Discussion.

The Author. The AUTHOR, in exhibiting a number of lantern-slides, pointed out that a portion of the west mole had been allowed to remain, so as to give a certain amount of protection to smaller boats and the fishing-fleet in the roadstead eastward of the harbour. The actual removal of the reclaimed ground had not been undertaken, as, the seaplane quay having been blown down, it was considered that the action of the sea would gradually render the area useless. It was a great satisfaction to him, and he was sure to all the members, that Admiral Sir Edward Charlton, who had been head of the Inter-Allied Commission, was able to be present that evening, and that other members of the Admiralty staff who had been employed on the work were also present, as well as a representative of the War Office who had been connected with the work before the demolition was carried out. It was a matter of regret that Brigadier-General Knox, who had been Commandant, was not able to be present that evening, nor was Lieut.-Colonel Warren, whose statistics were really the basis on which the Paper had been written, and who had been Engineer in charge of the demolition work.

Admiral Charlton. Admiral Sir EDWARD CHARLTON, K.C.B., K.C.M.G., remarked that there was little he could add to the Paper from an engineering point of view, but some other matters in connection with Heligoland might be of interest. He had been President of the Naval Inter-Allied Commission in Berlin, and there were several sub-Commissions, of which the most important was sub-Commission C at Heligoland. The other places under the supervision of the sub-Commissions could be visited easily, but owing to the weather and the situation of Heligoland, and also to the disinclination of some of his confrères to go afloat, there was a certain difficulty in supervising the work at Heligoland, and sub-Commission C had to be left to themselves. The manner in which they had done the work entirely justified the confidence placed in them. He had had the good fortune to visit Heligoland in a yacht about 1902 with the, in some respects, late lamented Erskine Childers, the author of " The Riddle of the Sands." He had then seen Heligoland without fortifications, which had been planned but were only just about to be commenced. There were only two 6-inch guns on the Oberland, and the harbour had not been commenced. When he visited it afterwards, in 1920, the island resembled an unsinkable battleship—it had four main turrets and numerous secondary batteries. In some places the cast-iron armour was 1 metre thick, and the only method of destroying it

was to use the oxygen flame, which had proved very successful. He would advise yachtsmen who wished to cruise in those waters not to do so without seeing that their papers were in order. His party had been rather adventurous in proceeding without papers, and had been treated very well. They were allowed through the Kiel canal, but on going back they were stopped and their papers were asked for. When the officer in charge was told that they were in the possession of the captain, he said, "You are Scotch." On being asked why he thought so, he replied: "We do not mind the Scotch; it is the beastly Englishman we do not want." The following year a party paid a visit to Wilhelmshaven and lost an anchor, and when they started to sweep for it the Germans asked for their papers. As no papers were forthcoming, the Germans took the yacht into Wilhelmshaven and stripped her thoroughly, even to unshipping the mast, but found nothing, and the party had to put everything in order again. One of the slides exhibited by the Author had shown the submarine "Deutschland" going into the harbour and people cheering her from the pier; but those people were the garrison—not Heligolanders, who were British in every way. During the war the whole population was transplanted and interned. When the island was transferred to Germany in 1890, all the Heligolanders who wished to remain British were allowed to do so, but all born on the island afterwards had to become German. When he first went there, in 1902, there was a large number of British, and on being asked whether they preferred being under Germany or under England, they invariably said under England. It was suggested that they were better off under the Germans, but they said that under the English they had had only one policeman, and under the Germans they had 270! It had often been asked why Heligoland was destroyed, and also it had been said that it was a pity Great Britain gave it up; how very much better, it was contended, it would have been to have possessed it during the war. He himself was quite certain that one of the best things Lord Salisbury ever did was to give up the island. During the war it would have been almost impossible to hold it. Before the war it would have been necessary to make it a first-class fortress, and during hostilities a large part of the British fleet, open to destruction by mines and Zeppelins, would have had to defend it. In exchanging it for Zanzibar, Great Britain obtained something of very much more value than Heligoland. It certainly seemed wicked to destroy such a good harbour; and the first proposal had been to leave it as a harbour of refuge for fishing and other boats. As a harbour of refuge for ships in the North Sea it would have been perfect.

Admiral Charlton.

Admiral Charlton. He had seen, however, a German photograph which showed the inner harbour absolutely packed with submarines—he believed there were sixty-nine in the harbour at one time, December and January, 1916–17, when there was a very severe frost and the submarines were unable to work from the Weser or the Elbe, which were frozen over. Submarines could lie at the bottom during a gale of wind, but when there was ice on the surface they were absolutely helpless, unless they had a channel broken for them; therefore they had to use a port where they could work freely, and the only place they could go to was Heligoland. During the two months those submarines used that harbour as a base, the damage to shipping done by them amounted to 30 millions sterling. As the cost of the works in Heligoland was 35 millions, the Germans were pretty well compensated for the money they had spent on the island. At present Germany was not allowed to build any submarines, and all the submarines and engines they had possessed had been destroyed; in fact, some 300 Diesel engines which were being built to go into submarines had to be destroyed in different parts of Germany, so that they should not be used ostensibly for commercial purposes. Four days before the outbreak of the war the thirty-eight inhabitants of Heligoland who were of British nationality were summarily put into prison. Afterwards, when the whole population were removed to Germany, the British were sent with them. It was quite evident that the Germans knew Great Britain was going into the war, or they would not have thrown the British into gaol. The fortifications of Heligoland were finished in 1914, a date which coincided with the completion of the widening of the Kiel canal, and those two events finished the preparations of Germany, as far as the sea was concerned, for the war which broke out in that year. He had had a great deal of difficulty in persuading General Nollet, who was President of the Military Commission in Berlin, that the fortifications at Heligoland were naval and not military, but he had finally agreed that they were naval, and they became the property of the Naval Commission. The island of Ascension in the South Atlantic was run in a very similar manner to that of Heligoland—exactly as a ship. It was not, however, fortified. The naval garrison of Heligoland consisted of 4,300 men, who were shut up during the war, when they could probably have been used much more effectively. According to the Peace Treaty, the navy of Germany could be rebuilt in 1923, within limits, if Germany could find the money. After the sinking of the ships in Scapa Flow and the confiscation of the light cruisers, there was nothing left to Germany which was not at least 18 or 19 years old.

There was not very much enthusiasm for the navy in Germany, where the people attributed all their woes to it, and considered that, had it not been for the navy, the army would not have come to grief. Books had been written in Germany showing that the nation was undefeated both at sea and on shore, and it was very difficult to make them realize that they had suffered any defeat at all. In spite of their present situation, it would appear that the Germans did not realize that they had lost the war; but if they could only see the slides that had been shown that evening, and could read the Paper, it would bring that fact home to them. Admiral Charlton.

Mr. MAURICE F.-G. WILSON considered The Institution was much indebted to the Author for his Paper. The subject of the Paper was rather novel, and it was doubtful if any similar work had been carried out before. The exceedingly interesting details given in the Paper would be valuable to engineers if, in the future, they had similar work to carry out. He did not think any particulars were available elsewhere of such extensive destruction of work by explosives. Although he agreed that the destruction of the harbour was necessary, he thought it must have been rather a melancholy task for those who had to carry it out. He considered that the chief interest in the Paper lay in the Tables and the detailed information which could be derived from them: otherwise it did not contain matter upon which it was easy to offer criticism. There were several points of interest with regard to the construction of the harbour itself, but on those it was probable the Author would not be in a position to give information. There was, for instance, the method of constructing the west mole and a portion of the east mole by means of caissons. That method was very often used, but he had some doubt as to how far it was economical, and had it been possible he would have liked to know whether the caissons were towed over whole from Emden or put together in Heligoland. He did not know whether the Admiralty had constructed any reinforced-concrete oil-tanks, but if so it would be interesting to know how such tanks compared with steel tanks. The drilling by means of the oxygen flame seemed to have been very successful. The holes did not appear to be very deep, and with such shallow drilling it was probably possible to complete each hole in one operation, even though each foot of drilling consumed about 20 feet of steel tubing. The caissons were described as having been filled up with concrete placed in situ by the "trémie" process, and he asked whether the Author could give any information as to whether, when drilling the holes for blasting, the concrete was found to be thoroughly solid throughout. He considered there was always a certain amount Mr. Wilson.

Mr. Wilson. of doubt in that respect in the case of concrete put in under water. He had put together a few comparative figures from the Tables given, and they gave interesting results. With the exception of one or two cases on the west and north-east moles, which were rather exceptional, it appeared that on the whole work about 1½ lb. of explosive was used per cubic yard of concrete or brickwork demolished. In the case of cast iron the same quantity of explosive (1½ lb.) demolished 1 ton. A good many years ago, about 500 feet of quay-wall had been blown up in order to make a new entrance to the Albert dock in London.[1] The wall was first cut back to a thickness of about 5 feet 6 inches, and was then demolished by the simultaneous firing of a number of charges. It was not known what the effect of such a heavy explosion would have on the surrounding houses, and considerable anxiety was felt on the matter. The work, however, was successfully carried out, and no damage done. As far as he could make out, about 17,000 cubic yards of concrete and brickwork was blown down by the use of about 3,000 lbs. of glycerine and gelatine, representing about 5 cubic yards per pound, which was considerably higher than the corresponding quantity at Heligoland. He had found that for quarrying granite about ¼ lb. of explosive was required per cubic yard of solid stone, which corresponded fairly closely with that used at the Albert dock. That was to say, in the examples he had given, about six times as much solid material was removed per pound of explosive, as compared with that removed at Heligoland.

Colonel Matheson. Colonel J. C. MATHESON remarked that, from the military point of view, he was inclined to regard Heligoland as a horrible example of what not to do. The Germans had had the most exaggerated ideas of what to do there, and the result had been favourable to the Allies, because a large part of the many millions laid out probably went into fortifications, whereas they might have spent the money on much more dangerous weapons. Heligoland had probably suffered from people interfering in the scheme. The first German scheme for fortifying the island was itself too extensive, comprising four 9·2-inch guns and numerous big howitzers. It was impossible to make it into a real coast fortress, because it was too small. For one thing, no base longer than 2,500 yards could be got for measuring ranges for guns, and that was much too short. The first guns dated from about 1893, and then, apparently, some influential persons in the German Empire considered that the original scheme was not sufficient, and the 12-inch guns were put in. Sometimes

[1] Minutes of Proceedings Inst. C.E., vol. lxxxvi, *p.* 329.

the influential people of the earth, with more money than knowledge, interfered with schemes and spoilt them; but generally they said that, if £50 was asked for, only £10 should be given. Heligoland practically was an outpost of the coast fortresses along the northern shore of Hanover, and it was no nearer England than were other submarine bases; it was only 10 miles nearer Scapa Flow than Emden was. It could, however, be of use as a submarine base during the 2 months when other places were closed by ice. The Germans thought it was of value, because they spent 35 millions on it, and he was quite certain that the Author would be very glad to have such a sum to spend at Singapore. Colonel Matheson.

Sir ALEXANDER GIBB, referring to Mr. Wilson's remarks with regard to the explosives used on the concrete, said that, as far as he could see from the figures given, the German contractors had been extravagant with explosives, but economical of labour. Possibly the reason was that war explosives had to be got rid of, and if explosives were cheap enough, it paid to use more of them. He rather thought they had been right in keeping down the cost of labour by increased use of explosives. He agreed, generally, with what Mr. Wilson had said about the cost of explosives in rock excavations. In pre-war times, when explosives cost about £60 per ton, the usual cost of explosives for a railway-cutting in rock in Scotland or Wales was about 4*d.* to 5*d.* per cubic yard. That was less than 1½ lb. to a cubic yard and might be taken as a fairly safe figure. It had struck him that the low cost of explosives in connection with the wall at the Albert dock was due to the fact that the sides were free and open, and consequently not so much work had to be done by the explosive. He congratulated the Author on presenting the Paper to the Institution, because it gave information which probably would not be obtainable again, and gave it in a very useful form. He was particularly pleased to see that the Author gave costs in men-hours and not in money, which would have been useless. By multiplying the number of men-hours by the price per hour paid in any part of the world it was possible to obtain a comparative cost. Personally he took a very great interest in the subject, because, before the Author became Civil Engineer-in-Chief at the Admiralty, he himself had held that position; and the earlier part of the civil engineering work in connection with Heligoland had fallen to him. The whole subject had then been thoroughly considered; but it was a little difficult really to know how much ought, or ought not, to be told about war matters. The first proposal in connection with Heligoland was for entire demolition of the whole island and casting the debris into the sea, but that was abandoned on account Sir Alexander Gibb.

Sir Alexander Gibb.

of cost. He had also been responsible during the war for kindred matters, namely, the destruction of ports under certain eventualities and also the rebuilding of Belgian ports after the Germans had retreated. In connection with the studies for rebuilding, it was essential to estimate as far as possible the damage that would be likely to be done to the ports. Air photographs of the Belgian ports were taken about once a fortnight. By this means it was known exactly what the Germans were doing there, and it was expected that the re-building work might be very difficult. If the German officers had known their work, they could have put the ports into such a condition that they would have been useless for many years, but, although after the war the ports looked in a very bad state, they had not been damaged in a scientific manner. The works on the railways inland were scientifically damaged, but the demolition work in connection with the ports was nearly all done above water, and it was therefore possible to get at it and do the repairs. On making inquiries it was found that the personnel left in the ports when the Germans retreated had little knowledge of engineering work. If the British had blown up the ports, he believed that full use of them would not have been had for many years. Tripod drills were mentioned in the Paper. He asked whether they had been the only type used, or whether any drilling-machines had been used of the type of the Flottman, a German machine. These were quite as effective as the tripod, less costly in the first instance, and very much cheaper to work. He had made a rough estimate of the total cost of demolition, by taking the average number of men per day for the 2 years and multiplying that number by the wage it might be expected they would get; and, by assuming that labour accounted for half the expenditure, he found it was approximately £240,000, which did not seem a very large sum of money for destroying 35 million pounds worth of work. Taking the number of men, on the same basis it appeared that an average of 10,000 men were employed for 25 years in building the works; and an average of 800 men were able to blow them up in 2 years. With reference to Mr. Wilson's question about concrete oil-tanks, no doubt the Author could give details on the subject; but he had built one himself at Rosyth, which, so far as he recollected, held 60 million gallons; he believed it was by far the largest in the world. It was of reinforced concrete, with metal expansion-joints every 20 feet, and had a camouflaged timber roof. As far as he knew, that tank had been entirely satisfactory. At the time it was built, 1915, it cost considerably less than steel tanks, but whether the comparative cost would be the same to-day he did not know. He felt certain, from

what he knew of the Admiralty staff, that the efficiency and cheapness of the work at Heligoland was due quite as much to them as it was to any efficiency on the part of the Germans. Sir Alexander Gibb

Major G. H. LITTLETON remarked that his connection with the Heligoland Commission was peculiar and interesting. On three occasions during the war and twice afterwards the Admiralty found it necessary to organize certain engineering units to carry out special work. During the war that was submarine defence work; and immediately afterwards, one part was the completion of the repairs at Ostend, and the other the demolitions at Heligoland. All the work was arranged by Sir Alexander Gibb, and he himself had the honour of being an officer in the service connected with the work. On all such occasions, when it was necessary to hold men under discipline and direct control, they were put for the moment into the Royal Marine uniform and called a unit of the Royal Marines. He wished to pay his tribute to the members of The Institution who had formed the nucleus of all three of those units. The Royal Marine Engineers accepted, cheerfully and without complaint, any position, high or low, in which their abilities could be utilized. He had watched all the three units in Belgium and Heligoland, and would like to bear testimony to their sportsmanship, their cheerfulness, and their good work under very difficult conditions. When the Commission went to Heligoland they were not received with open arms. They did not know what the island was like, or whether food was available. The food proved to be very scarce and particularly bad, and arrangements had to be made to procure provisions from England, Denmark, or from anywhere where they could be obtained. Although they offered food to the children, it was refused, because he learned, a German schoolmaster on the island had told the children that it might be poisoned. On one occasion the French paid a visit to the island, and a French Captain asked why so much trouble was taken to blow the place up bit by bit, when the tunnel might be filled with explosives and the whole thing blown up at once, but the engineers explained to him that they would go with it! The Germans and British eventually worked in harmony. There were certain difficulties, because the mark was fluctuating so rapidly that it took the men all their time to find out what they were being paid. He was quite sure that the Commission left with the goodwill of the people of Heligoland. Major Littleton.

Mr. G. E. DUTTON remarked that the cost of the explosives used at Heligoland had been merely the cost of transport; the cost of labour had determined the actual expenditure. He did not think it would have been possible with Flottman drills to get down, to the Mr. Dutton.

Mr. Dutton. necessary depth, holes of sufficiently large diameter to hold the requisite quantity of explosive. The holes in the moles were drilled wet, and the explosives were all put in in canisters with waterproof ends to take the detonators. At first the explosives had to be broken to fill the canisters, but a large saving was made later by utilizing graded shell-filling, the explosives exactly fitting the canisters. The firing was done by two detonators to each canister; the canisters were wired in groups of four to six canisters in series, and the groups were connected to the firing main in parallel. At first the caissons were fired in small portions, but it was found that neighbouring uncharged holes were often shattered, and that it was impossible to drill a partly-demolished caisson; and subsequently the whole of one caisson was fired at a time. The Author stated that the demolition of the superstructure was executed by drilling 1½-inch diameter holes down to a level of +3 metres; but that was only in the first case. Explosives being cheap, plasters were used to blow up the wall behind the culvert, and then two holes were drilled from the culvert invert and one from the upper level in each bay. The cost of drilling on the north-east mole was apparently lower than on the west mole. At first there was trouble with the unions with regard to bonus; to overcome this, the men on the west mole were allowed to leave work after drilling 8 metres in a shift. The north-east mole was done later by a different contractor, and the men there worked their full shift; in some cases more than 11 metres were drilled per shift. The dry dock was blown up differently. The keel-blocks were of granite with two anchor-holes in each block. All the damage to the bottom was done by blowing up the keel-blocks, the anchor-holes being filled with explosives. The culvert wall was blown down by plasters, and a hole was then drilled down the centre of the wall from the culvert invert-level.

Mr. Anderson. Mr. Athol L. Anderson said he had had the honour of being appointed by the Author to represent him at the Heligoland inspections after the sub-Commission had left the island, and it might be of interest to describe an item of demolition for which the Author had not found room in the Paper, namely, the demolition of the inclined tunnel. The tunnel was 4 metres wide, 1·65 metre to the springing, 3·15 metres to the crown, and about 170 metres long: it was used for taking up heavy guns and munitions from the Unterland to the Oberland by means of a 3-metre-gauge railway and two narrow-gauge lines. It was originally intended to demolish the tunnel by blasting it down entirely, but it was feared that, if that were done, the whole of the cliff might collapse or subsidence might occur in years to come. The Inter-Allied Commission accordingly

approved a scheme of blocking the tunnel and demolishing between the blocking-pieces, and three 10-metre blocking-pieces of concrete were deposited in the tunnel. First a small reinforced-concrete conduit was built from the bottom end of the tunnel to the top end to take water and electric mains. The blocking-pieces were built up to the haunches of the conduit, and then the middle blocking-piece was completed. The two outer blocking-pieces were then built up to a certain height, leaving room for the demolition of the two intervening parts, after which they were completed. No detailed records of the work had been made, because nobody had been present to take them. The demolition of the tunnel proved very successful, and at the final inspection the close of the work was signalled by the explosion of 150 kilogrammes of picrine fired at the top end of the tunnel. Mr Anderson.

The AUTHOR, in reply, remarked that no information was available with regard to the construction of the harbour-works, and he was unable to give reasons for the different methods adopted. The large concrete oil-tank at Rosyth, which had proved quite satisfactory, held 250,000 tons of oil, and was constructed with mass-concrete walls faced with fine concrete deposited at the same time as the mass concrete, the concrete being reinforced with $\frac{7}{8}$-inch diameter rods, 3 feet apart vertically and 1 foot 4 inches apart horizontally. Certain underground tanks had been built, and were under construction by the Admiralty, with a reinforced-concrete lining. As to the question of using reinforced-concrete tanks as against steel tanks, the latter were the type preferred by the Director of Stores, whose objection to large tanks was that the mixing of various oils in correct proportions was rendered difficult; the designs were therefore more or less limited to what was considered the normal and most economical size, namely, a 12,000-ton steel tank. About 2 years ago, when the price of steel was rather high, designs were offered for reinforced-concrete tanks, and it was possible at that time that a reinforced-concrete tank of 12,000 tons might have proved cheaper than steel tanks. Then came a sudden slump in the price of steel, and since then there had been no question that the steel tank was the cheaper, for which, personally, he was very thankful, because he was doubtful as to what would be the effect of oil on the thin wall of a reinforced-concrete tank of that kind. The tanks at Heligoland were lined with steel, so that they were not simple concrete tanks. Mr. Dutton had not mentioned the experience in connection with bad concrete in the caissons. The concrete was not dug out, but was blown to pieces, so that there were no means of seeing exactly what it was like, but an indication of bad concrete was given in certain places, as it was found that, in drilling, certain holes The Author.

The Author. had to be abandoned because there was a layer of a sort of semi-fluid concrete which filled up quickly. It was thought that when concreting had been stopped at the end of a shift, a layer of silt had been deposited on the concrete and had not been cleared off before the next shift recommenced concreting. As to the total cost of the work, he had questioned Lieut.-Colonel Warren, who replied that it was quite impossible to give it, because the Germans were very secretive about the cost in money, and at that time the mark varied enormously; but a fair indication might be obtained by adding up the number of men employed each month and making certain allowances for explosives which were used. As, however, the bulk of the work was carried out through the agency of contractors, it would be necessary, in order to obtain the absolute total cost, to add the employing contractors' on-costs and profits and the cost of the supervising staff of the German Commission, in addition to the cost of the maintenance of the British Sub-Commission, which cost was paid by the Germans under the terms on which the demolition was carried out.

Correspondence.

Dr. Faber. Dr. Oscar Faber thanked the Author for putting at the disposal of the members so much valuable information on a subject in regard to which opportunities of obtaining personal experience on so large a scale were few and far between. The Author referred (p. 61) to the advantage of hydrogen in that it could be delivered in cylinders, whereas acetylene had to be produced in generators, which were more cumbersome. Could not acetylene also be delivered in cylinders, if that was more convenient? It had struck him, immediately he saw the section of the dry dock shown in *Fig. 5*, that it was not stable at high water, a point also mentioned in the Paper. If that dry dock had really been dependent on the stability of the coffer-dam on the outside, constructed with steel sheet piling, it seemed to be a very remarkable structure, seeing that the coffer-dam would rust away in a few years and then apparently expose the dry dock to serious risk of collapse. The value of the figures of cost given in the tables would be still further enhanced if a more complete description could be given of the items referred to, such, for example, as the size of the rods forming the reinforcement, their distances apart, the composition of the concrete, and so on. It was remarkable to note in items 12 and 13 in the Table on p. 82 that the brickwork and mass-concrete walls appeared to have cost