R. & M. No. 2909
(13,928)
A.R.C. Technical Report

MINISTRY OF SUPPLY

AERONAUTICAL RESEARCH COUNCIL
REPORTS AND MEMORANDA

Experiments on the Flow into a Swept Leading-edge Intake at Zero Forward Speed with Notes on the Wider Uses of a Slotted Intake

By
J. Seddon, Ph.D., and W. J. G. Trebble, B.Sc.

LONDON: HER MAJESTY'S STATIONERY OFFICE
1954
FIVE SHILLINGS NET

Experiments on the Flow into a Swept Leading-edge Intake at Zero Forward Speed with Notes on the Wider Uses of a Slotted Intake

By

J. SEDDON, Ph.D., and W. J. G. TREBBLE, B.Sc.

COMMUNICATED BY THE PRINCIPAL DIRECTOR OF SCIENTIFIC RESEARCH (AIR), MINISTRY OF SUPPLY

Reports and Memoranda No. 2909*

January, 1951

Summary.—The flow into a swept intake at zero forward speed (ground running conditions) is shown to be analogous to the flow round a sharp corner in a duct. Tests have been made on a model of a swept-wing leading-edge intake to measure the losses involved.

It is found that the distribution inside the duct can be improved by the use of straight guide vanes, alternatively by means of a special intake slot, or further by a combination of both. Guide vanes increase the mean loss, but the intake slot improves (*i.e.*, reduces) this also.

The slot would require to be sealed under flight conditions. It is suggested that this form of slotted intake may have wider applications in the future. Using the results of the experiments and an analogy with the slotted wing, conclusions are drawn regarding the main points of design of the intake slot.

1. *Introduction.*—Most of the wind-tunnel work on air-intake design has in the past been concerned with obtaining the best compromise for the requirements of the normal level-flight condition. Relatively little attention has been paid to the efficiency of an intake when running up on the ground. It has usually been assumed that:—

(*a*) the loss of a small amount of engine thrust during take-off is not a matter of first importance

(*b*) there is a standard cure for excessive static† loss which is to increase the inside radii of the entry lips. In some cases, a small degree of convergence over the first few inches of the duct has been recommended, but this second prescription is only a variant of the first. A previous collection[1] of data on static losses showed these measures to be effective in general (Fig. 20 of Ref. 1).

It has recently become apparent that the case of flow into a swept intake under static conditions poses a special problem. A swept intake in this sense is one in which the plane of the entry is not at right-angles to the centre-line of the duct. With any intake working under static conditions, since the suction induced by the engine is free to act on all the air outside the duct, the average direction of flow at the entry is more or less normal to the entry plane. If the entry is swept,

* R.A.E. Report Aero. 2409, received 19th April, 1951.

† The term ' static ' refers throughout to the condition of flow into the intake at zero aircraft speed.

then as illustrated in Fig. 1, the air is faced with the task of turning through an angle of the same order as the angle of sweep in order to proceed down the duct. Further, since the rearward end of the entry is nearest the suction centre (the engine), the highest velocity is at that end, that is on the inside of the turn. These points will be seen more clearly by reference to Fig. 1.

The most important case is that of a leading-edge intake in a swept wing. If the angle of sweep is high, say 45 deg or over, and the intake is of the usual elongated form, having a large width/height ratio, than by analogy with the flow round corners in ducts, which has been described by Patterson[2], considerable losses are to be expected. The bad distribution produced at the compressor inlet by this type of flow may be more important than the mean loss itself, particularly in the case of an axial-flow compressor.

Model tests have been made to investigate the type of flow in a particular case, and to explore the possibilities of improvement without detriment to the qualities of the swept intake when working under flight conditions. Results include the development of a slotted intake somewhat similar in principle to a slotted wing. The report discusses briefly some of the possibilities for the wider use of slotted intakes, and sets out the main principles of design of this type of slot.

2. *Method of Test.*—The tests were made in the Low-Speed Wind-Tunnels Section of Aerodynamics Department, Royal Aircraft Establishment, during August and September, 1950.

The model was one which had been used earlier for an investigation of the properties of swept intakes under flight conditions. It represents on 1/7-scale a twin-engined delta-wing aircraft with intakes in the wing root leading edge. The entry has a tapered cross-section, width/mean-height ratio 4·5, and 52 deg sweepback (this being approximately the same as the angle of the basic leading edge). The duct curves inwards to an assumed engine position in the body. Relevant dimensions are given in Table 1, and sketches of the intake are included with the diagrams giving the results.

Flow through the intake was produced by coupling the exit of the duct to a suction plant in the usual way for static testing of model duct systems. The quantity flow was measured at a section near the model exit. The mean velocity at entry (based on the projected entry area) was around 250 ft./sec. throughout the tests. Total head was measured at the engine position on a cross of pitot-tubes (Fig. 3) giving a single horizontal and a single vertical traverse of the section. A preliminary survey of velocity distribution and direction of flow at the entry plane was made, using a Conrad-type yawmeter which has been described elsewhere[3]. The survey was later repeated for two other conditions of the intake.

Results are assessed on the basis of a mean loss coefficient and a distribution criterion. The loss coefficient is in the usual form $\overline{\Delta H}/q_i$, where $\overline{\Delta H}$ is the mean value of the readings (ΔH) of total-head loss up to the engine position, and q_i is the mean entry dynamic head. For a criterion of distribution, it was thought best to use the standard dispersion σ of the set of total-head readings. The standard dispersion is the root-mean-square of the differences between the individual readings and the mean, defined by the relation

$$\sigma^2 = \frac{1}{N}\sum\left(\frac{\Delta H}{q_i} - \frac{\overline{\Delta H}}{q_i}\right)^2,$$

N being the number of measuring points. The criterion takes into account both the relative areas of good and bad flow and also the suddenness of transition from one to the other. This may be seen by comparing for example, the three distributions shown in Fig. 2. These all have the same mean and on some such basis as (maximum-minimum) or (maximum-mean) value they would be equivalent distributions. But the standard dispersion shows example (*b*) to be worse than (*c*) because of relative areas, and worse than (*a*) because of suddenness of transition.

It should be noted that, assuming the static pressure to be constant over the engine face, fluctuations in $\Delta H/q_i$ are the same as fluctuations of dynamic head q/q_i. The corresponding fluctuations of velocity V are given by

$$\Delta\left(\frac{q}{q_i}\right) = 2\frac{V}{V_i}\,\Delta\left(\frac{V}{V_i}\right),$$

or in terms of mean velocity $\bar{V}$ at the engine face,

$$\Delta\left(\frac{q}{q_i}\right) \simeq 2\left(\frac{\bar{V}}{V_i}\right)^2 \Delta\left(\frac{V}{\bar{V}}\right)$$

$$= 2\left(\frac{A_i}{A_m}\right)^2 \Delta\left(\frac{V}{\bar{V}}\right)$$

A_i, A_m being the duct areas at entry and measuring sections respectively. In the present case, $2(A_i/A_m)^2$ is nearly equal to 1 (Table 1). Hence the fluctuations in $\Delta H/q_i$ give directly the order of magnitude of the corresponding fluctuations in velocity relative to the mean.

3. *Tests and Results*.—3.1. *Intake Before Modification*.—The results of tests on the unmodified intake are given in Fig. 3, in which the upper diagram illustrates the character of the flow. Velocity distribution at the entry is shown by the broken-line arrows, these indicate both relative velocity and direction. The combination of high velocity and large angle of approach at the rearward end of the entry is well demonstrated. The mean angle of approach over the whole entry area (weighting for velocity) is 46 deg to the axis of the duct, or roughly 0·9 of the angle of sweep of the entry.

The full arrows give an indication of the directions of flow near the surface of the duct. They are taken from a flow pattern obtained in the lower half by applying white oil to the surface near the lip and allowing it to be blown down the duct. The flow separation at the rearward end of the entry, *i.e.*, on the inside of the turn, is shown clearly. This is followed by a region of vorticity in the outboard part of the duct, which persists all the way back to the engine position. The outward drift in this region, which can be noticed about half-way back, indicates a tendency for the flow to rotate in an anti-clockwise direction. This rotation, or swirl, appears to be set up by an asymmetry in the initial separation, resulting from a small forward stagger (15 deg) of the entry lips. The effect of the stagger is to make the separation more pronounced in the lower corner than in the upper, and swirl is set up in the subsequent equalisation of pressures. With larger amounts of stagger, say 25 deg, the swirl might become in itself an additional complication.

Total-head losses from the horizontal and vertical traverses at the engine position are plotted in the lower diagram. The principal feature is a large loss over the outboard half of the horizontal traverse. Evidence of the swirl can be detected in an asymmetry between the two halves of the vertical traverse: this shows higher losses near the top than near the bottom.

The mean loss coefficient $\Delta H/q_i$ has the value 0·50. This agrees closely with an estimate from Patterson's review for a 45 deg sharp turn in a duct of equivalent rectangular section. To make the comparison it is assumed that the duct of the present intake is equivalent to the after-pipe of length 4 duct diameters, used in the experiments recorded by Patterson. In view of the different conditions of entry into the bend, the agreement must be regarded as partly fortuitous, but the comparison is interesting, as the two types of flow are clearly related. It seems logical to conclude that the variation of the present form of loss with angle of sweep will be similar to that found for duct corners. That would imply that for a 30 deg turn, corresponding to about 35 deg sweep of the entry, the severity of the loss would be reduced by half.

The dispersion σ has the value 0·38, which must be studied in relation to the values obtained subsequently by modification of the intake. Ideally, of course, σ should be zero.

3.2. *A Squared Intake.*—Results for a second intake similar in most respects to the first, but with the entry squared to the axis of the duct, are shown in Fig. 4. The comparison of mean loss coefficients (0·30 for the squared intake) is not of much interest, because it happens that the gain from elimination of the sweep is partly offset by the effect of having with the squared intake a longer duct and thinner entry lips. But since the squared intake is of common type, the distribution at the engine would be expected to be satisfactory, and therefore the value 0·16 for the dispersion sets a useful, if rough, standard for the swept case. It is possible that when the characteristics of axial-flow engines are properly established, a still better distribution (lower value of dispersion) than that of the squared intake will be required.

3.3. *Effect of Guide Vanes.*—The first suggestion for improving the flow in the swept intake was to divide the entry into a number of passages of more favourable aspect ratio (height/width) by means of guide vanes. Ideally, the vanes should be curved to match the initial and final directions of the air stream, but highly curved vanes would interfere severely with the flow into the entry in flight. Arrangements of simple straight guide vanes parallel to the axis of the duct were therefore tested. These are shown in Fig. 5a. Fig. 6 gives the results in detail, and in Fig. 5b the variations of loss coefficient and dispersion with the number of vanes fitted are shown.

It is seen that adding vanes successively from the outboard end improves the distribution progressively up to an optimum, which occurs when three vanes are fitted. After this the horizontal distribution becomes unsymmetrical in the reverse sense (Fig. 6) and the value of the dispersion (Fig. 5b) rises. The minimum dispersion, 0·13, represents a considerable improvement in distribution from the original condition, and is slightly better than the result for the squared intake.

The mean loss-coefficient increases consistently as vanes are added. This is to be expected, since the uncambered vanes are set at a high incidence to the flow at the entry. Examination of the flow showed a separation from the inboard surface of each vane, similar in character to the separation in the unmodified intake, only smaller in extent. The high loss-coefficient detracts from the merit of the vane method, since apart from the resultant loss of thrust, it is clearly more difficult to ensure good distribution in a given case with several individual sources of loss present.

Under flight conditions, the presence of two or three vanes in the entry should have only a small effect on the intake loss. The vanes are then much more nearly aligned to the incident flow, so that their loss is limited largely to the skin friction. Against this the aspect ratio of the passages is improved, in respect of the loss in flight due to sweepback. It is therefore possible that vanes would actually reduce the net loss. Tunnel tests on this point are desirable.

3.4. *Use of a Special Slot.*—Clearly one would like to be able to remove or reduce the sweep of the entry for running up on the ground, and restore it for flight conditions. It is possible to envisage the use of adjustable entry lips to achieve this, but most schemes would involve considerable mechanical complication. A relatively simple device, having a similar effect to the reduction of sweep, is the intake slot, tests of which are now described.

A transverse slot, or system of slots, is used to provide auxiliary inlet area for the ground running. The slot itself must have a negligible sweep (*see* section 4.3 for further remarks). The aim is to decrease both the loss, by reducing the quantity of flow taken in through the main entry, and particularly the dispersion, by feeding air into the region of separated flow.

The slots tested on the model are shown in Fig. 7a. They were straight, parallel-walled passages, 3 to $3\frac{1}{2}$ in. wide (full-scale), sloping backwards at 45 deg and cut in both upper and lower surfaces of the wing. Two fore-and-aft positions were tried, as shown. In general these were used separately. The rear slots extended across the full span of the entry, the front slots across the outboard half-span only. In the tests the proportion of span used was varied by filling in from the inboard end keeping the outboard end fixed. The total inlet area added by the full-span rear slots (top and bottom, area measured normally across the slot passage) was equal to two-thirds of the projected area of the main entry.

In practice, the slots would need to be sealed in flight. This could be done by means of sliding panels or hinged flaps at the wing surfaces. Hinged flaps could be arranged to open inwards under the suction on starting, and be spring-loaded so as to close under the ram at any desired forward speed*. No seals were represented on the model, but the edges of the slots at the wing surfaces were purposely left sharp.

Fig. 7b gives a summary of the results, which are shown in detail in Fig. 8. It is seen that the addition of slots has the desired effect of reducing both the mean loss coefficient and the dispersion. With full-span rear slots ($3\frac{1}{2}$ in. wide) the mean loss coefficient is $0 \cdot 16$, and the value of σ $0 \cdot 13$, *i.e.*, the distribution is as good as with the best arrangement of guide vanes and the loss coefficient is very much lower.

In relation to the inlet area added, the front slots give even better results. The more forward position helps the front slot to 'correct for' the main flow separation at an earlier stage, and also retains a greater mixing length before the engine position. The half-span front slots (3 in. wide) give a loss coefficient of $0 \cdot 21$ and a value $0 \cdot 16$ for the dispersion, which is as good as the result for the squared intake. By extrapolation it is estimated that full-span front slots would reduce the dispersion to below $0 \cdot 1$.

3.5. *Combination of Guide Vanes and Slots.*—Figs. 9 and 10 show the results of combining various numbers of guide vanes with the 50 per cent span front slots, and Figs. 11 and 12 those for various slot arrangements in conjunction with a single mid-vane. The former series is not of particular interest, but the latter contains the following results.

(*a*) The mid-vane alone (without slots) gives the same low dispersion ($0 \cdot 13$) as the previously obtained optimum arrangement of mid- and two outer vanes. This is probably because the outer vanes are too short, as tested. The result indicates that further improvement could be obtained by lengthening the outer vanes, which would then have to be curved to follow the line of the duct.

(*b*) The combination of single mid-vane and 50 per cent span front slots gives an extremely good distribution (third diagram in Fig. 12, dispersion $0 \cdot 05$). Owing to the presence of the vane, the loss coefficient is higher than can be obtained with slots only, though lower than that of the unmodified intake. Regarding distribution as the more important aspect of the two, this is the best result obtained throughout the tests.

(*c*) The rear slot is again proportionately less efficient than the front slot (Fig. 11b). Opening front and rear slots together is less efficient still. This indicates a mutual interference between the slots, suggesting that for a given additional area a single slot in each surface is better than multiple arrangements.

3.6. *Summary of Main Results.*—The results for the main cases in each of the preceding five sections are summarized for convenience in Fig. 13. Reviewing these results it is concluded that guide vanes, intake slots, or a combination of both can be used to improve the standard of distribution in the swept intake beyond that of the squared intake. The use of guide vanes increases the mean intake loss under ground running conditions but their effect in flight may be insignificantly small. The use of slots has the double advantage in ground running of improving the distribution and also decreasing the loss. If the slots are properly sealed, their effect in flight should also be insignificant.

Since the actions of the vanes and slots are different in character, a still better distribution can be obtained by combining the two. The particular arrangement found to give the best result here may not be precisely the optimum in all cases.

Flow patterns for arrangements with 50 per cent span slots, with and without the mid-vane, are shown in Fig. 14. It is seen that in both cases the flow behind the slot (in what was originally the region of separation) is smooth, hence the improved distribution at the engine position.

* This method has been used by Messrs. Rolls Royce for intake doors on plenum chamber engine installations.

This of course applies primarily to the flow near the surface of the duct. The total-head distributions already examined show that some non-uniformity persists across the centre of the duct, suggesting that the duct length from slot to engine is inadequate for complete mixing (hence also the relative advantage of the more forward slot position).

The effect of adding the mid-vane is seen in an improved velocity distribution at the entry, corresponding to two passages each of more favourable height/width ratio than the unmodified entry. The existence of a second region of separation, on the inboard side of the vane, is seen. Vorticity shed into the main stream from this region explains the increase of loss found with the guide vane.

4. *Note on the Slotted Intake for Static Running*.—4.1. *Suitability for General Application*.—The intake slot developed during these tests has potentially a wider application to the design of future aircraft intakes. While in the past, as already mentioned, it has usually been possible to satisfy static running requirements by providing a sufficiently generous radius on the lips of the entry, in future this may often be impossible. With the swept intake as investigated here, increasing the lip radius by any practicable amount would be quite ineffective. This is a special case, but more generally it can be said that the emphasis on reaching higher Mach numbers in flight increasingly restricts the allowable amount of rounding of the lips, while at the same time it calls for relatively smaller entries, with consequently higher rates of internal diffusion which aggravate the static running problem. In the case of supersonic intakes it seems that this trend will be still more marked because of an additional need to keep the entry small in order to avoid high 'spillage drag'.

The other important factor appearing at the present time is the swing from centrifugal to axial-flow engines. This may mean a revision of the standards of intake requirement, since available evidence points to the fact that the axial engine is more sensitive to changes in the type of flow in the intake. Thus some present-day intakes which are acceptable for centrifugal engines might not be so under all conditions with axials.

Hence it is likely that on most future intakes, a device which improves the flow under static running conditions without repercussion on the flight characteristics will be an advantage, if not a necessity. The intake slot described in section 3.4, which is depicted in a general form in Fig. 15, may be capable of fairly wide application for this purpose. The action of the slot in the static condition or at low forward speed (*i.e.*, so long as the air is converging into the entry) is analogous to that of a conventional leading-edge slot in a wing at incidence, the inside of the intake corresponding to the upper surface of the wing. Flow through the slot removes, or compensates for, any tendency to separation just inside the main entry, which is the usual source of excess loss in the static condition. If a slot is provided, the main entry lip can be designed more specifically for the high-speed condition (*see* Fig. 15). The slot should not be allowed to remain open at speeds beyond that at which the direction of flow in the slot is reversed. It can be arranged to close at a convenient speed below the reversal value, as for example by spring-loading the sealing flap.

4.2. *Points Affecting Slot Design*.—Since virtually all forms of excess loss under static conditions originate at the entry lips, the provision of an auxiliary inlet in the form of a slot is practically certain to bring about some degree of improvement. Nevertheless to obtain the best result it is advisable to follow certain design principles. These can be deduced partly by analogy with the wing slot and partly from the results of the experiments. In addition to the tests already described an auxiliary experiment was made on a second model, consisting of a 52 deg swept intake with a straight duct of constant rectangular section (Fig. 16a). In this case the slots were adjustable both in span and in width. Total head was measured across the span of the duct at the mid-height only. The loss coefficients are therefore not true means, but the individual distributions (Fig. 17) and the variations of dispersion (Fig. 16b) can be used to illustrate points of design.

The slots in the auxiliary experiment were curved along their length, the walls of the slot at entry being normal to the outer surfaces of the wing, and at exit nominally tangential to the inner surfaces, as shown roughly in Fig. 16a. On the whole the results with this type of slot were poorer than those obtained with the straight slot used in the main experiment. The reason was probably that at the required widths the curved slot had insufficient length to exercise proper directional control of the flow through it. It is concluded that in practice a straight slot would usually give the better results. The following remarks are therefore intended to apply to a straight slot, although some of the deductions are made from the results with the curved slot.

Terminology regarding the dimensions of the slot is apt to be confusing. In what follows the transverse length (longer dimension) of the entry is termed the slot span. The perpendicular distance between the long walls is termed the slot width. The length of the passage from entry to exit (perpendicular to the other two dimensions in the case of a straight slot) is termed the slot length.

(*a*) The slot should incline backwards into the duct. Fig. 17a shows a series of distributions obtained by varying the width of the slots in the auxiliary experiment. As these were curved slots (Fig. 16a) the effective direction at the slot exit steepens as the width is increased. The results show that when this direction approaches the vertical, the distribution deteriorates across the whole span. On the other hand a fairly steep angle of cut probably accelerates the mixing, and is satisfactory provided that the diffusion pressure gradient in the duct behind the slot is not too adverse. On the whole the 45 deg angle used in the main experiment seems to give a satisfactory compromise.

(*b*) The slot width should be small, in order to get good directional control in the passage. The ratio slot length/slot width should be at least 2.

(*c*) The entry aspect ratio, span/width, should be high. A value of at least 4 is suggested, where possible. An inclined slot has of itself a swept entry and therefore it is necessary to guard against slot-entry loss in the true static case. This is a point of distinction from the wing slot. The effect of entry aspect ratio is shown by comparing the two series of distributions in Figs. 17a and 17b and the corresponding dispersion curves in Fig. 16b. In the first series full-span slots were used and the slot area was increased by increasing the width. The dispersion falls rapidly to begin with (the aspect ratio being high), but rises later as already mentioned (Note (*a*) above) when the optimum width is passed. In the other case the slot width was fixed and the area obtained by adjusting the span. For very small areas (aspect ratio below 2) the slot is actually detrimental, but later the dispersion falls steadily as the area and aspect ratio are increased.

(*d*) The slot should be properly ducted from entry to exit. Merely cutting holes in the inner and outer surfaces is aerodynamically poor. Apart from the absence of directional control, which is bad, the thin-edged holes are liable to cause additional losses. An example of this occurred on the auxiliary model, where owing to the method of construction the short ends of the slots originally had thin edges. Fig. 17c shows how the distribution at each end of the traverse was improved by a fairing forming a complete end wall to the slot.

(*e*) Inside the duct the rear edge of the slot should be rounded. This follows a principle of the wing slot. On the other hand the edges at the outer surface can be sharp, provided that the passage is of good proportions.

(*f*) A hinged flap at the slot entry (outer surface) appears to be the simplest device for sealing the slot in flight, but may be difficult to arrange if the circumference of the intake is curved. The method seems particularly suitable to the case of wing intakes of elongated shape, because straight hinge-lines on the wing surfaces will usually be possible. It should not be necessary to seal the slot on the inside surface, but tunnel tests on this point are desirable.

Acknowledgement.—The authors wish to acknowledge the help of K. Emslie, who did a large part of the experimental work and the preliminary analysis.

LIST OF SYMBOLS

ΔH	Total-head loss at a point of the measuring section, equal to minus the total-head reading
$\overline{\Delta H}$	Mean value of ΔH at measuring section
q_i	Mean entry dynamic head, based on projected entry area
N	Number of readings at measuring section
σ	Standard dispersion of total-head readings; such that $\sigma^2 = \frac{1}{N}\sum\left(\frac{\Delta H}{q_i} - \frac{\overline{\Delta H}}{q_i}\right)^2$
ϕ	Angle of sweep of entry

REFERENCES

No.	Author	Title, etc.
1	J. Seddon and A. Spence	A wind-tunnel investigation of entry loss on propeller turbine installations. Part I. R. & M. 2894. August, 1948.
2	G. N. Patterson	Note on the design of corners in duct systems. R. & M. No. 1773. October, 1936.
3	G. G. Brebner	Boundary-layer measurements on a 59-deg swept-back wing at low speed. C.P. 86. August, 1950.

TABLE 1

Dimensions of intake (full-scale)

Scale 1/7

Entry

Area (projected normal to duct axis)	2·60 sq ft
Span	3·41 ft
Mean Height	0·76 ft
Angle of sweepback	52 deg
Angle of forward stagger	15 deg

Measuring section

Area	3·9 sq ft
Radius	1·2 ft

Vanes

Vane number (from outboard)	Length (ft)	Height (ft)
1	1·0	0·55
2	1·9	0·66
3	2·6	0·77
4	3·5	0·88
5	4·2	0·99

Slots

	Front Slot	*Rear Slot*
Width (normal to walls)	0·23 ft	0·29 ft
Angle to vertical	45 deg	45 deg
Maximum span	1·46 ft	2·92 ft
Maximum area per slot	0·34 sq ft	0·85 sq ft

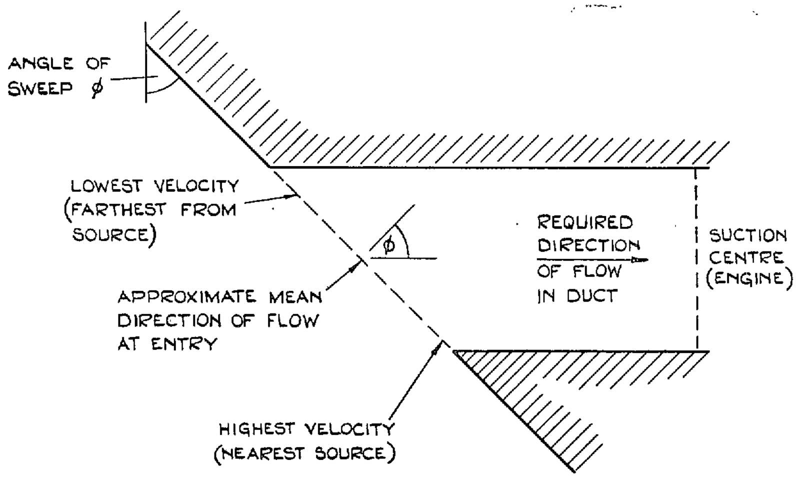

FIG. 1. Flow by suction into a swept intake.

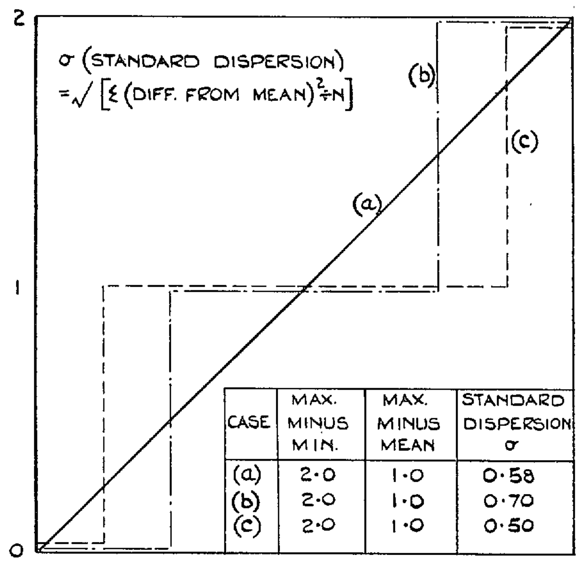

FIG. 2. Comparison of distribution criteria.

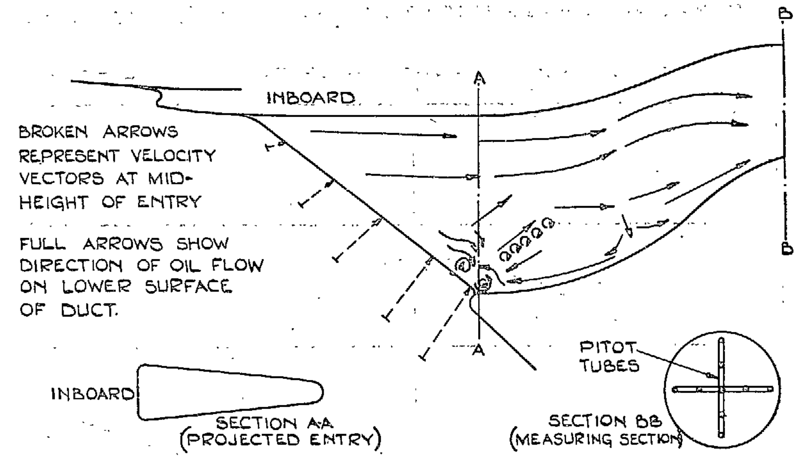

FIG. 3a. Swept intake showing details of flow.

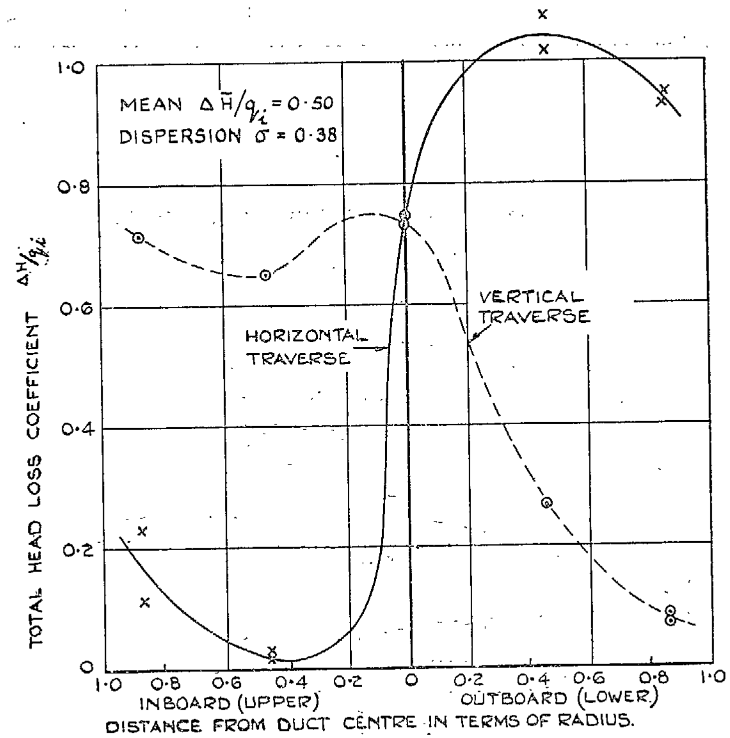

FIG. 3b. Distribution of total head.

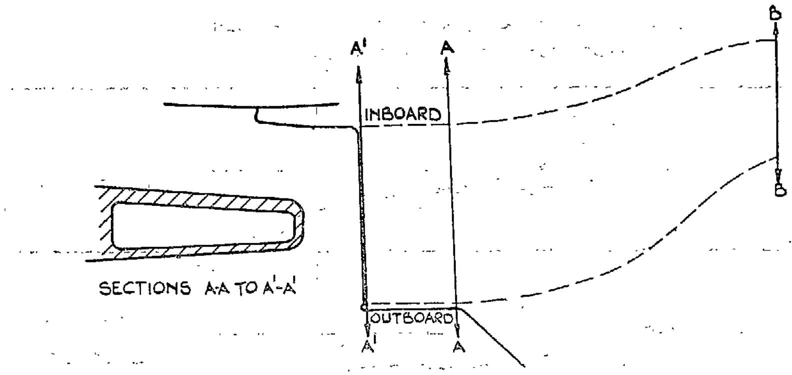

FIG. 4a. Squared intake.

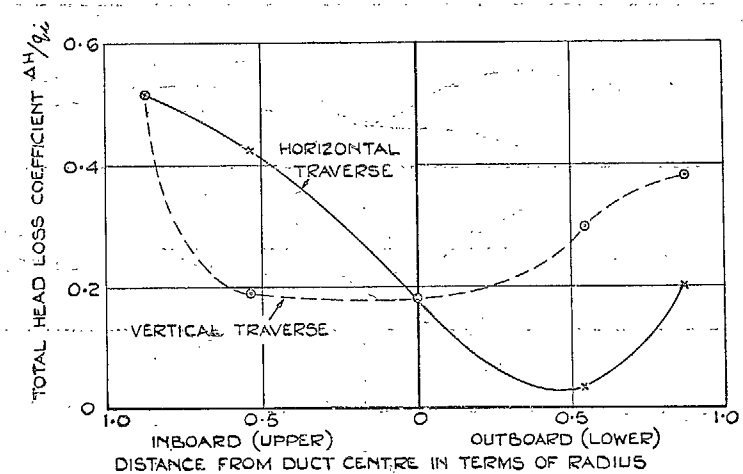

FIG. 4b. Distribution of total head.

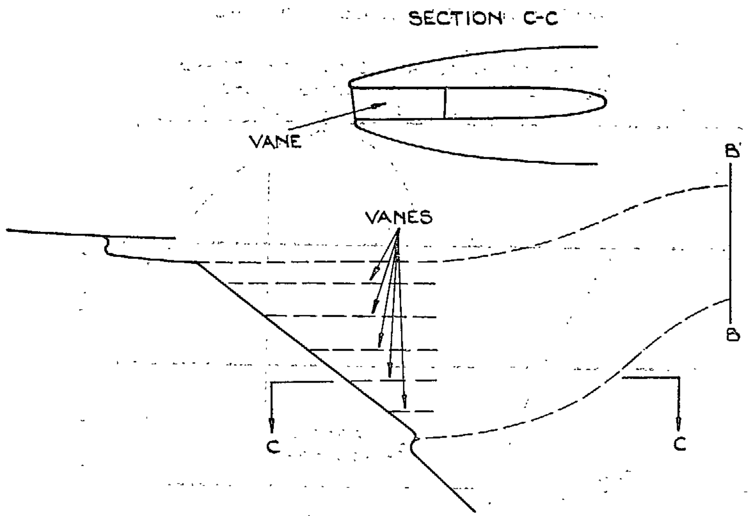

FIG 5a. Swept intake with guide vanes.

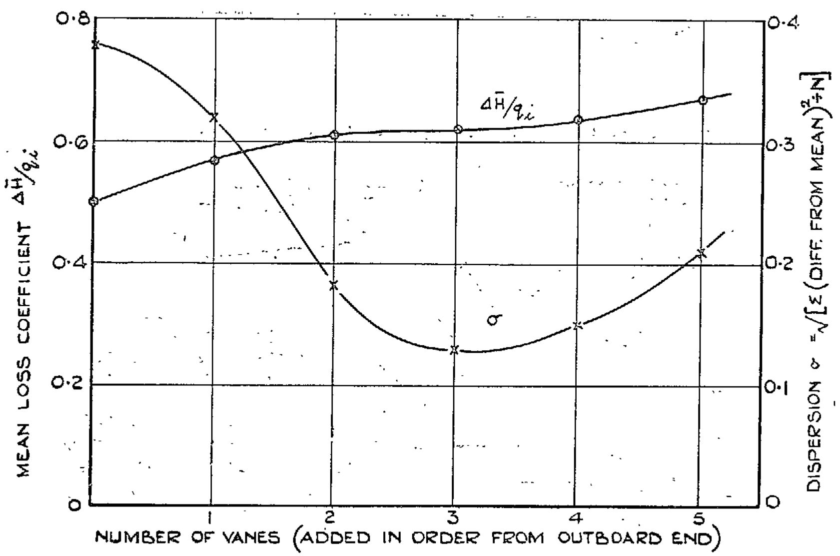

FIG. 5b. Variation of intake characteristics with number of vanes.

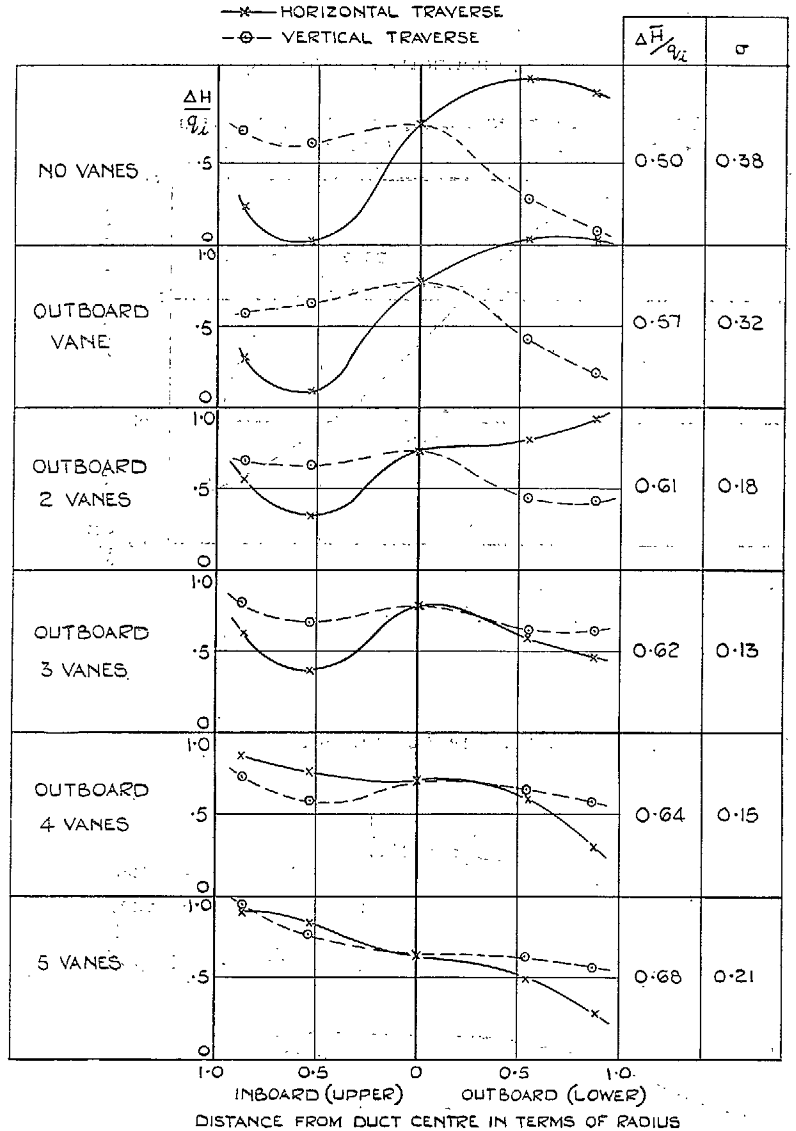

FIG. 6. Effect of vanes on total-head distribution.

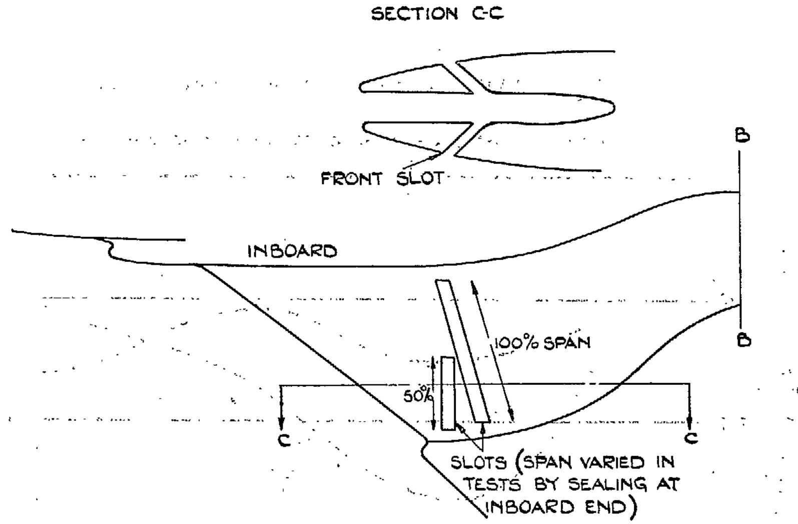

FIG. 7a. Swept intake with slots.

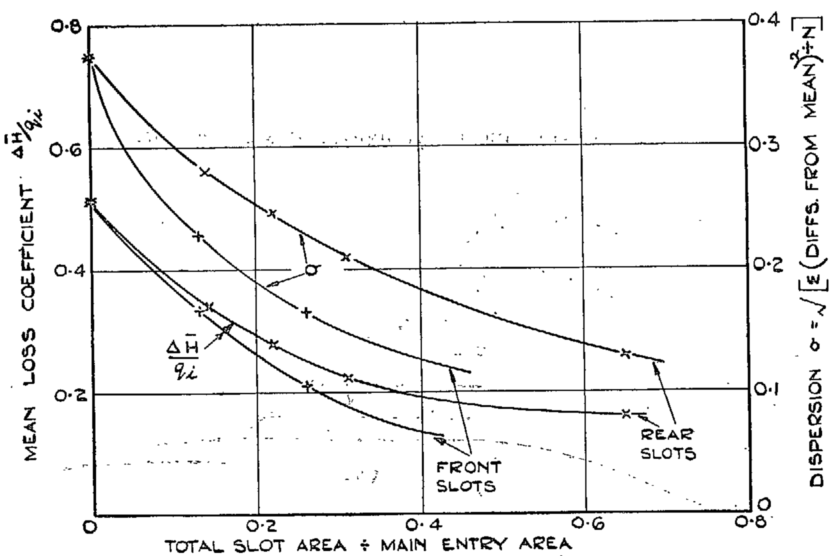

FIG. 7b. Variation of intake characteristics with slot area.

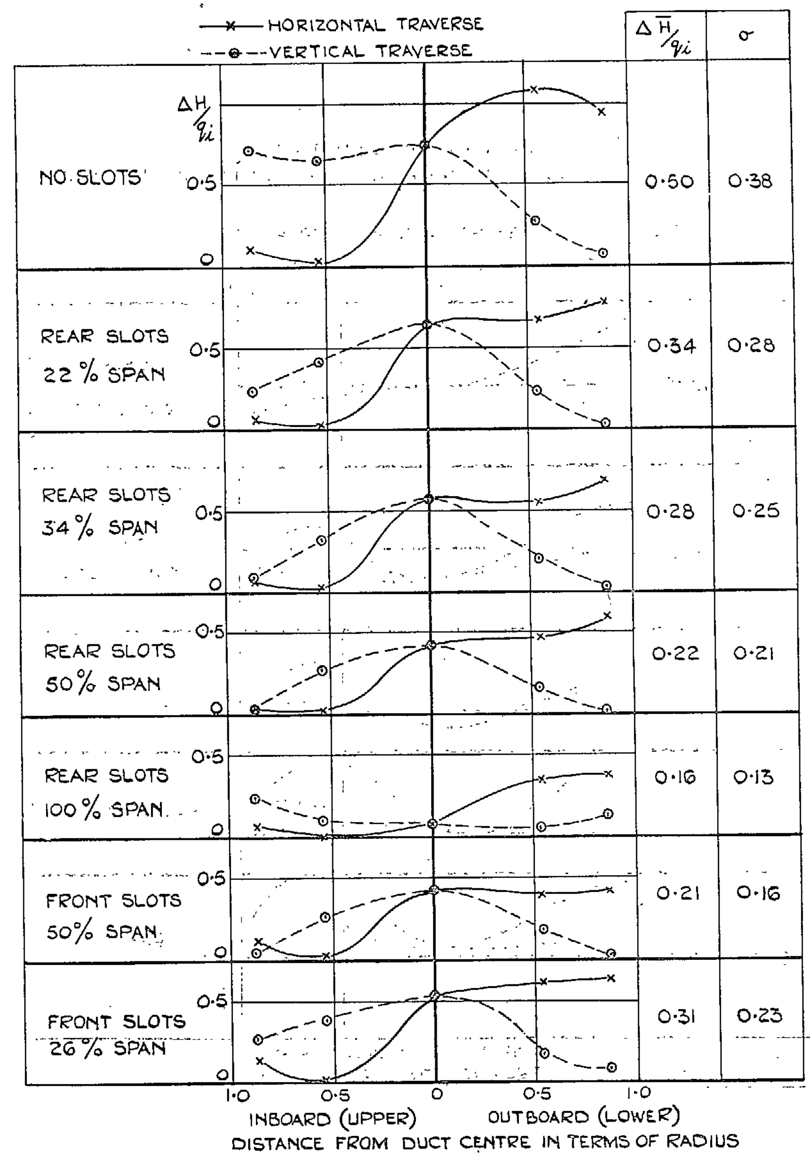

FIG. 8. Effect of slots on total-head distribution.

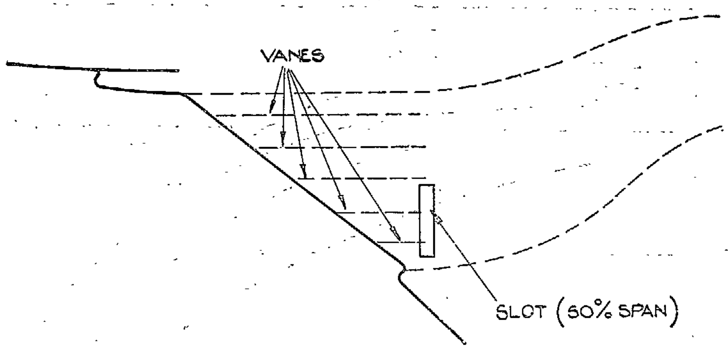

FIG. 9a. Swept intake with front slots and vanes.

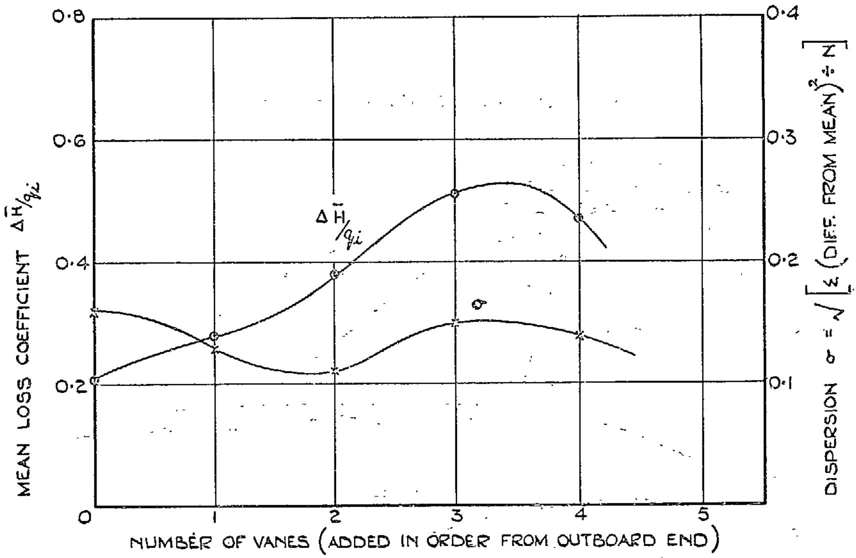

FIG. 9b. Intake characteristics with front slots and vanes.

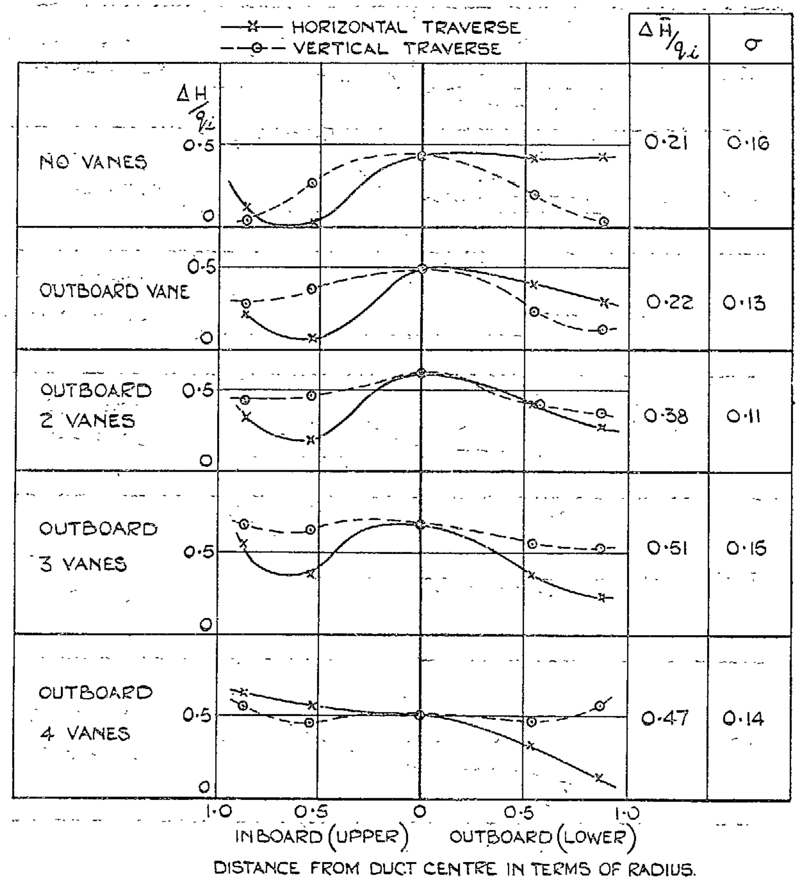

FIG. 10. Effect of vanes with front slots (50 per cent span) on total-head distribution.

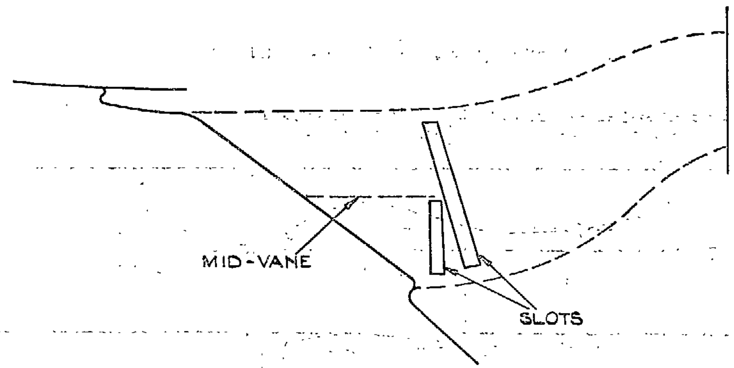

FIG. 11a. Swept intake with mid-vane and slots.

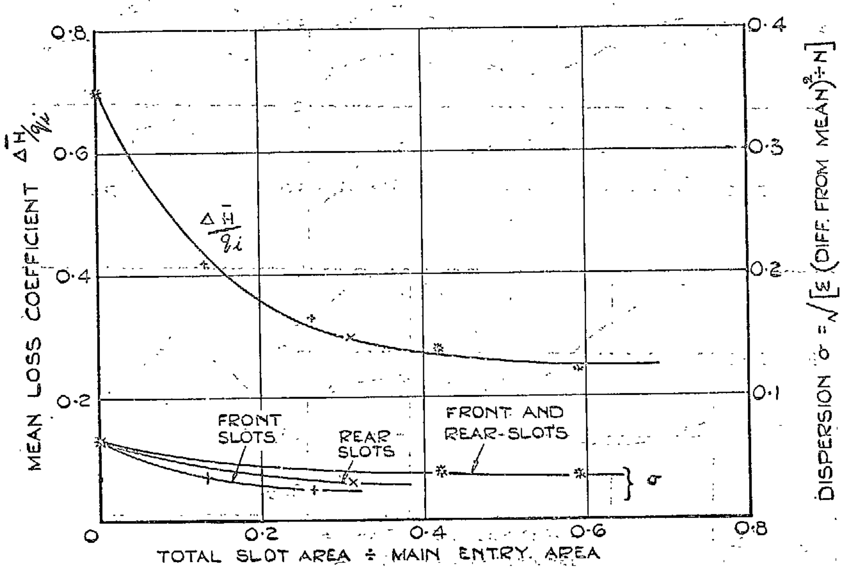

FIG. 11b. Intake characteristics with mid-vane and slots.

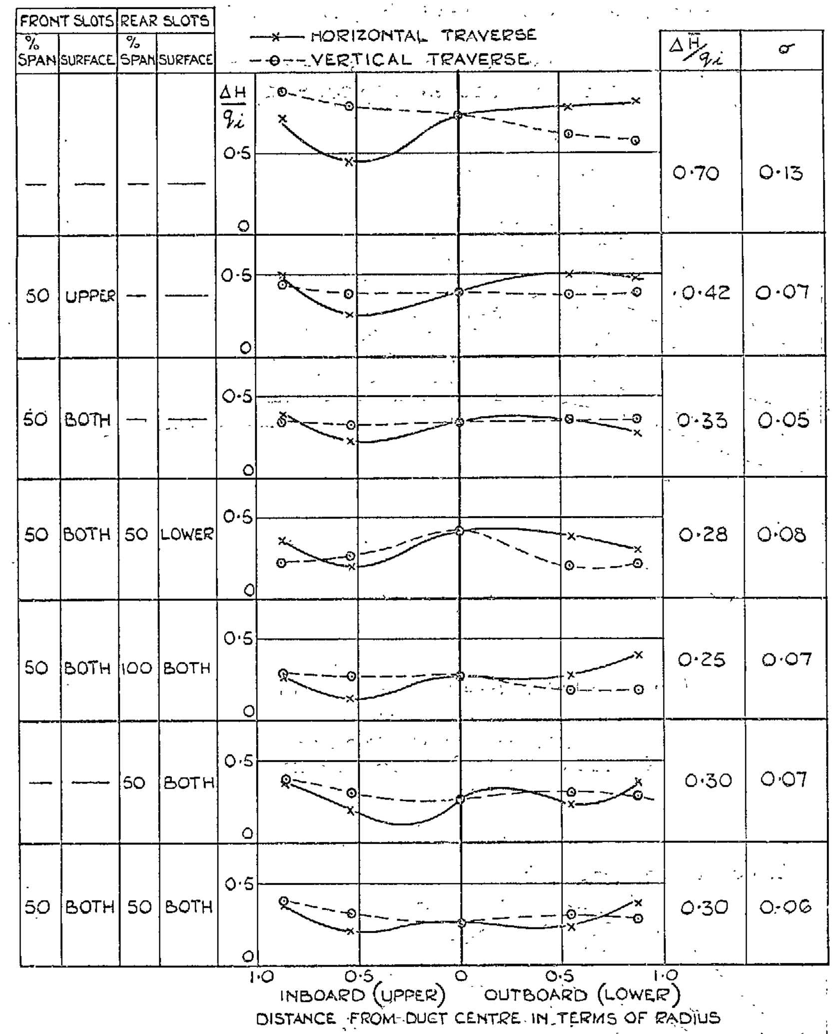

FIG. 12. Effects of slots with mid-vane on total-head distribution.

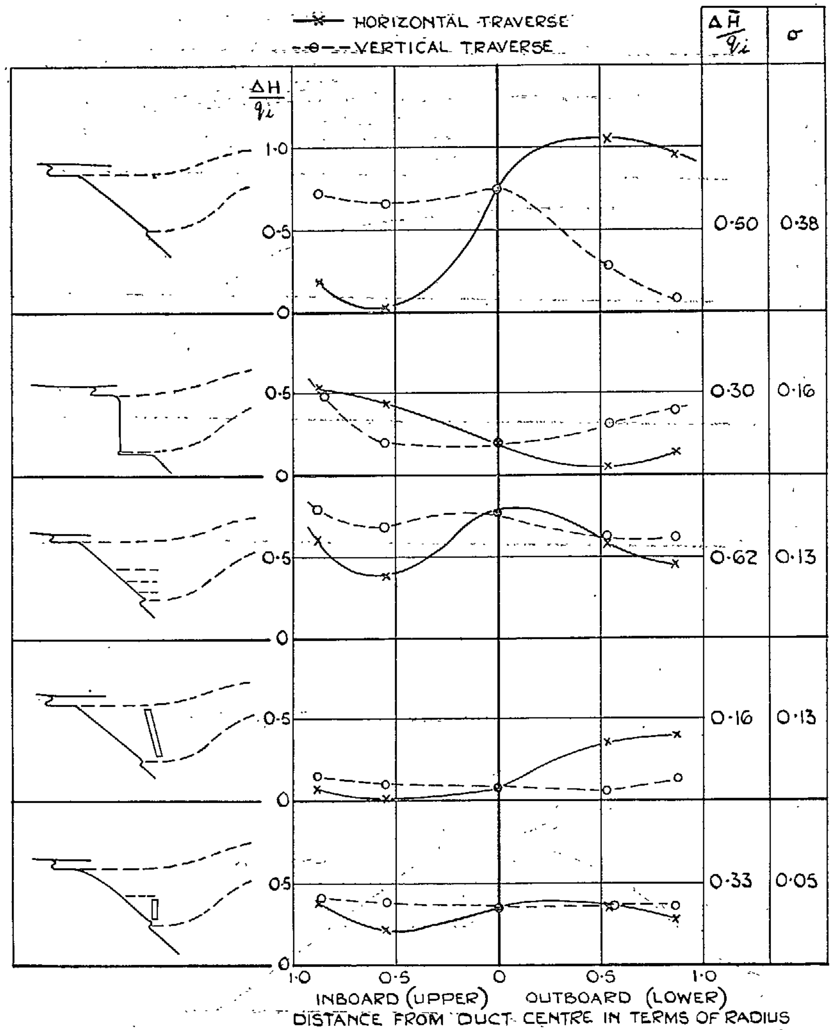

FIG. 13. Summary of main cases.

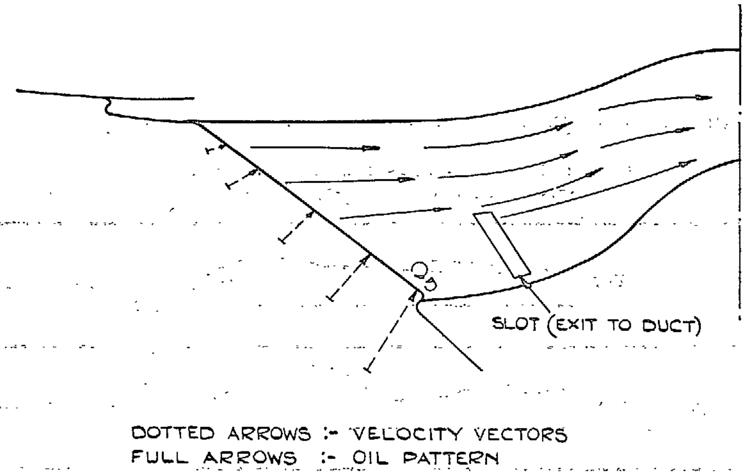

FIG. 14a. Half-span rear slots (no vanes).

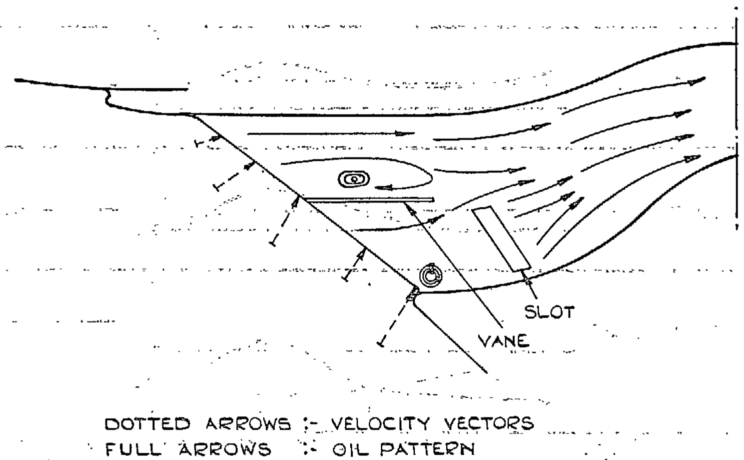

FIG. 14b. Half-span rear slots with mid-vane.

FIGS. 14a and 14b. Entry velocity distributions and duct oil patterns.

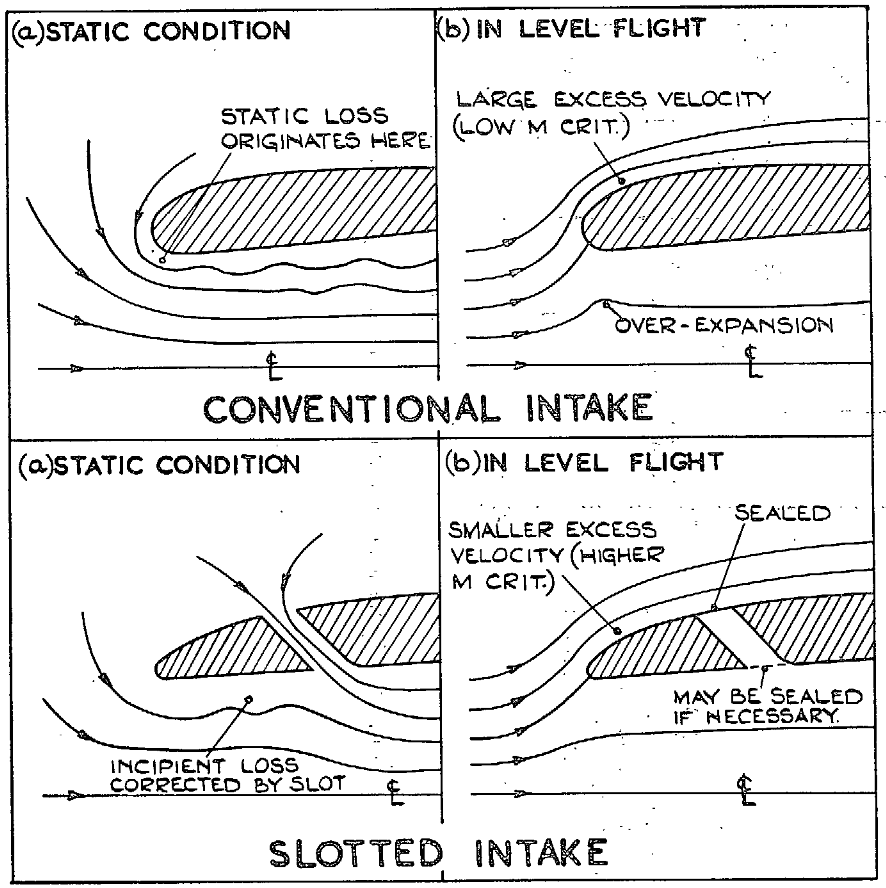

FIG. 15. Illustration of a slotted intake for general application.

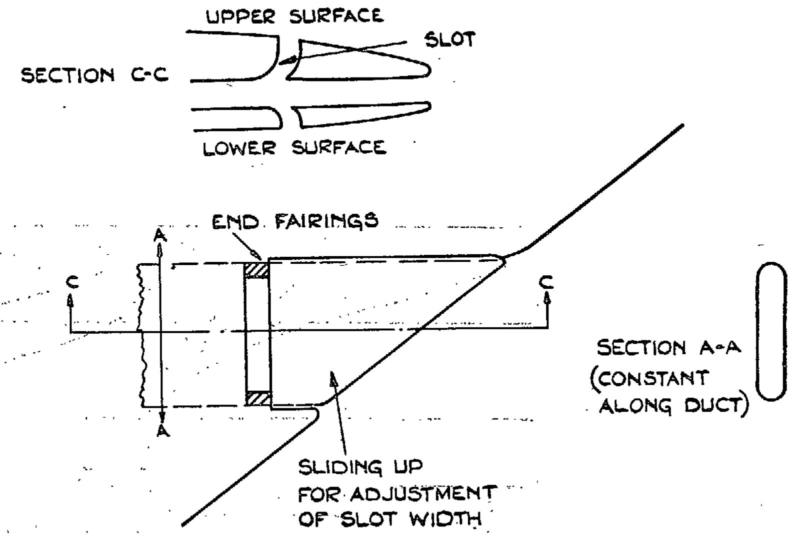

FIG. 16a. Swept intake with slot (auxiliary model).

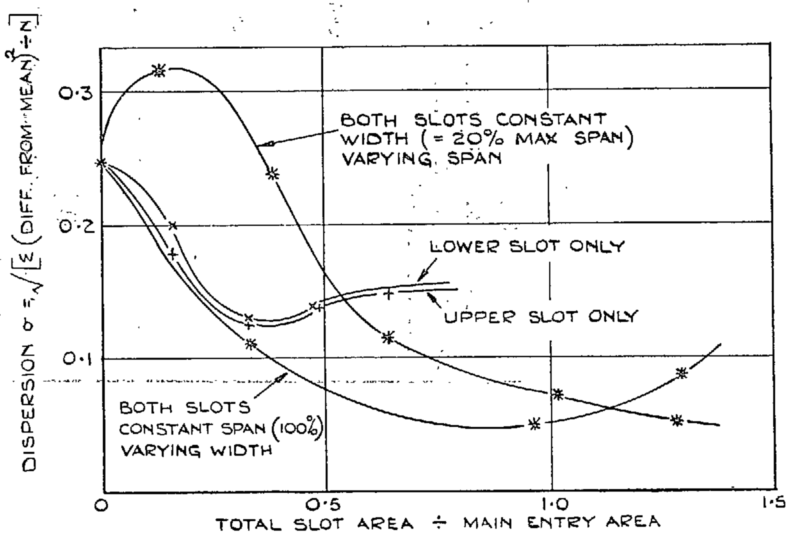

FIG. 16b. Effect of slot span and width on total-head dispersion (auxiliary model).

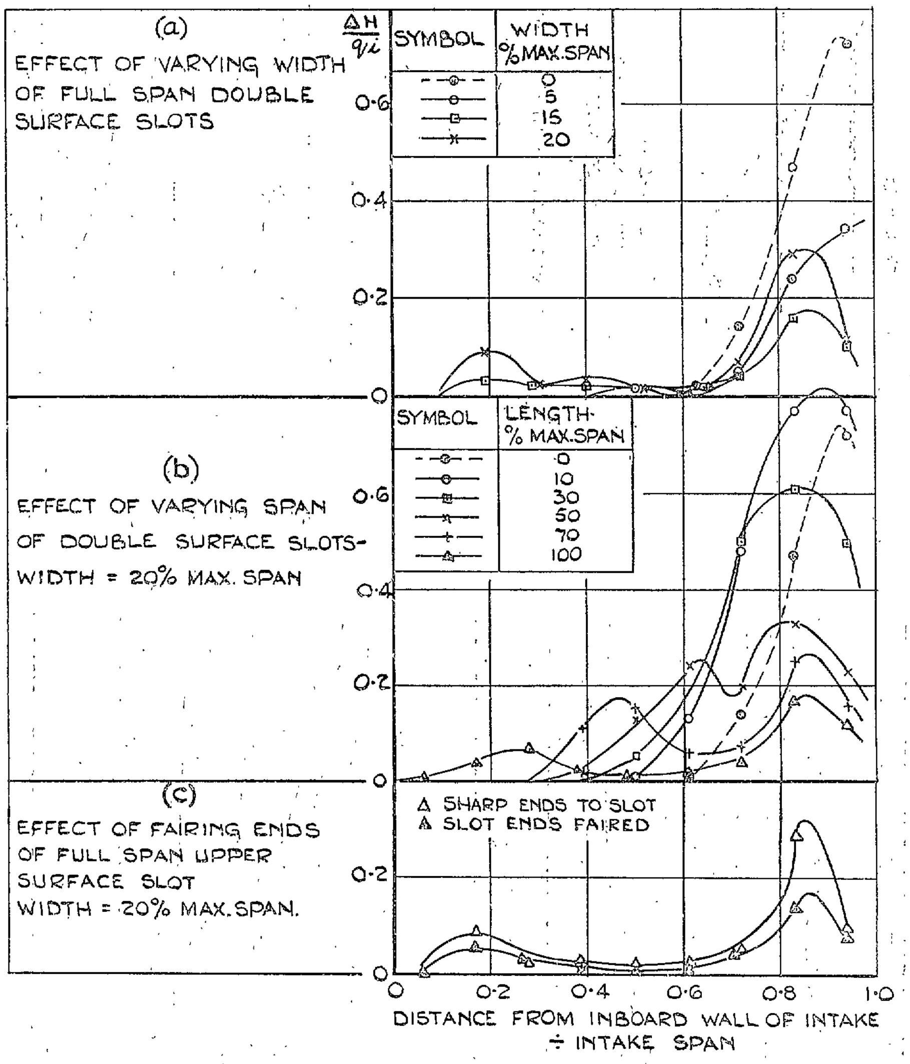

FIG. 17. Total-head distributions on auxiliary model.

(61783) Wt. 17/680 K.9 6/54 Hw. PRINTED IN GREAT BRITAIN

Publications of the Aeronautical Research Council

ANNUAL TECHNICAL REPORTS OF THE AERONAUTICAL RESEARCH COUNCIL (BOUND VOLUMES)

1936 Vol. I. Aerodynamics General, Performance, Airscrews, Flutter and Spinning. 40s. (41s. 1d.)
Vol. II. Stability and Control, Structures, Seaplanes, Engines, etc. 50s. (51s. 1d.)

1937 Vol. I. Aerodynamics General, Performance, Airscrews, Flutter and Spinning. 40s. (41s. 1d.)
Vol. II. Stability and Control, Structures, Seaplanes, Engines, etc. 60s. (61s. 1d.)

1938 Vol. I. Aerodynamics General, Performance, Airscrews. 50s. (51s. 1d.)
Vol. II. Stability and Control, Flutter, Structures, Seaplanes, Wind Tunnels, Materials. 30s. (31s. 1d.)

1939 Vol. I. Aerodynamics General, Performance, Airscrews, Engines. 50s. (51s. 1d.)
Vol. II. Stability and Control, Flutter and Vibration, Instruments, Structures, Seaplanes, etc. 63s. (64s. 2d.)

1940 Aero and Hydrodynamics, Aerofoils, Airscrews, Engines, Flutter, Icing, Stability and Control, Structures, and a miscellaneous section. 50s. (51s. 1d.)

1941 Aero and Hydrodynamics, Aerofoils, Airscrews, Engines, Flutter, Stability and Control, Structures. 63s. (64s. 2d.)

1942 Vol. I. Aero and Hydrodynamics, Aerofoils, Airscrews, Engines. 75s. (76s. 3d.)
Vol. II. Noise, Parachutes, Stability and Control, Structures, Vibration, Wind Tunnels. 47s. 6d. (48s. 7d.)

1943 Vol. I. Aerodynamics, Aerofoils, Airscrews. 80s. (81s. 4d.)
Vol. II. Engines, Flutter, Materials, Parachutes, Performance, Stability and Control, Structures. 90s. (91s. 6d.)

1944 Vol. I. Aero and Hydrodynamics, Aerofoils, Aircraft, Airscrews, Controls. 84s. (85s. 8d.)
Vol. II. Flutter and Vibration, Materials, Miscellaneous, Navigation, Parachutes, Performance, Plates and Panels, Stability, Structures, Test Equipment, Wind Tunnels. 84s. (85s. 8d.)

Annual Reports of the Aeronautical Research Council—

1933–34	1s. 6d. (1s. 8d.)	1937	2s. (2s. 2d.)
1934–35	1s. 6d. (1s. 8d.)	1938	1s. 6d. (1s. 8d.)
April 1, 1935 to Dec. 31, 1936	4s. (4s. 4d.)	1939–48	3s. (3s. 2d.)

Index to all Reports and Memoranda published in the Annual Technical Reports, and separately—

April, 1950 - - - - R. & M. No. 2600. 2s. 6d. (2s. 7½d.)

Author Index to all Reports and Memoranda of the Aeronautical Research Council—

1909–1949. R. & M. No. 2570. 15s. (15s. 3d.)

Indexes to the Technical Reports of the Aeronautical Research Council—

December 1, 1936 — June 30, 1939.	R. & M. No. 1850.	1s. 3d. (1s. 4½d.)
July 1, 1939 — June 30, 1945.	R. & M. No. 1950.	1s. (1s. 1½d.)
July 1, 1945 — June 30, 1946.	R. & M. No. 2050.	1s. (1s. 1½d.)
July 1, 1946 — December 31, 1946.	R. & M. No. 2150.	1s. 3d. (1s. 4½d.)
January 1, 1947 — June 30, 1947.	R. & M. No. 2250.	1s. 3d. (1s. 4½d.)
July, 1951.	R. & M. No. 2350.	1s. 9d. (1s. 10½d.)

Prices in brackets include postage.

Obtainable from
HER MAJESTY'S STATIONERY OFFICE
York House, Kingsway, London, W.C.2; 423 Oxford Street, London, W.1 (Post Orders: P.O. Box 569, London, S.E.1); 13a Castle Street, Edinburgh 2; 39, King Street, Manchester 2; 2 Edmund Street, Birmingham 3; 1 St. Andrew's Crescent, Cardiff; Tower Lane, Bristol 1; 80 Chichester Street, Belfast, or through any bookseller

S.O. Code No. 23-2909

R. & M. No. 2909