King George Dock, Hull: major developments, 1959-1963

by

D. G. McGarey, B.Sc.(Eng.), M.I.C.E.

The Chairman (Mr W. G. Harris) was most interested in the method of piling, with which difficulties were encountered both with hard driving on No. 7 Quay and with running into a soft stratum on one of the other quays, resulting in cracking of the piles. It would be useful if the Author would expound a little on that in his reply.

63. Could the Author give some idea of the centres at which bores or test piles were driven in the survey before the design was completed? He had implied in the Paper that the result of the soil survey was not borne out in practice, nor were the deductions from it.

64. Why were prestressed concrete piles used for the anchorages on No. 7 Quay, whereas reinforced concrete piles were used for anchorages in the other quays.

65. Had the hydrographic survey, carried out to determine the position of the pumping station, proved successful in the sense that it was now possible to determine the optimum pumping periods, and had this resulted in a reduction of siltation in the Dock?

Mr J. H. Jellett (Chief Docks Engineer, Southampton Docks) had great pleasure in offering his congratulations to the Author on the Paper he had presented.

67. He had been interested in the reference to radiographic examination of the welded joints. Had the Author found his contractors agreeable when pressing this arrangement on them? Only recently Mr Jellett had had occasion to have a rather important welded structure constructed, and when he suggested to the contractor that he would wish to examine at least the more important structural welds by ultrasonic equipment, the contractor indignantly replied that that would mean extra rates for all his welders. Apparently, according to the contractor's philosophy, only people who built pressure vessels for nuclear reactors were so indecent as to expect the welds to be examined by other than visual inspection! However, he had managed to persuade the contractor that if the welds he was providing were satisfactory, then there was no reason to fear the examination. A friendly settlement was finally achieved and Mr Jellett was glad to say that the ultrasonic examination did not reveal any serious defects. It would be interesting, however, to know whether the Author had been made to feel in any way disreputable in including that clause in his specification.

68. He noticed that the crane tracks were provided at 15-ft gauge. There would seem to have been plenty of room on the quay for the 18-ft gauge, which was another of the standards widely adopted, so, in view of the slightly more favourable sub-structure loading that that gauge produced for the same operational features, was there any reason for not doing this?

69. He had seen the sheds a number of times in their various stages of construction and they were indeed a most fortunate solution to the problem. He was, however, interested to know whether the Author gave consideration to the possible use of

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corrugated fibreglass sheeting for the skylights, which tended to make a rather easier detail than the continuous skylight shown. It was essential that this corrugated fibreglass should be used as individual separated sheets, for although the manufacturers insisted that the corrugations matched those of the aluminium sheeting, in point of fact they did not quite match, so that at the end of about 10 sheets they were about half a pitch out; the simplest way was to alternate them so that any one fibreglass sheet was surrounded only by aluminium sheets. It gave a very happy lighting effect and allowed the sheeting of the roof to go through as a continuous operation.

70. He wished to thank the Author for the inclusion of Appendix 2 and, generally speaking, for his great frankness on the subject of costs. Mr Jellett felt that a description of an engineering project without some indication of its cost would take away a great deal from the value of a paper. He would not discuss the details of the costs the Author had disclosed, nor Appendix 2, because he and the Author had had a long correspondence on the subject about two years ago, when they carried out a very interesting comparison, item by item, of the costs of these sheds and the costs of some rather smaller sheds that were completed at about the same time in Southampton. It was extremely interesting to note, as the cost was built up, how sometimes one shed gained a little and sometimes the other, but broadly speaking the comparison was very favourable. He had to admit that his own sheds were a little more expensive than the Author's, but the difference was nothing for which a satisfactory explanation could not be found, and he had been struck at the time by the tremendous value of this sort of exercise for estimating future projects.

71. One large omission in the Paper that he wished to stress was that there was insufficient attention given to the ergonomics with regard to the design; in other words, how was it going to be used, what was the potential through-put in terms of traffic to be handled of these sheds, and how far were the various steps, taken in the design to meet this through-put, realizing the hopes that were placed on them. He felt that this was very important for projecting forward into future projects.

Mr J. E. G. Palmer (Partner, Messrs Rendel, Palmer & Tritton) congratulating the Author on a clear and concise Paper, said that he was most interested in the basic planning of the layout. His own opinion was that the basic 3700 ft of continuous North Quay was absolutely right. He sincerely hoped that the Dock Superintendent was highly pleased with what he had been given, but wondered whether he had told the Author so! However, supposing the Author had to start all over again now and replan an improvement to the Dock, would he use the same layout or redesign it? Had the Author heard any criticisms at any time that ships were pinned along the Quay and could not get away in southerly gales? (He had in mind an entirely different British Transport Docks port where, he had heard, the long straight quay apparently no longer found favour.)

73. Most engineers would probably not drive concrete piles down through sand, since it was very much easier to jet them down; but going through layers of clay, admittedly the jet holes sometimes became clogged. He wondered whether the cracks and spalls might not have originated as very fine hair cracks brought about by the lifting of the piles. No doubt many engineers had noticed that great care was taken lifting long concrete piles until the stage was reached when the pile actually came within reach of the piling frame. What was often done then was to take hold of the pile by the head and pull it straight up, and that certainly did not do it any good.

74. He noticed the Author had three rail tracks along the front of the North Quay. He was certain this was correct; but he was not sure whether road vehicles were also allowed to use the apron in front of the sheds. Some dock operators insisted on this. If so, he would have liked to see another 20 ft of width.

75. It was stated in § 36, with regard to railway layout, that a cross connexion from the back railway tracks to the quay-side railway tracks was necessary, and a large gap was left between shed 8 and shed 9 in order to bring these railway connexions

across from the back to the front. His own opinion was that in a six-berth length of quay, a cross railway connexion was not necessary. What did the Author think about this?

76. In the finished job, between the minimum impounded level of +11 ft O.D. down to dock bottom of -26.7 ft O.D., there was just about 38 ft of water. Would the Author give the dimensions of the largest ships which at the present time were able to get through the lock and use the Dock? He had no doubt the Author had in mind that one day there would be a new lock and bigger ships.

77. Mr Jellett had hinted at another important side of dock planning and construction, and he wondered whether the Author was closely associated in any way with the enormous amount of traffic studies that must have been made before the late Sir Robert Letch agreed to an expenditure of £5 million. If he had been, Mr Palmer would like to know if he had managed to estimate by what date the trade of Hull would be doubled. Lord Rochdale, he believed, had suggested 1980.

78. On the financial side, he thought it was right to say that an extra £350 000 revenue per year would be required to pay for the capital cost. With virtually six new berths, it should be possible to get that increased revenue very easily if the trade were there to occupy them.

79. Finally, would the Author please state the name of the proprietary quick-setting mortar for patching the underwater piles, and would he please give more details about the computer analysis which enabled them to work out the ground conditions likely to lead to damage in the piles?

Lt-Col. R. H. Edwards (Civil Engineer, South Wales Docks) said how very fortunate it was that similar designs were adopted for all the sheds, as this must have simplified the work enormously. Before construction of the Hull sheds was begun, a shed similar in design in some respects, but of only 100-ft span, had been completed at Newport Dock. Mr Langdon worked as resident engineer on this contract at Newport before moving to the project at Hull. The Hull sheds had walls of wholly brick construction both front and back, and whereas this looked very pretty, it seemed to him a somewhat expensive way of building the walls. He did not think brick walls were warranted except on the quayside, where they were liable to damage from crane loads. On the other side, a wall 8 ft high above the floor, with metal cladding above it, was very much cheaper. Would the Author say why brick walls were provided both front and back of all the sheds?

81. He liked the steel-framed doors and thought these were an improvement on the timber ones he had used at Newport. Doors of sheds suffered considerably and needed a great deal of maintenance. The steel-framed doors on the Hull sheds were an excellent design.

82. In § 32 the Author referred to the asphalt floor surface. How was this behaving and standing up to wear? In all the shed construction he had carried out, granolithic concrete had been used. Had any trouble been caused by oil on the asphalt, possibly dropped from the fork-lift trucks? He believed this could cause disintegration.

83. Lt-Col. Edwards asked the Author to define 'clough' which was referred to in § 48.

84. In § 52 it was stated that the minimum impounded level would be +11 ft O.D., this being 4 ft 6 in. above M.H.W.N. This would entail locking ships into the dock, as distinct from working them on a level as previously. It occurred to him that whereas the dock would now accommodate ships of deeper draught, the rate of docking would have been decreased due to the necessity of locking ships up and down. Would the Author please comment on this and say whether they were finding any difficulties in getting the requisite number of vessels through the lock?

85. Since the dock was dependent on a single entrance to be used as a lock except on spring tides, when there would be a level, would the Author say what

would happen in the event of it being necessary to take out either or both the inner gates for repair or overhaul? He presumed that the middle and outer gates were interchangeable but saw no reference to the provision of a reserve pair of inner gates, even though the capital investment on the new works was nearly £5 million.

Mr G. D. Lloyd (Chief Docks Engineer, Humber Ports) said that the impounding scheme was not yet in full operation; the pumps were working but the dredging had not yet been completed.

87. No doubt it would be of interest to engineers to know the percentage of the total cost involved in administration. The apportioned time of the more senior engineers associated with the scheme, together with the time of the design staff and of the staff engaged in actual supervision, amounted to only 4% of the total cost. As that included wages, salaries, and expenses of all site staff, it compared very favourably with the usual level of consulting engineers' fees.

88. Mr Palmer had implied criticism of the quay layout. It had been seen from the slides and in the Paper that some quays had as many as three railway lines in front of the shed, and at No. 12 Quay there were four. It might have been thought that if traffic were working from ship to shed, there need be no railway lines on the quay at all. The reason was that Hull was perhaps rather different from some other places; there was such a miscellaneous variety of general cargo. It ranged from bales of wool to Tasmanian apples. If anyone was looking for a formula as to what 'tonnage per annum' meant, he would not find it at Hull in terms of so many feet of quay or square yards of shed. With mechanical handling a ship could be turned round more quickly than a shed could be cleared. The unfortunate thing on so many docks was the element of warehousing in transit sheds. Distributors sometimes found it advantageous to keep goods in the transit sheds for a period. Since penalty rents were not the answer, it might be suggested that the distributive trades should build temporary warehousing accommodation well away from the docks and possibly the National Ports Council would want to give attention to the problem.

89. The previous week every one of those six sheds was full but all the berths were working because of the facilities for open cargo traffic given by the allegedly superfluous wagon tracks on the quays.

90. Lt-Col. Edwards had suggested that there had been more emphasis on appearance than utility. Docks must be functional, but why should they be dowdy? Taking a long-term view, it was just as economical to build an aesthetically pleasing brick structure as it was to build a dowdy tin tabernacle. Perhaps the developments at Hull would encourage other engineers to follow the lead of the British Transport Docks Board and put forward more pleasing designs.

Mr H. R. Boyce (Senior Engineer, Messrs Rendel, Palmer & Tritton) said it was a pleasure to read such a lucid account of a major dock work. The scheme had meant a remodelling of the King George V Dock, and the only dock system he could recall which had been remodelled was part of the Royal Group of London Docks, where in 1938 the Royal Victoria Dock was transformed from a number of single piers into a straight line quay.

92. He had had the opportunity of visiting Hull last year and he thought that there were a large number of railway tracks. Admittedly, the port was not particularly busy then. Whilst he could see the necessity for the tracks for the handling of timber and bulk cargoes on a quay side (because Hull was a major timber port and had very large timber storage areas in the vicinity), he wondered whether they were all necessary at the back of the shed. He supposed that practically all the goods handled at Hull were sent to or received from the towns within a 75-100 mile radius of Hull. Of the goods received, a large proportion went by lighter to places as far away as Nottingham and Sheffield. This quantity might amount to one-third and probably one-third left the port by road and one-third left by rail. The general export cargoes,

probably 70% were received by road and 30% by rail, and if the foregoing were correct then there appeared to be too many railway tracks for the proportion of cargo handled.

93. Possibly, at the rear of the sheds, where the platform was 12 ft wide, it could, with advantage, had been made wider, possibly to 15 ft, in order to facilitate the use of fork-lift trucks in and out of the doors. On the other hand, the platform at the end of the shed was about 20 ft wide, which he thought was just about right.

94. Regarding the dock itself, the impounded water level was +12 ft O.D. and the dock level was 17 ft O.D., and he assumed that the dock water level would be maintained as near 12 ft O.D. as possible. It seemed to him rather expensive to have fendering all the way round an impounded area of water when possibly a skirt could have been formed, say, from +17 ft O.D. down to +13 ft O.D. round the greater part of the dock, with occasional openings. This would have saved the cost of the rather elaborate fendering for an enclosed system of water.

95. The pile driving on the site must have been a most interesting subject and he hoped that the Author would enlarge upon this in his reply. In particular, he hoped the Author would comment on the various hammers used because he assumed that both diesel and steam hammers were used; he wondered whether the characteristics of the driving of these two kinds of hammers had been compared with the various types of pile which had been driven.

96. Mr Boyce could not understand why tension cracks should have been found in the main part of the piles after they had penetrated a hard layer of sand (§ 16). He would have thought that if damage were to occur, it would have been at the head of the pile and that tension cracks such as those mentioned would have arisen during the transport to the site and handling at the site. Would the Author please say whether the piles were cast on site or at some central depot and were then transported to Hull on a timber drag type of wagon; if the latter were the case it was possible that the piles were not supported at the most suitable points during transport. His own experience of driving concrete piles had not been too happy; it had usually been in hard conditions, and there had been failures. Mr Boyce would much prefer to use steel piles where there was heavy driving.

97. Finally, would the Author say what measures he took to prevent electrolytic action between the aluminium sheets and the steelwork?

Mr F. A. Page (Assistant Engineer, Port of London Authority), referring to the quay sheds and the impounding station, said that when he was at Hull a few weeks ago, he had an opportunity to look at the sheds in the company of some of the Author's colleagues, and there was no doubt that the sheds were very impressive and very pleasing to look at. However, it was the usefulness of the space that the shed enclosed which was of first importance; these sheds had 20-ft-high doors and 25-ft clear headroom at eaves, increasing to 46 ft at the ridge. In London they had come to the conclusion that it was the minimum clear headroom in a transit shed that was useful. It was possible that with warehousing, with a fairly uniform cargo and where speed of handling was not critical, the space above this level could be utilized. For transit purposes, however, where rapid handling was essential, a constant clear headroom was considered to be best, and it was neither economic nor desirable to expect operators of mechanical equipment to be continually checking the available roof clearance.

99. This consideration led to an entirely different approach to shed design. In London, the quay sheds usually provided 20-ft clear headroom, but sometimes 30 ft was required. Two slides of a 30-ft shed were shown to illustrate this difference. The shed in question provided 31-ft clear headroom throughout. The main roof member was the bow-string truss now normally used for transit sheds in the Port of London Authority but in other respects the framing was somewhat unusual. Lateral stability was provided by crossed ties which traversed the length of the shed at eaves level and to which each truss was connected. The ties were anchored at the

corners of the shed which were the strong points of the system. The stanchions simply propped the trusses in position and acted as sheeting columns spanning from floor to eaves. Vertical tension at the corners was about 25 tons and all other loads were small and vertical.

100. The interior of the shed was illustrated on the second slide. He considered that the 31-ft clear height coupled with the 150-ft span gave pleasing proportions and that this was enhanced by the 31-ft doors opening cleanly up to the eaves. This was a 'one-off' shed finished in 1962 at an all-in price of 31s./sq. ft complete.

101. Too close a comparison should not be made, but while the aluminium cladding was obviously cheaper than the brick work in the Hull sheds, the area of the door openings provided was proportionately twice as great. More significantly, the weight of structural steel was about 15% less and fabrication was simple. Since the foundations were also simplified, he suggested that it was an intrinsically cheaper form of construction, and it had more useful working space in addition. However, this depended, in part, on how operations were carried out in the shed. Could the Author say how useful the space provided above eaves level in the Hull sheds had proved in practice?

102. Turning to the impounding station, the question of transportation of silt into the dock was a problem common to most impounded docks. The silt either entered through the locks with run-in at high tide or came in through the impounding pumps and settled out. The dredging resulting from this was expensive and fairly elaborate measures to reduce it were justified.

103. The Author mentioned 'a full scale hydrographical survey' very briefly in § 6(g), the result of which decided the location of the impounding station intake. He had no doubt that in Hull this involved a great deal of work over an extended period. The effects of salinity gradient might have been important, and if the Author could be persuaded to disclose some of this information it would no doubt be valuable and interesting.

104. In the conditions usually appertaining to this sort of problem, it was impossible to locate an intake position where the silt content was invariably low. The best one could hope for was to find a spot where relatively clean water occurred at certain times, and that these occasions followed a pattern. Having done that, one has to overcome the technical problem of extracting clean water when it occurred.

105. The Author was surprisingly fortunate in being able to locate the intake of the Hull station so close in shore and to have the invert so low as to be able to pump over most of the tide cycle. Was this arrangement in fact the best, hydrographically speaking, or was it a compromise influenced partly by other considerations?

106. Did he, for instance, at any time consider taking the intake further into the river possibly beyond the line of the jetty shown in one of the illustrations?

Mr G. A. Wilson (Chief Engineer, Port of London Authority) said that he did not think that such heavily constructed sheds would be justified on their earning capacity. He was certain that no one could be sure of the type of buildings general cargo would require in future.

108. On a point of detail design, he hoped the rain-water pipes went straight through the deck into the dock, otherwise his criticism that, placed at 80-ft intervals, they were needlessly expensive, would be reinforced. He suggested pipes at ends of sheds only with weir overflows for protection in heavy rain.

109. The £4½ million estimate was interesting but needed to be confirmed as the actual cost. The cost of design, etc. had been quoted at 4%, and compared with consulting engineers' fees, it was only reasonable to mention the design done by contractors and ask if the 4% included all the chief engineer's office overheads.

110. Mr Jellett had made an important point about welders; he had had similar experience. If Trade Union practice were dictating design, it was a matter which the Institute of Welding should take up.

111. He noted the 18-ft span of quay cranes, and while London also use 18-ft for local reasons, he would record that 15-ft span was technically sufficient.

112. The layout should be governed by the size of the entrance and the area of land, which was now generally taken as about 12 acres per berth although as much as 20 acres per berth was discussed. There appeared to be too many railway lines. In London, 75 miles or so of railways were losing £250 000 a year after doing everything possible for the last five or six years to encourage railway traffic. Mr Wilson was building new quays without railway lines. The British Railways proposal to have liner train depots from which distribution would take place over 25 miles with road vehicles supported the conclusion that no railway lines were required in docks. Someone had asked what the trade was, and Mr Lloyd had given the information that the transit sheds were full and, because of this, another ship could not use the berth. This problem was well known and in London 'out-of-time' sheds were provided to which goods delayed in transit could be moved to allow the next ship to come in.

113. Mr Palmer had asked when the trade was expected to double. According to the Rochdale Report, Appendix E, § 20, imports, excluding oil, might double by 1980 compared with 1958-60, and for this reason, all ports should be endeavouring to improve and increase their facilities.

114. With regard to the pumping station, the Paper stated that experiments were carried out by both Mr Evans' Research Station and the contractors, but there was no mention of what these experiments were. The results would be interesting.

115. For a London impounding station, design experiments were being carried out at the Hydromechanics Research Station using air in place of water to obtain uniform pressure across the pump intake. He doubted from this work if the triple expansion of the main culvert to a right angle bend to the pump intake would be satisfactory.

Mr G. A. Wrigley (Senior Engineer, Messrs Harris and Sutherland) said that whereas the Paper gave the costs of some aspects of the scheme, it was not possible to judge its overall economy without further details. In particular, he would like to know if it was intended to increase the capacity of the lock and thereby enable the King George Dock to accept the size of ships appropriate to its new depth. Appendix F of the Rochdale Report compared unfavourably the number of berths of comparable sizes existing in this country and in the three ports of Rotterdam, Antwerp, and Hamburg. There were, in 1962, 51 berths in this country having over 35 ft of water alongside compared with 224 berths on the Continent. The Report emphasized the need for this country to increase its supply of deep berths since there was a clear trend in most classes of shipping for owners to take advantage of the economy arising from larger units. If it were possible to utilize the whole or a substantial part of the new depth made available by impounding at King George Dock, then the works would increase the British total of deep berths by 15 representing an increase of 29·5%. Even though an additional £3 million would probably be needed to provide a new deep water lock, the scheme would still be good value at some £½ million per berth.

117. Mr Wrigley realized that navigation depths in the Humber at present limited the draughts of vessels reaching Hull, but since the river was virtually unimproved by the hand of man, there was ample room for improvement. Mr Wrigley had commenced his career 25 years ago as a very junior servant of the Humber Conservancy Board, and as a result of his subsequent experience, had often contemplated the strange lack of development of his native river. Potentially, the Humber was one of our great natural assets. Unlike many other rivers which had been improved from small natural beginnings and were now encumbered with outdated riparian development, the Humber had ample room for industrial development as well as first class water connexions with the industrial Midlands. The Humber had areas 60 ft at low water and was capable of development to proportions suitable to the very largest of modern bulk carrying vessels. The task, however, would be huge, requiring national

FIG. 15: ISOMETRIC DETAIL OF CONSTRUCTION, NO. 1 QUAY, TEES DOCK

enterprise on a scale only rivalled by the Dutch Delta Scheme. It was enterprise of this order that was required if Britain was to maintain her place in the commercial world.

118. Regarding the wharf design, Mr Wrigley had long ceased to use soffit shuttering for extensive slabs over water. It had always seemed to him to be an unsatisfactory solution involving the contractor in difficulties and hence the employer in unnecessary costs. Today, with the approaching overemployment of the construction industry, it was more than ever necessary to relate design to the available labour resources. Carpenters were scarce and purpose-made soffit shuttering with numerous openings for service provisions was particularly expensive of their labour. All this led one to think in terms of prefabrication.

119. Mr Wrigley wished to compare the type of construction used at Hull, which was quite appropriate to building construction, with that used at the new Tees Dock No. 1 Quay where a continuous monolithic deck plate had been produced by transverse stressing of dovetailed prestressed members (Fig. 15). These members were just within the capacity of the standard 15-ton derrick and were jointed with cement mortar before stressing. The resulting 17-in.-deep plate was topped by 24 in. of concrete which, although generally plain, was reinforced where necessary to give additional strength for exceptional crane and rail locomotive loads. All services and drainage facilities were located within this depth of topping concrete and thus allowed great flexibility if the need for future modifications arose. The main consideration in deciding the thickness of the prestressed plate was the growing size of unit loads, and over a span of 30 ft, the plate was suitable for a 300-ton load with a factor of safety of 2.7. The net cost of this deck, exclusive of the supporting structure, was 20s./sq. ft. Would the Author please indicate the comparable figure for Hull and also say what had been done about services both immediate and future.

The Author, in reply, thanked the contributors for their comments and questions. As some topics had been raised by more than one speaker, he proposed to reply in order of subject matter rather than sequence of actual contribution.

121. Questions relating to basic planning had been raised by Mr Palmer and Mr Wilson. The Author had no doubt as to the soundness of the layout adopted in the replanning of King George Dock and, apart from certain matters of detail referred to later, would do much the same if he had to start all over again. He was not aware of any criticism of ships being pinned along the North Quay at times of southerly gales. In replanning within a dock estate which was already fully utilized it was hardly practicable to provide land areas per berth in the way that might be done if one were starting completely afresh. On the North and No. 12 Quays the areas of land directly related to the berths worked out at about $8\frac{1}{2}$ and $7\frac{1}{2}$ acres per berth respectively, which was not too far short of Mr Wilson's suggestion of 12 acres. The Author thought that the larger figure of 20 acres would be more relevant to berths specially designed for container traffic but this had not been a feature of the planning at King George Dock.

122. With regard to what had been termed the ergonomics of the scheme, this aspect had been deliberately omitted from the Paper, in common with a number of other features which the Author would have wished to include had there been space to do so. He thought, therefore, that it would be wrong to use his reply to try to work in a topic which had not been dealt with in the Paper and would only say that, although traffic studies had been made over a number of years before the scheme was put together, no elaborate calculations had been made in this instance. The need for additional transit sheds and shed berths had been regarded as self-evident and the development of the layout had followed almost directly from considerations of existing road and rail connexions together with operating requirements to accord with practice in the remainder of the dock estate.

123. The Chairman had asked about trial borings and test piles. Before any

drawings or contract documents had been completed a series of trial borings had been put down to cover the sites of all the component works. For the quay extensions, these had been spaced at approximately 300-ft centres but this dimension had been reduced for the impounding culvert, etc. to 100-ft centres. In addition, numerous tests and samples had been made to determine C.B.R. figures for road and paving works. In all the trial borings, a series of disturbed and undisturbed samples had been taken and laboratory tests carried out for determining the significant properties of the materials. The whole of this information had been shown on contract drawings in the usual way. Although the results of these borings and samples showed a normal degree of variation from point to point, it was not until excavation and piling were actually commenced that unforeseen conditions had become apparent. A study of the experience obtained during pile driving led to the conclusion that variations in soil characteristics were more erratic than could have been expected, but that they were very local and that any reasonable increase in the number of preliminary trial borings would have been unlikely to add much to the exactness of the information obtainable.

124. The only test piles carried out in advance of permanent construction were a series put down on the site of the North Quay. There was some difference of opinion amongst those concerned with the work as to the value of these test piles and the Author is inclined to the view that, in the particular site conditions, the complication of providing for their driving was not outweighed by the value of the results obtained.

125. In reply to several contributors the Author wished to make it clear that the existing lock entrance was regarded as being of adequate capacity for the size and number of ships using the dock and likely to use it for many years to come. Apart from grain traffic and the facilities afforded at No. 7 Quay with its grabbing cranes, the handling of bulk cargoes was not of great importance at King George Dock. In the circumstances, the largest ships likely to require accommodation would be of approximately 25 000 dwt, and the impounding facilities were designed to ensure that such vessels could be brought into the dock and kept afloat at any berth, whatever the tidal conditions, with a reasonable margin for siltation.

126. Colonel Edwards was justified in drawing attention to the possible effect of impounding on the rate at which ships could be worked through the lock entrance when penning became the rule rather than working on a level at all tides. Some of the local operating staff had expressed apprehension that difficulty might arise on this account and, although a preliminary study did not support this fear, the question was made the subject of an exercise in operational research. Although full results were not yet available, an interim report indicated that there was, in fact, an ample margin of capacity which would enable a considerable increase of traffic to be dealt with through the lock entrance.

127. The provision of a reserve pair of gates, another point raised by Colonel Edwards, had also received consideration. All three pairs of gates dated from the construction of the dock in 1914 and had been overhauled more than once. The middle and outer gates were interchangeable but the inner gates were 3 ft less in depth. In view of the age of the gates it was not thought that they could be expected to justify a further major overhaul; a new pair would therefore be required in due course. When these came to be installed it would probably be decided to retain the existing pair as a reserve after carrying out such re-conditioning as was considered necessary for this purpose. The Author apologized for using in the Paper the term 'clough', which was, however, he thought, in fairly common use on the north-east coast for what was more usually termed a sluice.

128. The provision of rail facilities had been the subject of comment by several contributors and this was one item which the Author thought would certainly be reconsidered if the scheme had been planned at the present time. Not only the Docks

but also the Railway Authorities had in recent years been re-examining the whole question of the extent to which rail facilities should be provided within the dock estate and, in the Author's view, much of what had hitherto been regarded as essential could now be eliminated or drastically reduced. Nevertheless, the number of tracks provided on the quays was no more than was necessary to deal with traffic contemplated in 1959, most of which was in fact still being worked by the methods then envisaged. Had a decision been taken to omit certain tracks, the operators would no doubt have found other ways of handling the tonnage, but it is not certain that it would be possible even now to reach agreement between all interested parties as to the proper level of facilities which were necessary and economic.

129. On the points of detail raised by Mr Palmer, the Author confirmed that road vehicles were allowed to use the apron in front of the sheds. As there were three lines of rail track on the North Quay and four on No. 12 Quay, it was not considered necessary to add further to the width of the aprons by allowing for an additional lane for road traffic only. A cross rail connexion between the front and back of sheds had been allowed between Nos 8 and 9 Sheds as previous experience on the original No. 1 Quay had indicated that it would be necessary. When visiting the Port of Bremen in October 1963, the Author had been interested to find that in the new general cargo developments now being commenced west of the River Weser, allowance was to be made for cross connexions between every pair of sheds, i.e. at about 1600-ft intervals.

130. With regard to crane tracks, the gauge of the majority of cranes at all the docks at Hull was 15 ft; only a few older cranes were on 13 ft 6 in. tracks but these were on their way out. As there was a frequent interchange of cranes between one dock and another, it was considered that standardization of gauge was the right policy and 15 ft had proved to be perfectly satisfactory in practice.

131. A number of speakers had commented on piles and pile driving. On the choice between prestressed and normally reinforced concrete piles it should be said that it had been standard practice at Hull to use prestressed piles for supporting crane beams in quay modernization schemes and this practice was followed in the present scheme where the piles were wholly buried, as for the anchorage piles at No. 7 Quay. In the case of piles driven through water and having an appreciable free standing length, it was found that the compression induced by prestress made an unduly large inroad on the compressive strength which could safely be allowed on these piles as columns. In the circumstances, normally reinforced piles were substituted and where this was done it was not considered worth while to revert to prestressed piles for the comparatively small number of wholly buried piles supporting the shed structures.

132. The Author thought that most contributors who had commented on pile driving had expressed or implied some degree of sympathy with his experience, which was admittedly disappointing to all concerned. He felt, however, that he must resist the Chairman's invitation to enlarge on this topic in the reply, as to do so usefully would really take up more space than could be afforded. One or two points perhaps deserved special mention but the matter had been dealt with more fully in the Informal Discussion on recent developments in piling theory (reported in the Proceedings of April 1964, p. 843) and a certain amount of information had been supplied direct to the Civil Engineering Research Association.

133. The pile hammers used on the several contracts comprised single-acting steam hammers of 4, 5, and 6-ton weight, drop hammers of weights between 3 and 5 tons and Delmag D.22 diesel hammers. On every contract the specification called for pile sets to be measured under the impact of drop hammers. If the Contractor asked for and obtained permission to use another type of hammer, it was on condition that a drop hammer should be used under the same conditions in order to calibrate and establish the final set. In actual practice the Delmag hammer was largely used for the landward piles and steam or drop hammers for free standing piles. In addition,

McKiernan-Terry hammers were used for driving sheet steel piling in cofferdams and curtain walls.

134. Although, as mentioned, information had been supplied to the Civil Engineering Research Association about comparisons between different types of hammers, the results obtained at King George Dock were thought to be rather inconclusive. There seemed to be little doubt, however, that the rated output of the Delmag hammer was greater than was found to be available in practice when compared in actual trial against a drop hammer. In one case of a 16-in. pile 65 ft long, a set of 2.75 in. was obtained under ten blows of a 4-ton drop hammer falling 4 ft 6 in., whereas at the same penetration ten blows from the Delmag D.22 hammer gave a set of only 1 in.

135. The Author was not satisfied that all the cracks found to exist in the piles after driving were caused solely by the driving conditions and was prepared to agree with the contributors who had suggested that in some cases they might have originated as very fine hair cracks during the casting, transport and lifting processes. After making allowance for such possible causes it was still true, however, that many cracks arose during actual driving. There was very little evidence of their originating, as Mr Boyce had suggested, at the head of the pile on account of hard driving, but there was ample justification for concluding that easy driving conditions had been responsible in many cases. The computer analysis, about which Mr Palmer had asked for further particulars, had shown quite clearly that where toe resistance was low a compression wave travelling down the pile from the hammer impact could be reflected as a tension wave, which could easily give rise to tension cracks. There was nothing very abstruse about the computer analysis, which was simply a matter of applying the rapidity and ease of calculation afforded by the computer to a basically simple examination of the behaviour of a pile (considered as a finite number of contiguous segments) under known or assumed conditions of construction, ground resistance, and driving conditions. As had been said in the Paper, once the teething troubles had been overcome it had been found possible to account fairly readily for failures observed in certain conditions where the soil characteristics had been ascertained.

136. The proprietary cement adhesive used in effecting patch repairs to the cracked piles was Quickscrete P, manufactured by Chemical Building Products Ltd. It had been difficult to find a plaster which would adhere to the relatively smooth concrete pile surfaces under water in the presence of various impurities. A number of different materials and compositions had been tried, of which two or three had been found reasonably satisfactory, but this material had given good results and was considered by the divers to be easiest in application and had therefore been adopted for the bulk of the work.

137. Mr Wrigley had raised a number of points about quay construction and in particular had drawn a comparison with the well-publicized work carried out at the new Lackenby Dock on the Tees. There need be no argument about the merits of prefabricated construction under certain conditions and it may suffice in answering his criticism to say that the cost of the reinforced concrete structural deck at the North Quay, including an appropriate share of contractors' general charges, was 19s. 6d. per square foot. That included the portal and crane beams, which were part of the in situ deck construction, but if these were excluded, to give a figure for the cost of the plain deck slab, the unit price would be brought down to 17s. per square foot.

138. As regards accommodation in the new quay for services, it would no doubt have been understood from the references given in the Paper that electric cables for crane supply were carried in ducts formed in the structural deck slab. These opened up into plugbox pits at 45-ft intervals and were thus readily available for connexion or alteration if this were ever to become necessary. Ducting was also available for small cables, e.g. for lighting and telephone services. Fresh water mains, including hydrant branches, were suspended in hangers beneath the deck and were well lagged for frost protection.

139. Mr Boyce may have been under some misapprehension regarding fendering. No fendering whatever was provided for the existing solid quay walls of the dock and the fendering system described was designed only for the protection of the new reinforced concrete quays of open pile construction. If the Impounding Station could have been completed and brought into continuous service before the new quays were made available for shipping it might have been possible to reduce the range of dock water levels over which protection was required. In fact it was decided that the new fendering must give protection over the full range of levels and in these circumstances investigation showed, as mentioned in § 26 of the Paper, that the cost of any fendering system wholly supported by the quay structure would have been more expensive than that of the fender pile system actually adopted.

140. The Author regretted that the statement in § 28 regarding radiographic examination of the welded joints in structural steelwork was not quite correct. Only a proportion (about one in four) of the joints was actually inspected, selection being made partly after visual examination and partly at random. Care had been taken to specify in the contract documents that inspections would be required and no real difficulty had been experienced in obtaining the contractors' compliance during the progress of the work. The Board was fortunate in having the services of a very good Inspector, who personally examined the workmanship of all welders employed, both in the shops and on the site, and who was effective in ensuring satisfactory results. Only about 1% of the total length of all welds had to be cut out and rewelded and this was not thought to be a bad performance.

141. In his comments, Mr Lloyd had given an answer to Colonel Edwards on the justification for using brickwork in all the shed walls, but the Author felt that he must correct any impression which Mr Wilson may have given as to the construction of the sheds being unduly heavy. The figures of cost quoted in Appendix 2 would, he thought, show that the capital cost of the walls was not excessive and there was no doubt that annual maintenance costs would be less than would have been the case if metallic sheeting, so vulnerable to damage, had been employed.

142. Mention had been made of the behaviour of the asphalt floors in the sheds. Asphalt had been used in preference to concrete because in a number of existing sheds concrete wearing surfaces had not been very satisfactory. Cracking, dusting, and unequal settlement had been all too frequent and the use of asphalt would either eliminate these defects or enable repairs to be carried out more easily. In the three years which had elapsed since the first sheds were brought into use it had been found that the asphalt floors had stood up to working conditions extremely well. Isolated depressions caused by heavy local stacking had occurred but could be repaired readily. Occasional instances of local softening, where oil had been accidentally dropped, did not cause difficulty if the oil was cleaned off quickly, as the asphalt very soon hardened again. It was true that 12 ft was rather narrow for the platforms at the rear of the sheds. It would have been understood, however, that the intention was to use the rear platforms principally for loading rail wagons, road vehicles being concentrated at the end platforms. In view of the present trend away from rail and towards road it might have been advantageous to increase the platform width to, say, 15 ft as Mr Boyce had suggested.

143. Mr Page's description of the sheds being provided in the Port of London was interesting. Notwithstanding his able advocacy of roof trusses, however, the Author was of the opinion that it was a pity to take up roof space unnecessarily; experience, at least in Hull, was that the additional clear height available in the centre of the shed was of some value. It had been possible to make good use of mobile cranes inside the sheds for example, but if they had been restricted to the headroom available at the eaves they would have been much less effective.

144. The Author did not altogether follow Mr Wilson's remarks with regard to the disposal of rain water from shed roofs. Where practicable the down pipes would be taken through the quay slab straight into the dock, but this could only be done

for a relatively small proportion of the whole. Otherwise, the down pipes were taken into the local drainage system through gulleys and inspection chambers in the usual way. Due provision had been made for inspection elbows, etc. in the down piles and generally it was considered preferable to spend a little money on ensuring an effective drainage system rather than risk an overflow from roof gutters into the sheds.

145. The aluminium sheets of roof and gable cladding were separated from the bearing surfaces of steel purlins and rails by strips of roofing felt. In fact, the specification had called only for bituminous strips and in the Author's view a good coating of bituminous paint would have been quite adequate for preventing bi-metallic corrosion.

146. In answer to Mr Jellett, the Author would say that there seemed to be two schools of thought on the best means of providing roof lighting. It was true that individual skylights, whether in the form of corrugated fibreglass or other proprietary elements, did offer certain advantages in the way of structural detail and ease of fixing. As Mr Jellett would know, an investigation of such systems in comparison with continuous strips of patent glazing had been carried out by British Transport Docks some ten years ago. The conclusion had been reached that patent glazing in strips offered a balance of advantage in convenience and cost and the Author had therefore decided to follow that method and had no reason to be dissatisfied with the results.

147. Interest had been expressed in the hydrographic survey mentioned in connexion with the design of the Impounding Station. It should perhaps be made clear that the survey was of very wide scope and it would not be possible in the course of this necessarily restricted reply to deal with other aspects, including such questions as the effects of salinity gradients. It could be said quite definitely, however, that the results of the survey had enabled guidance to be given to the pump operators on optimum pump times. The Author believed that this would result in a reduction of siltation in the dock but it was too early yet to enable measurements to be made, as a comparison of the tonnage dredged over a fairly long period would be necessary before coming to a definite conclusion.

148. There was no merit in taking the intake out into the river as heavy concentrations of silt were liable to occur at all depths but were greatest near the river bed. In the circumstances it seemed obvious to aim at placing the intake under the Western lead-in Jetty, where a good depth of water was available and where the intake could be protected by screens and timber fendering without causing any encroachment on the shipping fairway. The hydrographic survey gave confirmation that this location would not involve undue difficulty in respect of silt concentrations or otherwise, and the Author would be ready to agree with Mr Page that this was a fortunate combination of circumstances.

149. Mr Wilson had asked about the experiments carried out by the Board's Research Station and by the Contractors. Paragraphs 53 and 54 of the Paper had mentioned in general terms that the Research Station experiments were concerned with ascertaining the best arrangement and appropriate dimensions for all parts of the water passages, i.e. the river intake, the suction culvert, and the pumping station fantail. On the discharge side, the corresponding features were the disposition of the connexions between the taper pipes and the discharge chamber and the arrangements of the discharge openings through the dock wall. In all these cases, scale models were constructed, usually one-twelfth full size, and a full range of flow studies were carried out at varying pumping rates, and with varying levels of water in the river and in the dock, all of which eventually resulted in a satisfactory design being achieved. Those results had since been confirmed in full-scale practice.

150. The experiments carried out by the pump contractors were aimed at investigating the flow conditions for one pump with its suction bellmouth when located within the terminal channel of the fantail structure. Apart from any guidance given to the contractor in designing the size and shape of the pump bellmouth, the experiments did confirm that the suction conditions in the fantail and around the pump

bellmouth were satisfactory. The Author did not contend that the design of fantail and pump bellmouth would give a uniform pressure across the pump intake and he was not sure that this feature would have any particular value in itself. He was sure, however, that the results obtained showed that, in the overall design, effective and efficient use of each individual pump had been obtained.

151. Mr Wilson had asked about costs. - The figures quoted in § 6 of the Paper were estimates but those given for the cost of the transit sheds in Appendix 2 were ascertained actual costs rounded off to the nearest £50. Final costs of the whole of the contracts had not then been ascertained as certain contractors' claims were still being investigated. Making allowance for these, however, it was known that the overall cost of the scheme, including all Chief Engineer's and Consulting Engineer's fees and overheads, would be approximately £5 100 000. This represented an excess of less than 8% on the original authority which, in view of certain additional works carried out and the general trend of rising prices, was thought to be not unreasonable.

152. The cost of design mentioned in § 109 was no doubt a quotation from Mr Lloyd's remarks in § 87. The normal practice at Hull Docks was for the wages, salaries, and expenses of all site staff to be charged direct against the authorized cost of the work, as were also the total amounts of Consulting Engineers' fees and expenses. The salaries etc. of the design staff and senior engineers in the Chief Docks Engineer's Office were represented by the addition of a standard percentage of the ascertained cost of the works, as determined by the Docks Accountant from time to time. It was understood that in the current case this amounted to about 3% of the total cost.

153. Mr Wrigley's remarks in § 117 were noted with interest. He would be aware that the British Transport Docks Board were interested in the Humber, not only as regards the Port of Hull but in relation to the estuarial ports of Grimsby and Immingham and the upstream port of Goole. The Docks Board had the interests of these ports, and of the Humber as a whole, very much in mind and schemes of further development were constantly under consideration. The next phases of development at Hull had already been authorized and work was to commence shortly. Parliamentary powers had been obtained for developments at Immingham and there was no doubt that a considerable expansion of facilities there would be seen in the next few years.

154. The Author felt that he could not conclude his Reply without making mention of the sad loss which the sudden death of Mr G. D. Lloyd, on 3 June, 1964, had occasioned to the Board and to all his colleagues. It was gratifying that Mr Lloyd was enabled to see the virtual completion of this large development scheme and it would be a matter of great regret that he did not live to continue the further schemes of development.