Some features of the civil engineering work in Cammell Laird's shipyard

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Mr B. F. Saurin (British Petroleum Company Ltd) remarked that the tanker cleaning berth had been built in very unusual and difficult circumstances, including ground which precluded ordinary piling, and the rough waters of the Mersey with a fierce tide. Naturally these circumstances called for an ingenious design and it was obvious that a great deal of time and thought had been devoted to it.

48. There was a certain difference in the general character of the various parts of the work and some parts were particularly elegant. The mooring dolphins, for example, were very simple and straightforward and were attractive from the first glance, and the approach also was a nice clean job. On the other hand, the berthing head suffered because since its construction or design there had been a number of developments in this type of structure. However, even taking the state of the art as it had been at the time of their design, he thought that the Authors might give a little more assurance that the choice of the tubular structure and in particular the method of jointing had been the happiest available.

49. The spherical joints with their bolted connexions looked rather clumsy and they would certainly appear to be very expensive, particularly when compared with the type of structure used in the oil industry and which had, at the time when the Authors' structure had been built, been used in the Gulf of Mexico for a number of years. In this design the tubular members were joined directly together by mitres and welds. It was true that the ends of the tubes had to be mitred by a special machine so that they fitted neatly together, and it might be that at the time when the Authors' structure was designed such a machine had not been available in this country. However, it would have been worth while searching the world for a means of avoiding the use of these cast steel junctions. He understood that all the joints were bolted, and perhaps the Authors would explain how they had been protected against corrosion and whether any regular or routine maintenance was called for on them.

50. Coming to another aspect of the berthing heads, namely the securing of the foundations, it might be asked whether it was really necessary to make the concrete blocks at the foot of the structures. Would not it have been possible to anchor them directly to the rock? In other parts of the work such ingenuity had been shown in drilling into the rock and anchoring down that he felt that that technique might have been extended a little to cover this point.

51. It might be only fair to say that if this structure were being built today presumably it would have been rather different. Since it had been built it had become possible to drill in the large tubes much more readily than at that time, and he imagined that the berthing heads if built today would consist of flexible Mannesman

tubes against which the ship would berth, with, in between the two, a comparatively simple platform carrying the crane. The Authors might like to comment on that; he was sure that they would be familiar with the work done elsewhere since their structure had been built.

52. He had one or two questions about the functioning of the berth. The spacing of the berthing heads was 207 ft, which was very small for tankers of the size described and would be more appropriate, one would think, for small vessels of between 16 000 and 20 000 tons. As this was a difficult site, with a strong current, was there any difficulty in holding ships quietly against these berthing heads? Did ships tend to oscillate first on one head and then on the other, tightening and slackening the moorings, as a result of the tide running by?

53. Any comment on the behaviour of the fendering would also be of interest, and perhaps further details might be given of how the fender panels were supported. The drawing showed a strut underneath and a link to locate the panel sideways, but perhaps the Authors could say more about that.

54. Turning to the next section, the mooring dolphins, the drilling with a rake of 1:4 with the Reich drill was most interesting. He had never heard of it before, but it seemed to be a useful tool, and drilling with a rake of 1:4 was not always easy. Perhaps the Authors would say whether the drill drilled straight at 1:4 or whether the hole tended to droop. That question would be important if it were desired to anchor the structure by a stiff tube passed down the leg instead of by bundles of bars which, of course, were fairly flexible.

Mr P. A. J. Hernu (Assistant Managing Director, Cammell Laird & Co. (Shipbuilders and Engineers) Ltd), as a representative of the principals concerned, dealt with the subject of the planning and execution of major works of the type with which they had been concerned. Apart from the tanker cleaning berth, all the other works had been carried out within the shipyard. One of the stipulations which the Company considered essential was that these works should not interfere with its normal business of building ships. That had been difficult enough in respect of the construction of the new shipbuilding shops, covering 11½ acres, the new dock, and the major re-organization of electrical supplies; but the problems could well be imagined of building a piled jetty, 60 ft wide and over 900 ft long, between two of the largest and busiest slipways in the shipyard. The contract had lasted over a period of nearly two years, and during most of that time ships had been under construction on both the slipways.

56. The jetty had to be built to carry two 100-ton electric travelling job cranes. Each crane, with load, weighed nearly 1000 tons and had an outreach of 122 ft with full load, which made them the largest of their type in the world. Although the civil work had not been described in detail in the Paper, he would regard the contract for the construction of this jetty as an outstanding example of the kind of co-operation one dreamed about between consulting engineers, contractors, and principals in carrying out civil engineering works under very difficult conditions. Secondly, it was the kind of situation which most shipyards must expect to have when they undertook major works of reconstruction of the kind in question.

57. He thought, therefore, that a number of points, or even lessons, emerged from the experience gained from this contract. First, any major work of development or reconstruction in a shipyard had to be planned against a background of congested working area and the normal day-to-day shipbuilding activities, so that considerable ingenuity in design and in the method of carrying out the work was essential.

58. Secondly, because of the congestion in the average shipyard the lack of working area for the contractor could be a real problem. Here again a great deal depended on the ingenuity of the engineer at the design and planning stage.

59. Thirdly, as a closely-timed programme would undoubtedly be necessary, it was essential that discussion should take place with potential contractors regarding plant

for the works, and particularly specialized plant, and its actual availability on the award of the contract.

60. Fourthly and lastly, it was obvious that interference and frustration were bound to occur during the execution of the works. In the contract in question, working conditions for the shipbuilder and contractor, particularly in the winter months, appeared at times to be chaotic. In such circumstances, therefore, and to ensure reasonably smooth working conditions for both parties, both must be reasonable and accommodating under the diplomatic guidance of the representative of the consulting engineers. As in all human relationships, much depended on the personalities involved.

61. The particular contract to which he referred embodied all the worst features to be found in carrying out major civil works in a shipyard. It was a measure of the successful design, planning, and construction principles that the value of the contractor's claims at the end of the day amounted to 3% of the total value of the job. He thought it would be agreed, therefore, that the contract was a remarkable example of what could be done.

62. In conclusion and in the light of experience he would say that a negotiated contract with the contractor known to the principals and consultants merited serious consideration for major civil engineering works in a shipyard.

Mr G. B. Godfrey (Stewarts and Lloyds Ltd) said that his company had from time to time made films on tubular construction, including one entitled 'Off-shore structures'. He then proceeded to show an extract from this film which described the fabrication and construction of the strong-points for the tanker-cleaning berth.

64. Subsequently, he added that Mr Saurin, as well as other engineers, had questioned the economy of the spherical joints. The designers had been faced with the problem of joining as many as twelve tubes, varying in outside diameter from 14 in. to 10½ in., at one point. The spheres employed seemed to provide the only logical solution. He would be pleased to learn from other members present, or from the Authors, what reasonable alternatives there were.

Mr E. D. A. Smy (Contracts Manager, Monk & Co. Ltd), referring to the dry dock construction, was surprised that the Authors had made no reference to the faulted and fissured rock which they had found at the entrance to the dock, because he had always understood that the unique design of the north roundhead had been rendered necessary largely by the presence of this fissured rock. If in fact that had not been considered, why had they not employed reinforced-concrete struts and ties above and below the camber to tie the north roundhead back to the main wall of the dock?

66. In fact, during construction it had been necessary to do a considerable amount of certain pressure-grouting in an effort to make the holes watertight and in order to close the fissures that existed in the rock so as to obtain a good anchorage for the cables. He would like to hear the Authors' comments on this and also their explanation, if they had one, of the various and peculiar water levels obtained in the holes at various stages of the tide.

67. He was a little disappointed that no reference was made in the Paper to the methods which his Company had adopted for blasting and excavating the sandstone in the dock, because he thought it was to the credit of the methods used that there had been no complaints either from the shipyard or from the local church authorities of vibration from blasting. They had employed a system whereby they cut a chase round the periphery of the dock prior to actual excavation. Perhaps the Authors would comment on these points.

Mr G. L. Hargreaves (Assistant Chief Civil Engineer, Ministry of Public Building and Works) confined his remarks to the strongpoints, and in particular the intrusion-grouted concrete, and put one or two questions to the Authors. Dealing first with the

background to this, he said that ever since the invention of concrete, engineers had sought for a satisfactory way to place it under water and get a sound job. They had in the past used tremies, concrete in bags, and various other methods. He had hailed *intrusion grouting or colloidal grouting or pre-packed concrete* in its various guises as a gift from heaven, giving the ideal answer. For many years he had thought that it was, but a few years ago he had been concerned with a job very similar in character to that which the Authors described, an offshore jetty or rock where they had cast a large concrete block at the bottom as a base and an anchor, in their case a gravity anchor. The job had seemed satisfactory and had followed lines similar to those described in the Paper, with the grout tubes and tell-tales, but after the first block had been made and stripped the senior engineer said that something had gone badly wrong, and it had.

69. Divers had gone down to examine it and had found that the concrete was of the quality that the speculative builder put in foundations where he did not think anybody could see it. One could almost scrape it out by hand, and certainly do so with a knife. The concreting had been done by a firm specializing in that process and they had been very perturbed. A number of trials and experiments had been done with blocks and eventually the job had been carried out satisfactorily, but they had never been quite sure what had gone wrong. The senior engineer concerned held what seemed to Mr Hargreaves to be the most likely theory, that the grout had been emerging from the pipes at too high a velocity, some measure of segregation had taken place and that the stuff that reached the outside of the block had been more sand than anything else.

70. Were the Authors able to say what the velocity of the grout was when it emerged from their pipes? He had done some arithmetic on the basis of the information in the Paper and made it about 3 ft/s, but if they could confirm that he would be very grateful. Further, had they carried out examinations afterwards of the blocks or of the concrete, and if so what sort of results and consistency had they found?

71. His third point concerned the steelwork. Unlike some of the more experienced speakers he had thought that a sphere was a very good solution for an awkward problem of jointing tubes, but he had felt that it might be very expensive, and he would be interested to know whether or not the Authors could give any figures for the cost of that form of joint as compared with other types which had been suggested or that they might have considered.

72. Finally, he had found out from bitter experience that when assembling structures with flanged members, no matter how carefully they had been designed and made, one always ended up with a number of members with flanges not quite in line and/or which would not quite come together, and it was necessary to make some sort of filling piece or washer to make up the difference. Had anything of that kind been experienced in putting these completely flanged jobs together?

Mr R. A. Stephenson (Design Assistant, Mersey Docks and Harbour Board) said that alongside the jetty described in the Paper there was another berth of rather a different character, on the design of which he had himself been engaged. He could appreciate, therefore, the difficulties which had beset the designers of the tanker cleaning berth, and that those concerned had arrived at totally different solutions was not surprising, in view of the fact that they had been given quite different terms of reference.

74. He wished, however, to ask a few questions and make a few comments with regard to the design of the strongpoints. Where there was no cover over a rock foundation but a weak silt the obvious course seemed to be the removal of the silt and the erection on the rock of a heavy structure held down by its deadweight. But in this case it had not been possible to use a completely solid structure owing to possible interference with the flow of the river and the ingenious tubular framework had been substituted for the upper part of the solid structure. This resulted in a loss

of deadweight and he had been surprised to notice that the berthing load acting on the strongpoint was given as 800 tons. Not only did this seem to him a very large load to impose on the side of a tanker, but it also set a difficult foundation problem. In the event it had been found impossible to remove all the silt from under the foundation block and although the resistance to overturning was no doubt amply provided for by the anchorage of the front of the block, the resistance to sliding would appear to depend on a coefficient of friction of rather high value for a base resting on silt. Was in fact sliding resisted by anything in addition to friction?

75. It appeared to him bold to adopt anchors of the kind and dimensions used because, in advance of proving by stressing, how had it been decided how deep they should go and how was it possible to be sure that the grout would adequately bond with the rock? That equally applied to the anchors of the roundhead of the graving dock. He had been surprised to see that the holes for the latter anchors were only 7 in. in diameter, which did not give much circumferential area for grip.

76. With regard to whether the roundhead might have been strutted and tied top and bottom, rather than stress-anchored into the rock, he would like to know whether or not deflexions had been calculated for either method, because he thought that with a system of ties and struts there might be surprisingly large deflexions due to the heavy loads that came on to the quoins of caissons. The top ties and struts would, of course, have to be removable to allow the caisson to be floated into the camber.

77. The designers had certainly been wise to do what they could to keep silt out of the camber. Had the method adopted been successful? He would like the Authors to explain it more fully, because he was not clear whether it excluded the water entirely from the camber once the tide had dropped below half-tide level or, if not, how the restricted flow was achieved.

78. Finally, he noticed that top guide-rollers were provided to guide the caisson into the recess opposite the camber in case of deflexion of the caisson due to a difference of water level when closing. What sort of load could these rollers be expected to take? Unless they were fairly substantial, he would expect that the first time they came into action they might get badly damaged.

Mr J. Brown (Director, Sir Wm Arrol & Co.) as a member of one of the younger Institutions, appreciated the privilege of being invited to be present. His interest, he said, was in the caisson. The Paper described clearly the construction and functioning of the sliding caisson and illustrated an original solution of a complicated problem of dock design. It fitted very well the requirements, as he saw them, first of the most economic construction of the dock to accommodate a caisson which was required to impound water to high tide level for possibly a prolonged period, and secondly of avoiding so far as possible trouble arising from unusually difficult conditions of silting. Thirdly, it provided the maximum length of useful dock on a very restricted site, and fourthly, it could be claimed that the caisson had the virtues of reliability, simplicity, and speed of operation in all conditions of bad weather and darkness. Perhaps reliability, simplicity, and speed would be the features of the caisson which would be appreciated most by the dock master when dealing with large tankers on a Mersey tide, possibly at night.

80. In that connexion, it might be remarked that the machinery for hauling the caisson was essentially uncomplicated. Presumably that was a desirable feature in any engineering design, but it was particularly desirable in dock gate machinery. A good dock gate should outlast any of the people who had anything to do with the building of it. Maintenance was apt to be neglected as the years went by, so that simplicity was a feature of design which was always desirable. One important advantage was that no portion of the hauling gear, including the pulleys down at sill level and the winch, should be incapable of being visually inspected at any desired time.

That facility encouraged good maintenance and a good and efficient life for the caisson, which was a very important feature of the machinery.

81. He would like the Authors to enlarge a little on the considerations which had led them to a caisson of this kind, as distinct from a Box gate. He could see some of the difficulties, but the economy, both in the Box gate itself and in the masonry and concrete work of the dock, was very substantial, and it gave the maximum length to the dock. He realized that it would require to impound, but already a large Box gate had been designed and made to impound water, though not to the full head; but the design was being studied with a view to impounding to the full head, and it was quite a practicable proposition. The silt had probably been the governing factor. He wondered whether the pumping equipment of the dock could be so arranged as to sluice the entrance by running the pumps through the dock and just circulating water to get a very powerful sluicing effect, though with syphonic discharge that was perhaps not practicable.

82. The engineers in the case in question had been faced with a major problem of design in view of the restricted site and with No. 4 Dock so closely adjacent. The curved caisson and the curved camber provided a very ingenious and satisfactory solution and the engineers were to be congratulated on their success.

The Chairman, Mr J. H. Jellett (Chief Docks Engineer, Southampton Docks), commenting on Mr Scrutton's remark in presenting the Paper that many of the unusual features of the dry dock which it described had been the product of the site conditions, said it could not be too strongly emphasized how true that was of dry dock construction, almost more than of any other branch of civil engineering. It was only necessary to compare the conditions described by the Authors, where it was possible to leave what was often called the living rock more or less naked in parts of the dock, with the circumstances at, say, Southampton, where thousands of tons of concrete had to be provided simply to hold the dock down against hydrostatic pressure, a service which had been more sophisticatedly effected in more recent constructions by prestressed anchorages or vibrated anchorages into the ground below.

84. He was disappointed that in their very interesting Paper the Authors made no reference to that important feature, the cost of the work. He realized—he was sure that Mr Hernu, who represented the client in this case, would not mind his saying this—that very frequently clients were reluctant, and had very good grounds for being reluctant, to reveal what additions to their assets had cost them, but that information

FIG. 20: DOCK FENCING AT SOUTHAMPTON

was very important to members of the Institution. The Charter of the Institution defined their profession as 'directing the great sources of power in nature for the use and convenience of man'. He had always subdivided that definition in his mind by regarding 'the use of man' as being what engineers designed for him and how it worked, and 'the convenience of man', though man did not always realize it, was how much it cost him. Mr Jellett had a strong feeling, therefore, that when the Institution accepted a Paper describing an engineering work without any reference to cost it might be acting in breach of its Charter. 'I hope,' he added, 'that the Authors will find it possible to make an honest meeting of us.'

85. Referring to what he described as the contentious feature of dry dock fencing, he said that this had been made compulsory by legislation in recent years. It was a subject on which he had spoken more than once in the lecture theatre of the Institution. Everything, or almost everything, that he had said on previous occasions had been proved wrong by his own experience. When that had been fully brought home to him he had decided on the first occasion on which a Paper on dry docks was presented to make a full confession to a representative meeting of the Institution and point out how his errors had come to occur.

FIG. 21: BRINGING IN A SHIP BEFORE FENCING WAS INTRODUCED

FIG. 22: BRINGING IN A SHIP AFTER THE INTRODUCTION OF FENCING

86. Fig. 20 illustrated the type of fencing which had now been put round all six graving docks at Southampton. It was made of that engineering standby, old rails. He had contended in his previous remarks on the subject that a structure of this kind at a dock edge would interfere with the operation of dry docking, but experience had proved entirely the opposite. Fig. 21 showed a mooring party bringing in a ship in the days before the introduction of dry dock railings. It would be seen that the leading rope tended to drag the men into the water. Fig. 22 showed a similar operation subsequent to the introduction of railings, which had obviously made the operation very much safer by their presence.

FIG. 23: MOORING PARTY TAKING ROPES ROUND LEG OF CRANE

FIG. 24: GANGWAY ACCESS THROUGH FENCING

87. An essential feature of such an arrangement was that the railings should be strong enough to carry the weight of the ropes, even when they were under tension. It would be interesting to learn from the Authors what design had been used at Birkenhead. Fig. 23 also illustrated the increased safety obtained with railings. Here the mooring party was taking the ropes round the leg of a crane and the men were able to disregard the dangerous edge which they had to squeeze past. Fig. 24 showed the arrangements for gangway access for ships under repair. A length of the railing could be removed and the gangway inserted. He included this picture because he had heard that at Cammell Laird's yard there was an interesting alternative, and he hoped that it might be possible to hear it described. He had not forgotten 'the convenience of man'. The dry dock fencing which he had illustrated had cost £2 11s. 6d./ft, bearing in mind that it had had to be drilled into solid granite coping-stones round 9000 ft of dry dock edge.

Professor A. J. S. Pippard (Past President), commenting on the Chairman's suggestion that the Paper might have breached the constitution of the Institution by not mentioning costs, said it had probably done so in a more serious way, though he was sure inadvertently.

89. One of the principal features of the Charter of the Institution was the importance attached to the advancement of mechanical science, and he wanted to ask the Author for more in this connexion.

90. Not many space frames occurred in ordinary practice, and when they did they were usually simplified into a series of plane frames. The Authors, however, had provided very interesting examples in the strongpoints, and their construction had been admirably shown in Mr Godfrey's film, but nowhere had there been any reference to the method of design.

91. Professor Pippard had a particular interest in space structures, ever since his connexion with probably the two most elaborate examples ever designed: the two airships R100 and R101, and he felt—and he had said this many times—that Papers such as this lost a lot of their value by omitting details of the method of design.

92. A young man coming into the Lecture Theatre, knowing little of engineering, would be fascinated, if he had a mechanical bent, to see the pictures and the film, but he could easily get the impression that the only problem was to build these structures; he would have no conception of the enormous amount of calculation and design work behind them. He asked the Authors to describe at a later date how the stress analysis had been done.

93. It had been remarked earlier that in a space frame of this kind the joints were difficult and that it was necessary to have a central mass on which all the members converged. Professor Pippard had met that problem on a small scale forty years ago, in the design of a structure for experiments in connexion with the airships to which he had already referred. He also found that the only way was to connect members to spheres which, in his model, had been 1½-in. 'Skefko' ball bearings, softened and tapped to receive the various tubes and wires forming the framework.

Mr D. H. Little (Ministry of Public Building and Works) agreed with Mr Jellett in thinking that the Paper lost much of its value because no prices were given. 'What did it cost?' was a question which he had asked a good many times in the Institution and he thought it was essential to know. The Authors' designs for the berths were extremely fascinating, but what had they cost? That, to his mind, was one of the acid tests of any design.

95. Having said that, he wanted to ask a few general questions. The structures generally were tied into the rock. Masonry in Admiralty docks was tied into rock or the concrete floors, and he believed that the masonry in the Southampton docks was similarly tied; but the only way in which it was tied was to drill a hole, fill it up with grout and drop a bar in. Why had it been necessary in the Authors' case to preload

the rods? Were engineers becoming a little too prestress-minded? The other method would have been much cheaper.

96. With regard to the dock floor, he could not tell from the illustration whether the rock had been left just dressed off or if it had been taken down 6 or 12 in. below formation level and then been levelled off with concrete. If the latter, had any steps been taken to prevent the rock being lifted by water pressure? By-and-large was this rock reasonably dry, or did a fair amount of water seep out and go back to the pumping station to be dealt with in the usual way?

97. The galleries for holding the services were very wide. How were the services accommodated in those galleries? Were they put on the floor as well as on the wall? There did not seem to be two sides to the gallery, whereas an ordinary subway would have two sides, with the floor uncluttered.

98. The stops for the caisson were of three kinds: granite, plain concrete, and dressed concrete. Why were there three different types? He would like to know to what tolerances the stops were set. The masonry was dressed off in the usual manner, but where the concrete stops were dressed, what did that mean? Was it hammered in the way that granite was hammered, or set very accurately and just rubbed down with carborundum stone. The granite stops he had been associated with at one time were dressed to 0.004 in., but subsequently they had done away with that and used concrete blocks, precast and not dressed. They had been set to a tolerance of 0.1 in., not 0.004 in., and the watertight seal had been achieved entirely by a rubber gasket.

99. There were greenheart stops on the caisson with the rubber slightly proud and allowed to squeeze back into a hollow groove, the pressures being taken by the greenheart bearing on the concrete in each case, with the rubber gasket forming an unloaded watertight seal.

Mr B. N. Robinson, (Agent, Sir Alfred McAlpine & Son Ltd), referring to the tanker cleaning berth scheme, of which he had some personal knowledge, said that the Authors, as the Engineers, were to be congratulated on the selection of the original design, which allowed a large degree of prefabrication. This, together with the restricted nature of the site at Rock Ferry, where there was little or no opportunity for the large-scale assembly of components, had a considerable influence on the contractor's method of working.

101. With this in mind, an ex-marine salvage vessel had been purchased, having shear legs capable of lifting 40 tons over the bow, together with 5- and 10-ton overside derricks. This vessel was used both for transporting to the site prefabricated sections of up to 35 tons from a yard set up on the river wall several miles upstream of the site, and for setting up and moving the temporary platform on which the drilling rig was mounted.

102. This platform took the form of two spud-type piers mounted by means of hydraulic jacks on Rendhex pile legs so that they could be supported at a fixed level above H.W.L., taking account of the considerable variations in level of the river bed. Each of these piers was lifted as a single unit on the shear legs of the salvage vessel and set up to straddle the site of the bent or dolphin, a bridge being placed between the two on which the drill and guides for the tubes were mounted. The rig could be moved from one position to another and set up to work in the course of two days, having a high degree of mobility.

103. The design of the main strongpoint structures was again favourable, since this enabled the main fabrication of these intricate structures to be carried out in the dry. This work would have been difficult and slow if it had had to be carried out in the tideway, with an extreme range of tide and rapid current. The operation of placing the strongpoints went well, both structures going down within close tolerances of their designed position. There were, however, one or two criticisms which might be made here.

104. The jetty head was so designed that the travelling crane track ran directly

across the main deck beams of the strongpoints and the connecting bridge. These three units, therefore, had to be very accurately aligned. The method of placing them having been illustrated, the difficulties could be imagined. It might have been preferable to regard the main steel structures as foundations for a fairly massive concrete deck system constructed above H.W.L. in situ, which would cater for variations in the positioning of the strongpoints. Also, little margin under the maximum lifting capacity of the Mammoth crane had been allowed, and this led to difficulties in providing satisfactory guide piles and walings, which the contractor wanted to have fixed to the structures before the location of the structures in the river, to limit the amount of underwater work. In fact, bearing in mind the particular conditions of tide and current on this site, much of the point of prefabricating the strongpoint structures in large units had been lost by the subsequent need to construct massive foundations around them underwater after placing.

105. The use of intrusion grouted concrete had certainly been of advantage in construction, since the movement of tremie tubes or the use of bottom-opening skips in the fast-flowing tidal conditions would have been restricted to a very short period around what little slack water existed.

106. It proved impossible, however, to carry out the removal of the silt which accumulated inside the pilings without the use of divers and airlifts, although attempts had been made to do this using water jets in conjunction with submersible pumps. The difficulty of cleaning out such a large foundation, which it would have been extremely difficult to subdivide, due to the need for every subdivision to be grout-tight, proved considerable. The available diving time in every 12-h period had been restricted to a maximum of $1\frac{1}{2}$ h and visibility for divers had been nil.

107. Those criticisms might be answered by the fact that the work had been successfully completed, but the impression should not be given that this had been accomplished without difficulties which had tested both contractor and engineer. He would like to ask the Authors whether in the ensuing period they had had an opportunity to reconsider some of the features of the design.

Mr A. F. Daniell (Director, Intercontinental Marine Development, Ltd) said he found himself in an unusual situation, in that he was currently employed by Cammell Laird, though in the early stages of the design of the works described in the Paper he had been on the staff of the Consultants. His viewpoint was therefore not detached, but it was well balanced. As he had been living intimately with these works, if the Authors would forgive him for saying so, before either of them had been concerned with them, he thought it might be of some value if he were to touch on some of the design considerations affecting the most unusual features of these works. He referred to the design of the tanker cleaning berth and of the caisson for the graving dock.

109. So far as the tanker cleaning berth was concerned, the reasons why a solid structure was not permissible had already been fully discussed. It had therefore been necessary to use some kind of open structure. The first method to be considered had been the use of driven piles, but it had been decided after some investigation that it would be impossible to achieve a satisfactory structure in the particular ground conditions existing at the site. It had therefore become necessary to consider the use of piles or pile-like objects which were not driven. Their first reaction had been to examine the possibility of setting piles into holes drilled in the rock. That had been examined under two headings: the use of multiple-pile structures, using perhaps 6 or 8 piles on the strongpoint, or alternatively a single very large tube and some form of floating fender. It was interesting to see that the second solution had been used for parts of the berth described in Paper No. 6711 to be discussed in a week's time. In the circumstances with which they were faced both those methods had been discarded, on the question of cost and the availability of the highly specialized plant necessary for drilling the holes for a comparatively small project.

110. It was at that stage that the design of a prefabricated structure which could be built on land and taken out and attached to the rock had first been considered. On a preliminary analysis it appeared that it was possible to produce such a structure, which could be of a weight which could be lifted by the available harbour cranes and carried to the site. The use of tubes had suggested itself on the grounds of reduction of water resistance, the value of a tube as a compression member and a reduction in area subject to corrosion.

111. There had been some discussion of the method used for making junctions between these tubes. The designers had been aware of the fairly complicated junctions which had even at that time been made by the cutting and welding of tubes, but he thought it was a fact that the strongpoint structures used at Rock Ferry were probably the most heavily-loaded structures of their kind which had at that time been designed, and the designers had been very conscious of the necessity to avoid secondary stresses which could arise either from defects in the geometry or from welding distortion.

112. In these circumstances it had been decided, in consultation with Stewarts and Lloyds, Ltd, that it would be helpful to use the spherical connectors and take full advantage of the very accurate fabrication techniques which that firm had been able to offer. It was interesting that this very complex structure had been assembled without the use of any kind of shims or packing.

113. The structure had been designed as an elastic space frame using Professor Southwell's relaxation method. It was a very simple method of design but incredibly tedious to do. If ever Mr Daniell had to do it again he would call for a computer.

114. On completion of the primary design the structure had been analysed for secondary stresses in the more heavily loaded members, but these had turned out to be extremely small.

115. Turning to the caisson at No. 5 Dock, during the preliminary design the client had several times found it necessary to call for increases in the dock width, since at the time the designers of tankers had just been making the break-through from the then current sizes of 20 000 to 30 000 tons to the very big ones of today. In the course of the various projects which had been studied different sites had been examined, but all of them had had disadvantages either from the point of view of cost or from that of increased interruption to the shipbuilding activities of the client. Eventually they had been forced to use the present site.

116. The type of caisson to be used had been given most careful consideration in consultation with the client. The Box flap type of gate would have presented very great difficulties on this site, because silting was a major problem in this part of the Mersey and the necessity to keep a comparatively deep well open in front of the gate would, it had been thought, involve very great expense in dredging. A ship caisson was, of course, out of the question on such a site because of the extreme tidal range and current. The client had had considerable experience with the sliding type of caisson and was convinced that this was the most satisfactory answer.

117. It was at that stage, therefore, that the decision to build the curved caisson had been taken. It had been evident from the beginning that although at first sight this offered a neat solution to the problem, bringing it to a practical state would require the most careful consideration at the design stage and would entail calling for the very highest standard of site work and supervision. A tribute should be paid to the main contractors, the contractors for the caisson and the site staff that this very difficult piece of work had been carried out in so satisfactory a manner.

The following contribution was received in writing:

Mr F. Ewbank (Retired) noted that two new cranes were to be erected, each capable of lifting loads of 100 tons at 122-ft radius, commanding slipways 5 and 6 where the largest ships were built.

119. No doubt this capacity at so large a radius was for lifting into place the 100-ton prefabricated sections of the ships on the slipways. It was increasingly becoming the practice to instal the main propulsive units whilst the ships were on the stocks, previous to launching.

120. Could the Authors say (particularly of the crane situated near the aft end of the ships) if these cranes had an adequate capacity to lift and place a set of main engines into the main engine room? Could the cranes lift, say, 180/200 tons at the necessary radius? What was the maximum load and at what radius?

121. Comparing the new No. 5 Dock with that recently constructed on the Tyne it was to be noted that the Tyne Dock exceeded that at Birkenhead by 5 ft at width of entrance, and could be extended in length to 1000 ft.

122. Mr Ewbank thought that an additional width of 5 ft on the beam of super-tankers would add a great deal to the d.w. capacity. Further, the excavations for the No. 5 Dock at Birkenhead seemed to have reached their limit owing to congestion at the dock head. Could the Authors say if the limit has been reached or was it possible to add to the existing length of 950 ft?

The Authors, in reply, agreed with the comments of a number of speakers who had said there were several items of the works carried out in the shipyard which had not been dealt with in the Paper. They had, however, decided to concentrate on the five special features which they thought would be of greatest interest. For this reason also the costs of the works had not been included.

124. In reply to Mr Saurin, the spherical joints with their bolted connexions were the only type of joint which was considered adequate for bringing the large number of tubes together. It was admitted that the spheres were on the large side but they were the smallest and thinnest the contractors were able to cast. The prefabrication of the structure had enabled the joints to be made on land away from the site and painted with hot-applied bituminous enamel. There was no reason to think that they would corrode more than the remainder of the structure, the whole of which was under cathodic protection.

125. The concrete blocks securing the foundations were necessary to take the shear due to the berthing impact of the ship. The front tubes of each strongpoint were anchored directly to the rock.

126. There were disadvantages in the use of flexible Mannesmann tubes with a range of tide as great as that at Birkenhead. Mannesmann tubes had to be designed to withstand a blow at the upper end and would be too stiff if the impact were at a lower level, say, at half tide. The booms holding the pontoons at the Tranmere Berth (Paper No. 6711, *Proceedings*, October 1963) had been very ingeniously designed so that the load was taken at the upper end of the Mannesmann tubes irrespective of the tide.

127. The spacing of the berthing heads was 207 ft centre-to-centre, but the outer fenders were 252 ft centre-to-centre and no difficulty had been experienced by holding ships quietly against the berthing heads. Those in charge of the jetty had expressed themselves very pleased with the behaviour of the fenders. The weight of the fenders was taken on a strut underneath, and lateral struts took horizontal forces but the heads were free to take up the alignment of the ship. The chains on either side of the rubber blocks maintained a slight compression of the rubber, so holding the blocks in position.

128. So far as the Authors were aware, the Reich drill drilled a straight hole at a rake of 1 in 4. The sets of Macalloy bars when made up were reasonably stiff and were inserted in the holes without any difficulty. If the holes had been deeper the drill would no doubt have tended to sag.

129. The Authors fully concurred with Mr Hernu's opinion on the very satisfactory way in which the construction of No. 5/6 Jetty was carried out by the Contractor.

130. Referring to the remarks by Mr Godfrey, the Authors had not found a suitable alternative method for joining a similar group of tubes.

131. As regards the remarks by Mr Smy, the Authors concurred that the method of putting a cut through the rock with a Siskol cutter, and so separating it from the main mass, was an excellent one and had avoided any complaints of vibration, a very common subject for complaint when blasting had to be undertaken. Space had to be allowed for the caisson to float up and consequently the tie and strut across the caisson camber could not be put sufficiently near to the roundhead to be effective. It had not been considered that a movable tie and strut would be satisfactory.

132. In answer to Mr Hargreaves, the Authors confirmed that the velocity of the grout at the point of discharge from the grouting pipes was about 3 ft/s. Tenders for the tubular strongpoints had been invited on the basis of spheres to connect the tubes and no alternative form of joint had been priced. The Authors therefore regretted that they could not give any price comparisons. Though other types of joint were considered none was thought to be satisfactory. No shims or filling pieces had been necessary in assembling the structure.

133. In reply to Mr Stephenson, the Authors pointed out that the rock rose towards the rear of the strongpoints as shown on the section in Fig. 4 of the Paper. This, in addition to the rough surface of the rock and the anchorages, was considered to ensure protection against sliding. At the dock entrance roundhead, all anchor cables had been stressed before concreting up and none failed.

134. The top guide rollers had been put on the sliding caisson as a result of calculated possible deflexions should the gate be closed with a head of water on the inside. The actual stresses in the gate had proved to be very much lower than had been expected. The ballast in the lower chamber consisted of large pig-iron blocks, the spaces being filled in with concrete made with steel aggregate. The effect of this ballast had not been taken into account in the design, but it had undoubtedly strengthened the gate considerably and resulted in a bigger proportion of the horizontal load being taken on the sill with a consequent reduction in the deflexion at the top. It was therefore doubtful whether the upper rollers would be required to act. The rollers and brackets were substantial.

135. In reply to Mr Brown, the very considerable amount of silt in the river and the desire to impound water to the full height of the tide had been the two considerations which had led to the decision to use a sliding caisson. Mr Brown had referred to the haulage system of the sliding caisson. It had certainly been a problem, for the stability of the gate demanded that it should be pulled from the bottom. The solution adopted had been put forward by the Contractors and was very satisfactory in operation.

136. Mr Jellett had dealt with the question of dock surrounds at Southampton. At the request of the Client a reinforced-concrete wall had been constructed around the dock at Birkenhead. This had a timber capping and on top of that a galvanized steel plate to allow ropes to slide along the top. The wall was shown in Fig. 9 in the Paper. A gangway could be placed from the ship, its end resting anywhere on top of the wall with movable steps leading to it. It had been considered that removable railings might not be returned to their position immediately and that in such a case the employer would be considered liable for any accident.

137. Mr Little had questioned the necessity for prestressed anchorages. The Authors said that stressed high-tensile steel bars and strands had been used where an economy resulted from their use. The methods advocated by Mr Little had been used quite extensively in other parts of the works. The dock floor was 6-in. thick and vented at about 10-ft centres. Very little water came through, and this only occurred at high tide near the dock entrance.

138. As Mr Little had stated, the galleries were wide and this was their chief asset. The cables and pipes were bracketed off 'Unistrut' inserts set in the concrete wall, and the floor was left clear (Fig. 25). Different types of stop for the caisson had been

chosen varying with the amount of use expected. Granite blocks were set and ground to a tolerance of 0.02 in. in 10 ft. Concrete blocks for the impounding stop were accurately cast and set, and rubbed down where necessary with carborundum stone. The gate had been tested with the maximum head both inside and outside and in both cases was completely watertight.

FIG. 25: NORTH GALLERY, No. 5 DOCK

139. Mr F. Ewbank had raised the question of the size of the dock. A normal 100 000-dwt. tanker would be about 918 ft long and 128 ft wide and would, therefore, go into the dock quite easily. It was not anticipated that it would be necessary to lengthen the dock but as the dock head was mainly dressed rock it would not be difficult to lengthen the dock by another 50 ft.