Extensions to the Riverside Sewage Treatment Works

J. T. CALVERT & P. A. BANKS

Mr J. T. Calvert

I would like to pay tribute to the many individuals and organizations to whom we are indebted for co-operation and assistance in bringing this scheme to fruition and to acknowledge the help of our Architect and our assistants in the office and the site supervisory staff.

74. We have also had sympathetic help from the Port of London Authority who have appreciated the difficult problem posed by the nature of the trade effluent in Dagenham.

Mr P. A. Banks

The pilot scale trials of secondary treatment of trade waste mentioned in § 11 have now been completed. With the agreement of the Port of London Authority these trials have been conducted using a section of the full-scale domestic secondary treatment plant.

76. The object of the trials was twofold: first, to confirm the practicability of treating trade waste alone, i.e. without mixing it with the domestic settled sewage; and secondly, to find the minimum aeration period that could safely be used. Both these objectives have been achieved.

77. The plant was started on a mixture of trade and settled sewage, and in the course of eleven weeks the proportion of trade waste feed was increased to 100%. For eight weeks, whilst the retention period was kept at 12 h or more, satisfactory results were achieved, i.e. the BOD was around 20 p.p.m. under steady conditions. For the remaining weeks of the six month experiment the retention was reduced progressively to 8 h and the BOD figure worsened markedly. During the experiment there was no reduction of ammoniacal nitrogen when running at 100% trade waste.

Mr J. Perks, Hadsphaltic Construction Co. Ltd

My contribution to this discussion is restricted to the construction section generally, and in particular to Contract C1. The Authors within the text of their Paper have made reference to various management and construction techniques and I feel that it would be of general interest if some were more fully described.

79. In § 51, the Authors refer to programming and to the use by the C1 Contractor of network techniques, both manual and computer assisted. A major network for the Contract was prepared manually but the resulting programme proved to some extent to be unsatisfactory, inasmuch as structures bearing high float, despite resource restraints, were difficult to position. Upon the major critical structures it became evident that the most effective control could be maintained by restricting detailed programming to construction periods of three months, and it was on these that computer assistance was used. The most successful use of this technique was upon the power wing, where a saving in construction time was directly attributable to the control that the Contractor was able to exercise.

80. In § 56, dealing with the main power and pumping station, the Authors mention that the cofferdam frames created difficulties in shuttering, and Figs 15 and 17 illustrate this point. That this method of construction was necessary was clearly indicated by the Engineer in his tender documents, but I submit that the opportunity

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to give additional strength to the external walls, thereby allowing them to cantilever from the base slab while supporting the backfill necessary for the release of the top cofferdam frame, was neglected. The resulting problems of frame handling and making good were quite considerable, and I believe that valuable construction time could have been saved.

81. In § 58 the Authors mention that the superstructure frame to the pumping station was precast. The Engineers' design allowed for an in situ concrete frame but it became evident, as the substructure progressed, that the following advantages were to be gained from precasting: (a) saving in time; (b) access for machinery would be unhindered by shutter centring; (c) installation of machinery in the substructure could commence at an earlier date.

82. In § 59 the Authors refer to shuttering. The C1 Contractor employed the services of C. Parry (Engineers) Ltd to assist in the design of shutters for both the settlement tanks, hopper and walls, and the effluent culvert. The hopper shutter, 16 ft 6 in. top dia. to 6 ft. bottom dia. by 9 ft 6 in. deep, was steel fabricated and in a single piece, placed to an accurately formed kicker and secured against upthrust by Macalloy bars, striking being effected by screw-jacks fabricated into the base of the shutter. This shutter was most successful, although it presented some handling problems.

83. It is interesting to note that the wall shutter could be moved at a rate of 40 sq. ft/man hour, resulting in a construction rate of a segment per day. Consecutive bay construction was adopted, support being provided to each bay at the time of striking until such time as a group of bays was self-supporting. There is evidence that this form of construction minimizes shrinkage at construction joints and it was found that horizontal distribution steel in the final bay had been subject to compression and deflected out of cover.

84. Withdrawable through ties were used at the base of the shutter, made good by driving kiln-dried taper plugs to the centre of the wall with concrete filling to each face.

85. The elevated rectangular open-topped effluent culvert was supported upon piled trestles and a shutter, with a soffit to the culvert hung from stressed-skin wall shutters. An internal shutter was suspended and the culvert poured to full height.

86. It was upon tanks 5-8 of the primary settlement tanks that the C1 Contractor used a finishing boom designed and manufactured by Stelmo Ltd. Supported by a bearing in the base of the hopper, the boom spanned to a circular track mounted on the floor perimeter shutter and carried a movable power float. This technique enabled the Contractor to produce a standard of finish equal to that of hand-laid granolithic surfacing—an operation which had proved to be most difficult on tanks 1-4.

Mr B. E. Roberts, Sir Alexander Gibb & Partners

The design population is given in the Paper as 392 000, and the dry weather flow as 15.7 mgd. That is almost exactly 40 gal/head per day. We have heard a great deal in recent years about the increasing water demand in Britain, and some of us have experience of large increases in certain areas over the last ten years. It is well known that water demand per head is by no means the same thing as the volume of sewage per head that reaches the sewage treatment works. There are losses to the ground and to the air, which are appreciable. Even so, and while 40 gal/head per day is probably entirely adequate for the present time, I would have thought that a rather higher figure might have been used to cater for the future. This is a matter which is not, I appreciate, always entirely within the decision of consulting engineers; nevertheless, I feel that it is a matter which the Authors must have considered very carefully, and any further comments from them on this point would be most interesting.

88. The maximum flow to treatment is 51 mgd ($3\frac{1}{4}$ times dwf). A figure of 3 dwf was recommended by a Royal Commission many years ago. I know that there are often reasons for increasing this figure but nothing is stated very clearly in the Paper. Would the Authors tell us how the figure of 51 mgd was actually determined?

89. The types of sewerage in the catchment areas are not mentioned. It would appear that Barking, with a recorded maximum discharge of $2\frac{1}{2}$ dwf, must be on a separate system. Nevertheless, the installed pumping capacity for the Barking sewer is now put in at 4 dwf, while that of the Havering sewers is a little above 6 dwf. The total combined pump capacity seems to be just about 5.4 dwf for domestic sewers only, excluding the main trade waste sewer.

90. Pumping arrangements are kept separate for the different domestic sewers, presumably because of the different levels at which the sewers enter the works. Other than that I cannot see much advantage in the separate arrangements. At first reading the 3 million gal storm tanks seemed rather small for a dwf of nearly 16 mgd. However, the difference between the maximum combined pump output of 5.4 dwf and the $3\frac{1}{2}$ dwf to treatment indicates a retention period in the storm tanks of a little more than 2 h, which seems to be in line with normal practice.

91. The secondary treatment is similar to that adopted in the original works. Do the Authors know why the two different forms of treatment, i.e. diffused air re-aeration of activated sludge and surface aeration of mixed liquor, were used? It is interesting to compare the extensions of the works for these two functions. For the re-aeration of activated sludge the extension duplicates the original both in surface area and volume, whereas the extension of the surface aeration tanks increases the original capacity by an additional 160%.

92. I note that the new total tank capacity for mixed liquor gives an aeration period of 6 h at dwf. On the basis of normal domestic sewage to be treated to Royal Commission standards, with a reasonable margin of safety, this seems just a little generous in design. The Authors' comments on this point would be of interest.

93. With regard to structural design, apparently a number of the demolished tanks were found to be in very good condition, although their design had not been carried out in accordance with the requirements of CP 2007. This was not available when the works were designed, nor were the earlier recommendations of the ICE for liquid retaining structures, so that the original designers had to rely entirely on their own judgement, which appears to have been very satisfactory. In what particulars did their design differ from the requirements of CP 2007? In my own experience, apart from the necessary limitations of tensile stresses in accordance with the code, an adequate cross-sectional area of distribution steel is most important—especially in countries where conditions for concreting are less favourable than in Britain.

94. Finally, with regard to the cost of the works, taking the total cost of £4 384 000 and the design population of 392 000, the cost per head is a little over £11—not for a new works but for an extension involving demolition and rebuilding. Have the Authors ever estimated what would have been the cost of these works on a new site? It might be as high as £12–£14 per head. Perhaps the Authors would comment on this.

Mr R. A. R. Drake, Greater London Council

In many cases when it has become known that the GLC were taking over a works minimum maintenance has been done. In the case of Riverside, so far as *sewage* treatment is concerned this was clearly not the case. However, the design of secondary treatment works for trade effluent in a separate plant has not yet been started and the investigation of the effluents concerned has taken a considerable time. Undoubtedly, though, Messrs May and Baker, who produce several hundred different effluents of varying degrees of nastiness, have posed a problem.

96. As soon as it became apparent that the Riverside Works would be vested in the GLC, negotiations which had been started with Barking were continued and agreement in principle was reached with the Essex River Authority that they would be supplied with 8 mgd of domestic effluent treated to Royal Commission standard. The Essex River Authority would pay for further treatment to a 10:10:10 standard

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and would pump 6 mgd of the treated effluent to the headwaters of the Mardyke, NE of Riverside. Industry at the lower end of that river, at Purfleet, would abstract to augment borehole supplies which were tending to be over-pumped. The remaining 2 mgd would be passed to the River Beam to make up for some part of the removal of the Bretons Farm effluent from that river and to ensure continuity of supply to Messrs Ford. In fact, a temporary supply of normal works effluent of up to 2 mgd has already been made available, pending the installation of the tertiary plant.

97. To determine the best form of tertiary treatment, several small-scale experimental plants were set up at Riverside in 1968. The scheme for the Mardyke is of considerable interest to the GLC, which daily discharges about 550 million gal of effluent to the Thames and its tributaries. It is regarded as a prototype from which valuable experience will be gained for the preparation of schemes for re-use, which it is hoped may involve a large proportion of the 550 mgd.

98. The scheme will create an interesting precedent since the whole cost of improving the effluent from Royal Commission standard will be borne by the River Authority.

99. In the Paper it is stated that the effective oxygen demand required by the Port of London Authority of the works effluent is to be not more than 18 ton/day. This is when the secondary trade treatment plant has been commissioned. The export of effluent to Essex will, of course, reduce this 18 tons, but the PLA will probably want to take into account the effect of the tertiary effluent at the places where it will in future be discharged. If the PLA wish the pollution load from Riverside to be reduced below 18 tons by the amount exported, as if the export were to Royal Commission standard, I would wish to know the basis of their reasoning. Discussions are about to start between the GLC and the PLA on future pollution loads from all GLC works, and this will include Riverside.

100. Due to the economic situation, the Ministry of Housing and Local Government unfortunately refused to agree to the erection of the new administration and laboratory block. The control and operation of the works cannot be carried on efficiently in the present administration block, and it is hoped that it will not be long before this serious omission is repaired.

101. It seems a little odd to have a main lift pumping station at the beginning of the works and in addition to have a lift effluent from the works. Can the Authors say a little more about this?

102. I have always believed that on entering a sewage works one should not be confronted with sludge disposal plant, which may strike one in more than one sense. If this is a fault in design, no doubt it was governed by the original layout. It might be said generally of the scheme that perhaps too little attention has been paid to matters of detail: for example, screening and isolation facilities are not as adequate as they might have been. From a design and operation point of view a raising of ground levels would have been worthwhile. With elevated works there is a tendency for the layout to be cramped and for the channels to be shortened to a minimum, sometimes at the expense of hydraulic efficiency. The provision of elevated walkways is also a problem, and from an operational point of view works above ground *must* involve extra labour and maintenance costs. At Beckton and Crossness, where original ground levels were of the order of 4 OD and operating levels about 18 OD, and where conditions are very similar to Riverside, everything being supported on piles, the raising of ground levels has been felt to be justified.

103. Can the Authors please give a few more details of the 50 ton piles for the digesters, i.e. the ultimate load, dimensions and set? Was there any difficulty in achieving the 5 ft penetration into ballast on the piles for the storm tanks?

104. I find it rather strange that, as they stand, the works have to be run as a single unit. It would not have been expensive or troublesome to separate the returned sludge to the two halves of the works, and thus provide for greater operational flexibility. Perhaps the Authors would care to comment on this.

Mr J. Jewell, W. H. Allen, Sons & Company Ltd

My Company was associated with the supply and commissioning of the dual fuel-generating plant and the pumping station at the Riverside Works.

106. It is perhaps not fully appreciated by engineers or ratepayers how much they benefit by the utilization of a by-product of the sewage purification process, namely, sludge gas, as a fuel to power prime movers.

107. In the Paper the Authors refer to the fact that the new sewage works caters for a population sufficiently large to warrant full-scale generation of power. In recent years the size of town or city able to justify such generation has steadily increased until the economic size and population for schemes now being started is about 250 000. Until comparatively recently a population of 80 000–100 000 was deemed to be an economic size. The reason for the economic crossover point now standing at a population figure of about 250 000 is not that the price of purchasing electricity has been reduced or that the capital cost of the plant has been increased disproportionately, but rather that interest charges and labour costs have increased and skilled labour to operate and maintain the plant has become more difficult to find.

108. This is not to say that there is no case for private generation on smaller sewage works where sludge gas is available and would otherwise be flared off. In such cases it is often possible to negotiate an advantageous tariff with the Electricity Board on the basis of a low maximum demand during the day-time hours. The gas produced during the night can be stored for use during the following day and may be sufficient to run engines on dual fuel during the day and avoid incurring high maximum demand charges without the need for using any fuel other than that necessary to initiate combustion. A further advantage is that the plant can be used for standby operation in the event of failure of the Electricity Board supply.

109. In the case of Riverside the average number of bhp hours developed in a year is 14 million; the cost of generating this power with liquid fuel priced at about 1s 0d/gal would be £29 000. However, sufficient gas is available to replace approximately threequarters of this fuel oil, resulting in a saving to the ratepayers of approximately £22 000/year. At another much larger works also administered by the GLC, where dual fuel engines are used both to generate electricity and to drive low pressure turbo-compressors and an abundant supply of gas is available at all times, the average bhp hours developed per year total 48 million and the net saving to the local ratepayers is of the order of £100 000/year. This is in proportion to the saving which I calculate is being made at Riverside.

110. In the case of my own local authority at Bedford, where a dual fuel generating scheme is at present awaiting Ministry approval, it is anticipated that sufficient gas will be available to generate all the day-time power requirements of the sewage works. This will enable the Corporation to take advantage of the Electricity Board's industrial off-peak tariff, which results in a very low unit price for off-peak purchased power and eliminates the usual maximum demand charges.

111. Before reaching their decision the Corporation estimated the overall unit cost of power generated with various alternatives as follows:

- (a) purchase of all power from the Electricity Board: 1·76d per unit;
- (b) generation of all power using diesel fuel to make up the deficiency in gas availability: 1·21d per unit;
- (c) generation of power during the daytime with the purchase of off-peak power: 1·12d–1·24d per unit, depending on the timing of the period when the off-peak power is purchased from the Electricity Board.

This comparatively small scheme, which caters for a population of around 80 000, has an annual power consumption of some 3 million units.

112. The saving by generating the daytime power can be as high as 1·76d less 1·12d, i.e. 0·64d per unit. Taken over a year this is equal to £8000. That is not a

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Table 3

	Suspended solids	Permanganate value	BOD	Amm. N ₂	Ox N ₂
Domestic crude sewage . . .	545	79	389	—	—
Domestic settled sewage . . .	140	37	170	32	—
Domestic final effluent . . .	23	13	14	21	6
Trade sewage	489	132	477	—	—
Trade settled sewage	116	100	349	60	—
Mixed final effluent	53	33	90	29	5

Notes: (a) All BOD results are ATU suppressed.

(b) All values expressed in mg/l.

Fig. 19. Riverside Works: domestic effluent

large saving but sufficient to represent a payback of capital outlay in about 6–8 years, whereas the plant itself should have an economic life of certainly not less than 20 years and probably nearer 30 years.

113. The policy of the Electricity Boards in encouraging the off-peak demand for electricity is likely to increase the attraction of this type of scheme in the future.

Mr J. L. Dakers, Greater London Council

It is usually of interest to those who have been reading and discussing papers to have some information on the operation of the works. The average analyses for the period 4 November, 1968 to 27 October, 1969 are given in Table 3 and graphs of some significant data in Fig. 19.

115. It has already been said that until secondary treatment for the trade sewage is provided it will not be possible to approach the standard of 18 tons of EOD.

During the year the effluent EOD was as shown in Fig. 20. The average EOD was 31 tons, of which approximately 15 tons are due to trade settled sewage.

116. The danger of flooding of the catchment area is very great and flooding would cause extensive damage to some very large industries and densely populated areas should there be a failure of the pumping plant. In this situation did the Authors consider a standby electricity supply from the National Grid with a smaller number of higher capacity pumps and alternator sets?

117. There is a considerable amount of duplication of equipment provided, including 17 pumps of varying sizes. However the inlet screens are not inter-connected, and there is no standby on the Barking and trade sewers where the danger of flooding due to blockage is highest.

118. During the late summer (August–September, 1969), the activated sludge plant was in an unstable state of partial nitrification. This was accentuated by the fact that the surplus sludge meters were still not commissioned. Secondly, hydraulic conditions caused by the use of the old works made even distribution of settled sewage and return sludge difficult to control. Thirdly, there was the loss of some aeration capacity due to the experimental work on trade sewage. These together caused a gradual drop of density of the activated sludge, and during the low flows of September considerable denitrification took place which culminated in almost complete loss of activated sludge solids.

119. Although using separate re-aeration and aeration units, would it not have been advantageous to provide a method of feeding settled sewage to the inlet of the re-aeration channels to give flexibility in operation? It would probably also have been easier to operate in these conditions if the two halves of the plant had been independent rather than with a common return sludge pumping station.

Fig. 20. Riverside Works: Mixed final effluent

Table 4. Running costs

	£
Capital repayment and interest.	477 000
Operating budget*	149 000
Sludge disposal (to sea).	45 000
	<hr/>
	671 000†

* Includes laboratory and management costs but not head office.

† Excludes general and water rates.

120. Whilst appreciating the expense involved in excavation, it would seem essential to me to have a final settlement tank with a floor slope of about 30° for satisfactory collection of light activated sludge. However, having decided on a large diameter flat floor tank design, did the Authors consider de-sludging machinery of the suction lift type?

121. In the digestion plant, rapid gas generation caused raising and tilting of the floating roof of the primary digesters in October 1968. This was overcome by feeding twice daily. However, this difficulty again arose during the same period in 1969, and the guide channels in digestion tanks 3, 5 and 6 were torn from the wall, or wheel brackets broken on the roof. This would appear to be due to the low surface area/depth ratio of the tanks, the high concentration of volatile acids in the consolidated raw sludge, and the tank roof design. It is not normally possible to use the screw pumps for stirring purposes.

122. As far as the power house is concerned, there have been several minor troubles, which would be expected on a complex plant of this nature. The average loading of 1150 kW with direct on-line starting of pumps has meant a close margin between running two or three engines, the latter giving a large increase in the unit cost of generation.

123. Costs are difficult to give accurately as a full financial year has not passed, and until a booster fan was fitted to the gas supply to the engines it was not possible to operate more than one engine at a time on dual fuel. For interest, however, the figures for the year commencing 1 April, 1969, are given in Table 4.

Mr K. Guiver, Essex River Authority

The discharge from the Bretons Farm Sewage Works of the London Borough of Havering, prior to the reconstruction of the Riverside Works, caused severe pollution of the River Beam due to the works being grossly overloaded. The sewage flow being received was over 7 mgd against a designed flow of 4 mgd, and there was little nitrification. During one winter a dispensation for the discharge of settled sewage from the works had to be given, to avoid the filters becoming completely blocked and septic.

125. I would like to ask about the future capacity at Riverside. Even without the Brentwood Urban District coming into the scheme, the design population figure for Riverside (392 000) is large, and I wonder whether the works are yet up to this. Have the Authors any idea when expansions might be expected in order to cope with the future population increase and the potential increase in winter usage and sewage flows?

126. I am particularly interested in § 12 (effluent standards). I think this is probably the first case of a river authority wishing to accept pollution from a sewage works and put it into one of its own rivers. The flow, however, will only be taken intermittently. The basis of the Riverside re-use scheme is to make up the flow in the Mardyke to allow abstraction by industrialists, whenever the river flow drops below about 6-8 mgd. The natural flows are probably only above this figure for a month or so each year, but it does mean that the sewage flow at Riverside will not be required at all times.

127. I wonder also whether the removal of 8 mgd will in actual fact reduce the effective oxygen demand load on the River Thames to the extent anticipated by the Authors. On the basis of the existing carbonaceous and nitrogenous oxygen demand of the effluent, possibly only 3 tons will be transferred from the river, and even then sludge from the wash waters of the sand filters will be returned. Even if the demand for treated effluent to the Mardyke in future increases up to 15 mgd this will still not dispose of more than a fraction of the 18 tons allowed to be discharged to the River Thames.

128. Underground waters are growing more and more saline in the Thames-side area as the requirements for water supply increase, and it is the intention of the

effluent re-use scheme to cut back on the underground abstraction by allowing the industrialists to abstract from the Mardyke. The groundwater levels in the area are well below OD, and with the constant incursion of saline water from the River Thames it is important to get a fresher supply and cut back on underground abstraction.

129. The scheme has so far been only on a pilot scale, but sand filters of three different types have been removing roughly 80% of suspended solids in the final effluent from the Riverside Works, and also achieving a BOD removal of 60%. The BOD is still high, however, and I would like the Authors to give an indication of the reason for the very fine solids which are produced by the final settlement tanks from the Riverside activated sludge plant. The tank effluent generally has less than 15 mg/l of suspended matter, but still blinds the sand filters fairly readily and has a high BOD. To improve nitrification it is now proposed to put the effluent through nitrifying filters at high rates of up to 2000 gal/cu. yd. A short period of trying this on a clinker filter has achieved a considerable clarification of the effluent, but whilst doing so and converting 30 mg/l of ammonia to about 20 of nitrate at the same time, the BOD, as measured by conventional analysis, has increased, although obviously the effective oxygen demand, as calculated from carbonaceous and nitrogenous demand, must have decreased.

130. In § 35 the Authors mention the sludge main to the outfall works and certain difficulties in regard to the epoxy resin coating. Will the coating be effective against the abrasive nature of the sludge being pumped? Are any tests being carried out regularly on that main, particularly below the creek, in order to detect whether corrosion or erosion is taking place?

Mr G. J. Newman, John Taylor & Sons

I should like to mention some aspects of the work carried out by the Resident Engineer's staff during the 3½ years I spent at Riverside.

132. There were six main contractors concerned with the construction of the plant and the sludge disposal pipeline, and the Employer's own staff were also on site, maintaining the existing plant in full operation. These factors, together with the large size and complex nature of the works, produced some unusual problems. On such projects it is helpful if a spirit of co-operation and confidence exists between the contractor's and the engineer's staffs. In order that this could develop it was important to ensure that the specification and other contract documents were properly and uniformly applied to each contract and to achieve this frequent policy discussions were held between the RE and the members of his staff.

133. The number of engineers and quantity surveyors that each contractor employed on site varied considerably, even for contracts of a similar nature. One contractor for instance had at one time as many as 15 such staff while another (albeit on a much smaller contract) had only one engineer on site throughout the whole period. In general terms the staff to contract value ratio varied between 1 and 3 staff per £1 million of contract value.

134. The strength of the RE's staff was based on the principle that there should be one assistant RE and one inspector attached to each contract with the RE and deputy maintaining overall responsibility. Because work loads would vary considerably, arrangements were made to boost the number of assistant REs as and when required. In spite of this, there was difficulty in coping with the full amount of quantity surveying measurements. The bulk of the £4 million worth of work was completed in 40 months and the RE's staff was therefore required to remeasure and value about £100 000 worth of work each month. This difficult task was made more arduous because large amounts of work had to be carried out under dayworks or variation orders, and because both the building and civil engineering methods of measurements were used. This work really warranted the attention of a full time quantity surveyor or measurement engineer on the site.

135. Something which is peculiar to schemes involving several contractors is the importance of co-ordinating their activities and those of the design team, and in the case of Riverside the sewage works manager and the many nominated suppliers and sub-contractors. A master programme was compiled for this purpose based upon the individual contractors' programmes. This was then updated about twice a year, and helped considerably in avoiding difficult situations by drawing attention to future activities which interfered with each other, etc.

136. The programmes submitted by the contractors included simple bar chart programmes and sophisticated network programmes. Having seen the full effect of these I am inclined to believe that the quality of the agent and general foreman has the greatest effect on progress and not the type of programme.

137. The quality of concrete, shuttering and steel fixing was generally very high and was not difficult to supervise. Nevertheless, difficulties did arise in respect of shuttering for small non-repetitive units, possibly because the carpenters were hampered by muddy site conditions and perhaps because of bonus arrangements which probably favoured those working on repetitive units.

138. The specification limited most pour lengths to a maximum of 25 ft and required an interval of seven days to elapse between consecutive pours. These requirements were gradually relaxed in the light of experience. Pours 35 ft long were allowed, and elsewhere adjacent pours sometimes followed each other at 24 h intervals. Regular surveys were made to record the number and widths of the cracks appearing in the concrete both at construction joints and within the pour length. Crack widths were measured with a portable microscope and ranged between 0.004 and 0.01 in. There was, however, no significant difference in the number or size of cracks occurring in concrete poured to the original specification requirements and concrete poured to the relaxed conditions. No problems of leakage through these cracks were experienced.

Mr D. H. Lacey, Kottler and Heron Ltd

Mr Perks referred to the use of a shutter every day. If we could use a shutter every day on all contracts profits would be considerably increased and the costs of this class of work would be considerably reduced. In spite of all the propaganda and information about striking times, recommendations, etc., supervising engineers still sometimes stick to the book. If all contractors priced every specification word for word the costs of work and the prices submitted would rise enormously. Generally specifications are treated in a reasonable manner.

140. I would appeal to all supervising engineers to examine the question of striking times very seriously and to adopt a very realistic attitude. If a contractor strikes a wall too quickly he has to put it right. On the other hand, there is nothing worse than having highly skilled men and plant standing idle for a few hours just for the sake of a piece of paper.

Mr D. A. H. Everett, London Borough of Croydon

My Authority has just completed a regional works of similar size to Riverside on the southern boundaries of Greater London. Completion of the Beddington works, preceded a little earlier by the Riverside works, completes the ring of regional sewage treatment works for Greater London envisaged in the 1935 Report of the Ministry of Health.

142. With regard to the design population of 392 000, it is not stated for what date this population was taken. One infers that the population is rapidly increasing, and, coupled with the water consumption figures of 40 gal/head, this does suggest that further extensions may well be needed in the not too distant future. Looking at the layout plan, one wonders just how readily these can be fitted in.

143. With regard to secondary treatment, the Paper does not give the strength of the incoming sewage, so perhaps it is a little difficult to comment on the capacities

and power provided. However, with the apparent provision of 8 h detention and 40 hp/mgd, this would suggest that this is sewage of normal strength.

144. It is interesting to note that the present design repeats the earlier one, which must now, as a design, be almost 40 years old. Extensions contemplated to the Croydon works in 1930 included a similar scheme for aeration of activated sludge using diffused air, followed by full aeration utilizing the Simplex system. Those extensions were never built and perhaps today such a design may be considered a little old-fashioned. Is it possible to convert the re-aeration tanks to full aeration tanks at some future date?

145. I would question the large number of sumps provided in the pumping station. I can see the necessity for having a separate sump for the trade sewer, but there seems to be little difference in level between the other sewers, and surely the multiplicity of sumps has proved to be a rather expensive arrangement.

146. Many papers on sewage works describe problems with screens. At Croydon there is a similar pumping installation of a similar depth. Screens at low level have been discarded altogether and pumps capable of passing a 7 in. solid have been installed. Time will tell how these behave. The station has been in operation for two months, and even with heavy storm flows there have been no problems from rags in the impeller.

147. So far as construction is concerned, at Croydon the system of floor construction adopted was the same as for tanks 5–8. These were primary tanks of somewhat larger diameter and this proved reasonably satisfactory.

148. On wall construction, I think these can with advantage be concreted sequentially rather than on the hit-and-miss principle. After starting on this principle at Beddington we later converted to the sequential system, and obtained a much quicker turn-round with equally satisfactory results.

The Chairman, Mr T. A. L. Paton

In § 50 the Authors refer to the number of main civil contractors and I was interested to hear from the Resident Engineer that they had no less than six. Were these medium sized contractors more efficient than the large ones? Are the consultants more efficient in the co-ordination of a number of contractors rather than large contractors? Would the Authors repeat this exercise? Were there fewer claims? Did the division of work enable the Consultants to keep up with the working drawings?

150. It must have been interesting to note the competitive spirit between the various contractors, to see them carrying out the same sort of work and to observe which method proved the better. But from what the RE has said I have the impression that the Authors took the lowest common factor in workmanship. Could they comment?

Mr D. Leather (M)

It is stated in § 45 that 'All the circular tanks were designed with a joint at the base of the walls. This showed the greatest advantage structurally in the tall digestion tanks, but it made for ease of construction in all tanks.'

152. It would be interesting to know whether the joint referred to was of the construction or movement type and, if the latter, how its inclusion was of advantage structurally. How thick are the walls of the digestion tanks, which presumably retain a depth of sludge of about 50 ft? Has a membrane lining been applied to ensure watertightness, or were the tanks designed in accordance with CP 2007?

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

The Paper contains much useful information of benefit to engineers concerned with public health engineering. There are three points which I would like to raise.

154. The Authors state that the charges laid down by the London County Council

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for the reception and disposal of sludge were based on wet tons. Was this purely domestic sludge or a mixture of domestic and trade sludges, and if only the former, how did the addition of trade sludge affect the measurement?

155. Could the Authors also say what the moisture content of the domestic sludge was after dewatering, and to what extent this was adjusted by the addition of trade sludge to improve the pumping characteristics of the thicker domestic sludge. Did the final sludge mixture behave as a Newtonian fluid or were special investigations necessary to determine its viscosity?

156. With regard to § 34 relating to the pipeline would the Authors use an in situ epoxy resin coating in future pipelines or was the loss of adhesive due to insufficient preparation and cleaning of the steel prior to application of the primer?

Mr D. F. H. Pharoah, Binnie and Partners

I was particularly interested in the proposal to pump the sludge for 5 miles to the Northern Outfall Works of the London County Council. Can the Authors say what was the moisture content and viscosity of the combined sludge which was pumped? What velocity was the sludge pumped at and how did the Authors estimate the hydraulic resistance of the pumping main? Have any tests been carried out subsequently to determine the frictional resistance, and if so how does it compare with the estimated value?

Messrs J. T. Calvert and P. A. Banks

The Authors would like to thank contributors to the discussion for their interesting and informative remarks.

159. To deal first with **Mr Paton's** questions, splitting up a works of this type into smaller contracts has many advantages in co-ordination and in progressing the work. The sections of the work which would take longest were included in the first contract and because other sections which could start later were not included it was possible to put it out to tender sooner. Furthermore with just one contractor on a large site, unless one is lucky there may be enormous difficulties, although basically this depends on the quality of the site staff, particularly the agent. If there are three site agents, two may be good; if there is only one, he may be good or bad! There seems to be no basic principle determining whether one should divide up the work or put it all out to one contract. We do not believe that a lowest common factor approach operated in supervision, but perhaps **Mr Paton** would like to arrange an Institution visit so that members can see for themselves!

160. **Mr Roberts** and other contributors commented on the figure of 40 gal/head. It must be realized that in addition to the 16 mgd dry weather flow there are 5 million gal of trade effluent, which represent another 13 gal/head, so that the overall figure for which we are providing is 53 gal/head. Much of the forecast future growth in water consumption is for industry and in this area we think we have more information on what industry is going to produce than in many areas where the position is less certain.

161. We did not estimate the cost of the works on a new site, but this would certainly have been more expensive: £11/head is certainly on the low side and, with a works even of this size, nowadays the figure would probably be somewhere between £15 and £20, particularly for a site such as **Riverside** with difficult ground conditions.

162. Comments have been made about the multiple sumps (§§ 90 and 145). The trade effluent had to be kept separate from the domestic sewage. The wisdom of that has been shown by the use that the Essex River Authority are making of the treated domestic effluent; they could not have used it if it had been mixed. Also it was known that sludge digestion would be inhibited if trade sludge or even surplus activated trade sludge was mixed with domestic sludge. The separation would ensure that any nitrification on the domestic side was not inhibited and any risk of

failure of carbonaceous oxidation due to new trade waste constituents would be confined to only about 25% of the total flow. But the other separation was partly because the levels were different (the station layout was dictated by the trade/domestic split) and also because at the time of designing the works the Clients comprised three different authorities, Dagenham, Romford and Hornchurch, so that there was a certain amount of feeling on the part of the Clients that separate sumps would ensure that there was no risk of one sewer surcharging another.

163. **Mr Jewell's** remarks were most interesting, bearing out very much of what we have found—that the population for which it is economical to install generation is rising all the time. Immediately after World War II we put in generation at one works for an estimated population of about 60 000. Today they have turned over to buying their power at night and producing it on site during the day, as Mr Jewell indicated.

164. **Mr Guiver** talked about nitrifying filters increasing the BOD. The BOD test seems unreliable, because one can hardly get a worse effluent by putting it through a percolating filter. It is a matter of finding the proper method of representing the quality of the effluent, since when an effluent has been nitrified it is better for the river.

165. **Mr Perks** suggests that the main pumping station walls should not have had to rely upon the motor floor slab as a prop before backfilling. This could have been arranged at the expense of 6 in. of extra thickness or additional stiffening walls across the sumps. The granolithic surface he mentions was used only on primary settlement tanks 1–4. On all other tank floors the reinforced concrete surfaces were satisfactorily finished when placed.

166. Mr Roberts points out that the flow to treatment is $3\frac{1}{4}$ dwf. This figure derives from the combination of pump capacities provided and ensures that normal peaks do not overflow. The incoming partially separate sewers from Havering are designed for 6 dwf and the new Barking sewers, mainly from pre-war separately drained development, for 4 dwf. Since in our experience sewers sooner or later are used to the full capacity, it was felt right to provide equivalent pumping capacity to avoid a surcharging and flooding risk. Storm tank capacity is related to the capacities of the sewers in excess of 3 dwf, i.e. 1 dwf in the case of Barking and 3 in the case of Havering.

167. The probability is that the two types of aeration derive from the assumption that mechanical surface aerators would not hold the high solids content of the return activated sludge in suspension. Less importance is now attached to re-aeration, and so it was felt reasonable only to duplicate the existing tank and provide the rest of the required aeration capacity in new surface-aerated tanks. Total capacity, including re-aeration, is equivalent to 8 h and for mixed liquor it is 6 h. This is not unduly generous for a moderately strong sewage (see Table 3).

168. On the question of CP 2007 and the design used in the original works, the difference seemed to lie mainly in the minimum thicknesses which were used. There were walls of 6 in. or less, and the amount of cover was often quite small. Lack of cover had led to spalling of concrete away from the reinforcement, and rusting. The walls of the original re-aeration tanks were gunited externally to increase the cover on the old steel.

169. **Mr Drake's** comment on the time taken to deal with the trade waste problem is justified from a reading of the Paper. There were, however, good reasons. To start with two consecutive sets of experimental work were commissioned from the Water Pollution Research Laboratory which demonstrated that a Royal Commission standard effluent could be obtained, but that nitrification could not be achieved even using filters. It was apparent that inhibitors were present in the May and Baker element of the waste. The PLA effluent standard for Riverside had been set in 1963 as 18 tons of effective oxygen demand. In terms of BOD and oxidizable nitrogen content this was 20 ppm and 35 ppm respectively, although strict compliance with

these individual limits was not insisted upon as long as the total demand was kept to 18 tons of oxygen.

170. The trade waste has an ammoniacal nitrogen content of about 70 ppm and an organic nitrogen content of about 20 ppm, so that without a substantial reduction in these figures or dilution of trade waste with a fully nitrified domestic effluent the PLA standard was not achievable. Dilution did not seem justified economically even if it were possible consistently to nitrify the domestic waste. Discussions were therefore held with the Company, who undertook two further series of experiments with WPRL to identify the inhibitors. In all, over 50 separate process effluents were screened and those which were shown to be inhibitory were excluded from subsequent samples fed to the activated sludge plants at the laboratory, but even then these samples could not be nitrified. Exhaustive but unsuccessful efforts were made in the factory to identify all the inhibitors but it was finally concluded that exclusion of inhibitors on a permanent basis was not practicable.

171. All this took time, and eventually led to further discussions with the PLA and the pilot scale trials described in §§ 75–77.

172. We are grateful to Mr Drake for his description of the re-use proposals for the Riverside domestic effluent and to Mr Guiver for the additional detail.

173. The reasoning behind the two lift pumping stations for crude sewage and effluent was that if all the flow was pumped only once to command the highest tide level in Rainham Creek then it would have to be pumped to the extra height continuously and not just an average of 8 h/day. To raise the flow at the inlet would also have meant building many of the units on fill, making working conditions even worse than they were. Furthermore it would have been impossible to incorporate any of the existing aeration tanks.

174. To raise the ground levels, as Mr Drake suggests, would have required a great deal of costly imported fill and deep sumps on the pumping stations. Although the works are on quite a large site, they were surrounded by sludge lagoons and there was not sufficient room to provide the more spacious layout which filling would have needed. The overhead walkways and connecting footbridges, etc., are certainly much cheaper in first cost, and once up an operator can move over most of the tanks without returning to ground level.

175. The 50 ton piles under the digesters were 12½ in. in diameter driven to a set of 4 blows/in. Their actual working loads varied from 35 to 42 tons. There was no difficulty in achieving the 5 ft penetration into the ballast on the storm tanks using the Raymond system. Using the West system, penetration beyond 2 ft or 3 ft did tend to be more difficult; but in any case this system was not used for tension piles.

176. The then Works Manager was consulted regarding splitting the return sludge pumping station, and it was not felt to be necessary. Whilst such consultations are desirable in theory and are often urged upon designers, the passage of time has a way of reducing their value.

177. We are grateful to Mr Dakers for his information on the plant performance and running costs which add greatly to the value of the Paper. A standby grid supply was considered, but since at that time the grid supply in the area was very fully stretched and not entirely reliable (there had been power failures and there were more during the construction period), it was felt that better standby could be provided with an adequate number of engines. Another factor, of course, was the high standing charge which would have been incurred for a guaranteed standby supply of sufficient size. Maintenance may also suffer if it is known that a standby supply is available at the touch of a switch.

178. The position on the screens is that the two regional inlets are interconnected upstream of the screen penstocks and so each provides an emergency standby to the other. The Barking screen has an emergency by-pass into a regional sump. The trade waste sewer has no such arrangement but does not carry as much material to be screened.

179. As Mr Dakers points out, trouble has been experienced with the sealing on the magnetic flow meters. The oil filling has now been arranged with a header tank, which it is hoped will avoid the shrinkage which occurred with the earlier grease filling. These meters are needed for accurate control and it is very much to Mr Dakers's credit that he has overcome this handicap and maintained a good effluent apart from the period mentioned.

180. To provide a means of feeding settled sewage to the re-aeration tanks would have involved extra cost since the tanks operate on a counter flow principle, i.e. the return sludge enters at the downstream end in relation to the main flow stream of mixed liquor. Mr Everett made a similar point, but the Authors feel that what matters is the amount of capacity and horse power provided rather than how it is arranged, which is of secondary importance.

181. Whilst appreciating Mr Dakers's preference for final tank floor slopes of 30° , these would have been extravagantly expensive on this site in view of the ground conditions. A reasonably generous capacity and good scrapers with variable speed drives were provided. The more expensive suction lift scrapers in the Authors' experience are not satisfactory and they no longer use them.

182. On the question of fluctuating rates of gas production, a ring main was provided to enable all the tanks to be fed at once. The cause of rapid gas generation is probably the dosing in turn of each tank which, even if done twice a day, is still a considerable shock load on one tank. There is also the fact that the GLC has not yet chosen to refurbish the two original tanks, which were cleaned out and inspected for the first time for 35 years after the new ones were commissioned. The use of these tanks as standby storage means that digestion capacity is 25% less than intended and also that there are only four tanks to share the dosing.

183. When the trade waste secondary treatment plant is commissioned the load factor for the three engines will improve, but the problem Mr Dakers speaks of is an inevitable one unless a multiplicity of generator sizes is to be used to match the capacity with the load. The Authors tried to arrange that engines would not need to be run underloaded, which would be inefficient and damaging, but this does require care in matching. To assist the operator, an electrode boiler was provided as an additional load. Mr Dakers refers to the gas booster. It was originally hoped that this complication would not be necessary but as a comparatively light roof was used to the digestion tanks its omission was something of a calculated risk. Gas meter orifices and other losses used up too much pressure, however, and a booster has had to be installed.

184. Mr Guiver and Mr Everett ask about future population and flow increases. This question was studied during late 1968 and it was concluded that the population was then about 352 000. The current best estimates from the planners are 387 000 in 1981 and a possible long-term population of 433 000. Current average flows are shown by Mr Dakers in Fig. 19. There is plenty of space on the site now that the sludge disposal problem is solved and with the several sewers entering from different directions the location of extensions will be relatively easy.

185. The 3 tons of EOD that the Mardyke scheme will remove is about the minimum figure needed to reduce the EOD of the combined effluent to 18 tons on the basis of Royal Commission standard domestic and trade effluent, although the domestic effluent has been better than this most of the time.

186. The fine solids which Mr Guiver found in the final effluent were associated with the period when the domestic plant was in the unstable condition referred to by Mr Dakers in § 118. This was during the pilot experiment on trade waste which deprived the domestic plant of capacity.

187. The epoxy coating on the sludge main (Mr Guiver and Mr Flemons) simply peeled off soon after it was put on, and was swept out of the line during testing. It would probably have withstood the abrasion of the sludge quite well if it had stayed on, although it was quite thin. We are tolerably sure that the reason for the failure

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was that the previously applied primer was not sufficient to keep the pipe surface rust free, or to provide a good base to the next coat applied in situ. Furthermore the in situ coats of epoxy were not cured properly and therefore solvent trapping almost certainly caused a loss of intercoat adhesion, and indeed complete loss of adhesion to the pipe wall.

188. There is now no internal protection at all on the pipes below the creek and none of any significance on the remainder of the line. This we consider is not a bad thing: sludge is, by its nature, greasy and has not acquired a reputation anywhere for corroding pipelines. We would have preferred that the epoxy resin under the creek had stayed in place, and would use this material again if we could be sure it would stay on. In fact the technique of placing it in situ was beyond the sub-contractors' abilities at that time.

189. We are glad that **Mr Lacey** emphasized the way in which the engineer can help the contractor to improve productivity in the construction of sewage works.

190. **Mr Everett** asks about the sewage strength and **Mr Dakers** has provided some information on this.

191. The Riverside pumps are designed to pass a 4 in. solid and the screens were meant as pump protection only. The pumps will readily pass rags, and since the ability to pass a 7 in. solid will not stop damage by an even larger object we would not consider the decrease in efficiency justified.

192. **Mr Leather** asks about wall joints. The joint referred to in § 45 was a movement joint with complete structural discontinuity and a water bar (see Figs 10 and 11). Hinging the wall at the base simplifies the design of the base and considerably reduces its thickness, e.g. the digestion tank wall thickness was 33 in. and the base between ring beams 15 in. The amount of vertical reinforcement required in the digestion tank wall for a fixed base (on the inside face at lower stresses) would have necessitated a thicker wall to accommodate it. The steel for the slightly higher hoop stresses in a hinged design can be readily accommodated anywhere in the section and the vertical steel can be to higher stresses at the outside face.

193. No lining was provided to the digestion tanks or any of the structures for that matter, and all were designed in accordance with CP 2007.

194. In answer to **Mr Flemons** the LCC charges were to have been based on measured volumes (gal) of mixed sludge which was taken to have a constant density and was converted to tons using a standard factor.

195. **Mr Flemons** and **Mr Pharoah** ask about the pumping of sludge. The sludge has been pumped at moisture contents as low as 91%, but as the viscosity will clearly vary considerably in service no attempt has been made to measure it. The frictional resistance assigned to the sludge at the design stage was four times that of water.

196. Since the works have been operated by the GLC the question of charges does not arise and until recently the dewatering of sludge has not been of paramount importance. The digested sludge and trade sludge have moisture contents of about 97.5% and 95% respectively. The sludges tend to be batch-pumped rather than mixed, and the pressures indicate a frictional resistance about 1.5 times that of water. The velocity is about 1.7 ft/s. It is possible to use both pumps together when pressures double, indicating a reduction in frictional resistance at higher velocities.

197. Efforts are now being made with some success to reduce the water content of domestic sludge before pumping.

Corrigendum

Paper 7212, *Proceedings*, September 1969, p. 15, § 36, line 2: for 600 kVA read 600 kW.