Discussion

The Author, in introduction, said that he had been asked to draw attention to two points which he had not mentioned in the Paper.

The first was that, on undulating sites, it was often difficult to decide how far cost should be incurred in eliminating longitudinal changes of gradient along the runways. Although limiting gradients and rates of change of gradient were set out in the I.C.A.O. report, if they were strictly applied they sometimes produced unsatisfactory results from the pilot's point of view.

That had never come within the Author's experience on aerodromes which had been designed to the I.C.A.O. standards. Perhaps the answer to it lay in what he had tried to stress in other connexions in the Paper—that the designer should apply the standards with reference to the aeronautical arts, and, if he had not the knowledge to do that himself, he should refer his proposals to somebody in authority who had. For example, the early airstrip at Mtwara—referred to in the Paper—had been cut out of a sisal plantation with the minimum of regrading. After a time it had proved to be short for the planes that used it, so that they had had to touch down on the extreme end of the runway and, when landing into the south-east monsoon, they had touched down on a rising gradient. Quite soon after landing, the gradient reversed over a crest, and that either threw them into the air again or, if it did not actually do that, it introduced an unpleasant element into the landing process. Of course, in that case, the gradients had not been to I.C.A.O. standards, but it was an illustration of the kind of thing to avoid.

The second point was a question. How far could increased constructional costs be justifiably incurred in order to produce a convenient and compact runway and taxiway pattern? That problem again usually arose on undulating sites.

The Author did not think it was possible to generalize on that question. Each site presented an individual problem. The anticipated volume and nature of air traffic was usually the deciding factor in determining the extent or complexity of the lay-out to be provided and, generally speaking, the usual course was to provide at first only sufficient for the traffic expected during the next few years, within the framework of a master plan of ultimate possible development, more and more of which could be added as time went on and as increasing traffic created the need and warranted the expenditure. Of course, care should be taken that what was planned for the future could be built without interruption of the air traffic using what was there already.

Mr R. L. Fitt remarked that he would first like to endorse all that the Author had said about the various unknowns which had to be solved before

a modern aerodrome could begin to take shape on the drawing-board and in the field. In fact, since he had helped the Author a little in the preparation of the Paper he could not very well do other than agree with all that the Author had said. Ahead there lay uncharted territories of aircraft development, and the engineer felt a bond of sympathy with Christopher Columbus, of whom it had been said that when he set off to discover America he did not know where he was going, when he got there he did not know where he was, and when he got back he did not know where he had been.

In facing those perplexities the engineer might take comfort from the fact that a similar state of affairs existed in the early days of rail and road development, and in the gradual evolution of water-borne traffic from small sailing craft to the present great ocean liners. In connexion with railways, one thought of the cost which the Great Western Railway had incurred in having to change its gauge, and of the similar problems which confronted such countries as Australia, India, and, particularly at the present time, the continent of Africa, as railway systems extended and needed linking up if traffic was to flow quickly and cheaply.

In the case of air transport, development was proceeding at a bewildering pace, and, as the Author had pointed out, the time-lag which inevitably resulted between the collecting together of information, its discussion at various international conferences, and subsequent issue in the form of official documents for the guidance of the engineer, was such that much of the information necessarily remained somewhat vague and nebulous and some of it was out of date before it became available for general use.

In common with the aircraft designer, the civil engineer—and it was true also of his mechanical and electrical colleagues—had two main considerations before him : the first was to ensure the safety of air travellers, and the second was to achieve maximum economy in costs. The growth of popularity of air travel had not suffered from accidents brought about by inadequate design of airports. The Author had quoted the only such accident which was known to him. Such few accidents as had occurred in or near airports had generally arisen from some error of judgement on the part of the pilot, or from failure of aircraft engines or equipment at take-off. Improvements in lighting and radio aids were continuing to increase the serviceability of airports at night and in adverse weather conditions, but those developments brought in their train associated problems of the proper width and length of runways and over-runs. Up to the present, however, it could not be said that safety had been sacrificed by the engineer in the service of economy.

With regard to cost, the engineer had to bear in mind not only the initial capital cost and the cost of maintenance but also the incremental costs which might occur as and when extensions to runways and taxiways became necessary to meet the demands of new and heavier types of aircraft. Here the airport engineer was on common ground with his col-

leagues who were concerned with the design of trunk-road systems. He had to ensure, so far as he could predict it, that the foundations which he had created in the initial development were of sufficient strength to carry any loading which might be called for in the future. That he could do in the case of flexible runways, for instance, by thickening the runway surfacing ; but he could perform a valuable service in the initial stages, if funds permitted, if he could arrange for the major element of strength to rest in the base-course materials, which were in most cases available locally and at less ultimate cost to his employer.

By far the largest item in the cost of any new airport was that of the runways, and it would be of inestimable value if some limitation in overall basic length could be established and if aircraft designers could be called upon to work within those limits. Such a development had been forecast in a Note issued by the International Air Transport Association in February 1950, in which it had been pointed out that the cost of aerodrome production had risen at such a rapid rate that an arbitrary limitation of runway length might be imposed by I.C.A.O. or by individual States in the near future. It was felt that a basic length of 8,400 feet would not impede aircraft development and would not affect the operating weights of present-day aircraft, but would serve as a guide to aircraft manufacturers when designing new aircraft.

It could be appreciated that, at the present period of rapid development in the aircraft industry, it might be considered a retrograde step to set limits to the length of runway and to the unit loading on runway surfaces. On the other hand, the introduction of a new type of aircraft, with heavier wheel loadings and requiring longer lengths to take off and land, might mean a very heavy capital expenditure on airports throughout the world. It was a sobering thought that the list of land aerodromes required for regular use by international air services in the European-Mediterranean Region alone contained more than a hundred names.

The Author had very rightly emphasized those points and had drawn particular attention to the possibility of achieving economy, where site conditions permitted, by a reduction in the length of fully paved runways with increased length of over-run. He had also drawn attention to possible economies on the runway verges and in the preparation of the supplementary strips. It would be helpful, particularly in the case of a very long runway such as was required at the altitude of Nairobi, if some critical angle could be established with its apex at the I.L.S. localizer beacon within which it was considered essential to provide a fully paved runway. Possibly that critical angle could be varied to cover differing degrees of minimum visibility at individual airports and the maximum cross-winds which were likely to occur at those airports.

The Author had also drawn attention to the gradual flattening of approach and take-off angles. There were surely existing airports at which it would be very difficult, and even impossible, to reduce the slope

from 1 in 50 to 1 in 100. That slope was of great importance in siting airports, and if it were to be reduced to 1 in 100 the figure should be established as the irreducible minimum for all future aircraft operations. Unless airports were going to be sited at long distances from important centres of population, the sterilization of large areas of land would represent a very considerable incremental cost to the authorities owning the airports.

On p. 288 the Author had drawn attention to certain shortcomings in the published information on basic runway lengths for various aircraft types. In that connexion, Mr Fitt was very pleased to note that the European-Mediterranean Regional Group of I.C.A.O. had recently drawn attention to the fact that the tabulated characteristics of aircraft did not include sufficient information on take-off and landing lengths under standard conditions, and had recommended that that information be made available. Furthermore, they had noted that adherence to the code limits of Annex 14 might eventually lead to standardization of aerodromes and of the aircraft using them.

Mr J. A. Skinner observed that in the present age of standards there was an increasing demand for clear-cut requirements for airfields. The problem which had to be faced in the laying down of standards was that they had to apply universally and, so far as airfields were concerned, they had therefore to apply all over the world, to all climates and to all nations, whatever their particular engineering outlook. That last point was perhaps sometimes overlooked. At the same time, the standards had to be reasonably permanent if they were going to be of any real use, because otherwise airfields would become out of date as quickly in the future as they had in the past.

It would be natural to say that no standards for airfields should ordinarily be written in the absence of complete standards for the aircraft using those airfields. Such standards did not exist. Perhaps the aircraft designer did not wish to be so standard-bound as the engineer. Although he understood that I.C.A.O. laid down certain operating requirements for aircraft, they were by no means comprehensive and they did not in fact cover precisely such important requirements as the ability to land across the wind, a factor which he considered had an enormous bearing on the cost of airfields. It was also noted that, as the Author had mentioned, in certain cases specified aircraft performances did not in fact agree with the airfield standards so far as approaches were concerned; but Mr Skinner understood that that had been put right by I.C.A.O. at a meeting held during the autumn.

To his mind, the three most important factors in the economics of airfield construction were the number of runways, the strength of the runway, and the length of the runway. He felt that other factors, such as clearances and widths, were insignificant compared with those. Even the approach clearances became less important as orientation became less critical.

The main factor which would affect the siting, the cost, and even the

possibility of building an airfield in a particular location was the number of runways required. On the question of the number of runways, I.C.A.O. Standards were very non-committal. The subject was largely bound up with the unspecified cross-wind component, and the fact that that cross-wind component was, he understood, constantly going up meant that the one-runway airfield all over the world was getting nearer and nearer. Fifteen years ago it had been assumed that aircraft required a triangular system of runways, but now military aviation had gone so far in some cases as to accept a single-runway airfield. In between, there were the criss-cross parallel runways, as at London Airport, Catherine-wheels, stars, and a host of patterns which might in the future be regarded as representing only a passing phase.

The other essential standard demanded by the engineer was the strength to which the runways should be built. There again the question was very complicated, since throughout the world there was no agreed method of expressing the load-bearing characteristics of aircraft, particularly those with multi-wheel undercarriages. There was also the fact that the undercarriage design seemed to be constantly changing. The aircraft designer was obviously trying to help the engineer by spreading the load and putting more wheels on the aeroplane, but Mr Skinner noticed that tire pressures were being increased in order to make those wheels smaller so that they could be stowed away, which in effect made the aerodrome engineer's problem more difficult, since more attention had to be paid to the surfacing. Until aircraft loading and undercarriage design had become much more stabilized and established than they were at present, it would be very difficult for any international organization to lay down strength figures for use by the airfield engineer. A possible solution was, of course, to accept the British Load Classification Number system, but that had not as yet been accepted internationally, and that it had not been generally accepted was bound up with the fact that there were so many compromises when it came to a question of applying that system to the multi-wheel undercarriage loading.

The third of the factors to which he had referred was the length of the runway. That was very important, but, knowing the ever-changing characteristics of aircraft, it was difficult to see how firm standards could be laid down. The present I.C.A.O. provisions regarding length seemed to suit present aircraft only up to a point, and the Author's example of Nairobi was an instance where they had to be disregarded; the Author related the length to a particular aircraft and not to an I.C.A.O. Standard.

Mr Skinner suggested that I.C.A.O. might place more emphasis on extensibility, since, up to the present, lengths had always been increasing. The Author had planned for 25,000 feet. When the engineer was planning an airfield, he certainly had to take extensibility into account. It was significant that the need for the new Nairobi airfield was largely bound up with the fact that the runway on the present airfield could not be extended

any further, although in the 1930's, when the present airfield had been built, it had presumably been thought that there was plenty of room.

If airfield engineers were compelled to assess the length of runway from operating characteristics, as apparently the Author had done at Nairobi, it would be more useful if I.C.A.O. dealt not with nominal lengths but with the specification of such things as the safety factors to be allowed in addition to the actual take-off and landing lengths. It would then be possible to work out, from the characteristics produced by the aircraft manufacturers, the length of runway required. The I.C.A.O., on the other hand, certainly ought to give guidance on adjustments for altitude and temperature.

The three points which Mr Skinner had mentioned—the number of runways, the strength of the pavement, and the length and extensibility—were in his view by far the most important items on which guidance was required from the international standardization organization, and, as he had already said, he felt that most of the other factors were insignificant by comparison. He therefore considered that the engineer should say to the Standardization Committee that he required far more guidance on those three items. Before the Committee would be able to issue that guidance they would have to look far into the future and visualize possible aircraft trends. It was only by doing so that they would be able to standardize airfield construction throughout the world. If that were done, it might be that the aircraft development of the future would be guided by the airfields which existed for their operation.

Mr R. F. Lloyd-Jones said that in any discussion of airport design one was immediately faced with the fact that many of the problems involved did not lend themselves to precise evaluation. That was a fact which most engineers were reluctant to accept; nevertheless it had to be faced. For example, one of the most obvious things that had to be determined was the length of the runway. It was not a question of selecting a runway which would enable the aircraft to get into the air or to land, but of knowing what margin to allow over and above the minimum requirement to enable those aircraft to operate with an acceptable degree of safety. The length of a runway might first of all be determined by the theoretical or normal landing and take-off length required by a particular aircraft, but to that length margins had to be added to allow for malfunctioning of the aircraft or its engines, human errors, bad visibility causing inaccurate navigation, deficiencies of the runway surface, and so on.

Those margins were substantial but indeterminate, and, when they were added to the minimum requirement to get the aircraft into the air, it was somewhat pointless to have attempted to arrive at an exact distance in the first instance. Apart from that, it had to be borne in mind that the runway was probably going to last for two or three times the life of any aircraft of which it was possible to get exact knowledge at the present

time, so that in any case it was necessary to make an estimate of what was going to be wanted in the future. It might be that a different type of aircraft would operate from the airfield. In any case some allowance had to be made.

It was inevitable and proper that standards should be evolved. Obviously it was only if there was some uniformity throughout the world that pilots could operate, knowing what margins were allowed, and could use the various airports with confidence. There was the further advantage that standardization would tend to make aircraft designers conform to some limits. One important fact which had to be borne in mind, however, was that any dimensional standard implied a safety standard. So far as he knew, no one had suggested what the odds should be—that was to say, what the limiting chances of an accident occurring ought to be. He imagined that the passenger decided that in the long run, but he felt that the dimensional standards produced by I.C.A.O. had not been arrived at by any precise or actuarial calculation, but as being a compromise of opinions of people who had had experience of operating aircraft over a number of years.

One could not have a standard unless the conditions which gave rise to the risk of accident were the same at all airports. If the conditions at one airport differed from those at another it was futile to provide a standard, which would only result in extravagance at some airports or dangerous risks at others, so that inevitably there would be certain factors in the design of any airport which were indefinite. It was with that in mind that he was not entirely persuaded by the Author that the runway length could be standardized by taking the performance of known aircraft and multiplying those lengths by some arbitrary standard factor. It might be that some such formulation would permit runways to be calculated to conform to a standard within very close limits, but that was not what was sought to be achieved; what was wanted was a runway which would provide a degree of safety which was acceptable.

The conditions which gave rise to accidents varied considerably from airport to airport. An airport situated amongst mountains or hills, where there were turbulent air conditions or where the pilot had to approach over high ground, usually meant that it was necessary to allow a rather longer runway; and there were other conditions. If one were to try to arrive precisely at the length of a runway one ought to consider not only the performance of an aircraft but its reliability, whether the operating companies at an airport maintained their aircraft satisfactorily and what standard of training they had for their workers. He thought that it was possible to arrive at a satisfactory safety position for runways only by leaving the decision to some expert or someone who had sufficient experience of similar operations elsewhere to exercise his judgement in deciding what the length should be, after making whatever allowances were necessary for the particular conditions which existed at the site in question.

There was another point which sometimes arose, and which he could perhaps illustrate by considering two hypothetical airports, both exactly the same and operating under exactly the same conditions, but where one of the airports was in frequent use and the other was used only occasionally. Was it reasonable to reduce the standards on the airport which was occasionally used ? Obviously the chance of an accident occurring during any given period of time would be greater at the busy airport, but that was not the point ; what one wanted was to have the same risk of an accident for only one movement, and, that being so, obviously the standards at the two airports had to be the same. It was possible to get round that issue by altering the limiting conditions under which the infrequently used airport would be operated, but the basic principle remained. He raised that point because in the Paper the Author had mentioned that at Dar es Salaam night landings were more frequent in one direction on the main runway than in the other, and had said that therefore the aviation lighting was more important in the frequently used direction. Mr Lloyd-Jones was not quite sure what was implied there, but he wondered whether that meant that in fact there was any reduction of standard in the less frequently used direction.

He was interested in the Author's discussion of the possible economy of increasing the length of the over-runs and decreasing the length of the runway proper. Obviously the amount of saving in cost would often depend on the strength which was required in the over-run areas, and the Author had said that some guidance ought to be given; but Mr Lloyd-Jones would be interested to know whether the Author considered that the ratio between the strength of the over-run and that of the runway proper should be a fixed amount or whether it should vary with the extent to which the main runway was reduced. The Author had also mentioned that the runway could be reduced in length up to 20 per cent. Did he consider that that was the greatest reduction which could be made, and, if so, what reasons had he for fixing it at that figure ?

The Author had suggested that there should be a greater range of runway widths within the international standards, and, as he rightly pointed out, a small addition to the width could mean a big percentage addition to the area of paving. Mr Lloyd-Jones thought that that matter required careful consideration. The question of runway widths was again an indeterminate matter, but it had been argued that it was important for psychological reasons to have a standard width. It helped the pilot to judge his distance during approach and landing. The width of 150 feet, which was predominantly used nowadays, was a width which had been proved by experience to be satisfactory for most types of aircraft and to suit the spacing of the runway lights. It would be interesting to hear expressions of opinion on whether that argument justified what might be a fairly heavy cost.

Many of the worries of the airport designer arose not so much from the

international standards as from the lack of them. It was very worrying to the engineer who had been trained in an exact science, but, as the Author had said, the engineer had to decide whether he was going to be a designer of the airport *in toto* or whether he was simply going to wait until someone told him what the various dimensions should be and then proceed to build it. Those were two very different jobs. Mr Lloyd-Jones did not think that it was possible to be an efficient designer of an airport without studying the aviation problems and the navigational and other problems which arose. It could only be done by very close association between an engineer and an aeronautical expert, but it was obviously better if the engineer had a sound knowledge of the problems himself. Above all, he had to have a lively imagination to be able to see what the future was going to require, and he had to have faith in his own beliefs and judgement, because, unlike engineers in other fields, he often had to persuade people to spend large sums of money which it was very difficult for him to prove essential.

Mr E. H. Lewis-Dale remarked upon the Author's reference to changes in gradient. Until fairly recently there had been just such a hump at Prestwick Airport in Scotland. The main runway had been built during the war, and so far as Mr Lewis-Dale knew there had been no standard at that time which determined the matter. The hump had been noticed by the pilots of Liberator aircraft, but then Liberator aircraft ceased to use the airport and nothing more was noticed until a Stratocruiser only just escaped bumping itself badly. The hump had been ironed out, and the process had been troublesome, because the runway had to be kept open. In ironing out the hump an improvement had been made upon the standards laid down by I.C.A.O.

Sometimes, however, standardization could be troublesome. If there were two flat runways which intersected, and it was decided to surface only one of them, because the other did not look so bad or was not used so often, in order to satisfy the letter of the requirements it would be necessary to feather out the 3 inches of macadam or asphalt on the first runway over a distance of 186 feet on the second, which put it outside the bounds of practical policy.

He was very glad that Mr Skinner had raised the question of the absence of standards, because that brought up the subject of the strength of verges. With the absence of standards of strength it was very difficult to say that a verge or an over-run should have a relation to the runway strength, when nobody was quite certain to what standard the runway had been built. At present, I.C.A.O. standards gave some wheel loads which he believed were called single isolated wheel loads, but unfortunately they left the tire pressure to the competent authority, which meant the country in which the aerodrome was built, and that was no help to anyone.

He had found some difficulty about the question of the strength of verges, because at airports in Britain, and no doubt at many airports in other countries, verges and over-runs were at present grass. Possibly on

some clay subsoils, if they were well drained and had good turf, that might be satisfactory, but it was extremely difficult to say that grass had such-and-such a strength, and it would be interesting to know whether the Author had any views on how the strength of grass ought to be determined.

It seemed to him a little difficult to say that the bearing capacity of a verge or an over-run should be a certain fraction of the strength of the runway. Perhaps that was not what the Author meant, but Mr Lewis-Dale felt that perhaps one should lower the standard (because of the infrequency of use, because it was going to need less maintenance, or because it would still support the aircraft) rather than say that the actual strength need not be quite so much, because in fact the same aircraft were going to use the runway and the verge.

On p. 293 the Author had suggested that the frangible fittings on the line-and-crossbar approach-lighting system might be a source of danger and additional expense. Mr Lewis-Dale had been told that those fittings caused no damage to aircraft that struck and broke them, and he would suggest that the expense of replacing them might be of secondary importance if indeed the line-and-crossbar was the best system of approach lighting and far more effective than any other. After all, it was to be hoped that aircraft would not use the over-run and approach area very much for running on, and if a machine did knock a fitting occasionally it would not take very long to put it back again.

Mr W. M. Hargreaves referred to the I.C.A.O. meeting mentioned on p. 282. The Author had suggested that there were several items of co-ordination necessary between the various Divisions of I.C.A.O., and that was in fact exactly what had been done at the AGA Division meeting held in October last. Mr Hargreaves had been a delegate at that meeting and would like to deal with a few of the points which had been raised.

On p. 288 the question of correction factors for runway lengths was mentioned, and Mr Skinner had touched on the same point. On that issue the AGA Division had agreed on corrections for altitude and temperature. The figures which they had agreed had been averaged, of course, over a number of aircraft types and chosen as more or less the mean of those types. It was clearly impossible to consider both the high and the low figures ; a mean had to be taken between the two, and that had been done in relation to that correction.

The AGA Division had also agreed that over-runs, referred to on p. 290, should be provided in excess of the 200 feet which had been allowed previously in Annex 14 of the Convention. A greater length of over-run could now be provided, but of course there were certain limitations on it. That would be a tremendous help in catering for a critical aircraft at a particular site. The Division had tended to stall on the making of any suggestion of what the strength of those over-runs should be, because it was, as several speakers had pointed out, a difficult point to decide or on which to make recommendations. They said that it should be provided

with such a surface that aircraft could run on it without hazard. That left it very wide open.

For a long time there had been no agreed cross-wind component which would make it possible to work out the number of runways required to give a certain usability, but the AGA Division had agreed upon a figure which was higher than it had been previously, with the result that a single runway would now cater for most locations—a very desirable state of affairs.

Those were the main points on which the AGA Division had succeeded in producing information which would permit the co-ordination necessary between the various Divisions concerned.

On p. 293, the Author had suggested that there should be a closer scaling of runway widths, because of the economy which would be achieved thereby, and that was, of course, very important; great economy was achieved by every yard of runway which was taken off. Mr Lloyd-Jones had pointed out, however, that there was much to be said for having a standard width of 150 feet. That had really been the intention of I.C.A.O. in the original suggestion that there should be no more than two standard widths. In fact, there was a third which provided for the few aerodromes of the smallest class, but in the main the widths suggested were 150 feet and 200 feet. There was a great deal in the point that the standard width helped the perspective view of the pilot landing the plane; he became used to a certain width and it gave him a certain scale and dimensional characteristics to which he was accustomed, so assisting his approach and landing. Mr Hargreaves was not in favour, therefore, of increasing the number of standard widths.

On the question of approach lighting, the AGA Division had, in fact, agreed on an international standardization of the centre-line-and-crossbar type. The Author had mentioned that there was something to be said for a " defined-funnel " type of lighting, but that type was now definitely out of favour, and I.C.A.O. had taken the sensible step of standardizing on the British system, so that the point made by the Author with regard to frangible mountings on centre-line lights was a very real one and would have to be tackled. It had already been stated that it was being tackled by the use of very lightweight fittings which could be knocked over without damage to the aircraft. That view had been accepted by most of the delegates at the international meeting and was accepted in Great Britain. The British policy that centre-line lighting should continue right down to the threshold of the runway had been generally accepted throughout the world.

In the section of the Paper on approach slopes (p. 298) it appeared that there was some misconception, for the Author had quoted a gradient of 1 in 66 as being a recommendation of the AIR and OPS Divisions. That figure of 1 in 66 was, in fact, a misinterpretation of the information in the AIR and OPS Divisions' annex; the requirement was that an aircraft should be able to clear obstructions by 50 feet plus one-hundredth of the

distance of the obstruction from the take-off point, which was not quite 1 in 66, and the AIR and OPS Divisions permitted aircraft to do a slight turn to avoid an isolated obstruction.

On those approach-surface slopes, no alteration had been made to the 1 in 50 slope ; it remained 1 in 50 so far as the international agreement was concerned. The only concession which had been made was that in particular difficult locations, either because of temperature or because of altitude, some flattening of the slope should be considered in consultation with the airport authority and the airline operator.

Mr John Briscoe suggested that both in the Paper and in the discussion there had been too much emphasis on the word " standards." In the annexes of I.C.A.O., he observed, the standards formed a very small proportion of the material which was available to the aerodrome designer. By far the larger part covered recommended practices, and those were put in as a guide where a standard was too difficult to set up for use everywhere. At many sites, indeed, it was impossible, or impossibly expensive, to lay out an aerodrome or a runway if every recommended practice was to be strictly observed.

The Author's general theme seemed to be that the users should lay down what they required and then leave it to the airport engineer to get on with the job. In Mr Briscoe's view, it was only the user of the aerodrome who could say how far the recommended practices of I.C.A.O. need not be strictly followed in certain cases, and those users were the people with the operational experience, the pilots. He wished that the Author had suggested more consultation with the users.

In particular, the Author had made mention of the users supplying sets of figures and suggested that the International Air Transport Association should publish them and that I.C.A.O. should later " rubber-stamp " them. That showed a slight misconception of the functions of I.A.T.A. and I.C.A.O. Mr Briscoe gave an example of one of the difficulties in giving those figures. Jet aircraft such as the Comet, with very high fuel consumptions, could carry fuel up to nearly 50 per cent of their maximum gross weight at take-off, but had a very limited maximum landing weight (in the case of the Comet, 75 per cent of the maximum at which it could take off). It did not follow, therefore, that those aircraft were penalized if a runway was not long enough for them to take off at the full weight permitted by their certificate of airworthiness. On shorter flights, from Bahrein to Karachi, for instance, if the aircraft had taken off at its maximum gross weight it would arrive over its destination at a greater weight than that at which it was permitted to land, and, if it had made such a take-off, might have to dump thousands of gallons of valuable fuel before it could land. With jet aircraft, therefore, it was necessary to examine each stage from an aerodrome to see what take-off weights were required before it could be said what the take-off length required was for that particular aerodrome.

The Author had suggested that marker beacons might be placed in small natural or artificial depressions, and asked whether that had been done. There had been an instance in America where not a marker beacon but a fence had been sunk in an artificial depression so as not to cause obstruction to an I.L.S. beacon. Two winters ago, a Skymaster aircraft had over-run the runway and ended up in that ditch. The fire engines had been unable to get to the aircraft, which had been considerably damaged and had then caught fire, leading to considerable loss of life. It would seem, therefore, that any artificial depression was a considerable danger, and any such depression limited the amount of ground which could be used as over-run.

One point relating to economy in the design of aerodromes on which it would be interesting to hear further views was how much longer a runway should be made in aerodromes where high temperatures were involved, since such high temperatures occurred only at certain times of the day and in certain months. There had been a usability laid down on cross-winds for runways : did the Author think that a usability might be adopted for temperatures, and, if so, what did he think that it should be ?

The Author had suggested that most pilots would prefer to have over-runs made stronger, rather than verges. In Mr Briscoe's view, the choice would depend on a number of factors, such as the width of the runway and how many runways had been provided, from the point of view of whether it would be necessary to land often with a strong cross-wind. He would also suggest that over-runs were normally required only when there had been an engine failure at the critical point, but engine failures, if they occurred at all, were liable to occur at any time during a take-off rather than at the critical point, and when earlier, the aircraft often ran off the side of the runway. On such occasions it was preferable for the money to have been put into strengthening the verges rather than the over-run.

The Chairman agreed with the Author that runway width was not a function of the basic runway lengths to which the different airport classes referred, and that important changes in runway width had no justification solely on that basis. He also agreed with the Author that where standards were adopted they should be on some scientific basis ; so many standards seemed to have very little scientific basis. The Chairman knew of one busy international airport where the runway was only 100 feet wide, and nobody had ever complained ; the only reason for that was that no one had ever been told. That aerodrome had carried up to 100 aircraft a day, of all sizes.

The Author, in reply, thanked all the speakers for the kind, if at times slightly mixed, reception which they had accorded to the Paper. He had expected a mixed reception, because certain parts of the Paper had been put in deliberately as kites which he had thought might be shot at.

Despite an apparent disparity of view, he wondered if Mr Skinner and Mr Lloyd-Jones were not really expressing the same objective as he had

attempted to formulate in the Paper, when discussing runway lengths. Mr Skinner considered that the I.C.A.O. should specify the safety factors to be allowed in addition to the actual take-off and landing lengths, whilst Mr Lloyd-Jones had said that it was necessary to know what margin to allow over and above the minimum requirement to enable aircraft to operate with an acceptable degree of safety. Although perhaps he had not made it very clear, that was what he had had in mind when he suggested the formulae shown on pp. 288 and 289 of the Paper; it would be for the I.C.A.O. to determine the values of the multipliers X, Y, and Z, so that the resultant runway lengths would provide the safety factor necessary for practical operation. He agreed, however, that such formulae would give only a minimum basic length, and, as Mr Lloyd-Jones had rightly pointed out, it would need to be subject to upward adjustment for adverse local conditions. However, he could not see eye to eye with Mr Lloyd-Jones in saying that the reliability of the aircraft and of their operators should be taken into account; surely that would make the problem immensely complicated and indeed insoluble in the case of international services. It seemed to be necessary to assume a practical and reasonably uniform and efficient standard of operation and maintenance of all aircraft allowed to fly. In the same connexion, he was grateful to Mr Fitt for noting that the European-Mediterranean Regional Group of I.C.A.O. had voiced the need for the publication of more aircraft performance data; that seemed to be a step in the right direction.

The feeling of the meeting about specifying a ratio of the strength of over-runs (now called " stopways ") and verges to that of the runways appeared to be mixed: perhaps it was for a similar reason that the I.C.A.O. had " tended to stall " on the question, as Mr Hargreaves had aptly put it. Replying to Mr Lloyd-Jones and Mr Lewis-Dale on that point, the Author felt that an endeavour should be made to assess a fixed " target " ratio of the bearing capacity of a stopway or verge to that of the runway proper, and that that should be recommended to the engineer as something desirable but to be achieved only if it could be done economically. That would leave the question less wide open than the I.C.A.O. had done to date, and the ordinary civil engineer with little knowledge of what would and what would not safely support an aircraft in emergency conditions without hazard—and indeed of exactly what was meant by " hazard " in that connexion—would not be completely in the dark. It was fairly common to reduce the strength of the less frequently used edges of a runway below that of the more heavily trafficked centre portion, and the Author wondered if something could not be arrived at on those lines, using estimates and possibly, later on, statistics of the number of times that the stopways and verges needed to be used. He agreed with Mr Lewis-Dale about the difficulty in the case of grass verges, but that did not apply in many parts of the world. There were aerodrome sites abroad where turf, as it was known in Great Britain, could not be grown and where local

materials already on the site could be used for the construction of stopways and verges but it was essential to import the runway materials. If some desirable ratio of strength were specified, the engineer would find it easier to say whether the economy provided by stopways and verges should receive consideration.

He was glad that Mr Lloyd-Jones supported his view that runway widths required careful consideration. Mr Hargreaves was not in favour of increasing the number of standard widths, and neither was the Author, except that economy had to be sought. What he really objected to were the big increases of 50 feet in single jumps. He appreciated the psychological advantage to a pilot landing a plane on the lowest possible number of standard widths (he had in fact said so in the Paper), but it seemed to be an inordinately expensive way of providing perspective and scale, and one which was no advantage at all when landing conditions were most difficult, by night or in bad visibility. Nor did he believe that the answer lay in standardizing on a 150-foot width of runway only : for example, in certain conditions of high cross-winds on a single runway it might be that widening the runway would be a cheaper practical solution than building a second runway. The Chairman's remarks encouraged him in his hope that there might be further discussion of the question of runway widths.

Mr Lloyd-Jones had queried his remarks about the provision of lighting at Dar es Salaam ; it was not a question of which direction of landing was the more important from the point of view of safety, because obviously both were equal, but of what should be provided in the way of fixed installations in the first instance during the early development of the aerodrome, with limited finances and limited night traffic. In the case of the taxiway lighting, the economy meant only a reduced convenience of taxying route for the less frequently used direction of landing.

He did not quite see the force of Mr Briscoe's argument that jet aircraft were not always penalized when they were unable to take off at their full weight. He would have thought that when dealing with an international airport one would usually want to provide for all possible uses of the runway, not for short stages alone. Nor did he fully appreciate Mr Briscoe's point about usability for temperatures ; was that not already taken care of by I.C.A.O. in their definition of the temperatures to be used in the calculation of the runway length correction factor ? However, he inclined to agree with Mr Briscoe's dislike of the frequent use of the word " standards " in the Paper ; unfortunately, that was inherent in the title, but he had tried to make it clear that they were not rigid in most cases and that reference to and consultation with the aeronautical side was essential in their application. It was often the case abroad that the engineer had to stand very largely on his own in any matter of an airport and that was the main reason for the Author's plea that things should be made easier for him, and for his suggestions for doing so.

The other points made in the discussion seemed to have been answered

by the recommendations of the Fifth Session of the AGA Division of I.C.A.O., which had been mentioned by Mr Hargreaves and whose Report was now publicly available. It was gratifying that so much progress had been made at that Session.

Correspondence

Mr Robert Marwick, of Nairobi, observed that the presentation of the Paper was timely, since many Authorities were faced with the task of fulfilling the requirements which were arising through the introduction of jet airliners on trunk routes and of larger aircraft on regional services. The financing of the necessary work was becoming increasingly difficult and airport designers were thus under a strong obligation to reconsider the fundamentals of their work in relation to the trends of aeronautical requirements and practices. Although I.C.A.O. had not imposed on aircraft designers any maximum standards for such requirements as runway length and bearing capacity, it appeared that restrictions imposed by the size and strength of existing airports had been having an equivalent effect in recent years. That trend, coupled with the successful development of turbine engines, had enabled the envisagement of some maximum airport standards, including runway lengths for jet airliners, which were well within the provisions of Annex 14 to the Convention on International Civil Aviation. He understood that, in Britain, the length requirements of the Comet 1 were being regarded as maxima and he had recently noted that the United States Air Transport Association had specified similar maximum runway basic lengths—5,500 feet for landing and 7,500 feet for take-off, for a 70-80 seater jet airliner of 3,200 miles range ; the latter specification also required that the aircraft should be capable of landing in a 40-mile-per-hour cross-wind. The consideration of such trends, together with those of operating practice, might well affect the manner in which the currently required improvement, or replacement, of an airport was carried out.

After the question of the number and orientation of the runways, which the Author had covered very fully, the possibility of reducing the fully paved length of runway offered the greatest scope for possible economies, since it affected the length of any parallel taxiway joining the traffic apron to the runway ends ; the possible savings included reduced costs of providing lighting and drainage for those two pavements. It was not yet provided for in Annex 14 ; the operational Standards laid down in Annex 6 did, however, appear to cover its use, since they allowed the inclusion of any available additional length between the runway end and the commencement of the clearance plane in the climb zone to be included in the distance required to be available for take-off and climb to 50 feet after failure of the initial engine ; they also permitted the completion of accelerate-stop movements on " suitable ground " beyond the runway.

Fig. 2 showed that the total length of a shortened runway plus one over-

run equalled the length of a normal runway. A further economy was, however, permissible where, owing to temperature and altitude conditions, the length required by the critical aircraft to take-off to 50 feet after an engine failure exceeded both its accelerate-stop distance and its required landing runway length ; the strip length would be determined by the take-off distance but part of it need not be paved. For take-off, the ratio between the runway plus over-run length and the strip length might, in theory, be varied from that determined by the two normal performance distances ; that would, however, vary the critical speed of a particular aircraft and thus possibly increase the risk of a pilot making an error of judgement between continuing or stopping a take-off in the event of engine failure ; and the required landing runway length might restrict the extent to which the runway plus over-run length could be shortened in that way.

It had once been common practice to make the landing runway length $\frac{100}{70}$ times the landing distance for I.F.R. conditions or $\frac{100}{80}$ for V.F.R. conditions and, owing to the comparatively small effect of temperature and altitude on landing distances, the landing runway length thus obtained was often appreciably shorter than that for take-off. Annex 6 to the Convention, however, now required that the landing distance for the critical aircraft should not exceed 60 per cent of the available length and the longer landing runway length thus required might, in some circumstances, exceed the take-off length. The length of high-quality surfacing could, nevertheless, still be reduced, since the more extreme landings, such as occurred in bad visibility conditions, could be completed on an over-run ; but it might not be desirable to reduce it to the landing distance only, since that might give pilots an impression of inadequacy. The landing runway length beyond the landing distance also required a higher-quality pavement than an accelerate-stop over-run, because abnormal landings were more frequent than uncompleted take-off movements ; but it did not have to be uniform, since the frequency of abnormal landing movements decreased with distance. The appropriate solution in the case of a runway to be used in one direction thus appeared to be the provision of full pavement over a little more than the normal landing distance ; then surfacing of the same appearance, but not necessarily of the same thickness, on a tapering base-course for the remainder of, say, 80 per cent of the landing runway length ; and, finally, an over-run.

It thus appeared that the runway, over-run, and strip lengths should each be determined from separate basic lengths and temperature-altitude correction factors, rather than by fixed proportions of the actual length of the equivalent normal runway ; otherwise one type of movement might not be fully provided for.

The more extreme reductions might not be economical when a runway had to be used in both directions and restrictions arose where, in addition, an instrument landing system was, or might be, necessary. The localizer

beacon could be set back beyond the over-run, but the inner marker would have to be at a standard distance from the threshold and the runway itself would therefore have to have at least the required landing runway length. The beacon could not be sunk in the accelerate-stop over-run but the placing of the aerials only on the extended centre-line of the runway, with the transmitter placed 200 feet to one side (as recommended in Annex 10), might be accepted as a risk in consideration of the low frequency of accelerate-stop movements.

The strip in the proposed lay-out for the new airport at Nairobi extended at least 1,000 feet beyond the ends of the runway ; further reductions might be made but the more extreme measures, which might be theoretically possible, might not be practical or economically effective. Similar proposals were under consideration for increasing the effective lengths on the new airport which was under construction at Dar es Salaam.

Mr Marwick pointed out that the Load Classification system in Annex 14 gave no more guidance to the designer than did the parallel system for runway lengths. Studies in recent years had shown the earlier estimates of equivalent wheel loads to be excessive for most pavements and I.C.A.O. had recently given more realistic figures for particular aircraft ; it should, however, be borne in mind that the equivalent wheel load was a function of the depth below the surface of the critical layer of the subgrade.

The Author had mentioned the need for guidance on the bearing capacity of over-runs. Mr Marwick suggested that that could be obtained from the chart in the United States Army Engineers Manual showing the percentages of the full design thickness which should be adequate for wheel coverages down to twenty in number ; that could be also used to design part of the runway to reduced standards for lower frequency of operations. Further guidance might be obtained from shear-strength methods of pavement design by reducing the factors of safety which they included.

The Author, in reply, welcomed Mr Marwick's submissions : he considered that his discussion of the factors affecting the achievement of economy of paved runway length would materially assist towards an understanding of the principles now made public by I.C.A.O. in Document 7341, the Report of the Fifth Session of the AGA Division, to which he had already referred in his reply to the oral discussion.

He agreed that an acceptable solution to the problem of the inner marker might be found along the lines which Mr Marwick suggested, the aerial only being placed within the stopway or " over-run " and being made frangible ; it did seem, however, that 300 feet might be more acceptable to the interested authorities as the distance by which the transmitter would be placed to one side of the centre-line. The intention of the increased distance would be to provide a margin for wing-tip clearance.

Correspondence on the foregoing Paper is now closed and no further contributions will be accepted —SEC. I.C.E.