R. & M. No. 2553
(5659)
A.R.C. Technical Report



MINISTRY OF SUPPLY

AERONAUTICAL RESEARCH COUNCIL
REPORTS AND MEMORANDA

# Wind-tunnel Tests on the Spoiling Effects of Engine Cooling Gills on Radial Air-cooled Installations on a Wing

*By*
J. SEDDON, Ph. D. and J. A. KIRK, M.P.C.



LONDON: HER MAJESTY'S STATIONERY OFFICE
1952
PRICE 7s 6d NET

# Wind-tunnel Tests on the Spoiling Effects of Engine Cooling Gills on Radial Air-cooled Installations on a Wing

*By*

J. Seddon, Ph. D. and J. A. Kirk, M.P.C.

Communicated by the Principal Director of Scientific Research (Air)
Ministry of Supply

*Reports and Memoranda No.* 2558*

*January,* 1942

*Summary.—Reasons for Enquiry.*—Information was required on the spoiling drag associated with opening cooling gills on radial air-cooled engine installations on a wing.

*Range of Investigation.*—Maximum lift, drag up to high $C_L$, and cooling flow were measured on a 1/12 scale model of a flying boat, showing

1. the effect of opening cooling gills to 25 deg. and the variation of these effects with gill position relative to the wing;
2. the results of emitting the cooling air at specified regions of the exit;
3. comparison with a scheme for return-flow cooling.

*Conclusions.*—The spoiling drag associated with fully open gills at high $C_L$ can be very large (of the same order as the wing induced drag) if the gill exit is nearer to the wing leading edge than about 10 per cent. of the local wing chord; but the effect diminishes rapidly as this distance is increased. To avoid the effect it is recommended that the exit of the gills should be at least 15 per cent. of the chord forward of the wing leading edge.

The drag due to spoiling is also reduced if the cooling air is kept away from the nacelle-wing junction by emitting it at specified regions round the exit, preferably at the bottom where the lift is a minimum. Larger gill angles would be needed to satisfy maximum flow requirements in this way.

The return-flow cooling system, with nose-exit, shows no evidence of large spoiling drag at high cooling flow.

The data obtained may be useful for estimating the effects of other forms of discharge of low-energy air in front of a wing leading edge.

1. *Introduction.*—1.1. *General.*—It is known from flight experience that conventional engine cooling gills on multi-engined aircraft, when opened to angles of 20 deg. or more, can give very large drag at the higher incidences of flight, accompanied by some loss in maximum lift of the wing. The present report contains an account of wind-tunnel tests of a general character which have been made to measure such effects and to explore possible methods of reducing them. The investigations represent an extension of the work by Seddon and Haile[1] (1941), which, in discussing the contribution of air-cooled engine nacelles to the profile drag of aircraft at high incidence, does not take into account any opening of the cooling gills.

Consideration is given to the importance of the work for Service aircraft under operational conditions.

The data obtained may be useful for estimating the effects of other forms of discharge of low energy air in front of a wing leading edge.

1.2. *Experimental Details.*—The tests were made on a 1/12 scale model of the Sunderland (Fig. 1) in the $11\frac{1}{2}$-ft wind tunnel of the Royal Aircraft Establishment at a wind speed of 120 ft/sec. As shown in Fig. 1, the model was complete except for the tail unit, which was omitted in order to avoid misleading results due to changes in tail induced drag.

* R.A.E. Report Aero 1724, received 5th March, 1942.

The main measurements were of maximum lift, drag up to high $C_L$ and cooling flow, with engine gills set at various angles and for different positions of the nacelles relative to the wing. In addition the effect of gills opening unsymmetrically, letting out most of the cooling air at specified places round the exit was investigated. Finally, comparisons were made with a scheme for return-flow cooling, which removes the exit to the nose of the nacelle and so away from the wing leading edge.

Three sets of symmetrical gills were used, of 8 in. chord and set at angles of 0, 10 and 25 deg. These are shown in Fig. 2. On the unsymmetrical or " part-opening " gills (Fig. 3) the angle varied from 0 to 25 deg. round the exit. Four nacelle positions were tested, three fore-and-aft positions and one dropped, as shown in Fig. 4. For comparing with the return-flow scheme (Fig. 5) the results for position B of Fig. 4 are used.

Cooling flow was measured by observing the pressure drop across the baffle plate (representing the engine) as recorded by two static tube rings, one on either side of the baffle plate (*see* Fig. 2), each measuring the mean pressure from 8 or 9 holes round the ring. The apparatus was calibrated at the start of the tests by measuring the flow at the exit for three gill settings at a low incidence. For the majority of the tests the baffle plate was set to give a baffle constant* of 0·15, representing a fairly loosely-baffled Pegasus engine of diameter 57 in, with a large cooling-flow requirement. In a few tests, including those of the return-flow system, the baffling was tightened to give baffle constants of 0·5 and 2·0 approximately.

1.3. *Method of Analysis.*—In analysing and discussing the drag results obtained, the method adopted in Ref. 1 is again followed. Defining profile-drag coefficient $C_{D0}'$ to be total drag coefficient less minimum induced-drag coefficient, *i.e.*,

$$C_{D0}' = C_D - C_L^2/\pi A \, , \qquad (1)$$

we introduce a parameter $k$ defined as the mean slope of the curve of $C_{D0}'$ against $C_L^2$ in the range $C_L^2 = 0{\cdot}1$ to $0{\cdot}8$ ($C_L = 0{\cdot}3$ to $0{\cdot}9$ approximately). Thus $k$ represents roughly the mean rate of increase of profile drag coefficient with $C_L^2$ over the range of $C_L$ from top speed to slow cruise or climb conditions. The value of $k$ can therefore be compared with the factor $1/\pi A$, which, from equation (1), represents the corresponding rate of increase of induced drag coefficient $C_{Di}$.

Using this method of analysis, the increase in drag due to opening cooling gills may be expressed as follows. Writing

$$C_{D0}' \text{ (gills 0 deg.)} = a_0 + k_0 C_L^2 \, , \qquad (2)$$

$$C_{D0}' \text{ (gills 25 deg.)} = a_1 + k_1 C_L^2 \, , \qquad (3)$$

we have

$$C_{D0}' \text{ (due to opening gills)} = (a_1 - a_0) + (k_1 - k_0)\, C_L^2 \, . \qquad (4)$$

In this expression, $a_1 - a_0$, the drag increment at no-lift, is found to be practically independent of nacelle position. Broadly speaking, we may say that the first term in (4) represents the gill drag at low incidence, and contains little or no spoiling effect; while the second term represents the additional drag at high incidence, and is largely due to spoiling of the main flow over the wing. In this sense the parameter $k$ gives a direct measure of the adverse effects of cooling gills at high incidence.

2. *Results Summary.*—2.1. *Lift.*—Curves of $C_L$ against $\alpha$ are given in Figs. 6 to 9, showing

(i) the effect of gill angle and nacelle position relative to wing;
(ii) results with unsymmetrically opening gills;
(iii) comparisons with return-flow cooling.

---

* Baffle constant is defined as $B = h/\sigma(Q/100)^2$ where $h$ is the drop in total head across the engine (in inches of water) corresponding to a flow of $Q$ cu ft/sec, $\sigma$ being the relative density of the air.

The following are the values of maximum $C_L$, flaps down, for the conventional nacelles in the four positions A, B, C, D shown in Fig. 4.

| Nacelle Position | $C_{L\max}$ (flaps at 24°) | | |
|---|---|---|---|
| | Gills 0° | Gills 10° | Gills 25° |
| A | 1·65 | 1·61 | 1·50 |
| B | 1·66 | 1·63 | 1·55 |
| C | 1·68 | 1·66 | 1·59 |
| D | 1·67 | 1·63 | 1·51 |

$C_{L\max}$ is plotted in Fig. 10 for the four nacelle locations, the unsymmetrical gills, and the return-flow cowl. The value of $C_{L\max}$ is found to be practically independent of the degree of baffling, and mean values are therefore given in the above table and in Fig. 10.

2.2. *Drag*.—In Figs. 11 to 14, $C_{D0}'$ is plotted against $C_L{}^2$, giving the same comparisons as those of maximum lift in Figs. 6 to 9. Fig. 15 shows how the parameter $k$ varies with gill setting for the conventional nacelles in the various positions. Results for the unsymmetrical gills and for the return-flow cowl are also included. In Fig. 16 $k$ is plotted against fore-and-aft position of the nacelles relative to the wing, showing how the spoiling drag is reduced by moving the cowls forward. The main results are summarised in the following table, which gives the increment in $k$ due to the nacelles, *i.e.* $k$ for wing plus body plus nacelles less $k$ for wing plus body.

| Nacelle Position | $\Delta k$ Due to Nacelles | | |
|---|---|---|---|
| | Gills 0° | Gills 10° | Gills 25° |
| A | 0·008 | 0·009 | 0·032 |
| B | — | — | 0·012 |
| C | 0·006 | 0·004 | 0·005 |
| D | 0·009 | 0·010 | 0·024 |

For comparison, $k$ for wing + body = 0·004; induced drag factor, $1/\pi A = 0{\cdot}042$, $(A = 7{\cdot}55)$.

3. *Discussion*.—3.1. *Effect of Gill Angle and Position Relative to Wing*.—Fig. 11 shows that even at low incidences ($C_L < 0{\cdot}3$) there is a large increase in drag when the gills are opened. The following table of nacelle drags shows that this increment is almost wholly accounted for by the change in internal drag of the engine, due to the increase in flow. There is no evidence of the flow stalling from the inner surface of the gills up to 25 deg. gill angle.

| Gill Angle | Drag per Nacelle at $C_L = 0{\cdot}3$, lb at 100 ft/sec | | |
|---|---|---|---|
| | Total | Internal | External |
| 0° | 28 | 3 | 25 |
| 10° | 53 | 23 | 30 |
| 25° | 100 | 74 | 26 |

At low incidences there is no change in this drag with nacelle position (Fig. 11), implying that the flow over the wing surface is not seriously affected.



(93007) A 2

With gills open at higher incidences, however, the wing spoiling becomes large if the exit of the cowl is close to the wing leading edge. The effect is most clearly seen from the curves of Fig. 15, where the parameter $k$ is plotted against gill angle. Since changes of internal drag with incidence are relatively small, the internal drag gives only a small contribution to $k$; any large increase in the value of $k$ therefore indicates the presence of large spoiling drag. At a particular $C_L$ the spoiling drag due to gills, in accordance with equation (4), is given approximately by

$$\Delta C_D = (k - k_0)\, C_L^2\,, \quad \ldots \quad (5)$$

where $k_0$ is the corresponding value of $k$ with gills at 0 deg. Thus curve A of Fig. 15 shows that when the gill exit is about 5 per cent of the wing chord forward of the wing leading edge (position A), the spoiling-drag coefficient due to gills open at 25 deg. is about $0 \cdot 024\ C_L^2$ or 57 per cent of the wing induced drag. It should be noted that

(1) this large interference is only present for large gill angles. Up to 15 deg. of the gills the increment in $k$ is small. In practice, therefore, the effect may not generally be important except in climb or in level flight under reduced power, *e.g.* with one engine cut. This aspect is given further consideration in a later section.

(2) the effect is worse with higher engine baffling (*cf.* curves $A_1$ and $A_3$) owing to the lower total head of the cooling air emerging from the cowl. This is an important point in view of the present tendency towards more tightly baffled engines.

The spoiling drag can be reduced by increasing the distance of the cooling exit forward of the wing leading edge, thus allowing more time for mixing of the retarded air with the main stream before passing over the wing. Fig. 15 shows that the spoiling at large gill angles is very much less for positions B and C (*see* Fig. 4) than for position A; Fig. 16 shows more precisely how the value of $k$ falls off as the cowl exit is moved forward. A forward movement of 10 per cent of the local wing chord (*i.e.* to position B) reduces the spoiling drag to one quarter of its value at A, *i.e.* to about 14 per cent of the wing induced drag. At C, 25 per cent chord forward of A, the spoiling is effectively zero.

From these results it is concluded that when designing to avoid large spoiling effects under all conditions, the exit of the gills should be at least 15 per cent. of the wing chord forward of the wing leading edge. This corresponds to the nose of the nacelle being about 40 per cent of the chord in front of the leading edge, instead of 25 to 30 per cent, which gives optimum conditions at small $C_L$, according to earlier work by Smelt and Smith[2] (1938) and by Wood[3] (1932). The increase in top-speed drag due to this change is very slight (Figs. 4 and 5 of R. & M. 2406[2]) and, in practice would be partly compensated by the reduction in tailplane size made possible with the further forward C.G. position.

Dropped nacelles (position D, Fig. 4) give a smaller value of $k$ than central ones (position A) for large gill angles, as shown in Fig. 15. At a $C_L$ of $0 \cdot 6$ for example, this reduction is equivalent to a decrease in nacelle drag of about 5 per cent drop of 1 per cent chord. The comparison is, however, qualified by the fact that the dropped nacelles give somewhat smaller cooling flow (Fig. 17a). No such reduction of drag due to dropping the nacelles is found for the other gill angles (0 deg. and 10 deg.).

The variations of maximum lift with gill angle and position show much the same effects as are found on drag at high $C_L$. The lowest value of maximum $C_L$ occurs with wide-open gills (25 deg.) in position A, closest to the wing leading edge, where the loss (compared with gills at 0 deg.) is 9 per cent with wing flaps down (24 deg.) and 12 per cent with flaps up (Fig. 10). With the nacelles extended to position C the corresponding losses are 3 and 6 per cent for the flaps down and flaps up cases, position B giving an intermediate improvement. Maximum lift is generally slightly higher with the dropped than with the central nacelles (Fig. 10).

3.2. *Part-opening Gills* (*Fig.* 3).—With nacelles in position A, the following types of unsymmetrical or part-opening gill were tested, their purpose being to direct most of the cooling flow to specific parts of the exit:—

(1) Gills open to 25 deg. at bottom, closing to 0 deg. at sides and top.
(2) Gills open to 25 deg. at top, closing to 0 deg. at sides and bottom.
(3) Gills open to 25 deg. at top and bottom, closing to 0 deg. at sides.
(4) Gills open to 25 deg. at sides, closing to 0 deg. at top and bottom.

The first two types had approximately the same exit area as the 10 deg. symmetrical gills; but the drag due to spoiling is in each case rather less than with 10 deg. symmetrical gills (*see* Fig. 15). With the gills opening at top and bottom, a small value of $k$ is again obtained, but the gills opening at the sides give a larger value. It seems, therefore, that the drag due to spoiling can be reduced to some extent by keeping the cooling air away from the nacelle-wing junction. The gills opening at the sides, however, have a smaller basic drag at low $C_L$ than those opening top and bottom (Fig. 12), which offsets their disadvantage up to a $C_L$ of about 0·6.

The highest values of maximum lift are obtained with gills opening at the bottom or sides; these give slightly better $C_{L\,max}$ than symmetrical gills for the same flow (Fig. 10). The lowest values of $C_{L\,max}$ are obtained with gills opening at the top.

The first two types of part-opening gill give roughly the same cooling flow as 8 deg. symmetrical gills; types 3 and 4 give the same flow as 15 deg. symmetrical gills. Larger angles of the part-opening gills, say (35 deg., 10 deg.) instead of (25 deg., 0 deg.) would therefore be needed in order to obtain the flow required for slow speed climbing. The effect of such gills on drag cannot be foretold with accuracy, but Fig. 15 suggests that at a given flow the wing spoiling with top-and-bottom opening gills would be less than with symmetrical gills in the same fore-and-aft position.

3.3. Return-flow Cowl.—A scheme for return-flow cooling is shown in Fig. 5. This is designed on the lines of a scheme described by Smelt and Smith[4] (1939), having wing leading-edge entries and an annular, flap-controlled exit near the nose of the cowl. The present tests demonstrate that when the exit is moved away from the wing leading edge in this way, the spoiling drag at high $C_L$ and large flow is thereby reduced. Figs. 13 and 14 compare the drag of the return-flow cooling scheme with that of a conventionally cowled engine in the same fore-and-aft position (position B) for two degrees of engine baffling. The corresponding curves of $k$ are included in Fig. 15; these indicate that while there is an appreciable spoiling effect from the conventional gills at 25 deg (curves $B_2$ and $B_3$) there is no such spoiling with the return-flow scheme, where the value of $k$ is roughly independent of the flow.

Comparisons of the basic drag (*i.e.* drag at small $C_L$) of the two systems are unreliable on the present small scale, and in this case further complicated by incomplete design of the ducts for return-flow cooling. The larger scale tests of a return-flow cooling scheme described in R. & M. 2403[4] show that duct deflectors and careful design of the entries are necessary in order to get full advantage. The flow comparisons shown in Fig. 17b are also unreliable for the same reasons.

4. *Scale Effect.*—Owing to lack of sufficient data from flight tests it is not possible to predict with confidence the nature and extent of scale effect on the results obtained in the present tests. Indications have, however, been received from time to time during flight work that engine gills can have very high drag and important associated effects. Specific tests were made during flight trials on a Blenheim, by Francis and Pringle[5] (1938) and by Morgan[6] (1939), when the following effects were observed due to opening the gills to 22 deg. angle:—

(1) 5 per cent increase in stalling speed, *i.e.* 10 per cent drop in maximum $C_L$. The position of the Blenheim gills corresponds approximately to position A of the present tests, and this result is therefore in agreement with the results given in Fig. 10.

(2) marked changes in certain other characteristics at the stall, such as controllability, or wing drop with fixed controls; implying considerable modification to the flow over the wing.

(3) a large reduction in the rate of climb on one engine. At 100 m.p.h. (C.A.S.) with flaps up, the reduction was 260 ft/min, which corresponds to an increment in $C_D$ of about 0·026 at a $C_L$ of 0·94. Again there is reasonably good agreement with the corresponding results of the present tests (Fig. 11).

(4) marked changes of trim, increasing with $C_L$, more particularly with engines throttled back.

Other indications that large spoiling effects of this nature may persist up to full-scale values of the Reynolds number are to be found in a report by Smelt and Smith[7] on the design of nacelles for the Albemarle, where it is stated that the flow spoiling behind the original nacelles in flight was at least as large as that observed in model tests; and by certain recent flight reports from the Aircraft and Armaments Experimental Establishment which investigate the effect of gills on level flight and climb performance for particular installations.

It seems reasonable to suppose, therefore, that the present model tests indicate at least the order of the results which may be expected in flight, apart from the additional effect of slipstream. This latter is difficult to assess, and no definite conclusions can be drawn. In the Blenheim flight tests the tendency seemed to be for the slipstream to clean up the spoiling on the wing, giving less loss of lift and hence a smaller change of trim—effect (4) above—but this cannot be clearly established. Model tests of a twin-engined monoplane with and without slipstream, by Johnston, Davies and Peters[8] (1939), support this conclusion. On the other hand, in the Albemarle model tests of Ref. 7 slipstream was found to intensify the breakaway behind the nacelles.

5. *Practical Application.*—It may be useful to indicate how far the effects described in this report are likely to be important for Service aircraft under operational conditions. It has been seen that large spoiling effects due to cooling gills are associated only with what in practice will usually amount to " full-gill setting." Various conditions of flight, at high values of the lift coefficient, are considered briefly.

(1) *Take-off.*—Full gill setting is normally used. Here the loss of lift may be the more important factor. In cases where the effect is large, an alternative take-off technique may be possible, *e.g.* with gills closed, as on the Blenheim.[6]

(2) *Climb.*—Fully open gills are normally required on climb, and in this condition the increase in drag due to opening the gills may result in an important loss of climbing speed. Using the results of Fig. 11 for example, for a typical full-throttle climb at a $C_L$ of 0·9 and a forward speed of 130 m.p.h., the gills in position A would reduce the rate of climb by about 400 ft/min. The corresponding reduction for an equal cooling flow with gills in position C would be 170 ft/min.

(3) *Cruise.*—If the zero gill setting is designed for adequate cooling at top speed, calculations for a typical case show that in general no opening of the gills will be necessary over the whole range of level cruising speeds normally used. The calculations take into account a 20 deg. increase in cylinder temperature due to the weaker mixture normally employed on cruise. Special conditions which might, however, require large gill openings include the following:—

(*a*) Cruising in a tropical climate if the zero gill setting is designed for temperate conditions.

(*b*) Bad distribution of the charge in the intake manifold, leading to large differences in the temperatures of the various cylinders. Such differences are particularly noticeable with the weaker mixtures used for cruising, and in recent engines have been as high as 50 deg. C.

(*c*) Cruising under reduced power, *e g.* with one or more engines cut.

(*d*) Towing gliders.

## REFERENCES


| No. | Author | Title, etc. |
|---|---|---|
| 1 | Seddon and Haile .. .. .. .. | Wind Tunnel Tests on the Increase of Profile Drag with $C_L$ as Applied to Heavy Bombers Cruising at Low Speed. A.R.C. 5087. April, 1941. (Unpublished). |
| 2 | Smelt and Smith .. .. .. .. | The Installation of an Engine Nacelle on a Wing. Part I. Model Tests on a Symmetrical Wing. R. & M. 2406. November, 1939. |
| 3 | Wood .. .. .. .. .. | Tests of Nacelle-propeller Combinations in Various Positions with Reference to Wings ; Part I. N.A.C.A. Report No. 415. 1932. |
| 4 | Smelt and Smith .. .. .. .. | Model Tests of a Return-flow Cooling Scheme, having a Wing Leading Edge Entry and a Nose-slot Exit. R. & M. 2403. March, 1940. |
| 5 | Francis and Pringle .. .. .. | Note on Flight Tests of Stability and Control at Low Speeds on Blenheim. A.R.C. 3680. July, 1938. (Unpublished). |
| 6 | Morgan .. .. .. .. .. | Research Handling Tests on Blenheim L.6595. R. & M. 2348. December, 1940. |
| 7 | Smelt and Smith .. .. .. .. | Note on Nacelles for the Albemarle. (Unpublished). |
| 8 | Johnston, Davies and Peters .. .. | Wind Tunnel Tests on the Gloster F.9/37. A.R.C. 4397. November, 1939. (Unpublished). |


## TABLE 1

*Leading Particulars and Notation*

Scale of model .. .. .. .. .. .. .. 1/12

Wing area, $S$ (sq ft full scale) .. .. .. .. .. 1,690

Aspect ratio, $A$ .. .. .. .. .. .. .. 7·55

$C_{D0}'$ = Profile drag coefficient, defined by

$$C_{D0}' = C_D - C_L^2/\pi A$$

$Q$ = Cooling flow, in cu ft/sec (full scale) at 100 ft/sec.

Baffle constant $B = h/\sigma\left(\frac{Q}{100}\right)^2$, where $h$ is the drop in head across the engine, in inches of water, when the flow is $Q$ cu ft/sec.

Values of $B$ used in the tests are

| | |
|---|---|
| 'Low' baffle, | 0·15 |
| 'Medium' baffle, | 0·5 |
| 'High' baffle, | 2·7 |

## TABLE 2

*Lift and Drag of Wing plus Body (No nacelles)*

(i) Flaps 0 deg.

| $\alpha$ | $C_L$ | $C_D$ | $C_{D0}'$ |
|---|---|---|---|
| 1·5 | 0·23 | 0·0256 | 0·0234 |
| 4·7 | 0·48 | 0·0326 | 0·0228 |
| 7·9 | 0·73 | 0·0462 | 0·0239 |
| 11·1 | 0·98 | 0·0674 | 0·0273 |
| 13·2 | 1·12 | 0·0843 | 0·0311 |
| 15·3 | 1·24 | 0·1060 | 0·0410 |
| 17·4 | 1·26 | — | — |
| 18·4 | 1·26 | — | — |
| 19·3 | 1·23 | — | — |

(ii) Flaps 24 deg.

| $\alpha$ | $C_L$ |
|---|---|
| 7·2 | 1·04 |
| 9·3 | 1·21 |
| 11·5 | 1·39 |
| 13·6 | 1·52 |
| 15·6 | 1·61 |
| 16·6 | 1·60 |

## TABLE 3

*Lift, Drag and Flow with Symmetrical Gills (Low baffle)*

(i) Nacelles in position A (Fig. 4)

| Gills | Flaps | $\alpha$ | $C_L$ | $C_D$ | $C_{D0}'$ | $Q$ |
|---|---|---|---|---|---|---|
| 0° | 0° | 0·4 | 0·13 | 0·0305 | 0·0298 | 145 |
| | | 3·6 | 0·39 | 0·0348 | 0·0285 | 154 |
| | | 6·8 | 0·64 | 0·0481 | 0·0310 | 220 |
| | | 10·1 | 0·90 | 0·0718 | 0·0375 | 229 |
| | | 13·3 | 1·14 | 0·103 | 0·0477 | 211 |
| | | 15·4 | 1·28 | 0·133 | 0·0637 | — |
| | | 17·4 | 1·32 | 0·180 | 0·107 | 201 |
| | | 19·4 | 1·31 | — | — | — |
| 10° | 0° | 0·4 | 0·13 | 0·0350 | 0·0343 | 290 |
| | | 3·6 | 0·37 | 0·0394 | 0·0336 | 305 |
| | | 6·8 | 0·61 | 0·0518 | 0·0359 | 338 |
| | | 10·0 | 0·88 | 0·0740 | 0·0416 | 327 |
| | | 13·2 | 1·11 | 0·104 | 0·0520 | 303 |
| | | 15·3 | 1·25 | 0·131 | 0·0655 | — |
| | | 17·3 | 1·28 | 0·177 | 0·108 | 281 |
| | | 19·3 | 1·27 | — | — | — |
| 25° | 0° | 0·4 | 0·13 | 0·0446 | 0·0439 | 398 |
| | | 3·6 | 0·34 | 0·0486 | 0·0438 | 421 |
| | | 6·7 | 0·53 | 0·0629 | 0·0511 | 439 |
| | | 9·9 | 0·72 | 0·0847 | 0·0627 | 404 |
| | | 13·1 | 0·96 | 0·110 | 0·0715 | 374 |
| | | 15·2 | 1·09 | 0·134 | 0·0845 | — |
| | | 17·3 | 1·13 | 0·172 | 0·118 | 312 |
| | | 19·3 | 1·15 | — | — | — |
| | | 20·3 | 1·14 | — | — | — |
| 25° | 24° | 7·0 | 0·92 | — | — | — |
| | | 9·2 | 1·09 | — | — | — |
| | | 11·4 | 1·27 | — | — | — |
| | | 13·5 | 1·44 | — | — | — |
| | | 15·6 | 1·53 | — | — | — |
| | | 17·6 | 1·50 | — | — | — |
| | | 16·6 | 1·52 | — | — | — |

(ii) Nacelles in position B (Fig. 4)

| Gills | Flaps | $\alpha$ | $C_L$ | $C_D$ | $C_{D0}'$ | $Q$ |
|---|---|---|---|---|---|---|
| 0° | 0° | 0·4 | — | — | — | 153 |
| | | 3·6 | — | — | — | 193 |
| | | 6·8 | — | — | — | 249 |
| | | 10·1 | — | — | — | 255 |
| | | 13·3 | — | — | — | 246 |
| | | 17·4 | — | — | — | 235 |
| 10° | 0° | 0·4 | — | — | — | 284 |
| | | 3·6 | — | — | — | 232 |
| | | 6·8 | — | — | — | 354 |
| | | 10·0 | — | — | — | 350 |
| | | 13·2 | — | — | — | 343 |
| | | 17·4 | — | — | — | 315 |

TABLE 3 (*contd.*)

(ii) Nacelles in position B (Fig 4) (*contd.*)

| Gills | Flaps | $\alpha$ | $C_L$ | $C_D$ | $C_{D0}'$ | $Q$ |
|---|---|---|---|---|---|---|
| 25° | 0° | 0·4 | 0·12 | 0·0443 | 0·0437 | 386 |
| | | 3·6 | 0·36 | 0·0481 | 0·0426 | 421 |
| | | 6·8 | 0·60 | 0·0603 | 0·0452 | 427 |
| | | 10·0 | 0·82 | 0·0800 | 0·0519 | 430 |
| | | 13·2 | 1·03 | 0·104 | 0·0589 | 420 |
| | | 15·3 | 1·15 | 0·126 | 0·0695 | — |
| | | 17·3 | 1·19 | 0·167 | 0·107 | 397 |
| | | 19·3 | 1·15 | — | — | — |
| 25° | 24° | 7·2 | 1·01 | — | — | — |
| | | 9·3 | 1·17 | — | — | — |
| | | 11·4 | 1·33 | — | — | — |
| | | 13·5 | 1·47 | — | — | — |
| | | 13·6 | 1·54 | — | — | — |
| | | 16·6 | 1·55 | — | — | — |
| | | 17·6 | 1·54 | — | — | — |

(iii) Nacelles in position C (Fig. 4)

| Gills | Flaps | $\alpha$ | $C_L$ | $C_D$ | $C_{D0}'$ | $Q$ |
|---|---|---|---|---|---|---|
| 0° | 0° | 0·4 | 0·13 | 0·0310 | 0·0303 | 163 |
| | | 3·6 | 0·38 | 0·0351 | 0·0291 | 208 |
| | | 6·8 | 0·63 | 0·0482 | 0·0312 | 249 |
| | | 10·1 | 0·90 | 0·0707 | 0·0365 | 253 |
| | | 13·3 | 1·14 | 0·103 | 0·0483 | 239 |
| | | 15·4 | 1·28 | 0·135 | 0·0651 | — |
| | | 17·4 | 1·31 | 0·183 | 0·111 | 224 |
| | | 19·4 | 1·29 | — | — | — |
| 0° | 24° | 7·2 | 1·06 | — | — | — |
| | | 9·3 | 1·22 | — | — | — |
| | | 11·5 | 1·41 | — | — | — |
| | | 13·6 | 1·57 | — | — | — |
| | | 15·7 | 1·67 | — | — | — |
| | | 16·7 | 1·67 | — | — | — |
| 10° | 0° | 0·4 | 0·12 | 0·0359 | 0·0353 | 290 |
| | | 3·6 | 0·39 | 0·0405 | 0·0342 | 320 |
| | | 6·8 | 0·62 | 0·0511 | 0·0351 | 354 |
| | | 10·0 | 0·89 | 0·0730 | 0·0399 | 365 |
| | | 13·2 | 1·12 | 0·105 | 0·0517 | 373 |
| | | 15·4 | 1·27 | 0·133 | 0·0654 | — |
| | | 17·4 | 1·29 | 0·178 | 0·107 | 336 |
| | | 19·4 | 1·28 | — | — | — |
| 25° | 0° | 0·4 | 0·13 | 0·0446 | 0·0438 | 367 |
| | | 3·6 | 0·38 | 0·0491 | 0·0430 | 411 |
| | | 6·8 | 0·61 | 0·0606 | 0·0448 | 432 |
| | | 10·0 | 0·85 | 0·0788 | 0·0485 | 440 |
| | | 13·2 | 1·07 | 0·105 | 0·0571 | 491 |
| | | 15·3 | 1·23 | 0·132 | 0·0708 | — |
| | | 17·3 | 1·22 | 0·180 | 0·118 | 414 |
| | | 19·3 | 1·20 | — | — | — |

TABLE 3 (*contd.*)

(iii) Nacelles in position C (Fig. 4) (*contd.*)

| Gills | Flaps | $\alpha$ | $C_L$ | $C_D$ | $C_{D0}'$ | $Q$ |
|---|---|---|---|---|---|---|
| 25° | 24° | 7·2 | 1·03 | — | — | — |
| | | 9·3 | 1·18 | — | — | — |
| | | 11·4 | 1·37 | — | — | — |
| | | 13·6 | 1·51 | — | — | — |
| | | 15·6 | 1·59 | — | — | — |
| | | 16·6 | 1·58 | — | — | — |

(iv) Nacelles in position D (Fig. 4)

| Gills | Flaps | $\alpha$ | $C_L$ | $C_D$ | $C_{D0}'$ | $Q$ |
|---|---|---|---|---|---|---|
| 0° | 0° | 0·4 | 0·10 | 0·0304 | 0·0299 | 152 |
| | | 3·6 | 0·35 | 0·0341 | 0·0288 | 204 |
| | | 6·8 | 0·61 | 0·0475 | 0·0317 | 218 |
| | | 10·0 | 0·87 | 0·0694 | 0·0375 | 212 |
| | | 13·2 | 1·11 | 0·100 | 0·0480 | 201 |
| | | 15·3 | 1·24 | 0·126 | 0·0613 | — |
| | | 17·4 | 1·29 | 0·170 | 0·100 | 187 |
| | | 19·4 | 1·30 | — | — | — |
| | | 20·4 | 1·28 | — | — | — |
| 0° | 24° | 7·2 | 1·03 | — | — | — |
| | | 10·4 | 1·31 | — | — | — |
| | | 13·6 | 1·54 | — | — | — |
| | | 15·7 | 1·65 | — | — | — |
| | | 17·7 | 1·67 | — | — | — |
| | | 19·7 | 1·66 | — | — | — |
| | | 20·7 | 1·66 | — | — | — |
| | | 21·7 | 1·66 | — | — | — |
| | | 22·7 | 1·66 | — | — | — |
| | | 24·6 | 1·58 | — | — | — |
| 10° | 0° | 0·4 | 0·11 | 0·0344 | 0·0339 | — |
| | | 3·6 | 0·34 | 0·0375 | 0·0326 | — |
| | | 6·8 | 0·59 | 0·0494 | 0·0347 | — |
| | | 10·0 | 0·85 | 0·0717 | 0·0413 | — |
| | | 13·2 | 1·09 | 0·102 | 0·0519 | — |
| | | 15·3 | 1·23 | 0·129 | 0·0655 | — |
| | | 17·4 | 1·27 | 0·171 | 0·103 | — |
| | | 19·4 | 1·28 | — | — | — |
| | | 20·4 | 1·27 | — | — | — |
| 25° | 0° | 0·4 | 0·11 | 0·0447 | 0·0442 | 389 |
| | | 3·6 | 0·33 | 0·0478 | 0·0434 | 405 |
| | | 6·8 | 0·55 | 0·0609 | 0·0501 | 395 |
| | | 9·9 | 0·74 | 0·0803 | 0·0571 | 370 |
| | | 13·1 | 0·97 | 0·105 | 0·0657 | 316 |
| | | 15·2 | 1·09 | 0·128 | 0·0776 | — |
| | | 17·2 | 1·13 | 0·169 | 0·115 | 269 |
| | | 19·2 | 1·13 | — | — | — |
| | | 20·2 | 1·14 | — | — | — |
| | | 22·3 | 1·16 | — | — | — |
| | | 24·2 | 1·14 | — | — | — |

TABLE 3 (*contd.*)

(iv) Nacelles in position D (Fig. 4) (*contd.*)

| Gills | Flaps | $\alpha$ | $C_L$ | $C_D$ | $C_{D0}'$ | $Q$ |
|---|---|---|---|---|---|---|
| 25° | 24° | 7·1 | 0·94 | — | — | — |
| | | 10·3 | 1·18 | — | — | — |
| | | 13·5 | 1·41 | — | — | — |
| | | 15·6 | 1·50 | — | — | — |
| | | 17·6 | 1·50 | — | — | — |
| | | 19·5 | 1·49 | — | — | — |

TABLE 4

*Lift, Drag and Flow with Unsymmetrical Gills* (*Fig.* 3)
(*Low baffle, nacelles in position* A (*Fig.* 4))

(i) Gills 25 deg. at bottom, 0 deg at sides and top

| Flaps | $\alpha$ | $C_L$ | $C_D$ | $C_{D0}'$ | $Q$ |
|---|---|---|---|---|---|
| 0° | 0·4 | 0·13 | 0·0349 | 0·0342 | 260 |
| | 3·6 | 0·39 | 0·0395 | 0·0330 | 265 |
| | 6·8 | 0·65 | 0·0529 | 0·0353 | 316 |
| | 10·1 | 0·90 | 0·0748 | 0·0406 | 313 |
| | 13·3 | 1·14 | 0·107 | 0·0523 | 283 |
| | 15·4 | 1·27 | 0·134 | 0·0662 | — |
| | 17·4 | 1·31 | 0·178 | 0·106 | 239 |
| | 19·4 | 1·31 | — | — | — |

(ii) Gills 25 deg. at top, 0 deg at sides and bottom

| Flaps | $\alpha$ | $C_L$ | $C_D$ | $C_{D0}'$ | $Q$ |
|---|---|---|---|---|---|
| 0° | 3·6 | 0·39 | 0·0395 | 0·0330 | 274 |
| | 6·8 | 0·64 | 0·0514 | 0·0342 | 312 |
| | 10·0 | 0·87 | 0·0718 | 0·0395 | 310 |
| | 13·2 | 1·07 | 0·0980 | 0·0497 | 308 |
| | 16·3 | 1·21 | 0·145 | 0·0827 | — |

TABLE 4 (*contd.*)

(iii) Gills 25 deg. at top and bottom, 0 deg. at sides

| Flaps | $\alpha$ | $C_L$ | $C_D$ | $C_{D0}'$ | $Q$ |
|---|---|---|---|---|---|
| 0° | 0·4 | 0·12 | 0·0393 | 0·0387 | 340 |
| | 3·6 | 0·38 | 0·0434 | 0·0372 | 360 |
| | 6·8 | 0·63 | 0·0554 | 0·0384 | 378 |
| | 10·0 | 0·86 | 0·0739 | 0·0425 | 359 |
| | 13·2 | 1·06 | 0·101 | 0·0532 | 328 |
| | 15·3 | 1·17 | 0·124 | 0·0658 | — |
| | 17·3 | 1·21 | 0·164 | 0·103 | 328 |
| | 19·3 | 1·19 | — | — | — |
| 24° | 7·2 | 1·02 | — | — | — |
| | 9·3 | 1·17 | — | — | — |
| | 11·4 | 1·31 | — | — | — |
| | 13·5 | 1·46 | — | — | — |
| | 15·6 | 1·55 | — | — | — |
| | 16·6 | 1·56 | — | — | — |
| | 17·6 | 1·55 | — | — | — |

(iv) Gills 25 deg. at sides, 0 deg. at top and bottom

| Flaps | $\alpha$ | $C_L$ | $C_D$ | $C_{D0}'$ | $Q$ |
|---|---|---|---|---|---|
| 0° | 3·6 | 0·37 | 0·0415 | 0·0357 | 360 |
| | 6·8 | 0·63 | 0·0546 | 0·0380 | 373 |
| | 10·0 | 0·87 | 0·0758 | 0·0441 | 354 |
| | 13·2 | 1·10 | 0·105 | 0·0539 | 338 |
| | 16·3 | 1·25 | 0·156 | 0·0893 | — |

## TABLE 5

*Comparison with Return-flow Cowl (Medium baffle)*

(i) Conventional flow, position B

| Gills | Flaps | $\alpha$ | $C_L$ | $C_D$ | $C_{D0}'$ | $Q$ |
|---|---|---|---|---|---|---|
| 0° | 0° | 0·4 | 0·10 | 0·0327 | 0·0323 | 178 |
| | | 3·6 | 0·35 | 0·0370 | 0·0318 | 184 |
| | | 6·8 | 0·60 | 0·0500 | 0·0348 | 260 |
| | | 10·0 | 0·85 | 0·0723 | 0·0418 | 275 |
| | | 13·2 | 1·10 | 0·105 | 0·0541 | 292 |
| | | 15·3 | 1·24 | 0·134 | 0·0693 | — |
| | | 17·4 | 1·27 | 0·178 | 0·110 | 299 |
| | | 19·4 | 1·26 | — | — | — |
| 0° | 24° | 7·2 | 1·01 | — | — | — |
| | | 10·4 | 1·28 | — | — | — |
| | | 13·6 | 1·53 | — | — | — |
| | | 15·7 | 1·64 | — | — | — |
| | | 17·7 | 1·64 | — | — | — |
| | | 19·7 | 1·61 | — | — | — |
| 10° | 0° | 0·4 | 0·10 | 0·0356 | 0·0352 | 235 |
| | | 3·6 | 0·35 | 0·0398 | 0·0346 | 243 |
| | | 6·8 | 0·60 | 0·0525 | 0·0376 | 305 |
| | | 10·0 | 0·84 | 0·0738 | 0·0440 | 315 |
| | | 13·3 | 1·08 | 0·105 | 0·0562 | 329 |
| | | 15·3 | 1·21 | 0·130 | 0·0683 | — |
| | | 17·4 | 1·25 | 0·173 | 0·106 | 330 |
| | | 19·3 | 1·21 | — | — | — |
| 25° | 0° | 0·4 | 0·09 | 0·0420 | 0·0416 | 278 |
| | | 3·6 | 0·34 | 0·0464 | 0·0414 | 291 |
| | | 6·8 | 0·58 | 0·0596 | 0·0453 | 340 |
| | | 10·0 | 0·81 | 0·0801 | 0·0526 | 357 |
| | | 13·2 | 1·03 | 0·106 | 0·0612 | 361 |
| | | 15·3 | 1·16 | 0·129 | 0·0721 | — |
| | | 17·3 | 1·21 | 0·168 | 0·106 | 321 |
| | | 19·3 | 1·19 | — | — | — |
| 25° | 24° | 7·1 | 0·99 | — | — | — |
| | | 10·3 | 1·23 | — | — | — |
| | | 13·5 | 1·46 | — | — | — |
| | | 15·6 | 1·55 | — | — | — |
| | | 17·6 | 1·53 | — | — | — |
| | | 18·6 | 1·53 | — | — | — |

(ii) Conventional flow, position D

| Gills | Flaps | $\alpha$ | $C_L$ | $C_D$ | $C_{D0}'$ | $Q$ |
|---|---|---|---|---|---|---|
| 25° | 0° | 0·4 | 0·10 | 0·0441 | 0·0437 | 260 |
| | | 3·6 | 0·34 | 0·0466 | 0·0418 | 310 |
| | | 6·8 | 0·55 | 0·0603 | 0·0474 | 335 |
| | | 9·9 | 0·75 | 0·0848 | 0·0614 | 319 |
| | | 13·1 | 0·94 | 0·112 | 0·0743 | 313 |
| | | 15·2 | 1·06 | 0·135 | 0·0875 | — |
| | | 17·3 | 1·11 | 0·184 | 0·132 | 282 |
| | | 19·3 | 1·15 | 0·211 | 0·155 | — |
| | | 21·3 | 1·13 | — | — | — |

TABLE 5 (*contd.*)

(ii) Conventional flow, position D

| Gills | Flaps | $\alpha$ | $C_L$ | $C_D$ | $C_{D0}'$ | $Q$ |
|---|---|---|---|---|---|---|
| 25° | 24° | 7·1 | 0·95 | — | — | — |
| | | 10·3 | 1·17 | — | — | — |
| | | 13·5 | 1·38 | — | — | — |
| | | 15·6 | 1·48 | — | — | — |
| | | 17·6 | 1·51 | — | — | — |
| | | 18·6 | 1·51 | — | — | — |
| | | 19·6 | 1·51 | — | — | — |
| | | 20·6 | 1·51 | — | — | — |
| | | 21·5 | 1·44 | — | — | — |

(iii) Return flow

| Exit Area | Flaps | $\alpha$ | $C_L$ | $C_D$ | $C_{D0}'$ | $Q$ |
|---|---|---|---|---|---|---|
| 2·42 sq ft | 0° | 0·4 | 0·08 | 0·0309 | 0·0306 | 197 |
| | | 3·6 | 0·34 | 0·0350 | 0·0300 | 203 |
| | | 6·8 | 0·60 | 0·0475 | 0·0323 | 196 |
| | | 10·0 | 0·84 | 0·0688 | 0·0388 | 168 |
| | | 13·2 | 1·08 | 0·102 | 0·0527 | 113 |
| | | 15·3 | 1·21 | 0·132 | 0·0797 | — |
| | | 17·3 | 1·24 | 0·183 | 0·118 | 67 |
| | | 19·3 | 1·20 | — | — | — |
| 2·42 | 24° | 7·1 | 1·00 | — | — | — |
| | | 10·4 | 1·26 | — | — | — |
| | | 13·6 | 1·51 | — | — | — |
| | | 15·6 | 1·61 | — | — | — |
| | | 17·7 | 1·65 | — | — | — |
| | | 18·6 | 1·51 | — | — | — |
| 4·31 | 0° | 0·4 | 0·08 | 0·0328 | 0·0325 | 265 |
| | | 3·6 | 0·34 | 0·0368 | 0·0320 | 271 |
| | | 6·8 | 0·59 | 0·0491 | 0·0343 | 264 |
| | | 10·0 | 0·83 | 0·0693 | 0·0401 | 234 |
| | | 13·2 | 1·07 | 0·102 | 0·0537 | 176 |
| | | 15·3 | 1·18 | 0·132 | 0·0737 | — |
| | | 17·3 | 1·20 | 0·181 | 0·121 | 100 |
| | | 19·3 | 1·16 | — | — | — |
| 7·34 | 0° | 0·4 | 0·08 | 0·0412 | 0·0409 | 341 |
| | | 3·6 | 0·34 | 0·0445 | 0·0397 | 344 |
| | | 6·8 | 0·58 | 0·0556 | 0·0412 | 332 |
| | | 10·0 | 0·83 | 0·0757 | 0·0468 | 298 |
| | | 13·2 | 1·06 | 0·107 | 0·0598 | 233 |
| | | 15·3 | 1·17 | 0·138 | 0·0802 | — |
| | | 17·3 | 1·18 | 0·186 | 0·127 | 159 |
| | | 18·3 | 1·17 | 0·221 | 0·163 | — |
| 7·34 | 24° | 7·1 | 1·00 | — | — | — |
| | | 10·4 | 1·26 | — | — | — |
| | | 13·5 | 1·49 | — | — | — |
| | | 15·5 | 1·57 | — | — | — |
| | | 17·6 | 1·49 | — | — | — |

TABLE 6

*Comparison with Return-flow Cowl (High baffle)*

(i) Conventional cowl, position A

| Gills | Flaps | $\alpha$ | $C_L$ | $C_D$ | $C_{D0}'$ | $Q$ |
|---|---|---|---|---|---|---|
| 0° | 0° | 0·4 | 0·12 | 0·0306 | 0·0299 | 81 |
| | | 3·6 | 0·38 | 0·0350 | 0·0290 | 81 |
| | | 6·8 | 0·63 | 0·0494 | 0·0328 | 104 |
| | | 10·0 | 0·87 | 0·0714 | 0·0397 | 110 |
| | | 13·2 | 1·11 | 0·105 | 0·0536 | 122 |
| | | 15·3 | 1·22 | 0·133 | 0·0695 | — |
| | | 17·4 | 1·25 | 0·179 | 0·113 | 135 |
| | | 19·3 | 1·22 | — | — | — |
| 0° | 24° | 7·2 | 1·03 | — | — | — |
| | | 10·4 | 1·31 | — | — | — |
| | | 13·6 | 1·54 | — | — | — |
| | | 15·7 | 1·63 | — | — | — |
| | | 17·7 | 1·65 | — | — | — |
| | | 19·6 | 1·57 | — | — | — |
| 10° | 0° | 0·4 | 0·13 | 0·0336 | 0·0329 | 103 |
| | | 3·6 | 0·37 | 0·0380 | 0·0321 | 102 |
| | | 6·8 | 0·61 | 0·0517 | 0·0359 | 122 |
| | | 10·0 | 0·85 | 0·0735 | 0·0433 | 124 |
| | | 13·2 | 1·08 | 0·106 | 0·0573 | 126 |
| | | 15·3 | 1·20 | 0·133 | 0·0725 | — |
| | | 17·3 | 1·22 | 0·181 | 0·117 | 136 |
| | | 19·3 | 1·21 | — | — | — |
| 25° | 0° | 0·4 | 0·13 | 0·0400 | 0·0393 | 112 |
| | | 3·6 | 0·36 | 0·0440 | 0·0384 | 113 |
| | | 6·8 | 0·60 | 0·0601 | 0·0449 | 131 |
| | | 10·0 | 0·77 | 0·0900 | 0·0651 | 130 |
| | | 13·1 | 0·98 | 0·123 | 0·0829 | 124 |
| | | 15·2 | 1·08 | 0·150 | 0·101 | — |
| | | 17·2 | 1·10 | 0·193 | 0·141 | 116 |
| | | 19·2 | 1·11 | — | — | — |
| | | 21·2 | 1·12 | — | — | — |
| | | 23·2 | 1·10 | — | — | — |
| 25° | 24° | 7·2 | 1·00 | — | — | — |
| | | 10·3 | 1·22 | — | — | — |
| | | 13·5 | 1·40 | — | — | — |
| | | 15·5 | 1·46 | — | — | — |
| | | 17·5 | 1·46 | — | — | — |
| | | 19·5 | 1·42 | — | — | — |

TABLE 6 (*contd.*)

(ii) Conventional cowl, position B

| Gills | Flaps | $\alpha$ | $C_L$ | $C_D$ | $C_{D0}'$ | $Q$ |
|---|---|---|---|---|---|---|
| 0° | 0° | 0·4 | 0·12 | 0·0308 | 0·0302 | 79 |
| | | 3·6 | 0·38 | 0·0345 | 0·0283 | 79 |
| | | 6·8 | 0·63 | 0·0485 | 0·0320 | 105 |
| | | 10·0 | 0·87 | 0·0705 | 0·0384 | 110 |
| | | 13·2 | 1·11 | 0·103 | 0·0513 | 115 |
| | | 15·3 | 1·23 | 0·130 | 0·0659 | — |
| | | 17·4 | 1·27 | 0·178 | 0·110 | 121 |
| | | 19·3 | 1·25 | — | — | — |
| 10° | 0° | 0·4 | — | — | — | 99 |
| | | 3·6 | — | — | — | 98 |
| | | 6·8 | — | — | — | 121 |
| | | 10·0 | — | — | — | 128 |
| | | 13·2 | — | — | — | 131 |
| | | 17·3 | — | — | — | 138 |
| 25° | 0° | 0·4 | 0·11 | 0·0383 | 0·0377 | 116 |
| | | 3·6 | 0·37 | 0·0426 | 0·0370 | 113 |
| | | 6·8 | 0·60 | 0·0567 | 0·0414 | 132 |
| | | 10·0 | 0·83 | 0·0761 | 0·0469 | 137 |
| | | 13·2 | 1·05 | 0·104 | 0·0570 | 136 |
| | | 15·3 | 1·15 | 0·128 | 0·0728 | — |
| | | 17·3 | 1·18 | 0·168 | 0·109 | 141 |
| | | 19·3 | 1·17 | — | — | — |
| | | 20·3 | 1·14 | — | — | — |
| 25° | 24° | 7·2 | 1·02 | — | — | — |
| | | 10·4 | 1·26 | — | — | — |
| | | 13·5 | 1·45 | — | — | — |
| | | 15·6 | 1·53 | — | — | — |
| | | 17·6 | 1·52 | — | — | — |
| | | 19·6 | 1·51 | — | — | — |

(iii) Return flow

| Exit Area | Flaps | $\alpha$ | $C_L$ | $C_D$ | $C_{D0}'$ | $Q$ |
|---|---|---|---|---|---|---|
| 1·97 sq. ft. | 0° | 0·4 | 0·09 | 0·0309 | 0·0306 | 93 |
| | | 3·6 | 0·34 | 0·0354 | 0·0304 | 95 |
| | | 6·8 | 0·60 | 0·0476 | 0·0326 | 94 |
| | | 10·0 | 0·05 | 0·0701 | 0·0395 | 80 |
| | | 13·2 | 1·09 | 0·103 | 0·0526 | 56 |
| | | 15·3 | 1·22 | 0·133 | 0·0706 | — |
| | | 17·3 | 1·21 | — | — | 38 |
| 1·97 | 24° | 7·1 | 0·99 | — | — | — |
| | | 10·4 | 1·27 | — | — | — |
| | | 13·6 | 1·51 | — | — | — |
| | | 15·7 | 1·61 | — | — | — |
| | | 16·7 | 1·62 | — | — | — |
| | | 17·7 | 1·63 | — | — | — |
| | | 18·6 | 1·51 | — | — | — |

TABLE 6 (*contd.*)

(iii) Return flow (*contd.*)

| Exit Area | Flaps | $\alpha$ | $C_L$ | $C_D$ | $C_{D0}'$ | $Q$ |
|---|---|---|---|---|---|---|
| 4·28 | 0° | 0·4 | 0·09 | 0·0321 | 0·0318 | 137 |
| | | 3·6 | 0·34 | 0·0365 | 0·0315 | 137 |
| | | 6·8 | 0·59 | 0·0486 | 0·0337 | 135 |
| | | 10·0 | 0·83 | 0·0687 | 0·0393 | 116 |
| | | 13·2 | 1·06 | 0·101 | 0·0539 | 97 |
| | | 15·3 | 1·18 | 0·130 | 0·0708 | — |
| | | 17·3 | 1·20 | 0·182 | 0·122 | 60 |
| | | 19·3 | 1·16 | — | — | — |
| 7·34 | 0° | 0·4 | 0·09 | 0·0406 | 0·0403 | 169 |
| | | 3·6 | 0·34 | 0·0443 | 0·0393 | 172 |
| | | 6·8 | 0·60 | 0·0555 | 0·0406 | 174 |
| | | 10·0 | 0·84 | 0·0770 | 0·0470 | 160 |
| | | 13·2 | 1·06 | 0·108 | 0·0609 | 135 |
| | | 15·3 | 1·17 | 0·137 | 0·0799 | — |
| | | 17·3 | 1·17 | 0·170 | 0·112 | 101 |
| | | 19·3 | 1·14 | — | — | — |
| 7·34 | 24° | 7·2 | 1·00 | — | — | — |
| | | 10·3 | 1·26 | — | — | — |
| | | 13·5 | 1·48 | — | — | — |
| | | 15·6 | 1·58 | — | — | — |
| | | 17·5 | 1·46 | — | — | — |



(93007) B

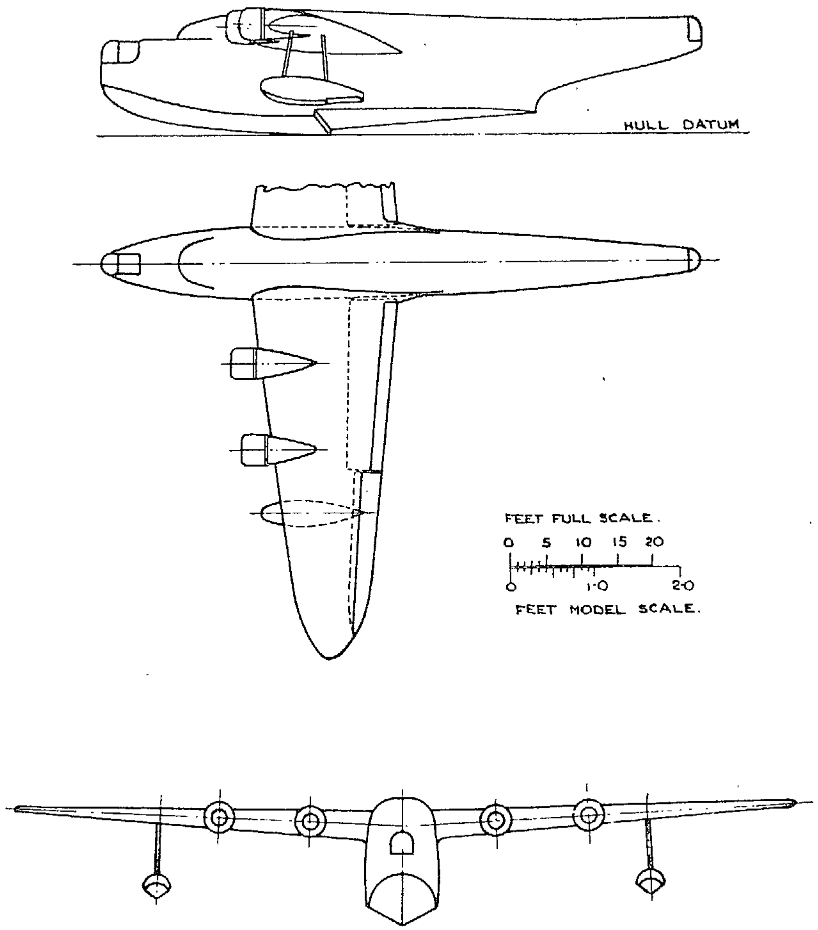



FIG. 1. General Arrangement of Model as Tested.

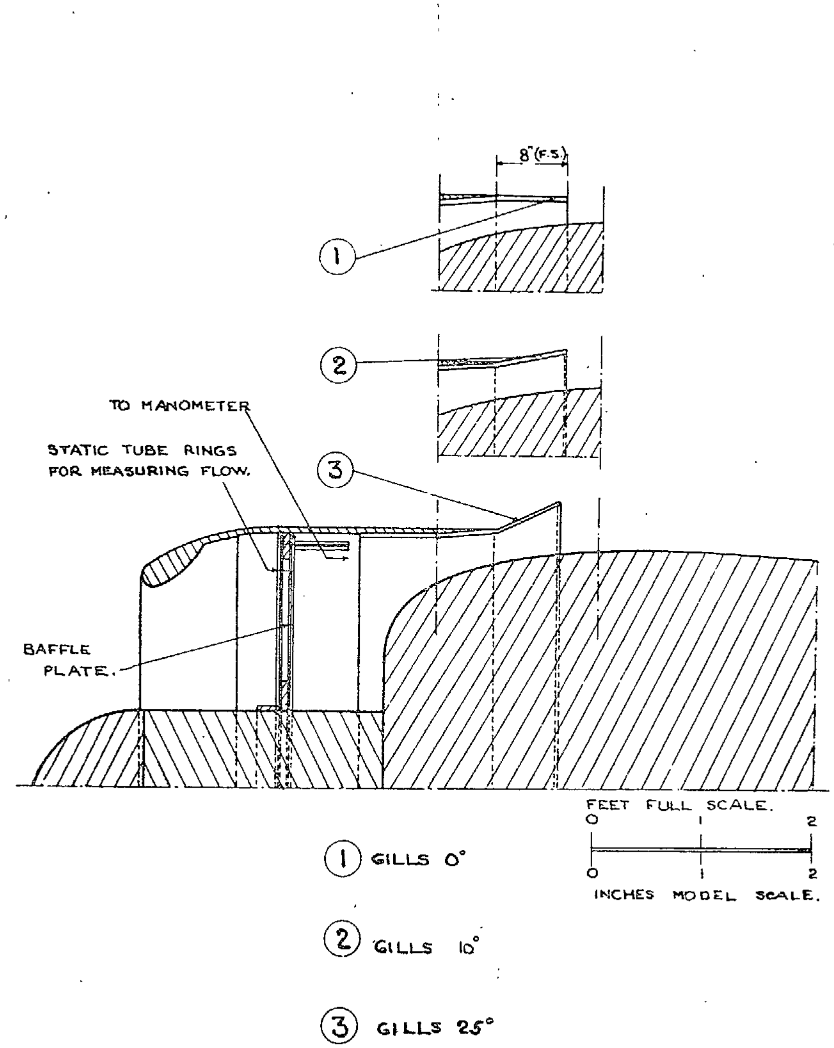



FIG. 2. Details of Nacelles with Symmetrical Gills.

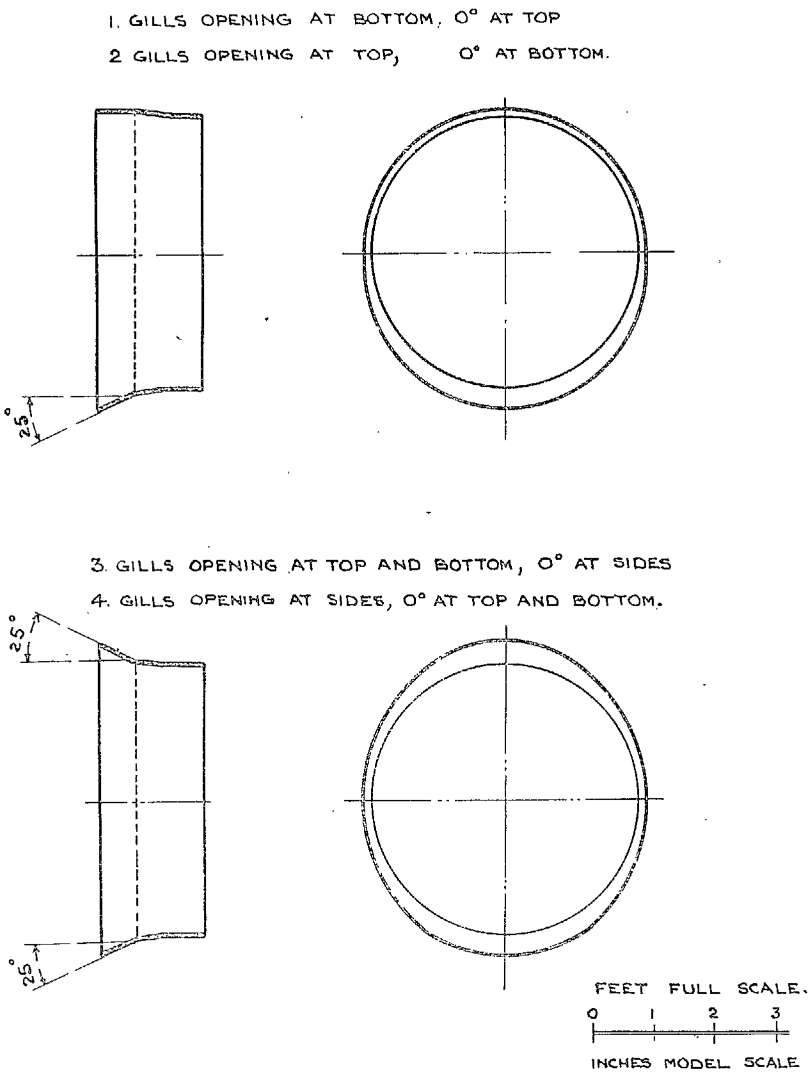



FIG. 3. Unsymmetrical Gills.

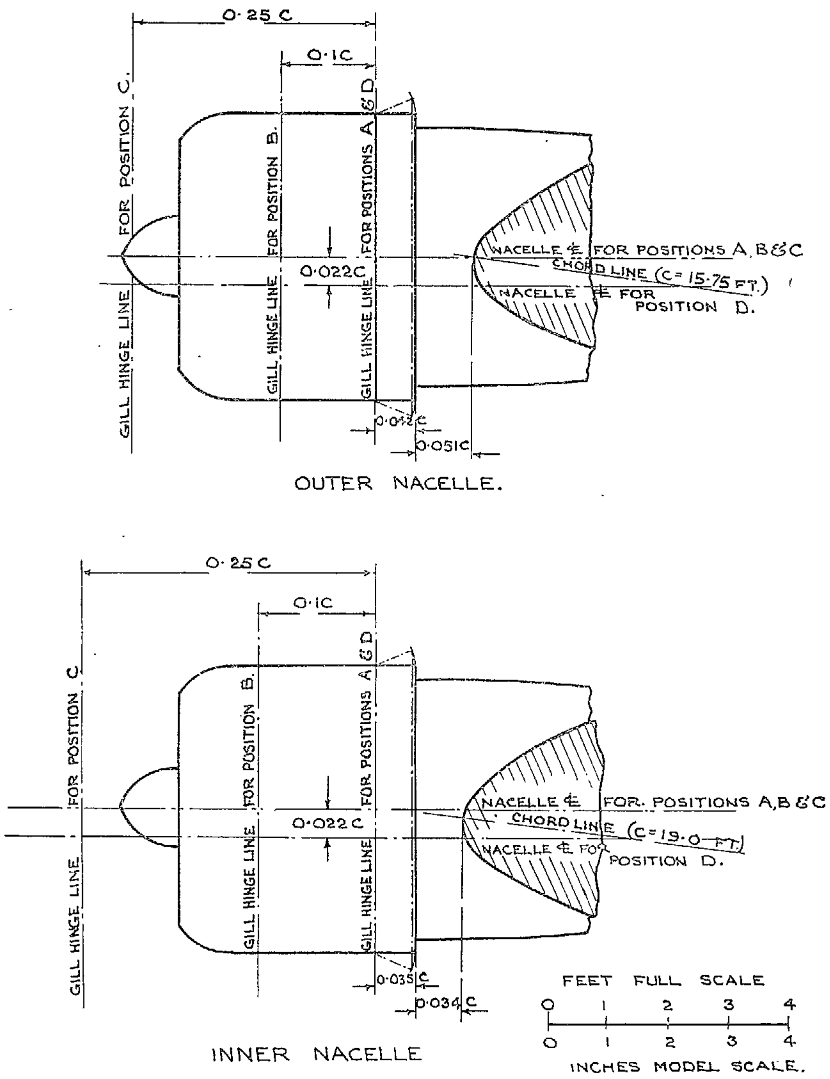



FIG. 4. Details of Nacelle Positions A, B, C and D.

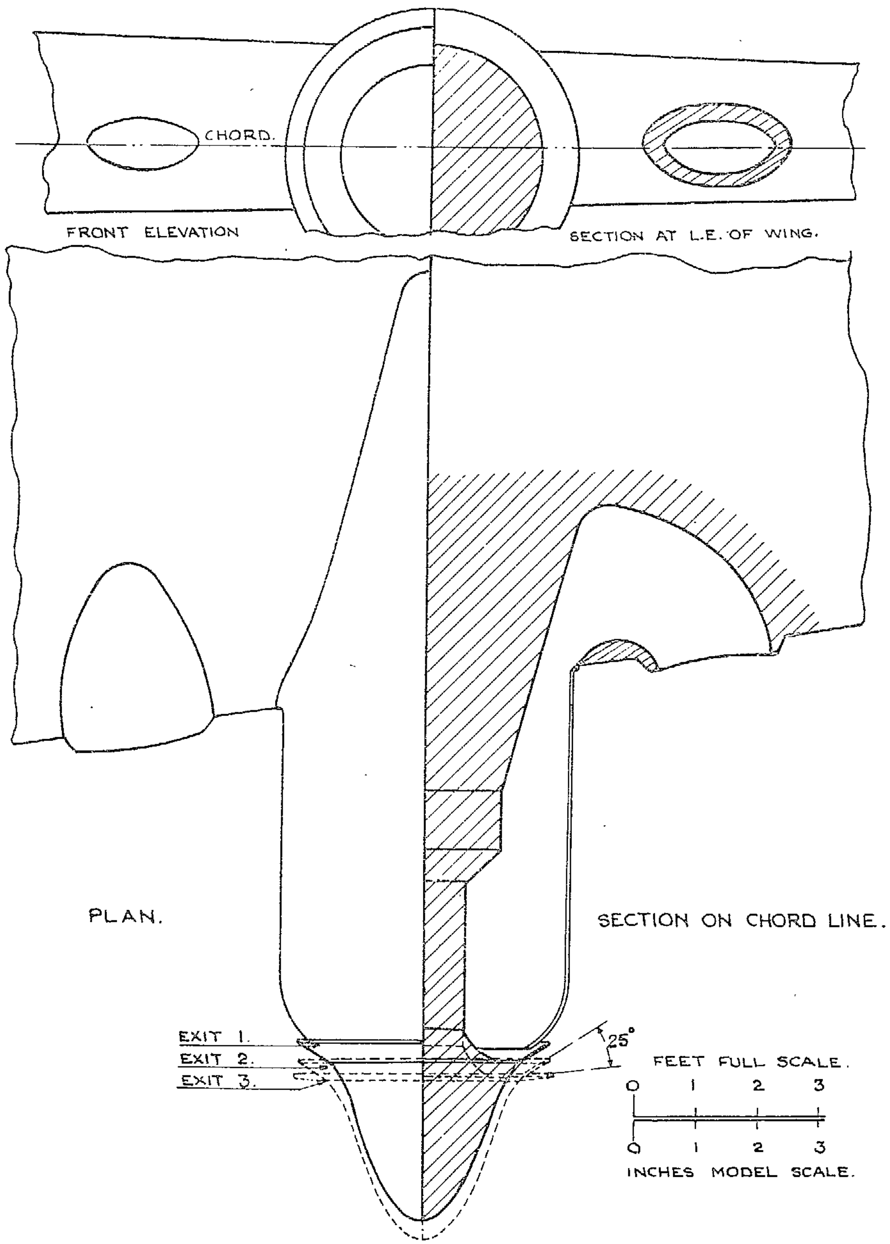



FIG. 5. Return-flow Cowl.

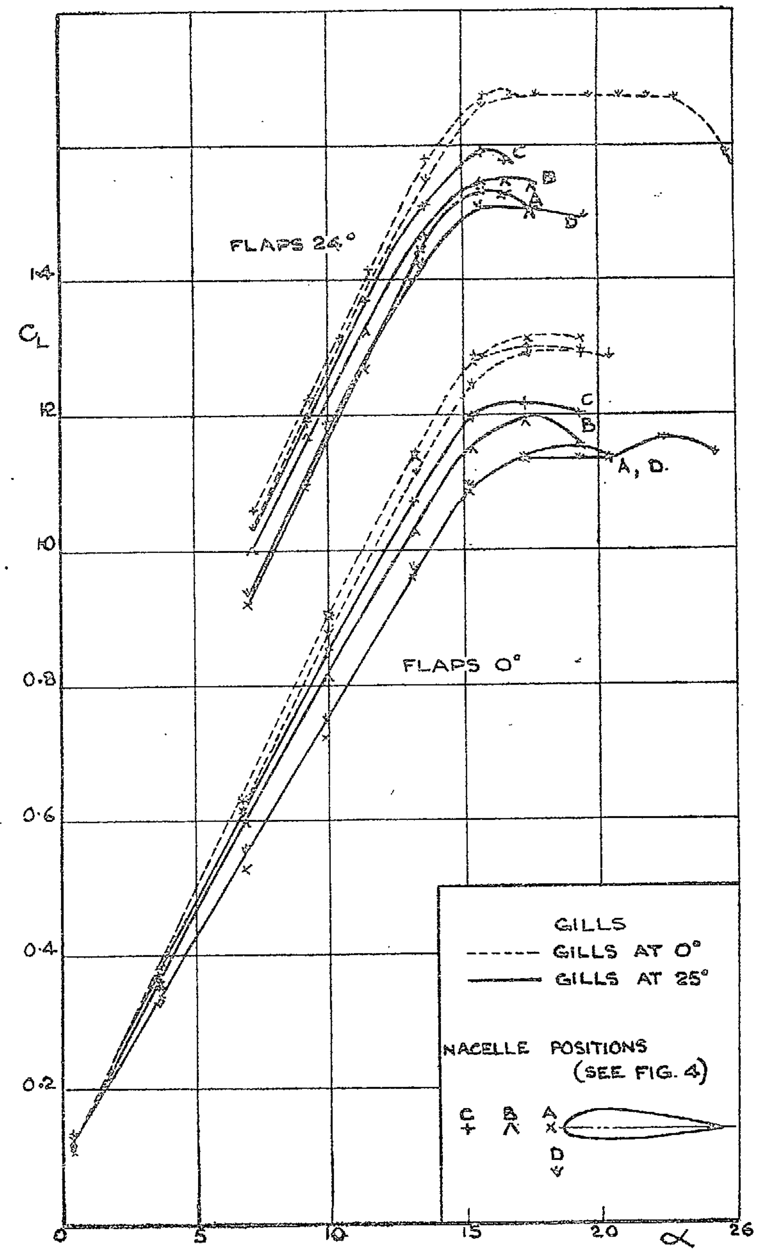



FIG. 6. Lift Coefficients—Effect of Gills and of Nacelle Position, Low Baffle.

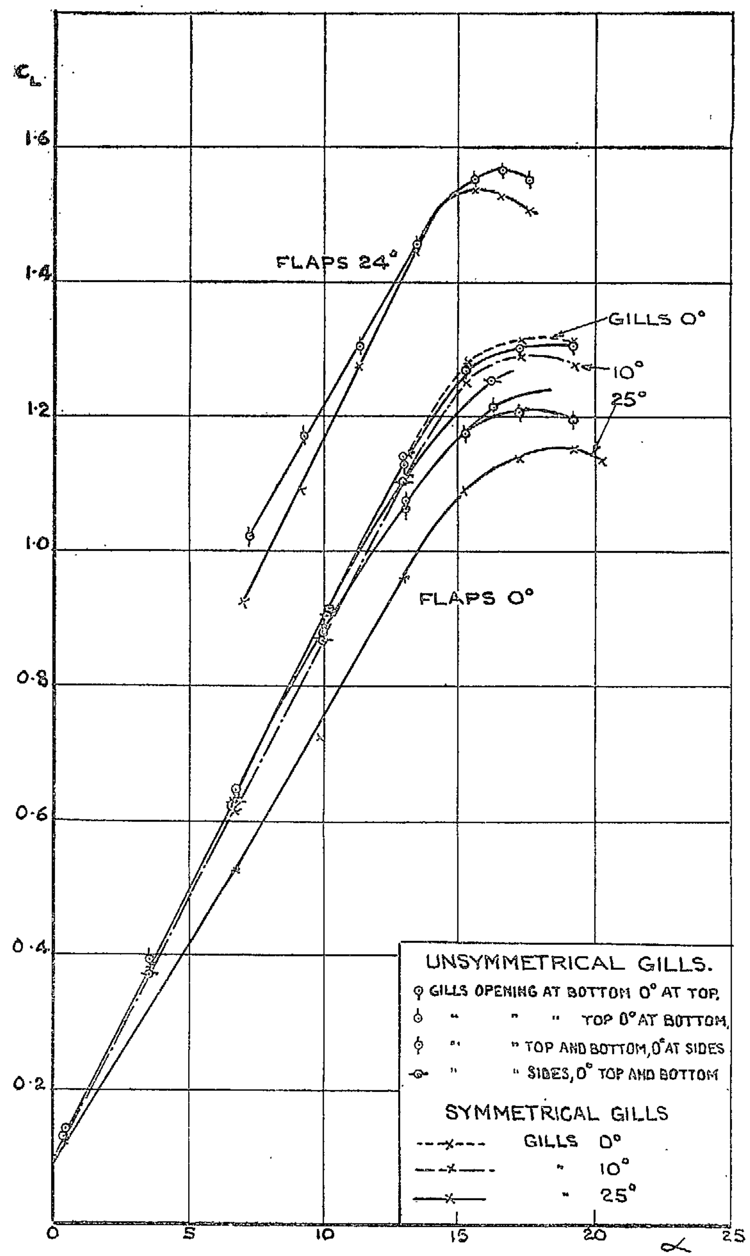



FIG. 7. Lift Coefficients—Effect of Unsymmetrical Gills, Low Baffle.

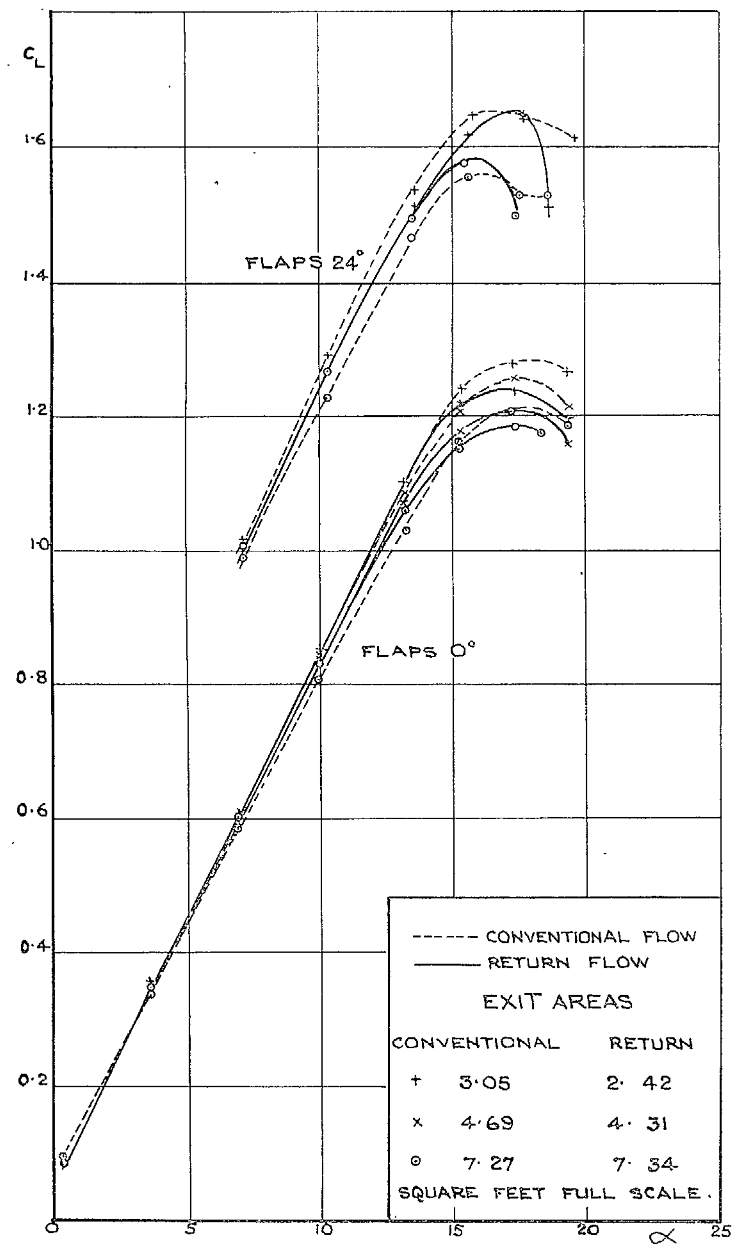



FIG. 8. Lift Coefficients—Comparison with Return-flow Cowl, Medium Baffle.

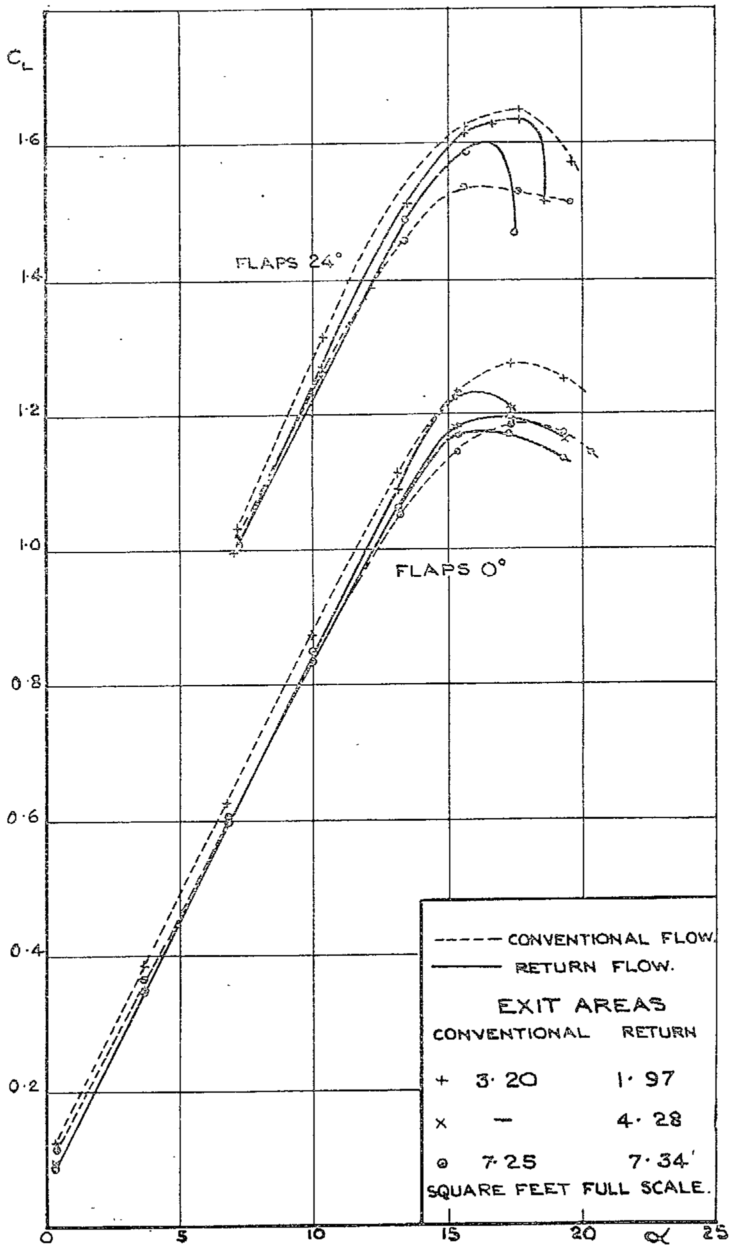



FIG. 9. Lift Coefficients—Comparison with Return-flow Cowl, High Baffle.

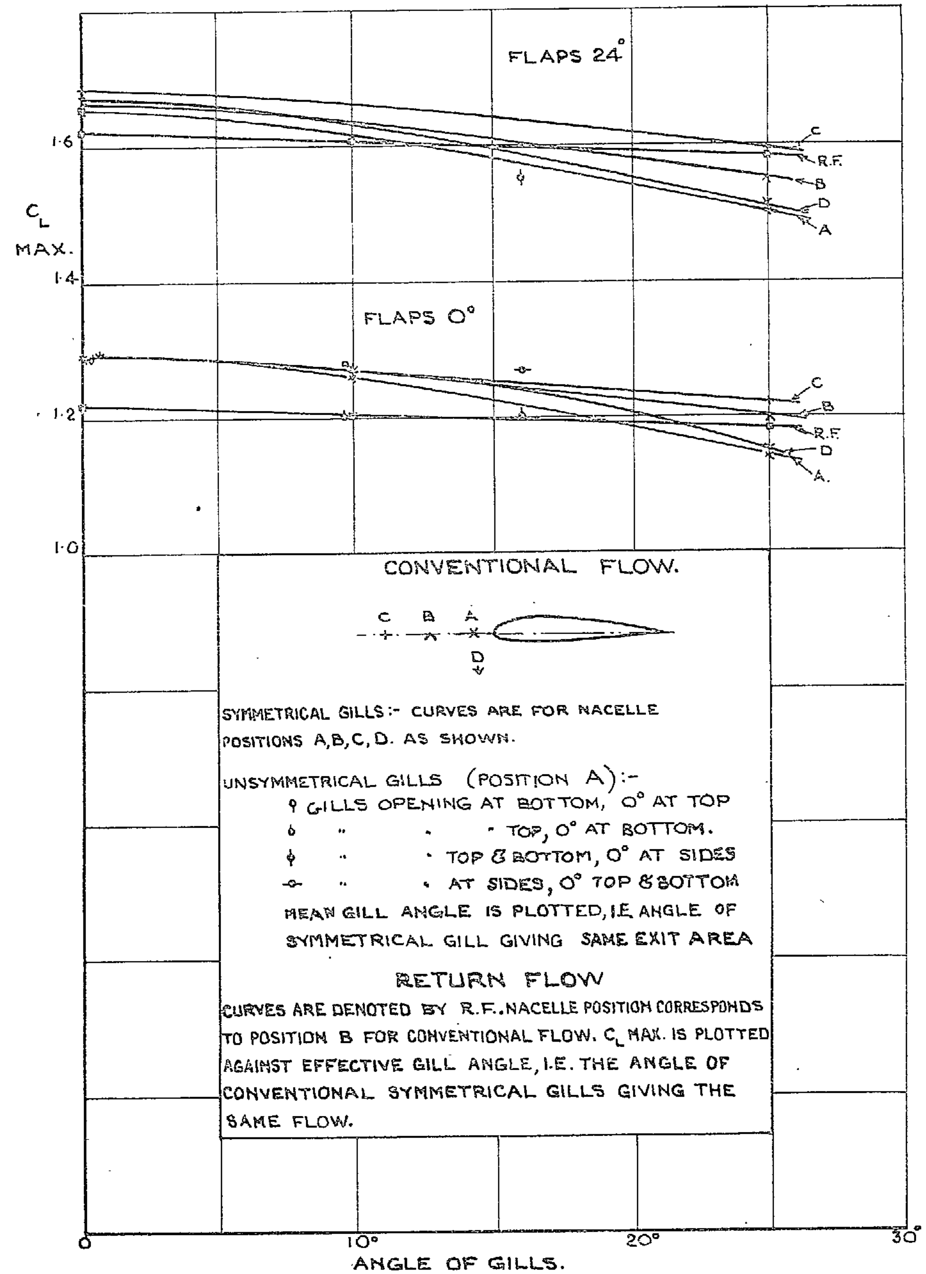



FIG. 10. Effect of Gill Angle and of Nacelle Position on Maximum $C_L$.

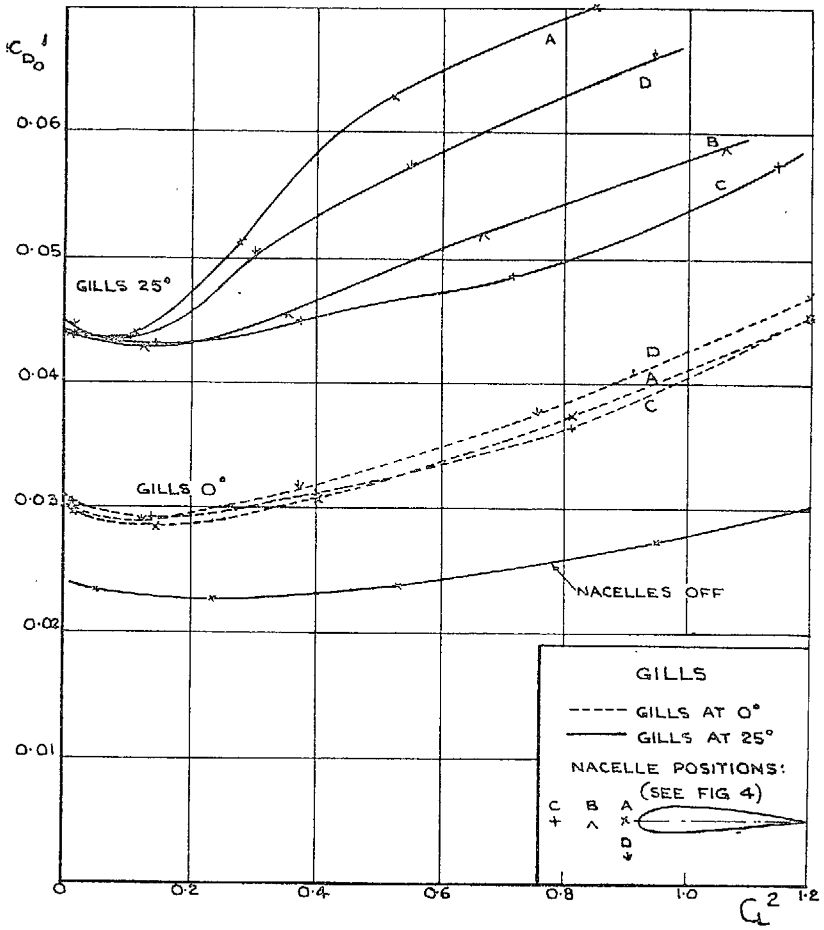



Fig. 11. Profile-drag Coefficients—Effect of Gills and of Nacelle Position, Low Baffle.

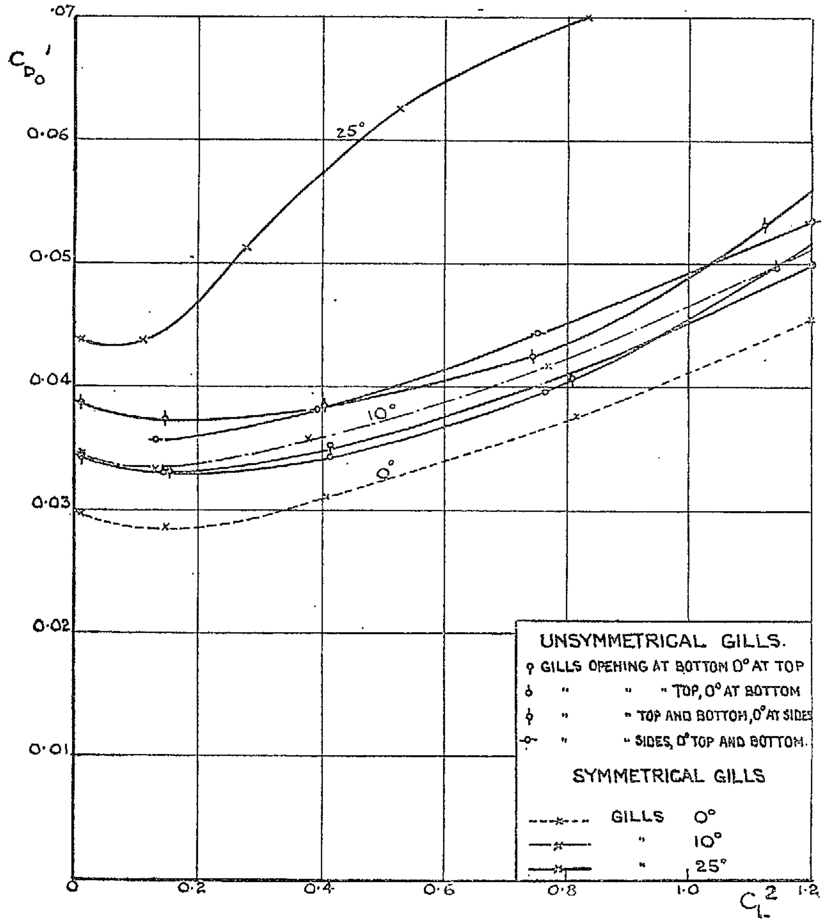



Fig. 12. Profile-drag Coefficients—Effect of Unsymmetrical Gills, Low Baffle.

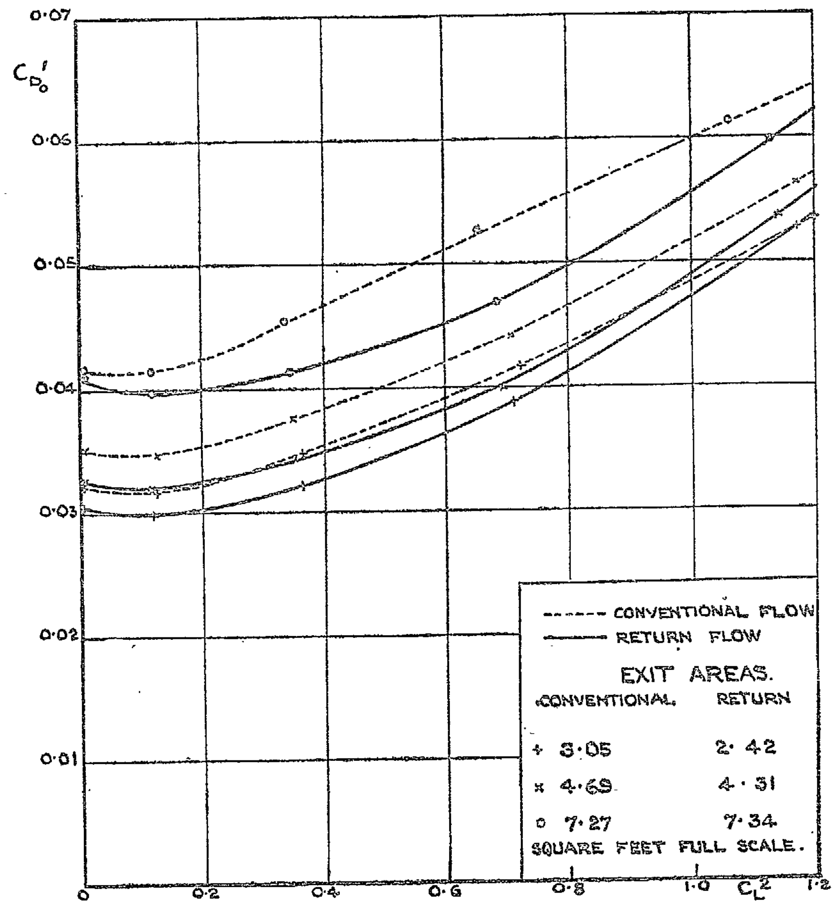



FIG. 13. Profile-drag Coefficients—Comparison with Return-flow Cowl, Medium Baffle.

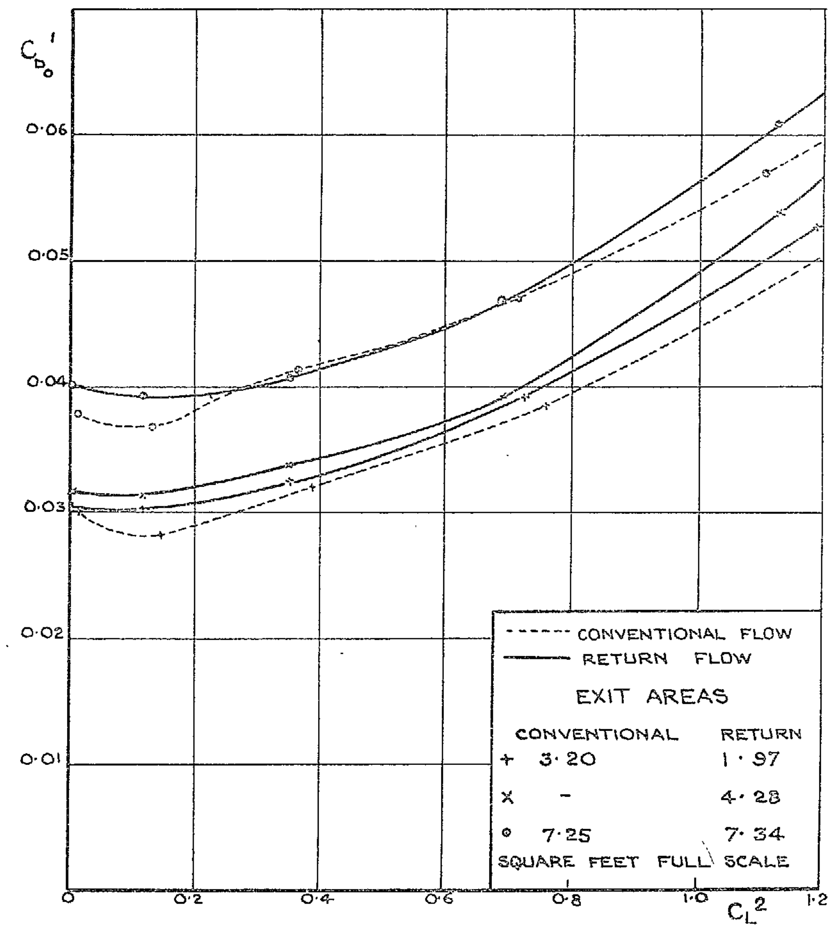



FIG. 14. Profile-drag Coefficients—Comparison with Return-flow Cowl, High Baffle.

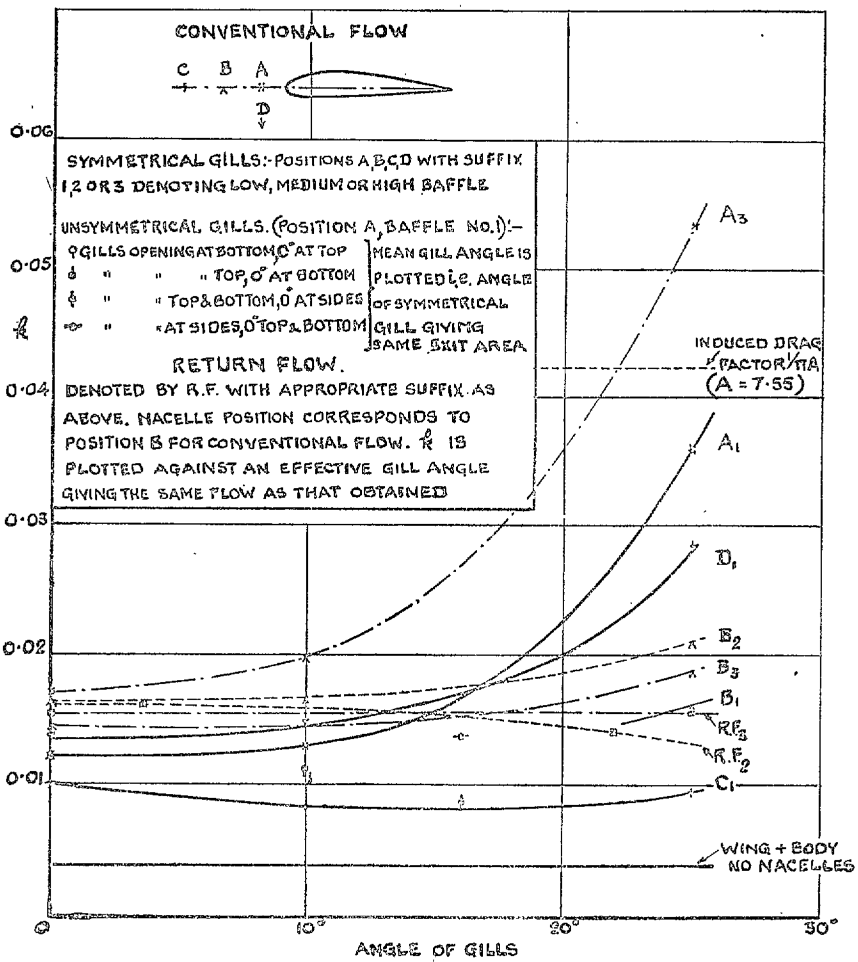



FIG. 15. Effect of Gill Angle and of Nacelle Position on $k$.

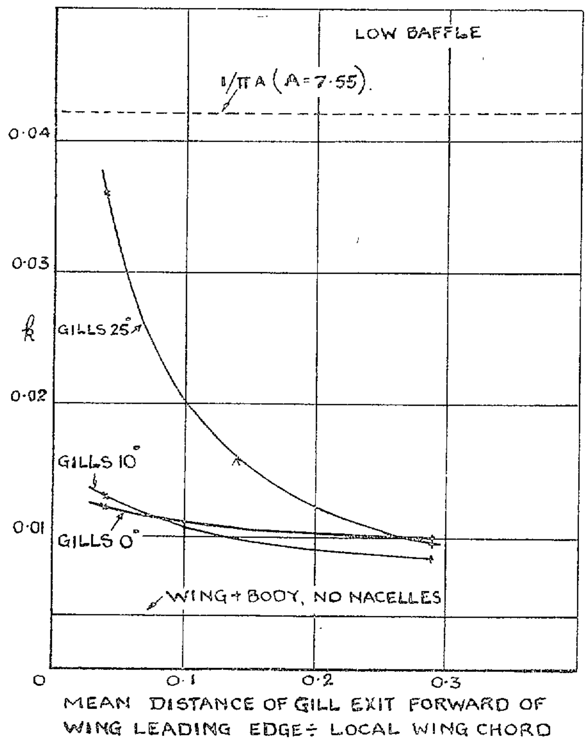
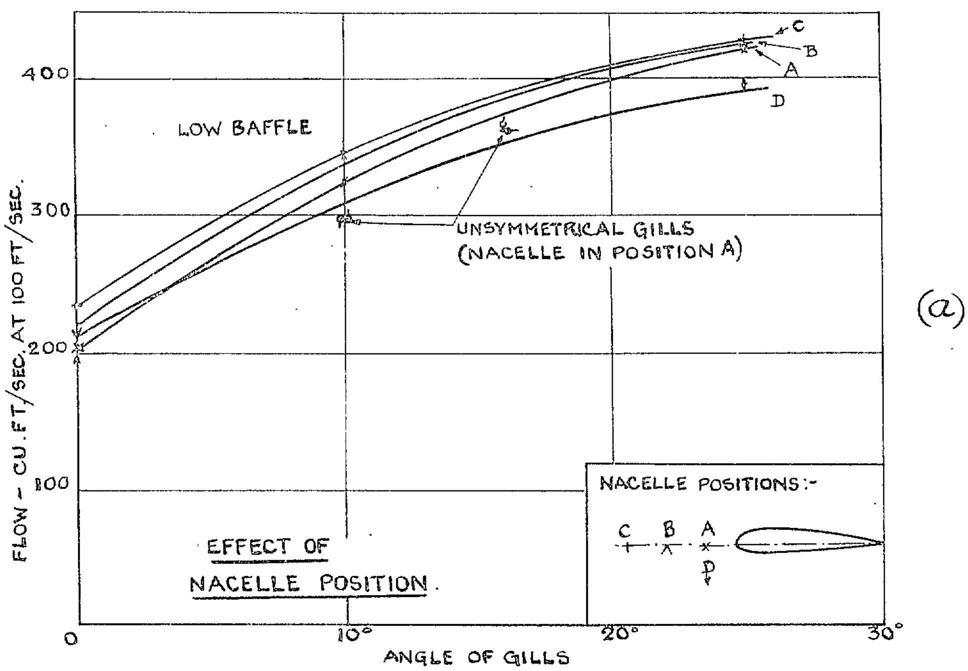



FIG. 16. Effect of Nacelle Fore-and-aft Position on $k$.



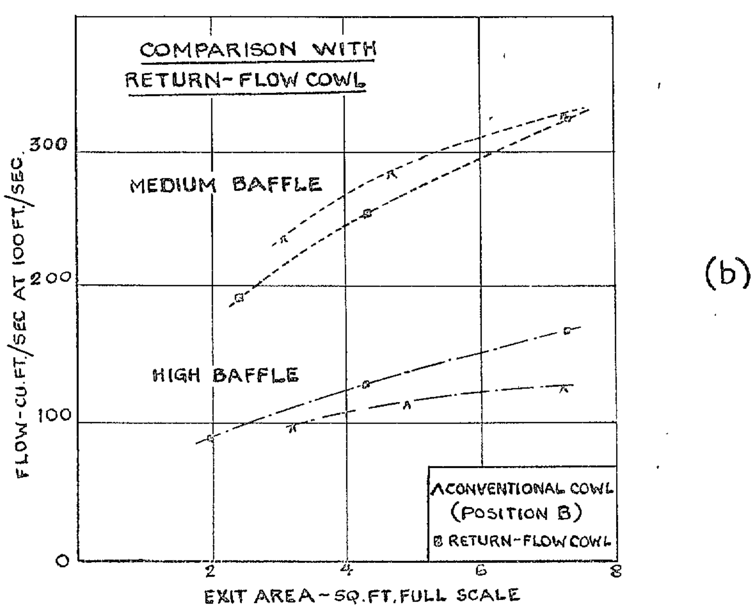




FIG. 17. Flow Pictures.



(93007) Wt. 13/806 K.5 2/52 Hw. PRINTED IN GREAT BRITAIN

R. & M. No. 2558
(5659)
A.R.C. Technical Report

# Publications of the Aeronautical Research Council

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

1934–35 Vol. I. Aerodynamics. *Out of print.*
Vol. II. Seaplanes, Structures, Engines, Materials, etc. 40*s.* (40*s.* 8*d.*)

1935–36 Vol. I. Aerodynamics. 30*s.* (30*s.* 7*d.*)
Vol. II. Structures, Flutter, Engines, Seaplanes, etc. 30*s.* (30*s.* 7*d.*)

1936 Vol. I. Aerodynamics General, Performance, Airscrews, Flutter and Spinning. 40*s.* (40*s.* 9*d.*)
Vol. II. Stability and Control, Structures, Seaplanes, Engines, etc. 50*s.* (50*s.* 10*d.*)

1937 Vol. I. Aerodynamics General, Performance, Airscrews, Flutter and Spinning. 40*s.* (40*s.* 10*d.*)
Vol. II. Stability and Control, Structures, Seaplanes, Engines, etc. 60*s.* (61*s.*)

1938 Vol. I. Aerodynamics General, Performance, Airscrews. 50*s.* (51*s.*)
Vol. II. Stability and Control, Flutter, Structures, Seaplanes, Wind Tunnels, Materials. 30*s.* (30*s.* 9*d.*)

1939 Vol. I. Aerodynamics General, Performance, Airscrews, Engines. 50*s.* (50*s.* 11*d.*)
Vol. II. Stability and Control, Flutter and Vibration, Instruments, Structures, Seaplanes, etc. 63*s.* (64*s.* 2*d.*)

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

*Certain other reports proper to the 1940 volume will subsequently be included in a separate volume.*

ANNUAL REPORTS OF THE AERONAUTICAL RESEARCH COUNCIL—

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

INDEX TO ALL REPORTS AND MEMORANDA PUBLISHED IN THE ANNUAL TECHNICAL REPORTS, AND SEPARATELY—

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

INDEXES TO THE TECHNICAL REPORTS OF THE AERONAUTICAL RESEARCH COUNCIL—

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

*Prices in brackets include postage.*

Obtainable from

## HER MAJESTY'S STATIONERY OFFICE

York House, Kingsway, LONDON, W.C.2 429 Oxford Street, LONDON, W.1
P.O. Box 569, LONDON, S.E.1
13a Castle Street, EDINBURGH, 2 1 St. Andrew's Crescent, CARDIFF
39 King Street, MANCHESTER, 2 Tower Lane, BRISTOL, 1
2 Edmund Street, BIRMINGHAM, 3 80 Chichester Street, BELFAST

or through any bookseller.

S.O. Code No. 23-2558