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Summary. Measurements were made at zero forward speed of the forces acting on a lifting-fan wing system of hexagonal planform. The diameter of the wing was reduced in the course of the experiment from five times to twice the diameter of the fan. The wing acted efficiently as a shroud, and for the same power input, the maximum total lift was increased by 60 per cent over that of the fan acting alone. With the wing in position, over 40 per cent of the total was 'induced' lift, *i.e.*, that developed on the wing alone due to a reduction in pressure on the upper surface caused by the inflow to the fan.

For wings with diameter four or five times that of the fan, there is a large reduction in induced lift as the ground is approached, the loss being roughly inversely proportional to the square of the ground clearance. For a ground clearance of 0·25 the wing diameter, 25 per cent of the overall lift is lost. The adverse ground effect was reduced when the wing was set at a large angle of inclination to the ground.

With smaller wings, the adverse ground effect is less, and for a wing/fan diameter ratio of 2, the loss in induced lift is counterbalanced by the small increase in the fan lift which occurs (for all values of wing/fan diameter ratio) as the ground is approached.

The loss in induced lift when in proximity to the ground can be attributed to a reduction in pressure over the lower surface of the wing caused by the inflow which provides air for entrainment in the spreading jet. The deflection of the jet by the ground causes an increase in pressure at the axis of the jet which acts over the hub of the fan and increases the fan lift.

Rows of parallel slats (fences) on the ground serve to partly channel the jet efflux, thus reducing the adverse ground effect. For the slats tested, with spacings equal to or larger than the fan hub diameter, the results depended critically on the transverse position of the fan axis relative to the adjacent slats.

1. *Introduction.* A type of V.T.O.L. aircraft currently of interest is one which rests on the ground in a conventional attitude and in which the lift for take-off is generated by one or more fans which are mounted in apertures in the wing, their axes of rotation being normal to the plane of the wing. In this case, the inflow to the fan over the upper surface of the wing induces an additional lift on the wing, increasing the efficiency of the fan. When the aircraft is close to the ground, however, the jet is obliged to spread out parallel to the ground and the air entrained by the jet causes a region of reduced pressure to develop on the undersurface of the wing, reducing the lift.

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The aim of the present experiments was to investigate these effects at zero forward speed. The work was undertaken concurrently with experiments by Wyatt[1] at the Royal Aircraft Establishment, Bedford; these, however, simulated the relatively high-speed efflux from a jet engine and the ratio of orifice area to wing area was more appropriate to a jet-engine supported aircraft than to a fan-lift arrangement.

2. *Model Details.* The model consisted of the rather idealized arrangement of an 8-bladed adjustable pitch fan of 8 in. diameter fitted, as shown in Fig. 1*, inside a 40 in. diameter flat-plate wing of hexagonal plan form. The outer portion of the wing consisted of a light built-up frame covered with doped tissue and this readily enabled successive reductions to be made in the size of the wing. The inner portion of the wing was solid and carried pressure plotting holes.

The wing and the motor were separately suspended (with the wing in a vertical plane) and connected to single-component mechanical balances, Fig. 2, so as to measure separately the lift and moment (about the vertical diameter) on the wing and the thrust and the torque on the fan. The rotational speed of the motor was indicated by means of a modified capacity bridge. The ground was simulated by a large vertical board (roughly 9 ft square) which could be moved up close to the wing as required.

The fan had a 3 in. diameter steel hub into which the eight blades could be set and adjusted. The blades had a constant 1 in. chord and were bent from $\frac{1}{16}$ in. sheet aluminium by hammering over a 3 in. diameter cylinder with the blade axis held skew to the cylinder generator. Thus twist and camber were readily incorporated. This technique was suggested by Mr. R. A. Wallis.

The performance of the fan in the wing was measured first so as to ensure that the fan was operating sufficiently far away from the stall point so that, later, any changes in the lift of the wing-fan system due to ground effect were not complicated by any critical changes in fan performance. Total-head traverses were made immediately behind the fan at various tip settings. The blade twist was adjusted to give uniform loading at 18 deg blade setting, measured at the tip, Fig. 4. The fan stalled at a blade setting between 38 deg and 48 deg.

The inflow into the fan, and hence the blade loading, were influenced by the shape of the surrounding duct. Total-head traverses are shown in Fig. 5 for the 18 deg blade setting for the fan in the wing, and in addition for the cases of the fan operating alone, and in a parallel duct far downstream from a well-rounded entry. When in the wing, the fan stalled at a higher blade setting than when operating alone, whilst when the fan was in the duct the blade setting for stalling was raised still further: this can be seen from some of the lower set of curves in Fig. 6 where the variation of a fan lift coefficient with blade setting is shown. At blade settings where the fan was stalled, the forces measured were very unsteady.

3. *Notation.* For convenience in comparing results obtained at different fan rotational speeds, the measured forces have been rendered non-dimensional, following Krüger[3], by dividing them by a dynamic pressure based on the peripheral speed of the fan blade tip and by the overall fan disk area (including hub).

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* The arrangement of Fig. 1 was adopted because the apparatus was designed, as a matter of expediency, round an available variable-frequency high-speed induction motor which was rated at $2\frac{1}{2}$ h.p. at 3,000 r.p.m.[2]. The motor had been fitted with a step-up gear box and with an extension shaft carried inside a 3 in. diameter fairing: acknowledgement is due to Admiralty Research Laboratory for the loan of this additional equipment.

It should also be noted that the efficiency of various systems can be compared in terms of a static thrust factor of merit, ζ. This can be interpreted as the ratio of the total static thrust (lift) actually measured to the maximum thrust theoretically obtainable for the same power input with an unshrouded fan of the same diameter.

α		Fan blade angle measured between chord and plane of rotation
α_0		Blade setting, the value of α at blade tip
d		Fan diameter
D		Wing diameter
h		Height of slat
H		Height of wing above ground
n		Rotational speed of fan (revs/sec)
r		Radius
r_0	$=$	$d/2$
s		Slat spacing
L		Lift or thrust
Q		Torque
M		Rolling moment
k_L	$\equiv$	$\dfrac{L}{(\pi^3/8)\rho n^2 d^4}$, lift coefficient
k_p	$\equiv$	$\dfrac{Q}{(\pi^3/16)\rho n^2 d^5}$, power coefficient
k_M	$\equiv$	$\dfrac{M}{(\pi^3/8)\rho n^2 d^5}$, moment coefficient
ζ	$\equiv$	$\dfrac{k_L}{(2k_p)^{2/3}}$, static thrust factor of merit

Subscripts

f	Fan
i	Induced on wing
∞	Used in tests in which H was varied to denote values appropriate to a large value of H

4. *Fan-Wing Performance away from the Ground.* The effect of variation of fan blade setting on the lift coefficient developed by the fan-wing combination is shown in Fig. 6, and on the static thrust factor of merit in Fig. 7. The greater stalling angle of the fan in duct over that of the fan in wing, and of that compared with the fan alone is clearly seen, but it is interesting to note that the lift developed by the fan at the stall is practically constant; the improvements in total lift are due to the increase in the induced lift as the wing or duct are acting as efficient shrouds. What is at first sight surprising is that the wing, which is confined to the plane of the fan, is acting so efficiently as a shroud. The effect of adding short cylindrical extension ducts on the underside of the wing was also investigated, but is shown in Figs. 6 and 7, and also in Fig. 8 to have little additional effect.

The theory of the ducted propeller has been described, for example, by Küchemann and Weber[4], and its application to the present experiment is of interest. Simple momentum arguments show that for a given fan diameter and power input, the addition of a duct enables a larger overall thrust to be obtained. This is due to the alteration of the inflow velocity distribution in the plane of the fan by the duct, and to the alteration in the contraction ratio of the slipstream. In addition to these changes, the duct acts as an endplate to the fan blades and the induced drag of the fan may be considerably diminished.

The increase in static thrust factor of merit shown in Fig. 7 due to the addition of the wing is, at moderate pitch angles, much the same as that reported by Kruger[3, 4] using a shroud whose axial dimension was 5/8 of the propeller diameter. The value obtained with a duct-type shroud approaches the maximum value possible for a fairing which maintains the slipstream area equal to that of the fan. In this case the thrust is shared equally between fan and shroud and ζ is equal to $2^{1/3}$ or $1 \cdot 26$ and thus represents the ideal towards which the fan in wing should aim. When the present wing was suspended over a large suction duct (without the fan in position), a velocity traverse of the aperture showed that the axial velocity rose to a value $1 \cdot 25$ of the mean velocity just outside the wing boundary layer. Pressure plotting carried out on the wing also showed that the velocity gradient was everywhere favourable on the upper surface round the entry into the plane of the fan. The velocity rose rapidly at the rounded entry and the pressure measurements showed that 50 per cent. of the induced lift occurred over the rounded entry inboard of the $4\frac{1}{2}$ in. radius ($1 < r/r_0 < 1 \cdot 125$) and that 85 per cent of the lift was carried between 4 and 8 in. radius ($r/r_0 < 2$). Later in the tests the diameter of the wing was reduced from a value of D/d of 5 to a value of 2 without much adverse effect on the static thrust factor of merit in the absence of the ground.

From the measurements described in this section it was decided that the tests on ground effect should be carried out with a fan blade setting of 38 deg, which was as close to the stall as it was thought advisable to approach; in addition, that check tests should also be carried out at the much lower setting of 18 deg.

5. *The Effect of Ground Proximity on Fan-Wing Performance.* The effect of varying the ground clearance on the lift and power coefficients and on the static thrust factor of merit of the wing-fan system is shown in Fig. 9 for the two blade settings of 18 deg and 38 deg. The measured forces were very unsteady until the ground clearance/wing-diameter ratio H/D exceeded about $0 \cdot 20$ at the 18 deg blade setting, and with the 38 deg blade setting the forces remained unsteady even up to an H/D value of $0 \cdot 6$. The results in coefficient form were little affected by alteration of the rotational speed between 4,500 and 5,500 r.p.m.

A rapid loss in overall lift occurs as the ground is approached, although the power absorbed by the fan remains unaltered, and there is a small increase in the lift of the fan. This loss in overall lift can be expressed in terms of the lift developed in the absence of the ground, and is shown in this form in Fig. 10 where it is seen to be independent of the fan blade setting.

This loss in lift has serious implications for a V.T.O.L. aircraft of this type, as Fig. 10 shows that to avoid even a 10 per cent loss an excessively long undercarriage would be required if no other method of alleviation were possible. The loss of lift appears to be due to entrainment of air by the fan jet as it spreads radially along the ground. This causes a balancing inflow along the undersurface of the wing and a consequent downward suction on the wing. As the extent of the wing is clearly of prime importance, the hexagonal wing was successively reduced in size, as the concluding item in the experiment, from 40 in. diameter to 32 in., 24 in., and finally to the 16 in. diameter circle which formed the basis of the wing's construction (Fig. 1). Measurements of ground effect were carried out at each stage and the resulting variation in the wing lift coefficients and in the static thrust factor of merit are shown in Figs. 11 and 12. It can be seen from Fig. 11 that as the ground is approached, the lift developed by the fan increases slightly, and that this is independent of wing diameter. About half the increase in fan lift coefficient in Figs. 9 and 11 observed as the ground is approached is the increase associated with the reduction in the induced velocity at the fan (in the absence of wing or hub) caused by the presence of the ground, according to the calculations of Knight and Hefner[5]. The remainder can be explained in the light of tests made by von Glahn[6] on the thrust of annular and circular nozzles. It appears that whilst the thrust of a jet issuing from a circular nozzle decreases as the nozzle approaches the ground, the thrust obtained from an annular nozzle increases. This is due to the back pressure caused by the deflection of the jet when the nozzle is close to the ground and which acts over the area of the base contained within the annular nozzle. In the present case it is probable that a similar pressure increment was acting over the area of the hub spinner, but no measurements were made to confirm this. Owing to the low speed of the flow through the fan the pressures and velocities of any flow over the lower surface of the wing were too small to be measured, so it was not possible to examine the precise details of the flow mechanism. The decrease in the induced lift on the wing as the ground is approached is shown in Fig. 11 to be less for the smaller wings. The curves become more closely correlated if the induced lift is plotted against the ratio of ground clearance to wing diameter, Fig. 13. The results for wings of diameter 4 or 5 times the fan diameter lie on the same curve, and the loss in induced lift turns out to be roughly inversely proportional to the square of the ground clearance. For the smaller wings the shapes of the curves in Fig. 13 are somewhat different.

The loss in overall lift is plotted non-dimensionally as a function of the ground clearance in Fig. 14 and of the ground clearance/wing-diameter ratio in Fig. 15. For the smallest wing size ($D/d = 2$) the increase in fan lift as the ground is approached exceeds the loss in induced lift and there is a small overall gain. For the larger wings there is an appreciable loss. The observations obtained for the largest wing sizes, D/d of 4 and 5, lie practically on the same curve.

This information has been used by Wyatt[1] who has correlated data available from several sources. For values of d/D of 4, and upwards to 70, Wyatt finds that observations fall within a fairly narrow band which covers the appropriate curves of Fig. 15 and the results are not significantly affected by the differences between circular and delta planform.

6. *Effect of Angle of Roll.* The effect of the angle of roll of the largest fan wing ($D = 40$ in., $D/d = 5$) on the normal force and on the rolling moment was measured at various ground clearances. The observations were taken with the fan operating with 18 deg blade setting and at 5,500 r.p.m., for which the coefficients at zero roll are shown in Figs. 9 and 10.

In all the observations where H/D was $0 \cdot 25$ or less, the flow was very unsteady. It can be seen from Figs. 16 and 17 that small angles of roll up to 12 deg have little effect on the lift but that at angles of roll greater than 15 deg and when the wing is close to the ground, *e.g.*, at $H/D = 0 \cdot 15$, the adverse ground effect is greatly diminished. This is because the jet efflux approaching the ground no longer spreads out equally in all directions, but flows towards the region of the higher wing where the ground interference is least. In consequence of the loss of lower-surface suction where the wing is closest to the ground the rolling moment at high angles of roll becomes stable, as is shown in Fig. 18. However, the magnitude of the maximum unstable moments may not be enough to impose any very great difficulties of control. It should also be pointed out that the forces measured on the wing and fan are normal forces although no distinction has been made. In addition to the lift component of the resultant force there would also be a component parallel to the ground which would tend to move the wing horizontally in the direction of its lowest edge.

7. *Methods of Reducing the Adverse Ground Effect.* A 3 in. long cylinder shrouding the fan was fixed to the underside of the wing in an attempt to direct the efflux closer to the ground and to reduce the adverse ground effect. Fig. 19 shows that little was achieved by this device.

Tests were also made on the effect of placing a number of slats or fences along the ground. These prevent the fan efflux which escapes across the surface of the ground from spreading radially and, to an extent which depends on the height (h) and spacing (s) of the slats and of the gap ($H-h$) between the slats and the undersurface of the wing, forces the efflux to flow parallel to the slats. As a consequence, the entrainment and undersurface suction are diminished. The effects of varying all these parameters have not been fully explored as this was being done more thoroughly in the R.A.E. programme[1] with a jet-supported wing. However, the measurements made are presented here so as to enable a comparison to be made with the R.A.E. results which were obtained with a very different ratio of the wing diameter to jet diameter. In addition some curious results are reported which are due to the annular shape of the jet.

In Fig. 20 is shown the effect on the variation of loss of overall lift with ground clearance of two heights of slats, $1\frac{1}{2}$ in. and 3 in. ($h/d = 0 \cdot 1875$ and $0 \cdot 375$), the slats being spaced 6 in. ($s/d = 0 \cdot 75$) apart. When H/D exceeded $0 \cdot 4$ (*i.e.*, the wing more than 16 in. above the ground) the smaller slats are too small to have any effect: the larger slats roughly halve the loss of lift. When the wing is closer to the ground, considerable scatter appears in the results as is especially indicated by the 'repeat' readings that were taken later in the experiment when the particular slat spacing was re-erected. Similar unexpected results were obtained when an examination was made of the effect of varying the spacing of slats 3 in. high, Fig. 21. The explanation was discovered when it was noticed that different results were obtained for a 3 in. × 3 in. slat configuration depending on the location of the fan axis relative to two of the slats. The variation of loss of lift with ground clearance for two positions of the fan axis is shown in Fig. 21, whilst the effect of varying the position of the fan axis relative to the slats is shown in Fig. 22 for two values of the ground clearance. For an H/D value of $0 \cdot 15$, the loss in overall lift due to the ground varies from between 0 and 10 per cent of the overall lift as the fan axis changes its location from over a slat to mid-way between two slats. This range was not appreciably affected by substantially reducing the swirl by fitting shrouded pre-rotation vanes of large chord on the upstream side of the fan: nor was the curve altered when in the above condition the spinner was removed.

The effect of the horizontal displacement of the fan axis from the nearest slat was reduced to its simplest terms by using only one or two slats and traversing them across the ground underneath the wing with a ground clearance of 6 in. ($H/D = 0 \cdot 15$). The variation of the fan coefficients in the two cases is shown in Figs. 23 and 24 whilst the variation of the loss of overall lift is given in Fig. 25. As in all the tests where the wing was close to the ground, the flow was unsteady and the individual readings were not very reliable. In particular, some of the torque readings were definitely untrustworthy and it has not been possible to give a power-coefficient curve for the test with the single slat.

Fig. 23 shows that a single slat intersecting the axis of symmetry did not affect the flow as the values of the coefficients were the same as without the slat. But when the slat was displaced from the fan axis by a distance between one hub radius ($0 \cdot 375d$) and about $1 \cdot 0d$ the adverse ground effect was somewhat reduced, and both the induced lift and the overall lift slightly increased. (The suction on the undersurface in the presence of the ground is given by the difference between the k_{Li} value in Fig. 23 and the value of k_{Li} of about $+ 0 \cdot 05$ in the absence of the ground, derived from Fig. 9. The reduction in undersurface suction due to the slat movement is therefore only about 12 per cent.) As the slat is moved away from the centre, however, a strong rolling moment arises, such as to tend to increase the ground clearance of the wing above the off-set slat. This is due to the reduction in the undersurface suction on the part of the wing shielded from the jet efflux by the slat, and as the slat is moved from the axis to the 4 in. position ($0 \cdot 5d$), the rolling moment changes to an extent equivalent to a movement of the centre of pressure of the undersurface suction component of the force on the wing of about 4 in. ($0 \cdot 5d$).

With two 3 in. ($0 \cdot 375d$) high slats spaced 4 in. ($0 \cdot 5d$) apart on the ground (Fig. 24), the results obtained when the slats are well outside the region of the fan aperture are identical to those obtained with a single slat. When the slats are centred about the fan axis, the overall lift is greatly increased, the undersurface suction being approximately halved. This is because a large proportion of the efflux is channelled away from the wing between the two slats, and the entrainment over the underside of the wing is correspondingly reduced. As the slats are moved away from the centre, the rolling moment that arises increases more rapidly than with a single slat.

The effect of adding additional slats with the same spacing was investigated. The wing remained at 6 in. from the ground ($H/D = 0 \cdot 15$) with its axis aligned between two slats. The value of the loss of lift parameter $(k_{L\infty} - k_{Li})/k_{L\infty}$ decreased from the value of $0 \cdot 62$ with 0 or 1 slats to $0 \cdot 24$ with 2 slats, to $- 0 \cdot 06$ with 4 slats and to $- 0 \cdot 01$ with 8 slats, beyond which it may be inferred that there would be little alteration with additional slats. With 6 or 8 slats it was also observed that the loss of lift did not alter very much as the wing axis was traversed sideways between slats, nor was any moment developed. These results, however, must be taken to apply only to this particular slat spacing and ground clearance. Although this particular configuration eliminated the ground effect at a clearance, H/D of $0 \cdot 15$ (a distance between the top of the slats and the undersurface of the wing equal to the slat height of 3 in.), Fig. 21 shows for a slightly different configuration (3 in. $\times$ 3 in. slats) that as the clearance was raised, the larger gap between the top of the slats and the wing meant that the slats were no longer so effective, and the loss of lift at first increased with increasing ground clearance.

The selection of a suitable configuration of slats for alleviating the adverse ground effect is thus seen to be a complicated matter, at any rate for the present configuration. *Ad hoc* model tests would certainly be required to make sure that the chosen configuration was satisfactory. For a fan-lift aircraft, the present tests show it to be desirable for the spacing between slats to be appreciably less than the fan diameter, a conclusion that was also reached by Wyatt. Wyatt's results also suggest that it is desirable to use fences with heights greater than their spacing, although such fences were not investigated in the present tests. Alternative ways of reducing ground effect should be investigated, such as the use of a perforated platform which allows the efflux to pass through the ground.

8. *Conclusions.* Tests made under static or 'hovering' conditions with a fan-wing combination in which the fan is mounted in the plane of a thin flat wing of hexagonal planform have demonstrated the following features.

1. The wing acts efficiently as a shroud and enables the maximum lift obtainable from the system to be considerably increased over that obtainable from the fan alone for the same power input. An increase of over 60 per cent in the maximum overall lift was obtained, and under these conditions over 40 per cent of the total lift was developed on the wing due to the reduction in pressure on the upper surface caused by the inflow to the fan. This inflow is developed mainly on and close to the rounded entry to the fan, and the efficiency of the system is not affected by variations in the ratio of wing diameter/fan diameter between 5 and 2.

2. For a given rotational speed, a small increase occurs in the lift of the fan itself as the ground is approached, and the power absorbed remains constant. This lift increase is associated partly with a reduction in induced velocity at the fan and partly with an increase in pressure acting over the area of the hub of the fan, both due to the deflection of the efflux by the ground. On the other hand, as the ground is approached there is a large reduction in the lift induced on the wing. This is due to a reduction in pressure on the lower surface caused by the inflow which provides air for entrainment in the spreading jet. For wings with diameter four or five times the fan diameter, the loss in induced lift is roughly inversely proportional to the square of the ground clearance. When the clearance is less than 1/3 the wing diameter ratio, the loss decreases with decrease in value of the wing/fan diameter ratio, and for a value of this ratio of 2 the loss of lift as ground is approached is counterbalanced by the increase in fan lift. On balance, however, the loss of overall lift is serious with a large ratio of wing diameter to fan diameter. For a ground clearance of 0·25 the wing diameter, 25 per cent of the overall lift is lost.

3. At small angles of inclination to the ground, the fan-wing experiences a small destabilizing moment. At large angles of roll, the rolling moment becomes stable, and when also close to the ground, the adverse ground effect on lift is reduced or eliminated.

4. Rows of parallel slats (fences) along the ground serve to partly channel the jet efflux and are effective in reducing the adverse ground effect, but for the fences tested, whose spacings were equal to or larger than the hub diameter, the results obtained depended critically on the transverse position of the fan axis relative to the adjacent slats. It would thus appear to be preferable to use fences with the proportions of those tested by the R.A.E.[1], *i.e.*, with spacings appreciably less than the fan diameter and with heights greater than the spacing, or to seek other methods of reducing the adverse ground effect.

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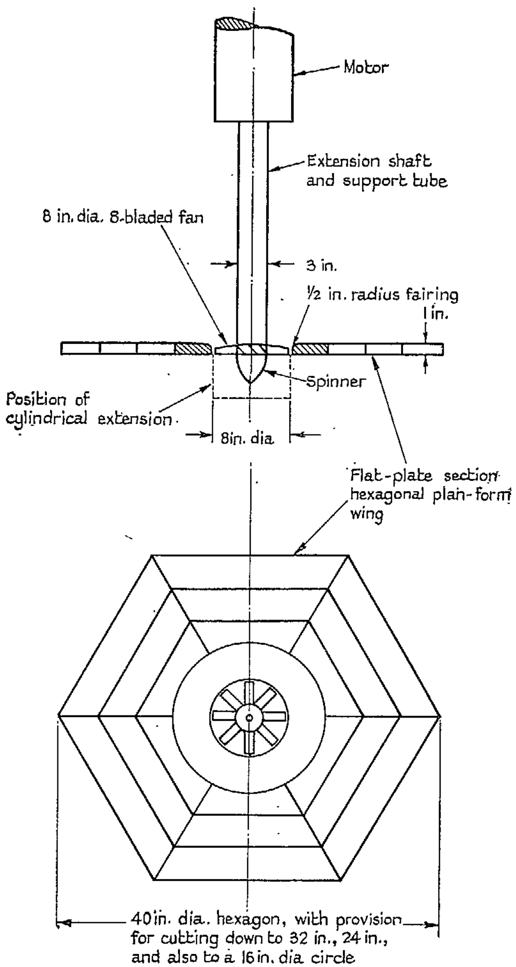

FIG. 1. Fan and wing.

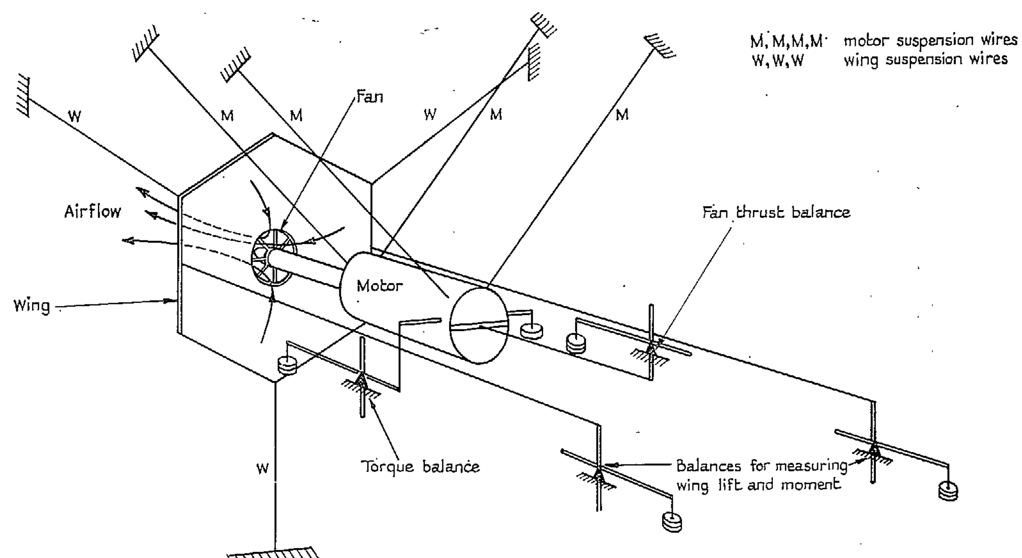

FIG. 2. Sketch showing suspension of fan and wing and location of balances.

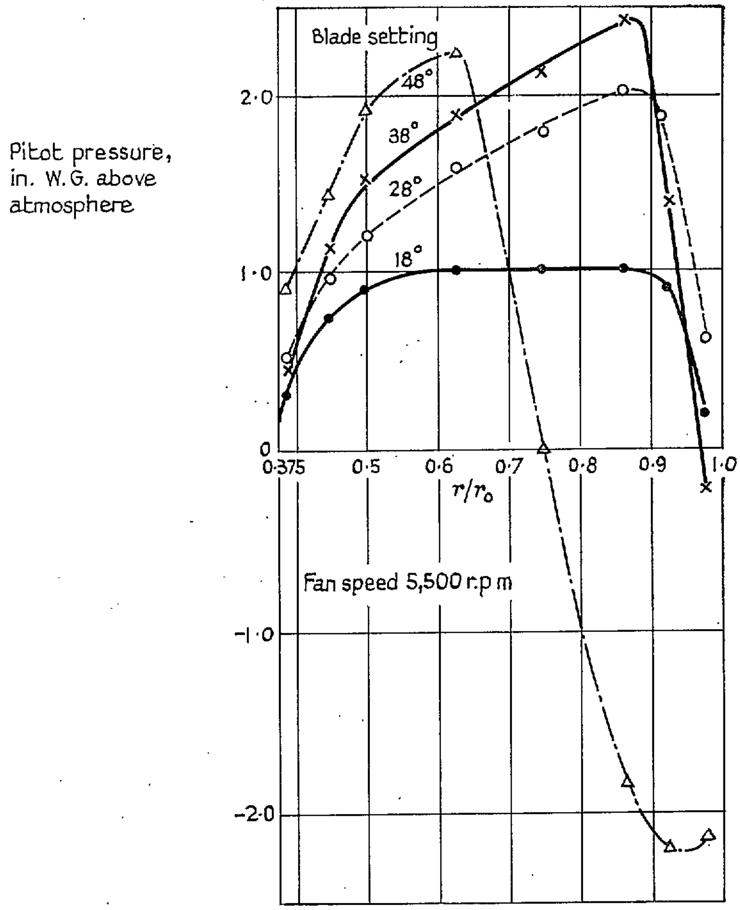

FIG. 3. Effect of blade setting on total pressure distribution downstream of fan.

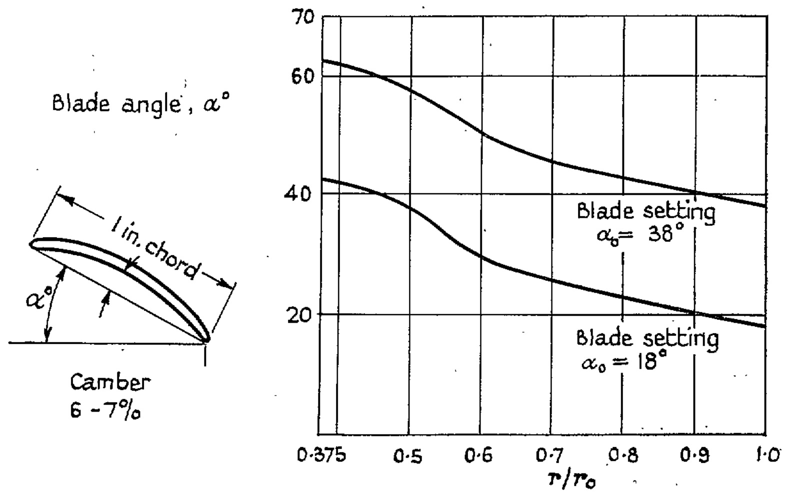

FIG. 4. Variation of fan blade angle along the blade.

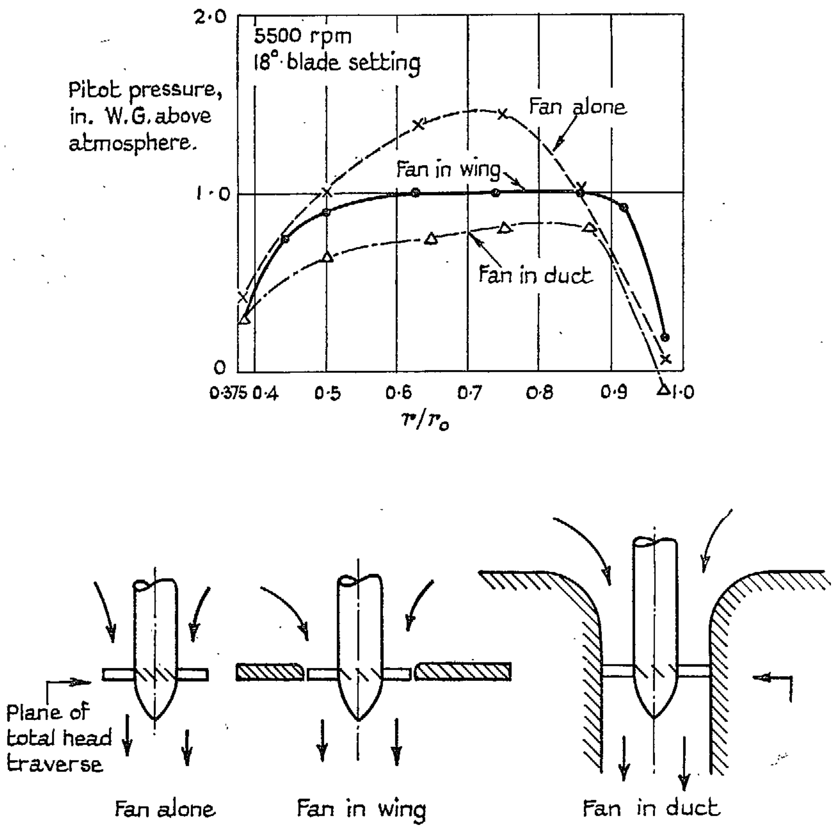

FIG. 5. Effect of entry conditions on total head traverse downstream of fan.

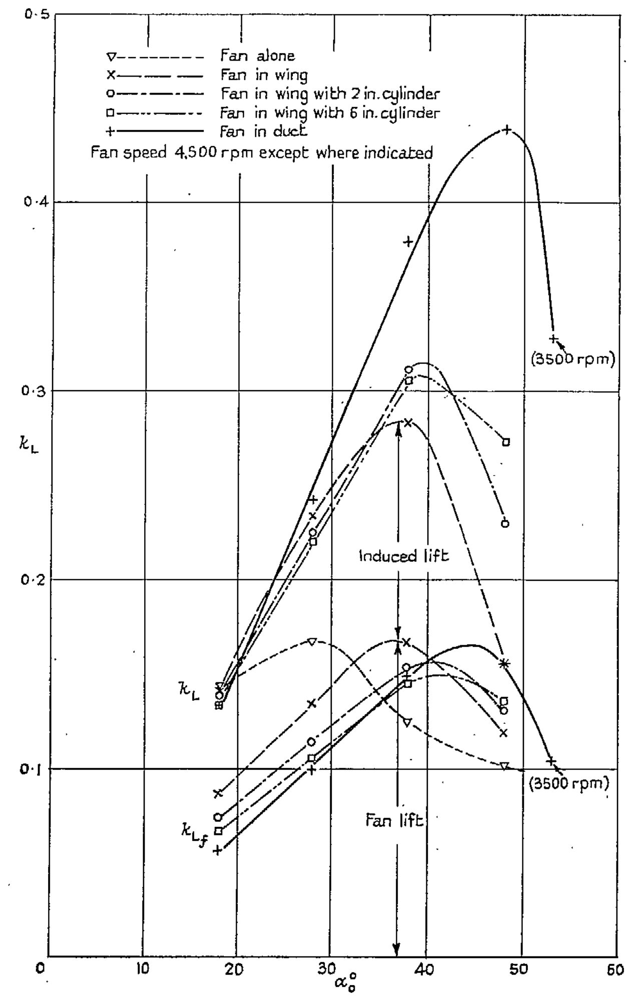

FIG. 6. Variation of lift coefficients with fan blade setting and type of shrouding.

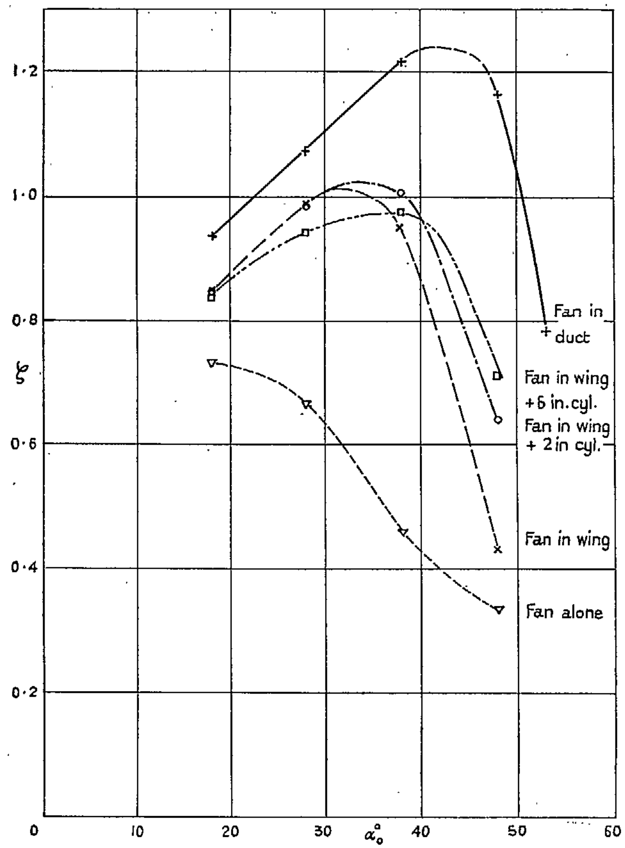

FIG. 7. Variation of static thrust factor of merit with blade setting.

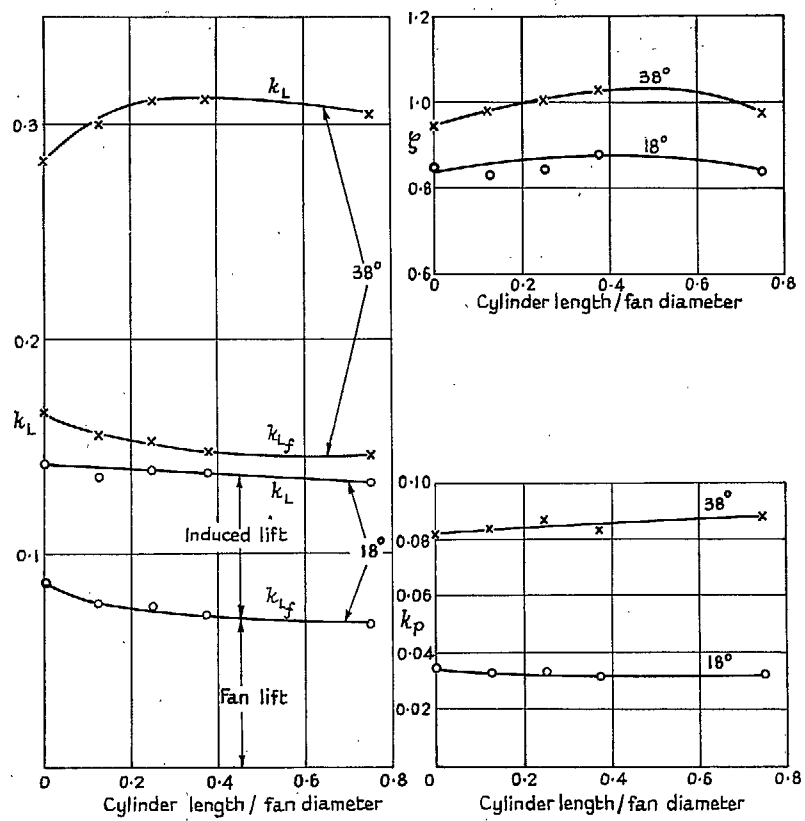

FIG. 8. Variation of fan coefficients with length of cylindrical duct for blade settings of 18 deg and 38 deg.

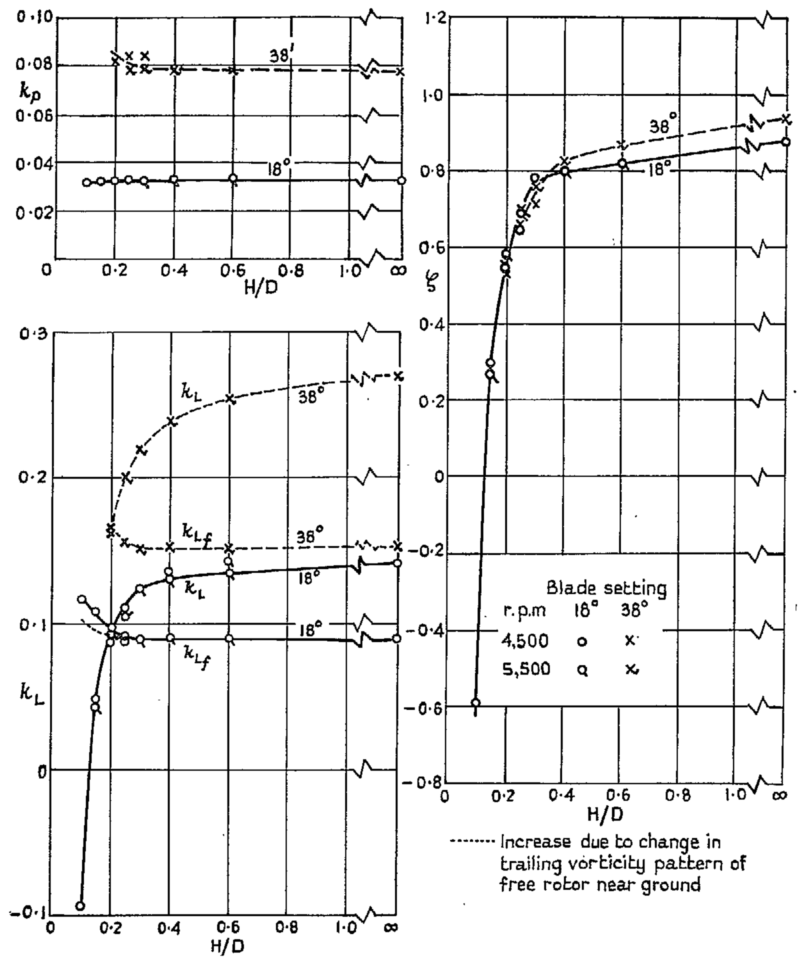

FIG. 9. Variation of fan coefficients with ratio of ground clearance, H, to wing diameter, D. $D = 40$ in. 18 deg and 38 deg blade setting.

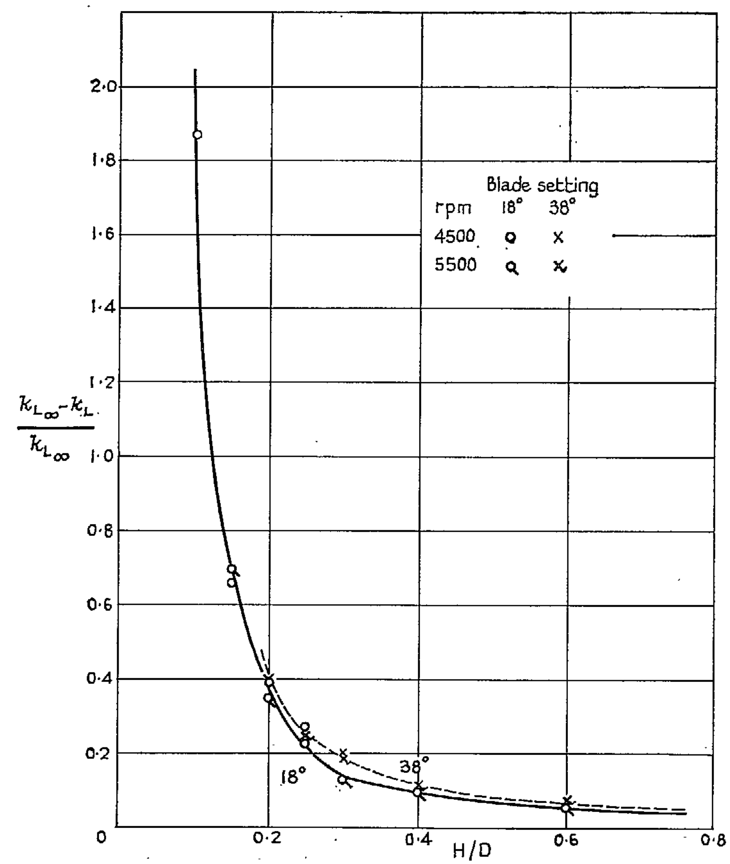

FIG. 10. Variation of loss of lift with ground clearance/wing diameter. 40 in. diameter wing.

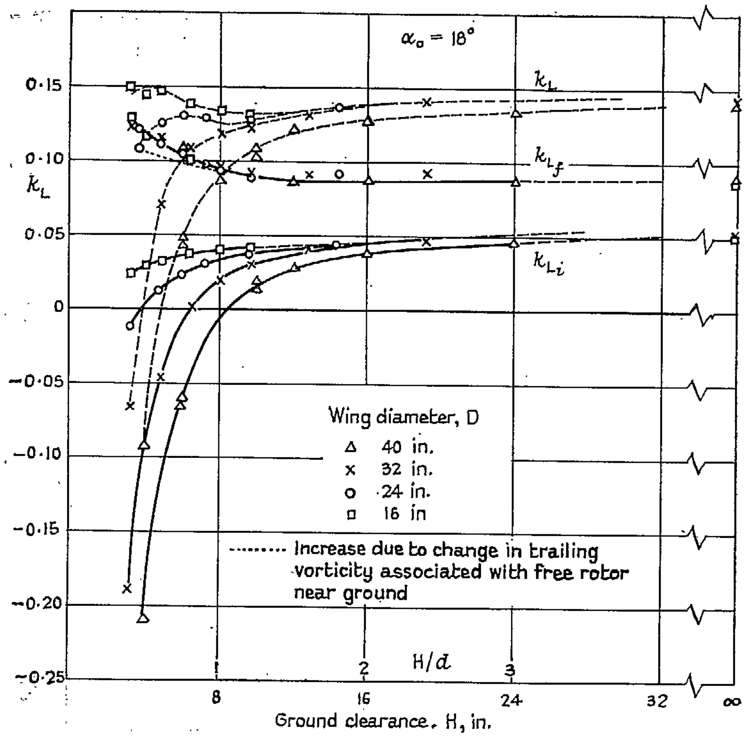

FIG. 11. Variation of fan lift coefficients with ground clearance, H, for various wing sizes.

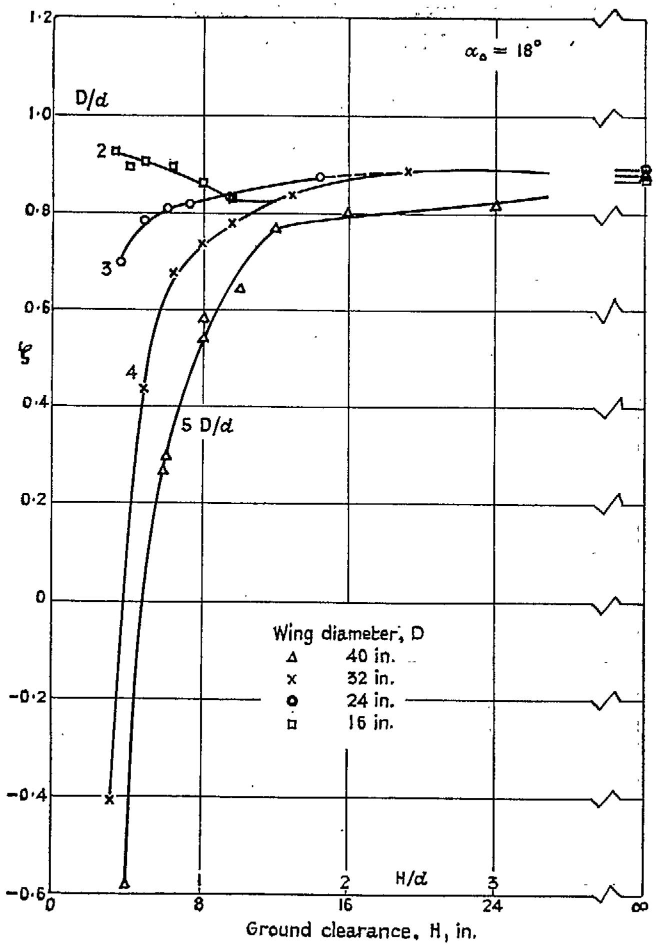

FIG. 12. Variation of static thrust factor of merit with ground clearance, H, for various wing sizes.

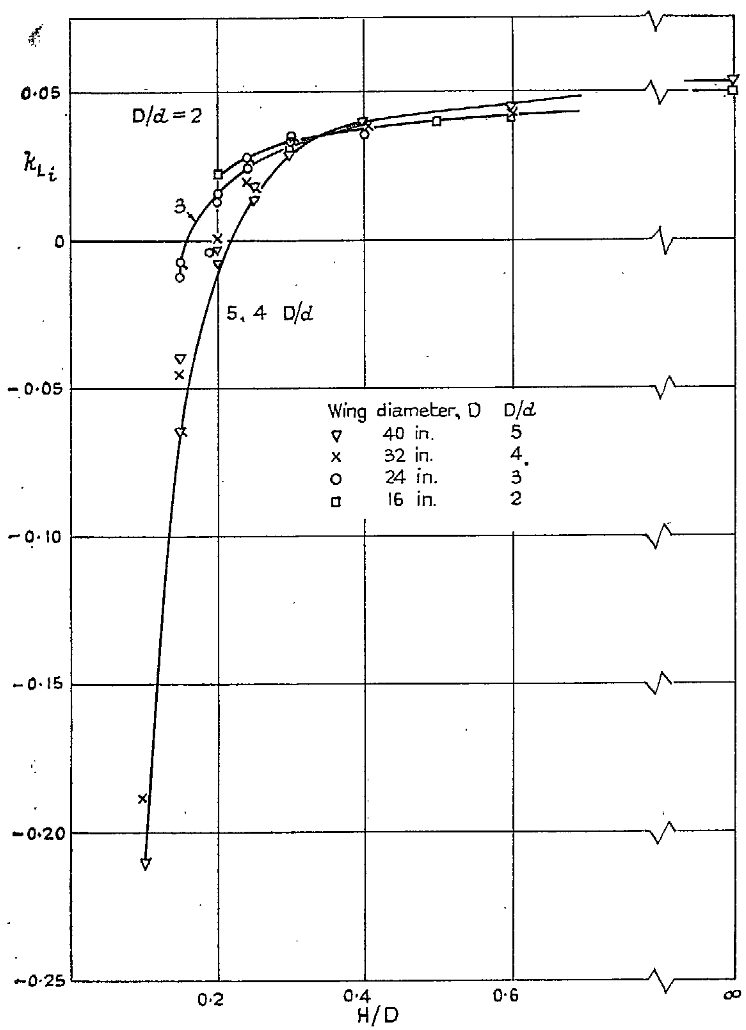

FIG. 13. Variation of induced lift coefficient with H/D for various D/d.

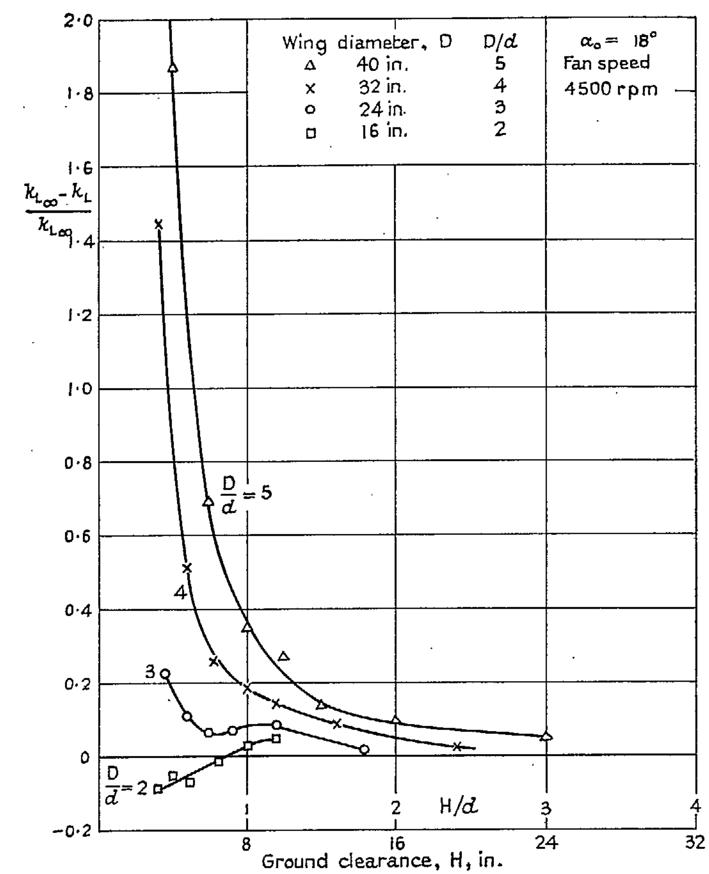

FIG. 14. Variation of loss of lift with ground clearance for various wing sizes. Fan diameter d = 8 in.

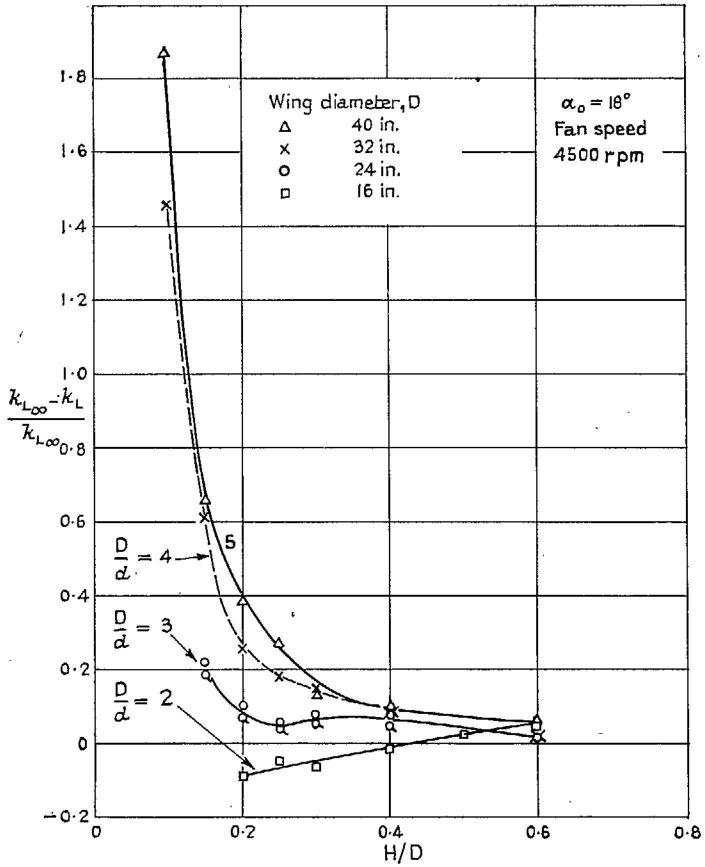

FIG. 15. Variation of loss of lift with ground clearance/wing diameter for various wing sizes.

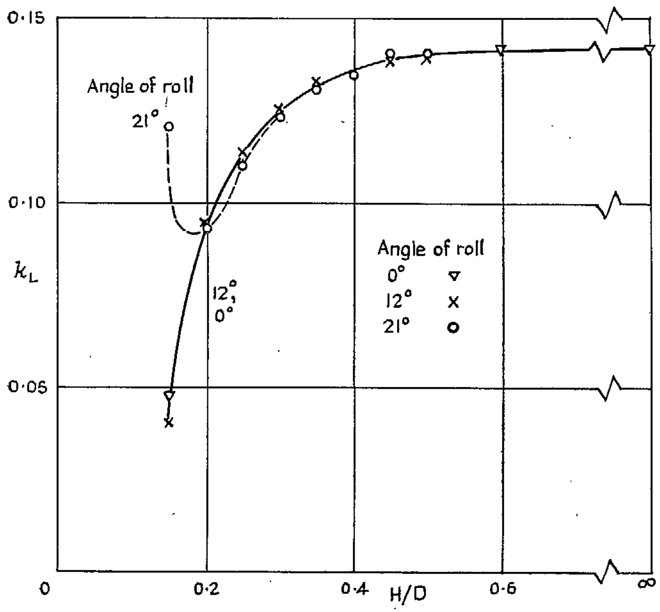

FIG. 16. Effect of ground clearance/wing diameter ratio on lift coefficient at various angles of roll.

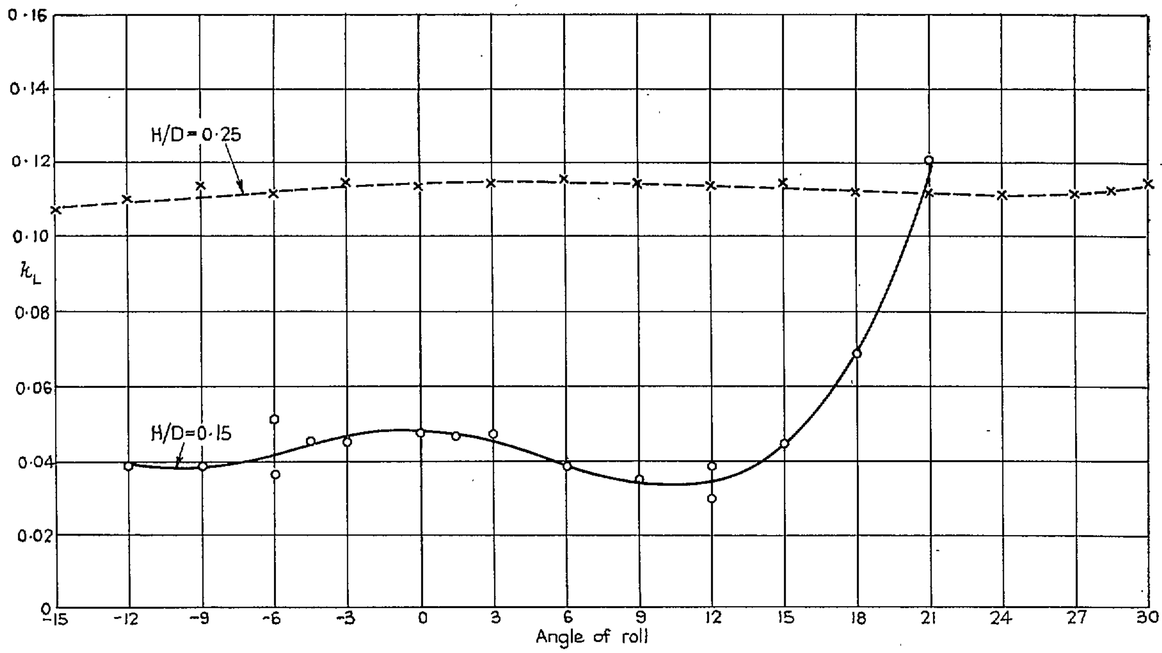

FIG. 17. Effect of angle of roll on lift.

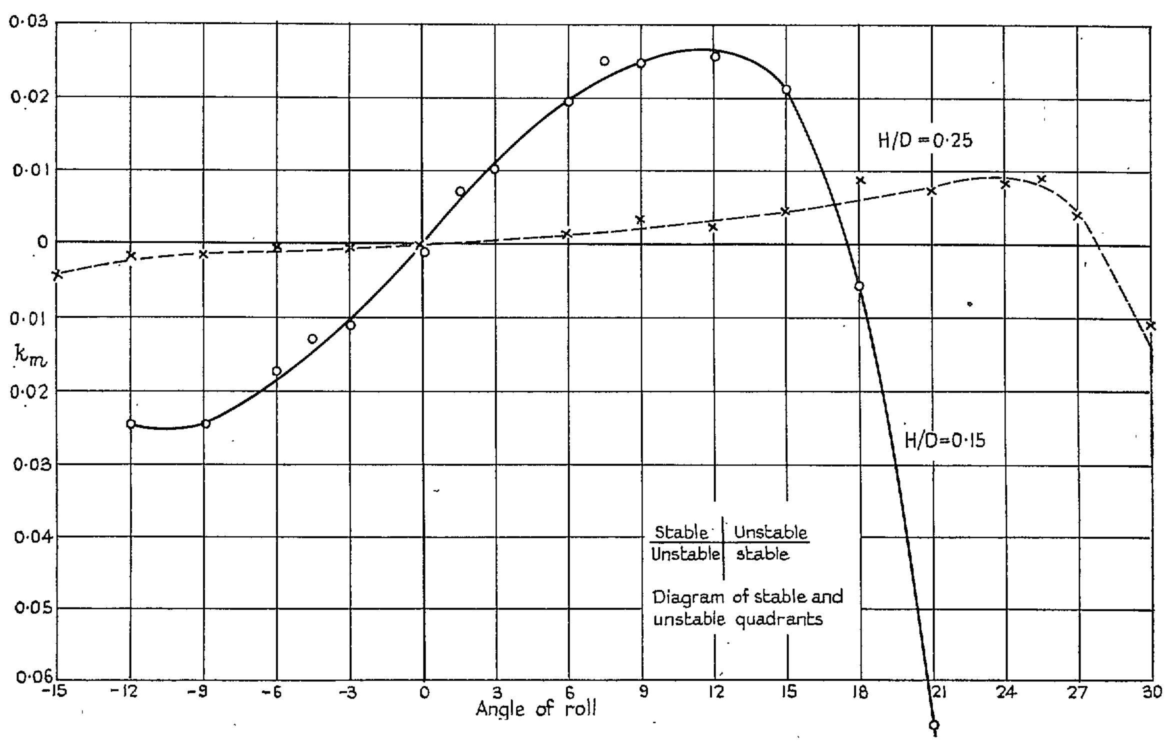

FIG. 18. Effect of angle of roll on rolling moment.

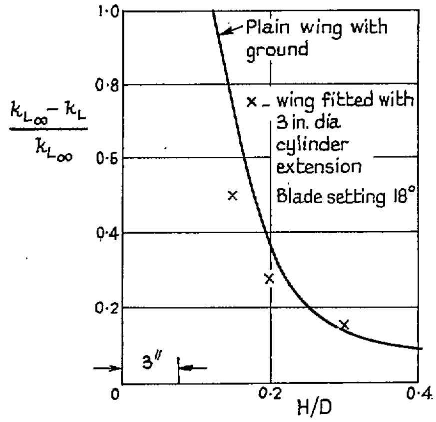

Fig. 19. Effect of 3 in. extension cylinder on the loss of lift due to ground interference.

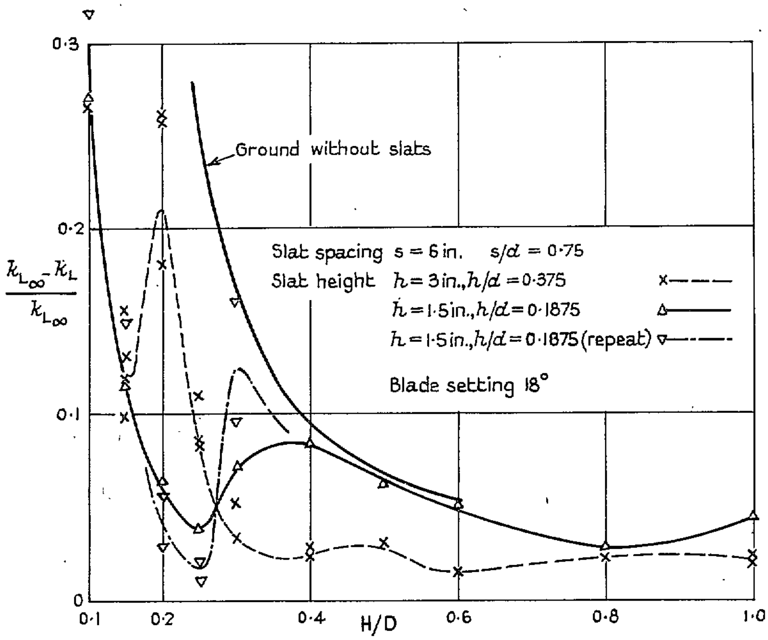

Fig. 20. Effect of height of slats spaced 6 in. apart on loss of lift due to ground interference.

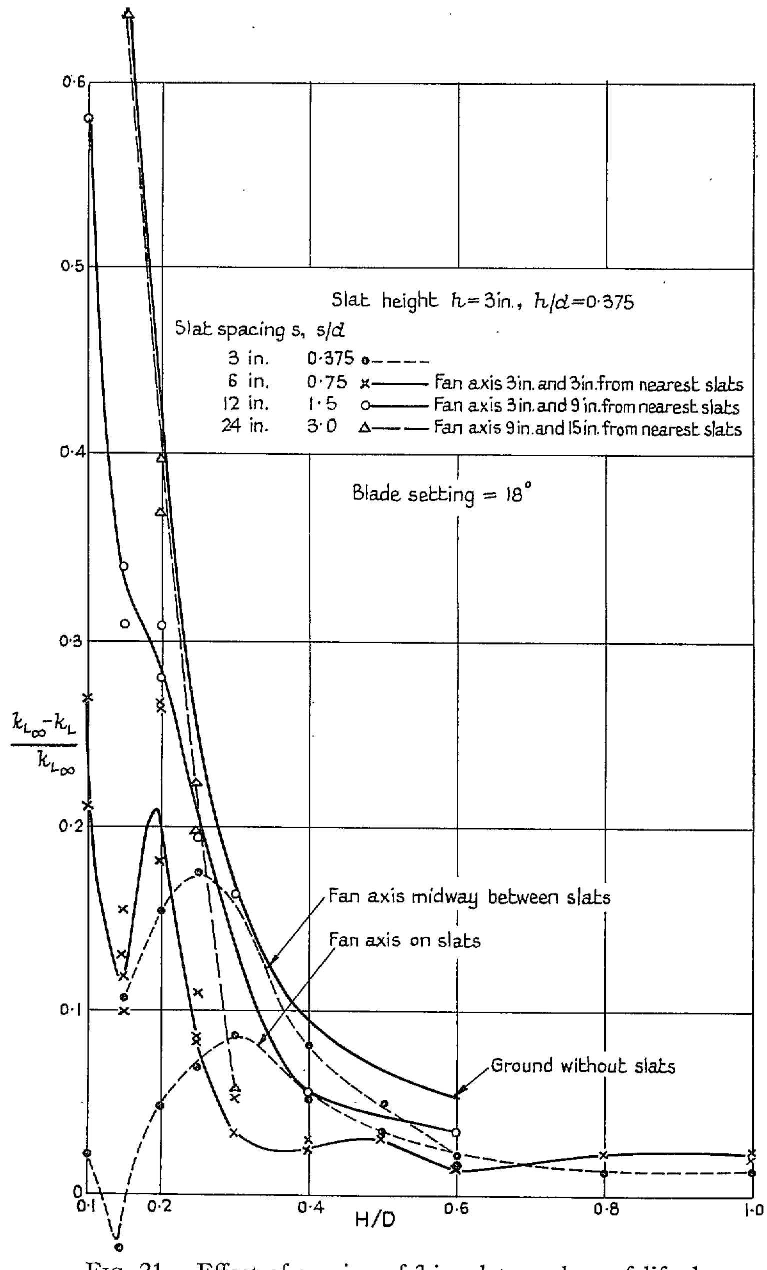

FIG. 21. Effect of spacing of 3 in. slats on loss of lift due to ground interference.

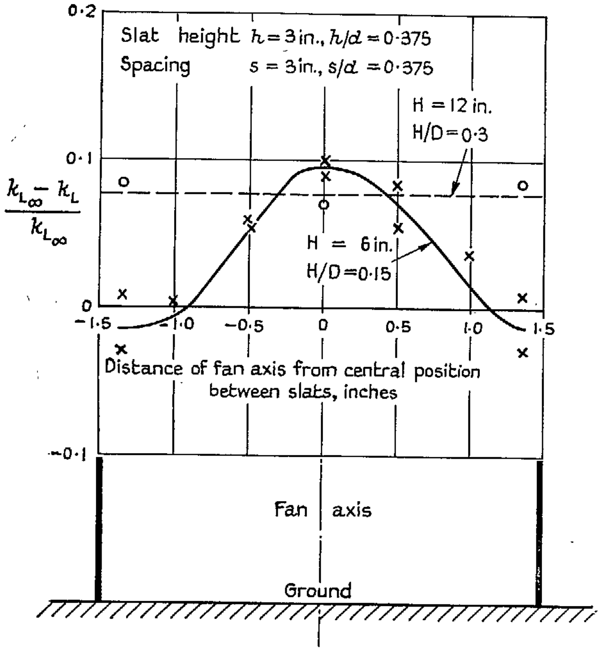

FIG. 22. Effect of varying position of fan axis relative to slats on loss of lift due to ground interference.

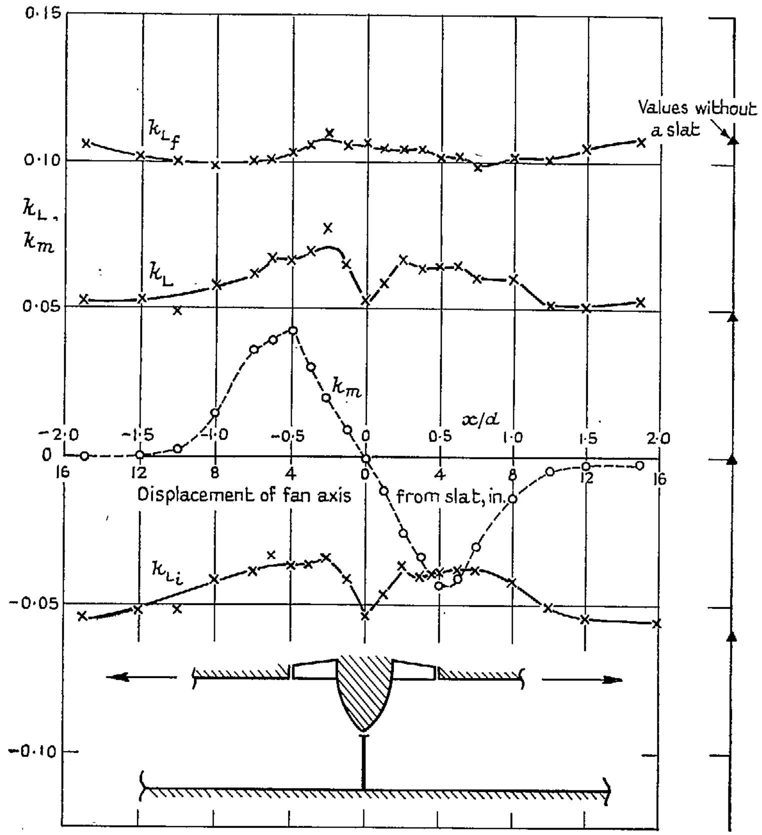

FIG. 23. Variation of fan coefficients with displacement of fan axis from a single slat on the ground. $H = 6$ in., $H/D = 0{\cdot}15$, $h = 3$ in., $h/d = 0{\cdot}375$.

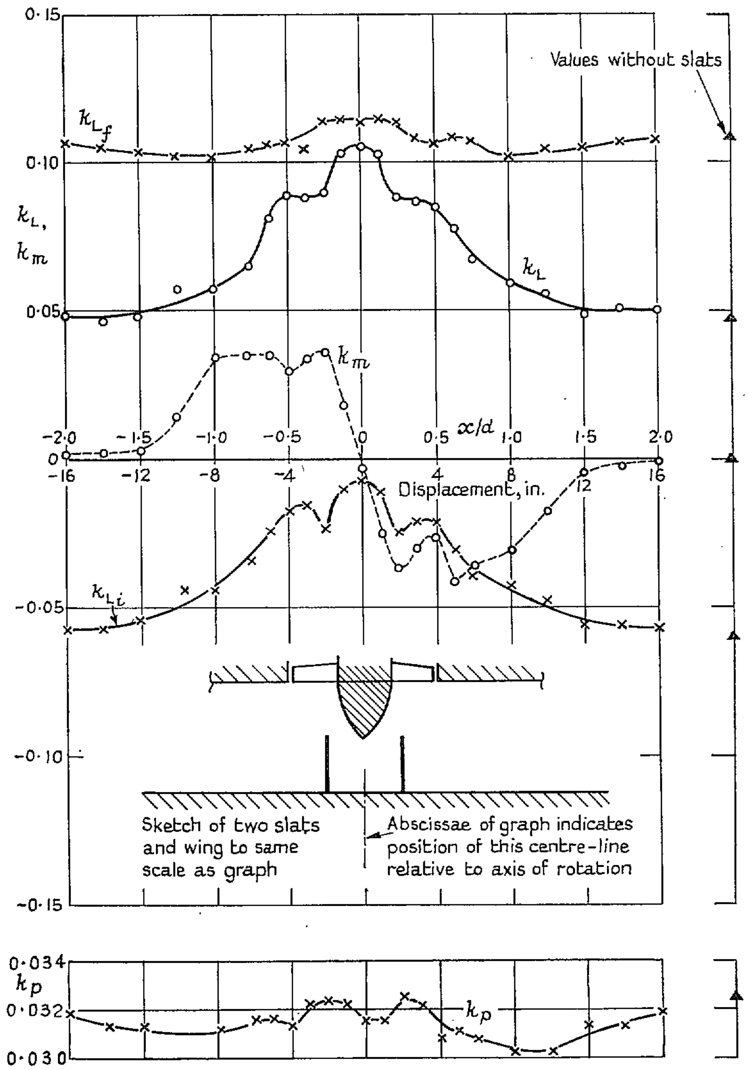

FIG. 24. Variation of fan coefficients with displacement of fan axis from position midway between two slats. $H = 6$ in., $H/D = 0{\cdot}15$, $h = 3$ in., $s = 4$ in., $h/d = 0{\cdot}375$, $s/d = 0{\cdot}5$.

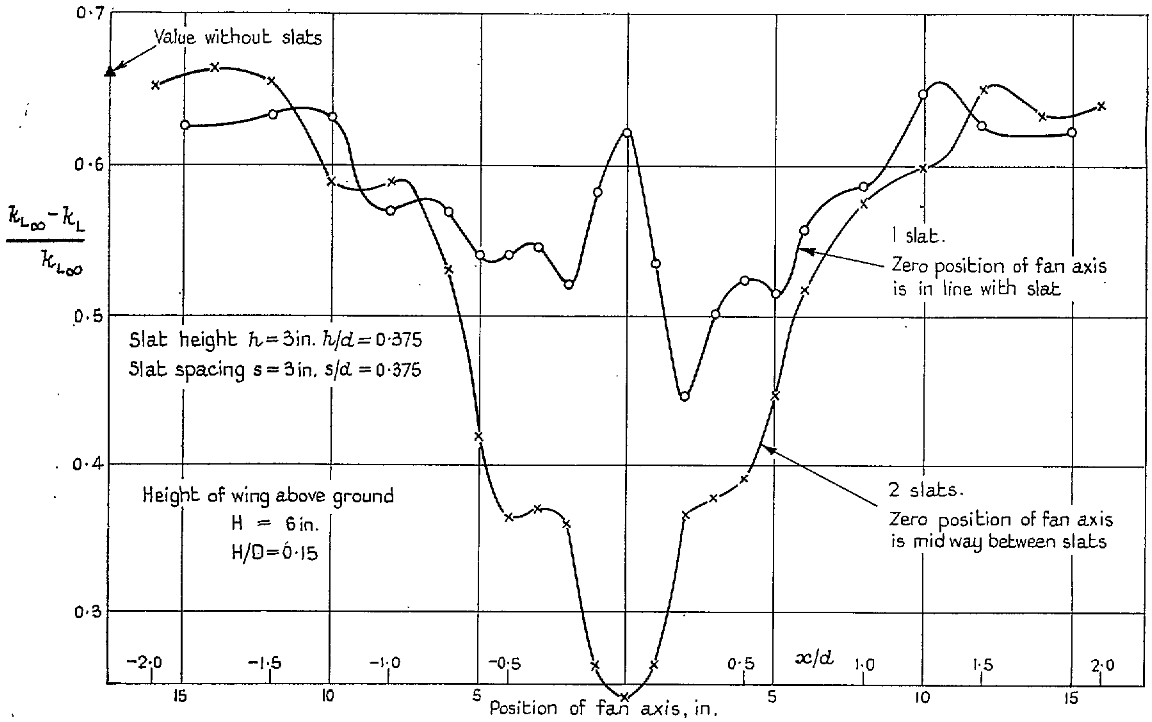

FIG. 25. Variation of loss of lift due to ground interference with position of fan axis relative to one or two slats.

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