The extensions to the Davyhulme Sewage Works (1957–67)

G. L. SYMES

Mr J. G. Wiltshire, Kennedy and Donkin

My remarks apply particularly to the last part of the Paper which deals with power generation and the electricity supply and distribution systems.

98. The 6·6 kV system consists of a single bus-bar ring main divided into six sections, one being the power section located in the generating station. No 6·6 kV supplies are utilized in the Works and this voltage is reduced to 415 V by means of 12 appropriately rated transformers associated with the five distribution sections of the 6·6 kV ring main.

99. Approximately 50 major feeders are taken from the 415 V sections to group starter boards and other minor supplies throughout the Works.

100. The power for the ring main is provided by six engines of the Diesel Type each rated at 1225 kW, and originally it was intended that they should be charged with a mixture of heavy oil and digested gas from the works.

101. In the early stages before sufficient gas was obtained heavy oil alone was used to provide the power required and this phase was followed by a short period of operation with heavy oil and gas. Subsequently, as stated by the Author, for reasons of economy, light oil and gas were used and this practice has been continued to the present time. Consequently, authoritative performance figures using light oil are not readily to hand.

102. The normal load on the generating plant under present operating conditions is a continuous one ranging from 2000 to 2500 kW over twenty-four hours as shown in Fig. 7.

103. The average production of gas from the Works is approximately 500 000 cu. ft/day at NTP and this when supplied to the engines, together with the appropriate quantity of oil, is sufficient to keep two engines running at approximately 60% full load.

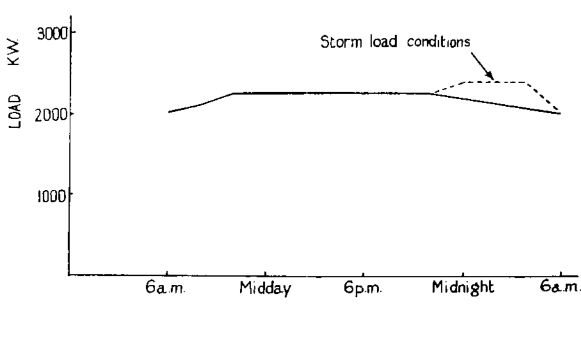

Fig. 7

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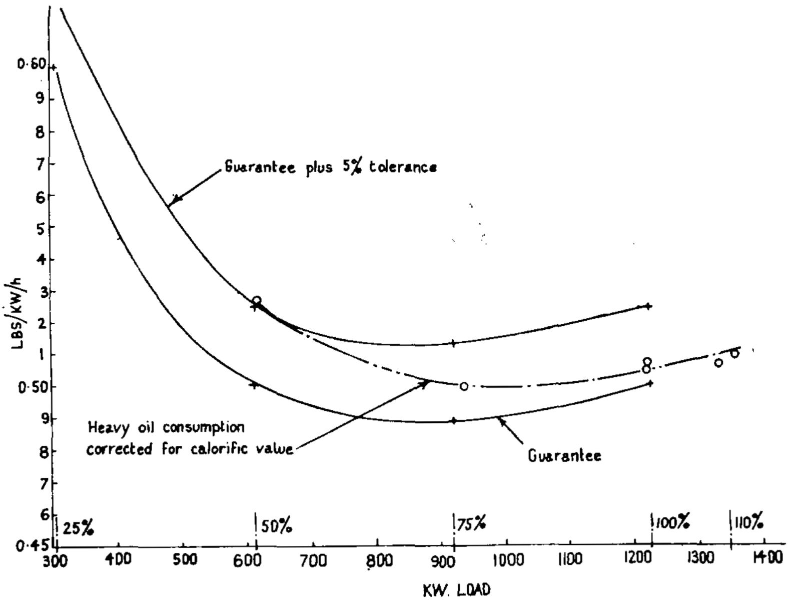
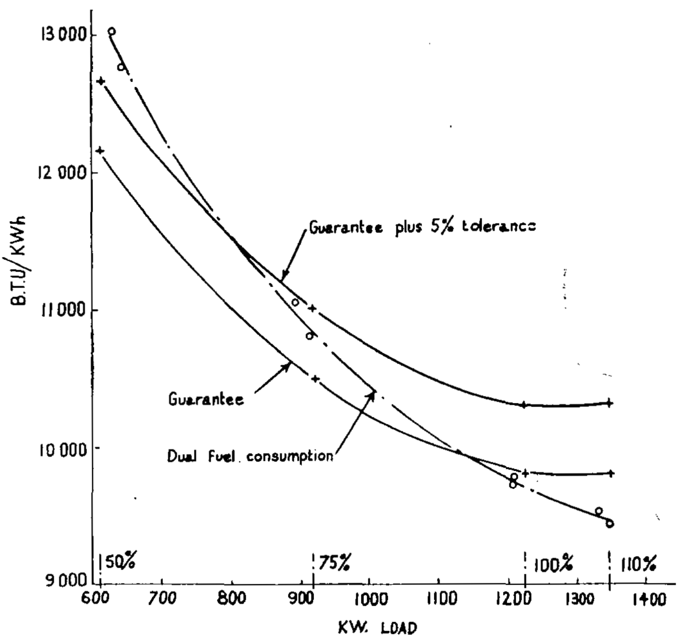


Guarantee plus 5% tolerance
Heavy oil consumption corrected for calorific value
Guarantee
LBS/KW/h
0·60
0·50
0·45
25%
50%
75%
100%
110%
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
KW. LOAD

Fig. 8



Guarantee plus 5% tolerance
Guarantee
Dual fuel consumption
B.T.U/KWh
13 000
12 000
11 000
10 000
9 000
50%
75%
100%
110%
600
700
800
900
1000
1100
1200
1300
1400
KW. LOAD

Fig. 9

104. Performance tests were made on the engines and it was established that a heat rate of 8860 BTU/kWh or an efficiency of 38·4% could be obtained at 100% load when charging with heavy oil.

105. Operation with heavy oil and gas produced a heat rate also at 100% load of 9749 BTU/kWh equivalent to an efficiency of 35%.

106. The proportion of heat input to the engine by oil to that by gas from the Works is approximately

$$\frac{\text{Oil}}{\text{Gas}} = \frac{14\%}{86\%}$$

107. Figure 8 shows the performance curve, from 25% to 110% load, of an engine running on heavy oil alone.

108. At 100% load the consumption of 0·505 lb/kWh (shown) coupled with calorific value of 17 550 BTU/lb produces the heat rate figure of 8860 BTU/kWh previously quoted.

109. Figure 9 shows the consumption from 50% to 110% load of the same engine running on heavy oil and gas.

110. At 100% load the consumption of 9749 BTU/kWh (shown) is coupled with a calorific value of 17 550 BTU/lb for oil and of 595 BTU/cu. ft at NTP for gas.

111. It is clear from these results that the use of gas reduces the full load efficiency by approximately 10%.

112. Heating for process throughout the Works is provided by a hot water system the heat being obtained, in the main, by the recovery of the heat rejected by the engines in the generating station. This amounts to approximately 10 million BTU/h.

113. At the beginning of the work consideration was given to the possibility of controlling the operation of the whole sewage system from a centralized control room. This was not included in the works as decentralized control was preferred not only for operational purposes but also in relation to the safety of personnel.

Mr R. W. Horner, Department of Public Health Engineering, Greater London Council

The design of the storm tanks is particularly interesting. The cross flow arrangement struck me as being a very good solution to the site problem. This gives long straight runs for the scrapers by running them along the tanks, whereas the flow is across the tanks, giving low velocities. Judging by the results—60 ppm to the Canal—the performance seems excellent.

115. To supplement the basic information, I wonder if Mr Symes could give figures for the contributory population, as this is a useful yardstick in giving an idea of the load on the plant.

116. In the London area the same problem of screenings as mentioned by Mr Symes is experienced with a combined system of sewers. Following even a moderate storm after a long spell of dry weather, large quantities arrive at the works at a high rate. This occurs on the south side of the river at Crossness to a greater extent than on the north side at Beckton. I have attributed this partly to the fact that screening is before the detritus channels at Crossness and after them at Beckton. When sited before the screens, the detritus channels intercept a proportion of the screenings, which can give trouble for the detritus pumps although this makes life easier for the screens. I agree with Mr Symes in his solution, that of not using disintegrators, which tend to be overtaxed in the circumstances, but discharging screenings straight to the ship. The high peak rate at which the screenings arrive causes the problem. It is almost certainly due to the screenings getting stranded in a combined system during the dry weather. Large quantities are then carried away in the first storm flow, leading to problems at the screening plant.

117. The point about the length of the detritus channels is interesting. Long detritus channels provide a very useful insurance against grit going forward, and causing trouble further on.

118. I would be interested to hear the evidence that the grit is going forward at the Davyhulme plant. Presumably it is deposited along the whole length of the channel, and this presupposes that some must have gone forward. No doubt there has also been other evidence.

119. Considering the primary sludge sedimentation tanks, I should like to know the capacity of the hoppers. Assuming that they might be conical, I get a low figure of 176 000 gallons. I am sure that it must be more than this, as this would be a surprisingly small amount of sludge per day. I was trying to get at the loading of the digestors, and I would be interested in the figures.

120. The aeration drive arrangements are interesting, and I wonder whether consideration was given to a means of adjusting the levels of individual drive units. It is difficult with line shafting, but it has attractions from the operational point of view. The distribution of dissolved oxygen through the aeration plant is rather complex, and it would be useful if it could be varied at individual pockets, to suit operating conditions. To arrange this probably means individual motors.

121. The horsepower to the cones, which I make to be about 50 hp/mgd, seems to be generous. I am not so happy about three hours' detention in the aeration plant. I am sure that the required results can be achieved with this detention period, but it does not give any margin for future loads. If a longer period is provided, when the load increases a little more quickly than expected, more horsepower can be provided and the plant will still go on quite happily.

122. With the digestion plant, I am surprised at the low gas production figure of 500 000 cu. ft/day, although without the population figure one cannot really comment. The proportions of the tanks call for some observation, as in London we have generally provided rather shallower tanks which give a better surface area/volume ratio. The 500 000 cu. ft/day gives only 20 cu. ft/sq. ft which is satisfactory, but with a production of, say, 1 million cu. ft per day, which could be expected from a plant of this capacity, the surface loading would be high.

123. I agree with the preliminary remarks about simple mechanization and keeping automation simple. The long weir is a good example, it does not give any trouble and is attractive compared with the automatic penstock that may go wrong at a particularly critical time.

124. It is very interesting that with the castellated weir Mr Symes is getting the same discharge as with a straight weir. It has considerable possibilities in saving space.

125. The 7% sludge discharged from the secondary thickening tanks to the ship seems to be excellent. The remark that with a greater quantity of surplus activated sludge this figure is beginning to fall is significant. 7% with a full proportion of surplus activated sludge is remarkable all the same. We do not get as high figures in London and I would be interested to know the detention period in the thickening tank.

126. In the final tanks, I think the high quality of the effluent is attributable to some extent to the provision of the launder some distance from the side of the tank. There is a tendency for activated sludge to rise up the side wall of the tank and to flow over a weir sited at the outer circumference.

Mr L. H. Thompson

It is now 6½ years since I left Manchester after working with Mr Symes for four years on sections of the Davyhulme extension. I congratulate him on producing a very informative Paper, with many interesting facts and figures and details of many excellent design features.

128. The main difficulty in compiling a paper covering work of this variety costing over £6 million and taking more than ten years to construct must have been what to leave out. Nevertheless, my major criticism is that no performance results are given so far as I can see. Mr Symes has also left us uninformed about the effluent standards

that are required by the Mersey and Weaver River Authority, with which the works were designed to comply.

129. The design and construction are not ends in themselves. No matter how well a sewage works is built, it is how well that structure and its associated plant perform that matters, and that should be the principal criterion for appreciating the value of the design and construction.

130. While I realize that a separate department at Manchester has responsibility for operational matters, I feel that the value of the Paper would have been enormously enhanced had some information been given. Even allowing for the very special nature of the sewage at Manchester, the advantages of certain features of the design described in the Paper would have been more apparent.

131. I am pleased to note that in § 63 the Author makes it clear, in spite of what has been said in § 52, that no attempt is being made to produce a nitrified effluent—and the three-hour detention period in the plant then appears sufficient. The co-operative attitude of the River Authority is fortunate and sensible. I have heard it suggested that the detention period that would be required for a fully nitrified effluent would be about 72 h. I am sure that the Author will agree that a detention period of anything like three hours is unlikely to be adequate for producing a stable effluent and that perhaps some of the design criteria found suitable for the very special Manchester conditions are not likely to have application elsewhere.

132. Finally, I should like to ask Mr Symes two questions about the storm water tanks, of which he is rightly proud. First, what criterion was adopted for assessing the size of the sludge hoppers? Second, if, as I understand, one tank overflows to the next along the whole length of the tank, does he feel that there would be any advantage, such as in reducing short circuiting, by having the overflow limited to a section of the tank furthest away from the inlet to that particular tank?

Mr D. A. H. Everett, Borough Engineer's Department, Croydon

My first thoughts on reading the Paper were of disappointment. I would subscribe to the remarks by Mr Thompson about the lack of information concerning the standard that has to be met. Perhaps the Author would elaborate on such things as sewage characteristics and the sort of standard that he is attempting to obtain to comply with the River Board's requirements and how successful the actual plant has been in that respect.

134. My next comment is a more general one. In every paper that we have had for some time on new sewage works, I find it depressing to discover that the works are already overloaded before we put the sewage in.

135. I was particularly interested to read about the Author's experience with the screens. Some years ago I had a similar experience at another works, not of the authority which I now serve, and I recommended that the coarse screens should be dispensed with. I left the authority shortly afterwards, and I believe that it is still struggling with those coarse screens today.

136. I find it a little surprising that even with two sets of fine screens in series apparently only some 65% or thereabouts of total screenings was retained on the first screen. Were there any particular differences between the types of screen? Is the channel narrower or wider for either screen? Also, can the Author give us an indication of the actual volumes of screenings per 1 million gallons?

137. On the storm tanks, I found this design of storm tank most interesting and perhaps unusual. I should like to ask whether from the point of view of operation there has been any difficulty in the removal of sludge in the first tank. It would appear that one would have a large build-up of sludge on the floor of the first tank, and it seems to me that it would probably be impossible to run a scraper for the full length of the tank at one go. What is the depth of the sludge blade?

138. Developing this a little further, with such a long tank if the machine has to make two or three partial passes in order to clear the floor of the tank, the length of

the tank combined with the speed of operation suggests that it will be very many hours before desludging can be completed and a good many hours after that before the tank is finally emptied.

139. I should like to know whether the horizontally mounted side wheels on the bridge scraper are quite effective in preventing crabbing. Perhaps the Author could give us the effective wheel base of the steadying wheels.

140. With regard to the primary sedimentation tanks, I am at present putting in circular sedimentation tanks at Croydon with picket fence thickeners and a simple sludge well. These picket fence thickeners are contra-rotated to the main bridge and scraper and are capable of varying speeds of rotation by means of a gearbox. Would the Author elaborate a little further on the design of his picket fence thickener?

141. With regard to § 44 dealing with sludge withdrawal, what is the frequency of sludge withdrawal, and has this proved entirely effective? One can imagine that with the timer set for daytime withdrawal only one could keep the sludge reasonably respectable, but that if it was set on the basis of withdrawal at any time of the day or night one might be drawing considerable volumes of water.

142. With regard to the aeration plant, I wonder whether any consideration was given to variable speed drive to the aeration cones, and, further, whether any form of automatic or semi-automatic control by means of Redox or dissolved oxygen was considered.

143. There is an oblique reference in § 55 to ½ dwf recirculation, which I should be grateful if the Author could clarify.

144. In § 58 on the final tanks, the Author refers to these as upward flow units. Looking at the figure, one would feel that they are more truly radial flow. The Author said that the tanks functioned satisfactorily unless overloaded. This tank is very nearly a flat floor tank, and I have found in the past that this type of tank will act satisfactorily up to about a rate of 1½ dwf and that at rates much in excess of this there is a tendency for the sludge blanket to rise and to lose a large volume of solids over the final weir.

145. My last comment is on § 84. It seems a little unfortunate that, having been caught once, the contractor or the engineer—I do not know which—was very quickly caught a second time. Perhaps the moral here is that when demolishing units one should demolish them in their entirety and not attempt to build on old floors.

Mr J. E. James, Greater London Council

The Author's views on the maximum practical size of circular sedimentation tanks would be appreciated as the 146 ft dia. primary tanks at Davyhulme would appear to be approaching this limit. The overflow rate at the weir could become very irregular due to the effects of wind on large tanks on an open site. Efficient scum removal is usually more difficult to achieve in circular than in rectangular tanks, and in the case of the former it is desirable to have the scum trough to leeward of the prevailing wind. Presumably there are also arrangements for scum removal from the pre-aeration channels or at some other point upstream of the sedimentation tanks.

147. It would be interesting to know if pre-aeration was regarded as part of the treatment process as well as a means of keeping solids in suspension. The latter purpose could perhaps have been achieved more economically by extending the twin self-cleansing culverts to the primary sedimentation tanks.

148. Aerating the final effluent might be regarded as river treatment rather than sewage treatment, and it could be argued that the channel capacity and power would be more profitably used in the aeration plant where the 3·5 h detention period at dry weather flow seems low. Perhaps the Author could indicate if such an alternative was discussed with the River Authority. The anti-foam oil distribution system is very effective, particularly if the low rate of application at 1 ppm includes oil used in the final effluent channel. Perhaps there is less objection to foam being discharged to the Manchester Ship Canal than to most rivers.

Mr H. C. Balfour, B. Balfour & Sons

I am particularly interested in the method of sludge treatment, primary digestion, secondary consolidation and dewatering and transport to sea. I was a little disappointed that more information was not given in the Paper on the decision to digest the sludge before transporting it to sea. Could the Author give more facts about this, and is there any possibility of having some figures dealing with the economics of it?

Mr A. L. Percy, Borough Engineer, Huddersfield

I should like to refer to the question of uplift. In some of the tanks to which Mr Symes has referred stringent precautions were taken to prevent troubles with the floors, but in the storm water tanks there did not seem to be any precautions, though these would seem to be the most likely to shift. I wonder whether Mr Symes would enlarge on this.

151. In regard to the primary sedimentation tanks, Mr Symes refers to the arrangements for allowing ground water to enter the sludge well. Are these pipes capable of letting the water in as quickly as you can draw water off from the tanks through the normal outlet? If not, how do you know when to stop lowering the tanks?

152. I am glad that in § 26 Mr Symes tells us the arrangements made for the diversion. These practical problems are often quite difficult to overcome. I remember being told many years ago of the troubles encountered when the Leeds Sewage Works was built by Mr Hart in the early 1920s. Large new works were built with an 8 ft or 10 ft connexion from the existing outfall sewer, but the question was how to make the actual junction between the old sewer and the new works. Those concerned held a conference on the works without coming to any conclusion, and went home that night to think it over. When they came back in the morning the foreman said, 'You need not worry. I have done it.' He had put some charges on the earth side of the old sewer wall and blown the side in!

153. This was not able to be closely inspected for a great many years—not, in fact, until a few years ago, when a collapse on the sewer a little further up stopped the flow. We found then that the explosion arranged by the foreman had made quite a good job.

Mr M. G. Healey, Borough Engineer's Department, Croydon

May I have some information about the very long walls, 846 ft long, of the storm sewage tanks? What type of joint was provided and at what spacing? Likewise, what provision was made in the floor screed of these tanks?

155. Mr James has touched on the matter of pre-aeration. There is a cryptic sentence in § 36: 'The cones keep the solids in suspension and some flocculation takes place'. Were these in fact design criteria?

156. Finally, with regard to sludge pumping mentioned in § 44, there are provided two centrifugal pumps and one ram pump. It seems that sewage engineers are confident that centrifugal pumps are capable of handling raw and digested sludges but they so often provide a ram pump just in case they cannot. What has been the experience with these pumps?

Mr J. P. Bamber, Assistant City Engineer, Manchester

I came to the meeting not with the intention of speaking, but merely to support my colleague, Mr Symes.

158. I am a little too close to the job to discuss any of the technical details, but I should like to make two points. First, I find it refreshing that in a Paper like this Mr Symes has made no attempt to conceal the difficulties in construction, nor what he may now feel are inadequacies of design. He has told you that there were a number of things which, if he had to do them again, he would do differently, and I think it is very nice to hear this.

159. Secondly, I should like to take up the point that Mr Thompson mentioned, that of maintenance. No matter what we do as civil engineers to build a works, all our efforts will be nullified if we do not have the co-operation of those who have to maintain and operate the works after it is constructed.

Mr G. C. Cox, *Beddington Sewage Treatment Works Reconstruction*

I should like to get a little more information from Mr Symes about the screeds that he mentioned in regard to the triple scrapers. He said that the triple scrapers were put down and then they were used to place the screed. I should like to know what area of screed he placed at any one time to avoid straining the mechanism. Were any special measures taken to stick the screed to the parent concrete, and has there been any subsequent failure of the screed in lifting or cracking?

161. There is another question concerning the number of different pump and electrical manufacturers employed. Is there any difficulty in maintenance which might have been avoided with a rationalization of supplier?

Mr R. J. Owens, John Taylor & Sons

I should like to ask one question on a subject which is mentioned briefly in § 65. It refers to the decision to proceed with the excavation and the piling work, followed by what is described as the detailed design.

163. How successful was this in view of the fact that the main work was carried out as a series of contracts rather than one major contract? Were there any problems associated with piles driven before starting the detailed design?

Mr R. C. Ramsay, John Taylor & Sons

I should like to know whether the extensions that Mr Symes is putting in will be based on an aeration period similar to that for the present plant or whether the intention is to increase the detention period in the aeration tanks. It seems to me that we have here aeration tanks which at dry weather flow provide a period of three hours under aeration, whereas on average the sludge will be in the final tanks for about five hours without any aeration. I wonder whether any ill effects have been noticed because of this relatively long period in the final tanks away from any oxygenation.

Written contribution:

Mr B. Kaul, Grant, Lyon & Co. Ltd

I should like to congratulate the Author on giving us a detailed description of Davyhulme Works. It was of particular interest to me, having worked as a Contractor's Engineer on part of the Works.

166. In § 8, the Author gives the maximum capacity of combined sewers as 8 × dwf, a relatively high figure compared to six times at Bristol.[2] What is the design population on which the Author has based his figures?

167. From § 70, I find that the walls of sludge digestion tanks are post-stressed but not the floors; the reason behind this would be interesting. Construction is my main interest but I find that such tanks are built to different proportions. Why was there such a big difference between the practice in this country and that in Germany, for example, where they tend to have them like elongated eggs. The latter, no doubt, was expensive but was it the right approach to the design of sludge design tanks?

168. With regard to the floors, did their construction produce crack-free and watertight concrete? Casting the floors of circular tanks was a difficult problem.

169. Did the Author reach any general conclusion regarding the relationship between expansion and construction joints in long straight walls and the frequency of their spacing? Did he favour the use of water bars at all construction joints in water retaining structures? Alternate bay or gap procedure, as favoured by some engineers,

could be a controversial subject on a contract and considerable expense was involved either to the authority or the contractor. Both methods caused disruption of logical sequences of shuttering, pouring and stripping, and depending on the time lag allowed, there were always follow up delays and increased difficulty of access for plant for subsequent filling. If gaps were incorporated, they are invariably difficult to clean.

170. In view of the wide divergence of practice among engineers, it would be interesting to know whether the position and type of all construction joints was fully specified or whether it was left to the contractor's discretion?

171. In § 54 the Author mentions ten miles of nylon tubing to carry anti-foam oil. Would the Author favour legislation to prevent sale of detergent containing foaming agents, hence obviating the need for costly and not fully effective oil pipelines for foam suppression?

172. The final cost of £6·2 million, excluding the staff costs, for the treatment plant represented a rather high figure per million gallon handled. Could the Author give an idea of the cost of sewage disposal/week/head of the population? Were the costs given in the Paper based on the tender figures or did they include the final cost of the extensions including claims, extras, etc?

Mr Symes

I may have misled Mr Wiltshire in § 92. Heavy oil is normally more economic than light oil, but when it became necessary, for reasons of air pollution, to switch to a low sulphur oil, heavy oil, complying with this requirement could not be obtained economically.

174. In reply to Mr Horner, the present population is about 835 000. In addition, Davyhulme receives about 24 mgd trade waste.

175. The problem of screenings accumulating in sewers is, I feel, largely a matter of gradient. As mentioned in § 13, the main inlet sewers have their gradient reduced by being backed up and a scheme is under consideration to install a screw pump in conjunction with a penstock in the main inlet channel to lift the flow and draw the sewers down to their natural depth of flow. If the flow were pumped until the rate reached 100 mgd and the penstock were then opened, the velocity of flow would be high enough to keep the screenings and the grit moving.

176. I have found that in the main inlet sewers not only the grit, but also the vast majority of the screenings, are carried by rolling along the bottom of the sewers. This may be due to the length of time the screenings are in the sewerage system. I think it would be useful if some research could be done on this subject, as it might have a bearing on the design of storm water overflows. Incidentally, screenings are not discharged to the ship because of the possibility of a floating nuisance.

177. The grit channels should certainly be longer—that grit is carried forward is evidenced by deposits in the pre-aeration channels and in the storm tanks.

178. The capacity of the hoppers in the primary tanks is about 70 000 gallons—a little more than a day's make of sludge.

179. I think it is a good idea to have means of adjusting individual cone levels in the aeration plant and this is to be incorporated in the next extensions, where each cone will have its own motor. This outlet weir will then be fixed.

180. Gas production at Davyhulme is inhibited by trade waste and barely exceeds 500 000 cu. ft/day. There is no evidence of foaming or scum formation. No doubt the three screw pumps on each digester help with this problem.

181. At present the sludge discharged from the secondary tanks has a solids content of between 8 and 9% but, because the final effluent has a BOD of about 50 ppm, the sludge does not contain a full proportion of activated sludge. Factors which assist in thickening are the cooling effect of the sludge to sludge heat exchangers and the mixing of digested and raw sludge. The arrangements for draining off water from the thickening tanks work well.

182. In reply to Mr Thompson, the Mersey and Weaver River Authority require the normal 20/30 standard. Methylene Blue stability and nitrification are not required but oxygen is added by final aeration. Even with a 72 h aeration period experimental evidence shows that nitrification is not possible. In fact, the only way to get nitrates in the final effluent is to tip them in from a sack. At present, because the old works is being demolished and the new units have to take the full dry weather flow of 68 mgd, the standard has been relaxed to 100/100. The effluent actually produced is about a 50/50 standard.

183. I felt it could be misleading to give operational figures as the plant has never worked without overloading.

184. I agree with Mr Thompson that design criteria suitable for Manchester are not likely to be applicable elsewhere.

185. The storm tank hoppers were designed to take the sludge settled from an average storm. With regard to the weir arrangement, I think it is advantageous to use the full length of the tank so that the depth of flow over the weirs is kept to a minimum.

186. In reply to Mr Everett, the width of channel at the primary screens is 6 ft compared with 8 ft at the secondary screens. Apart from this the screens are identical. The greater velocity at the primary screens will tend to force more screenings through.

187. The weight of dry screenings varies between 5 and 65 lb of dry solids per million gallons, which emphasizes the trouble experienced in storm time.

188. With regard to the storm tanks, the majority of the sludge is, of course, deposited in the first tank of each series and these two tanks are swept in several partial passes. The other four tanks can usually be swept with one pass. The depth of the sludge blade is 2 ft.

189. The wheel base of the side wheels on the storm tank bridge is 16 ft and this is effective in preventing crabbing.

190. The picket fence thickeners in the primary tanks are contra-rotated to the main bridge and rotate at twice the speed. Originally the scrapers at the bottom were hinged but it has been found better to fix them rigidly.

191. Sludge is withdrawn from the primary tanks once a day.

192. Consideration was given to the use of variable speed motors on the aeration plant but it was decided that the additional cost outweighed the advantages. Automatic control was considered and rejected because at that time the reliability of equipment available was doubtful. In my opinion it still is.

193. Recirculation is occasionally used in times of very low night flow to keep up the velocities in the various channels and culverts. The same pumping system is used to empty the storm tanks to the aeration plant.

194. Referring to the secondary sludge tanks, we were, as Mr Everett points out, caught twice. However, the final settlement tanks could not have been constructed without lowering the ground water table, so the second time was unavoidable. In fact, had the condition of the ground below the old tanks been known, the secondary sludge tanks would undoubtedly have been built on piles and it is likely that the expense of this would have exceeded the cost of the remedial works. Perhaps in this case it would have been 'folly to be wise'.

195. Mr James asked for my views on the maximum practical size of circular sedimentation tanks. I think the location of a site with regard to winds might influence this. At Davyhulme the 146 ft dia. tanks are satisfactory and two 156 ft dia. tanks are to be built in the next stage. In fixing the positions for scum removal, account must be taken of the direction of the prevailing wind.

196. Pre-aeration does lead to a slight decrease in the strength of the sewage and appears to improve the treatability of septic sewage. It also keeps the solids in suspension.

197. Final aeration was discussed with the River Authority and in the next stage

of the works it has been agreed that the extra power will be utilized in the main aeration units.

198. Mr Balfour queried the economics of digesting sludge before transporting it to sea. As explained in § 68, it is necessary to digest some of the sludge so that it can be pumped to Flixton if the ships are held up. I think that there is little, if any, economic advantage in digestion of the Manchester sludge.

199. In reply to Mr Percy, the ground water level is below the floor of the storm tanks. On the primary sedimentation tanks the pipes reduce the uplift pressure satisfactorily and no difficulties have been experienced.

200. In reply to Mr Healey, the walls of the storm tanks were cast without contraction or expansion joints. The floors were cast in 20 ft square panels, the joints being formed with Korkpak and a hot poured rubberized bitumen.

201. I agree that centrifugal pumps can handle sludge provided that the suction is drowned and the sludge is not too thick, but occasionally a sludge line becomes blocked and then a ram pump is essential.

202. I may have misled Mr Cox about the screeds on the final tanks. The scrapers were used to set the screed boards. The surface was roughened before laying the screed which has so far shown no sign of lifting or cracking.

203. The pumps supplied by different manufacturers are for basically different duties and even had they been all of one manufacture, few, if any, of the spares would have been interchangeable.

204. Mr Owens queried the decision to proceed with the excavation and piling before the detailed design had been completed. The design was sufficiently advanced to fix the pile loads and positions and the detailed design of superstructure; the bending schedules and the bills of quantities were done during the piling period. In this way 12 months were saved and the total cost was probably lower than if all the work had been carried out under one contract.

205. In reply to Mr Ramsay the aeration plant in the next extensions will have a detention period of 5 h, but, because 6 mgd of trade waste, with an average BOD of 1300 ppm, will be brought to this plant by a separate pipeline, the BOD per unit volume will be much greater in this plant.

206. In the final tanks the triple scrapers enable the sludge to be removed quickly and sludge does not rise.

207. I have already given the population figures and in reply to Mr Kaul the River Authority in this area now require 8 × dwf to be carried to the works.

208. The walls of the digesters are hinged at the base and stressing of the floors is not necessary. The only difficulty with the construction of the floors was forming a watertight joint between pours.

209. The 840 ft long storm tank walls were constructed without expansion joints and are quite satisfactory. I do not favour the use of waterstops at construction joints as I find that the difficulty of compacting concrete against them often causes more trouble than they cure. The position of construction joints was agreed with the contractor on site. I do not think it good practice to define all construction joints at the tender stage as it may restrict the contractor in his method of working.

210. Detergent manufacturers have already co-operated and are producing detergents which are more readily biodegradable than formerly. The short aeration period at Davyhulme accentuates the foaming problem.

211. I would not have thought that the cost of £6·2 million was high. Although the new primary tanks and aeration plant are designed for a dwf of 45 mgd most of the rest of the works is designed for 82 mgd.

Reference

2. STEEL P. H. The Bristol regional foul water drainage scheme. *Proc. Instn civ. Engrs*, 1967, **38** (Dec.) 595–620.