Swansea Docks—entrance works

by

H. R. Boyce, M.I.C.E.

Lt-Col. R. H. Edwards (South Wales Docks) congratulated the Author on an excellent Paper. In § 5 the Author referred to the changing pattern of trade at Swansea and in particular to the decrease in coal exports. However, since the Paper was written there had been a further change and there was now an upsurge in the coal trade.

71. The schemes for improving the working of the dock and increasing the capacity of the lock were prepared in 1953, and the work that was eventually carried out was basically the same, although several alterations were made.

72. At the time the work was authorized, the tanker traffic was such that delays were occurring, and to deal with this and the anticipated increase, the improvements were necessary.

73. Few humans have the power of clairvoyance, and at that time the Milford Haven Angle Bay Terminal had not been visualized; as a result of this there had been a reduction in the number of tankers bringing oil into Swansea. This, however, had been compensated by an increase in exports, and it was hoped that this would continue to grow. The general cargo traffic, however, had improved and the expenditure on the new works had been justified.

74. The Author's description in § 9 of the lead-in jetty could be misleading since normally, when one referred to a lead-in jetty, one thought of a fender jetty, which was necessary at some entrances to guide the vessels into the lock, such as at Newport. The Swansea jetty was a cross between a lay-by and a lead-in since it was only after a vessel had used it as a lay-by that it became a lead-in. The jetties at Newport were provided to lead-in ships coming from the channel, and, if a ship ran into these timber jetties it did not damage itself.

75. The result of the work at Swansea had been a speeding-up of the time taken to dock large ships since the pilots could now bring these either to the jetty or to the roundhead, even though the lock was not clear, and wait there for the vessels in the lock either to leave for sea or to pass into the dock, a saving of some 45 min each time.

76. The additional dredged area in the entrance allowed a large loaded vessel to swing if it should be necessary to put back to sea. The ship could then sail bow first and avoid the hazardous operation attendant upon a vessel being towed stern first with the possibility of grounding and blocking the channel. The pilots would not agree to the scheme without that swinging area.

77. Lt-Col. Edwards was happy to report that the fendering, described by the Author in § 34, had proved quite satisfactory since the jetty had been commissioned nearly four years previously. However, one such feature was worth mentioning: the elm rubbers were fixed by trenails and that was an undesirable practice since it was not possible to locate the holes in the greenheart when replacements were necessary. Replacements, therefore, had to be fixed with spikes.

* *Proc. Instn civ. Engrs*, vol. 26, November 1963, pp. 425–448.

78. In § 41 the Author referred to the demolition of the old timber jetty and the use of a 50-ton floating crane for withdrawing the piles. It was unfortunate that there was no suitable craft available in the Bristol Channel for this work and that the contractor decided to make use of one of the authority's cranes, for not only did it increase his costs. The results were far from satisfactory and a number of pile stumps were left, as was found when dredging took place subsequently. These were pulled by means of the winch on the grab dredger assisted by floatation. With the crane it was not possible to get such a steady pull as over the bows of a vessel.

79. The new roundhead was referred to in § 45 and one often wondered whether the design of fendering provided was what was necessary. The fendering had recently been struck bow-on by a loaded tanker of 16 000 d.w.t. when the engines failed to go astern, the damage to the timber work being small. Although the stem of the ship had been set back some 3 ft, the cost of the repairs to the roundhead was only £365.

80. Lt-Col. Edwards had also witnessed a vessel falling broadside-on to the fendering, out of control, in a gale and expected to see considerable damage, but this had not happened as the momentum had been absorbed perfectly with the timber fendering and the rubber blocks. This proved that the design was correct.

81. The figures for the cost, referred to in § 69, were for the civil engineering work only, to which must be added £133 000 for the cost of the pumps and installation, and the consulting engineers' fees and expenses, making a total cost of about £1½ million.

Mr J. H. Wilson (Contracts Manager, Richard Costain & Co. Ltd) congratulated the Author on his Paper and added that it was refreshing to hear such a thoroughly practical approach.

83. He wished to raise three main points in discussing the Paper. First, he wondered why the job had been let as three contracts, and particularly why the lead-in jetty and the roundhead had not been embraced in one contract. This would have permitted greater flexibility in planning and in the use of plant and resources.

84. At the time that the work was carried out in Swansea, there was a shortage of skilled labour, and particularly of carpenters. The carpenters were employed principally on the fendering, and this was critical; it was not only a finishing operation but a very long and important operation. Had the two contracts been run as one, this would certainly have ensured the utmost use of the skilled manpower.

85. Another point was that the two contracts overlapped in time, and when this occurred the carpenters finishing the first were perhaps a little unsettled. Under those conditions it had not been unknown for them to ask for increased incentive bonuses. This was a danger because it unsettled the labour on the second contract and, in certain cases, might lead to difficult labour relations in the port as a whole. These were purely contractor's considerations.

86. His second comment followed on from the first: the two contracts overlapped, and yet it was essential that work on the lead-in jetty should be completed before the whole of the western roundhead could be made available for construction. With the best will in the world, there was a delay in completing the lead-in jetty which restricted the area of site available on the other side of the opening on the western roundhead.

87. His third comment had been answered to some extent, but he wanted to know the detailed consideration which had been given to the problem of the piles in the very hard driving area near the intake. Driving the cofferdam piles had shown that conditions were not suitable for sheet piles. Although the difficulties were overcome, this took a long time. He wondered whether the Author had given detailed consideration to the use of sinking concrete tubes or a similar method.

88. He thanked the Author for his references to the skill and patience of both sets of site staff, and he endorsed those comments.

Mr H. E. Eilenberg (Partner, Broughton & Partners) said that he had been interested by Fig. 8 which showed the cylindrical fendering block and the great spread of the contact faces. The Author mentioned that the blocks had been tested to full load 200 times. It would be interesting if the Author gave the results of this repeated loading on the performance of the fender blocks.

90. Fig. 5 showed a small vessel alongside at low water. Mr Eilenberg would like to know the resistance of the fendering when hit low down.

Mr E. R. Radway (British Transport Docks Board, South Wales Docks) said that the Author had been unable, owing to space limitations, to give very much detail of one of the most important features of the work. Quite apart from the lead-in jetty, the pumping station at Swansea Docks was one of the most important assets. It was the first in the world to have concrete volute axial-flow pumps with a siphon applied. The concrete volute type of pump had been used for some time in drainage schemes where the load factor was often low and possibly the head conditions were not as onerous as in this case. The first of these pumps on impounding duty had been installed in Cardiff in 1952 in the conversion of a steam-driven station where

FIG. 16

FIG. 17

on-site conditions were very restricted, necessitating the discharge through a gravity closing sluice valve.

92. The Author had not given much detail of the construction of the volutes, and therefore Figs 16 and 17 might be of interest as they showed the construction of the volutes for Cardiff, which had to be used three times and had to collapse inwards to go through the openings shown. The only reference given in the Paper was a drawing showing the type of shuttering for the volute of a very different kind. The problem of getting the shuttering out was not as serious in the Swansea scheme, but in the ultimate the larger shuttering sections of the Swansea scheme did not make such a good job as that shown, which had been accurately done and kept well within the limits of ± 5 mm in 4 ft.

93. The solenoid-operated type of siphon-breaking valve had been considered, but the simplicity of the gravity type, it had been felt, gave the right answer. Two siphon-breaking valves were thought necessary in each system. This had been the right decision, because recently the pumping station culverts had been examined, and one of the siphon paddles was missing.

94. This type of low specific speed pump had a reasonable, flat, non-overloading characteristic which enabled the robust induction motor to be used quite efficiently. In Swansea it was direct switched by the circuit-breakers, with remote solenoid control giving a starting current of four times full load, and a starting time of 4 seconds. This had proved to be very successful both at Cardiff and at Swansea, but the circuit-breaker needed an oil change about every 250 operations.

95. One would not expect trouble from single helical gearing, but although good quality gear, well within its rated loading, had been used, there had been signs of abrasion. This had been overcome relatively simply by nitriding the wheels, and a good polish had now developed.

96. Thought was given to the possibility that the reverse flow conditions might give trouble, and it had been specified that the pump should operate as self-limiting on reverse flow at 25% over speed. Both the motor and the pump had been tested for this, and the maximum reverse speed recorded was 23%.

97. The volutes at Cardiff, which had been in operation since 1953, showed no signs of deterioration, and Mr Radway saw no reason why similar conditions should not obtain at Swansea, but he had noticed recently that in the construction joints a little spalling had occurred.

Mr J. E. G. Palmer (Partner, Rendel, Palmer & Tritton) pointed out that in § 16 the Author said the importance of a lead-in jetty could not be too strongly emphasized. Mr Palmer agreed with the Author that a lead-in jetty was normally required and that a properly aligned lead-in jetty would speed up the movement of traffic through a lock in every case. Nevertheless, would the Author please answer a question: How did they manage without at the great port of Liverpool?

99. In § 18 the Author said that 750 ships might use this lay-by or lead-in berth in a year. A note which he had received from a senior operating official—not a civil or mechanical engineer—from the South Wales Docks, pointed out that 'instead of having to wait until the approach channel had been cleared of outward-bound ships, a large loaded tanker or other vessel could now go to the jetty as soon as the draught permitted and wait for one or sometimes two loaded vessels to leave. This was a considerable advantage at this port where two large loaded vessels could not pass one another in the approach channel. It saved about one hour in waiting time. These advantages were considered to be of the greatest value to this port.'

100. In §§ 34 and 35 the Author had described the suspended rubber fender blocks illustrated in Fig. 8. What the Author had not stated was the original design of these blocks, where the rubber block had been simply hanging on the suspension chains; with the run of the tide and waves coming up from the south-west, a number of these fenders had been moved. They had travelled along the chain until they could travel

no further. This was why, during the course of the job, the stops illustrated had been added, restraining the longitudinal movement of the blocks.

101. § 41 referred to the removal of the old timber jetty, and the loosening of the ground and rubble around the piles had been done by blasting. It ought to be recorded that this job had proved much more difficult than the contractor had expected and had caused him a lot of trouble. Since the claims had been entirely settled, Mr Palmer felt that he could safely say that the cost had been more than £27 000 recorded in the Paper.

102. To solve the difficulty he had gone to one of the greatest experts in the country on the problem of foundations, to get an independent opinion. It should be recorded that the eminent engineer consulted on this occasion was the present President of the Institution of Civil Engineers, Mr Harding!

103. The difficulties found in extracting these timber piles raised a very interesting and important contractual problem regarding the procedure for getting out tender documents. Where a consulting engineer was certain that some part of a job was bound to be difficult to carry out, would it be the proper thing for him to specify in detail the actual methods which he believed should be adopted? Lt-Col. Edwards had perhaps hinted at this because he had said that some of the most obstinate and badly broken-off old stumps had had to be pulled out with a winch from the grab dredger using the buoyancy of the rising tide. Mr Palmer believed that the contractor would have done better with a special pile-grappling barge rigged up and brought on to the job. But if Mr Palmer believed that, why did he not ask the Author to specify it? Then all the contractors would have included for this in their prices.

Mr E. Newton (Section Engineer, Port of London Authority) said that the Author had considered four types of structure for the jetty: a braced timber jetty; a beam on a single row of piles; a concrete deck on vertical piles; and a concrete deck on vertical and raking piles. He had given his reason for selecting the concrete deck on vertical and raking piles.

105. The Port of London Authority were reconstructing the lower arm of the lead-in jetty to the main entrance lock at Tilbury. They had selected all the three types of jetty construction which the Author had rejected, no doubt for good reasons, and had rejected the one which he had selected! This, of course, only proved that different forms of construction had their place in the design of lead-in jetties, and their use would depend on various factors such as the need of ships to berth alongside the jetty prior to docking, the degree of vulnerability of different parts of the jetty, ground conditions, prevailing currents, and so on.

106. In § 17 the Author said that in an enclosed dock system, or one where the tidal range was small, it was probable that fixed timber fendering or one of the hard tubular-rubber fenders would be provided.

107. It might be of interest to point out that no fendering was generally provided within the Port of London Authority's enclosed dock systems. This policy had been applied not only to mass wall and monolith construction and to quay walls constructed with steel sheet piling and a relieving platform on piles, but also to false quay construction on piles.

108. A solid concrete cope extending a short distance below minimum impounded water level had been found to be quite adequate without any form of timber or rubber fendering. In the relatively sheltered conditions of an enclosed dock it had been found that those responsible for berthing the ship experienced no undue difficulty in carrying out this manoeuvre without causing damage to either quay or ship.

109. In § 22 the Author referred to the resilience of a braced-timber structure but went on to say that a structure of this type would still have been subject to possible heavy damage between strong points. It was perhaps worth pointing out that damage to braced-timber jetties occurred because of their limited resilience or energy absorption capacity. Movement was restricted to double curvature bending of the piles

below bottom bracing level and to some play in the timber joints. It was for this reason that the Port of London Authority, in replacing the lower arm of the lead-in jetty to the Western Entrance, Tilbury, had decided to substitute a more resilient form of construction for the existing braced-timber structure which had suffered very heavy damage in the past.

110. With our present knowledge of construction techniques, the only advantage which could still be claimed for a braced-timber jetty was the absence of serious damage to a ship after an accidental collision and the relative ease of effecting repairs to the jetty.

111. In §§ 23–26 the Author examined and rejected the possibility of a beam on vertical or raking piles. One might agree with the Author that this type of structure, which was sometimes referred to as a spring-fender beam, would not have met the requirements of a berthing jetty at Swansea because the degree of resilience provided by a structure of this type would have been excessive, and the water levels created a problem.

112. The Port of London Authority were constructing a spring-fender beam for that part of the lower entrance jetty, Tilbury, where ships were not expected to make contact during a normal berthing manoeuvre but only under accident conditions.

113. A pile test had recently been carried out at Tilbury. The calculated horizontal load of 14 tons was applied 13 times over a period of 7 days to a raking steel pile carrying 24 tons of kentledge and was released suddenly to simulate ship impact conditions. It was found that the pile suffered no permanent horizontal displacement after deflexions of up to 18 in., despite the fact that ground conditions at Tilbury were rather poor.

114. In § 28 the Author examined and rejected a jetty design with only vertical piles and a concrete deck. He referred to a possible zone of weakness which might be formed in the ground around the piles due to horizontal loading from a ship impact.

115. This type of jetty, which was sometimes referred to as an 'Admiralty' type of jetty and which had, in fact, been used by the Admiralty in many parts of the world, had been selected for the major part of the new lead-in jetty at Tilbury. Horizontal loading tests at Tilbury for this type of construction also confirmed that there was full recovery of the pile after the full design load of 4 tons, which caused a deflexion of 16 in., had been applied 14 times in 8 days.

116. In a structure of this type very high amounts of energy might be absorbed by permitting movement in the main structure, and the deck acted as a load distribution beam. Movement, though desirable, was of course restricted by providing fixity at the top of the piles and by contraflexure in the piles themselves. If rubber fenders were added, they provided useful additional resilience but would not be the sole means of providing energy absorption capacity.

117. Turning to the Author's design, it was noted from § 30 that the only movement allowed for in the main structure was $\frac{3}{4}$ in., which was apparent when one looked at the rigidity provided by the raking piles intersecting at main slab level. It would seem that the Author relied almost entirely on rubber fenders to cushion the structure and the ship. This was probably adequate for normal berthing, but should the ship hit the jetty at an angle at rather more than normal berthing speed, it would seem doubtful whether sufficient rubber buffers could be brought into play to absorb the shock over a reasonable length of jetty. The only cases mentioned so far were of impact with the roundhead.

118. Finally, given the type of design selected by the Author, it would be of interest to know why he had not chosen substantial precast-concrete piles in preference to the much more costly steel piles. By inspection it was clear that the raking piles would be subject to direct loads only, and under normal ship impact the jetty could not move far enough to put any appreciable bending stress into the vertical piles. Steel piles, which cost two to three times as much as concrete piles, were sub-

ject to corrosion, and the Author had, in fact, provided cathodic protection at additional expense. The criterion would seem to be the value of the piles as piles in the ground in end bearing and friction and not as columns. Perhaps the Author would also indicate what led him to reject precast-concrete piles in his design.

Mr D. G. McGarey (Chief Technical Officer, British Transport Docks Board) also commented on the design of the lead-in jetty. He had been concerned with the design of another jetty which, although comparatively small, had since stood the test of about 7 years of continuous use. It was at the entrance to the fish docks at Grimsby, where the previous lead-in jetty had suffered severe damage over the years by reason of impact from trawlers. Trawlers were small vessels compared with those mentioned in the Paper, not exceeding about 1200 tons displacement, but they were sometimes navigated rather recklessly, and such was the speed of impact on occasions that the previous rigid timber-braced structure had been so damaged as to require complete reconstruction. It had been decided that when the structure was rebuilt a more resilient pattern would be adopted.

120. What had been done was to construct the jetty by driving greenheart piles in pairs, the heads of each pair then being braced together to form a portal by means of two horizontal beams about 6 ft apart vertically, and a single diagonal strut. By thus clamping the upper parts of the piles rigidly together, they were constrained to remain vertical even when deflected appreciably under impact; it followed, of course, that there was a point of contraflexure partway down before the piles entered the ground. A series of greenheart walings distributed impact loads over a number of pile bents.

121. Although this jetty had been subjected to numerous severe impacts, so that the rubbing timbers had had to be repaired, the main frames had shown no signs of permanent distortion. He was in no doubt that there was movement of the ground about dredged level but he felt that at a short distance below this level the movement of the pile was negligible and that one need not fear any permanent deformation nor that the jetty would gradually be pushed over. The bracing of the heads of the piles to form a square portal meant that the piles naturally tended to return immediately to the vertical position, and the settlement of any loose ground around the piles at bed level helped to consolidate them into their normal position.

122. In § 39 mention was made of cathodic protection of the jetty, presumably of the steel piles, but no mention was made of the form of paint or protective cover given to the steel. One expected that that cover would be applied carefully and that cathodic protection would be applied on the principle of belt and braces. Mr McGarey would like to know what form of protection had been given to the steel piling, if it had been applied before driving, and whether it had been necessary to make it good afterwards.

123. Mr Radway had given a good deal of supplementary information about the pumps. Mr McGarey had been surprised to find that gearbox drive was interposed between the motors and the pumps. He was inclined to think that this was because mixed-flow pumps had been used, possibly to make use of existing shuttering for the volutes. But it might have been better to use axial-flow pumps, which could have been run at a higher speed and which, with the use of medium-speed motors, would have obviated the need for the gear box.

124. There was another point in favour of omitting the complicated and expensive shuttering for the concrete volutes—there must have been some uncertainty as to how they would match up with the castings. One could not test such pumps until after construction had been completed and they were working under operating conditions. It seemed preferable to have complete pump units assembled at the manufacturer's works and to test them, with the motors, under simulated conditions so that one could get a much better idea of the performance of the complete unit. It would be interesting to know if the concrete volutes of the Swansea pumps had been

examined since they were brought into use, and whether or not any signs of cavitation or other troubles had been observed.

Mr D. H. Little (Superintending Civil Engineer, Ministry of Public Building and Works) wished to comment on the lead-in jetty—about 20 000 sq. ft costing £400 000. At £20/sq. ft this seemed rather expensive, but in effect there were two jetties, since there were two decks and twice as many piles as in most jobs. It was not clear from the description in the Paper what twin 14 in. $\times$ 14 in. fender piles were, since the drawings suggested only one main fender pile. Even so, with the longitudinal bracing, this would mean twice the amount of the usual fendering.

126. Did this come about because of the conditions of the design? It had been stated that the berthing approach was for $\frac{3}{4}$ ft/s, but no mention was made of the weight of the vessel. Would big tankers go to this port?

127. The Author had decided to spread the whole energy over only 35 ft, involving three fender piles, and given this, then this type of jetty was necessary. There was an energy capacity in each rubber of 400 in./ton so they were designing for upwards of 2000 in./ton every 35 ft, which was very high. The force necessary to develop this energy was 500 tons.

128. The Author had said that the jetty had been designed for 750 tons, and presumably the factor of safety was $1\frac{1}{2}$. But the Author had not stated the distance over which the 500 tons was to be distributed. If it was 120 ft, then the jetty was designed to take 4 tons/lin. ft run of coping.

129. Mr Little had never adopted less than $\frac{1}{4}$ ton/lin. ft but, for the largest ships, 45 000–50 000 tons, he would not exceed 1 ton/lin. ft.

130. Since over 700 vessels would use the jetty a year, it was essential that everything went smoothly there, and this might mean that the heavy design was necessary.

131. Mr Little noticed that in 900 ft there was one expansion joint. In the past 20 years, he had never put expansion joints in jetties. The longest run he had designed was 1800 ft. He knew of many tanker berths with approaches 700 ft, 800 ft, and 1200 ft long, but none had expansion joints.

132. Points had been used on the piles where the sheet piles could not be driven, but they appeared to be chisel points. In the last few years he had found that the chisel point of a pile tended to go off line, which meant that it was dodging the boulder, and not pushing the boulder out of the way. Recently he had used long pointed piles—box piles being brought to a solid point. The point was about 2 ft 6 in. long and it was narrowed and tapered like a pencil. This penetrated rock of a certain character. He believed that a very long, thin, tapered point might have done the job a little better than the chisel point used in this case.

133. On the 'A' shed jetty, greenheart had been used for the decking. He gave the example of a jetty with many service pits covered with precast concrete. When these had been knocked about they were replaced by greenheart planks which were extraordinarily tough and strong and did not seem to be so brittle as concrete.

134. Whenever Mr Little had come across a demolition problem it had always been difficult. On one old timber jetty it had not been possible to pull some of the piles out because they had broken at mud level. Fortunately it had been necessary to dredge where the jetty was and the stumps were removed by the dredger.

135. In another case he had had to remove wartime dolphins constructed of steel box piles driven 12 ft into the gravel with a 4-ft-thick concrete slab on top. The contractor had moved the slab easily enough in one piece with a 150-ton floating crane. He had one of the biggest extractors ever made hanging on the end of this crane, but he had not been able to shift the piles. The biggest problem had been to get the tackle to hang on to the piles and even then he had been obliged to blast them out of the water.

136. At times it was rather difficult to build a jetty but it was even more difficult to get rid of one.

Mr J. W. Hunter (Senior Engineer, Coode and Partners) said the Author was to be congratulated on completing a jetty which, without the slightest doubt, would prove satisfactory in use. First, he would ask the Author if it was entirely satisfactory that large tankers should pass through the entrance lock into the impounded waters of the docks system? That might lead to a serious accident in the impounded waters.

138. Putting the strength deck of the jetty between high water springs and high water neaps meant that little use was made of the energy absorption capacity in the greenheart fendering itself. This was one of the reasons why Mr Little felt that the job was too strong. Another factor was the considerable strength in the vertical piles of the jetty. Had the deck been taken right through from one end to the other, and the rakers omitted, there would have been a strong beam which would have spread the berthing loads over the vertical piles. That would have given reasonable movement at the strength deck, but the movement there would not have been such that cone troubles would have occurred in the sea-bed around the piles. By putting the rakers in, the Author limited the movement of the strength deck to $\frac{1}{2}$ in. He might have had six or ten times that movement and additional absorption of energy if he had allowed the strength deck to move.

139. Mr Hunter had made a rough analysis of the absorption capacity of the fendering system at the lead-in jetty. If one took the $\frac{1}{2}$ in. and applied it to the 750 tons mentioned, with a factor of safety of 2, there was an energy absorption of about 150 ton-in. The rubber might absorb 1500 ton-in. and the ship without going itself any damage would absorb 250–400 ton-in. This made a total of about 2000 ton-in.—the same figure as Mr Little had obtained by another process and including other factors. Taking a 21 000 ton ship berthing on the jetty, as shown in Fig. 3, there would be a kinetic energy of roughly 1800 ton-in. in the ship. In addition, allowances had to be made for the energy which went into the fendering system from windage on the ship while it was displacing the fenders and from the tide working over the same distance in cross-current in the berth. These factors might add 800 ton-in. to the energy brought in by the ship itself.

140. Taking two-thirds of the ship's kinetic energy gave about 1200 ton-in. and adding 800 ton-in. from the wind and tide brought the total to 2000 ton-in.: the same as that at which he assessed the fendering system would work as built.

141. On the basis of a berthing speed normal to the jetty of $\frac{3}{4}$ ft/s, the energy which could be absorbed seemed to be about right. But was $\frac{3}{4}$ ft/s normal to a jetty a reasonable speed? It was a high speed, and he agreed that speeds under $\frac{1}{2}$ ft/s were reasonable for design and had been used in the past. However, he had not the slightest doubt that this jetty would satisfy the users and give no trouble in service.

The Author thanked speakers for their kind reception of the Paper. It was interesting to see that very few speakers had overlapped in their comments, which fell under four main headings: those of a general nature, those of a contractual nature, those relating to the pumping station and lastly those relating to the design.

143. Col. Edwards had rightly pointed out the difficulties of a port authority in dealing with the changing pattern of trade. When the Llandarcy Refinery was built the King's Dock Lock was of ample dimensions to take a 16 000-ton tanker but the recent developments in size of tankers led to the establishment of the oil discharge berths in Milford Haven. It now appeared that there was likely to be a further change in trade; coal was said to be coming back into its own and larger ships were being provided for coal exports. British Transport Docks were understood to be concentrating coal exports in South Wales at two ports (Barry and Swansea), whereas in the past the exports were spread over five ports.

144. In the Paper reference had been made to the use of the jetty by possibly 750 ships annually. It was of interest to note from the recently published Annual Report of the British Transport Docks Board that there were 11 800 movements of

shipping entering and leaving Swansea, of which about 30% were coastwise ships. The average daily figures through the only lock were therefore 16 ships entering and 16 ships leaving; that called for reliability in all matters affecting the entrance of ships.

145. In reply to Mr Hunter, the building of berths within impounded dock systems for the discharge of crude oil had been a logical decision at the time because the locks could have taken any tanker then afloat and the turn round of the tankers was slower than today. The Author believed that Antwerp was the only major Continental port to have an oil dock within an impounded dock system, and in the British Isles the Queen Elizabeth Dock, Manchester, Grangemouth and Swansea, were the only three impounded docks where crude oil was imported. Some of the other impounded dock systems had berths for the receipt of cargoes of refined products but the size of ship was usually smaller and the quantity handled per annum in the distributive trade was smaller. So far as large tankers carrying 30 000–100 000 tons of crude oil were concerned, if facilities could be provided in tidal waters then it was wrong, in principle, to waste time taking them through locks when less than 24 hours was required to discharge them.

146. It might have been better to have had only two contracts as suggested by Mr Wilson, one to get the demolition work going whilst the general planning for the rest of the work was under way; the second contract could then have covered the jetty and the pumping station. However, a substantial part of the pumping station contract, the western roundhead, could not be undertaken until the lead-in jetty was partially completed and the contract documents for the pumping station were prepared on the basis that when the jetty reached two-thirds completion ships would stop using the old western roundhead and start using the lead-in jetty. In the event, the people who handled the ships changed their minds when they saw the new jetty structure under construction and would not use it until it was 100% complete.

147. Mr Palmer had asked whether the author felt that the contract documents should outline the methods by which works should be undertaken. The time for the completion of the works which had to be inserted in the invitation to tender or even contract documents by the Engineer in order to receive comparable tenders could not be adequately estimated unless the designer had a clear scheme of construction in mind; also the quantities could not be billed. The three contracts afforded a useful illustration of that.

148. The demolition contract included the construction of three piled marker-dolphins which could only be done from a floating pile frame. The Author expected that the contractor, when he had finished driving piles, would fit a cat-head over the end of the pontoon and withdraw most of the piles on the rising tides. He also thought that he would fit a small derrick, of say 5-ton capacity, on the pontoon to handle timbers from the old jetty on to a barge. However, before work on site commenced, the client decided to omit the three dolphins so that it was not essential for the contractor to have a pontoon and he therefore relied on using the end-over-end method for the demolition of the jetty. The contractor could not obtain an adequate pull for the extraction of the piles and had to resort to the use of a floating crane of the British Transport Docks, to which reference had been made by Col. Edwards.

149. The specification included several clauses dealing with divers and explosives which would not normally have been in the contract documents; for example, there was provision for the divers to be out of their suits before explosives were used so that there was no possibility of divers being caught by falling timbers. This was an indication that the Engineer envisaged explosives being used to break and loosen timbers and for divers to go ahead loosening and burning off bolts. Work would then not necessarily be restricted to tide work.

150. In the lead-in jetty the bill of quantities was prepared on the basis that the contractor would drive vertical piles, cast part of the lower slab and drive raking piles through the slab but the contractor decided to use the end-over-end method

of construction. Another direction given in this contract was that enamelling of piles was to be done under cover.

151. The pumping station job really fell into four parts. The only directions given in the pumping station contract were the minimum size of pours of the relieving platform so as to have as few major operations as possible in the tidal zone, and a limiting date for the start of construction of the roundhead. The bill of quantities was prepared on the basis of a cofferdam surrounding the foundations after which a large drainage pipe was to be in a trench on the outside, but the contractor drove his cofferdam so that he put his drain inside the cofferdam on back filling. Even though flexible joints were used in the pipes a little settlement occurred and remedial measures had to be taken; this would not have occurred had the method envisaged been followed.

152. The author believed that the specifications and drawings usually went a long way to indicate the Engineer's ideas and he would not consider it essential to have to specify, for instance, that floating plant or a dragline should be used. Contractors would say that they were the people with the 'know-how' on such matters. But the Engineer should specify the sequence of works if third parties were involved.

153. The fendering on the jetty had been the subject of comment by several speakers and the Author agreed with Mr Hunter that a ship arriving at high water and berthing against the jetty did not make much use of the fendering from the point of view of absorbing energy. But it did snake and spread the blow over a considerable distance of 35–40 ft; the blow was then taken straight through fenders to the rubber blocks over that length. Small craft, such as coastal tankers as seen in Fig. 6, came alongside the jetty after low water and they gave the fendering some heavy blows. The greenheart piles in this case were considered as being a propped cantilever so that there was bending in the piles and compression of the rubber blocks at the top.

154. The twin fender greenheart piles comprised two nominal 14 in. $\times$ 14 in. piles bolted together so providing a face of about 2 ft 4 in. which pressed against the rubber blocks 2 ft 4 in. long. This could be seen in Fig. 8 which showed the stops required to stop the blocks from moving along the suspension chains—a point to which Mr Palmer referred.

155. Mr Eilenberg had asked for information concerning the tests on rubber blocks. The blocks used on the jetty were 2 ft 4 in. long, 1 ft 9 in. in diameter, with a 6-in. dia. hole and they were tested at the makers' works in a 200-ton compression machine up to a radial load of 90 tons. A rod or chain was placed through the hole to simulate the suspending chain as used on the jetty. The load was applied 80 times at intervals not exceeding 2 min and most loads were applied at 1-min intervals. Whilst in practice such hard use would not occur to a block it was the only way in which a large number of compressions could be applied in a reasonable time. It was found that there was slight abrasion at the end of the holes and that there was a slight temperature rise during the test. The hysteresis effect was small and the change in major dimensions at the end of the tests was not more than $\frac{3}{16}$ in. At the start of the tests the dimensions were within tolerances of -0 and $+\frac{1}{16}$ in. The first ten blocks were tested and slight adjustments made to the rubber mixture and to the size of hole and thereafter one in ten blocks were tested.

156. The blocks at the western roundhead are referred to in §46; they were 3 ft 4 in. long by a nominal 12 in. $\times$ 12 in. cross-section with a 5-in. dia. hole. The first block, with a $1\frac{1}{4}$ -in. dia. bar through it, was tested in a 200-ton compression machine and the load to compress it $6\frac{1}{2}$ in. was 191 tons. It was compressed a second time and the load required was 176 tons. Further compression tests were not done on that block. In the main manufacture, nine blocks were subject to compression tests to produce a 6-in. deflexion; the load required varied from 164 to 220 tons

which compared with the makers' figures of 135 tons without a rod through the block. The machine was held to maintain a 6-in. deflexion and after 5 mins it was found that there was a load loss of about 25%. These blocks were not subject to repetitive testing because the object was to obtain a slight give to the fendering on the roundhead rather than give large scale deflexion. The extrusion method of manufacture of these blocks would appear to lead to wide variations in the results of the compression tests.

157. The Author wished to thank Mr Radway, who was responsible for the contract for the pumping equipment, for filling in the gaps in the description of the pumping station. He agreed that the pumping station was an essential part of the Swansea Docks improvement although the main interest in the discussion had centred on the jetty.

158. The Author understands that Mr Radway had had to replace steam driven pumps at Newport and at Cardiff and that the pump well in both those pumping stations for the siting of the pumps was small. On the other hand the pumping station was large and housed boilers and steam engines to drive the pumps. The new pumps had to join into the existing intake and discharge culverts and had to be installed, one at a time so as to keep the stations in use. Those features probably influenced Mr Radway in his choice of mixed-flow pumps at Newport and Cardiff. When, therefore, tenders were invited for pumps at Swansea, which were of almost identical duty, the firm which had supplied those for Newport and Cardiff was obviously in a very favourable position to put in a competitive price. Mr Radway referred to the fact that large duty pumps having concrete intakes and volutes had, in the past, been confined to land drainage work. The Author had been associated with one large scheme and found that there was no difficulty in attaining first class concrete junction with the steel casting providing that the casting was ground to provide a clean face against which the concrete could be cast.

159. Mr McGarey has enquired whether cavitation had occurred and the fact that some fibrous jointing material had been withdrawn from between two sections of the syphon would indicate that there was slight cavitation.

160. Mr Little had referred to the expansion joint and the Author agreed that he would not include an expansion joint in a jetty of that length if he were doing the job again. It was a nuisance because the discontinuity involved extra piles on either side of the joint which also had to be designed to take full shear.

161. Mr Little assumed that 500 tons was spread over about 120 ft at normal stresses and that was about right; as had been stated earlier the jetty was subject to continual use throughout the year. The heaviest use of the jetty by general cargo ships and oil tankers occurred when there had been a delay at the port. For instance, in February about two years previously there had been a heavy storm lasting several days so that tugs and the pilots' launch could not go out to Swansea Bay where ships had anchored. As soon as the storm had abated slightly, ships were brought into the lock and others locked out as quickly as possible under conditions which were 'just about suitable'. During that time the jetty received a number of heavy berthings from large incoming ships and the Author had seen the rubber blocks over a distance of 35–40 ft, compressed.

162. In his view one could not afford to take risks on a jetty which, under near-storm conditions, would receive many ships and which, under normal conditions, was used by ships continually throughout the year. He would agree that if there was a berth which was used possibly once a week for the discharge of the occasional oil tanker then a lighter design could be adopted because, if damage occurred, there was plenty of time to repair it, or alternatively, time to make some temporary arrangement for the receipt of the next tanker.

163. It is perhaps of interest to refer to a short but instructive paper presented to the Institution in which G. B. Marriott⁵ had assessed the strength of a ship's bows to head-on impact as perhaps 1000 tons. Whilst site conditions at Swansea

would only permit a head-on blow to the head of the jetty or the roundhead, heavy oblique blows could occur to the fendering and the jetty structure.

164. If therefore a 500 ft long jetty were to have horizontal resistance of 1 ton per foot as mentioned by Mr Little then a load of 500 tons (at normal stresses) would have to be spread by means of a horizontal beam within the structure over the whole length.

165. Mr Little had referred to the greenheart decking. The Author had adopted it because some years ago when he had been in Takoradi, port equipment had damaged precast manhole-covers and surface drain-covers which, to be of a reasonable weight, had not been made very thick. In their place it had been decided to use covers of 10-in. $\times$ 3-in. Opepe with two timber straps underneath. These had stood up to all uses. Consequently, when he had wanted to put in a deck in this case, which could be removed for maintenance purposes—it was impossible to get under it normally because of high water level—he had decided to use greenheart as the best solution. These could be knocked about without being damaged in their lifetime.

166. Some of the matters raised by Mr Hunter had been covered by replies to previous speakers but he would be interested in Fig. 18 taken by the Author which showed a cargo vessel about to hit the jetty. Also, one night the bow of a ship cut right through the greenheart fendering of the jetty and the ship must have been at an angle of 60° to the jetty. A figure of $\frac{3}{4}$ ft/s at right angles to the jetty was considered reasonable.

FIG. 18: THE *Kumba* COMING ALONGSIDE THE JETTY IN WINDY CONDITIONS

167. Mr Newton had outlined a scheme which the Port of London were putting in hand at Tilbury and the horizontal deflexion tests had provided useful information.

168. The fact of not having to provide fenders over a tidal range of 30 ft had helped Mr Newton in his designs and he had stated that his jetty was fundamentally a crash barrier. The information given was helpful and the Author hoped

that a record of ground conditions around the piles would be made available to members in due course.

169. Mr Newton had queried the use of the term 'resilient' when referring to timber jetties. Provided that they were not overstressed, jetties of greenheart or pitch-pine would spring back but they were essentially structures which received damage rather than that the damage should occur to the ships hitting them.

170. The Author has noted in many ports that the concrete walls and wharves were unprotected and he had worked on schemes of the protected and unprotected kind. He preferred to have some protection to reinforced-concrete work because spalling could cause so much damage.

171. Precast and prestressed piles had been considered but the nature of the ground and the difficulty of estimating the length required, particularly after the omission of guide dolphins on the Demolition Contract, had led to the choice of steel piles. They were lighter and withstood far heavier pile-driving than did concrete piles.

172. Piling had received a priming coat and then a Wailes Dove enamel coating before driving. The specification called for padded slings and also special rollers on the pile frame and guides to prevent damage. Even so, it had occurred, for the piling gang tended to look upon those requirements as a nuisance and damage was very difficult to put right.

173. The Author agreed with Mr Wilson that the pile driving in the cofferdam for the pumping station through the cobbles and sand was hard but piles went in plumb and when withdrawn were not distorted. This did not cause the Engineer to expect boulders of the scale experienced, although the borings had indicated that there were some in the ground.

174. The steps taken to overcome such difficulties were dependent upon the stage in the contract and the plant available. Clause 12 of the Standard Conditions of Contract placed the first proposals for overcoming unforeseen difficulties upon the Contractor which enabled him to consider how best he could utilise his existing plant and what extra plant he should bring on to the site. The Engineer considered this and either accepted the proposals or gave other instructions. In the present case the unforeseen difficulties came towards the end of the contract and the decision was taken to make best use of the plant on site. Had the difficulties been met in, say, the first half of the contract, then the piling plant could have been used elsewhere and special plant could have been brought on the job to drive or sink a series of tubes of about 24-in. dia. or even Larssen Box piles, the obstructions being broken out as the tubes or box piles were sunk. There would have been ample time to do this work, which would have been a slow operation, without holding up other work.

175. The Author wished to thank Mr Roger Ling, whose firm converted the Prince of Wales Entrance Lock to a pumping station, referred to in § 5, for drawing attention to the date which should have read 'early 1930s' not '1924'.

176. It was of course difficult to answer Mr Palmer's question about locking at Liverpool without a detailed knowledge of the Port, but the locks of the three principal docks (Gladstone, Langton and Waterloo) pointed to the south, and the east wall of each continued in a southerly direction so that ships could lie alongside and, in effect, could use the wall as a lead-in jetty.

177. The Chairman had asked about the number of contracts and about the curved or straight jetty. It had been a straight jetty because of the greater distance in a limited width for a ship to swing. That was the point which had made the pilots decide to have a straight jetty rather than a curved, as had been suggested, for the curve would have reduced the width available for a ship to swing should an emergency arise.

REFERENCE

5. G. B. MARRIOTT. A modern coal-loading plant on the River Tyne. *Proc. Instn civ. Engrs*, vol. 5, pt. 2, October 1956, pp. 432-446 (Appendix).