

### Discussion

**The Chairman**, in proposing a vote of thanks to the Author, said that those responsible for the maintenance of dock gates realized that that was not just another branch of engineering but was, in many ways, a science of its own—especially in view of the costs involved. As an example, the contract figure for a pair of gates built in 1945 had been £38,759, and the cost of the site-work £15,761, making a total of £54,520. A current contract, let within the past few months, for a pair of gates of similar size, showed a big difference. The contract price for the gates was £66,000, and, after allowing a similar figure for the site-work, the total cost would be about £82,000. That was a great deal of money for what to the lay mind were two simple structures. He thought that all those concerned with the subject would agree with him that the subject of dock gates was not only an interesting one but one of vital importance.

**Mr J. H. Jellett** applauded the Author's unequivocal statement, in the first paragraph of the Paper, that "Under normal circumstances, it is considered advisable to overhaul lock gates at intervals of not longer than 15 years." Members of the Division might perhaps recall that, about 5 years previously, that matter had been discussed in connexion with a Paper which he had presented.<sup>5</sup> On that occasion, if he remembered rightly, the fact that the gates of the Port of London Authority had remained in position undisturbed for from 20 to 27 years had been referred to as a sign of exceptional virtue. He was very glad to note that apparently judging by the coincidence of the dates, the discussion on that Paper had given rise to second thoughts.

He was interested in the Author's remark that the docking of gates in the vertical position had been found to prolong the operations of repair. Was that attributable entirely to the position of the gates in the dock or could it be ascribed also to the additional factor to which the Author referred, namely, that the dock had at the same time been used for ordinary ship-repairing purposes, which had involved periodic floodings with the gate in position? Mr Jellett asked that question because he would have thought that, assuming the exclusive use of the dock, the gate, once placed in position upright, might be considered, by reason of the large reduction of overhead work compared with that required with the gate docked in the flat position, to be in a more convenient position for working.

It was proposed next spring to remove for docking and maintenance purposes the caisson from the King George V Graving Dock at Southampton, which had not been removed for 20 years, and, owing to its dimensions and to the dimensions of the only graving dock which could be

<sup>5</sup> J. H. Jellett, "Maintenance Operations 1946-47 on the Box Gates at Dover Train-Ferry Dock." Maritime Paper No. 11, Instn Civ. Engrs, 1949.

made available for the purpose without seriously disturbing the normal docking programme, it would be necessary to turn the caisson over on its flat. That was regarded not as an advantage, but as a serious operation forced upon them by circumstances; Mr Jellett had thus been interested to read the Author's opinion that he preferred gates (with which he would, it was to be hoped, classify caissons) turned on their flats for docking purposes.

The Author used an expression on p. 49 which Mr Jellett felt sure was intended to read slightly differently from the way in which it had been worded, namely, "since the period covering one tide was usually required to carry out any of the above operations." In Mr Jellett's experience, it was not that all that period was usually required to carry out the operations, but that they had to be completed within that time, lest the next low tide found the gate, caisson, or whatever it might be in some awkward position where it was likely to strand or suffer some other form of marine disaster. Perhaps the Author would make clear what were the circumstances in the cases under his supervision.

Reference was made in the Paper to the wear of the mitre-posts, and Mr Jellett thought, therefore, that it might be of interest to mention a little device which had been found useful to ensure accurate mitreing every time the gate was closed, and which he thought went a long way to reduce some of the wear which had been mentioned. Briefly, it consisted of a back stop fastened to one gate; when the gates were closed, the last few inches of closing of the left-hand gate were effected by the right-hand gate bearing on the stop. The stop acted as an automatic aligning device, bringing the gates into perfect mitre every time.

There was one other point where it would be of value if the Author would amplify a little the description given in the Paper, and that was under the heading "Repairs to Roller Paths." It was not easy to follow the arrangements shown in *Figs 12*. In the Rawlbolt hole under the grouting pipe a wooden plug was shown, and, if Mr Jellett's interpretation of the procedure and the drawing was correct, the whole space above the plug was ultimately filled with grout. How, then, was it possible subsequently to get the holding-down bolt into the holes where the grout had been applied?

**Mr J. S. S. Ramsay** recalled a debate<sup>6</sup> which had been held at the Institution in 1948 on the proposition that mitre gates were becoming obsolete. He observed that the present Paper would have made a valuable contribution to that debate.

He noted that after 30 years working of the Entrance Lock to the King George V docks with three pairs of gates it had been decided to provide a fourth pair, to be kept as spares, in view of the possibility of serious damage

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<sup>6</sup> A. B. Porter and F. M. Easton, "That Mitre Gates are becoming obsolete." Maritime and Waterways Engg Div. Debate, Instn Civ. Engrs, 1948.

to the gates. He thought that that was a splendid idea, and he hoped that it would be widely adopted.

He thought that it was a tribute to the designers, the builders, and the maintenance staff that so many gates had been kept in working use for so many years without any major repair or overhaul—or at any rate, he had thought so until he had read the section of the Paper headed “Gate Structure”; he had then realized that, as in the case of so many bridges, it was sheer force of habit that kept those gates in use.

It was stated, on pp. 45 and 46 of the Paper, that at Tilbury it had been possible to dock a pair of gates and to complete their overhaul, without interruption by shipping calls on the dry dock, “in the comparatively short period of 4 months.” Did that explain the difference in cost between the lower and upper entrance gates given in Table 3? Four months might be a comparatively short period, but he would not consider it a short period for the complete occupation of a large dry dock. Incidentally, it would be interesting to know whether the dock charges were included in the cost of repairs.

On p. 84 of the Paper, the cost of “Handling, floating craft, etc.,” was given as 10 per cent of the total cost of repairs. Did that include all labour and supervision in docking, removing, and re-stepping gates, and all charges for hand tackle, tools, and floating craft? The Port of London Authority were well equipped for such operations and had an experienced staff regularly engaged on them. The figure of 10 per cent would probably be higher for dock authorities less well equipped.

On p. 51 of the Paper it was stated that “When the floating crane was handling large gates . . . in the outer position, the programme was arranged to ensure that the gate was stepped at or near high water and before the tide ebbed to a level where the loss of buoyancy caused the load on the crane to approach the safe working limit.” Had it been possible, as a result of any untoward delay, for the tide to fall to a level where the loss of buoyancy would cause a dangerous overload on the crane, and, if so, how would that situation have been dealt with?

On p. 51, reference was made to difficulties caused by mud when landing gates. It was stated that, in one case, the weight of the gate plus the mud was more than the crane could be expected to lift with safety, and secondly, the gases present in the mud were a source of danger to the workmen. No one who had been in contact with Thames mud would question that statement. Thirdly, when the tidal chamber contained a significant quantity of mud and, for one reason or another, the buoyancy chamber was filled with water instead of air, what the Author described as a “heavy condition” arose, which placed an undue load on the anchors, pivot, rollers, roller path, and on the structure generally. Had the measures taken to keep the gates clear of mud been effective?

The wear on the greenheart heel-posts, detailed in Table 1, raised some questions: 2 inches of wear at the bottom of the heel-posts would result

in a gap of 4 inches between the bottom of the mitre-posts. How was that gap filled? Had it been done by adjustment of the rollers, or, where there were no rollers, by fitting tapered pieces on the mitre-posts? In either case it would be difficult to maintain as good a contact between the mitre-posts as on new gates, and that was bound to result in excessive pressure at points of contact; the sill prevented the mitres closing at the bottom and distortion occurred, causing unknown stresses in the gate. Leakage to a greater or less degree, depending on the success in closing the gap, was inevitable. With a lock entrance that was not a serious matter, but it made one wonder if all the time and the labour spent on the initial fine dressing of the new gates to a tolerance of 0.004 inch was really necessary. The fine dressing was responsible for a considerable part of the cost of greenheart.

The information given by the Author under the heading "Heel-Posts, Mitres, and Sills" well deserved study. Greenheart was becoming an increasingly difficult problem. That fact had been borne out by a recent Paper<sup>7</sup> on the reconstruction of Greenwell's No. 1 Dry Dock at Sunderland, where a new type of meeting-face had been adopted. The Author of that Paper had stated that, by using the method he described, all expensive granite construction for the entrance had been eliminated, together with all the problems of accurately setting the granite quoins and the precise dressing of the meeting faces. Furthermore, it became possible to abandon the use of greenheart completely, which in turn eliminated one of the frequent sources of leakage at dry-dock entrances. The Port of London Authority had had no choice in the matter so far as existing dock entrances were concerned. The cost of finished greenheart—£12 per cubic foot—was very high. Perhaps the Author would confirm the accuracy of the statement on p. 77 that it cost more to dress a flat surface than to dress a curved surface, because Mr Ramsay's experience had been the reverse of that. An allowance of 3 inches on the finished dimensions for dressing seemed extravagant, and 1 inch was usually ample.

It would be interesting to know the cost of repairs to the masonry, which presumably was not included in the figures given in Table 3.

Although he appreciated the advantages gained by adopting the U-strap type of anchorage, Mr Ramsay pointed out that, if the U-strap was not properly adjusted it had to support the weight of the gate in the open position, and that might produce excessive bending stresses in the legs of the strap. Also, in the open position, the bearing area was much reduced, and that would lead to excessive wear. Satisfactory lubrication was extremely difficult. In the case of the drop-over plate and link anchorage, maintaining the anchorage in correct adjustment was a remarkably simple operation. The drop-over plate could have an anti-friction

<sup>7</sup> Harry Ridehalgh, "The Reconstruction of Greenwell's No. 1 Dry Dock and Ancillary Works at Sunderland." Proc. Instn Civ. Engrs, Part II, vol. 2, p. 321 (June 1953).

bush, good lubrication could be provided, and the bearing area of the gate in the open position was greatly increased as compared with the area provided by the U-strap.

Table 3 emphasized the ever-increasing level of costs, and it was to be noticed that, in some cases, repairs cost almost as much as new gates, if the Author's estimated figures were accepted. Incidentally, it would be interesting to know whether those estimates had been made at a time corresponding to the repairs, because otherwise they would not be comparable. Mr Ramsay thought that the estimates were all on the light side. If allowance were made for the scrap value of the old gates, there was not much difference between the cost of repairs and the cost of new gates ; so that perhaps when materials became more plentiful and quicker deliveries could be offered it might pay to scrap the old gates rather than repair them.

**Mr G. A. Wilson** observed that much of the Paper might serve to show designers where improvements were needed. On the other hand, those 56 pairs of gates had been working without any great interruption for 20, 30, and in one case 40 years, and, with such a record, change in design could not be lightly undertaken. The type of improvement which seemed worthwhile was the sort of thing mentioned in Mr Ridehalgh's Paper, on the reconstruction of Greenwell's Dry Dock, where the cost of dressed granite and greenheart had been avoided.

A number of design points had been mentioned in the present Paper, and it might be useful to list the alterations which had been made in a recent pair of gates for the Gallions lower entrance, which was being reconstructed. At the time of making out the contract, the quoins had not appeared to require renewal, so no alteration in the design of heel-post was considered.

Two obvious changes had been made. The old riveted gates with rollers and roller paths had been replaced by welded buoyant tank gates, and ram operation was being provided instead of chains, because the latter tended to wear the sills and restricted the useful depth of the entrance. Both hydraulic and electric operation of the rams had been considered. Whilst hydraulic machinery could be very satisfactory, occasionally it required fairly heavy repairs ; and when it was found that the electrical machinery had a lower first cost, it had been decided to try electrically-operated ram gates. The design was not yet complete, so that he did not propose to commit himself any further on that.

The heel castings had had dowels added to them and were welded as well as bolted so that they would not work loose. The lozenge in the gudgeon of the heel casting was going to be held in with set screws, because sometimes when a gate was lifted the lozenge fell out and had subsequently to be sought for in the mud at the bottom of the lock. The heel-post bolts were welded into the gate to prevent leaks ; it was considered that the prevention of leaks was more important than being able to tighten the bolt during the life of the heel-post.

The gangways and stools on top of the gates were bolted to angle cleats welded to the upper deck so that they could be easily removed before lifting the gate, since damage frequently occurred if that were not done. Tidal scuppers had been increased in size considerably and put on the pressure side of the gate, so as to get the maximum buoyancy and to reduce the collection of mud. Provision was made for fixing cover plates over the scuppers when it was desired to float the gates. Trunkways had been placed as near the pressure side of the gate as possible to assist in balancing when the gate had to be removed by flotation.

No pipes had been taken through the interior decks because they could cause leaks and maintenance was costly. Where it was necessary to have pipes they went down the trunkway. In the new gates they were only for blowing air to clear the tanks. Hydraulic ejectors were not fitted since it had been found that portable electric pumps lowered down the trunkways would do the job, and when not wanted in the gates were useful for other purposes. Sluices on the gates had been omitted because they were not particularly successful in cleaning mud from the aprons and required expensive maintenance.

Plate and link anchorages had been adopted in preference to rigid brackets, because, as Mr Ramsay had indicated, the rigid brackets endeavoured to restrain forces which were so great that eventually the brackets loosened the masonry. It was better to have the link and plate, which was positive and adjustable without making other difficulties.

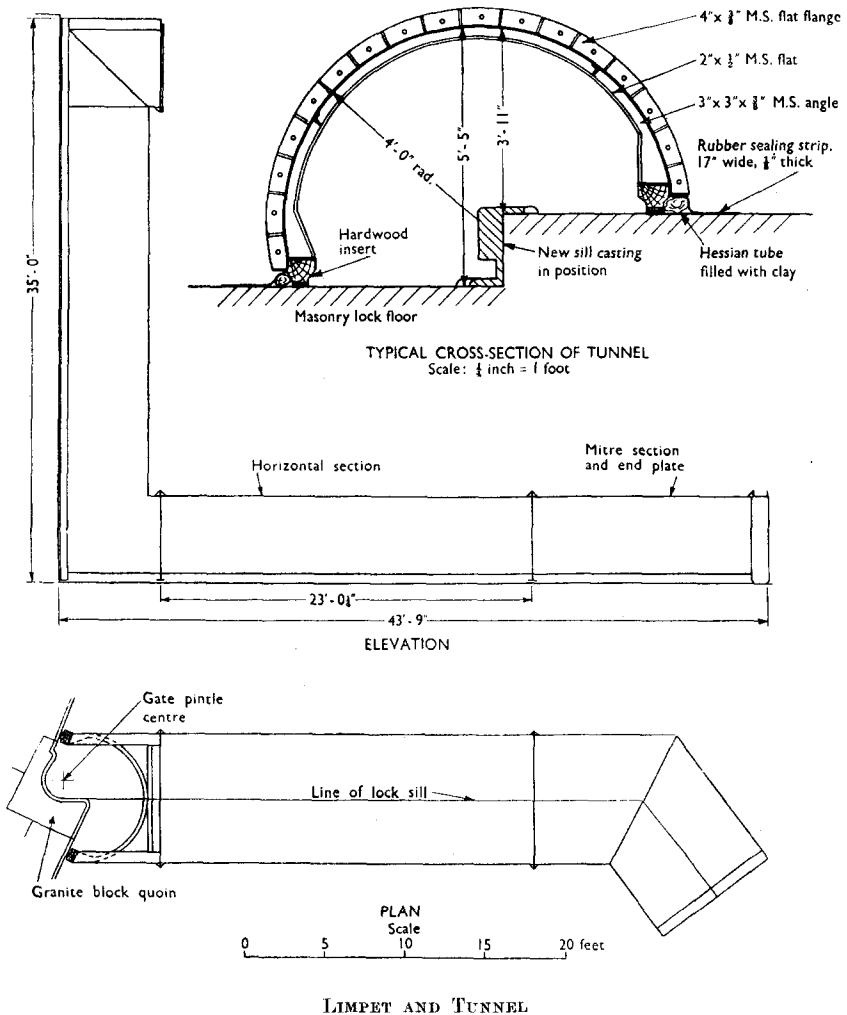
**Mr V. H. Tripp** described a new development which had recently been successfully carried out in connexion with the renewal of the ship lock gates at the Regents Canal Dock, which had only one entrance to the River Thames. The under-water work of renewing the pintles, dressing the quoins, and putting in a new cast-steel sill in place of the existing timber one had had to be carried out with the minimum of interference to shipping.

The method chosen had involved a limpet dam with a tunnel extension. That idea had been developed and a design prepared, from which a scale model had been produced and tested successfully in a tank. The results had been quite encouraging, and the fabrication of the full-size job had then been put in hand.

Essentially the limpet and tunnel consisted of five sections (*Figs 26*): (1) a vertical section which was the limpet proper, which had flanged connexions for attaching the tunnel at the top and bottom, so that it could be used on either side of the lock; (2) a removable diaphragm, incorporating an 8-inch sluice valve, to enable the limpet to be dewatered independently before the tunnel sections were attached; (3) a straight tunnel section; (4) a mitred tunnel section; and (5) an end cover plate shaped to fit the step of the sill.

The tunnel extended approximately 6 feet beyond the mitre so that a little more than one-half of the sill would be dewatered at a time, and then it was transferred to the other side. The limpet weighed 7 tons and was

Figs 26



35 feet deep ; the tunnel was of semicircular section, 8 feet in diameter and had a total length of 43 feet. In all, about 14 tons of steel were used. It was constructed of welded mild steel,  $\frac{1}{4}$  inch thick, suitably stiffened, and terminated with 8-inch-by-3-inch channels welded along the edges. Stiffened flanges were provided at the extremities for bolting the sections together.

Oak timbers were fitted into the channels to carry packings to form the

joints with the masonry. The limpet joints were made with tallow-dressed spun yarn fastened to the timbers with canvas strips, and the horizontal tunnel joints with  $\frac{1}{2}$ -inch rubber insertion bonded to the timber. The vertical joints between the sections were sealed with  $\frac{1}{2}$ -inch rubber insertion bonded to the steel.

All joints proved satisfactory except the rubber bonded to the timbers, which showed signs of failure after a fortnight's immersion. When the apparatus was transferred, the rubber was found to be quite loose. Softwood strips were substituted with satisfactory results.

The final sealing of the tunnel had been carried out by means of 5-inch-diameter "sausages" of puddle clay in hessian bags. Those had been placed along the outside edges of the timber, and 18-inch-wide strips of rubber insertion, fastened to the timbers, had been drawn over them, and laid on the floor of the lock.

Dewatering was effected by means of a 7-inch submersible pump, and subsequent seepage was dealt with by a small hydraulic ejector. At the first attempt to dewater the limpet, it had been found that the upstream leg of the limpet was sliding inwards along the wall of the lock, the maximum movement being at the bottom, diminishing to zero at the top. There had been no movement of the downstream leg.

The limpet had been withdrawn and found to be distorted. It was restored to shape by jacking, and additional stiffening was welded on.

The behaviour of the model had induced undue reliance to be placed on the friction between the limpet and the wall. To remedy the defect, stiffened channels were bolted to the lower half of the lock wall by divers, so that the limpet could be lowered over those channels with  $\frac{1}{2}$ -inch clearance to the inside of the limpet channels. No difficulty was then experienced and the dewatering was accomplished.

The sill castings, which weighed 2 tons each, were placed along the sill and the tunnel sections positioned over them and bolted into place.

The floor of the lock was reasonably level. Any major depressions, such as the grooves hollowed out by the gate-operating chains and the recesses from which the old roller paths had been removed, were filled in with concrete by divers before the sections were placed in position. Minor variations were filled by means of specially prepared softwood packing-pieces, which were placed in position by divers. The resulting seating of the tunnel was excellent, and after the sealing had been carried out the leakage was very small.

As a safety measure, short channel stops were bolted to the floor of the lock close to the diaphragm before removal of the latter, and also at intervals along the tunnel after dewatering before work in the tunnel was commenced.

A further safety measure consisted of anchoring the tunnel and limpet by means of chains and turnbuckles attached externally to the sections and to ring bolts set in the walls and floor.

An electric derrick crane of 7 tons capacity at 90 feet radius handled all lifting from the lock side.

Inside the tunnel a small travelling cradle with three-dimensional motion was used to handle the sill castings. (*Fig. 27.*)

The working height in the tunnel was 5 feet 6 inches and the work proceeded with the minimum of discomfort. The limpet and tunnel being at atmospheric pressure, with no air-lock, unhampered movement was possible and the compressed-air tools working inside prevented the air from becoming foul.

A heavy fender of steel framing faced with timber and bolted to the lock side protected the limpet. This reduced the lock width from 60 feet to 51 feet. The dock was able to continue in operation subject to a draft restriction at certain states of the tide; the depth of water over the tunnel varied from 28 feet to 5 feet.

Disregarding the initial setback, the time taken to set, dewater, and seal ready for working was 1 week for each side, including time required for setting the fender.

*Fig. 28* showed the completed sill inside the tunnel.

**Mr I. S. S. Greeves** observed that one of the main factors contributing to the successful use of the limpet dam at the Surrey Docks had undoubtedly been the provision of ample pumping capacity during the initial stages of securing it. The rapid draw-down inside the dam had created sufficient difference in pressure to enable the canvas and oakum strip to take up the contours of the dock wall. It was surprising how tight the seal became when the full hydrostatic head had been developed. All too often when the creation of a seal in a cofferdam depended on the establishment of difference in pressure, those on the site tended to lose heart because they did not employ sufficient pumps in the initial stages.

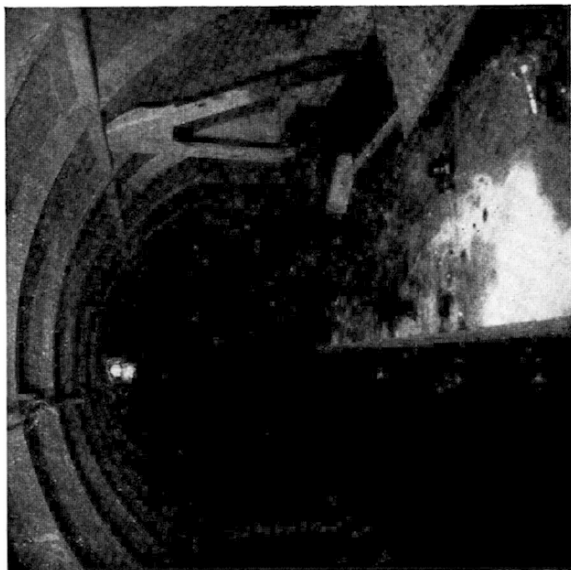
The Author had perhaps been fortunate in that in most instances he had encountered little wear on his granite hollow quoins. The re-dressing of granite quoins to fine tolerances might be a very costly business in present times, particularly since there was a shortage of skilled craftsmen capable of carrying out that work.

In the case of extensive repairs to quoins, did the Author consider that it might be satisfactory to put them back in a high-grade concrete?

On p. 75, mention was made of the use of the Port Authority's diving bell. One of the engineer's difficulties in marine work was very often the interpretation of a diver's report. In very silty water, particularly such as was found in the Thames, the diver might be working purely by touch, and by the time the messages got back to the engineer it often became little more than a question of wishful thinking. Where the bottom of a dock had to be examined, the diving bell was quite a simple and effective means by which the engineer could go down and see for himself what had to be done.

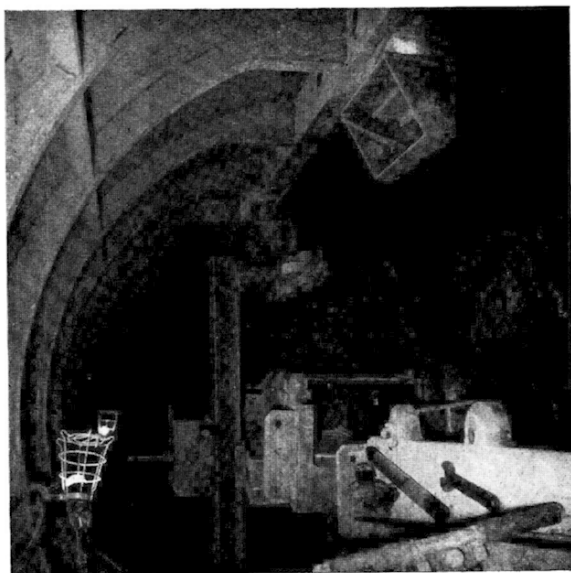
With the Port of London Authority engineer, Mr Greeves had spent

*Fig. 28*



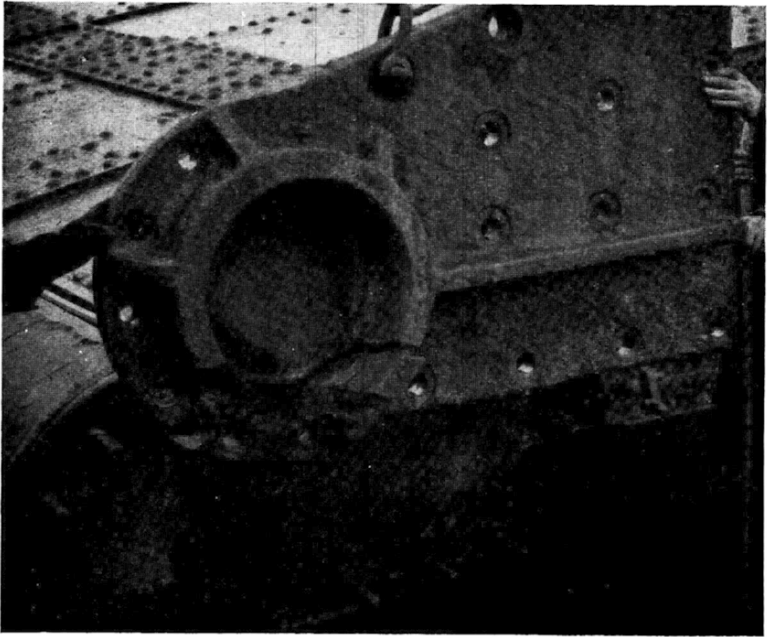
COMPLETED SILL INSIDE TUNNEL

*Fig. 27*



INTERIOR OF TUNNEL SHOWING TRAVELLING CRADLE

*Fig. 29*



FRACTURED HEEL-SOCKET CASTING

*Fig. 30*



USE OF MACHINED TAPERED PACKINGS TO AVOID JOGGLING DIFFICULTY

2½ hours one afternoon at the bottom of the St Katharine Dock entrance trying to find out the cause of the trouble and how best it could be overcome. Working in a diving bell in that way might be a little hard on the ears as compared with tunnelling in compressed air, because there could be sudden changes of up to ½ lb. per square inch or so, owing to the crane driver picking the bell up and dropping it down again when one was moving about the bottom. By blowing a quantity of compressed air out below the bottom of the bell it had been possible to exclude almost all the water, and the bottom could be made quite dry.

Mr Greeves then showed a short film illustrating some work carried out in the St Katharine Dock entrance with the aid of a diving bell.

**Mr J. A. Fisher**, referring to the all-welded limpet dam shown in *Figs 19*, pointed out that the rubber seal which was shown as the joint between the lock wall and the dam had not been used or adopted in that form, and had been replaced by canvas and oakum in the more normal way.

On p. 45, the gates installed at the King George V entrance to the Royal Docks were referred to as weighing 350 tons. That was the weight of the original gates, which had been of riveted construction; the all-welded gates which had recently replaced them weighed between 240 and 250 tons. That showed the tremendous advantage to be gained by the use of an all-welded gate—a saving in steel of almost 100 tons in a single gate.

Referring to the method described by the Author for handling gates, Mr Fisher said that he fully appreciated that, in the Port of London, the authorities had been faced by the problem of a large number of old gates which had not been attended to for many years, owing to the war, and which were not very reliable from the point of view of being handled by means of flotation. Moreover, the Authority had been favourably situated in having not only the four wreck lighters but also the 150-ton crane to handle those gates. In the circumstances, the arrangements adopted had been admirable and had enabled a most comprehensive programme to be carried out in a comparatively short time.

Once the gates had been repaired and were in an improved condition, however, he felt that there would be opportunity to consider the method of controlled flotation referred to by the Author on p. 49. That had not so far been used, but Mr Fisher felt that it would be possible at a later date and might effect a considerable saving of money and time in the handling. Controlled flotation was, in his view, a perfectly well tried method. The Dover Train-Ferry gates, weighing about 540 tons, had been well handled and quite successfully floated into position on a slipway in a comparatively short time.

As a further example, Mr Fisher mentioned that a new gate for the Royal Docks had been launched at Thornaby-on-Tees on the afternoon of Friday, 23 May, 1952, towed to London, held in position against the wall of the dock, prepared, and actually stepped on Wednesday, 28 May, 1952—a period of only 5 days (including a week-end) between leaving the slipway

at Thornaby and putting the gate on its pintle ready for immediate use in the mid-position of the King George V entrance. That gate displaced, in its buoyant condition, about 250 tons.

On pp. 53 and 54, the Author had given some interesting figures for the wear-down on the greenheart heel-posts and, on p. 74, the wear on a granite quoin, taken from examination of gates recently repaired. Had the Author had an opportunity to ascertain whether or not it had been possible to arrive at any relationship between the wear-down figures and the actual operation of those gates, that was to say, the number of times which they had been operated since their previous repair? It might be possible for the Port of London Authority to give such figures, which would be interesting because it was always a difficulty, when considering the replacement of gates, to know whether it would be necessary or not to re-dress the hollow quoin. If it were known that a gate had operated so many thousand times since the quoin had last been inspected, it might be possible to say roughly what wear-down on the granite quoin might be expected.

**Mr F. M. Easton** said that the comments which he had to offer arose from experience in the maintenance and renewal of dock gates in the South Wales ports during the period from about 1923—shortly after the South Wales ports had been brought under Great Western Railway ownership—until they passed under the control of the Docks and Inland Waterways Executive.

His first comment related to the statement on the first page of the Paper that “it is considered advisable to overhaul lock gates at intervals of not longer than 15 years.” Why take out a gate simply because it had been in service for 15 years? The factors which determined whether a gate needed to come out were the efficiency of its design and the service conditions which it had to sustain, with the result of those conditions in corrosion and wear. The deciding factor was almost always the condition of the greenheart. A gate was seldom or never taken out in order to paint it. It might be necessary to take it out for roller trouble or heel-socket failure, but usually gates had to come out when the sealing timbers showed, by leaking, that something had to be done. The period might vary from 10 years to 30, or even longer.

With regard to the Tilbury gates shown in *Fig. 3 (a)*, he considered that the subdivision was overdone. All that a gate needed by way of watertight subdivision was a watertight deck to separate the buoyancy chamber from the tidal chamber and a central watertight diaphragm to make it possible to keep ballast water in the heel end or the mitre end when handling the gate for removal or stepping; further watertight subdivision was not worth while. He agreed with Mr Fisher that controlled flotation was quite a good method of handling gates; it was cheap and quick, but it did need experience, especially under tidal conditions.

On p. 50, the Author had stated that “The gates were also cleared

beforehand of as much mud as possible and wooden plugs were inserted in the scupper holes of the tidal chambers . . . .” No mud should be allowed to accumulate in a gate. It was not possible to stop the mud accumulating in the tidal chamber of an inner gate, where the dock water was at constant level, if the tidal chambers had the scuppers on the back—the pressure side. If, however, those scuppers were moved to the face of the gate the tidal chamber would become accessible and it would be possible to keep the gate clear of mud by periodically flushing out with fresh water, and at the same time to keep an eye on the condition of steelwork or ironwork. Friction between timber heel-posts and masonry hollow quoins would provide ample margin against hydrostatic uplift.

On p. 52, reference was made to the gases present. That had been mentioned by Mr Ramsay, but Mr Easton thought that Mr Ramsay had misinterpreted the point which was made there. The gases which the Author had in mind were, Mr Easton believed, those which accumulated in a sealed chamber and which were dangerous to men before the gas could be cleared out. That had been the experience at Barry Docks in 1925, when a man had been killed by the explosion of a mixture of methane (marsh gas) and air present in a buoyancy compartment which had not been opened for many years. That gas was produced by the decay of marine organic matter which got into the chamber in minute quantities, possibly through seam laps and bolt holes under pressure of the tides. As a result of that accident, the practice had been instituted in the South Wales docks of keeping all gates open for access and inspection, and providing ventilation by the installation of pipes where necessary. No compartments were left permanently sealed.

The wear referred to on p. 53, was common in Mr Easton's experience and just about normal for the conditions mentioned, but in the 90-foot entrance at Cardiff the maximum wear on the heel-posts in 43 years had not exceeded  $\frac{1}{16}$  inch, and there had been similar wear in the 100-foot entrance at Newport. That low rate of wear could be attributed to the unusually large radius of the heel-posts—2 feet in each case. Referring to the clearance between the bottom gudgeon (the heel socket) and the pivot, he agreed that a 1-inch clearance was normal and proper for the larger entrances, 60 feet or more in width. For an entrance of 50 feet or less at least  $\frac{3}{4}$  inch clearance was necessary, so that as the timber wore down, the socket should not press and wear on the pivot. The base of the heel socket should be kept a like distance, radially, inside the heel-post timber so that the socket should not bear into and score the hollow quoin. The projecting rivet heads which had been mentioned should not project; they should have countersunk heads, only slightly raised, to the proportions specified by Lloyd's. Ordinary structural countersinking was far too shallow for watertight work.

The trouble referred to on p. 55 had also been experienced at Swansea Docks, with badly supporting deck angles kneed to clear the corner angles

at the heel end, and considerable racking and loosening of rivets had been found. The supersession of riveted by welded design would obviate the considerable difficulties which might otherwise be expected through the increasing scarcity of competent angle-smiths who could produce those single and double joggles, and similar work.

Mr Easton presumed that the small amount of corrosion and the good behaviour generally of the gates in the Port of London docks were partly attributable to the low salinity of the water. He imagined that the water was nearly fresh, at any rate by comparison with the ordinary sea-water at the South Wales docks, except where there was a fresh-water feeder into the dock. It appeared also that the Port of London engineers had not been troubled in the way that the South Wales docks engineers had been by *teredo* infestation.

He thought that the idea for taking the weight at the top of the spear rod shown in *Figs 11 (c)* was one of the most interesting and novel features in the Paper. It gave a better chance of adjustment than the customary gibs and cotters, which usually seized up so that one could not move them when one wanted to do so. But why have any rollers at all, especially on inner gates? If gates were designed with medium preponderance of weight over buoyancy, the need for rollers disappeared. Those highly expensive fittings were needed only where there must, of necessity, be an unusually heavy preponderance to keep the gates steady while being operated in a very heavy swell, as at Plymouth Docks.

He wished to express his approval of the drop-over type of anchorage, which he thought was the best possible means for keeping the non-roller gates in proper adjustment. The anchorage should be so designed as to eliminate the possibility of thrust coming upon it from the top gudgeon, and so tightly screwed up as to keep the heel-post bearing well into the hollow quoin over as great a part of its length as possible. By that means, wear on the greenheart would be minimized.

Mr Easton then displayed a series of lantern slides illustrating the points he had raised. Two of his slides, reproduced as *Figs 29* and *30* respectively, showed a heel-socket casting which had fractured under heavy service conditions; and a way of obviating the joggling difficulty, using machined tapered packings which enabled a "lazy joggle" to be employed.

Mr M. W. Leonard described, with the aid of lantern slides, some remedial work which had been undertaken in 1950 to the sill of the inner lock gates to the main entrance to Avonmouth Dock. The main sill was about 8 feet wide and 4 feet deep. A head of 32 feet of water was acting from the back. The bedding joint had become very defective, and those responsible had been very concerned about the erosion effect of the water coming through in very large quantities.

The sill was about 75 feet across. It was exposed in the spring tides, and there had been a limited time in which it had been possible to get to

work, and a certain number of physical hazards in getting on the sill and working. The men had to work in diver's suits without helmets, immersed right up to their shoulders in some cases. The idea had been to plug or caulk the open joint with hardwood wedges. The gap had been about  $\frac{1}{2}$  inch in places for the wedge to enter, and the depth of the void anything from a few inches to 5 or 6 feet. It had been decided to work from the heel across to the mitre, and progressively stop the water interfering with the men as they worked.

A jack-hammer was used to bore  $1\frac{1}{4}$ -inch holes into the bedding joint, in which grout pipes were inserted at 6- to 8-foot intervals. An attempt had been made to use fantail grout pipes to get a wider insertion at the joint, but he did not think that that had any beneficial effect at all. Each of the grout pipes had been fitted with a cock, so that it was possible to isolate the work as they proceeded. After the first pipe had been connected up, the lock was filled and a diver worked his way along linking up the hose with the remaining pipes. As each was grouted up under pressure he turned the cock off to stop any back flow.

After grouting along the face, the sill was exposed and it was found that the remedial work had been effective. Some holes had, however, been drilled round the back to grout up any void not filled from the front. They then had a stiff face to force the grout against. About 9 tons of grout had been pumped in, together with 4 tons of very fine sand dredged from the Bristol Channel. It had taken about 37 shifts to complete the work.

**The Author**, in reply, said that many fundamental points about the design and operation of lock gates had been raised by the discussion. With regard to the suggested 15-year period for the overhaul of lock gates which had been referred to by Mr Jellett the Author hoped that that did suggest some change of heart, because it was important that the maintenance of lock gates should be carried out on a properly planned basis at not too infrequent intervals. Experience seemed to suggest that if the gates were taken out for inspection, repainting, etc. after a reasonable number of years the heavy cost of deferred repairs would be avoided.

The repair of gates in the vertical position had taken longer because of the interruptions caused by periodic flooding required by the normal dry-docking programme. It was true that there was some reduction of overhead work when the gates were in a vertical position but there was also the disadvantage of having to erect heavy and complicated staging around the gate. The Author agreed with Mr Jellett that the whole period of one tide was not necessarily required for the operations, but it was necessary to complete the work within that time, not only for the safety of the gate and plant employed but also because generally the operation of the lock concerned could not be interrupted for longer without delay to shipping. In practice, only the outer gates were affected by tidal conditions. During the repairs to the roller path described, three adaptors and grout cocks were fitted to each half of the path. The pump was connected to one cock, and

discharge pipes connected from the other two cocks to the lock sides acted as observation points. The plugs could be withdrawn and bolts inserted before the grout set finally. Air pressure was applied later, as a test, by withdrawing two of the intermediate bolts.

Mr Ramsey had referred to the debate<sup>8</sup> on mitre gates which had been held in 1948. The Author felt that there was still a future for mitre gates, particularly in river entrances where limitations of space had to be taken into consideration. The gates at the Tilbury entrances were of very different design and structure and an appreciable amount of work had been put into the machinery, which probably accounted for the difference in costs. For various reasons the dry dock at Tilbury had been available for use and the Author did not think that any dock dues had been charged against the gates, but the use of all plant, etc. had been included in the item for handling. If, as the result of some accident, the tide had fallen to a dangerous level when handling outer gates, each gate could have been lowered to the bottom of the lock and, provided the floating crane was securely moored during the low-water period, everything would, he thought, have been all right.

Where the wear on the heel-posts had been appreciable tapered pieces had been fitted to the mitre-posts and, where possible, the rollers had been adjusted. With reference to the cost of greenheart, the cost of dressing the heel-posts on a pair of gates repaired by the Author had been £3 15s. per cubic foot, compared with £4 0s. per cubic foot and £3 2s. per cubic foot for the mitre-posts and sills respectively. An idea of the cost of repairing the masonry could be obtained from the costs quoted for operating the limpet dam, which included all the plant and labour on the job.

The Author had had roller gates in mind when discussing the U-strap type of anchorage, but he knew of gates which had worked for nearly 50 years with that type of strap without mishap, although the gate rollers had been worn until there were large flats on them. There was much to be said in favour of the more rigid type of anchorage, for cases of damage to heel-posts had occurred when the flexible type of plate anchorage had allowed the timber to come into contact with the projecting nib on the hollow quoin.

The Author considered that the repair costs given in Table 3 could be taken as comparable, but he did not think that old gates had much scrap value, for removing and cutting up an old gate was in itself a very costly business. Whether new gates should be ordered instead of repairing the old ones had depended on a number of factors. When many of those gates had been handled the delivery period for new gates was 2 years or more and there had been a world-wide shortage of steel at the time.

There had been some improvement as a result of the measures taken to reduce the accumulation of mud in the tidal chambers. Mr Wilson had referred to new welded gates ordered for the lower Gallions entrance and

<sup>8</sup>See footnote 6 on p. 89.

Mr Fisher had mentioned the saving in steel in the all-welded gates as compared with the riveted gates at the King George V entrance, and it was remarkable that that could amount to as much as 100 tons in a single gate of that size.

The Author had been concerned with the repairs to existing gates, but Mr Wilson had given details of a number of new features which had been incorporated in the design of the new gates now under construction for the Port Authority. It was interesting to note that amongst them was the adoption of electrically operated rams, because the Author had had experience of that type of machinery about 20 years previously at a dry dock in the West Country, and so far as he was aware there had never been any trouble with it. Operating conditions at entrance locks were, however, very different from dry docks, and it would be interesting to observe how the electrically operated machines and gearing behaved under such conditions. To substitute electric pumps for hydraulic ejectors in existing gates it would probably be necessary to make some alteration in the design of the trunkways to facilitate the handling of the pumps.

The repairs to the sill at the Regents Canal Dock entrance, which Mr Tripp had described, were of great interest because the Authority were faced with similar problems at some of the older entrances in the Port. Mr Tripp could be congratulated on a very fine achievement, but he had been fortunate in that the depth of water over the sill gave a substantial margin for the vessels regularly using the lock. In some of the entrances to the Authority's docks there was, on occasions, very little depth of water to spare and therefore the solution adopted by Mr Tripp was not possible. The position was made worse in some instances by the fact that no alternative entrance was available.

The Author was interested to note that it had been found that the friction between the limpet and the wall had been insufficient to prevent it from sliding, because that seemed to justify the struts which had been employed in the limpet used at Surrey Docks and described in the Paper.

Mr Greeves had stressed the importance of ample pumping capacity to provide the rapid draw-down required to set up the initial seal between the limpet and the wall. The Author would agree that the success of the limpet was largely attributable to the pumping capacity available. The use of concrete for repairing hollow quoins had been limited to small patches. If a high-grade concrete were to be used extensively for that purpose, careful attention would have to be paid to the materials used. It was doubtful, however, whether anything approaching the finish possible with granite could be obtained on a large scale, so that more rapid wear of the heel-post timbers might result.

Mr Greeves had mentioned the sudden variations in pressure caused inside the diving bell by the operation of the crane. There had also been an uncomfortable increase in the pressure when the bell had been used in places where a considerable depth of silt had accumulated. If the bell

were lowered too suddenly under such conditions there could be a momentary intensification of the pressure to a dangerous degree. There had been some difficulty in manipulating the diving bell over sills where the invert of the lock had appreciable curvature.

The Author was grateful to Mr Fisher for pointing out that the original design of the all-welded limpet had been altered to include a canvas and oakum seal instead of rubber. He agreed that when the gates had been restored to an improved condition it might sometimes be more convenient to handle the gates by controlled flotation. But, as Mr Ramsey had remarked, the Port of London Authority were well equipped with floating plant, and if it was available the Author felt that it was better to use it and thus eliminate a certain amount of risk during transit of the gate from the repair site to the lock through a dock crowded with lighters, whose movements were sometimes quite unpredictable. It was worthy of note in that connexion that the new gates fitted at the new Waterloo river-entrance<sup>9</sup> at Liverpool were not fully self-docking because suitable floating plant was available for gate-docking operations. Mr Fisher had suggested that it would be of value if the wear-down of the heel-posts and hollow quoins could be related to the number of times the gates had been operated since their previous repair. That information could be made available from the Dockmaster's logs at each lock, for now that each gate had its own identification number, a corresponding log of its movements could be kept. The operation of the gates varied considerably. Internal gates such as those between a basin and the main dock might be operated only once or twice on each tide, and always with the water at the impounded level. A check had been made on the use of the Greenland entrance, where, on an average, about twelve locks were made on each tide. During 15 years therefore the gates were operated nearly 200,000 times.

That fact, the Author thought, partly answered Mr Easton's question as to why it was suggested that gates should be taken out of service after about 15 years. He had derived much benefit from Mr Easton's own valuable Paper<sup>10</sup> on the subject and welcomed his remarks. He (the Author) thought that the degree of sub-division in the Tilbury gates might be an advantage when handling the gates by controlled flotation, because it limited the quantity of "free water" in the gate which would make for better stability.

Mr Easton appeared to be in favour of putting the scuppers on the non-pressure side of the gate, but it was noticeable that that was a controversial point among engineers. No doubt local conditions and the position of the entrance did have some bearing on the point.

The Author had always thought that the precautions taken to test for gas were in some cases a little unnecessary and it was comforting to have

<sup>9</sup> R. A. Stephenson, "Design and Construction of the Waterloo River-Entrance." Maritime Paper No. 15, Instn Civ. Engrs, 1950.

<sup>10</sup> F. M. Easton, "Dock Gates." *Structural Engineer*, vol. 16, p. 359 (Nov. 1938).

confirmation that accidents might have been avoided by taking that amount of trouble.

It was true that the salinity of the Thames water was of a low order, typical values being 1.6 to 6.0 parts per 1,000 of chlorine at 7 miles below London Bridge and 0.1 to 2.3 parts per 1,000 in the Upper Pool, depending upon the season and state of the tide, but he believed that the quantities of impurities present were giving the responsible authorities some cause for concern. He confirmed that they had no trouble, at present, from marine borers in the Port of London.

In recommending the drop-over type of anchorage Mr Easton had referred to the importance of keeping the anchorage tightly screwed up. In practice, that might give more trouble from a maintenance point of view than the more rigid bracket type, which the Author had referred to earlier in his reply ; but, as Mr Wilson had stated, it had now been decided to adopt the former type at the reconstructed Gallions lower entrance.

The work which Mr Lennard had described was typical of the problems with which dock engineers were faced at some of the older works for whose maintenance they were responsible, and it was instructive to learn that the technique employed on that occasion had been effective.