Discussion.

Mr. Bentham.

The AUTHOR, after showing a number of lantern slides giving views of the plants under construction and completed, remarked that many schemes had been thought out and prepared before the final schemes were adopted, the problem having been considered for more than 20 years. The favourite alternative to the sluing cantilever at Nauru was a fixed cantilever; but it was finally decided that the fixed cantilever was too dangerous for shipping, and that type was therefore rejected. The primary consideration in such plants was that there should be no connection between the plant and the ship, consequently a design had been adopted which allowed the plant to be brought into position over the ship and the phosphate poured into the ship's hold without even a rope connection. In case a wind or swell arose the plant could be withdrawn from the ship and the ship moved out to sea without any delay. With the old method, when it was necessary to load into barges and then discharge the barges into ships, the ships would often be delayed for weeks or, in exceptional cases, for months before they could be loaded, because of the heavy swell. One difficulty in carrying out the construction was that it was such a long way from their base. Most material had had to be transhipped in Australia. A letter or report took at least 8 or 10 weeks in transit, so that it was impossible to keep in very close contact. A complete staff had to be sent out from England, and many of the men suffered from skin disease, the water being impregnated with the coral and other zoophytes. Working on the foundations in the water, the slightest scratch on the flesh set up irritation and in many cases caused considerable trouble. In fact, some of the men had to go away for a change until they had recovered. The Ocean Island job had had a very tragic termination. When the engineer in charge had finished his work, which was extraordinarily well done, and was waiting to board the ship for England, some railway-trucks ran away down an incline, and knocked him and one of the employees of the Phosphate Commission into the sea, both being killed.

Sir Alexander Gibb.

Sir ALEXANDER GIBB congratulated the Author on his most useful and instructive Paper, which showed how a somewhat difficult problem had been tackled. It might be of interest to compare the Nauru scheme with one with which his firm had been connected for the past 10 years, namely, the equipment for shipping phosphate from Christmas Island, which was 190 miles S. of Java, latitude 11° S. and longitude 105° E. The two installations were somewhat different, Sir Alexander Gibb.

but the problems had been more or less similar, in that both plants eventually delivered 600 tons of phosphate per hour on board ships of about the same size, both loaded direct into the ships, and both were worked by movable cranes. The Nauru plant had large movable cranes, while at Christmas Island there were fixed jetties with movable arms at the end. Christmas Island had been worked for phosphate since about 1891, so that a good deal of experience of seas and local conditions had been acquired.

Until two years ago there were two jetties about 150 feet apart, each being 90 feet long and formed of tube piles about 8 inches in diameter braced with tie-rods $1\frac{1}{2}$ inch in diameter. Owing to their light construction, ships were not allowed to tie up alongside, but were moored to buoys to the seaward and gradually manœuvred until they came to within about 15 feet of the jetties. The shipment of the phosphate was effected by means of movable-boom loaders extending 30 feet from the end of the jetty and fed by a belt conveyor from the bins on shore. Unfortunately in 1932 during a very severe storm the sea got behind the south jetty and completely washed it away. It was interesting to notice that the wind velocity during the storm was not more than from 20 to 25 miles per hour, though the waves reached a height of 30 feet. The worst storms did not occur directly at the Island, but were the result of tempests several hundred miles away, which produced severe wave-action at the Island. After this jetty had been washed away, the Company decided they would build a new jetty 150 feet long and 20 feet wide, of a stronger construction, with a loading head of 36 feet by 24 feet. The jetty was built of 10-inch diameter tube-piles 1 inch thick braced and strutted by means of 8-inch diameter tubes. The tube-piles were provided with 4-inch pintles, 5 feet long, which were driven into holes previously prepared in the coral. At the jetty head the available depth of water was about 40 feet. The ships were moored 20 feet from the structure, but were never allowed to go directly alongside. The new jetty was arranged to be in line with the existing north jetty and about 230 feet from it, so that both could be used for loading simultaneously into ocean-going vessels of a cargo capacity of 6,000 tons and upwards. The system of loading adopted at the new jetty was by belt conveyor along the deck, rising up to a loading appliance at the jetty-head, which was a fixed structure with a movable boom 60 feet long and a radius of swing of 90 degrees, sufficient to command the hatches of vessels moored alongside. This conveyor and that on the other jetty handled 300 tons per hour each, so that the total capacity, 600 tons per hour, was similar to that of the Author's scheme. The machinery was supplied by Messrs. Fraser and Chalmers, and the steelwork fabricated by Messrs. Redpath, Brown. The Phosphate Company themselves carried out the erection. It was interesting to compare the weights of steelwork in the two schemes. He could not quite understand the figures given on p. 217, where it was stated: "The weight of each arm, which, including equipment, is 560 tons, is balanced by a counterweight attached to the back end. The total weight of steelwork forming each cantilever arm, without supporting steelwork, track, and extension boom, is 260 tons, each of the lower girders weighing 50 tons." Taking only the first 560 tons, the steelwork in the two arms alone weighed 1,120 tons. At Christmas Island the whole of the steelwork in the new jetty only weighed 300 tons, the difference being very great. The old jetty had had only about 100 tons of steel in it, and although it had been washed away, after about 30 years' service, it had done good work. He was afraid he might have misunderstood the figures given in the Paper, and so made an unfair comparison. It appeared from the drawings that the distance which the ship was kept from the shore line when loading was 130 feet at Nauru and 100 feet at Ocean Island. Why was that? Could the ships not have been brought closer in and so saved some of that steelwork? On p. 212 it was stated: "Ships loading have to keep steam up all the time, so that they can be moved quickly out to sea in case of a sudden squall, and every precaution has to be taken to ensure their safety." Those were exactly the conditions which obtained at Christmas Island. The Paper went on: "As the vessels used range from 360 feet to 450 feet in length"—the same sort of ships were used at Christmas Island—"moorings cannot be laid closer than 125 fathoms from the reef-edge, and in some cases up to 150 fathoms is necessary." What was the depth of those moorings? The depth of water was not given, but the bottom appeared to drop suddenly off into deep water, as it did at Christmas Island, where they seemed to take bigger risks than the Author had done. Could the Author give the approximate total cost of the whole installation and show what it amounted to per ton of material dealt with, which, after all, was the basis upon which all engineers had to work? Lastly, where did the barges go in the very rough weather referred to; was there some shelter or protection for them, as, unlike the ships, they could not go out to sea? Sir Alexander Gibb.

Mr. Asa Binns observed that the Author had given no capital costs relating to these two schemes; and, even more important, he had given no costs whatever of their working. Possibly there were trade reasons why he could not state them in full, but any particulars that he could give would be welcome. Mr. Binns had been rather impressed with the courage displayed in laying these foundations under such very great difficulties. Had the same firm been providing Mr. Binns.

Mr. Binns. such foundations in this country, they would probably have had some borings made, they would certainly have had some levels taken, a good deal of excavation would have been done, and a fairly high degree of accuracy would have been insisted upon, especially for the swinging arms, weighing over 500 tons each. But out there, with the most difficult natural conditions and with the worst of unskilled labour, they seemed to have got over their difficulties without any of the first-rate appliances that they would have demanded in this country. Perhaps the Author would say whether those foundations had been entirely satisfactory. No information was given as to how long the plant had been installed, or whether there had been any difficulties or accidents since it had begun to work. He knew something of the difficulty of discharging ships in still water, and he could visualize the trouble there would be in loading ships in the difficult and dangerous conditions with which the Author had had to contend. The plant at Nauru reminded him of nothing so much as a steeplechase—over the sticks, up and down, up and down! He could quite understand the temptation to elevate the material, throw it down and pick it up again, just to show how well it could be done; but there must really have been some very strong reason for that. He would like to know what class of belt the Author had used as he did not see any reference to it in the Paper. He was very much impressed with the courage of everybody concerned with this plant: they had had not only to install it, but to run and maintain it, a thousand miles from anywhere. He supposed that they had had to import their diesel oil, to generate and distribute electricity, import coal for the dryers, and keep the whole of the gear in working order. Somebody had always to be on the look-out for any dangerous weather conditions, or the results might be disastrous. They were to be congratulated on tackling the problem boldly and making a success of it.

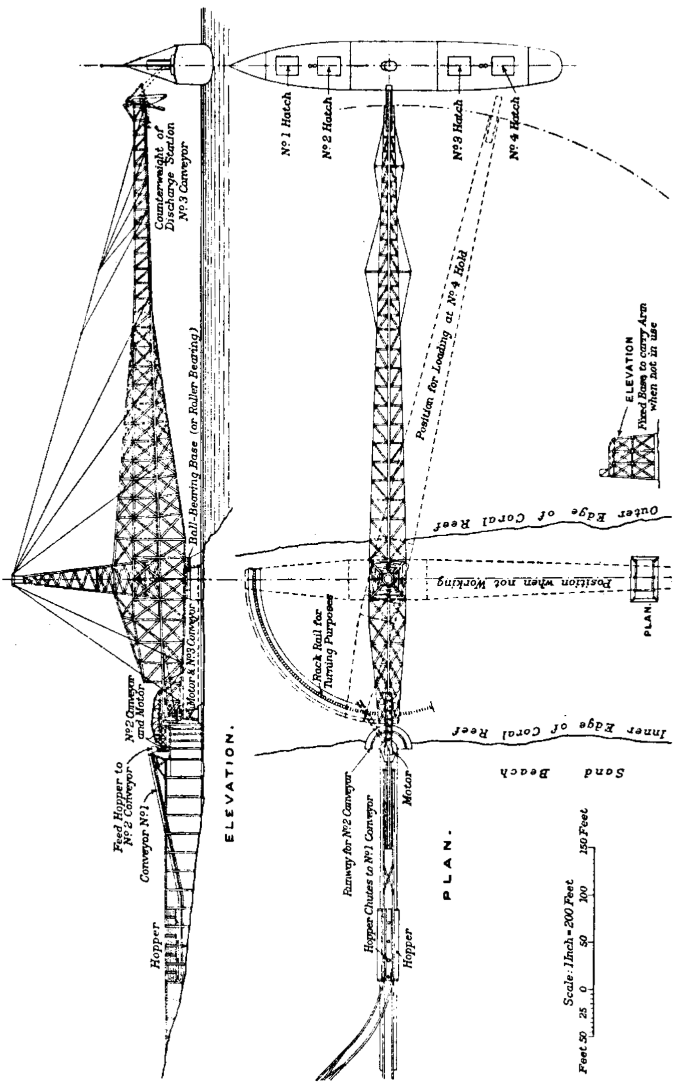
Captain Clarke. Captain JOSEPH CLARKE said that he thought he had a right to claim to be the originator of the loading scheme many years ago. He went out to the islands in 1908, taking out with him the first generating sets with diesel engines, and electrified the whole of the plant on the islands. There was very little plant there at that time, most of the work being done by hand; the phosphate was raised by natives and dried by the sun, the natives raking it with hand-rakes. In those days the loading arrangements were rather crude. The original jetties were of timber, with trams propelled by natives running down the deck. The phosphate was shipped through shoots to small lighters, which each held four baskets, the total load being about 2¼ tons. The jetties only extended just over the edge of the reef, on which the surf was always breaking, and the boats coming in had to hang on under the shoots by ropes, which was very dangerous in bad weather. The boats then rowed off to the ship, and the baskets were hoisted up with the ship's winch. Even with those methods it was possible to load 1000 tons of phosphate per day if the sea was smooth. The ships had to lie a long way off the reef in the open ocean, not as at Christmas Island, where they could lie quite close to the reef in fairly shallow water. The water right up to the edge of the reef was anything between 120 and 180 fathoms deep, so that it was quite impossible to anchor ships, which had to lie out at moorings. The shipping people always insisted that no ship should be tied up unless the conditions were such that it was able to swing right round the moorings without touching the shore. The moorings were, he thought, the deepest-laid moorings in the world. The buoys to which the ships tied up were about 20 feet by 12 feet; they were constructed with water-tight compartments, having tubes for the detection of leakage, and had huge wooden fenders surrounding them, so as to keep the ships from bumping them. There was a steel ring round them with a bridle-ring at the top and a swivel at the bottom, with three wire ropes. Two of them were made fast to the shore, and the third was carried out seawards to an anchor weighing about $\frac{3}{4}$ ton. The mooring ship pulled on it until it got a grip, and then it was tied up to the buoy. Those moorings were very good in smooth weather, but very difficult in the rough weather often occurring in the open Pacific. At times the sea got up very rapidly and there was a terrific swell. No ship was allowed to lie there unless she had steam up ready to proceed to sea directly she was signalled from the shore. According to the state of the tides, currents and weather, a ship might lie parallel to the shore, or might tail out to sea or tail in towards the shore. Under those conditions the rate of loading varied very considerably. On a smooth day, with the ship lying parallel to the shore, the boats from the jetties were able to go out fairly quickly, discharge their cargo, come back again and pick up another cargo; but, if the tide or the wind was such that a ship was tailing away from the buoy out to sea, it meant a longer pull out for the boys, and coming back they might have to go a big circle round to get back to the jetty, which would sometimes take them half or three-quarters of an hour. Later on, searchlights were used to allow of work at night, but even then in the bad-weather season on some days it was only possible to load perhaps 300 tons of phosphate. Then the weather might become so bad that the ship would be ordered to sea, and all the boats would have to be taken ashore. Inside the ship moorings were a series of small buoys to which they tied the boats in fine weather; but in bad weather all the boats

Captain Clarke.

Captain Clarke. had to be taken up a slip on shore. Next morning, if it was fine, the ship would come in and tie up, and loading would proceed; but it would probably be 10 a.m. before the ship could tie up; and then work might have to be stopped at 4 p.m. because a bad night was anticipated. If it was a bad day, moreover, the ship would have to go back to sea, and there would be no work done. That would sometimes go on for a fortnight or even longer at a time, and a ship would be at sea with say 400 tons of phosphate on board and not able to load anything else. The demurrage on ships at times was enormous. He had seen there as many as five or six ships waiting to load, coming in every morning, asking whether they could work, and being sent off to sea again. Under those circumstances they had had to find some means of improving the method of shipping. They built steel jetties for use with the same method of loading, with tram lines running down them; rubber bands were later added for loading into the boats. Telpherage schemes were next considered, but had the objection that there would be a connection to the ship. Furthermore, a lot of heavy gear would have had to be taken out to every ship that came in, and it would have been unsafe to attach such gear to some ships. A better scheme was to have large steel lighters carrying 150 to 200 tons, with elevators to lift the phosphate from the lighters into the ships. The objection to that lay in the problem of storing the lighters during bad weather, because at certain seasons of the year they could not be left out at the moorings, and would have to be hauled ashore, so that that scheme was abandoned. They then got out a scheme of which he made the first drawings (*Fig. 9*). It was laid down that the ship must lie at least 500 feet from the shore, as no shipmaster or anybody connected with the shipping business would allow a ship to come in closer, as if a ship once got on the reef, nothing could save it. That meant that a very long loading cantilever was required, so the arrangement shown in *Fig. 9* was drawn out by his draughtsman in 1910, it being signed in 1911, and he brought it home to London. The Board of the Phosphate Company approved the scheme as an outline, not as a detailed design. From that a similar scheme was prepared by an English firm which again provided for an outreach of 500 feet.

He returned to the islands at the end of 1912, and experiments were commenced to bring the ships in nearer to the reef. On one occasion they had a ship anchored right close to the edge of the reef; that was on a very smooth day, but it did prove the possibility of doing so. Eventually the prejudice of the shipping people was overcome, and they were allowed to bring the ships in closer than 500 feet. In the original scheme, with 500 feet overhang, only one hatch could be loaded at a time, as it would not be practicable to have two arms of that length out to one ship. Two hatches could be reached with the ship in one position and then the ship would have to be moved to get the other two hatches within reach. That Captain Clarke.

Fig. 9.



would have involved great difficulty in loading, because only a certain quantity of material could be loaded into one of the hatches at a time, and then another hatch would have to be loaded. Other-

Captain Clarke. wise the ship would get all out of trim, which would be dangerous if the weather became so bad that the ship had to go to sea. Only 200 or 300 tons could be loaded into one hatch at a time; then the ship would have to be moved to enable another hatch to be loaded with 200 to 300 tons. That would have greatly retarded the work. From that idea, therefore, the present scheme with two arms had been developed, and had been very successful. On test it loaded 635 tons per hour, and at present it was loading 1,000 tons per hour into the ships, which could now haul in, tie up to the buoys, and be loaded in one day, whereas formerly it might have taken a ship several weeks to be loaded.

Sir Alexander Gibb had mentioned Christmas Island and the differences between the methods employed. At Christmas Island the water was not very deep; it was possible, he thought, for constructional work to be done alongside the island, whereas at Nauru and Ocean Island it was quite impossible to have any foundations beyond the reef.

The Author had spoken of his men working on the reef and suffering from skin disease. He himself had been on the island for ten years, and was very often on the reef; but he had never suffered from anything of that kind, though possibly skin diseases might ensue if abrasions were not looked after. Of course, the men of whom the Author was speaking were working there constantly for a considerable time, and under very difficult conditions.

The Author. The AUTHOR, in reply, said that Captain Clarke had answered a number of queries that had been raised, particularly with regard to the barges, and it was not necessary to say more about them. Sir Alexander Gibb had asked what the weight of the cantilever equipment on Nauru Island was. The figure of 560 tons given in the Paper referred to the whole of the equipment for one cantilever; namely, the cantilever, mechanism, conveyors and balance-weight.

He had not dealt with the question of capital cost of the plants, but had confined himself more particularly to the technical construction, and in any case the British Phosphate Commission were not desirous of the figures relating to the capital cost of the plant being published. He had no information regarding the operating costs, and it would be extremely difficult to get them together in such a form as to be of real interest. Some doubt appeared to be expressed in the discussion as to whether it was worth installing the extensive equipment shown in the Paper solely for the purpose of loading ships, but experience in the operation of the plant had already satisfied the Phosphate Commission that the plant was a very profitable investment. As Captain Clarke had said, sometimes several ships at once would be waiting to be loaded, and would all be held

The Author.

up for weeks at a time by bad weather. The demurrage on those ships was a very serious matter, and that factor alone justified the plant from the point of view of cost. It was also of very great importance to ensure the safety of the ships, and it was very desirable that the best plant for that purpose should be constructed.

Several questions had been raised regarding the details of the plant, but he had confined the description of it to points of unusual interest and had not gone into such questions as the construction of conveyors, because he felt that they were matters of common practice. Regarding the performance of the Nauru plant, Messrs. Henry Simon, Ltd., had undertaken that it would load phosphate at the rate of 550 tons an hour into the ship, but when the official test was made in the presence of representatives of the Phosphate Commission, 630 tons per hour were loaded. Since those tests were carried out, as Captain Clarke had already stated, the plant had actually been loading up to 1,000 tons an hour. There could, therefore, be no doubt that the plant easily reproduced test results at any time. From an operating, as well as an engineering, point of view the plant was meeting all requirements under the exacting conditions existing at Nauru. The plant at Ocean Island was of a simpler type, and there was no difficulty in meeting specified conditions. It was not yet known what the cost of upkeep would be, but the plant had been working for over 3 years, and during that time no difficulty had been encountered and very little upkeep expense incurred. He could assure Mr. Binns that the foundations as laid down had proved to be perfectly satisfactory. The only addition which had been made since the plant was constructed was the laying-down of an extension to the apron round the concrete piers. That had been done to prevent undermining of the edges of the concrete.