Discussion.

The President remarked that he would like to say a few words on the Paper, as he had visited the aerodrome during various stages of its construction. The feature of the greatest interest was the way in which the mud was dried out so as to enable material to be deposited on the top of it. It seemed to be an almost impossible task when he first visited the aerodrome-site, since the bund system had only just been started; he had been asked on that occasion whether or not he could suggest any other method of drying out the mud, but he could not think of any other method: it was the only possible way in which it could be done.

The water-mains had to be brought from the Johore reservoirs across a creek not far from the site of the airport. The two 36-inch diameter mains were connected together to form an arch, and were built as a footbridge. The bridge had had to be built on a different site from that originally intended, and no proper explorations had been made. It was hoped that the material would cause a skin-friction of about 1 cwt. per square foot to develop, and with that in view the abutments were designed as hollow boxes turned upside down to give the largest possible surface. The abutments sank gradually, however, and it did not look as though they would ever stop. Fortunately, it was found that by driving some very long piles it was possible to get down to more solid strata.

There was very little in the technical details, apart from the drainage problem, with which he was competent to deal, but he would like to say that natural conditions were not very helpful in that neighbourhood. There was an average rainfall of about 100 inches a year, and it was never possible to be certain when it was going to rain. He had taken out the average rainfall of each month of the year for a good many years and had found very little difference between the figures; there was never a long dry period of sunshine when the surface of the bunded area could dry properly.

Sir Leopold Savile, Vice-President, said that several years ago, when he was in Singapore for the selection of the site for the Singapore naval base, he had been asked by the Air Ministry to collaborate with Group-Captain F. E. T. Hewlett, of the Royal Air Force, in the selection of a site for an aerodrome and seaplane base. Although the site where the Seletar aerodrome was constructed was only 15 miles away from the Singapore airport constructed by the Author, the conditions to be dealt with were entirely different. Sir Leopold then showed five lantern-slides illustrating the site of Seletar aerodrome, which consisted largely of creeks and jungle, the country being therefore difficult to survey. When the Johore cause-

way was made it was very difficult to find any granite suitable for the quoins, the only satisfactory material being obtained from boulders on the edge of one of the creeks shown in the lantern-slides.

Turning to the Paper, he thought that every one would realize that the Author had had quite a different proposition to deal with from that of the Royal Air Force at Seletar; there was not much doubt that, in spite of the fact that at Seletar the country was very bad, the Author had had a far more difficult problem, and one which, considering its magnitude, had hardly ever been solved before. To take a site all of which was under water at high tide and a large proportion of which was under water at low tide, with mud over an indefinite depth, and to construct a stable landing ground on it, was a work the undertaking of which required an enormous amount of courage.

A point to notice was that the whole work had been carried out departmentally without going to contract, and in Sir Leopold's view there was not the slightest doubt that in the case in question that was the right procedure. The engineers of Public Works Departments in the East were used to carrying out big works themselves in a very cheap way. There was very little doubt that if an attempt had been made to let a contract, it would have been very difficult to have tied down a contract to allow for the possible alterations which might have had to be made during the construction of an aerodrome of the kind in question; in any case, a contract would have been liable to lead to fairly heavy claims before the work was completed.

In regard to the suggestion that the work might have been done more cheaply if it had gone to contract, it would be noticed that on p. 73 the cost of excavation and transport of the dry material, of carrying it more than 3 miles by railway, and of depositing it in the reclamation, worked out at about 8*d.* per cubic yard, and he could not imagine many contractors tendering on that basis. He doubted whether, even if they had tendered on that basis, they themselves could have carried out the work as cheaply as the Author had been able to do.

The reinforced-concrete buoys (*Fig. 9*, p. 79) were 8 feet 6 inches in diameter, but the sides were only 4 inches thick. In the experiments which were carried out on the deterioration of structures in sea-water, it was found that any cover for concrete in sea-water under 2 inches was liable to deterioration within a comparatively short time, and with a thickness of 4 inches it was quite impossible to get 2 inches of cover. Singapore, moreover, had a particularly bad climate for ferro-concrete, and a box of the kind in question in that climate would have a very damp hot atmosphere inside it which would tend to make the inside deteriorate, whilst the outside would always be subject to sea air. He would be inclined to doubt whether a ferro-concrete buoy was the best type for the purpose, but no doubt the Author had very good reasons for using it, and perhaps in his reply he would explain his reasons for doing so.

Mr. C. L. Howard Humphreys observed that in the section of the Paper headed " General Considerations " (p. 71), the quantity of filling which it was estimated would be required was stated to be 8,770,000 cubic yards, and he would like to know whether the Author could say how much was actually used. Experience in the Zuyder Zee, for example, had showed that where there was a soft bottom it was quite possible to exceed the estimated quantity of filling by 40 per cent., and in Valparaiso harbour there was a record that in certain parts the estimate was exceeded by 57 per cent.

Another point on which further information would be of interest occurred on p. 72, where the Author classified the various soils which he found in his borrow pit, and noted that class C, the lowest material, was very good. The Author did not mention class B, and, as they were both clays with varying percentages of sand and both had to be drained, it would be interesting to know the Author's opinion of class B soil.

The President had referred to the dewatering of the mud. When the Author had constructed his bunds he had had to dewater the mud, and it was interesting to find it stated (p. 74) that borings showed that penetration of the tipped soil had reached a depth of more than 40 feet in places when it was being tipped on to the soft mud before it was dewatered. The Author also said that after the mud had dried a depth of 12 feet of filling depressed the mud only approximately 2 feet. To what depth had the mud to be dried in order to give it such an enormous increase in bearing capacity ?

The aerodrome was in the form of a dome, and had a gradient of 1 in 190. What was the maximum gradient on which it was possible to land an ordinary commercial machine without risk and inconvenience to the passengers ? With a big aerodrome of that kind there was the risk of two machines simultaneously approaching the centre from the opposite ends of a diameter, and colliding because the pilots could not see each other.

The piling also presented a small point of interest. It was stated that the foundations for the hangars were on piles varying from 55 to 90 feet in length. Such piles were very long, and he wondered whether the Author had found, as Mr. Humphreys had found, that a pile driven into soft ground would, if left for a short while, become so gripped by the ground as to become completely immovable, after being what had previously been regarded as apparently hopeless for bearing purposes.

The administration building was a very fine piece of work ; too often, however, when landing from a ship or from the air on British territory, passengers were taken into a wooden or corrugated-iron shed, and made rude mental comparisons with arrangements in other countries. He was also very glad to see that the Singapore airport, apart from the buildings, was wholly the work of an engineer.

There was one thing mentioned in the Paper which was a ground for hearty congratulations to the Author, and he was certain that it was a

ground of great satisfaction to the government of the Straits Settlements; it was a feat which he was sure had never been accomplished before in the annals of The Institution: it would be seen from the figures of cost (p. 90) that what the Author spent on contingencies amounted to only 0·00006 per cent. of the total cost!

Mr. Malcolm Millar said that he wished to give some idea of the results of the work described in the Paper from the point of view of the air operator. At any point where he might reasonably expect a fair volume of traffic, an air operator's requirements were manifold, but, broadly speaking, they could be grouped under the following heads. First and foremost came safety; there was no room for risk in present-day air transport. Secondly came aids to navigation and approach, thirdly general facilities, and fourthly accessibility.

The problem under the first heading, that of safety, was easy to understand, as it was so obviously desirable to have both aerodromes and seadromes free from surrounding hills and clear of obstruction on all sides, having an adequate area reserved for the purpose in view, and, so far as the landing ground itself was concerned, a surface firm enough to avoid the risk of bogging, even in the worst conditions. There were many aerodromes in use to-day where those obstacles and difficulties did exist, and, although they did not constitute any real danger, they added to the many difficulties with which an air pilot had to contend; it was the constant task of the air operator to reduce those difficulties to a minimum.

Aids to navigation could be divided into so many different sub-headings that it would be necessary for him to confine himself to the broader principles. Aids to navigation were of prime importance in the successful operation of present-day air transport, which should, roughly speaking, be able to carry on its work under any conditions. Much still remained to be done in that direction. Further, of those aids the two most important went together: wireless and meteorological information. With the former there were direction-finding stations and blind-approach schemes, and following them there were night and blind-landing equipment, obstruction lights, marker beacons, and similar equipment.

Under the third heading, general facilities, could be grouped all those other things which appertained to airport equipment. From the point of view of the passengers the air operator tried to give them shipboard comfort and railway service at airway speed. The air line wished to take its passengers from one point to another with the least inconvenience to them. From the air operator's point of view the operator desired to have all his equipment so placed that he could carry on his own work as efficiently and rapidly as possible. Time was money, and in actual operations a period of 1 hour could also mean a distance of 160 miles.

Lastly, there was the question of accessibility and proximity to the point which the aerodrome served. It was somewhat absurd to spend

2½ hours on a journey of 400 miles and perhaps ¾ hour in reaching the aerodrome at each end, but that position did exist in many places.

It was of interest to see how the Singapore civil airport met those requirements. From the point of view of safety, the landing ground left little to be desired. There were easy approaches from all sides, and the hangars and administration building were so placed as to offer little or no obstruction for a landing or take-off in any direction. The landing ground was amply large enough for present-day commitments, and although it might be difficult, an extension of the area or the provision of runways should not be impossible if it were ever found necessary. The actual marine alighting area was in the Singapore harbour proper. As in the case of a landing ground reserved for land craft, so would those operating flying boats like to see an area entirely reserved for their craft, and so placed that the moorings and administration buildings were situated on the boundaries of that area. With the approach channel as it was at present, in certain conditions flying boats might be left with rather too long a distance to taxi to their moorings, both from the engineering point of view and for the comfort of the passengers, but it had to be remembered that flying boats were, relatively speaking, still in their infancy, and the present arrangements at Singapore were in advance of those at many other places in the Empire.

With regard to aids to navigation, Singapore was splendidly equipped, as was Malaya generally. The existing organization included a civil-aviation wireless station, which kept in touch with all craft approaching or leaving Singapore either until they had arrived or until they had safely reached the next point ahead. There was a medium-wave direction-finding station and a meteorological office in the administration building. As was stated in the Paper, visibility could be reduced to nil during severe, but fortunately usually localized, storms, which were generally of short duration; at all other times visibility was good, fog being unknown, and there was no need for blind-approach systems such as were fairly widely used in America. The night lighting for the landing ground was excellent, and the buildings, which might constitute a danger to craft making a particularly low approach, were adequately lit. The illuminated wind-tee enabled pilots to ascertain the wind direction without any difficulty.

For the marine area it had been found that the old type of paraffin flares mounted on twin hydroplane floats still provided the most suitable means for night landing. They had disadvantages, and it was not possible, as with the aerodrome floodlights, immediately to illuminate the alighting area at a moment's notice. The approach was large enough to allow two flying boats of the Empire type to manœuvre and pass each other without difficulty.

Under the heading of "facilities", the general facilities were good, and those for land planes left nothing to be desired. The telescopic covered ways provided enabled passengers to be embarked and disembarked in

complete comfort during the heaviest tropical storms. The hangars were conveniently situated, and the system of doors enabled large transport craft to be housed with the least possible difficulty.

With regard to marine craft, operators would naturally prefer to see arrangements such as a dock or a railway station, or at least facilities comparable with those enjoyed by the land craft, but there again Singapore was some way in advance of other marine stations, being able, as it was, to handle passengers and loads effectively in adverse conditions. Viewed from the ideal arrangement, the customs and emigration departments, at present housed in the administration building, were perhaps a little too far off, even though the journey was undertaken by car. It was desirable in marine air transport to have some arrangement for the berthing of aircraft which would allow passengers to be disembarked direct on to a covered pontoon or platform, whence they could continue under cover to comply with the various official formalities. However, possible alterations and alternatives in that direction were already being actively considered by the Civil Aviation Department of the Government.

It was always preferable to have the hangars as near as possible to the slipway to prevent loss of time. Even with a skilled shore crew, towing craft to the hangar sometimes took longer than beaching them. It was not always possible to beach them, however, and it would be of immense help if the necessary maintenance could be carried out under cover when the flying boats were afloat. Other excellent facilities for marine craft were the arrangements for lighting buoys at night, the mooring buoys, the crane, which had already been used for handling engines, and the ability to beach craft at any state of the tide. Singapore was probably more fortunately placed in regard to accessibility than any city of comparable size. From the airport proper to the main hotels was not more than 5 minutes by car, and it was only 2 or 3 minutes farther to the business area.

To sum up, Singapore civil landing ground met almost every possible need of the most exacting air operator. When it was borne in mind that the first flying boats did not operate regularly to Malaya until 8 months after the opening of the airport, the excellence of the marine facilities was, he thought, ample proof of the energy and foresight with which the problems had been tackled by the Government, and particularly by the department concerned. From what he had seen in some fourteen different countries, he would like to support the view which had been expressed in other quarters that Singapore was the Empire's finest civil airport.

Mr. G. B. Gifford Hull remarked that, like Sir Leopold Savile, the costs of the work had impressed him. It appeared that transport over a distance of 3·38 miles was done at a cost of something like 2*d.* per cubic yard. He would be grateful if the Author could amplify the figures given. The cost for excavation, transport, reclamation, and staff and general, came to 28·71¢ per cubic yard, whereas the same items in Table I (p. 91)

gave a figure of 44¢ per cubic yard. He noticed that the cost of railway plant was shown as $630,000, but that did not seem to be included in the costs at all. Before he very reluctantly dispelled an illusion which he had had for some years—namely, that when he and his associates had been building the earth dams for the President's water undertaking at Singapore they had done their work economically—he would be very glad if the Author could give some greater details with regard to his figures. He noticed that the costs applied to cubic yards loose in the wagon, which would in any case put them up to some extent.

An interesting item in Table I was the coolie lines for 1,000 men, the cost of which were shown as $144,376. A figure of $144,000 for 1,000 men worked out at $144, or 360*s.*, per man. If the regulations governing the number of cubic feet of space per man which obtained in the East—namely, 350 cubic feet—applied in the case in question, the cost worked out at over 1*s.* per cubic foot, for which proper houses could be built even in Great Britain, where labour was expensive. He would like to know, therefore, what kind of coolie lines were provided, whether or not they were of the ordinary type usually built in Singapore with wood, whether or not they had water-borne sanitation, and whether or not the cost of paths round them, and so on, was included, because coolie lines for the 3,000 men employed on the President's recently finished work in Hong Kong, and which were regarded as excellent coolie lines for the East, cost less than $144,000, although for three times the number of men.

Mr. C. E. O. Wood said that he had been representative of the Works Directorate of the Air Ministry in the Far East for 10½ years, and thus had been most interested in the remarks of Sir Leopold Savile, who went out there in the early days to select the site for the future Royal Air Force station at Seletar. It had been his pleasure to have been connected with the Author during the period of construction of the civil airport in Singapore, which from an earthwork point of view was approximately 7 times the size of the Royal Air Force station, and he entirely agreed with Sir Leopold Savile that the Author's problems and those of his resident engineer were much more difficult, from an earth-formation viewpoint, than were the problems at Seletar. Seletar was an undulating site which involved, from the point of view of the landing ground alone, earthworks to the extent of 1,000,000 cubic yards ; during its construction they had realized that if 1 cubic yard of earth were excavated and removed to a new site, it did not occupy 1 cubic yard in its new position, owing to the fact that, according to the formation on which it was being deposited, it was necessary to contend with the shrinkage- and compression-factors ; at Tengah aerodrome the losses were 18½ per cent. through the compression- and shrinkage-factors. That was taken into account when dealing with Sembawang, where 3,500,000 cubic yards had to be dealt with, and he estimated there that possibly the final figure

for loss would be in the neighbourhood of 9 per cent., owing to the increased volume.

It had been his privilege to be called in by the former Governor of the Straits Settlements, Sir Cecil Clementi, to examine with him the proposed site for the civil aerodrome of Singapore in February, 1930; at that time it was proposed to site the landing ground at Tengah, which was now the Royal Air Force Station, but Tengah would not have had any marine facilities, and after careful inspection of the site Sir Cecil Clementi decided that a site had to be selected within 5 miles of Government House, which would provide requirements not only for land machines but also for seaplanes and flying boats. Within 3 days of Sir Cecil Clementi's visit the site which had been developed was selected, and he was sure that the Author and all others concerned would agree that Sir Cecil showed marked foresight in emphasizing that the Kallang basin was the ideal site for the future civil airport of Singapore.

Mr. C. I. Robinson, referring to the doming of the aerodrome, said that a rise of 8 feet at the centre over the circumference sounded a good deal, but he believed that he was correct in stating that despite that tremendous amount of doming, aircraft had experienced difficulty with regard to water on the surface when landing or taking off. The great amount of subsoil drainage was referred to in the Paper, and it seemed difficult to realize that at any time there should be so much water on the surface that the wings of aircraft in motion were damaged. It might be that the present vogue for low-wing machines would pass and that that danger would pass with it, but it would be of interest if the Author would say whether or not there was any way of eliminating the danger of damage to aircraft from surface water.

He noticed that 16-inch octagonal piles were used in connexion with the slipway, and were apparently surrounded by 21-inch spun-concrete pipes. What was the reason for putting pipes around piles of that size?

At first sight it would appear that dredged material should have been partially or entirely used for filling the swamp. The Author gave as his reason for not doing so that they had some other use for the dredged material; eventually, however, nearly 1,500,000 cubic yards of material were dumped to sea. That, it would appear, might well have been used in the initial stages on the site. The Author stated that dredgings would not have proved very satisfactory material, but since the area had had to be bunded in cells and each cell drained in order to provide a surface upon which material could be dumped, Mr. Robinson could not see that there would have been any disadvantage in pumping dredged material into those cells before they were drained off.

Mr. H. G. Lloyd remarked that in view of the fact that the construction was carried out in a country where there was a high rainfall and also where there was a moist atmosphere, it would be of interest if a few details could be added to the Paper which would indicate the proportions of the concrete

which had been used in the various works, and also the steelwork which had been used in the reinforcement. Another point which was of considerable interest, and which had already been touched upon by Sir Leopold Savile, was how much cover there was to any reinforcing steelwork, especially in view of the fact that in some places the concrete was only 4 inches thick. It would be of interest also to know whether the materials used for the concrete work were obtained on the site, and what those materials were, together with some indication of their sizes, so that later on, when reference was made to the Paper to find out what had happened, information would be available regarding the materials used in the construction. Some reference might also be made to the cement.

Mr. R. F. Lloyd-Jones, referring to the drainage of the aerodrome, said that with the rainfall common in Great Britain it had become very difficult to ensure that surface water was kept off the landing surface; with a grass-surfaced aerodrome the only way in which it had been found practicable to achieve that end was to put a fairly stiff gradient on the surface, or else to fill the drains and drain trenches with porous filling up to the surface to intercept the surface water. In the Paper it was not stated whether or not the drains were filled to the surface, or to a level anywhere near the surface, with porous material. It was usually found easier to do that, because, where there was a very large area of water, pooling would almost certainly occur in places if reliance were placed on the gradient of the surface to remove the water.

He was not quite clear what the bearing capacity of the ground was at the airport, and whether it was well able to resist the wear of aircraft. There were many reasons for supposing that runways would be necessary at almost every major airport, and he wondered whether that point had been considered in the design of the airport at Singapore. He noticed that the drainage was set out on a purely symmetrical plan, and did not appear to be designed to take the surface water from any impervious areas which might be put down in future.

Had the question of having a V.H.E. direction-beacon been considered? Despite the fact that there was no fog at Singapore, visibility was apparently reduced to zero at times; in any case, a beacon of that kind was useful for approaches through low cloud, although he did not know whether low clouds were experienced at Singapore.

The Author, in reply, observed that Sir Leopold Savile was interested in the question of the reinforced-concrete buoys, and that the same point had been referred to by other speakers. The first reason for utilizing reinforced concrete in preference to steel was that of cost, since steel buoys for the same duty would have cost more than twice as much as reinforced-concrete buoys. A good deal of experience had been gained with reinforced-concrete pontoons and other marine structures at Singapore, and it was felt that it was justifiable to try reinforced concrete for the buoys under discussion. He admitted that 4 inches appeared to be

rather thin, and did not give a great deal of cover; so far as he was aware, however, the buoys were satisfactory, and none had so far shown signs of deterioration, although he admitted that experience was limited to 2 years.

Mr. C. L. Howard Humphreys had referred first to the actual quantity of filling. He was sorry that he could not give that figure without referring to his office in Singapore, but his impression was that the difference between the estimated and actual quantities was not very great. They had been very fortunate in some respects; the amount of depression of mud surface due to the superimposed weight was rather less than they had expected, and that had helped to make up for the other places where bunds had slumped. Mr. Howard Humphreys also referred to the classes of soil mentioned in the Paper. The Author had expressed a preference for what he termed class C soil largely on account of its greater porosity. He thought that better conditions would have been obtained in the end had all the material been of that category and had it not been necessary to utilize first of all the class B soil, which had only 24 per cent. of sand instead of 43 per cent. Class B soil had had to be taken as well as class C, however, because class B was on the top. Another question was the depth to which the mud was dried out. The herring-bone drains had been dug to a depth of 2 or 3 feet, and they had endeavoured to keep the area pumped out until such time as they judged that it would take the weight of the material. It was largely a matter of trial and error, as was most of the job. They found by a certain amount of experience that when it was possible to walk about comfortably on the surface, it was necessary to wait another week if the weather were fine before commencing dumping.

Mr. Howard Humphreys had also asked a question about the maximum gradient which could be permitted on a landing ground from the point of view of the pilot. In certain circumstances it was possible to land on a very steep piece of ground indeed, but for a landing ground which had to be in constant and safe use by civil air traffic, he did not think the gradient should exceed 1 in 50, and it was better to have it not so steep as that. It was possible, especially with a grass surface, for an aeroplane to have its wheels locked when it came in to land. The pilot put on the brake to pull the machine up, and if the grass were wet the wheels might lock and the machine would skid over the surface with no signs of slowing down. That might happen to some extent on a level surface, and with a gradient steeper than 1 in 50 it might be impossible to stop the machine.

In Singapore they were used to long piles. Under the Drill hall at Singapore piles as much as 125 feet in length had been used, and a length of from 70 to 100 feet was quite common. It was true that a pre-cast pile might " seal itself up " with skin friction while an extension was being cast, but it was necessary to proceed with the extension, because the pile might not have sealed itself up; one or two piles had occasionally been

left in the hope that extension would not be necessary, but when a test load had been applied the pile had run away. One or two piles had been broken in carrying out the work, particularly down at the jetty, but they had managed to get over that difficulty.

Mr. Millar had spoken about the provision of a kind of railway station, into which the flying boat would taxi at the end of the journey, and in which all the repairs could be done. The Author remarked that the flying boat was a fairly recent development and he did not know that it was a permanent one. He was inclined to think that it was, and that the large aircraft of the future would be flying boats. That being the case, it would be necessary to tackle the problem, which he did not think had been attacked anywhere yet, of marine terminal stations for flying boats. One of the difficulties met with was the different types of flying boat: some had wing-tip floats and others had short stubs to prevent them turning over; those and other differences in size and design made it extremely difficult to design a terminal station which would suit all present and future types, and he did not know at the moment what the answer to the problem was. It was, however, a matter which would have to be dealt with by collaboration between airport authorities and aircraft manufacturers.

Mr. Hull had raised some questions about the earthwork costs. The Author regretted that Mr. Hull might have been misled by the figures given on p. 73. What had happened was that in submitting the Paper he had enclosed a detailed Table showing all the costs in one typical month, when the work was in full swing. Unfortunately the Table had not been reproduced with the Paper, and only the summarized figures had been extracted therefrom. It would be appreciated that the first item in Table I (p. 91) included a great many preliminary and other expenses of a non-recurrent character. The costs on p. 73 were purely operating costs and did not include costs of plant and machinery; he could, if necessary, furnish the detailed costs in question. The item in Table I "Coolie lines for 1,000 men: $144,376" should be amended to include the words "and quarters for supervising staff." Mr. Hull's figure of $48 per man was about right for that class of coolie line.

Mr. Robinson and Mr. Lloyd-Jones referred to water lying on the ground. It was perfectly true that it was not possible to have a grass surface, however smooth, absolutely dry just after a heavy storm, unless the ground was extremely porous. Possibly chalk might remain dry, but he had not had enough experience of chalk recently to be able to say whether chalk was sufficiently porous. It was inevitable that grass itself should hold up a certain amount of water, and he had made a number of measurements at times of the amount of water on a typical piece of the surface, and it was something like 1 inch in depth. He had also seen aircraft landing on concrete runways after very heavy rain, and, just as in the case of a grass surface, it created the impression of a destroyer

going very fast. He did not know of any case of damage to an aircraft owing to the water on the surface. The presence of water caused drag which would pull up a landing aeroplane more quickly and would likewise absorb some of the power when an aeroplane was taking off. Nevertheless there had been only one case of a deferred departure since the airport was opened in June 1937. That had happened in January of the present year, when the captain of a Dutch aircraft decided, without looking at the ground to see if he could take off safely, that the weather was too bad for him to proceed. As far as he knew, there had been no case of a deferred arrival on account of airport conditions. The machines did at times cut the grass up. When landing after heavy rain, with the grass still very wet, the wheels of an aircraft sometimes locked when the brakes were applied, and tore the grass up. All that it was necessary to do in such a case was to plant a little more grass. There was, of course, a big area of concrete near the building itself where most of the manœuvring was done. On the whole, the grass surface was standing up very well. There were one or two places where recent landing of heavy aircraft had left a mark, but there was no danger to the aircraft of sinking or anything of that kind; the surface was much too hard. As a matter of fact, it was impossible to drive a peg into the ground.

Mr. Robinson referred to the pipes round the piles of the jetty. They were simply put there for additional protection against bumping by boats.

With regard to dumping the dredgings at sea, the main reason for that was that the dredgers were not available for the seaplane channel until the airport reclamation was well in hand, and that the output of the dredgers then exceeded the rate at which the material could be accepted at the alternative reclamation. It was most important to complete the airport as quickly as possible, and to have used some of those dredgings for the airport reclamation would have materially delayed the work. The key to progress was the rate at which the bunds could be laid down, and had there then been delay in filling that area partially with dredgings, he was afraid that the completion of the airport might have been quite considerably delayed.

Mr. Lloyd inquired about the concrete materials. Excellent granite and sand were available on Singapore island, whilst cement and steel were imported from England. To a very large extent, a mix of 1 : 2 : 4 was used in the concrete work at the airport, the granite being crushed to $\frac{3}{4}$-inch gauge for reinforced concrete. When possible 2 inches cover was given, but as Mr. Lloyd and other speakers had observed, it was not practicable to give that in all cases, and then 1 inch had to suffice.

Mr. Lloyd-Jones had referred to drainage from possible future runways. The Author did not consider that drainage from any future runways which might be put down would present material difficulty. The curb-side drains could deliver at convenient intervals down into existing intercepting drains; he had not yet worked the design out in detail. It was

possible that it might become necessary to put runways down, but a full system of concrete runways at Singapore would cost something like $2,000,000, and for every year for which the putting of them down was deferred there was a saving, at 3 per cent., of quite a considerable sum of money.

The test for bearing capacity of the landing-ground surface was 3 tons per square foot, the tests being carried out by means of loaded lorries.

No need had yet been shown for the provision of any wireless approach systems; when visibility was bad, the air was generally so disturbed as to make an approach and landing inadvisable, but the duration of such storms was, fortunately, brief.

*** The Correspondence on the foregoing Paper will be published in the Institution Journal for October, 1939.—SEC. INST. C.E.