Southern Outfall Works of the London County Council

by

E. H. Vick, M.I.C.E.,

J. G. Paterson, M.I.C.E.,

L. B. Escritt, A.M.I.C.E.,

V. F. Cornish, B.Sc.(Eng.)

and

W. C. Andrews, O.B.E., M.I.C.E.

Mr H. D. Manning (Partner, J. D. & D. M. Watson) said that he would limit his remarks to points of detail.

137. It would be interesting to know the standard of purity of effluent at which the designers were aiming and he wondered whether they had been engaged long enough to be able to tell what they were, in fact, producing.

138. They had been given a great many dates at the beginning of the Paper but over the last 60 years only one date was mentioned. One gathered that a very considerable amount of progress had been concentrated in the last six years of that period.

139. In § 13 there seemed to be some duplication in the screen house, which was pressurized, presumably to prevent any odour problems arising, but he found it rather surprising that the head part of the screens was enclosed in fibre glass boxes. Another example was in the arrangements for the electricity supply where both duplicate cables from the power station and a direct feeder from the grid were provided.

140. Could the Authors develop their reasons for the choice of Simplex aeration plant? This appeared to rest primarily on the fact that a few hours' stoppage did not matter with that type of plant but could the Authors tell them something of the economic comparisons and relative efficiencies. In this connexion, in regard to the aeration tanks, reference was made in the Paper to the usual arrangements for incremental feed. He wondered whether the Authors had considered that tapered aeration might be needed at some stage of development. Could this be achieved with this type of plant?

141. With regard to § 15, he wondered whether the Authors could elucidate what was meant by: 'these pumps, delivering from low-level to high-level, are provided primarily for the purpose of trimming the flow so as to give a true measure of discharge to the treatment works'. This particular sentence was a little obscure to him.

142. He wished to refer to a construction point—the precast weirs suspended on cantilevers. Reference was made in the Paper to some difficulty in placing these weirs accurately. He wondered what tolerances of accuracy for the work were set for level and what tolerance was in practice achieved.

Mr W. L. Kent (Director, W. & C. French Ltd) said that members might be interested to have more details of certain aspects of Part III of the Paper from the Contractors' point of view.

144. Conditions had to a large extent dictated many of the methods and processes involved in the construction of the works. After the general excavation had been completed, a comprehensive network of reinforced concrete temporary roads was laid out approximately on the lines of the final road system. Those roads were quite adequate during the period when the silt was in a state of moisture deficiency, but once the point of equilibrium was passed, many of the slabs failed. The heavy machinery moving around the site to carry out the following operations caused the underlying silt to ooze through the slabs, and the roads gradually sank.

145. Towards the end of the contract period when culverts were excavated across the line of many of the roads, the original cracks and broken slabs were found to be at an average of about 4 ft below the surface. In one heavily-rutted road through the centre of the site the slab was over 8 ft deep. The roads were kept open by maintenance gangs constantly laying hardcore and consolidating this throughout the winter periods. Approximately 100 000 cubic yards of hardcore were imported in order to keep access open to all parts of the site.

146. These conditions had caused a change in the predetermined methods of construction. As had been stated in the Paper, the system of delivering concrete by conveyor from the main batching plants had had to be abandoned because of the difficulties in delivering a consistent mix at the point of placing. The difficulties experienced could most likely have been overcome by modification of the plant, but due to programme requirements and site conditions, it was considered more expedient to remove the conveyors and to introduce concrete pumps for which pipelines could be laid across the site without the concrete becoming contaminated.

147. Considerable difficulty was experienced in holding an adequate labour force to maintain the contract programme, due to the extremely intricate nature of the work and the conditions under which the men had to carry it out. The turnover of labour was some three times in excess of the average turnover for the company during that period. The most critical shortage was of carpenters, and in some instances the use of timber shutters was abandoned in favour of steel. By that means, in the third year of the contract they were able to step up the monthly average of shutters fixed and struck from under 1000 to over 4000 square yards per week. The shutter systems described in the Paper were in the main those adopted after it had become apparent that the programme could not be maintained using the shutters on which the tender had been based because there were not enough carpenters to handle them.

148. It would be remembered that in 1958 the industry was threatened with a shortage of steel. It was, therefore, considered expedient to call forward very large quantities of reinforcement steel from the suppliers at a very early stage in the contract. Subsequently, it was found that any rods which had been exposed to the polluted atmosphere in the area needed cleaning prior to fixing. In many instances, final wire brushing was carried out after fixing.

149. Despite the many problems involved, the works were substantially completed by the overall programme date and were put into use smoothly and without undue difficulty. The Contractors' supervising staff was in many cases changed after approximately two years of work on the site, as it was found that the rigours and stresses of working under the conditions described made that advisable.

Mr R. V. Hines (formerly London County Council Main Drainage Division) said that the Paper had an even greater interest to him because it happened that he had left the London County Council just at the time the construction work was about to start. Up to that time as the engineer in charge he had been working quite heavily on the question of the borings and the test piling programme on which so much depended for the final design of the tanks.

151. He would like the Authors to comment on one or two points in the piling section of the Paper. The first object of the test piling programme was to test the

ballast, to discover its composition and thickness. The second was to test the London clay loading. The third was to cross-check the boreholes, by pile driving. They also sought to test cycle loading, the uplift of the west piles, and possible vibrating of the cores.

152. The basis of using both core shell and precast piles was to ascertain whether there would be any advantage in one or other of the systems, because if the length could be established in advance, it would avoid a considerable amount of adjustment, i.e. cutting to waste or lengthening, either being costly. He would also like to know whether the adjacent piles were affected by driving in the vicinity.

153. Also, it was decided that the vibrating of the core of the shell pile was not thought to be necessary when driving the major piling contract. Any comments as to whether site tests were done on the core piles would be appreciated.

154. As the general basis upon which to design the piles had been established by these tests, he wondered how the pile length varied against design lengths when they were actually driven in the major contract.

Mr A. W. Shilston (Consulting Engineer) said that he invited the Authors to enlarge a little on some of the details of the Paper.

156. First, §§ 14, 15, and 17 referred to the sewage pumping station. He would like to ask whether squirrel-cage motors with direct on-line starting were used to drive the pumps or whether some form of speed control was adopted, and, if so, what.

157. With regard to § 21, he would be very interested to learn more about the measures taken to introduce equitable hydraulic flow conditions through the various units in the works. He imagined that the feed culvert referred to from which the eight 48-in. diameter pipes emerged was drowned at all times. He was rather puzzled as to the function of the remote-controlled disk valves. Did these isolate each sedimentation tank from the feed culvert, and were they, therefore, sited downstream of the Venturi tube. Could the Venturi itself be isolated?

158. On the theme of flow distribution, could some indication be given of the method by which distribution of flow to the final settling tanks was achieved? Fig. 2 did not help a great deal. Could the difference in level between the primary and the final tank weirs be stated?

159. He would like to say a word on the question of floor slopes of circular sedimentation tanks—a subject full of mystique. The western group of tanks had only very gently sloping floors in association with clarifier-type mechanisms. He could imagine there might have been a conflict between the desire to have steep floor slopes, and construction and cost difficulties. Now that operational results were available, he would be interested to hear whether the Authors had any reservations about using flat floors with positive floor sweeping mechanisms.

160. Was speed control of the returned activated-sludge pumps used? With regard to sludge digestion, in particular § 35, could the Authors enlarge on their reference to foaming in sludge digesters? Surely surface area was not the only factor involved? Could something also be said about the surface preparation and painting scheme adopted for the steel gasholder? Fig. 14 clearly ruled out any prospect of a floor-sweeping mechanism, but he would be interested to hear the Authors' opinions as to the desirability or otherwise of having a floor-sweeping mechanism to carry the grit forward to the draw-off point.

161. He wished to make one or two remarks about the concrete construction aspects of the Paper. Could it be taken that the various tank units were designed in accordance with the now obsolescent Institution of Civil Engineers Water Retaining Code, which specified nominal concrete mixes and did not make express provision for a design mix form of proportioning, as did the new British Standard Code of Practice, C.P. 2007 of 1960? Were the basement reinforced concrete structures in water-bearing ground also designed to that Code, if, in fact, the Code was used, or were they designed as normal structural reinforced concrete? An indication of the

mode of concrete specification for the prestressed concrete secondary sludge-digestion tanks would also be interesting.

162. He wondered whether any general conclusion had been reached regarding the relationships between expansion and contraction joints in long straight walls and the frequency of the spacing. Did the Authors favour the use of water bars at all construction joints in water-retaining structures?

163. Finally, with regard to the primary and secondary digestion tanks, did the construction of the floors described produce crack-free and watertight concrete? Casting the floors of circular tanks was a difficult problem and it would be interesting to know whether the method was successful.

164. With regard to § 111, he wondered whether the very high lift of concrete placed in the primary digesters produced standards of watertightness which would encourage the Authors to repeat the procedure again.

165. Did § 114 imply that the decision about choice of reinforcement bar lengths and the lapping arrangement was made following the choice of the shutter design, or was the shutter design evolved around an irrevocable disposition of reinforcement which was in accordance with the earlier and original bar bending schedules?

166. In §§ 115–118 no reference was made to the mode of construction of the core wall of the secondary digestion tanks. Were similar forms used as those adopted for the primary tanks? If not, perhaps the Authors could indicate what form of shuttering was adopted. Could the actual thickness of the core wall be stated?

Mr J. T. Calvert (John Taylor & Sons) said that there were two points which fascinated him. The first was the limited range in the flows from the minimum at night of 58 million gallons to the maximum of 119 million gallons per day during dry weather up to 216 million gallons per day during wet weather, the peak flow under treatment. This was a range of only about $3\frac{1}{2}$ to 1, which was low when compared with many similar works. A shorter aeration period than would be normal with a bigger range of flows might on this account be possible.

168. Similarly, he had noticed that the final settlement tanks had a capacity of about six hours and an upward velocity of about $4\frac{1}{2}$ ft per hour. He would have thought that the capacity might have been reduced or the upward velocity increased slightly. He would be very interested to know whether the limited flow range was taken into account in the design of either of these units.

169. The second point that he wished to make had already been touched on. He had not found the reasons given for the selection of surface aeration convincing. He wondered if there was not perhaps a more obvious reason for having the diffused-air method on the north side and trying the alternative on the south. He had been faced with a similar problem in Baghdad, where they had had two works, one on each side of the River Tigris. He had suggested to the Sewerage Board that because precise economic comparisons were difficult, while they were putting in two works it might be an ideal opportunity for testing out for the future the relative efficiency of the two systems and had added: 'I am sure that this is the right thing to do, because it is what the London County Council is doing'.

Mr R. D. Taylor (Resident Engineer, Birmingham, Tame and Rea District Drainage Board) said that he would welcome further comments on the forming of joints in the water-retaining structures, both expansion/contraction and construction.

171. He noticed from § 97 that the primary sedimentation tank floors were constructed initially on the alternate bay system, and a trial quarter-tank pour was made, 122 ft 6 in. $\times$ 33 ft, but that the alternate bay system was later resumed. For the eight eastern tanks, 6 ft 6 in. gaps were left to 30-ft bays, giving, he estimated, 24 gaps per tank. According to § 103, concreting to the outer walls of the aeration tanks was first done on the alternate bay principle, but later changed to allow 12-in. gaps

every 32 ft, which were filled a long time after. He estimated that about 100 gaps would be required.

172. In his experience, the alternate bay or gap procedure could be a very controversial subject on a contract, and considerable expense was involved either to the authority or to 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 fillings. If gaps were incorporated, there were two faces at each gap, and in excavations below the natural ground water level, sumps at 30-ft intervals, which collected not only water but every conceivable piece of dirt, rubbish, and oil, with the added difficulty of cleaning.

173. In view of the number of different types of tanks constructed, he would be glad if the Authors could give suggestions as to the best method of overcoming the problems: (1) whether to concrete on the alternate bay principle or use gaps, and, if so, of what size; (2) whether to use water bars and/or notched joints on both sides of the gap; (3) whether to use a retarder on the shutter face, or to strip and water jet, the latter often being required to be done at midnight; (4) whether the contractor should be given the option to quote a bill rate per joint or gap, or whether this was better allowed for in the general concrete rate, which should cover the construction as specified by the water retaining code.

Mr B. C. Bridges (Grant Lyon & Co. Ltd) said that he had been particularly interested in the use of the large steel shutters in the primary sludge digestion tanks, which were over 30 ft in height and which entailed the pouring of concrete to the full height. He had also been interested in the use of the ten immersion vibrators, which he understood were raised and lowered by means of winches. He wondered whether the Authors could advise him about the factors which influenced them in their decision to install ten vibrators instead of the usual one, two or possibly three vibrators to be operated manually.

175. He would be interested to know whether any difficulty was experienced in over-vibration of the concrete, and also whether any difficulty occurred if a vibrator broke down. Presumably, each vibrator would be in a fixed position, and a breakdown of one would leave a portion of the bay unvibrated.

176. He also wondered whether the Authors could give any information concerning the average rate of construction of the primary sludge-digestion tanks. He noticed that one of the tanks was constructed in ten days. As there were ten bays per tank, this implied construction of one bay per day.

177. Mr Kent had stated that the steel frame work had been adopted because of the difficulty in obtaining tradesmen. Could indication be given whether tradesmen were used on this type of shuttering, and roughly the strength of the gang needed to turn round the shutters in one day? He would be interested to know the approximate rate of pouring of the concrete on the 30-ft high pours using a pump.

Mr D. A. H. Everett (Chief Assistant Engineer, Borough Engineer's Dept, Croydon) said that his comments on the Paper would be confined mainly to points of detail and would all be concerned with the first section.

179. With regard to § 7, he would be interested to learn why the apparently low figure of only $2\frac{1}{2}$ times dry weather flow was taken as the maximum flow for full treatment.

180. He had a further comment on the disintegrators which he understood were in fact stereophogous pumps. In his experience he had found that these were not as efficient in maceration as disintegrators and he would like to hear the comments of the Authors.

181. In § 19 it was stated that the velocity of flow varied between 1.07 and 1.09 ft/sec, permitting settlement of grit but keeping organic solids in suspension. He had

yet to find any constant velocity channels which produced a truly organic-free grit. He noted that no provision had been made for the washing of grit and would like to hear from the Authors whether the omission had proved to be any embarrassment from the point of view of possible smells arising from the grit lagoons. Perhaps the Authors could give some indication of the actual amount of organic matter present in the removed grit. He would also be interested to learn whether any undue difficulties had been experienced with the priming device of the grit pumps.

182. With regard to the aeration plant, the actual provision in terms of horse-power/mill. gal seemed a little low. He wondered also whether the Authors had considered the difficulties of maintenance of gear heads and vertical shafts in the central areas of very large blocks of aeration tanks? Had the Authors considered any means of variable speed drive as an alternative to changing the sprockets whenever a variation in speed of rotation was required?

183. He would have welcomed more information about the power house, particularly on the question of the stand-by power facilities from the grid. He understood that the stand-by power available was the equivalent of about three of the diesel generator sets provided. He wondered whether the provision of additional generators giving absolute reliability of generation would not have been preferable to a sometimes uncertain supply from the London Electricity Board.

Mr D. H. Hughes (J. D. and D. M. Watson) said that he had two brief points to make on the general layout. First, he would be interested to know how the position of the grit channels was determined. From Fig. 2, the impression was that the sewage went along three sides of a rectangle before arriving at the head of the primary sedimentation tanks. Why did it not go in a straight line?

185. Secondly, Mr Vick had said that the design work was now in progress on further developments for the Southern Outfall Works. He would like to know if the basic design incorporated any provision for extensions.

The following contributions were received in writing:

Mr J. G. Sanderson (C.B.A. Engineering Ltd, Vancouver) wrote that he had read the Paper with great interest and offered the following comments to the Authors.

187. Was the population given (1 600 000 persons) the actual population or the equivalent population in terms of residential plus industrial?

188. The minimum flow of 36 gal/capita seemed high. Could the Authors say what proportion of this flow was attributable to sanitary sewage and what to ground water infiltration into the collector system. The daily B.O.D. and suspended solids loading per capita of 0.158 lb and 0.1861 lb respectively seemed to be very low. They might be expected to be in the order of 0.18 lb and 0.20 lb respectively especially since there must be some industrial wastes associated with so large a population. Were industries required to treat waste before it was discharged to the collector system?

189. The loading rates on the primary and secondary sedimentation tanks of about 350 gal/day/sq. ft on D.W.F. basis seemed much lower than was usually allowed, especially in the primary sedimentation tanks. What reduction in B.O.D. and suspended solids did the Authors anticipate in these two parts of the works? It was also suggested that de-sludging of these tanks be done manually. Could the Authors give any figures for the number of man hours required for this operation? Did the Authors consider the use of automatic continuous desludging of all tanks since a moisture content of about 96.3% for wet primary sludge had been allowed in the design, which seemed well within the figure that automatic equipment could produce?

190. The hp of the aeration equipment seemed low in terms of that required for diffused air equipment. This worked out to the provision of 1 hp for every 66 lb daily B.O.D. removed, assuming 35% removal in primary sedimentation tanks and 92% removal in aeration tanks. Had the Authors any figures in terms of the pounds

of the B.O.D. removed per day by a typical unit of the Simplex aerator when running continuously?

191. The production of only one cubic foot of gas per capita per day seemed low for an activated sludge plant. Did the Authors anticipate any odour problems with open secondary tanks? Was any consideration given to gas recirculation in the primary digesters, and was the plant effluent chlorinated before final discharge into the Thames?

Mr D. H. Lacey (Kottler and Heron Ltd) wrote that it was stated in §§ 61 and 87 that resistance to pile driving varied considerably even between adjacent piles. This would indicate a difficulty in forecasting the length of precast piles which according to § 54 was overcome by the use of shell piles. In a handout at the site visit the total number of precast piles, including the jetty, was given as 19 000, and that of shell piles as 3700, the latter being used in the digestion tanks and main effluent channel. It would appear from this that a large number of precast piles was driven in variable driving conditions. This might not be so, but could the Authors enlarge on the point and give more information on factors affecting the choice of pile. While referring to this, some indication of the actual sets used would be useful.

193. Arising from the several different procedures for concrete bay pouring, e.g. alternate bay, gaps, etc, it would be interesting to learn if the Authors had reached any definite conclusion as to which procedure was to be preferred from the point of view of crack control for any one particular set of circumstances. In this respect it was interesting to note that the walls of the primary sludge tanks were concreted in alternate bays, presumably to comply with the specification and not by choice of the Contractor. He would like to know whether in the light of their experience on this contract the Authors considered it really necessary to concrete circular walls, with their greater freedom of movement, in alternate bays.

194. In view of the wide divergence of practice amongst engineers, it would be interesting to know whether the position and type of all concrete joints was fully specified or whether any discretion in this respect was left to the Contractor. In his experience the recommendation of C.P. 2007 (published during the contract) that all joints should be fully specified and shown on the drawings was admirable.

Mr P. A. Banks (John Taylor and Sons) asked how far into the load-bearing stratum did the test piles penetrate? This penetration was given only for piles 6 and 7 (Figs 22, 23) and he thought the information indicated that the bearing value of the piles was related to penetration into gravel or stiff clay and not solely to the set attained. It was interesting that pile 6 (the shoe of which was founded in blue clay according to Fig. 23, and not ballast as indicated in Table 1) had the smallest settlement and a total penetration into load-bearing strata of 16 ft. Further, in §§ 87 and 88 mention was made of piles not reaching sets, but on testing proving to be satisfactory. In § 127 'sets' of 2 to 3 in. per blow were reported. If driving resistance proved to be an unsatisfactory measure of bearing value, what criteria were used on the site?

196. The uplift values given in Table 2 seemed to be related to the surface area of the whole pile. Did the Authors consider this would have been satisfactory if the pile did not penetrate the gravel or was the uplift value of the pile derived from gravel penetration? Was the possibility that negative skin friction would result in additional loads on the piles taken into account, bearing in mind the softness of the alluvial peat and silt overlying the gravel and the weight of made ground above the old marsh level?

197. On a different subject, could the Authors give any information on operating experience with the digested sludge de-watering tanks? How much de-watering had been achieved and what detention periods had been necessary to achieve it?

Mr B. Hall (A. G. Tate and Partners) wrote that §§ 120, 121, and 122 mentioned the

use of gamma radiography. Members might be interested in the technique employed on this occasion.

199. The radio active source used for the examination was Cobalt (Co^{60}) of 50 mc. strength and films used were Kodirex X-Ray films fixed to the sides of the beam webs remote from the source. Exposure times were 3 hours 35 minutes for beam web $6\frac{1}{2}$ in. thick and 8 hours 20 minutes for the beam web 9 in. thick, with the source at distances of 3 ft and 4 ft 3 in. respectively. Lead intensifying screens were used and lead markers were fixed to the films to identify their location. The work was carried out outside normal working hours, and a safety area 90 ft in diameter was necessary.

Mr E. H. Ely (Messrs J. D. and D. M. Watson) enquired whether the design of the sedimentation tanks had been influenced by the results obtained from the flow studies carried out by the L.C.C. using radioactive tracers. Also, whether operational experience gained at the Northern Outfall had been reflected in the design of any major unit at the Southern Outfall.

201. In view of the need for the many interconnecting pipelines of the plant to be laid on piers, were any special routings devised to group a number of lines which, in better ground, would probably have taken separate routes?

202. Mr Ely wrote that the extent of the instrumentation of the new works was outstanding and might have been made the subject of a paper in itself. The cost must have been considerable but with works spread over so vast an area, the elaboration would be justified.

Mr P. C. Edwards (Harris and Sutherland) wrote that after spending the greater part of two years as one of the L.C.C. supervisory staff at the works described in the Paper he could say without hesitation that the attention paid to aesthetic considerations at the design stage had been well worth while. In locating the major part of the sludge digestion pipework underground, however, it was arguable that the Authors had gone too far in their desire to obtain a pleasing appearance. Surely the loading diagram (Fig. 28) was evidence that a considerable saving in pile loads could have been achieved by avoiding the enormous earth loads carried by the buried pipes? A wider band of pipes at or near ground level would indeed have raised very difficult 'traffic' circulation problems, especially in the primary sludge digestion area, but it was doubtful if a more expensive scheme could be devised! The only pipes actually required to be at low level would appear to be a washout pipe in P.S.D. (Fig. 14) and sludge outlet in S.S.D. (Fig. 16). Could the Authors justify the burial of the sludge digestion pipework on other than aesthetic grounds? The height and close grouping, especially of the primary sludge digestion tanks made any complex pipe layout at ground level insignificant visually from within the works, and the 5-ft river wall hid anything below this level from the river.

204. The only visual blots on the landscape, in his opinion, were the sheds perched over the primary sedimentation bridges and detritus channels, and the booster station on the jetty. The last was the only 'building' structure not designed by the L.C.C. architects department and appeared to belong to a different era. Could the Authors explain why the booster station had to be on the jetty pierhead? It would have fitted better into the landscape in front of the high dense mass of primary sludge tanks, and would not have placed a very costly set of pumps in an exposed reach of the river and in a position where, despite the 9-in. gap round the basement, the possibility of damage through accidental collision could not be ruled out. The design of the jetty pierhead itself did not seem to have taken into account the damage which could be caused by accidental collisions, nor did the location of the sludge mains, oil fuel mains, and water mains below the deck make access for maintenance easy. Would the Authors agree that it might have been better to locate all pipes at or near deck level, alongside a walk (or drive-way) or between two parallel access platforms, the whole of

the pipework being located behind either a 'berthing beam' or dolphins on the mooring line. Could the Authors justify the complexity of the structure of the upstream and downstream dolphins, and their location so near the ends of the jetty pierhead (about 2-ft maximum clearance)?

205. Could the Authors explain the necessity for the floating boom which appeared more likely to damage the sludge vessels than to serve any useful purpose. If its presence could be justified at all, would not a simpler type such as that at Woolwich Ferry have been more economical and not quite so difficult to erect? (The contributor had personal and painful experience on the latter point!)

206. Would the Authors, in designing future work of a similar nature, consider the use of flat-bottomed tanks for Simplex aeration plant?

207. Would the Authors agree that the necessity for the costly and not fully effective oil pipelines for foam suppression could be obviated by early legislation to prevent the sale of detergents containing foaming agents?

208. Could the Authors say whether they would consider it more economical to develop works of the size described in the Paper in small units in future? The writer could see several possible advantages: (1) continuous review of latest developments would allow for the incorporation of improvements in the design of sewage treatment methods, machinery, and structures, to be effective at, for example, 4- or 6-year intervals, instead of 20-year intervals; (2) continuity in the employment of all types of building and civil engineering workers might lead to greater ease in finding local labour and in giving more continuous employment; (3) shorter contracts might alleviate the labour and supervision difficulties described by Mr Kent.

Mr T. Whitaker (Building Research Station), wrote that at the time of the construction of the Southern Outfall Works he and his colleagues were developing the method of pile testing which had become known as the Constant Rate of Penetration (C.R.P.) method⁸ and were grateful for the opportunity of trying the new method on piles driven as part of a normal contract.

210. In carrying out the C.R.P. test, the pile was made to penetrate the soil at a constant speed from its position as installed, while the force applied at the top of the pile to maintain the rate of penetration was continuously measured. The principal objectives of the tests at the Southern Outfall Works were: (a) to determine the effect of different rates of penetration on the ultimate bearing capacity found by the C.R.P. method; (b) to compare the C.R.P. method with the conventional method of pile testing where the load was applied in stages, each stage being maintained until settlement was completed before applying further load to pass to the next stage.⁹

211. The results of these experiments made a valuable contribution to the general assessment of the C.R.P. test, the details of which have been published elsewhere¹⁰ and he intended to deal only with other information which was derived from the tests.

212. The piles for testing were selected by the Resident Engineer because they had not achieved the specified 'set'. They were a normal design of reinforced concrete, driven by drop hammer (Table 3). The bearing capacity was calculated by the Resident Engineer's staff by means of Hiley's formula.

213. The loading reaction for testing was provided by kentledge supported on extensive timber cribwork. The settlement of each pile was measured relative to a reference beam of 8 in. $\times$ 6 in. R.S.J. 35 ft long supported at its ends on small concrete foundations. Vertical movements of the ends of the reference beam were measured by dial gauges reading to 0.001 in. fixed to adjacent unloaded piles or to rods attached to datum points driven into the bed of gravel in which the piles were founded. Fig. 41 showed the general arrangement of the reference beam. Fig. 42 showed the movement of the reference beam in a typical testing cycle, that on pile No. 3, relative to the datum points fixed in the gravel about 32 feet deep and illustrated the 'spongy' nature of the ground above the gravel and the need for referring settlement measurements to a reliable datum.

TABLE 3

Pile No.	1	2	3	4	5	6
L.C.C. location No.	7081	7135	2138	2140	11451B	11478
Cross section	14 in. sq.	14 in. sq.	16 in. sq.	16 in. sq.	14 in. sq.	14 in. sq.
Length	34 ft 8 in.	34 ft 8 in.	32 ft 8 in.	32 ft 8 in.	40 ft 8 in.	42 ft 8 in.
Embedded length	28-79 ft	33-27 ft	30-0 ft	30-0 ft	39-59 ft	41-34 ft
Hammer weight	2½ ton	2½ ton	3 ton	3 ton	3 ton	3 ton
Height of drop	3 ft 3 in.	3 ft 3 in.	3 ft 4 in.	3 ft 4 in.	2 ft 8 in.	2 ft 8 in.
Specified set (10 blows)	1½ in.	1½ in.	1½ in.	1½ in.	1½ in.	1½ in.
Set achieved (10 blows)	1½ in. final	none	2½ in.	3½ in. final	1½ in.	2½ in.
Bearing capacity by Hiley's formula	117 ton	—	101 ton	80 ton	105 ton	85 ton
Bearing capacity by C.R.P. test:	221 ton (by extrapolation)	198 ton	207 ton	199 ton	112 ton	161 ton
(a) At a penetration equal to 10% of the width	un-obtainable	un-obtainable	236 ton (by extrapolation)	215 ton (by extrapolation)	134 ton	186 ton
(b) At a penetration equal to 20% of the width

FIG. 41: ARRANGEMENT OF DEEP DATUM POINTS FOR MEASURING THE MOVEMENT OF THE REFERENCE BEAM

FIG. 42: MOVEMENT OF THE ENDS OF THE REFERENCE BEAM IN THE LOADING TEST OF PILE NO. 3

FIG. 43: FORCE-PENETRATION DIAGRAM FOR PILE NO. 3

FIG. 44: LOAD-REBOUND DIAGRAM FOR PILE NO. 5

214. In the C.R.P. test of an end-bearing pile the force-penetration diagram for a cycle of loading was typically as shown in Fig. 43, giving the result of the test on pile No. 3. The ultimate bearing capacity was reached at that point where the curve became substantially straight, in this case at A, but in some cases there was difficulty in locating a point such as A and two values were obtained representing the probable higher and lower limits of the ultimate bearing capacity as given in Table 3. However, in certain tests the kentledge provided was insufficient to reach the larger penetration and extrapolation had been used where this appeared admissible. Comparison of the values with the bearing capacity calculated by Hiley's formula showed that the latter generally gave an underestimate of the actual bearing capacity.

215. Van Weele had advocated a method of testing whereby the point and frictional resistances of a pile might be determined.¹¹ In Van Weele's method, when carrying out a conventional loading test, instead of proceeding directly to the next higher stage of loading the pile was first unloaded and then reloaded to the next stage. The rebound of the pile on unloading from each stage was plotted against the load at that stage, a line being obtained which was curved near the origin but straight for the higher loads. The point of intersection of the production of this straight portion with the load axis gave, according to Van Weele, the value of the frictional resistance on the shaft. Pile No. 5 was tested in this manner, and Fig. 44 showed the load-rebound diagram, the intercept being at 14 tons. Samples of the clayey organic silt which overlay the gravel were obtained by piston sampler and their cohesive strength determined. The frictional resistance on the pile shaft, assuming that the full value of the cohesion might be taken as the skin friction, was 46 tons. If the remoulded strength of the clayey silt was used in the calculation, the resistance was about 16 tons.

The Authors thanked those who had contributed to the discussion and hoped that the questions and replies would add to the value of the Paper.

217. Referring to Mr Manning's comments, it was an innovation to make the screen house fly-proof and pressurized. The purpose of the feature was to prevent flies from having contact with screenings and the pressurizing was intended to keep damp air from rising from the sewers and causing condensation and rusting of the machinery, which, certainly, would otherwise occur. The head-gears of the screens were provided with fibre-glass covers for aesthetic reasons and to restrain splash from the sparges.

218. The trimming of the flow in the pumping station meant an arrangement of the pumps so as to ensure that flow from the low level pumps did not pass to the storm tanks at a time when the total flow from high level and low level was less than the rate of flow to be given full treatment.

219. The reasons for the choice of the Simplex system were the overall economics and the simplicity of maintenance.

220. The plant had not been working long enough to make a full comparison between the use of surface aeration and the diffused air system. It was hoped to present this information at a later date.

221. The pile-test programme referred to by Mr Hines was carried out in conjunction with the river wall which was built before the actual main contract started. The Contractor was using a proprietary type of pile which was the type chiefly driven in the pile-testing programme, although some precast piles were also driven. Operations were restricted to the narrow strip of land along the river front. The results had a very limited use on the site as a whole, which extended over more than 100 acres.

222. The uplift tests on the shell piles were made with regard to the anchorage of the river wall only, although, later on, several test pile loadings for uplift were carried out in conjunction with the construction of the jetty.

223. Mr Hines had asked whether the tests were any guide to choosing the length of the piles. The answer was that they were not. Adjacent piles proved to be quite different in their length, and that was so for different areas. With regard to piles

driven adjacent to each other, there was no movement of the pile driven first, although resistance was increased in close piling.

224. In reply to Mr Shilston, for the sake of economy and simplicity, variable-speed motors had not been used for the pumping plant. There was a reference in the Paper to the theory by which the capacity of a suction-well could be related to the capability of the electrical gear of the pumping plant. Neglect of this theory elsewhere has resulted in a burn-out of the electrical gear or, where surge had been set up, causing all the pumps to cut in almost simultaneously. The Authors felt that they had made an innovation in installing very large pumps in a sewage pumping station which had no suction-well but relied on the calculated storage capacity of the incoming sewers.

225. The flow to the primary sedimentation tanks was distributed from a surcharged culvert through a number of Venturi meters and disk valves, the latter being remote-controlled so that the operator could quickly adjust the flow to all sections of the plant in equal quantity. The disk valves were not guaranteed to be watertight: other means were provided for isolating them and the Venturi meters.

226. The distribution of flow to the final sedimentation tanks was achieved by a system of progressive bifurcation. Model experiments had been carried out at two different scales to determine the accuracy of distribution by this method. The weirs of the final sedimentation tanks were 5 ft 6 in. lower than those of the primary tanks. The slopes of the floors to the final sedimentation tanks had been arranged according to the type of machine installed: in both cases the results were satisfactory.

227. As to the foaming of primary digestion tanks, the results at the Northern Outfall Works confirmed the figures given in American text books to the effect that foaming was likely to occur at gas-emission rates of much more than 30 cu. ft/day per square foot of surface. The results at the Northern Outfall Works did not suggest the need for any floor sweeping mechanism in primary digestion tanks of the design used. At Northern Outfall Works no serious trouble had been experienced with foaming inside the gas-holders but foaming of the light scum in the annular space between the ladder and the walkway had been a source of nuisance.

228. The method of painting the gas-holders involved water being put into the tanks so that the gas-holders could be lifted under air pressure to expose the skirts. The tanks were welded on site, and all the painting, including the priming coat, was put on afterwards.

229. Mr Shilston and Mr Taylor had asked for further information on the use of water bars in construction joints. The specification had required all joints to be provided with a copper strip water bar. The expansion joints consisted of 22 S.W.G. copper strip, 12 in. wide, five times bent. Some construction joints were treated with retarders on the shutter face: in other cases the shutter was stripped and the concrete surface treated. When using a retarder, care had to be exercised to ensure that no more than sufficient retarder was used. To ensure watertight joints all laitance was removed, but without damage to the concrete.

230. Mr Shilston had asked whether the high lift which had been poured on the primary sludge digestion tanks had produced watertightness. It had. He had also referred to the lapping arrangements for the reinforcing steel of the digestion tanks. The location of the joints in the circumferential steel reinforcement had been altered from what was shown on the drawings to suit the length of pour caused by using the special shutter, and no delay had resulted.

231. The use of either gaps or alternate bays had been agreed with the Contractor. The contraction of concrete is most rapid in the early period after casting, therefore leaving a gap between pours appeared to be the better method.

232. Mr Bridges could be assured that there had been no over-vibration. It had been considered that the concrete should be placed and vibrated in horizontal layers, and this method proved efficient. As the concrete reached certain levels the vibrators

had been lifted, the required position of the vibrator being known from the length of the wire holding it.

233. Mr Shilston had asked whether the work was designed according to the code for water retaining structures and which code was used. The initial designs were to the old code but during the detailed design period a draft of the new code became available and was worked to. The economies which resulted were considerable. The concrete used in the prestressed structures was quality control concrete working to a minimum strength of 6000 lb/sq. in.

234. Mr Calvert had referred to the very small variation between minimum flow at night and peak flow during the day. This was due to the long time of concentration of the sewerage system—about 10½ hours—which flattened out the peak and the valley in the curve and would not have any appreciable effect on the required aeration period. The final sedimentation tanks were of large surface area and capacity compared with those at some works, but works with more moderate capacities had been in trouble at times of sudden increase of flow.

235. In reply to Mr Everett, although the rate of flow to be treated had been fixed at 2.4 times dry-weather flow in view of the small variation of rate of flow during the day, the plant had been designed hydraulically so as to permit a 50% future increase of maximum rate of flow to be given full treatment, if this should be found desirable. The washing of the grit was at present under consideration.

236. Mr Sanderson had asked for figures of the actual population served by the works. The resident or night population was approximately 1 600 000, the day population being somewhat smaller. The exact proportions of domestic sewage flow, trade waste, and infiltration, were not known. The supply of water by the Metropolitan Water Board was, of course, known, but all of this water did not reach the sewers: on the other hand, there were water supplies to factories from private wells. The B.O.D. and suspended solids figures for the crude sewage were very near what had been considered average values for English sewage works.

237. The performance of the primary sedimentation tanks was good but not phenomenal. The tanks were sludged mechanically but arranged so that the actual withdrawing of the sludge would take place during the day shift only and under observation, so as to obtain a sludge of low moisture content. Continuous automatic sludging could result in a wet sludge at night.

238. The estimate of gas production of the digestion plant had been kept low intentionally and better results were, in fact, to be expected. No serious odour problem was expected as a result of having open secondary tanks. Consideration had been given to gas circulation at the Northern Outfall Works, but the method had not been put into practice and it was thought that there were other, more economic, means of preventing scum accumulation. The final effluent from the works was not chlorinated.

239. With reference to Mr Lacey's contribution, the piling and pile tests referred to in §§ 54 to 64 were confined to the area in which the sludge digestion tanks were constructed, supported on shell piles.

240. Estimating the lengths of the piles to be made had been difficult and piles longer than required by the specified 5-ft penetration into ballast had been ordered. Although this resulted in more cutting to waste, the practice was better for progress than waiting for the pile to be extended and redriven. Table 4 gave the information of pile sets requested by Mr Lacey and Fig. 45 showed some of the results obtained while driving piles.

241. One of the factors which influenced the selection of piles, where the contract allowed for different types, was the respective rate in the Bills of Quantities.

242. With regard to the procedure for pouring concrete in order to prevent cracks, the conclusions reached were that, for straight walls or slabs, it was essential to have gaps or alternate bays between pours. In both cases the construction joint showed some contraction of the concrete. In the case of circular tanks, the floors and walls

FIG. 45: PILE-DRIVING DATA

were cast in complete rings and no cracks appeared, but the full circle had to be completed in one operation of continuous pouring. If a shutter was used that required several positions and, therefore, separate pours, the alternate bay method was essential. Complete rings were poured for the final sedimentation tank floors and walls, the floors and walls of the secondary digestion tanks, and the floor of the primary digestion tanks. The walls of the primary digestion tanks were poured on the alternate bay principle although the specified time of 14 days between pours was in some cases reduced to ten days in order to maintain progress: no vertical cracks appeared.

TABLE 4: TYPICAL DRIVING RESULTS

No. of piles driven	Size in.	Location	Energy of blow ft/ton	Sets in inches for ten blows	
				Specified	Actual
<i>Nov. 1958</i>					
103	14	Detritus channels	8	1.43	$\frac{1}{2}$ to $1\frac{1}{2}$
404	14	Prim. sed. tanks	8	1.43	$\frac{1}{2}$ to $1\frac{1}{2}$
475	16	Aeration tanks	10	1.25	298 no. $\frac{3}{4}$ to $1\frac{1}{2}$ 177 no. $1\frac{1}{2}$ to $2\frac{1}{2}$ additional piles added for low sets
None		Final sed. tanks			
44	$17\frac{1}{2}$ dia.	Sludge digestion	12	1.43	$\frac{1}{4}$ to $\frac{1}{2}$
21	$14\frac{1}{2}$ dia.	do	9	1.5	$\frac{1}{4}$ to $\frac{1}{2}$
<i>April 1958</i>					
84	14	Detritus channels	8	1.43	$\frac{1}{2}$ to $1\frac{1}{2}$ 1 no. pile extended
351	14	Prim. sed. tanks	8	1.43	7 no. @ 3 additional piles driven
358	16	Aeration tanks	10	1.25	$\frac{3}{4}$ to $1\frac{1}{2}$ 30 no. $1\frac{1}{2}$ to $2\frac{1}{2}$ 3 no. redriven after extension Additional piles added for low set
796	14	Final sed. tanks	8	1.43	$\frac{3}{4}$ to $1\frac{1}{2}$ 1 no. pile extended
None		Sludge digestion			
37	14	Jetty	8	1.43	1 to $1\frac{1}{2}$

Note.—Five feet minimum penetration into ballast was specified. This was not insisted upon when high sets were reached after 3 ft penetration.

243. In reply to Mr Banks' query on dewatering in secondary digestion tanks, considerable quantities of supernatant water were removed at the Northern Outfall Works, and with improved decanting arrangements, still more effective dewatering could be made possible. The capacity of these tanks was not, however, based purely on the dewatering requirements: the tanks had also to give storage during fog periods when the ships could not go to sea and, at the Southern Outfall Works, one third of the capacity was intended to be reserved for this purpose.

244. Mr Ely had asked if the experiments on the Northern Outfall Works sedimentation tanks with radio-active tracers had influenced the design of the tanks at

the Southern Outfall Works. In fact, these experiments had shown only that tanks at the Northern Outfall Works were performing as expected. The design of the Southern Outfall Works was based on operational experience at many places: naturally any faults found at the Northern Outfall Works had been taken into account in the new design.

245. While Mr Edwards was right in saying that the placing of the digestion pipe-work underground increased the earth loads that had to be borne by the pipe supports, there were so many pipes running parallel in this part of the works that if they had been laid side-by-side above ground level, it would not have been possible to walk between the tanks, let alone drive through the special crane and other vehicles that were necessary for regular maintenance. It had also been necessary to arrange the different categories of pipes at several levels as, if this had not been done, multiple air-locks would have been set up, leading to surge and excessive head on the pumps: it should be borne in mind that there was no satisfactory automatic air-release valve available for use with sludge.

246. Flat-bottomed Simplex aeration tanks could be considered in future plants with higher rates of cone rotation.

247. The means of suppressing foam selected were considered to be the best of all known methods for effective and economical working.

248. The works had been constructed in one large contract because only in this way could the necessary service be rendered in a reasonable period of time.

249. The questions which had been asked about the primary sludge digestion tanks had been referred to Mr W. L. Kent, who wished to make the following replies.

250. The method of construction was gone into very thoroughly with Mr Parry, the designer of the shutter and also with the manufacturers of the selective vibrators. An immense amount of planning was done on the operation. They had to think of every possible contingency. He thought that the fact that the method worked from the outset rather proved that time spent on reconnaissance was seldom wasted. They did not have any demolition of any sort to do.

251. The concrete was dropped for the full height and the vibrators were raised with small winches. Vibrator failure was not invariably detected, but very often they were able to detect one by the vibrations in the wire that suspended the vibrator, or by holding the hoses. The air vibrators were suspended by steel wire ropes and on most occasions a failure could be noticed. When a vibrator failed it was withdrawn, a new head was put on it and it was dropped back again.

252. With regard to the labour strength, the gang was an all-in gang on concrete and shutter fixing. The cycle at which they eventually arrived was a pour every other day and one week to move the shutter from tank to tank, giving an average of one completed tank per month. The gang worked an average of from 12-14 hours a day. The concreting time was between $3\frac{1}{2}$ and 4 hours. The concreting of a section of the tank every day was really an experiment.

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