured but provision for this has been made in the extensions. Although scum troubles have not been extensive, provision has been made in four of the new tanks for gas recirculation; this will be extended if found to be beneficial. Digestion is provided mainly to produce a less offensive and more amenable sludge which can be further dewatered; the gas is a useful by-product giving an alternative fuel thus avoiding dependence on power from the grid.

193. **Mr Horner** raised the question of whether or not the opportunity should have been taken to pump at the works inlet, by drawdown, and thus improve conditions in the outfall sewers. Certainly this would have provided adequate head through the works but it would involve the provision of pumping plant for maximum flow and continuous pumping instead of occasional short duration pumping of the effluent on the peak of the higher tides. The fact that plant already existed providing for 100% preliminary treatment, 50% primary treatment and 30% secondary treatment was a further complication.

194. The figure of 15% for sludge falling directly into the primary sedimentation tank troughs was deliberately conservative and was used as a check. We were concerned with storage capacity and the figure is on a volumetric basis.

195. Air requirements depend to a large extent on the use to which the final effluent is to be put and in 1964 this was not clear. Re-use of at least part of the effluent is in mind and nothing in the new works inhibits the provision of further treatment to any necessary standard.

196. Rectangular final tanks might well have been suitable and have occupied less space. However, they were untried for this purpose in 1964 and I would prefer to prove them on a smaller project.

197. I would endorse **Mr Potter**'s comment on the value of good operation. A

good works badly operated cannot do justice to the designer and, conversely, a less well designed works can be made to operate very efficiently by a dedicated manager. Throughout the design period we have had close liaison and co-operation with works managers.

198. I think the GLC is more constrained by history than territorial limits. Land is in short supply even downstream of London and the problems of conveying the sewage to a new site would be formidable. As it stands, the final effluent is well placed when considering re-use.

199. **Mr Shephard** would have liked to see more precast concrete used. We set out with the idea of using it wherever possible and hoped to have more than we finished up with. Piled foundations were among a number of factors restricting its use.

200. One can never have enough site investigation. Ninety bores were made but even if we had had 180 they would not have revealed all the facts. We relied to some extent on recent experience on adjoining land.

201. The use of several smaller contracts for the civil engineering work was considered. The most obvious way of dividing the work would have been by units of treatment processes but it would not then have been possible to commission any one of these until all were complete. If split into parallel streams, each contractor would have required identical sets of shuttering and so on and to some extent the advantage of scale would have been lost. It would also have been difficult to make sufficient land available for several civil engineering contractors.

202. **Mr Banks** referred to overall capital costs. These work out at about £12 a head if allowance is made for the fact that the preliminary treatment plant required no extension.

203. We investigated the justification of dissolved oxygen control in the aeration plant and came to the conclusion that, despite the large scale of the Beckton works, it might be only marginally advantageous. Therefore it is being installed in one tank initially and, if experience justifies its use, it can be added to the remainder.

204. The need to keep head losses to a minimum throughout the new treatment plant was due to the greatly lengthened flow path with no corresponding increase in the overall head between water levels in the incoming sewers and the river. With the 'in line' arrangement of the six final tanks to each aeration tank, minimizing the head loss also lessens the tendency to unequal distribution to the final tanks.

205. In deciding to use precast piles we took into account the relatively high sulphate content of the groundwater. The best defence against sulphate attack is good dense concrete which is more likely to be obtained consistently in precast work.

206. In reply to **Mr Reeve**, the primary sedimentation tank design was influenced by the existing plant which had proved remarkably efficient. The only significant change was in the scum removal arrangements. Beckton tanks tend to have large quantities of scum, possibly due to the pre-aeration.

207. Sludge storage in each tank consists of 436 m^3 in a 5·5 m wide by 1·5 m deep trough and of 27 m^3 in a hopper. The trough is swept continuously. By de-sludging on each of the three daily shifts and by improved control it is expected that the sludge solids content will be about 4%. There has been consultation with Upper Tame MDA on their experience with closed circuit television. However, local conditions at Birmingham are different. A unit on trial for six months at Beckton did not suffer from splashing. The de-sludging chambers are to be covered so that artificial light will always be used and the operator will not need to make adjustments to the cameras.

208. **Mr Drew** mentioned the possible re-use of final effluent. The GLC are to serve on a working party set up by the DOE to consider uses to which the treated effluent might be put.

209. If necessary, the air supply could be increased in the same proportion as retention time by adding a further stream of secondary treatment. There is a small

bonus in that the air supplied to the settled sewage channels to prevent settlement has not been included in the calculation.

210. The existing diffused air plant is supplied through trunk air mains by compressors in the powerhouse some distance away. To avoid large trunk mains, the compressors on the new plant are adjacent to the aeration tanks, thus there was no simple way of creating a common system. Furthermore, there were strong economic arguments for having shallower tanks and hence a lower air pressure if this could be done without detriment to oxygen transfer efficiency. Although both plants are of the diffused air type there are fundamental differences in several aspects of the design so that there was little point in striving to maintain the same air pressure. The air lifts for both activated sludge and final effluent are served from the air supply of the associated aeration plant. To have provided separate compressors solely for the occasional use of effluent lifting could not be justified, particularly when the peak condition of maximum rate of flow coinciding with a high spring tide would be an extremely rare occurrence.

211. The adjustment to air supply mentioned in the Paper is not to balance the supply between tanks but to reduce the supply to any of the six separate areas within each tank. This might be used in connexion with dissolved oxygen control if adopted.

212. Spiral heat exchangers were provided in the original sludge digestion tanks and considerable trouble was experienced with encrustation on the sludge side. However, after experimental work, double spirals with larger sludge passages were evolved and these, subject to an annual acid cleaning, have proved very satisfactory. They are considerably more economical in space than straight tube heat exchangers.

213. Mention has been made of hydraulic symmetry being used in the original tanks for raw sludge feed. It was also used in the design of gas draw-off pipework, with greater success than for raw sludge, and no trouble is experienced with gas blowing from dome skirts.

214. In answer to **Mr Healey**, it was decided to give full treatment to $3 \times$ flow of domestic sewage, plus $1{\cdot}1 \times$ trade effluent flow, plus $1{\cdot}0 \times$ infiltration flow in dry weather, the net result being to give full treatment to $2{\cdot}4 \times$ average daily flow.

215. It is not expected that domes at Beckton will need cleaning at intervals of less than ten years. However, at some of the GLC's works, where less emphasis has been placed on cleaning air, much more frequent dome cleaning has been necessary.

216. In reply to **Mr Davis**, the original requirement did not call for nitrification but it is likely that a high degree of nitrification will be obtained at least during the summer months.

217. There has been little trouble with rising sludge in the existing final tanks. Consideration is being given to separate thickening of surplus activated sludge, in the first instance at Crossness, with a view to improving the stability of operation.

Mr Shephard

In reply to **Mr Tricker**'s point about reducing the cost by using less massive structures, I assume he was not referring to the superstructures but to the sub-structures. I do not think they are unduly massive. Some are very long and wide. If one designs to CP2007 one is restricted as regards stresses, which automatically make members heavier than they would be in normal design, and the concrete cover and amount of reinforcement is due more to the reduced stresses.

219. **Mr Horner** raised the point about being over conservative in the matter of expansion joints. We have separated circular structures from culverts and channels from large tanks by means of joints. Whether or not joints in the primary sedimentation tank are really necessary is debatable. I feel that if one does not put a joint in and cracks occur, then one may be criticized. The worst conditions for temperature movement occur early on in their life when the tanks are empty.

220. With reference to **Mr Potter**'s remark that the life of materials need not be

too long if the design techniques are likely to change, that is a very subtle observation. We do not know whether design techniques will change. I was involved in the old paddle design in the 1930s and it is still working; it has not done too badly. I think the structures that are built now will last better if only because the gasworks now seem to have been largely demolished. This is a valid point because the fumes that were emitted from that gasworks had a terrible effect on concrete.

221. **Mr Sheppard**'s point about the production of working drawings prior to the contract is a good one. I think the GLC's drawings were wonderful. We, as reinforced concrete designers, would be informed that a drawing was ready for detailing. This would be a contract drawing, which had remained correct since its inception.

222. The question of prefabrication in lieu of in situ is difficult, because one does not know who the contractors will be, and sometimes if one arranges something in advance the contractors prefer to do it in situ, and vice versa.

223. Regarding trial borings, we should perhaps have done more site investigation.

224. **Mr Banks** raised the question as to why we selected precast piles. The Paper in fact refers to various other types of piles that were considered and were rejected for the reasons stated, see §§ 13–16 of the Paper. The Contractor was invited to offer a price for prestressed piles but it was not as favourable as the price for the pile we had designed.

225. **Mr Flemons** asked about the lengths between construction joints. These were specified not to exceed 30 ft. He suggests increasing the percentage of reinforcement, and I think that would help. I do not know whether I would double it, but there are shrinkage cracks in some of the walls and it might help to obviate them.

226. As to precautions against cracking in the circular tanks, I looked at them recently and I was particularly concerned about the possibility of cracks between the heaters and the tanks, because here there is a considerable temperature difference. I was pleased to see that the new tanks had not given any trouble. A very fine crack occurs around the tanks, just above the internal corbels, but on the whole there was an improvement in the new sludge tanks compared to the old, and we seem to have got rid of most of the vertical cracks in the walkways.

Reference

6. Water Pollution Research Laboratory. Technical Research Paper No. 11, 1965.