the effectiveness of a barrier 50 feet away (a reasonable distance in practice) depends on the height of the barrier. It will be noted that in this case there is little to be gained by increasing the effective height beyond say 30 feet.

It could be assumed that the height of hangers and other large buildings at an airport will be about 50 feet, that is, an effective height of 40 feet above the aircraft engines, and Fig. 16 shows the effect on sound-level reduction of variations in distance between the source of sound and a barrier of this height.

APPENDIX III

SOUTH-EAST-FACE PASSENGER-HANDLING BUILDING. DETAILS OF ACCOMMODATION

The building contains ten parallel passenger-handling channels each 36 feet wide and providing accommodation as follows :—

Entrance hall	1,200 sq. ft
Concourse (proportion of)	1,080 ,,
Customs examination	2,450 ,,
Search room	80 ,,
Immigration control	1,140 ,,
Health control (includes M.O's room, waiting room and examination room, etc.)	1,150 ,,
Lavatories	240 ,,
Waiting room	1,080 ,,

In addition the principal items of public accommodation are :—

Entrance hall	approx. 3,500 sq. ft
Central concourse	approx. 9,500 ,,
Balcony lounge	6,300 ,,
Lounge, buffet, and bar	2,160 ,,
Public restaurant	1,800 ,,
Transit lounge and buffet	1,800 ,,
Transit restaurant	2,200 ,,

There is a separate concourse of 5,000 square feet and a waiting room of 3,600 square feet for passengers by internal airlines.

Discussion

Sir Hubert Walker was interested to note on p. 301 that it now seemed that only two runways would be required. If that was so, it might have been possible to have devised a layout giving an open entrance to the terminal area, and it would be interesting to know whether any more recent consideration had been given to some slight rearrangement—possibly by putting two parallel runways on one side of the terminal buildings. In the present layout the terminal area seemed to be restricted for all time, which was not a very cheerful outlook, having regard to the rate of increase in traffic. The point made about parallel runways on p. 301 was also extremely interesting from the point of view of maintenance, and should be borne in mind in all future designs, particularly if an airport was likely to become heavily trafficked.

On p. 302 the Author had stated that the runways should be constructed

THE REQUIREMENTS OF A CIVIL AIRPORT AS TYPIFIED BY LONDON AIRPORT

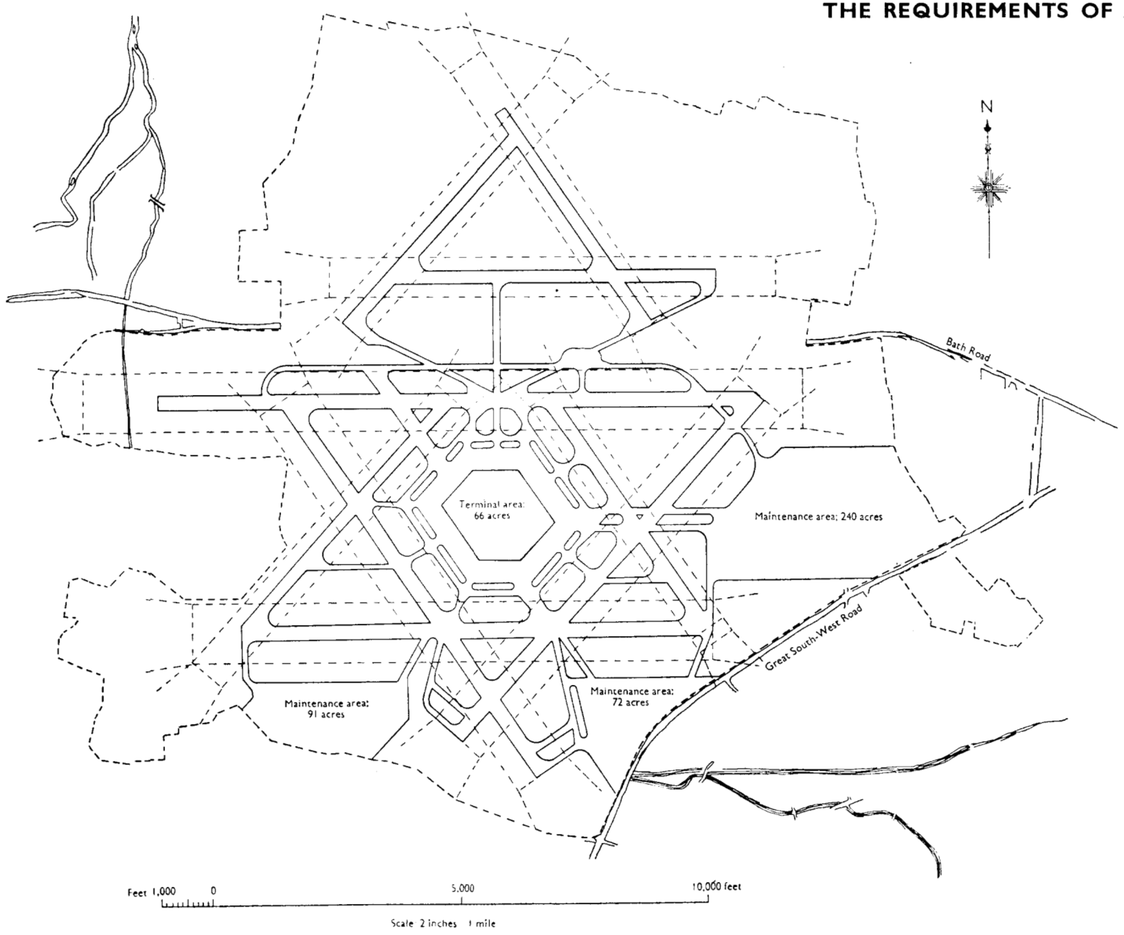

FIG. 1.—LONDON AIRPORT. FINAL LAYOUT RECOMMENDED BY LAYOUT PANEL, 1946

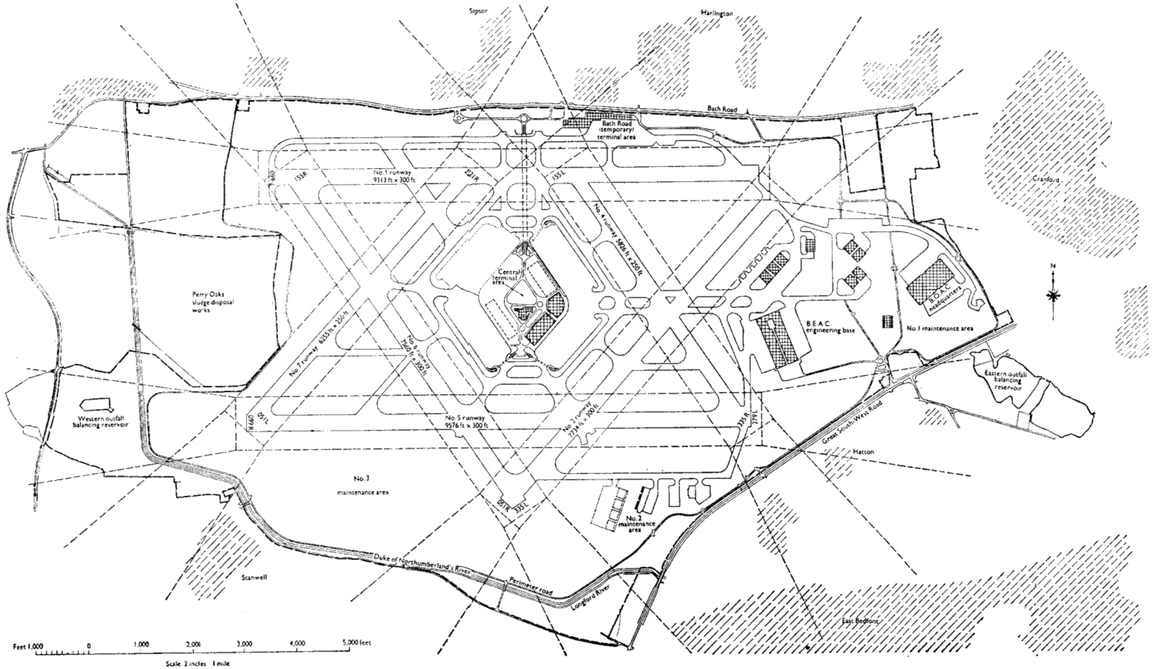

FIG. 2.—GENERAL LAYOUT OF LONDON AIRPORT—1954

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THE REQUIREMENTS OF A CIVIL AIRPORT AS TYPIFIED BY LONDON AIRPORT

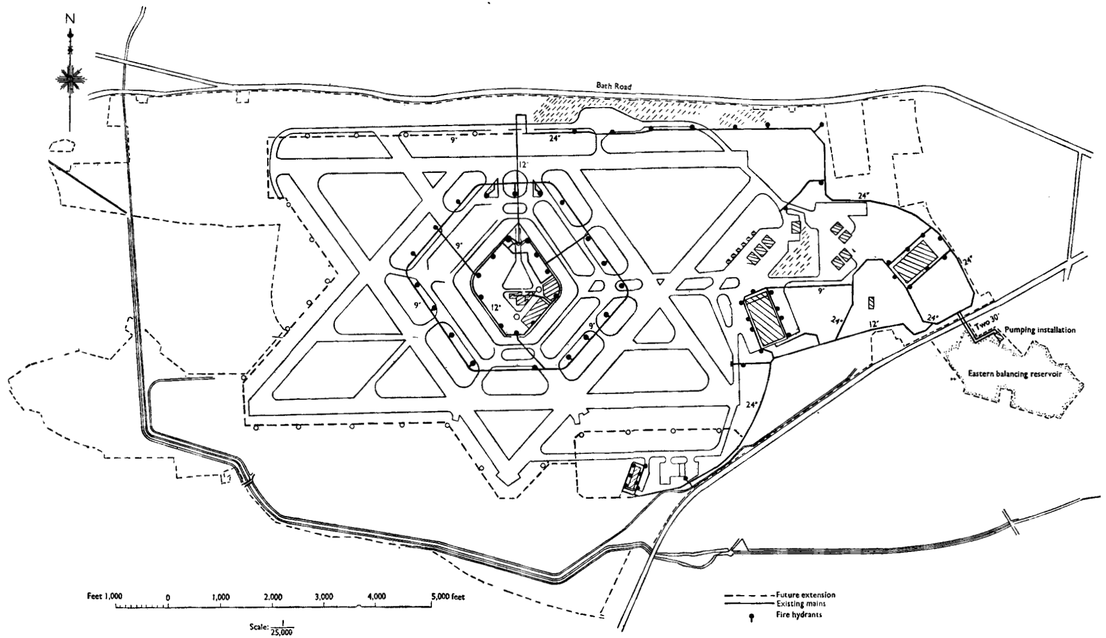

FIG. 9.—LAYOUT OF FIRE MAINS AT LONDON AIRPORT

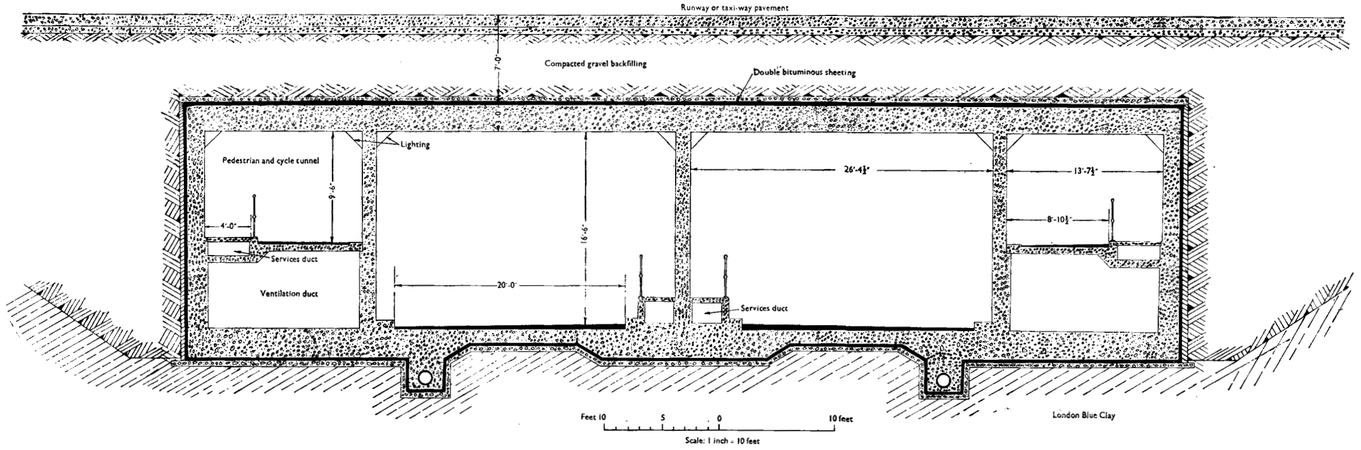

FIG. 11.—MAIN ACCESS TUNNELS. TYPICAL CROSS-SECTION

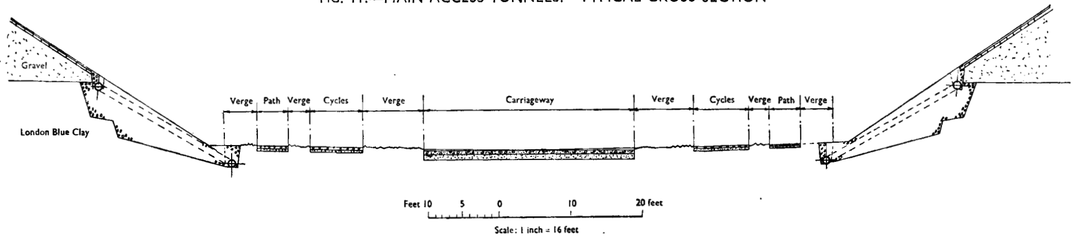

FIG. 12.—TYPICAL CROSS-SECTION OF MAIN TUNNEL APPROACH SHOWING METHOD OF CONTROLLING SUBSOIL WATER

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initially for the full foreseeable length. How was that length to be determined ? Many airfield engineers could remember the time when they had been told that 15,000 ft were necessary, not as a future requirement, but at that date, and he could remember selecting and having surveyed a site for an aerodrome with two runways of that length ; fortunately for the finances of the authorities concerned, it had never been constructed, but had the war lasted for another 6 months he thought that it would have been built.

He was not very clear about the point concerning stopways, on p. 302, and the example given in Appendix I. The airport authorities seemed to have been very fortunate in persuading the operators that the permissible take-off weight could be increased by that extent by so small an extension. He had himself never found that overruns influenced operators in that way. Would it make any difference if one merely cut 400 ft off the length of the runway by putting end-markers on it ?

He could sympathize with the Author on the problem of the bearing value of verges. The 1-in. depression quoted, as being satisfactory, seemed to be very small. He remembered that it had been the specification for a grass runway that the depression should not be more than 1 in. under wet conditions, but it seemed to be a very high standard for verges.

On the question of the central buildings, it would be interesting if the Author could give some of the leading dimensions and areas of the accommodation provided.* The question of scales of accommodation produced more argument than anything else in the design of terminal buildings, which Sir Hubert supposed were in some ways just as important as other parts of an aerodrome. ICAO had provided a large number of recommendations for runways, but had so far been reluctant to give any lead in regard to accommodation. The International Air Transport Association had also been reluctant to do anything, possibly from fear of treading on the toes of ICAO, although both of them had their headquarters in the same building in Montreal. The Author and his colleagues obviously had a wealth of information on that subject, and Sir Hubert suggested that if that information could be made available in a suitable form it would be extremely interesting and valuable to civil aviation authorities and operators—certainly in the oversea territories and probably throughout the Commonwealth. Some figures had been given by Mr Edkins [11] in 1951, but it was likely that they now needed revision, and in any case they had not been very comprehensive.

Mr J. A. Dawson agreed with the Authors comment on p. 299 that aerodromes had had to be superimposed on a civilization based on transport

11. R. G. Edkins, "Buildings for Air Transport Operators." Airport Paper No. 15, Instn Civ. Engrs, 1951.

* This information has, since the discussion took place, been added to the Paper in Appendix III.—SEC.

by rail and water, with the existing interests of which there was frequently conflict in meeting requirements for space and land. Having regard to what the Author had said later in the section of the Paper dealing with noise, he could not help feeling that the inhabitants of urban communities were fortunate that that requirement had not been foreseen and provided for in the planning of the cities.

The noise problem was a very difficult one. As had been indicated, much could probably be done by screening where engines were being run under test or on the aircraft in the maintenance areas, but, as the Author had remarked on p. 325, it was quite impracticable for any effective screening of the noise from aircraft on runways to be contrived. The Author had stated that the abatement of noise from aircraft in the air was entirely a matter for the aircraft designer; but his own impression was that the Author was setting the aircraft designers a problem which they would hardly be able to solve, at any rate for a very long time to come. On the other hand, it seemed to him that, in an indirect way, the problem of reducing the noise level of aircraft taking off from the runways was one to which the aircraft designer could make a contribution. If aircraft could become airborne after a much shorter run and if the take-off could continue at a much steeper angle than it did at present, the take-off run could commence generally at a greater distance from the end of the runway where the take-off run started, and the aircraft would also be high above the nearby accommodation when it crossed the airport boundary. It seemed to Mr Dawson that by that means the situation could be very greatly alleviated. From his own observation he had noticed that the noise when the aircraft was near was very disturbing indeed but by the time that the aircraft was 200–300 yd distant, it had reached what might be called a tolerable noise-level, giving no cause for reasonable complaint by the people living nearby.

He shared the belief expressed by the Author on p. 301 that a smaller number of runway directions would now be found to suffice, but the Author's warning that there must be alternative runways to enable maintenance to be undertaken was very timely. He thought he was right in saying that already at London Airport two runways were in regular simultaneous use, and he had the impression that it might be necessary to bring in even a third runway at peak periods; in those conditions the execution of maintenance work was becoming very difficult. The Author had said that the problem was already comparable with that of the railway engineer; but it was likely to become much more difficult, for the railway engineer generally had an alternative route if he chose his time, whereas the airport engineer might not have an alternative route.

In that connexion, he noted that at present there was high and low intensity approach lighting on two runways only—Nos 1 and 5; was there any intention of increasing the amount of approach lighting so

that more runways could be used in other than conditions of good visibility ? If so, the task of maintenance might be very greatly simplified.

Whilst more than two runways were likely to be required in the future for simultaneous operational use and would be necessary to enable maintenance to be undertaken, it might be (as Sir Hubert Walker had said) that the six runways now available would not be required indefinitely, and that one or even two could be dispensed with. If that were found to be the case, further central development might become possible.

On p. 306 the Author had said that there was no possibility of expansion of the central terminal area should the area originally reserved prove to be inadequate. That was certainly true at the present time, and the necessity for excluding activities which could equally well be carried out elsewhere could not be doubted ; but should the time come when the central area had been completely built up and further expansion was still necessary, it seemed to Mr Dawson that there might yet be a possibility for the central area to break out, as it were, across No 4 runway to the north-east or across No 6 runway to the south-west, thus providing additional space for additional buildings and aprons. He realized, of course, that very heavy expenditure would be involved if that had to be done.

Mr Dawson then referred to the problems which arose in connexion with the manœuvring and parking of aircraft on terminal aprons. With regard to the second system which had been used at London Airport, in which the aircraft entered and left the standing on the same side, the Author had stated on p. 307 that " unless mechanical aids were installed " (and it did not appear that they were proposed at London Airport) " the stand size was a function of the most critical wing-tip turning-circle or jet clearance." The result was that the number of aircraft which could be accommodated was less than would be the case if the aircraft were parked wing-tip to wing-tip, as in the first system, and still less than if they could be parked with fuselages parallel to the apron edge. That involved a considerable sacrifice of parking area which seemed to be rather undesirable if full utilization of the channels provided in the passenger buildings were to be ensured. The area of the inner stands was particularly valuable, for there could be no doubt that operators would have a strong preference for such stands, which could be reached on foot, almost under cover, from the passenger building. There appeared, therefore, to be reasons in favour of adopting mechanical devices : he gathered from the Author's remarks that the arrangements now being made need not be regarded as final and that some alternative might supplant it. There were possibilities of greatly increasing the parking accommodation, and this seemed specially desirable in respect of the stands on the inner face.

Mr Dawson had been personally concerned with the question of the blue clay in the tunnel. The tunnel excavation had passed through the

blue clay to a depth of 17 or 18 ft. The Taplow gravel upon which the airport was founded diminished northwards and faded out just north of Bath Road. If the runways which had been projected north of that road had ever been constructed, a modified design would have had to be adopted. The London Clay formed a first-class foundation, but it had a tendency to slip when wet. In the tunnel cutting it had caused a great deal of extra work. The greatest and earliest slips had taken place on the western slope of the cut, and he wondered if that had anything to do with the original flow of the river. The river had flowed from west to east and the particles of clay might have been laid down in such a way as to cause slips to take place much more readily on that side than on the eastern side where the flow had been away from the line of the cut towards the sea. In the main approach to the northern end of the tunnel the London Clay had been exposed to a considerable depth, particularly at the roundabout immediately north of the tunnel entrance, and precautions had had to be taken to ensure that the slopes were stable. One or two slips had taken place before the work had been completed. The precautionary measures taken included the drain mentioned on p. 329 and shown in Fig. 12, Plate 2 ; that Figure also showed the blue clay cut back and an envelope between the blue clay and the exposed slope. That was the form of the counterforts which it had been found desirable to construct in the blue clay. The main counterforts had been spaced at about 60-ft intervals and the intermediate ones at 30 ft. They had been very successful and there had been no further slips.

Mr R. F. Lloyd Jones referred to the number of runway directions required. Nearly all the developments that had taken place in aviation had complicated the design, but the tendency for aircraft to be able to land more out of wind had actually simplified the designer's problem and the airport operator's problem. He had served on the Panel who had advised on the layout of the runways, and at that time there had been much discussion of the number of directions that should be planned for. The Panel had of course realized the tendency for aircraft to be able to land more and more out of wind, but at that time one could not be quite certain how far the tendency would develop, so that finally it had been decided to recommend the three directions that had been adopted by the Royal Air Force. It might be that two directions would have sufficed, but the whole point of the design had been so to place the buildings that parallel runways came on either side of the terminal area. In that way the length that the aircraft had to taxi was reduced and better use could be made of the two runways. Even if only two directions had been adopted, it was difficult to see how one could have avoided having that central area.

With regard to maintenance, if the Panel had been over-cautious, it was at least a consolation to know that the added runway capacity would perhaps make the maintenance of the runways easier.

The arrangement of aircraft loading bays was still one of the fluid features of airport design. So far, flexibility in the use of the apron had really been one of the most important factors, especially in view of the doubt as to what would be the future clearances and manœuvrability of an aircraft equipped with jet or turbo-prop engines. But as the traffic had increased, the need to keep the aprons reasonably compact and clear of vehicles and people had become ever more important. The actual time taken to park an aircraft by mechanical means might be no less than the time in which it could be manœuvred under its own power, but mechanical equipment might be justified because of its ability to position the aircraft accurately in relation to the fixed servicing equipment, to passenger gangways, and to baggage conveyors; furthermore, it did enable aircraft to be placed much closer together, thus reducing the total area of the loading bays. Already, in present conditions, even in comparatively small airports, passengers had to travel considerable distances between the terminal area and the aircraft—possibly at night and in bad weather. The airline operators were increasingly insistent that the aprons should be so laid out that the passengers could reach the aircraft with the minimum of supervision and, if possible, under cover. The problem had been met to some extent by constructing covered ways between the loading bays, but the development of sufficiently inexpensive satisfactory mechanical equipment would go much further to enable the loading bays to be better arranged in relation to the terminal building.

When dealing with the layout of the runways and in particular of the central terminal area, the Panel had realized the disadvantage of having a restricted space, and it had then been proposed that the freight-handling section should be kept outside the central area. Freight was carried in passenger aircraft and he could understand that operationally there might be objections to isolating the freight-handling section; could the Author say whether in the planning of the airport now it was contemplated that possibly, as the amount of freight increased and there were aircraft specially designed to carry freight, that part of the traffic would be handled outside the central area?

The Panel had also been concerned with the question of how much interference would result from aircraft being removed from the central area to the maintenance areas by reason of the fact that in being removed they might very well have to cross one of the runways in use. It seemed to Mr Lloyd Jones that under peak conditions when the build-up of aircraft on the aprons might be quite rapid, or during conditions of bad visibility, it might still be quite a serious problem.

Mr L. B. Haley could not agree with the Author's comments on the journey time for passengers between London Airport and Central London. The coach-journey time of 50 min mentioned on p. 929 seemed to him to be too long. While he appreciated all the difficulties of siting and the

difficulties of the London traffic, he did not think that a journey time of 50 min should be accepted as the best that could be done. The passengers, when landed at London, wished to disperse to their personal destinations, whether hotels, railway termini or other points, and from the time they landed they were interested in getting to those personal destinations as quickly as possible. If a passenger were taken from the airport to some point in London which was not particularly convenient to him and then had a further journey to make, the total time involved might be an hour and a half.

Various suggestions had been made in the past about improving transport from the airport—for instance, by extending the Underground system or even the railway system. But the central area itself was so large that even if a station could be located in the central area, the passengers would still have an uncomfortably long walk to their particular channel from such a station, carrying their baggage with them. He therefore suggested that a coach which could deposit the passengers at the entrance to their own channel was probably the ideal conveyance at that stage. On the other hand, he suggested that at the other end of the journey, in Central London, a coach was the wrong conveyance. If the coach-journey time could be used on arterial roads, such as the West Road, and the passengers be decanted at some other point convenient to the London Transport system from which they could disperse to their own destinations, he suggested that the overall journey time might be reduced.

On p. 308 the Author had mentioned the use of the Brabazon initial weight for the design of the runways. Mr Haley agreed that at present it appeared that the all-up weight of civil aircraft was unlikely to exceed 250,000 lb., whereas the Brabazon weight used in the design had been 360,000 lb., but he felt that it should not be assumed that 250,000 lb. was likely to be the maximum weight indefinitely. It might well be that in 30 years' time operators would thank the designers for their foresight in using 360,000 lb.

On p. 312 the question of the use of mechanical aids for parking in the central area was raised. He was very pleased that there was reference in the Paper to single-wheel turn-tables. He understood that such turn-tables had been used very successfully in America for the maintenance positioning of aircraft. They were being considered in Britain for that purpose, and they might well be a useful aid in the parking not only of single-wheel aircraft but of bogie-undercarriage aircraft. It was stated in the Paper that the minimum turning radius for an aircraft with the bogie undercarriage was probably 15 to 35 ft. The lower figure was just about acceptable for the Comet I, but he thought that for design purposes 35 ft would be a much safer figure to use as the minimum. That was, even now, not quite the acceptable minimum for the Britannia. The distance between centres of undercarriage legs of an aircraft of that size

was about 30 to 32 ft, so that the turn-table could be used to position even bogie-undercarriage aircraft quite readily.

In the design of the passenger channels, briefly outlined on p. 315, obviously the aim was to give the passengers the shortest possible route from coach to aircraft. He knew of cases overseas where the layout of the central area was such that the passenger was made to walk an unnecessarily long distance in order that space might be given for concessionaires, for instance. Such walks were very irritating at the end of a long flight.

The part of the noise problem referring to buildings could be satisfactorily overcome. Recent experience in one of the maintenance buildings, mentioned in the Paper, had shown that precautions could be taken successfully against run-up noise at very short range. The problem of screening localities, however, was much more complex.

Mr H. G. Gullan pointed out that the airport was sited between two important trunk roads, A4 and A30, and on the west side it was bounded by the Perry Oaks sludge disposal works. Therefore, if it was necessary to extend the airport either in the east or the west direction, i.e., the direction of the main runways, the expense of undertaking that task might be considerable, not necessarily in the cost of the engineering work, but in the cost of acquiring land and buildings, which often reached many times the cost of the actual engineering work.

On p. 300 the Author had mentioned helicopter terminals. Mr Gullan felt that provision for such facilities should be planned. Once helicopters could be automatically controlled and greater pay loads were possible, they would no doubt be a very important means of transportation, particularly as road and rail transport in and out of London became more congested. Adequate sites at the main airport would require to be provided within easy reach of the terminal buildings.

With regard to the layout of the airport, he felt that possibly even at such a late stage careful consideration might be given to the adoption of dual runways in two directions. He suggested the possibility of removing, say, runways Nos. 2, 4, and 6, and possibly re-providing runway No. 2 parallel to and to the west of runway No. 7. He realized that No. 7 was a short runway in comparison with the other parallel one, but it could probably be extended. The advantage of doing that would be that it would immediately de-restrict four funnel areas and therefore give more land for industrial development adjacent to the airport. It was agreed that an airport should be as near as possible to its centre of population. Development of the central terminal area would immediately be relieved of the difficult car-parking problem and sites adjacent to the terminal area would be available. Helicopter sites might also be found. Underground subways would be reduced to the minimum, and, bearing in mind the high-water table level, those provisions called for considerable capital and recurring expenditure. Much easier access would be available

between the terminal area and the main maintenance area located in the eastern quadrant, which already appeared to be congested. Maintenance areas Nos 2 and 3 could be joined.

On p. 303 the Author had drawn attention to the hazards of an aircraft running off the runway. Mr Gullan mentioned the possible hazards of small objects in the over-runs, such as kerbs, small radio buildings, airfield lighting poles, and such facilities. There should be no tolerance allowed for such apparently minor obstructions, and he suggested that the change of strength of the surface from the pavement to the over-run area should be gradual.

Several speakers had already mentioned the handling of aircraft. He considered this to be a major problem at all airports, and unquestionably it was one that required a vast amount of research and ingenuity. He felt that before many years had passed, mechanical handling would reach a stage of perfection which would relieve many of the present-day problems. Possibly low-loading platform vehicles capable of taking each or all of the main wheels of the aircraft and being controlled either remotely or under their own power would be available for use. These low loaders could be operated by chain, rope, or worm gear and rail-guided to avoid possible collisions; small turning-circles could be arranged. Once the aircraft could be strictly controlled to particular flow channels, the extent of high-strength concrete paving required for taxiways and aprons might be considerably reduced. As an interim stage, would it be possible to provide channels formed in the concrete around the outer edge of the hard-standing which might guide the aircraft while turning ?

He noted (p. 314) that the visual control tower was located on the ninth floor at 126 ft above ground level. Was that building so high because of the restricted area within the terminal centre ? Lack of space in that area would increase the number of storeys which might normally be provided if adequate space were available.

Generally speaking, it was best to handle passengers and freight at ground level, but Fig. 8, p. 316, showed that when the passengers entered the airport they arrived first at ground level, then they dropped to subway level, then rose to ground level at the terminal building; next they descended from the bus, then ascended by a moving staircase to the first floor after a longish walk through the terminal buildings, dropped to apron level, and then finally climbed more steps into the aircraft, about 200 yd in all.

The baggage also arrived at ground level at the terminal buildings and was off-loaded on to a conveyor which took it direct to the first floor, then after customs inspection descended to a level below apron level, and once again was raised to apron level and finally into the aircraft. He had no doubt that there were very good reasons for that arrangement, but without further clarification it was difficult to see why so much energy

had to be expended by the fare-paying passengers and hard-worked porters who had to handle the baggage.

On p. 317 the Author had mentioned car parks and garaging. There was no doubt that car parking facilities and lock-up garages were an essential requirement on any modern civil airport. Space at ground level had to be provided if economical facilities could be readily provided. Underground car parks would be too costly, and above-ground parks would also be costly and might form obstructions to air-traffic control. He presumed that that facility had been catered for adjacent to the terminal buildings.

Navigational aids were mentioned on p. 318. In Mr Gullan's experience, they played such an important part in the design of any airfield that they had to be stated and settled in the very earliest planning stages.

It might appear that the fire-fighting equipment (p. 319) had been provided for with a somewhat pessimistic outlook. He noted the following water requirements were provided for: airfield, 800 g.p.m; buildings, 1,500 g.p.m; maintenance hangar, 7,200 g.p.m—a total of 9,500 g.p.m. The seven pumps each delivered 1,850 g.p.m—a total of 12,950 g.p.m. for the seven pumps. On p. 321 the Author had stated that the fire main was designed for supplying a total of 9,000 g.p.m. Should that not read 11,000 g.p.m, which allowed for a further 1,500 g.p.m discharged at the hydrants in the maintenance area ? If that was correct, then one pump was required to overcome the friction of the system, and no standby pump was provided. On that basis the installation was capable of dealing with two large aircraft on the airfield, a fire in the terminal area, in the maintenance area, and in a hangar where the deluge installation was provided, and not just two dissimilar incidents, as stated on p. 321.

He suggested that it would be helpful if the Author could indicate on Fig. 5, p. 308, the position of runways Nos 2 and 5. The distance between the centre-line of the runways and centre-line of the outer 120-ft taxiway was 760 ft. The area between the outer taxiway and the 150-ft diameter standings was grassed, and the dotted taxiway was given as 80 ft in width.

Dr R. A. Mackay referred to the geology and drainage of London Airport. His premises were the geological map and a few observations made from the Great South West Road (A.30). At first sight there should be no serious drainage problem. The airport was situated near the top of a height of land between the Thames and its tributaries, the Crane to the east and the Colne to the west. It was mainly on the Taplow gravel, and the flood-plain gravel lay to the south. Such a gravel site was absolutely ideal for an installation where drainage was important. Why, then, was there 80 miles of pipe, some of it very heavy, with more perhaps to come ? The mere placing of the large aprons did not increase the amount of water falling on the ground, and the run-off from a gravel terrain should mainly be handled by passing the water back into the existing natural drainage.

However, closer examination showed two unusual characteristics. First, there was clearly a permeability barrier to the south of the airfield, possibly near or at the boundary of the Taplow and flood plain gravels. That would result in a substantially higher water table north of the road than in the area of the Southern Balancing Reservoir. Secondly, the Longford River was in part artificial and the Duke of Northumberland's River totally artificial. Those rivers, both of which emanated from the Colne (despite cementing over part of their length), fed the upper, or perched, aquifer.

In 1954, Dr Mackay had noticed a large drain more than 4 ft in diameter, apparently leading to the Southern Balancing Reservoir; the manhole cover had been off and, despite recent rain, it had been empty. Two other parallel drains had sounded empty. At the same time the Duke of Northumberland's river had been running with an apparently greatly augmented content of storm water in contrast to the relatively sluggish Longford by its side. That suggested substantial pumping into the Duke of Northumberland's River (which incidentally had been running at a level above the cement and thus further feeding the aquifer from which it had presumably been pumped).

It seemed, therefore, that something had gone wrong with the original plan—to have those large pipes empty and an excess in the Duke of Northumberland's River. It might be that there was a danger of flooding, since there had been flooding round Feltham some time before. Perhaps there was an excess of water for which provision must be made if it was not to be allowed to go through the Southern Balancing Reservoir outfall.

As a geologist Dr Mackay wondered if the flooding at Feltham had been merely temporary, caused by a temporary breach in a clay barrier between the upper and lower water tables during construction of the Southern Outfall, which must have let down a great deal of water from the former to the latter. Thus protection (by pumping) was perhaps being provided for what was actually a temporary derangement. If that was so, it would seem that the cheapest way would be to let down water from the upper into the lower water table by suitable engineering means —the existing outfall plus a sub-surface weir, for example—during periods of light rainfall, thus creating reservoir space in the pores of the Taplow to take any heavy rains. Obviously a foot let-down would deal with rain in excess of 2 in. if that were put back down into the gravel.

A further point which might be considered was whether the Longford could not be stopped off at the Colne and re-fed from the Duke of Northumberland's River below the airport, through a little weir, with only that amount of water necessary for Hampton Court.

Finally, any expensive solution contemplating by-passing the water to the east could, apart from unnecessary expenses, lead to a deficiency of water for the gravel workers' pits near the Southern Boundary Reservoir.

Mr W. J. Nicholls asked whether anything had been done to the ends of runways to make them safer for aircraft landing. The pilots of heavy aircraft very naturally tried to put them on the ground near the end of the runway in order to give themselves a long run to a stop. Recently serious accidents had occurred because the aircraft had hit the proud end of the runway damaging the undercarriage. He suggested that the runway might be taken down into a slope of perhaps 1 : 20 or 1 : 30 and then covered with soil, so that the undercarriage of an aircraft landing short would be cushioned and not subjected to impact loads in a horizontal plane.

*** **Mr W. T. Shaddock** referred to the Author's mention of several miles of public highways which had had to be reprovided or diverted in connexion with the development of London Airport. The highways concerned included Hatton Road (A.312), Heathrow Road (B.379), Long Lane, Oaks Road, Tithe Barn Lane, High Tree Lane, Goathouse Road, Cain's Lane, Cranford Lane, Lock Lane, Green Lane, Spout Lane, and Stanwell Road. Those highways, having a total length of about 10 miles had been stopped by virtue of a series of Orders made at various dates from the 1st March, 1949 to the 22nd May, 1952, under either the Civil Aviation Acts or the Requisitioned Land and War Works Acts. Provision had been made for the construction of substitute roads having a total length of about 5 miles. The substitute roads were :—

(*a*) On the west side of the airport, a road extending from a point on the Colnbrook Bypass (A.4), west of the River Colne, in a southerly direction to the junction of Stanwell New Road (B.379) with Park Road (B.379).

(*b*) On the south side of the airport, a road extending from the junction of Stanwell Road with the Great South West Road (A.30) in a north-westerly direction to a point on Stanwell Road east of Stanwell Farm.

(*c*) On the east side of the airport, a road extending from a point in Faggs Lane (A.312), south-east of its junction with the Great South West Road (A.30), in a northerly direction to a point in Watersplash Lane, crossing both the Great South West Road (A.30) and the Great West Road (A.4).

The greater part of those works had been completed. The total estimated cost was of the order of £350,000.

Mr R. P. Whiting referred to the Author's point that the cross-wind component acceptable to modern aircraft meant that one or two runway directions would probably suffice. The Author had, however, also stated that " even though the slight increase in usability might not now alone be

*** This and the following contribution were submitted in writing upon the closure of the oral discussion.—SEC.

considered to make an additional runway direction essential, the need in addition for facilities to undertake maintenance work might well do so." In fact, however, that need justified only an additional runway and not an additional runway direction. If a runway was out of service the best substitute was a parallel runway, not one in another direction. Moreover, failing a parallel substitute, a runway at right angles was almost as good with regard to cross-wind component as a runway at 60 degrees; thus the need for additional runways to allow for maintenance scarcely justified having more than two runway directions at right angles.

The Author had attempted further to excuse the existence of four subsidiary runways at London Airport by stating that they were used as taxiways. However, since they were $2\frac{1}{2}$ or 3 times as wide as taxiways needed to be, that was scant justification.

It seemed clear that London Airport could provide substantially the same usability if it had four runways, two in each of two directions at right angles, instead of its present complement of six. The money spent on the additional two runways could have been better spent on another airport, such as Gatwick, to provide additional usability in bad weather. Mr Whiting was not criticizing those responsible for the layout of London Airport, for, at the time, as the Author had pointed out, it had been considered necessary to design for a lower cross-wind component than was accepted today. However, in the design of future airports it should be recognized that with modern aircraft there was normally no need for more than two runway directions, and often one was sufficient.

The Author, in reply, said that Sir Hubert Walker, Mr Gullan, and Mr Lloyd Jones had referred to the number of runways and to the possibility in the future of dispensing with some of them, thereby easing the problem of restricted space in the central area. It was probably true that if London Airport were to be replanned today, a smaller number of runways would be provided, but that did not necessarily mean that the runways which already existed were redundant. The runways were in use at the present time, and it was possible that with developments in the future they would continue to make such a contribution to the capacity of the airport as to justify their retention.

In the Paper he had referred to the fact that the runways when not in use for take-off and landing were utilized also as taxiways to gain access to other runways. If runways Nos 2 and 4 were scrapped, alternative means of access would be necessary from the central area terminal aprons to the end of runways Nos 1 and 5. Access would also be necessary from No. 1 maintenance area to the central area and to runways Nos 1 and 5. The space occupied by the taxiways thus required and the clearances from them would utilize quite an area of the land which might otherwise be considered to be made available by abandoning runways Nos 2 and 4.

Mr Lloyd Jones had raised the question of the interruption in the use of

the runways by the taxiway from No. 1 maintenance area. The Author could not give any factual information on the extent of interference thus caused, but the problem existed and obviously restricted the use of those two runways.

Several speakers had mentioned the maintenance problem on runways, to which he had referred in the Paper. Although it was a problem, he did not want it to be over-emphasized. It was merely one factor which must be considered in conjunction with others when the number of runways at an airport was under consideration. As he had mentioned in the Paper, there were often means by which maintenance work could be done even at a single-runway airfield. In a recent instance it had been found that, because traffic mainly occurred at night, the runway could be made available for maintenance work by day and be returned to use each night without interfering unduly with operations.

On the question of stopways, he thought that the problem of determining the length required was not so difficult as Sir Hubert Walker imagined. The solution was derived from formulae based on the performance of the aircraft, and those performance data were accepted by the operators in just the same way as they were by the authority which controlled the aerodrome.

On the bearing value of verges, it should be realized, in referring to a depression of 1 inch as being the criterion for a grass airfield in the past, that the tire pressure of aircraft was now very much higher than it had been. In the days of grass airfields, tire pressures had been of the order of perhaps 30 lb. per square inch and they were now rising to 100 and 120 lb. per square inch, and with some aircraft of the future would be even higher. That was a very different problem from the one which had been met with in grass airfields.

Sir Hubert Walker had asked for information on the extent of the accommodation provided in the terminal building. That information was given in Appendix III which had since been added to the Paper.

Mr Dawson, in referring to the noise problem, had mentioned his own observation that the noise of an aircraft seemed to diminish very rapidly with distance. It was perhaps a fortunate fact that the noise of the more objectionable frequencies was absorbed more rapidly as the distance increased, so that, although the noise still persisted at long range, with distance it became more of a low rumble rather than the piercing noise that people found so objectionable.

On the adequacy of the central area, the capacity which would be needed was necessarily tied to the capacity of the aerodrome to accept aircraft movements. It was true that the traffic through the central terminal area would be affected also by the number of passengers carried by each aircraft; but at least there was some limit to the amount of expansion that might be required.

Several speakers had referred to the use of mechanical aids for parking.

Mr Lloyd Jones had hit the nail on the head in that matter: the great point at the moment was the time taken in the use of the mechanical aid. At a busy airport, aircraft might be passing along the taxiway perhaps every minute at a peak period, and for a mechanical aid to be of value it must be such that it would not restrict that flow of aircraft. For a mechanical aid which would completely remove the aircraft from the taxiway to be of value, it had to be possible to load the aircraft on to whatever device was used for conveying it and to haul it completely clear of the taxiway within the space of a minute. So far as he knew, no device had yet been produced which would meet that requirement. The reason the single-wheel turn-table was more promising was that the turn-table was located on the standing and the aircraft taxied off the taxiway under its own power, so that the time during which the taxiway was obstructed was not a factor.

One other drawback to a mechanical aid was that at an airport which accepted aircraft of all types the spacing of the mechanical aids must be such that they could cope with the largest aircraft that need be handled, and even though a particular aircraft might be a very small one, it still needed to use the same mechanical aids. Thus the gain in the use of apron space and the greater concentration in the parking area referred to by Mr Lloyd Jones would not be perhaps all that might be hoped.

The Author was grateful to Mr Dawson, who had a very detailed knowledge of the problems that had been met in the construction of the airport, for the additional details which he had provided on the site problems in constructing the tunnel. There was no immediate intention of equipping additional runways with high- and low-intensity approach lighting.

Mr Lloyd Jones had inquired what arrangements were proposed for handling freight. At the moment freight had to be handled outside the central area because in the first phase of development no provision for it had been possible, but it was planned that a freight-handling shed should be provided there. At present the majority of freight was carried in passenger aircraft, the number of pure freighters being very small. That dictated that the freight accommodation should be located close to the passenger-handling buildings.

The Author agreed with Mr Haley's comments about access into London, although perhaps the matter was rather outside the scope of the Paper. The great difficulty about most of the schemes that had been produced for improving the access into London was that they would be extremely expensive if they were to reduce the time drastically, although it was possible that the time might be reduced by 10 or 15 minutes by road improvements.

Mr Gullan had mentioned the problem of helicopters. At the present time the requirements for operating helicopters were fairly modest, but there was still some doubt as to what would be required in the future. At

present they were being handled at London Airport at the end of No. 1 runway, that runway being temporarily not in use. For the future, various sites in and around the central area were under consideration. It might be that Mr Gullan's suggestion that part of a runway which was not in use might be the answer for the future ; but at present it was too early to say.

Mr Gullan and Mr Haley appeared to consider the planning of the passenger-handling building from different viewpoints. Whereas Mr Haley had referred to the shortness of the route through the building, Mr Gullan had commented on the complications of the passengers' journey. To reply to Mr Gullan, the explanation of what might appear to be the devious route taken was that the passenger-handling building had to provide for many activities related to the operation of the aircraft in addition to the mere handling of the passengers and their baggage. Those activities were such that there had to be ready access from the accommodation devoted to them to the apron and the aircraft. It was simpler to take the passengers up to the first floor and through the building at that level thus leaving the ground floor free for the ancillary services which had to handle bulky and heavy equipment. From the first floor, passengers and their friends also had ready access to the amenities provided for them on the upper floors of the building.

Mr Gullan had suggested that the siting of the airport between two main trunk roads was to be deplored. In fact, he thought that the future had been adequately safeguarded. As could be seen from Fig. 2, Plate 1, runways Nos 1 and 5 were sited so that extension westwards would readily be possible in the future without any interference with the sewerage works. In fact, the boundary of the land which had been acquired included sufficient space for some extension of the runways if required. There was also space available for the extension of the two principal subsidiary runways southward. He therefore felt that future extension should not be any great problem.

Mr Gullan had also referred to the danger presented by small obstacles in the runway approaches. In the past there had been obstructions of that sort, but now the number of radio aids, for example, which must necessarily be sited in the approach was very small and work was in progress to reduce the number still more. Airfield lighting poles and other obstructions which had to exist were designed to be frangible, so that if by mischance an aircraft should accidentally come into contact with them, they would break without causing any serious damage to the aircraft. He had anticipated that someone who had passed London Airport might refer to the steel gantries carrying approach lights that one saw from the main roads on the approaches to the runways there. But those structures were actually at such distance from the end of the runway that they were not obstructions.

The suggestion that the strength of the surface from the end of the

pavement should be subjected to a gradual reduction was perhaps an ideal, but he thought it would be very difficult to apply. It was difficult enough to draw up an engineering specification which would meet the present I.C.A.O. requirements for the strength of stopways and verges. To attempt to provide a gradually diminishing bearing strength would, he thought, be impossible. In a way the proposal was already met, because the recommendation in I.C.A.O. Annex 14 for a stopway was that the first portion beyond the end of the runway should be prepared so that an aircraft could run on to it without hazard, whereas the area beyond the stopway was defined as an area which had to be prepared in such a way that the hazards were minimized—a slightly lower standard.

Mr Gullan's suggestion that channels might be provided in the concrete paving to an apron as a guide to aircraft going into their parking bay would be rather difficult to apply, because the apron also had to be traversed by the many vehicles which were used in servicing and otherwise attending upon an aircraft; they would find channels in the concrete rather difficult to negotiate.

The height of the control tower was determined by two considerations: first, it had to be possible for the observer in the control tower to have an angle of vision to the most distant part of the airfield, sufficient to enable him to distinguish between one aircraft and another on the pavement; and secondly, he had to be able to see over the tops of the buildings by which the control tower would ultimately be surrounded; those buildings would be of three storeys, the number of storeys being dictated not so much by restriction of space as by the fact that a large number of facilities had to be concentrated near a limited frontage of apron in order to provide all the services which were needed.

It was the intention to provide car parks on quite a liberal scale in the central area, but the Author thought that the problem of the traveller who wished to leave his car for a period was best met by providing garages outside the central area to which cars could be driven by attendants.

On the question of fire-fighting facilities, he joined issue with Mr Gullan on his choice of words; he would prefer to say that they had allowed for the requirements on a prudent scale rather than on a pessimistic one. It was true that they might appear to have been looking on the gloomy side, but it was far better to have provided for all reasonable contingencies than to have insufficient water to deal with a disastrous fire. As to the capacity of the system, they had actually allowed for two dissimilar incidents, with one pump as standby, but the design of the pumps and the design of the installations which called for the quantity of water had proceeded concurrently, and the figures on which they had planned had changed after the pumps had been ordered, resulting in the discrepancies mentioned by Mr Gullan. The requirement of about 9,000 gallons a minute allowed for one deluge being in operation and the worst of the remaining contingencies,

i.e., a requirement for 1,500 gallons a minute for other fires, giving a round figure of 9,000 gallons a minute.

On the location of the runways in relation to the central area, No. 2 runway was parallel to the N.E.–S.W. length of the outer taxiway seen in Fig. 5 (p. 308) and located 760 feet away, centre to centre. Runway No. 5 was parallel to the E.–W. length of the outer taxiway seen in Fig. 5 also at a distance of 760 feet, centre to centre.

He was grateful to Dr Mackay for his exposition of the geology of the site. The explanation of the differing water levels in the upper and lower gravel beds was in fact that there was a clay barrier just south of the airfield which had been met when laying the outfall drains to the south. It was correct that the phenomenon of the empty drains had occurred because works were being carried out on the Southern Balancing Reservoir and for a time the flow was being pumped out of the outfall drains leading to the south into the Duke of Northumberland's River.

Parts of the area south of the airport were liable to flood and the discharge of storm-water into the flood plain gravel, although an attractive solution, was likely to lead to legal complications. Use of the Taplow gravel for storage had been considered, but since in the central portion of the airfield the subsoil water had to be controlled at a low level in connexion with the drainage tunnels, that expedient had not been adopted.

The possibility of discharging storm-water into the Longford or Duke of Northumberland's Rivers as a permanent arrangement had also been investigated but, apart from the continuous pumping costs which would have been involved, it was a solution which was not acceptable to the authorities controlling the rivers.

Mr Nicholls had raised the question of the ends of runways. The ends of runways should not present any hazard to aircraft, and in general it was sufficient if the end of the runway and the surface immediately beyond were prepared to the same level. But there were circumstances where merely to do that was not satisfactory, and the solution suggested by Mr Nicholls had in fact been adopted at a new runway with which the Author had been concerned in Khartoum about 2 years previously; the ground adjacent to the end of the runway had originally been prepared to the same level as the paved area, but during the dry season erosion by wind and during the wet season erosion by water had been such that very soon there was a step; the solution adopted had been that suggested by Mr Nicholls—sloping off the surface at the end and covering it over with soil, thereby safeguarding against any mishap.

The Author thanked Mr Sharrock for the information he had provided on the road diversions necessitated by the construction of the airport.

He agreed with Mr Whiting's comments that the best substitute for a runway which was out of service was a parallel runway, but observed that it was very doubtful whether an additional runway would ever be provided solely to facilitate maintenance work. Should an additional runway be

considered, other factors were likely to figure in the choice between a parallel runway and one with a different orientation. If, as in the passage quoted, the other factor was an increase in usability, the choice would be an additional runway direction even though that would not be the best alternative for the original runway.

Mr Whiting had accepted the necessity, at the time the layout was planned, of providing the additional runway directions, a conclusion with which the Author agreed. The comments in the Paper on the secondary functions which were met by the runways had not, therefore, been made in any attempt to excuse their existence but rather to draw attention to the merits of the layout as judged by the conditions which had to be met at the time it was planned.

The closing date for Correspondence on the foregoing Paper has now passed without the receipt of any communication.—SEC.