Pontoons and barges

Two piling pontoons each 61 ft long by 44 ft beam by 5 ft 6 in. deep. Braithwaite tank construction.

Two pontoons for 10-ton derricks. 74 ft 6 in. long by 55 ft beam by 5 ft 6 in. deep. Braithwaite tank construction.

Three pontoons for 15-ton derricks. 70 ft long by 50 ft beam by 7 ft deep. Fairmile construction.

Four barges of Philippine construction, 100 ft long by 28 ft beam by 8 ft deep.

Four barges of Fairmile construction, 88 ft long by 20 ft beam by 6 ft deep. Hatch 66 ft long, 16 ft wide.

One barge of Fairmile construction, 120 ft long by 24 ft beam by 6 ft deep, with flat deck.

Two pontoons for water and fuel, 42 ft long by 18 ft beam by 7 ft deep. Philippine construction. Hired from Royal Australian Navy.

Power plant

Two piling rigs, B.S.P. standard 65/80 ft power raking frame, No. 5 Zenith friction winch, No. 22 Spencer Hopwood boiler, 10 B3 McKiernan-Terry piling hammer, 9b semi-automatic piling hammer.

One piling frame, B.S.P. standard 50/65 non-raking frame.

Two 10-ton steam derricks by Butters Bros. 110-ft jib. Maximum full load radius 82 ft.

Three 15-ton steam derricks by Butters Bros. 110-ft jib. Maximum full load radius 82 ft.

Two concreting plants, each comprising one 21-cu. yd weighbatching plant, two 21/14 or 14/10 concrete mixers. Mounted on Fairmile barges.

Three cranes (two RB 19, one RB 22) mounted on Philippine barges.

Plant ashore

One 20-ton steam derrick by Butters Bros. 120-ft jib. Maximum full load radius 90 feet. Located at service jetty.

One 15-ton steam travelling derrick by Butters Bros. 110-ft jib. Maximum full load radius 82 ft. Located in casting yard.

One 12-ton mobile Coles crane.

One 42-cu. yd weighbatcher by Stothert & Pitt.

Two 14/10 Cumflow concrete mixers by Liner Machinery Co. Ltd.

One RB 22 diesel grab crane.

Four Aveling-Barford dump trucks 20 cu. ft capacity.

*Two D7 side-boom tractors.

*One International tractor model AW6.

Two Ruston & Hornsby diesel locomotives type D.S.48.

*Three 5-ton lorries.

Air compressors, portable welding sets, diesel lighting sets, and items marked * were supplied by the main refinery site to suit requirements.

The Paper, which was received on 24 February, 1956, is accompanied by twelve photographs, and twenty-three sheets of drawings, from some of which the half-tone page plates, folding Plates 1 and 2, and the Figures in the text have been prepared.

Discussion

Mr H. J. W. Braddick (Superintending Engineer, Eastern Refineries, British Petroleum Co. Ltd) said he wished to amplify what had been said about the need for speed in construction, which he thought had influenced the type of design chosen.

His company had planned a refinery in Australia some time before the Persian troubles but, with the loss of the refinery at Abadan, there had, of course, been an urgent need to obtain additional refining capacity at the earliest opportunity. But it had not been just

as simple as that so far as Kwinana was concerned. It would be appreciated that when any new refinery was commissioned there was a major change-over in the shipping and marketing arrangements covering the area served by the refinery. In cases such as Aden and Kent, it was possible to absorb any last-minute changes by redirecting tankers to other refineries in the vicinity. In the case of Kwinana, however, because of its remoteness from other centres, it had been necessary to plan some considerable time ahead the final commissioning and completion date.

The jetty formed part of an overall refinery job. So far as the refinery itself was concerned, it had been known that the subsoil foundation conditions involved no major problems. The jetty, on the other hand, in common with most marine structures, was always liable to the vagaries of nature, and, as had been seen from the film, the site staff had had their fair share to contend with. It was to the credit of the Authors—and to his own company's civil engineering staff, who had co-operated to the full in the early stages of planning and development—that the whole job had been completed in accordance with the planned date, which itself was 3½ months ahead of the original programme.

There had been criticism of the fendering arrangements. The jetty had now been in operation for about 18 months. Tankers had been damaged—the film had shown the sort of weather that was encountered—but there was no doubt that much of the damage had arisen from the inexperience of the local pilots in handling tankers in those waters. He had heard the view expressed that the 14-in. travel allowed in the fender units was not sufficient for the conditions and that the fender units themselves should preferably have been taken to deck level. The coming winter period would indicate to what extent the pilots were at fault and to what extent the rubber units which were referred to by the Authors would assist.

In conclusion, he added that the fender units were designed to absorb blows between the ship and the shore, and in his experience they had also to absorb the differences of opinion between the marine and the civil engineers' points of view.

Mr John Cuereel (a Partner in the firm of Rendel, Palmer & Tritton) observed that the Paper referred to the dry concrete caulking of the joints. He showed a slide of the caulking of the transverse deck joint. That method of making joints had been in use for about 30 years, but with the development of prestressed concrete and the rapid advance of precasting in general, emphasis was being placed on some method of forming a joint very rapidly which was densely filled and sound in every detail. The joints used on the Kwinana job met those requirements. There was nothing inherently difficult about making them, but when they were required to be a production job, as in the present case, it called for great thought and care in getting all the details correct. The trial runs carried out at Feltham had been invaluable in indicating the right tools and procedure to be adopted. They had also shown the complete soundness of the filling and the intimate contact of the joint concrete with the precast faces and had illustrated quite remarkably the way in which the concrete, although being hammered downwards, swelled up and filled under bars and ducts crossing the joint. Hammered concrete was, of course, very sensitive to water content. Mr Cuereel thought that perhaps the Authors might have stressed a little more that it was the effective portion of the water/cement ratio which counted, and that allowance should be made for losses by absorption by the aggregates and by the joint faces and by evaporation. It was not made clear in the Paper that the figures given for the water/cement ratio covered those losses; the allowance should be fairly close to the mark in order to get an effective ratio of about 0.2, which permitted full compaction by hammering without at the same time getting squashy.

In describing the fendering system, the Authors had outlined the energy-absorption requirements. Those, in conjunction with limit stops, were all right so far as the fender units themselves were concerned; but Mr Cuereel considered that for an important tanker jetty taking big ships it was necessary that there should be an adequate reserve of strength in the structure for the occasions when things did not go according to plan, and he thought that the aim should be an ultimate resistance of about 1,000 tons at each end.

The Paper referred to the permissible erection lift for the precast sections of the work.

The fact that the job had gone ahead rapidly and had been finished before time indicated that the decision to make a general limit of 15 tons was not wrong, but he thought that the permitted exceptions were more interesting.

Mr Cuerel concluded by showing slides of the skirt units; the first showed them in the casting yard, the second the transportation of a unit to the temporary loading jetty, the third and fourth the final lowering of the sections into position.

Mr R. M. Wynne-Edwards (Managing Director, Costain-John Brown Ltd) said that the Authors had referred to speed of construction controlling design almost as if it were unusual. Surely, to construct civil engineering works quickly so that the owner could begin getting returns on his capital outlay as soon as possible would always be of primary consideration.

He had visited the Kwinana jetty two or three times during the course of its construction and had been impressed by it being precision engineering on a large scale. When Mr Cuerel had made up his mind to use precast units he had resolved on a complete jetty of precast units, which meant that everything had to be accurate within much finer tolerances than were commonly used in civil engineering work. To achieve that required very nice judgement. The contractors who had had to carry out the work had quite rightly been brought into collaboration at an early date and the experiments at Feltham had been carried out. But Feltham was a long way from a jetty to be built in the sea in Western Australia and Mr Cuerel had had to judge how accurately the work would in fact be done on the site.

As the slides which the Authors had shown had demonstrated, the piles on which everything depended were in fact driven "spot on". The precast units were also fine achievements. The deck slab for instance, where each bay was made up of three units weighing 14 tons each, was tied together with transverse bolts threaded through from one side of the deck to the other. Plane faces were in fact plane and bolt holes matched exactly. As a result, when the time came to assemble all the parts together the work had gone smoothly and fast.

Mr C. H. E. Rebbeck (Project Resident Engineer, British Petroleum Co. Ltd) remarked that, as the representative of the client in Australia for the building of the refinery, he could say that the design and construction of the oil port had been completely successful.

When it was appreciated that as late as June 1952 it had not been finally decided whether three jetties were to be built, or the shore arm, the trunkway, and the three jetty heads, and that at the end of 1954 the first tanker was pumping crude oil ashore, he thought it lent a certain colour and romance to the job.

In common with the rest of the refinery construction, a decision had been made early on to incorporate a high degree of tooling for the job. One reason for that had been the necessity for speed. Another very cogent reason was that labour in Australia was extremely expensive, so that the less the manual work in a job the more economical it would be, provided that the plant was used to the best advantage. He could give an assurance that in the case of the Kwinana jetty that had been so. The job had not only been completed ahead of schedule, but also within the estimated cost.

Nearly 1,000 piles had been driven and more than 14,000 cu. yd of concrete had been placed within 17 months, with a peak labour force of only 600 men. Of those 600 men, thirty were specialists sent out from the United Kingdom.

The high degree of planning and of direction which that effort represented was self-evident; but it was interesting to note that the work had been carried out concurrently with the construction of a large refinery close by, and also a new township had been in course of building about $2\frac{1}{2}$ miles away. The State Government Departments had been very busy on schemes to bring water to the site and to widen the roads. The project had been carried out at a time of over-full employment and in an expanding country, which in any case suffered from a lack of skilled artisans.

Mr B. F. Saurin (Senior Civil Engineer, British Petroleum Co. Ltd) said he had been very interested in Mr Wynne-Edwards's remarks about the speed of construction and the

emphasis on speed in America. Those remarks had reminded him that people who had gone from Britain to America to find out how the Americans did things quickly in the building and construction world had come back and said that there were three essentials; the first was that the client or employer must know exactly what he wanted, the second was that very detailed planning in the early stages must be undertaken (planning not only of the main structure but also of the installations and equipment associated with it), and the third was that there must be no alterations.

Those were, of course, counsels of perfection, but since it had been hoped to make Kwinana the perfect refinery, it had had to have the perfect jetty and an effort had been made to follow those counsels of perfection. In the first place, the client had really tried hard to make up his mind what he wanted. That had not been too difficult because, of course, the Company had built several jetties before and several new refineries since the 1939-45 war. So it had been possible to write a design specification for the information of those concerned saying what the Company wanted in the way of berthing facilities, mooring facilities, pipelines, road access, and so on.

It would be noted from the Paper that, associated with each of those functions of the jetty, there was a separate part of the structure—the jetty head, the dolphins, pipe tracks, etc. There had been consideration of how those elements could best be combined to achieve economy in construction and fitting out, and also to suit the natural character of the site. Soundings and borings had been put in hand in order to get all the information available ready for the detailed planning, which was the next stage.

At that point the consulting engineers had been engaged and had been brought into collaboration with the refinery designers and the jetty contractors, and with their advice a final choice of the layout had been made. Then they had set to at weekly meetings to thrash out the details of all the installations—electrical installations and pipe-lines were the major items, with their associated valves and fittings. With so many precast members to be made, it was easy to imagine the trouble there would have been in drilling hundreds of bolt holes and fitting on clips, etc., if full particulars of the fittings had not been available when the precast units were drawn and their reinforcement detailed.

It was at that stage that the difficult decision had been made about the maximum lift. Mr Saurin thought that everybody concerned would have liked to have gone beyond 15 tons, but circumstances had been against them.

Schedules had then been drawn up of the design work required, the plant needed, etc. After that had come the detailed design and the preparation of the working drawings.

The risk of alterations for technical reasons had thus been minimized and since the circumstances of the oil industry had permitted the Company's policy to be maintained throughout the period there had in fact been no alterations.

The progress schedule of the work (see Fig. 31) was worthy of notice with a view to

Fig. 31

assisting similar work in the future. At the end of 1951 the first Company man had set foot on Kwinana; 3 years later the first tanker had come in. That was the span of the job. The early preliminary planning had been in the first half of 1952; the Consulting Engineers and contractors had been brought in on planning in the remainder of 1952. During 1953 there had taken place all the really hard work of preparing the working drawings—of

course, design had started earlier in a preliminary way. The first working drawings had been produced at the beginning of 1953. The first pile had been driven in the middle of 1953. The construction had taken 18 months.

Mr Saurin suggested that that was worth bearing in mind—one whole year's planning, a 6 months' lead of drawings over construction, 18 months to do the job.

Mr K. A. Spencer (Spencer & Partners) referred to the question of bonding between the steel piles. As could be seen in Fig. 25, it had been so designed as to prevent collecting the seaweed that drifted along the coastline, but the problem had been much more difficult than might appear. Probably had it been known a little earlier that cathodic protection was to be applied, a bar could have been provided for inserting through the concrete. He did not know whether that would have been possible from the civil engineering point of view, but it would have greatly facilitated the eventual application of cathodic protection.

Three 150A transformer-rectifiers supplied direct current for the cathodic protection of the jetty. The positive leads ran out in the foreshore to three graphite ground beds. The current flowed out from the ground beds through the sea to any bare metal on the piles on both the jetty and dolphins, and returned through the bonding bar shown in Fig. 25 back to the shore. The negative of the transformer-rectifiers was connected to the start of the jetty approach section.

Mr Spencer showed slides of the circuit involved and of the transformer-rectifiers in the cathodic protection house. The operating voltage of the transformer-rectifiers was between 25 and 30 V, so the circuit resistance was very low.

The amount of current required in such a case depended entirely on the coating on the piles. It was important that a good coating should be applied. It had been found preferable to have a hot-applied enamel coating. The bitumen types had been quite successful, although not always; it depended very much on the workmanship, which had been good at Kwinana. If workmanship was of high quality a very good current spread could be obtained. Only by use of an electrically insulating coating and also cathodic protection could corrosion of steel piles be prevented on a permanent basis of economic cost.

Mr A. H. Beckett (Chief Engineer, Sir Bruce White, Wolfe Barry & Partners) observed that there was no doubt in his mind that the engineers engaged in the work described knew a lot about making concrete. Some of the crushing strengths they had obtained for the joint mortar appeared to be almost unbelievably high, and he would be interested to know what the Authors considered as the working stress for concrete that gave a cube strength of 10,000 lb/sq. in. after 7 days.

The ingenious methods adopted for making the joints between the precast concrete units should go a long way towards providing the structural sturdiness and reserve strength that one associated with the more conventional type of cast-in-situ work.

In view of the excellence of the materials available for making concrete, would the Authors explain why, for piling, they had chosen steel box sections which had had to be sent out from Britain?

On almost every new oil jetty, one heard of another approach to the vexed problem of how to restrain gently a charging oil tanker. There was no doubt that any form of resilience was a great advantage both to the jetty and the ship. The introduction of such resilience on a rigid jetty almost always involved the use of some form of mechanism, which worked a little less well if it was rusted up. In the work described in the Paper there was an excellent attempt to provide a simple and robust device which, taking advantage of the small range of tide, ensured a centralized thrust on each rubber buffer by means of ball joints. Was there incorporated in that fender unit an hydraulic dash-pot system, and did the level of the sea modify the action of such a dash-pot. Was there the possibility of an incompressible hydraulic cushion finding its way into the mechanism?

It was stated that cathodic protection was installed to prevent the corrosion of the steel-work and the fender units. Could the Authors state if the intermittent dose of cathodic

protection that the fendering system received at high water was effective in retaining the working clearances of the sliding pistons?

Lastly, it was stated in the Paper that the fender system was designed to absorb the energy of a 40,000-ton vessel approaching at a speed of 1 ft/sec. The Paper also gave figures for energy absorption of the fender units, from which it was easy to calculate that twelve units must come into full working contact with the approaching vessel before the energy absorption could be found. Surely for that to happen the ship must lie truly parallel to the jetty face—a condition which would rarely obtain. The pilot would doubtless discover the limitations of that fendering system if he brought his ship at an angle to the jetty, but the price of his experience might be damage to the ship.

Mr Harry Ridehalgh (Sir William Halcrow and Partners, Consulting Engineers) said that the Paper was the third or fourth to be presented in recent years dealing with the provision of oil-loading facilities. It seemed now to be a regular feature of such Papers that whatever was described was bigger than anything yet built or had cost an astronomical amount. Curiously enough, the Authors had not mentioned the cost of the work, nor had anybody asked about it. The Authors had said, however, that it had been completed in 18 months and that the average labour force had been about 340—on a basic wage, plus overtime, which had probably come to about £17 a week. A little mental exercise showed that the labour bill on the job had been about £500,000. It was fairly easy from that to work up to quite a big figure for the cost of the work. He did not know whether the Authors would like to say how much it had cost, but one might well get up into the millions.

The Authors had given a good description of the plant used. There had been six tugs and launches, sixteen rowing boats, eighteen pontoons and barges, twelve derricks and cranes, five concrete mixers, two or three piling outfits, and odds and ends of heavy equipment in addition. That was quite formidable, but the Authors had agreed that it was fairly generous. The total weight of the piling had been about 4,400 tons. There had apparently been four or five senior engineers on the job and probably an equal number of junior engineers and inspectors. One could therefore get some idea of why the work had cost so much.

The point Mr Ridehalgh wanted to put was whether it had been unnecessarily expensive. The only comparison he had to offer was the three oil berths which his firm had built at Singapore, which were almost identical. They had been approached by piled spans, as at Kwinana, and there had been jetty heads. They had been designed to take 45,000-ton tankers as against the 32,000-ton tankers at Kwinana. The job had taken 16 months to build, it had cost £300,000, and the average labour force had been 150, as against 350 at Kwinana. The plant used had been two cranes, two piling rigs, two pontoons, two mixers, and one tug; whilst the total weight of the piling had been only about a quarter of that used at Kwinana. There had apparently been some meanness about the number of supervisory staff, since there had been only a resident engineer and one inspector; the contractor had had an agent and a junior engineer.

He would be interested to hear whether the Authors could offer any reasons for the very wide differences between the costs, plant, and labour on the two jobs.

Turning to the design of the jetty, Mr Ridehalgh hazarded the opinion that the roadway and trunkway design seemed unnecessarily complicated, and he was not very happy about using the particular type of prestressing in such close proximity to water. He felt that the jetty head was unnecessarily large having regard to the fact that only the centre 60 ft were used for oil handling facilities. At Singapore there had been a deck area of less than half that size, fronted by the berthing beam, 240 ft long, which absorbed the whole impact of the ships coming alongside. It might be that the size of the jetty had been dictated by the capacity to absorb ship blows, since Mr Cuerel thought it wise to have a large safety margin for the fenders. In the Singapore design the actual jetty head took no ship blow at all; it was all taken on the berthing beam—which brought him to the problem of energy absorbing fenders. Again, he thought that the design used was too

complicated for practical use. Special castings were required; those might get broken or rust up and they had a relatively low energy absorbing capacity. Each block would, in the travel given in the Paper, absorb rather less than 50 ft.-tons. The energy to be absorbed from a 32,000-ton tanker moving at 1 ft./sec was about twelve times that. Thus, for anything other than broadside blows, the eight fender blocks provided were going to be very much over-taxed or the jetty head would have to take a substantial portion of the blow. There appeared also to be no provision for the units to take longitudinal blows, although he knew that there was the stop at the end, but really that was only a structural transfer of the blow to the rest of the jetty head. In addition, at least 60% of the jetty face was unprotected from either the normal berthing blow or the inevitable exceptional blow which usually put the berth out of commission. At Singapore the berthing beam absorbed at least twice as much energy (about 750 ft.-tons) as all the eight units would do at Kwinana, and the whole of the berth was protected even from the exceptional blow. That was absolutely essential, for the cost of a berth being out of commission was exceptionally high, having regard to charter and demurrage rates at the present time.

It appeared nowadays that they were tending to lose sight of the costs of jobs because they thought they were perhaps getting something bigger and better and quicker than anything which had been built before.

Mr H. C. Visvesvaraya (Civil Engineering Department, Imperial College of Science and Technology), referring to the jointing of the prestressed precast units and the use of a special stressing device, said that at the same time as the Kwinana project was in progress stressing devices were being tried at the Imperial College with a view to developing a device capable of stressing tendons from within small pockets or recesses in the members in a convenient and safe manner. During that period a new jack was developed which was eminently suitable for establishing continuity between precast members. The jack that was made first was of a capacity of 25 tons and weighed less than 10 lb. Using the same principles a design for a jack with a capacity of 50 tons had been worked out; such a jack would weigh only 18 to 20 lb. and would have an external diameter of $5\frac{1}{2}$ in. compared with 82 lb. and $6\frac{1}{2}$ in. respectively for the jack used on the Kwinana jetty, and 140 lb. and $7\frac{1}{2}$ in. respectively for the standard Lee-McCall jack of similar capacity. The small size of the jack automatically resulted in much smaller pockets than those used in the Kwinana project.

On p. 789 the Authors stated that the strength of the concrete cubes was 10,000 lb/sq. in. at 7 days, whereas on p. 807 they said that the works tests showed an average compressive strength of 10,000 lb/sq. in. at 28 days. Would the Authors please explain that apparent anomaly?

He would also like to know whether the jointing faces were covered with neat cement grout before caulking.

*** * Mr F. P. Dath** (Civil Engineer, Central Electricity Authority) thought it seemed a little unfair and pointless to try to make a comparison between the costs of the Singapore and the Kwinana jetties, unless the labour costs which appeared to be the salient issue were considered in their relative proportion, irrespective of the design aspects. It was well known that the basic wage for a general labourer in Singapore was about 1/10th of that mentioned on pp. 812 and 820; therefore, since labour costs formed, in most cases, the major part of the cost in civil engineering works, that aspect alone was sufficient to rule out a direct comparison between the two constructions.

He had not carried out any construction works in Australia, but he had been acquainted with some of the difficulties in the labour problems there, and he thought it was generally recognized that Australian labour was the most expensive in the world. He was, of course, referring to the Australian and not to the European immigrant.

*** * *** This contribution was submitted in writing after the closure of the oral discussion.
—SEC.

Mr Murray, in reply, referred to the 15-ton limit for the weight of the precast units, mentioned by Mr Cuerel and others. The decision to limit the loads to 15 tons had been made after long and serious consideration by all parties in the light of known and anticipated site conditions and the availability and cost of plant. The works had been completed in excellent time, and therefore, it could be said that the decision was sound. At the same time, however, he thought that given suitable conditions and circumstances, great economies in construction could be made on similar works by precasting on a much heavier scale.

Mr Ridehalgh had criticized the cost of the works and had given some figures of a job in Singapore as a comparison. Mr Murray thought it was futile to compare one job with another without having knowledge of the respective requirements and conditions. Mr Ridehalgh had given only one clue—the quantity of piling at Kwinana was four times that at Singapore. If one followed that clue, it seemed clear that the essential work at Kwinana was several times greater than at Singapore. Yet the average labour force was 150 at Singapore; 340 at Kwinana. The time for completion at Singapore was 16 months; at Kwinana, allowing for preliminary works, 20 months. Mr Murray understood that the total cost of the Kwinana Jetties was about £1,700,000. When account had been taken of the scale of the work, the respective site conditions, and of the tremendous difference in labour rates, he thought that in the matter of cost comparison the boot might well be on the other foot.

Mr Collett, in reply, said that the particular criticisms of the fendering arrangements mentioned by Mr Braddick had not in fact been borne out in practice. There was no evidence to suggest that the fenders were being driven fully home and the fixed fendering above the flexible fender units was virtually untouched.

Mr Spencer had made reference to the bonding between the steel piles, and Mr Collett agreed that had the details of the cathodic protection been finalized at an earlier stage of the jetty design it might have been possible to cast bonding bars into the concrete units for that purpose. However, the method adopted was both neat and practicable and equally facilitated the eventual application of the cathodic protection.

In reply to Mr Beckett's queries regarding the working stress in the concrete used in the caulked joints, Mr Collett explained that the main object had been to obtain a fine dry concrete which, upon being rammed hard in the joint space, could then be immediately stressed. The cube strengths of 10,000 lb/sq. in. at 7 days thus obtained, had been pleasing, but such high strengths were not regarded as essential, bearing in mind the comparatively low working stress in the joint concrete.

With reference to Mr Beckett's remarks about the fender units, Mr Collett went on to say that the water which found its way inside the buffers did in fact escape freely when the fender units were compressed and there was no possibility of an incompressible hydraulic cushion forming. Regarding the efficiency of the cathodic protection and the retention of working clearances on the sliding pistons, Mr Collett said that such clearances were being retained, and after approximately 18 months in operation there was no sign of corrosion of the units.

In reply to Mr Beckett's remarks that twelve units must come into full working contact with a 40,000-ton tanker approaching at 1 ft/sec to bring it to a halt, Mr Collett said that that was incorrect since energy was absorbed in other ways than by the fenders themselves. In fact, it was a common assumption that only about half of the total energy was transferred to the fender system. In his estimation four to five units would safely halt a tanker berthing at the specified speed and that was proving to be the case.

With regard to Mr Ridehalgh's contribution, Mr Collett mentioned that he would confine his remarks to the design problems only. Mr Ridehalgh had remarked that he would not have used the particular type of prestressing in such close proximity to water but had not gone on to say why he would not have specified it. Mr Collett could not see why the system adopted was not the equal of any other system of prestressing for use in a marine structure; the steel was adequately protected by a fine dense concrete against the effect of sea-water and salt-laden atmosphere. Mr Ridehalgh had suggested that the

fender design was too complicated for practical use and yet, in practice, the fenders were performing a good job of work. Mr Ridehalgh had also raised the same point as Mr Beckett regarding the energy absorption of the fender system and the previous answer applied. Mr Ridehalgh had further suggested that the jetty heads were unnecessarily large (apparently at Singapore they were very much smaller). Mr Collett did not have sufficient knowledge of the details of the Singapore jetty to make a comparison, but the jetty heads at Kwinana with the number of pipes required, hose-handling equipment, fire-fighting installations, mooring arrangements, office, etc., had proved not to be unnecessarily large.

Mr Visvesvaraya had referred to a new jack which had been developed at the Imperial College and which appeared to offer certain advantages over the type of jack used at Kwinana. Mr Collett mentioned that when it was first suggested to Messrs McCall that their standard jack could be reduced in size and weight they felt it would be extremely difficult. However, they were able to bring it down from 140 lb. and 7½ in. dia. to 82 lb. and 6½ in. dia. Mr Collett would be pleased to see an equivalent jack with a weight of 18 to 20 lb. and he was sure that it would be welcomed generally.

Mr Visvesvaraya had drawn attention to an apparent anomaly in the concrete cube-strength figures mentioned on pp. 789 and 807. The figures on p. 789 related to the cubes made at Feltham during the trials, while those on p. 807, which are somewhat lower, had been obtained under site conditions.

Correspondence on this Paper is now closed.—SEC.