A Method for the Determination of the Effect of Propeller Slipstream on the Static Longitudinal Stability and Control of Multi-engined Aircraft

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This report consists basically of two parts. The first part, the main body and Appendix I to V were originally published as paper 7.3.4 in the Proceedings of the 19th Congress of the International Council of the Aeronautical Sciences, ICAS held in Anaheim, Cal. USA on 18-23 September, 1994.

The second and the largest part of this report consists of Appendix VI to XVIII. In these appendices the various subjects mentioned in the original publication are covered in much greater depth. Many more aircraft configurations are analysed by means of computations compared with test data and all calculation procedures are explained via step-by-step calculations for specific examples.
The effect of propeller slipstream on the static longitudinal stability and control of multi-engined propeller aircraft.

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1. Abstract

A method is presented for the determination of slipstream effects on static longitudinal stability and control of multi-engined propeller aircraft. The method is partly based on elementary momentum considerations partly on a correlation of windtunnel data. The method allows the determination of:

- The increase in lift due to propeller slipstream.
- The change in tail-off pitching moment, both with flaps retracted and deflected.
- The location of the propeller slipstream relative to the horizontal tailplane and the associated effect on average dynamic pressure at the tailplane.
- The change in average downwash angle due to slipstream at the tailplane.

For a number of aircraft configurations a comparison is shown between calculated results and windtunnel data.

2. Notation

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Unit</th>
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<tbody>
<tr>
<td>$A_s$</td>
<td>Aspect ratio of wing part immersed in the slipstream of a single propeller.</td>
<td>(-)</td>
</tr>
<tr>
<td>$A_{s,eff}$</td>
<td>Effective aspect ratio of wing part immersed in the slipstream of a single propeller at low thrust coefficients.</td>
<td>(-)</td>
</tr>
<tr>
<td>$A_v$</td>
<td>Total cross-sectional area of the combined fully contracted slipstream tubes:</td>
<td>(m$^2$)</td>
</tr>
<tr>
<td>$A_w$</td>
<td>Wing aspect ratio ($A_w = b^2/S_w$)</td>
<td>(-)</td>
</tr>
<tr>
<td>$A'$</td>
<td>Cross-sectional area of the part of the outer flow stream tube affected by the slipstream (see Appendix IV).</td>
<td>(m$^2$)</td>
</tr>
<tr>
<td>$A_{2,eff}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$C_{L}^{\text{p}}$</td>
<td>Power-off lift coefficient.</td>
<td>(-)</td>
</tr>
<tr>
<td>$C_{L,\text{sl}}$</td>
<td>Lift coefficient due to slipstream deflection by the wing.</td>
<td>(-)</td>
</tr>
<tr>
<td>$C_{L,\text{lo}}$</td>
<td>Lift coefficient due to slipstream deflection by the wing at the zero-lift angle for the wing with flaps retracted. (See fig. 20).</td>
<td>(-)</td>
</tr>
<tr>
<td>$C_{L,\text{lo}}$</td>
<td>Lift coefficient due to slipstream deflection at a given angle-of-attack.</td>
<td>(-)</td>
</tr>
<tr>
<td>$C_{T}$</td>
<td>Local lift coefficient at the propeller axis location in the absence of slipstream.</td>
<td>(-)</td>
</tr>
<tr>
<td>$C_{T,v}$</td>
<td>Vertical component of total thrust coefficient.</td>
<td>(-)</td>
</tr>
</tbody>
</table>
$C_{L_{ws}}$  Total wing lift coefficient in the presence of slipstream.

$C_{L_{w}}$  Wing lift curve slope.

$C_{L_{ba}}$  Horizontal tailplane lift curve slope.

$C_{L_{a}}$  Lift curve slope of a wing in free air with aspect ratio $A_g$.

$C_{L_{a_{eff}}}$  Lift curve slope of a wing in free air with aspect ratio $A_{a_{eff}}$.

$C_{l_{a}}$  Airfoil section lift curve slope.

$C_{l_{a_{a}}}$  Airfoil section lift curve slope at the propeller axis location.

$C_{l_{a_{s}}}$  Airfoil section lift curve slope.

$C_{M}$  Pitching moment coefficient.

$C_{w} = \frac{M}{\frac{1}{2} \rho V_0^2 S_w}$

$\Delta C_{MPS}$  Additional pitching moment contribution to the calculated pitching moment due to slipstream $C_{M}$ to improve comparison with test data.

$C_{m_{0,s}}$  Zero-lift pitching moment coefficient of the wing section at the propeller axis location.

$c'_{i_{0.25e}}$  Airfoil pitching moment coefficient about the quarter-chord point referred to the extended section chord $c'$.

$\Delta C_{M}$  Pitching moment coefficient due to total propeller normal force.

$\Delta C_{M_s}$  Total pitching moment coefficient due to propeller forces and slipstream.

$c_{s}$  Wing section chord at propeller location.

$\Delta C_{M_T}$  Pitching moment coefficient due to total propeller thrust.

$C_T$  Thrust coefficient.

$D$  Propeller diameter.

$D'$  Diameter of fully contracted slipstream.

$\Delta h'$  The (assumed) vertical displacement of the slipstream centre line due to the propeller axis at the propeller plane not coinciding with the streamline leading to the forward stagnation point.

$h_{oa}$  Total distance in the Z-direction between slipstream centreline and horizontal tailplane.

$\Delta h_{t}$  Vertical displacement due to angle-of-attack of the quarterchord point of the tailplane section at the propeller location.

$h_{s}$  Vertical distance between the tailplane section at the propeller location and the propeller axis.

$(\Delta h)_{apw}$  Vertical displacement of slipstream centre line due to upwash in front of the wing due to flap deflection.

$(\Delta h)_{ap}$  Vertical displacement of slipstream centre line due to angle-of-attack.

$i_{a}$  Incidence of wing section chord at the propeller location.

$L_w$  Wing lift not affected by slipstream.

$L_s$  Wing lift due to slipstream.

$i_{s}$  Tail arm. (Measured between wing and tailplane quarter-mean-aerodynamic chord points).

$\Delta L$  Distance between wing trailing-edge and tailplane quarter-chord points at the propeller axis location.

$K_a$  Downwash factor, $(K_a = Z/Z_s)$.

$n_s$  Number of propellers.

$N_p$  Normal force of a single propeller.

$q$  Coefficient in downwash formula.

$q_a$  Average dynamic pressure at the horizontal tailplane.

$q_s$  $(= q_a)$ Average dynamic pressure in the fully contracted slipstream.

$S_b$  Horizontal tail area.

$S_s$  $(= S_{s,b})$. Area of horizontal tail surface immersed in the idealized slipstream.

$S_w$  Wing reference area.

$T_{ws}$  Total propeller thrust.

$\Delta V$  Increase in velocity in the fully contracted slipstream.

$V_0$  Velocity of undisturbed airflow.

$X$  Coordinate parallel to the fuselage reference line.

$X_{cg}$  Centre-of-gravity position along the X-axes.

$X_{sys \ell}$  Dimensionless distance over which the lift due to slipstream is assumed to be displaced to obtain calculated pitching moment data due to
slipstream with flaps deflected which match with test data. 

\( \alpha_{\text{eff}} \) Effective angle-of-attack of the wing part immersed in the propeller slipstream. 

\( \alpha_{\text{refl}} \) Angle of attack related to the fuselage reference line. 

\( \alpha_{s} \) Angle-of-attack of the wing part immersed in the propeller slipstream. 

\( \beta_{r} \) Downwash angle. 

\( \beta_{*} \) Estimated average downwash angle of the flow affected by slipstream. 

\( (\varepsilon_{d})_{\text{no}} \) The average downwash angle at the horizontal tailplane at zero lift in the power-off condition. 

\( \varepsilon \) Calculated downwash angle in the slipstream. 

\( \varepsilon_{\text{no}} \) Downwash angle at \( \alpha_{k} = 0 \) at the power-off condition. 

The increase in average downwash angle at the tail due to inflow into the slipstream when the slipstream velocity is twice the velocity of the undisturbed flow. 

Angle defined in Appendix IV. 

1: Wing taper ratio 

2: Parameter used in ref. 6 

\( \rho \) Air density. 

\( \sigma \) Parameter defined in Appendix II. 

\( \phi \) Slipstream turning angle. 

3. Introduction

The effect of propeller slipstream on the longitudinal characteristics of an aircraft has caught the attention of aircraft designers since the early days of aviation. In particular on multi-engined aircraft propeller slipstream often leads to a decrease in longitudinal stability and non-linear control characteristics when speed or power setting is varied. This may severely limit the allowable centre-of-gravity range in particular on high-performance aircraft. But most of all the unpredictability of slipstream effects is a matter of concern, in particular when no windtunnel data with powered propellers are available for the configuration under consideration. For preliminary design purposes open literature provides guidelines for the estimation of the effect of propeller slipstream on lift and drag. Tail-off pitching moments, in particular with flaps deflected, downwash at the tail and the location of the slipstream relative to the tail and consequently the average dynamic pressure at the tail with slipstream present are to the author's knowledge not covered in open literature. In the present paper a semi-empirical method is presented which allows the estimation of these parameters. With these data available a first-order estimate of the effect of propeller slipstream on longitudinal stability and control should be possible.

4. Historical Overview

In the '20's and '30's the analysis of propeller slipstream effects was mainly limited to gathering data collections from which some general trends were derived (refs. 1-3). Some relevant work was also performed on the analysis of the characteristics of a two-dimensional model wing placed in an open windtunnel test section. This resembled a wing partly immersed in a slipstream at very low flight speeds (refs. 4, 5).
The first systematic investigation concerning the increase in lift on a multi-engined aircraft due to propeller slipstream was performed by Smelt and Davies in 1936. This resulted in the classic semi-empirical method reported in ref. 6. No configurations with high-lift devices were considered. The method was primarily aimed at conditions with low thrust coefficients. The increase in lift due to slipstream was thought to be primarily caused by an increase in dynamic pressure of the flow about the part of the wing immersed in the slipstream. The downwash was not considered explicitly.

In the late 1930's and early 1940's efforts were made to describe slipstream effects with theoretical models. Numerical values for the required coefficients of proportionality could not be determined however (ref. 7-12). Also more testdata were published (refs. 13, 14).

With the increase in engine power in the 1940's the need for better insight in slipstream effects on aircraft characteristics lead to several systematic windtunnel investigations such as presented in refs. 15-17.

With the advent of the turbojet engine the interest in conventional propeller aircraft disappeared in the 1950's in particular from the research programme's of the large research institutes.

However, in the late 1950's and throughout the 1960’s extensive research into the feasibility of V/STOL-aircraft lead to a renewed interest in propellers (refs. 18-32). Because of the emphasis on V/STOL-characteristics most of the research was performed at very low speed (and thus very high thrust coefficients). Also, most configurations investigated (except those of refs. 33-37) had the greater part of the wing immersed in the propeller slipstream. Based on these latter investigations Kuhn (ref. 38,1959) developed a semi-empirical method which allows the estimation of the increase in lift due to propeller slipstream with flaps deflected and at very low flight speeds up to \( V = 0 \).

In ref. 39 some results are presented of the application of the method by Kuhn.

In refs. 40 and 41 more recent analyses are presented of the effect of slipstream on longitudinal characteristics.

Although two oil crises and the deregulation in the US and subsequent developments in airline operation renewed the interest in conventional propeller aircraft no method has been published since then which allows the analysis of the combined slipstream effects on longitudinal aircraft characteristics.

Numerous investigations were performed and reported on propellers and propeller-airframe interaction. These were however mainly aimed at obtaining better insight in

details of the flow and at the development of computer codes based on full-potential, Euler or Navier-Stokes flow equations. None of these studies produced results up to now which could be used to determine overall aircraft characteristics.

5. Some remarks on the methods by Smelt and Davies and Kuhn

As mentioned before the method by Smelt and Davies (ref. 6) has the following characteristics:

a. Only clean wings are considered.
b. Only low thrust coefficients are considered

c. The increase in lift due to slipstream can be written as (in the present report’s notation):

\[
\Delta C_{L} = \frac{D_s^* c_s}{\Sigma V \lambda V \left[ \lambda C_{L_{f}} - 0.6 C_{L_{p}} (\bar{\alpha} - \bar{\alpha}^*) \right]}
\]

In the first term between brackets \( \lambda \) is estimated for two extreme cases:

\( \lambda = 2 \) when the ratio between slipstream diameter and average chord of the part of the wing immersed in the slipstream is large. This leads effectively to the assumption that the spanwise lift distribution over this part of the wing can be treated as a two-dimensional flow problem.

\( \lambda = 1 \) when the ratio between slipstream diameter and average chord of the part of the wing in the slipstream is very small. The reasoning behind the latter is rather qualitative.

Comparison with windtunnel data lead to a correlation curve where \( \lambda \) varied between 1 and 1.8 as a function of the aspect ratio of the total part of the wing immersed in the combined slipstreams.

The second term between brackets takes into account the change in local angle-of-attack due to downwash behind the propeller(s). The factor 0.6 is an empirical constant.

Although for very low thrust coefficients the method by Smelt and Davies may in certain cases give reliable results many cases have been reported where the comparison between theory and testdata was unsatisfactory.

The method by Kuhn (ref. 38) approaches the problem from the other side. The starting point is the static condition \( (V_0 = 0) \) where the lift is entirely determined
by the propeller slipstream. Windtunnel test data show
that the slipstream momentum is effectively rotated over
an angle \( \theta \) by flap deflection. Although Kuhn suggests
that the degree of rotation is a function of the ratio of
flap chord and propeller diameter \( C/D \) the shape of the
resultant empirical curve is identical to the curve that
gives the ratio of lift curve slopes due to flap deflection
and change in angle of attack (see fig. 8). Furthermore a
thrust-recovery factor \( F_r \) is introduced to incorporate
viscous effects. (See fig. 1c, Appendix I).

Having established empirical relations between propeller
thrust and the total force on the wing-propeller(s)
combination as a function of angle-of-attack and flap
deflection for different flap types at static conditions
\( (V_0=0) \) Kuhn then proceeds in formulating a model for
the total lift on wing-propeller(s) combinations at low
flying speeds.

Basically it is assumed that the total lift on the wing is
determined by the vertical component of the outgoing
momentum of the stream tubes determined by the
propeller diameters and the wing span. The downwash
angle of the propeller slipstream behind the wing is
assumed to remain equal to the value found for static
conditions. Thus no effect of forward speed or thrust
coefficient is considered. The downwash angle of the
remaining stream tube determined by the wing span is
taken according to lifting line theory for the condition
with power off:

\[
\varepsilon = 57.3 \times \frac{2C_L}{\pi A_w} \quad \text{(deg)}
\]

As the slipstream turning angle \( \varepsilon \) is kept constant a
correction factor is added to obtain the correct power-off
lift when the thrust coefficient approaches \( C_T = 0 \) and
consequently the turning angle \( \varepsilon \) approaches the power-
off downwash angle \( \varepsilon \).

Also, a comparison with test data required the addition
of a multiplication factor \( K = 1.6 \) to the calculated extra
lift due to slipstream.

Thus, although the method by Kuhn allows the
estimation of lift due to propeller slipstream with flaps
deflected it shows much room for improvement in
particular at lower thrust coefficients.

6. Determination of the effect of propeller slipstream
on static longitudinal stability

When at constant speed propeller thrust is increased the
total flow condition about an aircraft changes.

Four elements can be distinguished.

1. The wing lift increases.
2. The tail-off pitching moment increases in a
   negative sense, in particular with flaps deflected.
3. The average downwash angle at the horizontal tail
   changes.
4. The average dynamic pressure at the horizontal tail
   changes if the tail is partly immersed in the
   slipstream.

6.1 The increase in wing lift due to propeller
slipstream

Two established methods have been mentioned for the
estimation of the increase in wing lift due to propeller
slipstream, the methods by Smelt and Davies (ref. 6)
and Kuhn (ref. 38).

In the following a method is presented which offers
certain improvements over the methods previously
described.

The basic concept is identical to that of the method of
ref. 38
The total lift is assumed to be the sum of the vertical
components of the outgoing momentum of the stream tubes
determined by the fully contracted propeller
slipstream and the stream tube determined by the wing
span. The cross-sectional area of this latter stream tube
is a circle determined by the wing span minus the total
cross-sectional area of the fully contracted propeller
slipstream. (Fig. 1).

According to lifting line theory (valid for high-aspect-
ratio wings) the turning angle of the stream tube
determined by the wing span is equal to the downwash
angle:

\[
\varepsilon = 57.3 \times \frac{2C_L}{\pi A_w} \quad \text{(deg.)}
\]

For very high lift this leads, when the same stream tube
analogy is used, to:

\[
\sin \varepsilon = \frac{2C_L}{\pi A_w}
\]

The lifting theory developed by R.T. Jones (ref. 42)
states that for very low aspect ratios \( (A \leq 1) \) the same
expression is valid. However, in this case the lift-curve
slope, when the wing aspect ratio approaches zero, can
be written as:

\[
C_{1w} = \frac{1}{57.3} \times \frac{\pi A_w}{2} \quad \text{(per deg.)}
\]

and
or, for very high angles-of-attack:

\[ C_L = \frac{\pi}{2} A_v \sin \alpha \]

Thus: \( \sin \epsilon = \sin \alpha \) and \( \epsilon = \alpha \)

Stepniewsky (ref. 44 page 13) suggested that at least for clean wings for higher thrust coefficients the increase in lift due to slipstream could be estimated by considering the flow of the slipstream over the wing to be equivalent to the flow about a wing in a free stream of which the span was equal to the diameter of the fully contracted slipstream and the chord equal to the actual wing's chord at the propeller axis.

The dynamic pressure to be considered is equal to the dynamic pressure in the slipstream and the angle of attack \( \alpha_s \) should be measured between the airfoil section's zero-lift angle-of-attack and the centre-line of the propeller slipstream. On a propeller at a given angle-of-attack the latter means that with increasing thrust coefficient the slipstream is deflected more downward and the angle-of-attack \( \alpha_s \) of the equivalent wing decreases.

The validity of this concept was first checked on the test data from ref. 28. In front of a wing, spanning the wind tunnel test section a propeller was fitted driven by an electric motor. The propeller and electric motor were mounted separately and were physically detached from the 2-d wing model. The model was constructed such that spanwise lift distribution could be measured directly. With the propeller in a fixed position the angle of attack of the model could be varied.

Because the model extended from wall to wall in the test section the "free-air" lift could not be determined on the basis of a stream tube being deflected over an angle \( \epsilon \). The downwash angle was taken as zero. Then the lift due to slipstream was taken as:

\[ L_s = \rho \left( V_c + \Delta V \right)^2 \frac{\pi}{4} D^2 \sin \epsilon_s \]

or

\[ L_s = \rho \left( V_c + \Delta V \right)^2 \frac{\pi}{4} D^2 \sin \alpha_s \]

as the propeller was fixed to the tunnel, \( \alpha_s = \alpha \)

The test data of ref. 28 and the calculated data obtained according to the procedure outlined above are presented in Appendix II and in fig. 11.

This comparison shows that the principle is proved although the effect of varying angle-of-attack is not incorporated in the calculation method. It is unclear if this is a viscous effect or if it is more fundamental.

The increase in lift due to slipstream was then calculated according to the method described for a number of aircraft configurations for which data were available.

Figs. 2-6 show measured and calculated lift curves at various thrust coefficients for some of the clean wing configurations analysed. Ref. 49 presents a more extensive overview.

Fig. 7 shows that in general a comparison between test data and calculated data for the increase in lift due to slipstream on wings without flaps shows satisfactory results and that no correction factors need be applied.

As mentioned before, in ref. 38 a relation is suggested for wings with flaps deflected between the slipstream turning angle \( \theta \) per degree of flap deflection at zero flight speed \( (9/8) \) and the ratio between flap chord and propeller diameter \( (c_f/D) \). This relation is, however, identical to the relation between the ratio of the slope of the lift curves due to flap deflection and due to change in angle-of-attack \( (C_{l_{flap}}/C_{l_{\alpha}}) \) as a function of flap-chord-to-section chord ratio (fig. 8). (In the test data considered the propeller diameter was roughly equal to the wing chord).

In the present analysis the latter relation is taken as more relevant. This allows the model previously described for plain wings to be extended to wings with flaps.

This is not strictly in line with a later extension of Jones's theory for small-aspect-ratio wings (ref. 42) which states that when the aspect ratio approaches zero the lift on a flapped wing is determined only by the inclination of the trailing edge of the camber line i.e. the sum of angle-of-attack and flap angle. The theory of ref. 43 was developed for small angles only however. Also the approach as described above produces data far more in line with experimental results.

Again it is assumed that the lift due to slipstream is equal to the lift on a wing in free flow with a span equal to the diameter of the fully contracted slipstream and an airfoil section equal to the wing section at the propeller axes with flaps deflected. The angle of attack \( \alpha_s \) is measured between the zero-lift angle-of-attack with flaps deflected and the effective propeller slipstream centre line.
In figs. 12-16 examples are presented of the lift curves for several aircraft configurations with flaps deflected and varying thrust coefficient.

In fig. 17 the measured and calculated increase in lift due to slipstream is compared for a number of aircraft configurations. Note that no correction factor is required in the calculation procedure.

More examples are presented in Appendix XI.

Up to now fairly high thrust coefficients have been considered. It will be clear that when the thrust coefficient approaches zero the assumption

$$\sin \alpha_s = \sin \alpha$$

can no longer be maintained.

Following the suggestion from ref. 44 to assume an arbitrary fairing function for the downwash angle $\alpha_s$ the (slightly modified) function from ref. 44 was adopted. Here the gradual change from $\alpha_s = \alpha_0$ to $\alpha$ was accomplished by considering an imaginary aspect ratio:

$$A_{\text{eff}} = A_0 + (A_0 - A_3) \left( \frac{V_0}{V_0 + \Delta V} \right)^{A_0 - A_3}$$

such that

$$\sin \alpha_s = \frac{2C_{\text{t}} \times \sin \alpha_0}{\pi A_{\text{eff}}}$$

where $C_{\text{t}}$ is related to $A_{\text{eff}}$.

A derivation of the formulae used in the calculations is presented in Appendix I.

In the method just described the lift due to slipstream has been compared to the lift of a wing with small aspect ratio.

In refs. 5, 28, 31 the lift due to slipstream at zero flight speed has been analysed both theoretically and experimentally. The results obtained in these investigations indicate that when zero flight speed is approached this assumption seems no longer to hold (figs. 9, 10). This is also suggested by the data of fig. 11 when $\sigma$ approaches 1 and thus $\alpha_0/\alpha_0$ approaches infinity. For practical values of the thrust coefficient the approach followed produces satisfactory results however.

In the foregoing it has been assumed that the vertical position of the propeller axis does not affect the lift due to slipstream. This assumption is valid when the propeller axis is not more than 0.5 propeller diameter above or below the wing chord (fig. 18). However, recent wind tunnel tests performed at the Delft University of Technology suggest that at more extreme positions large variations in lift can occur. This will be reported on in the near future. Some test data obtained in this investigation is presented in Appendix XVII.

6.2 Change in tail-off pitching moment due to propeller slipstream

For clean wings the effect of slipstream on the tail-off pitching moment of an aircraft is limited to a term:

$$C_{\mu, 0} = \frac{D' c_s}{S_w} \left( \frac{V_0}{V_0 + \Delta V} \right)^2$$

Wind tunnel tests show that on clean wings the additional lift due to slipstream applies at the quarter-chord point of the wing section at the propeller axis.

With flaps deflected the situation is different. Glaeuert has shown in ref. 45 (see also ref. 46, p. 215) a relation between the increase in lift due to flap deflection and the change in pitching moment at constant angle-of-attack (see fig. 19a). This relation derived for potential flow is valid for small flap angles only and can be approximated by the formula:

$$\left[ \frac{dC_{\text{t}}}{\theta_{\text{t}} - \theta} \right] = -0.25 + 0.32 \frac{c_f}{c}$$

where $c'_f$, $c'_t$, and $c'$ refer to the extended chord when flap deflection also leads to chord extension.

Numerous wind tunnel tests have shown that in viscous flow the pitching moment is more negative.

Good correlation with test data is obtained by the following modified formula (see fig. 19b):

$$\left[ \frac{dC_{\text{t}}}{\theta_{\text{t}} - \theta} \right] = \left( -0.25 + 0.32 \frac{c_f}{c'} \right)$$

where $c'_f$ and $c'$ refer to the extended chord when flap deflection also leads to chord extension.

In this formula the reference length $c'$ is the extended chord and the moment reference point is also referred to this extended chord. If the reference length is the chord of the airfoil section with flap retracted $c$ and the pitching moment is taken about the 0.25c-point this formula should be written as:

$$\left[ \frac{dC_{\text{t}}}{\theta_{\text{t}} - \theta} \right] = \left( -0.25 + 0.32 \frac{c_f}{c'} \right)$$

$$\times \left[ 1 + 0.2 \left( 1 - \sqrt{2} \sin \delta' \right) \right]$$

For a cambered airfoil this increase in pitching moment due to flap deflection and extension should be considered at the zero-lift angle-of-attack for the clean
airfoil in order to distinguish between flap effects and angle-off-attack effects.

In the present calculation procedure (fig. 20) for a tail-off aircraft configuration the zero-lift angle for this configuration is taken.

At other angles-of-attack an extra change in pitching moment occurs due to a change in lift. This extra lift is assumed to apply at 25 percent of the extended chord c'.

Thus:

\[ \left[ \frac{dc_{L,0}}{dc_{1}} \right]_{c'} = - \Delta C_{L} \times 0.25 \left( \frac{c'}{c} - 1 \right) \]

It is now assumed that the lift due to slipstream produces a change in pitching moment according to the same relation as apply to free stream conditions.

Thus:

\[ \left[ \frac{c_{L}}{c} \right]_{c'} = -0.25 \left( \frac{c'}{c} - 1 \right) \Delta C_{L_{0},o} \]

\[ \times 1 + 0.2 \left( \frac{c'}{c} - 1 \right) \Delta C_{L_{0},e} \]

If the moment reference centre differs from the quarter-chord point an extra change in pitching moment should be added:

\[ \Delta C_{L_{0}} = X_{cg} - X_{cg,0.25c} \times \Delta C_{L_{0},e} \]

Furthermore, both the direct thrust force and the propeller normal force produce pitching moment contributions:

\[ \Delta C_{T_{eff}} = - \frac{Z_p - 2X_{cg}}{c} \times C_{T_{eff}} \]

\[ \Delta C_{L_p} = \frac{X_{cg} - X_{L_{prop}}}{c} \times C_{L_{p}} \]

The determination of \( C_{L_{p}} \) is covered in ref. 24 (see also Appendix I).

Finally, a comparison was made between the sum of the pitching moment contributions described above and test data. The difference was assumed to be caused by a shift in the point of application of the wing lift due to slipstream.

\[ \Delta C_{L_{0}} = \left[ \frac{C_{L_{0}}}{c_{1}} - C_{L_{0},calc} \right] = - \frac{X_{PS}}{c} \Delta C_{L_{0},e} \]

\[ \Delta X_{PS}/c \] has been determined for a large number of configurations and test conditions. Fig. 21 shows representative examples and the curve faired through the data points. The curve adopted is:

\[ \frac{\Delta X_{PS}}{c} = 0.05 + 0.5 \left( \frac{c'}{c} - 1 \right) \]

The total change in pitching moment coefficient due to operating propellers on a tail-off aircraft configuration can then be described as:

\[ \frac{C_{L_{eff}}}{c} = \frac{c'}{c} \left[ -0.25 + 0.32 \frac{c'}{c} \right] \times \left[ 1 + 0.2 \left( \frac{c'}{c} - 1 \right) \right] \Delta C_{L_{0},o} \]

\[ + \left[ -0.25 \left( \frac{c'}{c} - 1 \right) + \frac{X_{cg} - X_{0.25c}}{c} \right] \Delta C_{L_{0},e} \]

\[ + \frac{X_{cg} - X_{L_{prop}}}{c} \times C_{L_{p}} = Z_p - Z_{cg} \times C_{T} \]

\[ - 0.05 + 0.5 \left( \frac{c'}{c} - 1 \right) \Delta C_{L_{0},e} \]

Examples of tail-off pitching moment curves for configurations with running propellers at different thrust coefficients, both as calculated and as obtained from windtunnel tests are presented in figs. 22-26. More examples are presented in Appendix XIV.

6.3 The vertical position of the slipstream centre lines

When lift due to slipstream was discussed in chapter 6.1 the average downwash angle for slipstream and the outer flow were assumed to have different values \( \epsilon_s \) and \( \epsilon \) with no interaction between the two flows.

Measured average downwash angles at tailplane locations sufficiently far above the propeller slipstream show however (to a first order) a unique linear relationship between average downwash angle and total lift coefficient.

Whether high lift is generated by a high angle-off-attack, a very efficient flap system or by propeller slipstream, roughly the same \( C_L \)-versus- \( \epsilon \) curve is found (see figs. 27, 28).

Apparantly, the interaction between slipstream and outer flow is such that, at least in the region of conventional horizontal tail surfaces slipstream and outer flow can be considered as if they produce the same average downwash angle in the part of the outer flow stream tube between the outboard edges of the propeller slipstream tubes.

As a check the following analysis was performed:
In fig. 29 a cross section of the idealised flow behind a wing with two propellers is shown. The flow is assumed to consist of two stream tubes defined by the fully contracted propeller slipstream and the outer flow stream tube. In Appendix IV the formulae used in the analysis have been derived.

It is now assumed that the vertical components of the outgoing momentum of the flow through area $A^*$ (with downwash angle $\varepsilon$) and of the slipstream with total area $A'_s = 2 \times \pi/4 D^2$ and downwash angle $\varepsilon_s$ can be combined into the vertical component of a total momentum with different velocities but a single downwash angle $\varepsilon'$.

\[
sin \varepsilon = \frac{p v_o^2 A' \sin \varepsilon + p (v_o + \Delta v)^2 A' \sin \varepsilon_s}{p v_o^2 A^* + p (v_o + \Delta v)^2 A'_s}
\]

With the above equation and some of the formulae from Appendix I the downwash angle $\varepsilon'$ has been calculated for a number of aircraft configurations. As an example $\varepsilon'$ versus $C_l$ for the configuration of ref. 36 with the flaps deflected to 60 deg and the ailerons to 30 deg for thrust coefficients $C_t = 0$ and $C_t = 2.15$ is presented in fig. 30.

Thus, the assumption that the average downwash far behind the wing is only dependent on the total lift coefficient, irrespective of the way this lift coefficient is achieved seems to hold.

In real flow the downwash angle, averaged over the tailplane's span is dependent on the height above the wing wake. Fig. 31 shows that:

\[
\tan \varepsilon = \frac{p C_l}{\pi A_w}
\]

where $P$ varies on average between 1.5 and 2.5. When it is assumed that this relation also applies with propeller slipstream present it follows that with engines mounted on the wing the centre line of the slipstream should show a downwash angle corresponding to a value for $P$ close to 2.5. Varying $P$ between 2.5 and 2.0 showed best correspondence with test values for $P = 2.2$.

So, far behind the wing the inclination of the slipstream centre line is:

\[
\varepsilon_s = 57.3 \times \frac{2.2}{\pi A_w} C_l
\]

In particular at high lift coefficients the wing wake is not flat but curved with a higher downwash angle near the wing trailing edge.

For a straight wing with $A_w = 8$ and taper ratio $\lambda = 0.3$ the flow field has been calculated for $C_l = 1.2$ and 3.

Fig. 32a shows the flow field for $C_l = 2$. The vertical displacement of the wake relative to the wing trailing edge $Z_w$ is clearly larger than $Z_w = h_k \sin \varepsilon$. The ratio $K_e = Z_{wd}/Z_e$ as a function of $l/h_k$ as derived from the analysis mentioned above is presented in fig. 32b. It is assumed to be valid for wing aspect ratio's $5 < A_w < 14$. Fig. 35 shows that $K_e = 1.5$ when $l/h_k = 3.0$ to $4.0$.

With the data from fig. 32b the slipstream centre line can be determined for clean wings when the propeller axis lies on or close to the streamline that leads to the forward stagnation point on the airfoil. The slipstream centre line coincides, in the present model, with the wing wake.

The vertical distance between the horizontal tail surface and the slipstream centre line is than the sum of the geometrical distance between the tail surface and the propeller axis ($h_t$) at zero angle-of-attack, the vertical displacement of the slipstream centre line (or wing wake) passing through (or assuming its origin at) the clean wing's trailing edge ($\Delta h_t$), and the vertical displacement of the horizontal tail due to angle of attack ($\Delta h_t$):

\[
h_t = h_{k} - Z_t
\]

\[
\Delta h_t = l_{w} \times \frac{C_l}{\pi A_w}
\]

\[
\Delta h_t = -l_{w} \times \frac{C_l}{\pi A_w}
\]

where $l_{w}$ = distance from wing quarter-chord point to tailplane quarter-chord point.

On most aircraft configurations the propeller axis is situated above or below the wing chord plane at a distance $Z_t$ and is located 0.50 $c_h$ to 1.00 $c_h$ in front of the wing. Also when the angle-of-attack increases the propeller centre line moves up. When flaps are deflected the streamline leading to the forward stagnation point moves down with respect to the propeller axis.

In all these cases the slipstream centre line will not coincide with the wing wake.
In the present analysis it is assumed that the slipstream centre line is off-set from the wing wake for a clean wing at the same CL over a constant distance $\Delta h^\prime$. This distance is the sum of (see fig. 33):

1. $(\Delta h)_{\alpha}$: The (upward) vertical displacement of the propeller disc centre due to angle-of-attack.

   $$(\Delta h)_{\alpha} = -(X_{0.25c} - X_{prop}) \sin \alpha_R$$

2. $(\Delta h)_{\beta_f}$: The (downward) vertical displacement of the wing trailing-edge when the flaps are deflected.

   $$(\Delta h)_{\beta_f} = c_f \times \sin \delta_f$$

3. $(\Delta h)_{upw}$: The (upward) vertical displacement due to flap deflection of the streamline running through the propeller disc centre between the propeller and the quarter-chord point on the airfoil.

   $$(\Delta h)_{upw} = +0.25[X_{0.25c} - X_{prop}] \sin \alpha_{o.l}$$

The coefficient 0.25 was chosen somewhat arbitrarily after regarding the streamline pattern about a number of airfoil configurations such as presented in fig. 33.

The vertical displacement of the wing trailing edge relative to the propeller due to angle-of-attack is assumed to be compensated by an increased upwash of the slipstream between the propeller and the airfoil quarter-chord point.

The total vertical displacement of the slipstream can be written as:

$$\Delta h^* = (\Delta h)_{\alpha} + (\Delta h)_{\beta_f} + (\Delta h)_{upw}$$

The total height of the horizontal tail surface above the slipstream centre line can then be written as:

$$h_{sec} = h_e + \Delta h^* + \Delta h^*_t$$

or:

$$h_{sec} = h_e + \Delta h^*$$

$$+ 1_h \int_{0}^{h_e} \left[ \frac{dc}{dc_e} \alpha_2 + K_t \frac{dc}{dc_{\alpha_2}} \Delta C_{\alpha_2} + K_t \epsilon_e = 0 \right]$$

$$- 1_h \int \alpha_R \left[ X_{0.25c} - X_{prop} \right] \sin \alpha_R$$

$$+ C_f \sin \delta_f + 0.25 \left[ X_{0.25c} - X_{prop} \right] \sin \alpha_{o.l}$$

6.4 The average dynamic pressure at the horizontal tailplane

A model has now been established for the propeller slipstream centre line shape and location. If it is assumed that the slipstream cross section remains circular with diameter $D'$ and that no mixing with the outer flow or deformation occurs the position of the propeller slipstream relative to the horizontal tail surface can then be determined.

It is further assumed that:

a. Slipstream rotation and resultant lateral translation of the slipstream can be neglected. Handed propellers are not considered.

b. On configurations with more than two engines (four or six) only the two inboard engines affect the flow over the tail.

The average dynamic pressure at the tail can now be determined as a function of the vertical distance between the tail surface and the slipstream centre line and of the ratio between slipstream diameter and tailspan.

As shown in Appendix III the average dynamic pressure can then be written as:

$$\frac{g_v}{\rho} = \left[ 1 + \left( \frac{\Delta V}{V_o} \right)^2 \right] = (1 + b)^2$$

$$= \left[ 1 + \left( \frac{V}{V_o} \right)^2 \frac{S_{h,2}}{S_h} \right] \frac{S_{h,2}}{S_h} - \frac{S_h}{S_{h,2}}$$

where:

$$S_{h,2} = \frac{2 \times C_S}{D'} \sqrt{1 - \frac{h_{sec}}{D' / 2}}$$

In ref. 16 a detailed windtunnel test programme is reported where on a four-engined aircraft model downwash and average dynamic pressure at the tail were investigated for a large number of tailplane positions relative to the wing both with single- and counter-rotating propellers and both with split flaps retracted and deflected 60 degrees.

For this configuration the slipstream location for the inboard engines and the average dynamic pressure at the tail has been determined according to the procedure indicated above for a thrust coefficient $T_c = 0.40$.

$\Delta V/V_o$ (= b) as a function of $h_{sec}/D'/2$ as calculated is shown as a dotted line in fig. 34.

Figure 34 also shows test data on $\Delta V/V_o$ as derived from ref. 16 again plotted versus the calculated relative slipstream centre line position. The test data substantiate the assumptions concerning the relative position of the slipstream centre line.
However the average dynamic pressure starts to increase at larger distances between tailplane and slipstream centre line than indicated by the dotted line. This indicates that the assumption that no mixing between slipstream and outer flow or that no deformation occurs does not hold. Mixing and possibly also deformation apparently does occur with consequently a widening of the slipstream.

As no other detailed analysis data is available the continuous curve as drawn in fig. 34 is assumed to apply for all conventional aircraft configurations. The curve is redrawn in fig. 35 in a generalised form.

As a further check on the validity of the procedure given above for the determination of the average dynamic pressure at the tail two further examples are presented.

In fig. 36 \( \sqrt{\frac{\rho_s}{\rho_0}} \) as calculated and measured is presented for the DHC-5 Caribon in the clean configuration. The testdata were taken from ref. 47.

In fig. 37 \( \sqrt{\frac{\rho_s}{\rho_0}} \) is presented for the Fokker 50 for three flap settings. The testdata were taken from unpublished windtunnel test data. Note how flap deflection lowers the position of the slipstream relative to the horizontal tailplane.

6.5 The average downwash angle at the horizontal tailplane

In chapter 6.3 (and figs. 27, 28) it was shown that, when the horizontal tailplane lies sufficiently far above the propeller slipstream for practical purposes a single linear relationship can be assumed between the average downwash angle \( \varepsilon \) of the horizontal tailplane and the lift-coefficient for the aircraft-less-tail. Whether a given high lift coefficient is generated through a high angle-of-attack without slipstream or at a lower angle-of-attack combined with propeller slipstream, the same average downwash angle \( \varepsilon \) occurs.

When the distance between slipstream centre line and tailplane becomes less than one nominal slipstream diameter \( D' \) this is no longer true however. In the mixing region on the boundary between slipstream and outer flow an inflow into the slipstream occurs which causes the average downwash to increase when the tailplane is located in that area. This is illustrated in fig. 38a to g. This inflow angle increases with increasing thrust coefficient. For the present analysis it has been assumed that \( \Delta \varepsilon \) is proportional to \( \Delta V/V_0 \).

A large amount of available test data has been analysed on this extra downwash angle \( \Delta \varepsilon \) above the increase in downwash directly related to the increase in wing lift due to slipstream.

When the testdata are normalised to a slipstream strength \( \Delta V/V_0=1 \) the data points are shown to lie in a fairly narrow band as is illustrated in fig. 39. Note that the datapoints are not only taken from ref. 16 but also from refs. 7,21,36 and other sources. The drawn line in fig. 39 repeated in fig. 40 is the curve adopted for use in the present method for the determination of the downwash at the tailplane in the presence of propeller slipstream.

The average downwash angle can then be written as:

\[
\varepsilon = (\varepsilon_o)_{P-O} + \left[ \frac{\Delta \varepsilon}{dC_{l-P}-dC_{l-P}} \right] \times C_{l,P-s} + (\Delta \varepsilon)_{\Delta V/V_0} \times \frac{\Delta V}{V_0}
\]

The distance between slipstream centre line and tailplane, required to determine \( (\Delta \varepsilon)_{\Delta V/V_0} \) is determined according to the procedure outlined in chapter 6.3.

Tail-on and tail-off windtunnel test data on the C-160 Transall with and without running propellers were analysed to compare downwash data as calculated according to the equation given above and as derived from the test data. The average dynamic pressure at the tail was calculated according to chapter 6.4.

The comparison is presented in fig. 41. The effect of the vertical displacement of the slipstream due to flap deflection and the associated effect on the average downwash at the tail is clearly reproduced in the calculation.

More testdata on downwash characteristics are presented in Appendix XVII and Appendix XVIII.

7. Two examples of the decrease in longitudinal stability due to slipstream

Finally, the method to determine the effect of propeller slipstream on static longitudinal stability as described in the present report has been applied to the aircraft configuration from refs. 36,37 with both flaps retracted and with flaps deflected 60 deg. and ailerons deflected 30 deg.

\( C_{\alpha} \)-versus-\( C_L \) curves for the tail-off and tail-on configurations are presented in figs. 42, 43. The tail-on curves were calculated according to the following equations valid for a given angle-of-attack.
\[ \alpha_s \text{ and thrust coefficient } C_T \text{ with horizontal tail setting } \alpha_h = 4.3 \text{ deg. and elevator in neutral position:} \]

\[ C_L = C_{L_{\text{ref}}} + C_{L_{\alpha}} \left[ \frac{1}{\alpha} \left( \frac{d\alpha}{da} \right) \right] \left[ \epsilon_{\alpha} + \epsilon_{\alpha - \epsilon_0} \right] \times \frac{S_h}{S} \frac{L_h}{C} \]

\[ C_{M_{\text{e}}} = C_{M_{\text{ref}}} \]

\[ -C_{M_{\alpha}} \left[ \left( 1 - \frac{d\alpha}{da} \right) \right] \left[ \epsilon_{\alpha} + \epsilon_{\alpha - \epsilon_0} \right] S_h \frac{S_b}{S} \frac{L_b}{C} \]

2. When figures 42 and 43 were prepared it was noticed that better agreement between calculated and test data was obtained when the pitching moment contribution from the fuselage due to the upwash in front of the wing was extended to the increase in lift due to slipstream. Then, at a given angle-of-attack the following pitching moment contribution has to be added to the pitching moment calculated with the formulae given in the main part of this paper:

\[ \Delta C_{M_{\text{e}}} = \Delta C_{L_{\alpha}} \times \frac{X_{\text{ac,fus}}}{C} \]

where \( \Delta X_{\text{ac,fus}} \) is the forward shift in aerodynamic centre due to the presence of the fuselage.

This subject is analysed in more detail in Appendix XV.

8. Conclusions

A method has been presented for the analysis of the effect of propeller slipstream on the static longitudinal stability and control of multi-engined aircraft. The method allows the determination of the increase in lift and the change in tail-off pitching moment due to slipstream, the location of the slipstream relative to the horizontal tailplane and the average downwash angle and dynamic pressure at the tailplane. A comparison of calculated and wind tunnel test data showed the method to be suitable for preliminary design purposes.

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References


2. Bradfield, F.B. et al.: Wind tunnel data on the effect of slipstream on the downwash and velocity at the tailplane, ARC R&M No. 1488, 1932.


12. Priestley, E.: A general treatment of static longitudinal stability with propellers, with application to single-engined aircraft, ARC R&M No. 2732, 1944


33. Fink, M.P.; Cocke, B.W. and Lipson, S.: A wind-tunnel investigation of a 0.4-scale model of an assault-transport airplane with boundary-layer control applied. NACA RM L55G26a, 1955.


Figure 1 - Lift generation concept.

Figure 2 - Lift curves. Configuration ref. 35 with clean wing.
Figure 3 - Lift curves. Configuration of ref. 36 with clean wing.
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Figure 38 - Increase in downwash at the tailplane due to inflow into the slipstream.
Fokker 50
$\delta_f = 26.5$ deg

$\kappa_R = 5$ deg

- No propellers
- $C_T = 0.165$
- $C_T = 0.326$
- $C_T = 0.554$
- $C_T = 0.815$

$C_{LT-O}$ does NOT include $C_{LT} = C_T \sin \kappa_R$

Figure 38 - Effect of the slipstream position on the average downwash angle at the horizontal tailplane.
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Appendix I

The total lift on a lifting surface with running propellers

According to lifting line theory the lift on a wing with elliptic lift distribution can be written as:

\[ L_w = \frac{\rho}{2} \pi b_w^2 \frac{V_o^2}{2} \sin \epsilon \]

where \( \epsilon \) is the average downwash of the flow over the wing infinitely far behind the wing. The flow can thus be considered as a stream tube with circular cross section and diameter \( b_w \) which is deflected downward over an angle \( \epsilon \). This model is now assumed to apply to any conventional wing shape.

The lift due to slipstream is also considered to be equal to the momentum resulting from the downward deflection over an angle \( \epsilon_s \) of each slipstream tube with fully contracted diameter \( D' \):

\[ L_s = n \rho \pi \frac{V_o + AV}{2} \sin \epsilon_s = n \rho \pi D' (V_o + AV)^2 \sin \epsilon_s \]

where:

\[ D' = D \sqrt{\frac{V_o + AV/2}{V_o + AV}} \]

The lift due to slipstream can then be written as:

\[ L_{w+} = \rho V_o^2 \left[ \frac{\pi}{4} b_w^2 - n \frac{\pi}{4} D'^2 \right] \sin \epsilon + \rho \frac{\pi}{4} D'^2 (V_o + AV)^2 \sin \epsilon_s \]

On a lifting wing with slipstream present the cross-sectional area from the slipstream tubes has to be subtracted from the cross-sectional area of the stream tube describing the outer flow (see fig. 1). The total wing lift then becomes:

\[ L_{w+} = \frac{1}{2} \frac{F}{\rho V_o^2 D_n} = \frac{2}{S_n} \left( \frac{\pi}{4} b_w^2 - n \frac{\pi}{4} D'^2 \right) \sin \epsilon + \frac{F}{2S_n} \frac{\pi}{2} D'^2 (V_o + AV)^2 \sin \epsilon_s \]

where the factor \( \frac{F}{T} \) is discussed at the end of this appendix.

When the propeller thrust is parallel to the fuselage reference line the total propeller thrust can be written as:

(see fig. 1a)
\[ T = C_l \frac{1}{2} \rho V_w^2 S_p \left( \frac{1}{m_p} \Delta V = V \left[ \cos \alpha_p + \frac{\Delta V}{2} \right] \frac{\pi}{4} D_2 \cos \alpha_s \Delta V \right) \]

and the downwash angle far behind the propeller: \( \epsilon_p = \alpha_s - \alpha^* \).

where \( \alpha^* = \arctg \frac{V_0 \sin \alpha_p}{V_0 \cos \alpha_p + \Delta V} \)

An extensive comparison between calculated and measured increase in lift due to slipstream showed a much better correlation when \( \alpha^* \) was written as:

\[ \alpha^* = \arctg \frac{V_0 \sin \alpha_p}{V_0 \cos \alpha_p + \Delta V/2} \]

This means the downwash behind the propeller is considered at the propeller disc. This definition of \( \alpha^* \) is used in all further calculations.

For the wing part covered by the slipstream the average effective angle-of-attack relative to the fuselage reference line is equal to \( \alpha^* \).

However the aerodynamic angle-of-attack measured from the zero-lift line is:

\[ \alpha_s = \alpha^* + i_e - \alpha_0 - \Delta \alpha_o, f \]

where: \( i_e = \) angle of incidence of the local wing chord relative to the fuselage reference line.

\( \alpha_0 = \) zero-lift angle-of-attack relative to the chord line of the airfoil section at the propeller axis location.

\( \Delta \alpha_o, f = \) change in zero-lift angle-of-attack due to flap deflection

\[ \Delta \alpha_o, f = - \frac{dc_l}{dc_i} \frac{\Delta \delta}{\Delta \alpha} \times \delta_{eff} \]

As discussed in the main text the lift due to slipstream is considered to be equal to the lift on a wing with aspect ratio \( A_{s,eff} \) in a free stream with velocity \( V = V_0 + \Delta V \).

\[ \sin \epsilon_s = \frac{2 C_{l,eff}}{\pi A_{s,eff}} \sin \alpha_s \]

If \( A_{s,eff} \leq 1.5 \) then \( A_{s,eff} = \pi/2 \times A_s \) and \( \sin \epsilon_s = \sin \alpha_s \)

Note that strictly speaking \( C_{l,s} \) should be determined as indicated in fig. 1b.
However for small values of $\alpha'=(\alpha-\alpha_0+\varepsilon/2)$ the difference between $R_s$ and $L_s$ can be neglected. In the examples presented in this paper and ref. 49 this difference has consistently been neglected. At very large angles-of-attack and very high $C_T$-values this may no longer be acceptable.

Kuhn has shown that at large flap deflections momentum losses occur in the slipstream, possibly due to viscous effects. Fig. 1c shows the curves adopted in the present method for the factor $F/T$ as a function of flap setting for various flap types to account for these momentum losses.

For the total increase in lift due to running propellers the vertical thrust component

$$L_T = C_T \frac{1}{2} \rho V_0^3 S_w \sin \alpha_R$$

and the total propeller normal force

$$L_P = C_{L_p} \frac{1}{2} \rho V_0^3 S_w$$

has to be added to the total wing lift. $C_{L_p}$ is determined according to the method presented in ref. 24.

![Diagram of $F/T$ vs turning angle for four propellers and two propellers with slotted flaps and plain flaps.](Image)
Appendix II

Estimation of the lift due to slipstream for the configuration analysed in ref. 28. (UTIA TN No 11)

In report UTIA TN No 11 a parameter $\sigma$ was defined:

$\sigma = \frac{\bar{\alpha}_{\text{jet}}}{\bar{\alpha}_{\text{o}}} - 1 \quad \text{where jet = slipstream}$

This can also be written as:

$\bar{\alpha}_{\text{jet}} = \frac{1 + \sigma}{1 - \sigma}$

For $\Delta V/V_o = 0$ the total lift can be written as $L_{\text{tot}} = L_w + L_s$.

Then: $\Delta L_s = [L_w + L_s] \frac{\Delta V}{V_o} - [L_w] \frac{\Delta V}{V_o} = 0$

With the equations from Appendix I this can be written as:

$\Delta L_s = \rho \frac{[V_o + \Delta V]^2}{4} \frac{\pi}{D^2} \sin \epsilon_s - \rho \frac{V_o^2}{4} \frac{\pi}{D^2} \sin \epsilon$

The thrust $T = \rho \frac{\pi}{4} D^2 [V_o + \Delta V] \Delta V$ and $\frac{\Delta L_s}{T} = \frac{[V_o + \Delta V]^2}{(V_o + \Delta V) \Delta V} \sin \epsilon_s - \frac{V_o^2}{(V_o + \Delta V) \Delta V} \sin \epsilon$

As the model under consideration is a 2-dim. model $\epsilon = 0$.

So: $\frac{\Delta L_s}{T} = \left( \frac{V_o}{\Delta V} + 1 \right) \sin \alpha$ and $\left( \frac{V_o}{\Delta V} + 1 \right) \sin \alpha = \frac{\Delta L_s}{T \sin \alpha}$

As $\frac{1 + \sigma}{1 - \sigma} = \frac{\bar{\alpha}_{\text{jet}}}{\bar{\alpha}_{\text{o}}} = \left[ \frac{V_o}{\Delta V} + 1 \right]$, a unique relation exists between $\sigma$, $V_o/\Delta V$ and $\frac{\Delta L_s}{T \sin \alpha}$.

In the following table some numerical values are presented:

<table>
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<tr>
<th>$\sigma$</th>
<th>$V_o/\Delta V$</th>
<th>$\frac{\Delta L_s}{T \sin \alpha}$</th>
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<tr>
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<td>2.410</td>
</tr>
<tr>
<td>0.26</td>
<td>3.289</td>
<td>4.289</td>
</tr>
</tbody>
</table>

A comparison between these calculated data and windtunnel test results is presented in figs. 11a, b.
Appendix III

The theoretical average dynamic pressure at the horizontal tail of multi-engined propeller aircraft

The effect of propeller slipstream on the theoretical average dynamic pressure at the tail $q_s$, is considered under the following assumptions:

1. The slipstream is fully contracted at the tail location.
2. The slipstream cross-section is circular with diameter $D^*$.

No mixing on the slipstream boundary occurs nor any deformation of the cross-section. The average dynamic pressure in the slipstream is:

$$q_s = \frac{1}{2} \rho V_o^2 \left[ 1 + \left( \frac{\Delta V}{V_o} \right)^2 \right]$$

The average dynamic pressure at the tailplane location is:

$$q_h = \frac{1}{2} \rho V_o^2 \left[ 1 + \left( \frac{\Delta V}{V_h} \right)^2 \right] = \frac{1}{2} \rho V_o^2 \left( 1 + b \right)^2$$

According to fig. III a the width of the tailplane part covered by the slipstream of a single propeller is:

$$b_s = 2 \sqrt{D^*} - h_{tot}$$

or:

$$b_s = D^* \sqrt{1 - \left( \frac{h_{tot}}{D^*/2} \right)^2}$$

The tail area covered by the slipstream of two propellers is:

$$S_s = 2 \times b_s \times c_s$$

The average dynamic pressure at the tail is then:

$$\frac{1}{2} \rho \left( 1 + b \right)^2 \frac{V_o^2}{V_h} = \frac{1}{2} \rho \left[ 1 + \left( \frac{\Delta V}{V_o} \right)^2 \right] \frac{V_o^2}{V_h} S_s + \frac{V_o^2}{V_h} \left[ S_h - S_s \right]$$

or:

$$\left( 1 + b \right)^2 = \left[ 1 + \left( \frac{\Delta V}{V_o} \right)^2 \right] \frac{S_s + \frac{S_h - S_s}{S_h}}{S_h}$$

Then:

$$b = \left[ 1 + \left( \frac{\Delta V}{V_o} \right)^2 \right] \frac{S_s + \frac{S_h - S_s}{S_h}}{S_h} - 1$$

and

$$b_{\text{max}} = \left[ 1 + \left( \frac{\Delta V}{V_o} \right)^2 \right] \frac{2 \times D^*_f \times c_s + \frac{S_h - 2 \times D^*_f \times c_s}{S_h}}{S_h} - 1$$

For the configuration from report ARC R&M No 2747 (ref. 16) $b$ has been calculated as a function of $h_{\text{tot}}/D^*_f$ for $C_T = 0.40$.  

III - 1
\[ \frac{\Delta V}{V_0} = 0.506; \quad D^* = 9.12; \quad S_k = 197.3 \text{ sq.}; \quad \sigma_p = 5.80 \]

The result is shown as the broken curve in fig. 34. This figure illustrates that the estimated location of the slipstream centre line is correct. Slipstream spread and deformation does occur however. The curve for b to be used in the method described in the present report is also indicated in fig. 34.
Appendix IV

The theoretical average downwash angle at the horizontal tailplane behind a wing with running propellers

It is assumed that the average downwash angle at the tail of a multi-engined propeller aircraft is determined by the combined effects of lift due to wing angle-of-attack and due to slipstream.

As before, the lift of a wing with slipstream is considered to be equivalent to the sum of the vertical components of the outgoing momentum of a stream tube determined by the wing span and of the stream tubes determined by the fully contracted propeller slipstream.

The cross-sectional area of the basic wing lift stream tube is then divided into a central part with area $A'$ determined by the outer edges of the two inboard fully contracted slipstream diameters and the two outer parts with total cross-sectional area $2A$.

These areas can be written as

$$2A = \left(\frac{a}{2} \frac{b_2^2}{4} - \frac{b_2}{2} \cos \theta \times J\right)$$

or

$$2A = 2 \frac{b_2^2}{4} \left[\frac{a}{2} \cos \theta (V_a + D^*/2)\right]$$

then

$$A = \frac{b_2}{2} \cos \theta \left[\frac{Y_a + D^*/2}{b_2/2}\right]$$

or

$$A = \frac{b_2}{4} [\theta - \sin \theta \cos \theta]$$

and

$$\theta = \arccos \left[\frac{Y_a + D^*/2}{b_2/2}\right]$$

The slipstream cross-sectional area is:

$$A' = n_2 \frac{\pi}{4} D'^4 = 2 \times \frac{\pi}{4} D'^4$$

Then:

$$A'^* = \frac{\pi}{4} b_2^2 - \frac{b_2^2}{4} (\theta - \sin \theta \cos \theta) - \frac{\pi}{2} D'^4$$

It is now assumed that the mutual interference between slipstream and outer flow results in the same average downwash angle for both slipstream and the central part of the outer flow with area $A'$ determined by the addition of both the vertical components of the outgoing momentum and of the mass flow of the three stream tubes with cross-sectional area's $A'$ and $A_2$.

So,

$$\sin^* e' = \frac{p V_0^2 A'^* \sin e + p (V_0 + \Delta V)^2 A_2 \sin e_2}{p V_0^2 A'^* + p (V_0 - \Delta V)^2 A_2}$$

For the configuration from report NASA TN D-25 (ref. 36) with flaps deflected 60 deg and ailerons to 30 deg the average downwash angle $e'$ was determined for both power-off conditions and for $C_T = 2.15$. With

IV - 1
The lift was calculated according to the method described in the main body of this paper. This lead to the following results:

\[
\begin{align*}
\alpha_k = 0 & : C_r = 0 & C_l = 2.75 ; \varepsilon = 10.2 \text{ deg} & \alpha_k = 8 \text{ deg} & : C_l = 3.35 ; \varepsilon = 12.5 \text{ deg} & C_r = 2.35 \\
\end{align*}
\]

In fig. 30 a comparison is shown between calculated and actual test data. The assumption that slipstream and outer flow have identical average downwash angles seems to hold.

Note that the decrease in average downwash at the horizontal tail location which occurs when the tail is moved further away from the wing-wake/slipstream centre line remains. This account for the difference in actual downwash angle obtained from theory and windtunnel tests.
Appendix V

NOTES

1. When the direct thrust contribution to the pitching moment $\Delta C_{D_T}$ is considered not the thrust coefficient $C_T$ but the effective thrust coefficient $C_{T_{\text{eff}}}$ has to be taken. $C_{T_{\text{eff}}}$ is defined as

$$C_{T_{\text{eff}}} = C_T - \Delta C_T$$

where $\Delta C_T$ is a measure for the increase in wing drag due to slipstream. On the basis of the data presented in refs. 33-37 and under the assumption that $\Delta C_T = \Delta C$ due to slipstream figure Va was prepared.

2. When figures 42 and 43 were prepared it was noticed that better agreement between calculated and test data was obtained when the pitching moment contribution from the fuselage due to the upwash in front of the wing was extended to the increase in lift due to slipstream. Then, at a given angle-of-attack the following pitching moment contribution has to be added to the pitching moment calculated with the formulae given in the main part of this paper:

$$\Delta C_m = \Delta C_{L_{\text{a}}} \times \frac{X_{ac_{\text{ fus}}} \cdot \Delta C}{C}$$

where $\Delta X_{ac_{\text{ fus}}} / C$ is the forward shift in aerodynamic centre due to the presence of the fuselage.

This subject is analysed in more detail in Appendix XV.

Figure Va

\[\text{Figure Va}\]
Appendix VI

Geometric characteristics

Table I contains all geometry data of the various aircraft configurations analysed as required for the calculation of lift, pitching moment, downwash and dynamic pressure at the tail.

On pages VIII-4 to VIII-17 plan views or three-view drawings are presented of all configurations analysed.
| No | Conf. | ref. | b_w | S_w | α_w | C_s | C_p/C | C_p/(deg) | D_t/π | D_t/C | D_t (deg) | D_t/C (deg) | α_p | α_p (deg) | D_t/π (deg) | D_t/C (deg) | α_p (deg) | α_p (deg) | α_p (deg) |
|----|-------|-----|-----|-----|-----|-----|-------|----------|-------|-------|-----------|----------|------|----------|------------|------------|---------|---------|---------|---------|
| 1  | NASA  | 56  | 13.72 | 19.09 | 9.86 | 1.62 | 0.250 | 1.00 | 4      | 1.454 | 147.84 | 6.65 | 7.5  | -1.0 | 0.52 | -20.8 | 0.39 |
| 2  | NASA  | 35  | 13.72 | 19.09 | 9.86 | 1.62 | 0.250 | 1.00 | 2      | 2.057 | 147.84 | 6.64 | 7.5  | -1.0 | 0.52 | -20.8 | 0.39 |
| 3  | NASA  | 34  | 13.72 | 19.09 | 9.86 | 1.62 | 0.250 | 1.00 | 2      | 2.057 | 147.84 | 6.64 | 7.5  | -1.0 | 0.52 | -20.8 | 0.39 |
| 4  | ARC R & M | 16  | 100 | 996.5 | 10 | 11.07 | 0 | 2      | 10.0 | 785.4 | 314.2 | 0  | -0.9 | 0.10 |
| 5  | NASA  | 3304| -   | 10.250 | 4.55 | 1.568 | 0 | -      | 2.00 | 36.659 | 6.28 | 0  | -0.0 | 0.10 |
| 6  | NASA  | 3303| -   | 0.840 | 5.42 | 0.534 | 0 | -      | 2.00 | 35.636 | 5.64 | 0  | -0.0 | 0.10 |
| 7  | NASA  | 4448| -   | 352.8 | 6.52 | 7.40 | 0 | -      | 2.00 | 35.305 | 10.05 | 0  | -2.5 | 0.10 |
| 8  | NASA  | 6383| -   | 329.0 | 5.71 | 3.80 | 0 | -      | 2.00 | 1475.3 | 155.8 | 0  | -2.5 | 0.10 |
| 9  | NAE Rep. | -   | 8470 | 4.72 | 18.0 | 0 | 0.30 | 1.00 | 2      | 24.0 | 5536.5 | 904.8 | 0  | -4.0 | 0.10 |
| 10 | NLR   | -   | 2.100 | 0.630 | 7.00 | 0.300 | 0 | 0.300 | 1.25 | 4      | 2.000 | 3.464 | 0.127 | 0.55 | -13.2 | 0.97 |
| 11 | Fokker| 0.3111 | 12.0 | 0.180 | 40 | 0.300 | 1.12 | 2      | 2.49 | 3.935 | 0.0935 | 3.4 | -3.0 | 0.56 | -22.4 | 0.95 |
| 12 | Fokker| 26.27 | 12.0 | 2.80 | 0 | 256.27 | 130 | 2      | 2.78 | 660.52 | 22.80 | 3.5 | -2.7 | 0.56 | -7.7 | 0.93 |
| 13 | C-160 | 4.435 | 12.0 | 0.254 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 14 | Brege| 120.00 | 12.0 | 4.00 | 50 | 0.33 | 1.122 | 2 | 4.88 | 1137.7 | 37.4 | 3.0 | -3.0 | 0.57 | -28.5 | 0.93 |
NASA TN D-25

Geometry of the model.

Dimensions in feet

NASA Memo 12-3-58A
NACA TN 4365

Geometry of the model.

Dimensions in feet
General arrangement of model, with low wing, 0-deg wing-body angle, tail arm (f).

Wing-body arrangements and tailplane heights. Flaps up.

ARC R&M No 2747
Plan and cross-sectional views of model. (All dimensions in inches.)

ALL DIMENSIONS IN INCHES
Three-view drawing of 1/5-scale model and table of geometric characteristics. All dimensions are in inches (centimeters) unless otherwise noted.
Three views of model; dimensions in feet.

Model geometry.
Three-view drawing; dimensions, m (ft).

Figure 2.- Model geometry.
Conventional view of wing-tip locations with indication of pressure tube locations.

NLR TR 77... C

MOZZLE

I. \( \alpha = 6^\circ \) \( h = 0 \)

II. \( \alpha = 0^\circ \) \( h = 0.03 \text{ m} \)

III. \( \alpha = 10^\circ \) \( h = 0 \)

Nacelle positions relative to the wing model.

VI - 10
Fokker F-27 Mk 200

Three-view drawing of the model with F 3 fuselage (DO).

Scale 1:10 Dimensions in mm.
Fokker F-27 development model

Side view of the model with stretched fuselage (A180) and position of the three horizontal tails F 1, h 120 and h 240.
Messung mit Turbulenzsieb

<table>
<thead>
<tr>
<th>Symbol</th>
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<th>HLW</th>
<th>cS</th>
<th>Re ( \cdot 10^6 )</th>
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<td>ohne</td>
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<td>-</td>
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<tr>
<td>▲</td>
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<td>ohne</td>
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<td>0,43</td>
</tr>
</tbody>
</table>

geometrische Daten:

- Flügel (bis Schnitt I: NACA 63A218)
  - \( F = 0,4435 \) (m²)
  - \( \lambda = 10 \)
  - \( \eta = 0,220 \) (m)
  - \( \xi_F = 2^\circ \) (Schnitt I)
  - \( \psi = 35^\circ \) (Trapezteil)

- Höhenleitwerk (NACA 23012, negative Wölbung)
  - \( F = 0,1114 \) (m²) ohne Rumpfanteil
  - \( \lambda = 4,8 \)
  - \( \xi_F = -1^\circ \) (Schnitt II)

Bericht: Einfluß des Schraubenstrahles auf Abwind und Staudruck am Ort des HLW und auf die HLW-Wirksamkeit der TRANSALL C-160
CONDITIONS DES ESSAIS.

Les essais ont été réalisés à la soufflerie BREGUET de Vélizy du 3/1/59 au 23/1/59 en ce qui concerne la première partie et du 16/12/59 au 5/2/60 pour le reste.

La première partie des essais a été faite sur balance à mét central 5 composantes (strain-gages) du type Lillenthal. Centrage de la maquette $X = 25.7 \text{ mm}$, $Z = 4.28 \text{ mm}$ au-dessus du BA de la corde du plan central. En ce qui concerne la deuxième partie des essais une balance 2 râts à 5 composantes (strain-gages), du type Eiffel a été spécialement conçu.

Centrage de la maquette : $X = 25 \text{ mm}$, $Z = 11 \text{ mm}$ au-dessus du BA de la corde du plan central.
Figure 1: Front Elevation of Twin-engined Monoplane.

Report ARC R&M No 2310
De Havilland DHC-4 Caribou
From: ARC R&M
No. 1735

FIG. 1.-Twin-Engined Model.

ARC R&M No. 1797
Appendix VII

Total Propeller Normal-Force Coefficient

The propeller normal force is determined according to the method presented in the USAF Datcom and in ref. 24.

In the present analysis non-linear effects due to \( \cos \alpha = 1 \) and \( \sin \alpha = \alpha \) are neglected.

Thus, the total propeller normal-force coefficient is:

\[
C_{N} = K \times C_{s,1} \left[ \frac{da_{10}}{d\alpha} (a_{n} - a_{c_{z,0}}) + a_{c_{z,0}} + i_{prop} \right] \frac{n_{e} D_{2,prop}^{2}}{S_{y}} \frac{1}{57.3}
\]

where:

\[
c_{s,1} = \frac{4.25 \sigma_{e}}{1 + 2 \sigma_{e}} \sin (\beta + 8) \left( 1 + \frac{3T_{c}}{8 \sqrt{\frac{2}{3} T_{c}}} \right) \text{ per rad.}
\]

for single-rotation propellers, and

\[
c_{s,1} = \frac{3.86 \sigma_{e}}{1 + \sigma_{e}} \sin (\beta + 14) \left( 1 + \frac{3T_{c}}{8 \sqrt{\frac{2}{3} T_{c}}} \right) \text{ per rad.}
\]

for counter-rotating propellers.

Furthermore:

The local angle-of-attack gradient is:

\[
\frac{da_{10}}{d\alpha} = \frac{2A_{w}}{9A_{w} 10} \left( \frac{1}{x_{c,75}} + \frac{1}{10} + \frac{1}{x_{r,75}} \frac{1}{10} \right) + \frac{1}{2} \left[ \left( \frac{R_{fus}}{y_{L,75}} \right)^{2} + \left( \frac{R_{fus}}{y_{R,75}} \right)^{2} \right]
\]

\[
a_{prop} = \frac{da_{10}}{d\alpha} (a_{n} - a_{c_{z,0}}) + a_{c_{z,0}} + i_{prop}
\]

Notation

- \( C_{N} \) = normal-force coefficient based on free-stream velocity and propeller disk area.
- \( \frac{N}{q_{\infty} S_{p}} \)
- \( i_{prop} \) = angle between propeller thrustline and fuselage reference line
\[ c, \text{ wing root chord, ft} \]
\[ D, \text{ propeller diameter, ft} \]
\[ N, \text{ propeller normal force, lb} \]
\[ n, \text{ number of propellers} \]
\[ q_{\infty}, \text{ free-stream dynamic pressure, lb/sq ft} \]
\[ R, \text{ propeller radius, ft} \]
\[ R_{\text{fus}}, \text{ maximum fuselage radius forward of propeller plane} \]
\[ r, \text{ radial distance to blade element, ft} \]
\[ S_p, \text{ propeller disk area, } \frac{\pi D^2}{4}, \text{ sq ft} \]
\[ T, \text{ propeller thrust, lb} \]
\[ T_2, \text{ thrust coefficient based on free-stream velocity and propeller disk area} \]
\[ x, \text{ longitudinal coordinate measured positive forward from wing leading edge, ft} \]
\[ y, \text{ lateral coordinate measured positive to right of plane of symmetry, ft} \]
\[ \Delta_s, \text{ lateral distance from thrust axis of one propeller blade to element of another, ft} \]
\[ \alpha, \text{ wing angle of attack measured from zero lift, deg} \]
\[ \alpha_{\infty}, \text{ inflow angle at propeller disk, deg} \]
\[ \beta, \text{ blade angle at .75R blade station, deg} \]
\[ \sigma, \text{ propeller solidity, ratio of blade element area to annulus area at .75R} \]
\[ \sigma_e, \text{ effective propeller solidity (propeller solidity based on average blade chord)} \]

Subscripts
\[ \alpha_{\infty}, \text{ differentiation with respect to inflow angle, } \alpha_{\infty} \]
\[ L_{.75}, \text{ left blade position at three-quarters radius point} \]
\[ R_{.75}, \text{ right blade position at three-quarters radius point} \]
\[ \text{fus}, \text{ fuselage} \]
\[ K = \frac{C_N (\alpha, J \cos \alpha)}{C_N (\alpha_0, J \cos \alpha) x (\alpha_R - \alpha_c = 0)} \]

For all configurations considered in the present report it has been assumed that \( K = 1 \) (\( \alpha_{prop} < 30 \) deg).

The actual values of the various parameters can be found in the columns in the tables with the encircled number (XY).

\( C_{p} \quad (37) \quad T_{c} \quad (24) \)

\( C_{N_{a1a}} \quad (25) \quad A_{w} \quad (3) \)

\( \frac{d a_{in}}{d a} \quad (35) \quad \frac{X_R}{C_r} = \frac{X_{rot}}{C_r} \quad (27) \quad (29) \)

\( \alpha_{a} \quad (19) \quad \frac{X_R}{C_r} = \frac{X_{rot}}{C_r} \quad (28) \quad (30) \)

\( \alpha_{c1a0} \quad (18) \quad \frac{R_{fuse}}{Y_L} = \frac{R_{fuse}}{Y_{in}} \quad (31) \quad (33) \)

\( j_{prop} \quad (20) \quad \frac{R_{fuse}}{Y_R} = \frac{R_{fuse}}{Y_{out}} \quad (32) \quad (34) \)

\( N_{c} \quad (8) \quad \alpha_{prop} \quad (36) \)

\( D_{prop} \quad (9) \)

\( S_{w} \quad (2) \)

\( \sigma \quad (22) \)

\( \beta \quad (23) \)

VII - 3
### Table II  Total Propeller Normal Force Coefficient $C_{lp}$

<table>
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<tr>
<th>No</th>
<th>Conf.</th>
<th>Ref.</th>
<th>$S_w$</th>
<th>$A_w$</th>
<th>$\delta_f$ (deg)</th>
<th>$\delta_{CI,0}$ (deg)</th>
<th>$\delta_{CR}$ (deg)</th>
<th>$\bar{d}_{prop}$</th>
<th>$n_{prop}$</th>
<th>$D_{prop}$</th>
<th>$n_{blades}$</th>
<th>$S_e$ (deg)</th>
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<td></td>
</tr>
</tbody>
</table>

**Example of calculating procedure**
| No. | Conf. | \( x_{in} \) | \( x_{out} \) | \( x_{in} \) | \( x_{out} \) | \( x_{in} \) | \( x_{out} \) | \( x_{in} \) | \( x_{out} \) | \( x_{in} \) | \( x_{out} \) | \( \alpha_{pmp} \) | \( \alpha_{pmp} \) | \( C_{L-P} \) | \( C_{F} \) | \( K_{R} \) | \( \delta_{p} \) |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1   | NASA | 0.59 | 0.61 | 0.61 | 0.63 | 0.71 | 0.38 | 0.32 | 0.23 | Inboard | 1.633 | 3.3 | 0.0042 | 0.0111 | 0.015 | 0.0 | 0 |
|     | TN D-25 | 0.59 | 0.61 | 0.61 | 0.63 | 0.71 | 0.38 | 0.32 | 0.23 | Outboard | 1.305 | 15.1 | 0.0167 | 0.0273 | 0.15 | 0.12 |
| 2   | NASA | 0.59 | 0.61 | 0.61 | 0.63 | 0.71 | 0.38 | 0.32 | 0.23 | Average | 1.471 | 3.3 | 0.0057 | 0.0262 | 0.15 | 0.12 |
|     | TN D-25 | 0.59 | 0.61 | 0.61 | 0.63 | 0.71 | 0.38 | 0.32 | 0.23 | Inboard | 1.471 | 20.3 | 0.035 | 0.0284 | 0.15 | 0.12 |
| 3   | NASA | 0.59 | 0.61 | 0.61 | 0.63 | 0.71 | 0.38 | 0.32 | 0.23 | Outboard | 1.471 | 20.3 | 0.0405 | 0.15 | 0.12 |
|     | TN D-25 | 0.59 | 0.61 | 0.61 | 0.63 | 0.71 | 0.38 | 0.32 | 0.23 | Average | 1.471 | 20.3 | 0.0405 | 0.15 | 0.12 |
| 4   | NASA | 0.59 | 0.61 | 0.61 | 0.63 | 0.71 | 0.38 | 0.32 | 0.23 | Inboard | 1.471 | 20.3 | 0.0405 | 0.15 | 0.12 |
|     | TN D-25 | 0.59 | 0.61 | 0.61 | 0.63 | 0.71 | 0.38 | 0.32 | 0.23 | Outboard | 1.471 | 20.3 | 0.0405 | 0.15 | 0.12 |
| 5   | NASA | 0.59 | 0.61 | 0.61 | 0.63 | 0.71 | 0.38 | 0.32 | 0.23 | Average | 1.471 | 20.3 | 0.0405 | 0.15 | 0.12 |
|     | TN D-25 | 0.59 | 0.61 | 0.61 | 0.63 | 0.71 | 0.38 | 0.32 | 0.23 | Inboard | 1.471 | 20.3 | 0.0405 | 0.15 | 0.12 |
| 6   | NASA | 0.59 | 0.61 | 0.61 | 0.63 | 0.71 | 0.38 | 0.32 | 0.23 | Outboard | 1.471 | 20.3 | 0.0405 | 0.15 | 0.12 |
|     | TN D-25 | 0.59 | 0.61 | 0.61 | 0.63 | 0.71 | 0.38 | 0.32 | 0.23 | Average | 1.471 | 20.3 | 0.0405 | 0.15 | 0.12 |

Table II: Total Propeller Normal Force Coefficient (Concluded)
Appendix VIII

Total tail-off lift coefficient

The following equations were used:

\[ C_{L_{\text{TOT}}} = C_{L_w} + C_{L_s} + C_{L_T} + C_{L_p} \]  (57)

where:

\[ \Delta C_{L_s} = C_{L_{\text{TOT}}} - C_{L_p} - C_{L_T} - C_{L_w} \]  (58)  (59)

\[ C_{L_w} = \frac{2}{S_w} \left( \frac{\pi b_w^2 - n_o \frac{\pi}{4} D^2}{2} \right) \sin \epsilon \]  (53)

\[ C_{L_s} = \frac{F}{T} n_o \frac{\pi}{2} D^2 \left( \frac{V_o + \Delta V}{V_o} \right)^2 \frac{1}{S_N} \sin \epsilon_s \]  (54)

or:

\[ C_{L_s} = A \sin \epsilon \text{ with } A = \frac{2}{S_w} \left( \frac{\pi b_w^2 - n_o \frac{\pi}{4} D^2}{2} \right) \]  (51)

\[ C_{L_s} = B \sin \epsilon_s \text{ with } B = \frac{F}{T} n_o \frac{\pi}{2} D^2 \left( \frac{V_o + \Delta V}{V_o} \right)^2 \]  (52)

\[ C_{L_T} = C_T \sin \alpha \]  (55)

\[ C_{L_p} \]  (56)  (37)

\[ \sin \epsilon = \frac{2C_L}{\pi A_w^\text{eff}} \]  (50)

\[ \sin \epsilon_s = \frac{2C_{L_s, \text{eff}}}{\pi A_s^\text{eff}} \times 57.3 \times \sin \alpha_s \]  (49)

\[ A_{\text{eff}} = A_s + (A_w - A_s) \left( \frac{V_o}{V_o + \Delta V} \right) (A_w - A_d) \]  (44)
\[ A_s = \frac{D^*}{C_s} \]  

\[ \alpha_s = \alpha^* + i_{cs} - \alpha_0 - \Delta \alpha_{o, r} \]  

\[ \alpha^* = \arctg \frac{V_0 \sin \alpha}{\frac{\Delta V}{2} + V_0 \cos \alpha} \]  

\[ \frac{\Delta V}{V_0} = \sqrt{1 + \frac{C_T}{\frac{n\pi}{4} D^2}} - 1 \]  

\[ D^* = D \sqrt{\frac{V_0 + \Delta V/2}{V_0 + \Delta V}} \]  

With:

\[ b_v \]  (1)

\[ c_{is, err} \]  

\[ \Delta \alpha_{o, r} \]  (15)

\[ \Delta \alpha_{o, r} = \frac{C_{is} \times \delta_x}{C_{is}} \]  (5)/(14)

\[ s_v \]  (2)

\[ A_v \]  (3)

\[ \Delta \alpha_{o, r} \]  (15)

\[ D = D_{prop} \]  (9)

\[ \frac{\pi D^2}{4} \]  (10)

\[ F/T \]  (16)

\[ \delta \]  (22)

\[ c_{is} \]  (12)

\[ \alpha_0 \]  (13)

\[ C_{is} \]  (26)

\[ C_{is, err} \]  (38)

\[ N_0 \]  (8)
For the determination of $C_{L_5,eff}$ (eq. (49))
use upper left figure. ($\lambda = 1.0$)
(a) \( \delta \) range from 0° to 10°.

(b) \( \delta \) range from 0° to 20°.

Variation of section flap effectiveness with flap chord ratio for true-airfoil-contour flaps without exposed overhang balance on a number of airfoil sections; gaps sealed; \( \zeta = 0 \).

\[ \text{Section flap effectiveness, } \frac{\Delta \alpha}{\Delta \alpha_0} \]

\[ \text{flap-chord ratio, } E \]
Variation of turning angle with the ratio of total flap chord to propeller diameter for various flap configurations in hovering out of ground-effect region.
Variation of the average thrust-recovery factor $F/T$ for various flap and propeller configurations in hovering out of ground-effect region.

From: NASA Memo 1-16-59A

- Dotted line: One propeller per semispan
- Solid line: Two propellers per semispan, overlapped
- Dashed line: Two propellers per semispan, not overlapped

**Graph:**

- Slotted flaps (Refs. 4, 5, and 10)
- Combination sliding-slotted flaps (Refs. 7 and 10)
- Plain flaps (Refs. 2, 8, and unpublished data)
Table III

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<td>-0.160</td>
<td>-0.011</td>
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<td>1.56</td>
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</tr>
</tbody>
</table>
From: NACA TN 4365

\( \theta_f = 40^\circ \text{deg} \); \( \alpha_a = 0 \)

\( C_{p1} - C_{p_a} = 0 \)

TWO propellers

Calculated

Estimated from tail-on wind-tunnel test data

<table>
<thead>
<tr>
<th>( \alpha_R ) (deg)</th>
<th>( \Delta C_l ) (tail removal)</th>
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<td>0</td>
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<td>12</td>
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Propellers off
Propellers off  
(Estimated) 

TWO propellers

Calculated

Wind tunnel test data

From: NACA TN 4365

δf = 40 deg; δa = 30 deg

Cqf = 0.0028; Ca = 0.0010

κR (deg)

VIII - 12
From: NACA TN 4365
\[ \delta_f = 60 \text{ deg} \quad \theta_a = 30 \text{ deg} \]
\[ C_{Tf} = 0.0028 \quad C_{Qa} = 0.0007 \]

Propellers off
(Estimated)

TWO propellers
Calculated

\[ \alpha_R (\text{deg}) \]
From: NACA TN 3304

\[ C_T \]

\[ \Delta \]

Calculated

\( \bullet \)\( \square \)\( \triangle \) - W.T. Test data

\( \Delta \)

TWO propellers

(ONE propeller on half model.)
From: NASA TN D-4448
Medium span wing

- Calculated
-- W.T. test data

Flaps retracted
No. slats
FOUR propellers

\[ C_T \]

\[ \alpha (\text{deg}) \]

VIII - 15
From NAE Report LR-501

-4.0
-1.0
 3.5
 3.0
 2.5
 2.0
 1.5
 1.0
 0.5

Calculated
OD --- Wind tunnel
Test data

Propellers off

TWO propellers
(One propeller on
halfmodel)

\[ \alpha_{p} \text{ (deg)} \]
From: NLR \[ \text{\ldots} \]
\[ \delta \rho = 0 \quad \alpha_j = 0 \]

FOUR (simulated) propellers
(Two "propellers" on halfmodel.)

\[ C_{LT} \]
\[ C_T \]
\[ \Delta V \]
\[ \frac{\Delta V}{V_0} = 2 \]
\[ \frac{\Delta V}{V_0} = 1 \]
\[ \frac{\Delta V}{V_0} = 0 \]

Calculated
Wind tunnel test data

\[ \alpha_r \text{ (deg)} \]
From: NLR TR 77...C

\( \Delta \phi = 30 \text{ deg} \)

\( i_0 = 0 \)

FOUR (simulated) propellers

(Two "propellers" on half-model)

\( \Delta V = 2 \)

\( \Delta V = 1 \)

\( \Delta V = 0 \)

Calculated

Wind tunnel test data
From: NLR TR 27...C

$\delta_p = 0 \quad L_{jet} = 10 \text{deg}$

3.0

FOUR (simulated) propellers.

CLT=0

(Two "propellers" on half model.)

2.5

$C_T$

2.0

2.42

1.5

1.0

0.81

0.5

$\alpha = 0$

$\alpha = 0$

$\alpha = 0$

$\alpha = 0$

$\alpha = 0$

$\alpha = 0$

$\alpha = 0$

$\alpha = 0$

$\alpha = 0$

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$\alpha = 0$

$\alpha = 0$

$\alpha = 0$
From NLR TR 77...C

\[ \delta_f = 30 \text{ deg} \]

\[ L_{\text{jet}} = 10 \text{ deg} \]

FOUR (simulated) propellers

(Two "propellers" on half model.)

--- Windtunnel test data

--- W.T. test

\[ \varepsilon_s = \alpha_s \cdot \varepsilon_s + \delta_f + \alpha \cdot L_{\text{jet}} \]

\[ \varepsilon_s = \alpha_s \cdot \varepsilon_s + \delta_f + \alpha \cdot L_{\text{jet}} \]
Fokker F-27

Model with increased rear fuselage

$C_T = 0.635$

$C_T = 0.843$

$C_T = 1.07$

$C_T = 1.40$

$C_T = 3.5$

$C_T = 3.6$

Lines for constant power

Propellers off

$\delta = 40^\circ$

- Calculated
- Wind tunnel test data

(Derived from tail-on data)

- $\kappa_w (\text{deg})$

$-12 -10 -8 -6 -4 -2 0 2 4 6 8 10 12$
- - Calculated
-- - Wind tunnel test data

Fokker 50 (DNW)
flaps retracted

$V_0 = 40 \text{ m/sec}$
-Calculated

- Windtunnel test data

\[ C_L = 0 \]

\[ C_T \]

Fokker 50 (DNW)

\[ \delta_f = 16.5 \text{ deg} \]

\[ V_0 = 40/38 \text{ m/sec} \]

\[ (\text{deg}) \]
Breguet 1150 Atlantique

Propellers off

$\delta_p = 50 \text{ deg}$

Flaps retracted

Wind tunnel test data

$\kappa_r$ (deg)
Appendix IX

Tail-off Pitching Moment Coefficient ($\delta \neq 0$)

The following equations were used:

\[ C_{Nt} = \Delta C_{Nt} \]

\[ C_{Nt} = C' \left( -0.25 + 0.32 \frac{C_F}{C'} \right) [1 + 0.2 (1 - \sqrt{2} \sin \delta)] \Delta C_{\alpha e} + 
\]

\[ + \left[ -0.25 \left( \frac{C'}{C} - 1 \right) + \frac{X_{CO} - X_{0.25CO}}{C} \right] \Delta C_{\alpha e} + 
\]

\[ + \frac{X_{CO} - X_{PROP}}{C} C_{Lp} - \frac{Z_r - Z_{CO}}{C} C_T \]

\[ - \left[ 0.05 + 0.5 \left( \frac{C'}{C} - 1 \right) \right] \Delta C_{\alpha e} \quad (74) \]

Or:

\[ C_{Nt} = E \Delta C - L_{5,e} + F \Delta C_{\alpha e} + G \times C_{Lp} \]

with:

\[ E = \frac{C'}{C} \left( -0.25 + 0.32 \frac{C_F}{C'} \right) [1 + 0.2 (1 - \sqrt{2} \sin \delta)] \quad (62) \]

\[ F = \left[ -0.25 \left( \frac{C'}{C} - 1 \right) + \frac{X_{CO} - 0.25}{C} \right] \quad (67) \]

\[ G = \frac{X_{CO} - X_{PROP}}{C} \quad (68) \]

\[ H = \frac{Z_r - Z_{CO}}{C} \quad (69) \]
\[ c_{N} = (c_{M})_{C_{T_0}} + c_{H_{T}} \]

(\( c_{N} = \Delta c_{H_{T}} \))

(78)

at constant \( \alpha \)

\[(c_{M})_{C_{T_0}} \quad (76)\]

\[ \frac{c'}{c} \quad (7) \]

\[ \frac{c'}{c'} \quad (61) \]

\[ \delta_{\ell} \quad (5) \]

\[ \Delta c_{l_{x}, o} \quad (64) \]

\[ \Delta c_{l_{x}, \alpha} \quad (65) \]

\[ \frac{x_{cc}}{c} \quad (66) \]

\[ c_{l_{T}} \quad (37) \]

\[ c_{T} \quad (26) \]

Encircled numbers (X Y) denote columns in tables where actual values are presented.
Comparison of five different single slotted flaps.
The lift and pitching moment increments at $\alpha = 0$.

<table>
<thead>
<tr>
<th>FLAP</th>
<th>( \frac{C}{C_0} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$\ldots$</td>
</tr>
<tr>
<td>2</td>
<td>$\ldots$</td>
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<tr>
<td>3</td>
<td>$\ldots$</td>
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<tr>
<td>4</td>
<td>$\ldots$</td>
</tr>
<tr>
<td>5</td>
<td>$\ldots$</td>
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Influence of the rear flap deflection of flap 3 on the lift and the pitching moment increment at $\alpha = 0$.

<table>
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<th>FLAP 3</th>
<th>( \frac{C}{C_0} )</th>
</tr>
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<tbody>
<tr>
<td>$\ldots$</td>
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</tr>
<tr>
<td>$\ldots$</td>
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</tr>
<tr>
<td>$\ldots$</td>
<td>$\ldots$</td>
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</tbody>
</table>

The influence of the vane angle ($\alpha$) of flap 5 on the lift and the pitching moment increments at $\alpha = 0$.

<table>
<thead>
<tr>
<th>FLAP 5</th>
<th>( \frac{C}{C_0} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\ldots$</td>
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</tr>
<tr>
<td>$\ldots$</td>
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</tr>
<tr>
<td>$\ldots$</td>
<td>$\ldots$</td>
</tr>
</tbody>
</table>

IX - 3
The influence of the vane deflection of flap 6 on the lift and the pitching moment increments at \( \alpha = 0 \).

\[
\left( \frac{\Delta C_l}{\Delta \alpha} \right)_{\alpha = 0}
\]

\[ \begin{array}{c|ccc}
\Delta \alpha & -0.10 & -0.15 & -0.20 \\
\hline
\Delta C_l & 0 & 0 & 0 \\
\end{array}
\]

The influence of the rear flap deflection of flap 7 on the lift and the pitching moment increments at \( \alpha = 0 \).

\[
\left( \frac{\Delta C_l}{\Delta \alpha} \right)_{\alpha = 0}
\]

\[ \begin{array}{c|ccc}
\Delta \alpha & -0.10 & -0.15 & -0.20 \\
\hline
\Delta C_l & 0 & 0 & 0 \\
\end{array}
\]
Dimensionless distance over which the lift due to slipstream has to be shifted rearwards to obtain calculated tail-off pitching moment data due to slipstream with flaps deflected which match with test data.
<table>
<thead>
<tr>
<th>No</th>
<th>Conf</th>
<th>$\alpha_p$</th>
<th>$\kappa_p$</th>
<th>$\Theta_T$</th>
<th>$\Delta C_{m_5}$</th>
<th>$\Delta C_{m_5}^C$</th>
<th>$\Delta C_{m_5}^T$</th>
<th>$C_{m_5, \text{calc.}}$</th>
<th>$C_{m_5, \text{test}}$</th>
<th>$C_{m_5, \text{calc.}}$</th>
<th>$C_{m_5, \text{test}}$</th>
<th>$C_{L, \text{calc.}}$</th>
<th>$C_{L, \text{test}}$</th>
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<td>(deg)</td>
<td>(deg)</td>
<td>(deg)</td>
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<td>-0.045</td>
<td>(-0.552)</td>
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Table IV: Pitching Moment Coefficient (Concluded)
Curves for constant power

(See Page VIII-22)

\[ \alpha_R = -\theta \text{ deg} \]

- Calculated
- Windtunnel test data

\[ \alpha_R = 0 \text{ deg} \]

\[ \alpha_R = 10 \text{ deg} \]

\[ \alpha_R = 15 \text{ deg} \]
Fokker 50 (DNW)

\( \alpha \approx 16.5 \text{ deg} \)

\( V_0 = 40/38 \text{ m/s} \)

\( C_{L_T} \) and \( C_{M_T} \)

NOT included

- - - - W.T. Test

- - - - Calculated

\( C_{L_T} = 0.815 \)

\( C_{M_T} = 0.326 \)

Propellers off

CM 30
Fokker 50 (DNW)

$\alpha_p = 40$ deg

$V_c = 40/38$ m/sec

$C_{LT}$ and $C_{Mx}$

NOT included.

W.T. test

Calculated

$C_L$

0.815

0.554

0.326

0.165

Propellers off

-0.8 -0.7 -0.6 -0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2

$C_{Mz} 0.5$
Breguet 1150 Atlantique

$\delta \phi = 50\, \text{deg}$

- Calculated
- Wind tunnel test data

$C_{L \cdot T} = 0$

$C_{T} = 1.0$

$C_{T} = 0.6$

$C_{T} = 0.2$

$C_{m} = 25$
Appendix X

Downwash characteristics (I)

The vertical position of the slipstream centre-line at the tailplane location.

The following equations are used:

\[ h_{tot} = h_e + l_h \tan \left[ K_e \frac{d e}{d C_L} \frac{d C_L}{d \alpha} \alpha_R + K_e \frac{d e}{d C_L} \Delta C_{L_0} + K_e \varepsilon_{a=0} \right] \]

\[-l_h \tan \alpha_R + \left[ X_{0.25C_s} - X_{prop} \right] \sin \alpha_R \]

\[ + C_f \sin \delta_f - 0.25 \left( X_{0.25C_s} - X_{prop} \right) \sin \Delta \alpha_{o,f} \]

or:

\[ h_{tot} = h_e + P - l_h \tan \alpha_R + (\Delta h_e)_{a} + (\Delta h_c)_{\delta_f} + (\Delta h_c)_{upw} \]

where:

\[ P = l_h \tan [M+N+O] \]

with:

\[ M = K_e \frac{d e}{d C_L} \frac{d C_L}{d \alpha} \alpha_R \]

\[ N = K_e \frac{d e}{d C_L} \Delta C_{L_0} \]

\[ O = K_e \varepsilon_{a=0} \]
\[(\Delta h_c)_a = -(X_{0.25c_a} - X_{prop}) \sin \alpha_e \] 
\[(\Delta h_c)_t = +c_r \cdot \sin \delta_e \] 
\[(\Delta h_c)_{upw} = -0.25 \left(X_{0.25c_a} - X_{prop}\right) \sin \Delta \alpha_{o,e} \]

with:

\[h_i \quad (95)\]
\[\varepsilon_{a=0} \quad (104)\]
\[l_a \quad (94)\]
\[\left(X_{0.25c_a} - X_{prop}\right) \quad (96)\]
\[\alpha_e \quad (82)\]
\[c_r \quad (93)\]
\[L_{n^*} \quad (97)\]
\[\delta_e \quad (81)\]
\[K_e \quad (101)\]
\[c_r \sin \delta_e \quad (83)\]
\[\frac{dc_e}{dc_r} \quad (100)\]
\[\Delta \alpha_{o,e} \quad (84) \equiv (15)\]
\[\left(\frac{dc_r}{d\alpha}\right)_{c_r=0} \quad (102)\]
\[\Delta C_{t_a} \quad (103) = (58)\]

Encircled numbers \((X Y Z)\) denote columns in tables where actual values are presented.

Note:

\[h_i = z_i - z_i\] where \(z_i\) is the height of the propeller thrust line above the airfoil section chord at the thrust line location.

The equation for \(h_{ma}\) as presented at the beginning of this appendix has been applied to the majority of the configurations tested and presented in report R&M No. 2747 (ref. 16) for \(C_T = 0.40\) and \(\Delta V/\nu = 0.506\) for \(\alpha_e = 0\) and \(\alpha_e = 10\) deg

\(\alpha_e = -4\) deg \(\alpha_e = +6\) deg

\(\alpha_e = 0\) and \(\alpha_e = +8\) deg

The results are presented as \(h_{ma}\) and \(h_{ma}/D^{7/2}\) in columns (109) and (111).
For comparison with windtunnel test data the figures on pages X-8 to X-11 show the interpolated values for \( \frac{h_{\text{total}}}{D/2} \) for the angles-of-attack at which the windtunnel data were obtained.

Under the assumption that no slipstream deformation occurs the increase in average dynamic pressure at the tailplane can be calculated with the formulae derived in Appendix III.

With the equations from Appendix III

\[
D_{ss} = D* \sqrt{1 - \left( \frac{h_{\text{total}}}{D*/2} \right)^2}
\]

\[
s_{ss} = 2 \times D_{ss} \times c_{ss}
\]

\[
b = \sqrt{\frac{q_{\text{eff}}}{q}} - 1 = \sqrt{1 + \frac{\Delta Y}{V_0}} \left( \frac{S_{ss}}{S_h} + \frac{S_{b} - S_{R_b}}{S_h} \right) - 1
\]

\(b_{ss}, s_{ss}\), and \(b\) were determined for the various angles-of-attack and the associated values for \(\frac{h_{\text{total}}}{D*/2}\). The various data are presented in columns (112), (114) and (121) of Tables Va and Vb and in the figures on pages X-12 and X-13.

The actual windtunnel test values for

\[
\sqrt{\frac{q_{\text{eff}}}{q}} - 1
\]

as reported in report R&M No 2747 are presented on page X-14.

As mentioned in the main part of this report the location of the slipstream centre line seems to be correctly determined with the equations as presented.
### Downwash Characteristics

| No. | Conf. | \( \frac{L}{W} \) | \( \frac{L}{T} \) | \( Z \) | \( \Delta \phi \) | \( \Delta \phi_{eq} \) | \( C_T \) | \( \Delta \phi_{n} \) | \( C_{L} \) | \( \Delta C_{L} \) | \( D_{n} \) | \( D^{*} \) | \( C_{p} \) | Remarks |
|-----|-------|-----------------|-----------------|-----|-------------|--------------|-----|--------------|-----|----------------|-----|-------------|-----|-------|--------|
| 4   | ARC R&M | 3.78          | 0.16            | 0   | 0           | 0.40          | 0.506 | 0.09         | 0   | 0.03          | 1.24 | 10.0        | 9.12 | 11.1  | 2.20   |
|     | No. 2742 | 3.74          | 0.16            | 10.0 | 0           | 0.40          | 0.506 | 0.09         | 0   | 0.03          | 1.24 | 10.0        | 9.12 | 11.1  | 2.20   |
| 4   | ARC R&M | 3.78          | 0.31            | 0   | 10.0        | 0.40          | 0.506 | 0.10         | 0.23| 1.24          | 10.0 | 9.12        | 11.1 | 2.20  |
|     | No. 2742 | 3.74          | 0.31            | 10.0 | 0           | 0.40          | 0.506 | 0.09         | 0   | 0.03          | 1.24 | 10.0        | 9.12 | 11.1  | 2.20   |
| 4   | ARC R&M | 3.78          | 0.46            | 0   | 10.0        | 0.40          | 0.506 | 0.09         | 0   | 0.03          | 1.24 | 10.0        | 9.12 | 11.1  | 2.20   |
|     | No. 2742 | 3.74          | 0.46            | 10.0 | 0           | 0.40          | 0.506 | 0.09         | 0   | 0.03          | 1.24 | 10.0        | 9.12 | 11.1  | 2.20   |
| 4   | ARC R&M | 3.78          | 0.61            | 0   | 10.0        | 0.40          | 0.506 | 0.09         | 0   | 0.03          | 1.24 | 10.0        | 9.12 | 11.1  | 2.20   |
|     | No. 2742 | 3.74          | 0.61            | 10.0 | 0           | 0.40          | 0.506 | 0.09         | 0   | 0.03          | 1.24 | 10.0        | 9.12 | 11.1  | 2.20   |

**Example of calculating procedure**

- LW, CR
- MW, CR
- 2.20, LW, CR
- 2.20, MW, CR
Table V

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Table V: Downwash Characteristics (1) (Concluded)
DOWN WASH CHARACTERISTICS

By approximation,

\[ P = 5 \left( \frac{h_w}{l_w} \right)^2 - 4.5 \left( \frac{h_w}{l_w} \right) + 2.5 \]

\[ \frac{dE}{dE_1} = \frac{57.5P}{T/A} (\text{deg}) \]

0.25 MAC \( \Rightarrow \) 0.25 MAC

Average

\[ l_w \]

\[ h_w \]
\[ b_{sh} = D^* \sqrt{1 - \left( \frac{h_{tot}}{D/2} \right)^2} \]

\[ S_{sh} = 2 \times b_{sh} \times C_{sh} \]

\( D^* = 9.12 \text{ in} \)

\( C_{sh} = 5.80 \text{ in} \)

\( C_I = 0.40 \)

\( \Delta V = 0.506 \)

\( V_0 = 0 \)

\( h_{tot}/D/2 \)
$CT = 0.40$

$\frac{AV}{V_0} = 0.506$

$D^* = 9.12 \text{ in.}$

$S_h = 197.3 \text{ sq. in.}$

$b = \sqrt{\left(1 + \frac{AV}{V_0}\right)^2 \frac{S_{sh}}{S_h}} - \frac{S_h - S_{sh}}{S_h} - 1$
Appendix XI

Downwash characteristics (II)

A comparison of the vertical distance $h_{\text{ac}}$ between the slipstream centre line and the horizontal tailplane as calculated and as derived from windtunnel tests on a Fokker F-27 model.

On pages XI-5 to XI-8 dynamic pressure surveys are presented as measured in a vertical plane through the quarter chord line of the horizontal tailplane on a development windtunnel model of the F27 with lengthened rear fuselage. The figures show data for four of the six flap configurations investigated.

Under the assumption based on the data from Appendix X and in particular on figure X-8 on page X-14 that the dynamic pressure ratio $q_j/q$ starts deviating from $q_j/q = 1$ when $h_{\text{ac}}D/2 < 1.5$ the distance $h_{\text{ac}}$ can be estimated for each data point.

This distance $h_{\text{ac}}$ as derived from the windtunnel tests on the F-27 model is presented in column (110) in Table VI.

With the equations from Appendix X $h_{\text{ac}}$ has been calculated for the same configurations and $\alpha_i$ and $C_i$ as used in the windtunnel tests.

The calculated values of $h_{\text{ac}}$ are presented in column (109) of Table VI.

A comparison of calculated and test data is also presented in the figures on pages XI-9 and XI-10.
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Dynamic-pressure contours in the horizontal region.

Δ 180°, constant power (1950 s.h.p.); \( t_f = 0 \)
Dynamic-pressure contours in the hor. tail region.

Δ 180°; constant power (1950 s.h.p.); $c_f = 40-25-40$
Dynamic-pressure contours in the hor. tail region.

Δ 180° constant power (1950 s.h.p.); \( \delta_f = 70-25-70 \)
Dynamic-pressure contours in the horizontal region.

\( \Delta 180 \); constant power (1950 s.h.p.); \( \delta_r = 70 \)
Appendix XII

Downwash characteristics (III)

The increase in the average downwash at the horizontal tailplane due to propeller slipstream

As described in chapters 6.3 and 6.4 of the main text and in Appendix IV the average downwash at the
wing wake centre line can be estimated using simple momentum considerations from lifting line theory.
This downwash angle only depends on the wing lift coefficient independent from whether lift is
generated entirely by free flow conditions or partly by propeller slipstream.
This also applies when, with slipstream present, the downwash is considered sufficiently far away from
the slipstream.

The rate of change of the downwash due to lift coefficient in these cases $\frac{de}{dc}$ is given on page X-7.

Between the slipstream centre line and a distance $Z = 1.25 D'$ from the slipstream centre line an
additional change in downwash occurs which suggests an in flow into the slipstream from the external
flow.
This is illustrated in the following figure:

Based on windtunnel tests it is assumed that $\Delta e$ is proportional to $\Delta V/V_o$

$$\Delta e = \left(\frac{\Delta e}{V_o}\right) \frac{\Delta V}{V_o}$$

On page XII-5 to XII-37 all available test data on downwash with propeller slipstream present is
shown. Based on this information the generalized curve for $(\Delta e)_{AWC} = f (h/D'/2)$ as presented on
pages XII-36 and XII-39 was determined.

The calculation procedure followed for the determination of the distance between slipstream centre line
and horizontal tail surface is presented on pages XII-2 to XII-4.

On pages XII-40 to XII-47 some additional dowwash data, mainly from tests on an early F-27 model,
are presented.
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### Example of calculating procedure

**Step 1:** Identify the relevant parameters from the table.

**Step 2:** Apply the appropriate formula to calculate the desired value.

**Step 3:** Round the calculated value to the nearest decimal place.

**Step 4:** Check the units for consistency and correctness.

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**LW, CR**

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**MW, CR**

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### Table III: Downwash Characteristics (continued)

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Flaps retracted

△ Windmilling propellers (NACA RM 75626a)

○ C_T = 0.15

□ C_T = 1.15

△ C_T = 2.15

A_w = 3.86
δ_f = 60 deg (C_{\alpha} = 0.035)
δ_o = 30 deg (C_{\alpha} = 0.004)
P = 2.22

2 engines
<table>
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<tr>
<th>$\varepsilon$ (deg)</th>
<th>$\frac{\Delta A}{A_w} = 2.14$</th>
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<tr>
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<tr>
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<td>$\kappa_R = 0$</td>
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<td>$C_T = 0$</td>
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<td>$C_T = 0.10$</td>
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<tr>
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<td>$C_T = 0.20$</td>
</tr>
<tr>
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<td>$C_T = 0.30$</td>
</tr>
<tr>
<td></td>
<td>$C_T = 0.40$</td>
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</tbody>
</table>

For Low wing, $l_h/c = 3.78$ and CR Props, $Z_h/D = 0.16$.

ARC R&M No 2747

Flaps retracted

$\frac{d\varepsilon}{dC_L} = 3.90$
ARC R&M No 2747

Low wing \( \frac{Lh}{c} = 3.78 \) Flaps retracted
CR Props \( \frac{Zh}{D} = 0.16 \) \( A_w = 10.0 \)

\[ \frac{d\varphi}{dC_L} = 3.90 \quad P = 2.14 \]

\[ \kappa_{R} = 10 \text{deg} \]

\( C_T = 0.946 \)

\[ \kappa_{R} = 10 \text{deg} \]

\( C_T = 0.946 \)

Low wing \( \frac{Lh}{c} = 3.78 \)
CR Props \( \frac{Zh}{D} = 0.31 \) \( A_w = 10.0 \)

\[ \frac{d\varphi}{dC_L} = 4.05 \quad P = 2.22 \]

\[ \kappa_{R} = 10 \text{deg} \]

\( C_T = 0.946 \)

\[ \kappa_{R} = 10 \text{deg} \]

\( C_T = 0.946 \)

XII-8
Low wing \( \frac{l_h}{c} = 3.78 \quad A_w = 10.0 \)
CR Props \( \frac{z_h}{D} = 0.705 \)
\( \frac{dE}{dC_L} = 2.90 \)
\( P = 1.53 \)

Flaps retracted
R & M No 2747

\( C_T = 0 \)
\( C_T = 0.10 \)
\( C_T = 0.20 \)
\( C_T = 0.30 \)
\( C_T = 0.40 \)
Low wing  \( \frac{L}{D} = 4.41 \)  \( A_w = 10.0 \)
CR Props  \( \frac{Z_h}{D} = 0.61 \)

\[ \frac{d\alpha}{dC_L} = 4.05 \]

\( P = 2.22 \)

\( \kappa_R = 0 \)
\( \kappa_R = 10 \text{ deg.} \)

Flaps retracted

\( \alpha \)
\( C_T = 0 \)
\( C_T = 0.10 \)
\( C_T = 0.20 \)
\( C_T = 0.30 \)
\( C_T = 0.40 \)
4

ε (deg)

2

0

0.2 0.4 0.6 0.8 1.0 1.2 C_L

Flaps retracted

Mid wing \( l_h/\varepsilon = 3.78 \) \( A_w = 10.0 \)

CR Props \( z_{h_D} = -0.15 \)

\( C_T = 0 \)
\( C_T = 0.10 \)
\( C_T = 0.20 \)
\( C_T = 0.30 \)
\( C_T = 0.40 \)

R & M No 2747

6

ε (deg)

4

2

0

0.2 0.4 0.6 0.8 1.0 1.2 C_L

Flaps retracted

Mid wing \( l_h/\varepsilon = 3.78 \) \( A_w = 10.0 \)

CR Props \( z_{h_D} = 0.10 \)

\( d\varepsilon/dC_L = 4.10 \)
\( P = 2.25 \)

\( \kappa_r = 10 \text{ deg} \)

\( C_T = 0 \)
\( C_T = 0.10 \)
\( C_T = 0.20 \)
\( C_T = 0.30 \)
\( C_T = 0.40 \)

XII-14
Low wing \( l_{h/c} = 3.78 \quad l_w = 4\,\text{deg} \\
CR Props \( z_{h/D} = 0.15 \quad (z_{l/D} = 0.37, \, \text{R & M No. 2747}) \\
\frac{\Delta E}{\Delta C_L} = 4.20 \quad A_w = 10.0 \quad C_T = 0.946 \\
P = 2.30

\( \alpha_R = 0 \)

\( \alpha_R = 10\,\text{deg} \)

Flaps retracted.

R & M No. 2747

Low wing \( l_{h/c} = 3.78 \quad l_w = 4\,\text{deg} \\
CR Props \( z_{h/D} = 0.35 \quad (z_{l/D} = 0.57, \, \text{R & M 2747}) \\
\frac{\Delta E}{\Delta C_L} = 3.45 \quad A_w = 10.0 \quad C_T = 0.946 \\
P = 1.83

\( \alpha_R = 0 \)

\( \alpha_R = 10\,\text{deg} \)

Flaps retracted.
R & M No 2747

Low wing \( \frac{L_h}{C} = 3.78 \) \( \frac{L_w}{w} = 4 \) deg

CR Props \( \frac{Z_h}{D} = 0.55 \) \( A_w = 10.0 \)

\( \frac{dE}{dC_L} = 3.95 \) \( C_T = 0.946 \)

\( p = 2.17 \)

\( \alpha_R = 0 \)

\( \alpha_R = 10 \) deg.

Flaps retracted

\( -2 \) to \( 1.4 \) \( C_LT - 0 \)

XII-16
Low wing  \( l_h/c = 3.78 \)
SR Props  \( z_h/D = 0.16 \)
\( \kappa_R = 0 \quad A_w = 10.0 \)
\( \kappa_R = 10 \text{deg} \)
\( \gamma_T = 0 \)
\( \gamma_T = 0.30 \)
\( \gamma_T = 0.40 \)
\( \frac{d\epsilon}{d\gamma} = 4.40 \)
\( p = 2.30 \)
Flaps retracted

Low wing  \( l_h/c = 3.78 \)
SR Props  \( z_h/D = 0.31 \)
\( A_w = 10.0 \)
\( \kappa_R = 0 \)
\( \kappa_R = 10 \text{deg} \)
\( \gamma_T = 0 \)
\( \gamma_T = 0.30 \)
\( \gamma_T = 0.40 \)
\( \frac{d\epsilon}{d\gamma} = 3.85 \)
\( p = 2.11 \)
Flaps retracted

XII-17
SPLIT FLAPS

\( \delta_f = 60 \) deg

Low wing

\( l_h/c = 3.78 \)

CR Props

\( z_{h/D} = 0.06 \)

\( \Delta \frac{\delta}{\alpha} = 3.30 \)

\( P = 1.81 \)

\( C_T = 0 \)

\( C_T = 0.10 \)

\( C_T = 0.20 \)

\( C_T = 0.30 \)

\( C_T = 0.40 \)

\( \kappa_R = 8 \) deg

ARC RM No 2747

\( A_{W} = 10.0 \)

\( C_T = 0.946 \)
SPLIT FLAPS $\delta_f = 60$ deg.

Low wing $U_r/C = 3.78$ $A_w = 10.0$ $C_T = 0.946$

CR Props $Z_{r/D} = 0.16$ $P = 2.14$

$d\delta/dC_l = 3.90$ $\alpha_r = 0$

$C_T = 0.10$ $\Delta$

$C_T = 0.20$ $\square$

$C_T = 0.30$ $\triangle$

$C_T = 0.40$ $\triangleleft$

$\delta_f = 0$ $CT = 0$
SPLIT FLAPS $\delta_f = 60 \text{ deg}$

Low wing $\frac{L_h}{E} = 3.78$  
CR Props $\frac{Z_h}{D} = 0.46$  
$\frac{d\varepsilon}{dc} = 4.15$  
$P = 2.28$

$C_T = 0.346$

$\delta_i = 0$  
$C_T = 0$

$\Delta$  $C_T = 0.10$

$\nabla$  $C_T = 0.20$

$\triangle$  $C_T = 0.30$

$\square$  $C_T = 0.40$
NASA TND-3438

Large horizontal tail plane
at low position

Flap setting 45 deg

$C_T$ = 1.25

$C_T$ = 0.70

$Z_{\theta}/\beta$ = 0.279

$A_W$ = 5.42

$\delta^l$ = 6.85

$\delta_c$ = 4.95

$P$ = 2.07

$C_T$ = 0

No power

XII-24
NACA TN D-3438

Small horizontal tailplane at High position

Flap setting 45 deg

$\theta_w = 5.42$

$\Delta = 5.45$

$\Delta C_L = 1.62$

$z_{h'}/D = 0.331$

$z_{h'}/h = 0.70$

$C_t = 1.25$

$C_t = 0$

(No power)
ARC R&M No 2310
Medium Tailplane
$\frac{Z_n}{D} = 0$  $A_w = 6.75$

\[
\frac{d\theta}{dC_L} = 6.10
\]

$P = 2.25$

$\alpha_R = 0$

$\alpha_R = 7\text{deg}$

$\alpha_R = 15\text{deg}$

$C_T = 0$

$C_T = 0.079$

$C_T = 0.150$

$C_T = 0.281$

$C_T = 0.884$  ($\frac{\Delta V}{V_0} = 1$)
ARC R&W No 2310

Medium Tailplane

\( \frac{Zh}{D} = 0 \quad A_w = 6.75 \)

\( \frac{dE}{dC_L} = 6.10 \)

\( P = 2.25 \)

\( C_T = 0.884 \)

\( \alpha = 15 \text{ degrees} \)

\( \alpha = 7 \text{ degrees} \)

\( C_T = 0.281 \)

\( C_T = 0.684 \left( \frac{\Delta V}{V_0} = 1 \right) \)
Medium Tailplane

\[ \frac{Z_h}{D} = 0.25 \quad A_w = 6.75 \]

\[ \frac{d\xi}{d\alpha} = 6.20 \]

\[ P = 2.29 \]

\[ \kappa = 15 \text{ deg} \]

\[ \kappa = 7 \text{ deg} \]

\[ C_T = 0 \]

\[ C_T = 0.079 \]

\[ C_T = 0.150 \]

\[ C_T = 0.281 \]

\[ C_T = 0.884 \left( \frac{AV}{V_0} \right) \]
Medium Tailplane

\[ \frac{Z h}{D} = 0.50 \quad A_w = 6.75 \]

\[ \frac{dE}{d\epsilon} = 5.60 \]

\[ P = 2.07 \]

\[ \alpha_R = 0 \]

\[ \alpha_R = 7 \text{ deg} \]

\[ \alpha_R = 15 \text{ deg} \]

\[ C_T = 0 \]

\[ C_T = 0.079 \]

\[ C_T = 0.150 \]

\[ C_T = 0.281 \]

\[ C_T = 0.884 \left( \frac{\Delta V}{V_0} = 1 \right) \]
Small Tailplane

$\frac{z_h}{D} = 0.25 \quad A_w = 6.75$

$\frac{d\varepsilon}{dc_L} = 5.25$

$P = 1.93$

$\alpha_R = 15\,\text{deg}$

$\alpha_R = 2\,\text{deg}$

$C_T = 0$

$C_T = 0.073$

$C_T = 0.150$

$C_T = 0.281$

$C_T = 0.884 \left(\frac{\Delta V}{V} = 1\right)$

$R \& M \ No\ 2310$
Large Tailplane

$z_{\frac{1}{2}} = 0.25$

$d\theta = 5.95$

$\frac{d\theta}{dC_L} = 2.20$

$C_T = 0.884$

$\alpha_R = 15 \text{ deg}$

$C_T = 0$

$C_T = 0.029$

$C_T = 0.150$

$C_T = 0.281$

$C_T = 0.884 \left( \frac{\Delta V}{V_0} = 1 \right)$
Increase in downwash due to slipstream inflow

\[ \frac{(\Delta E)_{\text{cm}}}{(\Delta \theta)_{\text{deg}}} \]

-0.1
-0.01
0.5
1.0
1.5
2.0
2.5

Average curve
Fokker F-27 \((\Delta = 180 \text{ mm})\)
\(Z_h/D = 0.541 \quad (h=0)\)
\[
\frac{d\theta}{dC_L} = 3.85
\]

- From tuft measurements
- From air measurements

\(C_T = 0.525 \quad (T_C = 1.75)\)
\(C_T = 0.471 \quad (T_C = 1.57)\)
1950 Shp

- Port side
- Starboard side

\(C_T = 0.186 \quad (T_C = 0.34)\)
\(C_T = 0.054 \quad (T_C = 0.18)\)
\(C_T = 0.105 \quad (T_C = 0.35)\)

No power \(\Delta \Delta \)
No power \(\bigcirc \bigcirc \)

1950 Shp

\(C_{LT-0} \) includes \(C_{LT} = C_T \sin \kappa_R\)

\(\kappa_R = 10.7 \text{ deg.} \)
Appendix XIII

A comparison between the calculated increase in average dynamic pressure at the tailplane and wind tunnel test data.

In chapter 6.4 of the main text the process is described through which the average dynamic pressure at the horizontal tailplane can be determined.

In figures 36 and 37 calculated and measured data for two aircraft are compared.

This appendix presents the calculations.
### Table VIII (a) Downwash Characteristics (iv)

<table>
<thead>
<tr>
<th>No</th>
<th>Conf.</th>
<th>( \frac{L}{W} )</th>
<th>( \frac{D}{S} )</th>
<th>( \frac{h}{C} )</th>
<th>( \frac{D}{C} )</th>
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<th>( \alpha_{g} )</th>
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<td>0.326</td>
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</tbody>
</table>

### Example of calculating procedure
| No | Cont. | $v_h$ | $h_L$ | $s_{K_{\text{to}}}$ | $a_{K_{\text{to}}}$ | $d_C$ | $d_C$ | $d_C$ | $E_{K_{\text{to}}}$ | $M$ | $N$ | $O$ | $P$ | $R_{K_{\text{to}}}$ (dkg) |
|----|-------|------|------|----------------|----------------|------|------|------|----------------|-----|-----|-----|-----|----------------|--------|
| 12 | Fokker 50 | 0.76 | 3.32 | 0.85 | 0.23 | 0 | 3.90 | 1.5 | 0.090 | 0.16 | 4.7 | -2.34 | 5.95 | 9.05 | 0.68 | -8.0 | m |
| 11 | Fokker 50 | 0.76 | 3.32 | 0.85 | 0.23 | 0.06 | 3.90 | 1.5 | 0.100 | 0.24 | 4.7 | -2.34 | 5.95 | 9.05 | 0.68 | -8.0 | m |
| 11 | Fokker 50 | 0.76 | 3.32 | 0.85 | 0.23 | 0.06 | 3.90 | 1.5 | 0.100 | 0.24 | 4.7 | -2.34 | 5.95 | 9.05 | 0.68 | -8.0 | m |
| 11 | Fokker 50 | 0.76 | 3.32 | 0.85 | 0.23 | 0.06 | 3.90 | 1.5 | 0.100 | 0.24 | 4.7 | -2.34 | 5.95 | 9.05 | 0.68 | -8.0 | m |
| 11 | Fokker 50 | 0.76 | 3.32 | 0.85 | 0.23 | 0.06 | 3.90 | 1.5 | 0.100 | 0.24 | 4.7 | -2.34 | 5.95 | 9.05 | 0.68 | -8.0 | m |
| 11 | Fokker 50 | 0.76 | 3.32 | 0.85 | 0.23 | 0.06 | 3.90 | 1.5 | 0.100 | 0.24 | 4.7 | -2.34 | 5.95 | 9.05 | 0.68 | -8.0 | m |
## Table VII(a) Downwash Characteristics (Concluded)

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<th>No</th>
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### Table VIII(b)  
**Downwash Characteristics**

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### Table VIII(c)  
**Additional Parameters**

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### Notes:
- $l_h$ and $l_w$ are chord lengths.
- $Z_h$ and $Z_w$ are zero lift angles.
- $X_h$ and $X_w$ are zero lift coordinates.
- $C_Y$ and $C_L$ are lift coefficients.
- $C_{L,5}$ and $C_{L,5}$ are zero lift coefficients.
- $\Delta h_Y$ and $\Delta h_Y$ are changes in lift.
- $\Delta E_L$ and $\Delta E_L$ are changes in energy.
- $\Delta C_{L,5}$ and $\Delta C_{L,5}$ are changes in zero lift coefficients.

---

### Calculations:
- Downwash calculations are performed using the downwash equation:

$$\Delta C_{L,5} = \frac{\Delta h_Y}{\sin \alpha}$$

### Units:
- $l_h$ and $l_w$ are in meters (m).
- $Z_h$ and $Z_w$ are in degrees (°).
- $X_h$ and $X_w$ are in degrees (°).
- $C_Y$ and $C_L$ are dimensionless.
- $C_{L,5}$ and $C_{L,5}$ are dimensionless.
- $\Delta h_Y$ and $\Delta h_Y$ are in meters (m).
- $\Delta E_L$ and $\Delta E_L$ are in Joules (J).
- $\Delta C_{L,5}$ and $\Delta C_{L,5}$ are dimensionless.
### Table XIII (b)  Downwash Characteristics (I) (Concluded)

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From Fokker Report L-27-150 (A)
DHC-5 Caribou
flaps retracted
\[ \sqrt{\frac{q_h}{q_0}} \]

\( C_T = 1.12 \)
\( C_T = 0.37 \)
Appendix XIV

Downwash characteristics (IV)

Downwash of three aircraft configurations with and without propeller slipstream

For most of the aircraft configurations analysed in the present report downwash data were directly available. For three configurations the downwash had to be determined separately. This is presented in this appendix.

At constant $\alpha_R$:

$$(\Delta C_M)_H = C_{M_{\text{Tail-on}}} - C_{M_{\text{Tail-off}}}$$

$$\kappa_H = \frac{ (\Delta C_M)_H }{ C_{L\kappa_H} \times \bar{V}_H \times \frac{q_H}{q} }$$

When $(\Delta C_M)_H = 0$, then $\kappa_H = 0$

$\varepsilon = \alpha_R - \kappa_H + \iota_H$

So, when $\Delta C_M = 0$, then

$$\varepsilon = \alpha_R + \iota_H$$

$\delta_f = 45 \text{ deg}$

Handed propellers

For the three tail configurations tested $\iota_H$ for $(\Delta C_M)_H = 0$ has been determined for a number of angles-of-attack $\alpha_R$ and thrust coefficients $C_T$ on pages XIV-3 to XIV-4, XIV-6 to XIV-7, XIV-9 to XIV-10. $\varepsilon$ versus $C_{L_{T-0}}$ is presented on pages XIV-5, XIV-8 and XIV-11.

Note that the tail surfaces had inverted NACA 4415 camber lines. Thus, in an aerodynamic sense $\iota_H = 3 \text{ deg}$ when nominally $\iota_H = 0$. Therefore, all downwash data in the figures has to be decreased by 3 deg.
NACA TN D-3438
Small horizontal tailplane
at High position
Flap setting 45 deg
$\delta_w = 5.42$
$\delta_E = 5.45$
$\alpha_0$
$\mu = 1.62$
$Z/V_D$
$Z/h = 0.331$

$C_T = 0.70$
$C_T = 1.25$
$C_T = 2.42$

$E_{corrected} = E + 3^\circ deg$

XIV-5
NASA T.N. D-3638

Large horizontal tailplane at high position

Flap setting: 45 deg

A = 4.5

$C_L = 5.45$

$C_T = 2.42$

$C_T = 1.25$

$C_T = 0.70$

$C_T = 0$

(No power)

$E_{corrected} = E + 3 deg$
<table>
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<tr>
<th>Flap setting 45 deg.</th>
<th>$K_R$ (deg)</th>
<th>$l_h$ (deg)</th>
<th>$\delta$ (deg)</th>
<th>$C_{L-T-0}$</th>
<th>$C_{L-T-0}$ - $C_{T-sin K_R}$</th>
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NASA TN D-3438

Large horizontal tail at low position

$C_T = 0$

$\frac{dC_M}{dl_h} = -0.043 / \text{deg}$

$V_H = 1.04$

---

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<tr>
<th>Flap setting 45 deg.</th>
<th>$K_R$ (deg)</th>
<th>$l_h$ (deg)</th>
<th>$\delta$ (deg)</th>
<th>$C_{L-T-0}$</th>
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NASA TN D-3438

Large horizontal tail at low position

$C_T = 0.70$

$\frac{dC_M}{dl_h} = -0.043 / \text{deg}$

$V_H = 1.04$
Flap setting 45 deg

NASA TN D-3438

Large horizontal tail
at Low position

C_T = 1.25

<table>
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<th>( \theta_R ) (deg)</th>
<th>( i_h ) (deg)</th>
<th>( \beta ) (deg)</th>
<th>( C_{L,T,0} )</th>
<th>( C_{L,T,0} - C_T \sin \theta_R )</th>
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\( \Delta \) Wind tunnel test data

Large horizontal tail
at Low position

C_T = 1.25

\( \frac{dC_m}{d\theta_h} = -0.04 \) / deg

\( \theta_R = 16 \) deg

\( \theta_R = 20 \) deg

\( \frac{dC_m}{d\theta_h} = 0.04 \) / deg

\( \frac{V_h}{\theta_h} = 1.04 \) / deg
NASA T.N.D. 3438

Large horizontal tail plane
at Low position

Flap setting 45 deg

$\alpha_w = 5.42$

$\delta_f = 0.95$

$p = 2.07$

$\gamma_{h/p} = 0.278$

$C_T = 1.25$

$C_T = 0.70$

$C_T = 0$

(No-power)

$\epsilon_{corrected} = \epsilon - 3 \text{ deg}$
2. Transall C-160

At constant $\alpha_R$:

$$\Delta C_M = C_{M\text{Tail-on}} - C_{M\text{Tail-off}}$$

$$\alpha_H = \frac{(\Delta C_M)_H}{C_L \alpha x H \times \frac{a_H}{a}}$$

$$\epsilon = \alpha_R - \alpha_H + \Delta H$$

$$\Delta H = -1.2 \text{ deg}$$

$$A_H = 4.8$$

$$C_L \alpha x H = 0.059/\text{deg}$$

$$V_H = 1.113$$

### $CT = 0$

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<th>$C_L T_0$</th>
<th>$(C_M)_{i=1,2}$</th>
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### $CT = 0.242$

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### $CT = 0$ when $\Delta H / 9 = 1.00$

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<th>$(\Delta C_M)_H$</th>
<th>$\alpha_H (\text{deg})$</th>
<th>$\epsilon (\text{deg})$</th>
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XIV-12
\[ C_{-160} \]

\[ \text{Sp} = 0 \]

\[ C_T = 0.241 \]

\[ \Delta V / \Delta V_o = 0.349 \]

\[ b_{\text{max}} = 0.213 \]

<table>
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<th>( \chi_R ) (deg)</th>
<th>( C_{LT-0} \sin \chi_R )</th>
<th>( C_{LT-0} )</th>
<th>( \Delta C_M )</th>
<th>( h_{\text{tot}} / D^2 )</th>
<th>( b )</th>
<th>( \Delta h / \Delta h )</th>
<th>( E ) (deg)</th>
<th>( E_{\text{calc}} ) (deg)</th>
<th>( E_{\text{calc}} ) (deg)</th>
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\[ \text{Sp} = 30 \text{ deg} \]

\[ C_T = 0 \]

\[ C_T = 0.536 \]

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<th>( C_{LT-0} )</th>
<th>( (CM)_{LT-0} )</th>
<th>( C_{LT-0} )</th>
<th>( C_{LT-0} )</th>
<th>( (CM)_{LT-0} )</th>
<th>( C_{LT-0} )</th>
<th>( \chi_R ) (deg)</th>
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<tr>
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\[ \text{Sp} = 0 \]

\[ C_T = 0 \]

\[ \Delta h / \Delta h = 1.00 \]

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<tr>
<th>( \chi_R ) (deg)</th>
<th>( C_{LT-0} )</th>
<th>( \Delta C_M )</th>
<th>( \chi_H ) (deg)</th>
<th>( E ) (deg)</th>
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<tbody>
<tr>
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XIV-13
### Table 1: Results for \( \Delta f = 30 \text{ deg} \)

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<th>( \alpha_R ) (deg)</th>
<th>( C_{L_{T=0}} C_{L_{T=0}} )</th>
<th>( \Delta C_{M_{H}} )</th>
<th>( h_{loc} )</th>
<th>( b )</th>
<th>( a )</th>
<th>( \alpha_h ) (deg)</th>
<th>( \theta_h ) (deg)</th>
<th>( \Delta \theta \langle \text{deg} \rangle )</th>
<th>( \Delta \theta \langle \text{deg} \rangle ) CALC.</th>
<th>( \text{E} ) (deg)</th>
<th>( \theta ) (deg)</th>
<th>( \text{E} ) (deg) CALC.</th>
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<td>1.008</td>
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<td>1.7</td>
<td>6.4</td>
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<tr>
<td>-3.2</td>
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<td>0.705</td>
<td>1.41</td>
<td>0.004</td>
<td>1.008</td>
<td>-10.8</td>
<td>6.2</td>
<td>1.7</td>
<td>6.4</td>
<td>2.0</td>
<td>8.3</td>
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</tr>
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<tr>
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### Table 2: Results for \( \Delta f = 60 \text{ deg} \)

<table>
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<th>( \alpha_R ) (deg)</th>
<th>( C_{M_{i=1.2}} (\text{deg}) )</th>
<th>( C_{M_{T=0}} )</th>
<th>( C_{L_{T=0}} )</th>
<th>( C_{M_{i=1.2}} (\text{deg}) )</th>
<th>( C_{M_{T=0}} )</th>
<th>( C_{L_{T=0}} )</th>
<th>( \alpha_R ) (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-7.4</td>
<td>+0.360</td>
<td>-0.51</td>
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<td>-0.50</td>
<td>1.30</td>
<td>0.110</td>
<td>-0.840</td>
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<td>-3.5</td>
</tr>
<tr>
<td>-1.6</td>
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</tr>
<tr>
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### Table 3: Results for \( \Delta f = 30 \text{ deg} \), \( \theta_h \langle \text{deg} \rangle = 1.00 \)

<table>
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<th>( \alpha_R ) (deg)</th>
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<th>( \Delta C_{M_{H}} )</th>
<th>( \alpha_h ) (deg)</th>
<th>( \text{E} ) (deg)</th>
</tr>
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<td>7.9</td>
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<td>2.38</td>
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<td>-3.7</td>
<td>11.7</td>
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</tbody>
</table>
\[ C_{-160} \quad \delta_f = 60 \text{ deg} \quad \Delta V/V_0 = 0.948 \]
\[ C_T = 0.826 \]

<table>
<thead>
<tr>
<th>$\alpha_R$ (deg)</th>
<th>$C_{LT-0} = C_{LT-0} - C_T \sin \alpha_R$</th>
<th>$\Delta C_M$</th>
<th>$h_{bot.}$</th>
<th>$\frac{a_1}{a}$</th>
<th>$\alpha_H$ (deg)</th>
<th>$\epsilon$ (deg)</th>
<th>$\Delta \epsilon$ (deg)</th>
<th>$\epsilon$ (deg)</th>
<th>CALC.</th>
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<tr>
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<td>-</td>
<td>-</td>
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</table>

This data is also presented in figures on page XV- and XV.
<table>
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<tr>
<th>No</th>
<th>Conf.</th>
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<th>$\Delta y$</th>
<th>$x_k$</th>
<th>$\Delta x_p$</th>
<th>$l_h$</th>
<th>$l_h\alpha$</th>
<th>$\Delta C_{L\alpha}$</th>
<th>$\Delta C_{L\alpha}$</th>
<th>$C_T$</th>
<th>$\Delta V/\gamma_0$</th>
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<th>$C_L$</th>
<th>$D_{prop}$</th>
<th>$D^*$</th>
<th>$C_s$</th>
<th>$C_F$</th>
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Flaps retracted

$C_{T}=0$

$C_{T}=0.242$

$A_{w} = 10.0$

$\frac{dE}{dc_{L}} = 4.70$

$P = 2.58$

$\delta_{f} = 60 \text{ deg}$

$\delta_{r} = 19 \text{ deg}$

$C_{LT} = 0$

$C_{LT} = 0.536$

$K_{R} = 13 \text{ deg}$

$K_{R} = 0 \text{ deg}$

$\delta_{f} = 30 \text{ deg}$
3. Breguet 1150 Atlantique

At constant $\alpha_R$:

$$(\Delta C_M)_H = C_{MTail-on} - C_{MTail-off}$$

$$\alpha_H = \frac{(\Delta C_M)_H}{C_L \alpha_H \times \overline{V}_H \times \frac{q_H}{q}}$$

When $(\Delta C_M)_H = 0$, then $\alpha_H = 0$

$$\varepsilon = \alpha_R - \alpha_H + i_h$$

So, when $(\Delta C_M)_H = 0$, then

$$\varepsilon = \alpha_R + i_h$$

$$(\Delta C_M)_H$$ as a function of $i_h$ is presented on pages XIV-21 to XIV-23 for a number of $\alpha_R$'s and $C_T$'s.

Downwash is presented on page XIV-24.
Appendix XV

The effect of propeller slipstream on the tail-off pitching moment at small flap deflections (δ, < 30 deg)

As mentioned in Appendix V for tail-off aircraft configurations with flaps and slats retracted a good agreement between theory and test data is found for the pitching moment when the effect of propeller slipstream is expressed as:

$$\Delta C_{M_{ps}} = - \Delta C_{L_{a,e}} \times \frac{\Delta X_{AC_{puf}}}{C}$$

Thus, as is shown in figure 42 and on pages XV-2 to XV-4 the static stability dCm/dCₜ for aircraft configurations without tail and without flaps or slats is hardly affected by propeller slipstream effects.

For flap settings of 30 deg or above the best agreement between theory and test data on tail-off pitching moments is obtained when a term $\Delta C_{M_{ps}}$ is introduced where

$$\Delta C_{M_{ps}} = - \frac{\Delta X_{PS}}{C} \Delta C_{L_{a,e}}$$

(Chapter 6.2 of the main text)

Analysis of limited test data suggests that for flap settings below 30 deg best agreement between theory and test data is obtained when in the equations of chapter 6.2 instead of:

$$\Delta C_{M_{ps}} = - \frac{\Delta X_{PS}}{C} \Delta C_{L_{a,e}}$$

Analysis of limited test data suggests that for flap settings below 30 deg best agreement between theory and test data is obtained when in the equations of chapter 6.2 instead of:

$$\Delta C_{M_{ps}}^{*} = - \left[ \frac{\Delta X_{AC_{puf}}}{C} + \left( \frac{\Delta X_{PS}}{C} - \frac{\Delta X_{AC_{puf}}}{C} \right) \frac{\delta_{e}}{30} \right] \Delta C_{L_{a,e}}$$

is used.

The improvement in the comparison between the tail-off pitching moment for configurations with flap settings below 30 deg when using $\Delta C_{M_{ps}}^{*}$ instead of $\Delta C_{M_{ps}}$ is evident from a comparison of the data on page XV-5 and XV-6 with the data on page IX-9 and IX-14.

XV-1
$\delta_p = \delta_a = 0^\circ$; tail off

Variation of $C_m$ with $C_L$.
$\delta_f = 0^\circ$, clean leading edge.

Model with the medium-span wing; tail off.

$\delta_f = 0^\circ$, two propellers on.

Basic longitudinal characteristics; slats off, tail off.

$\delta_f = 0^\circ$, four propellers on.
Fokker 50 (DNW)

$\delta_f = 0$

$T_c = 1.7$

$C_T = 0.554$

Wind tunnel test data

$\frac{dC_m}{dC_L} = 0.18$

Propellers off

$C_L\_{T=0}$

$C_m_{30}$
From:
NASA MEMO 12-3-58A

$\delta_f = 20 \text{ deg}$
$\delta_a = 0$

$C_{Lp} = C_{Ld} = 0$

$C_T = 2.14$
$C_T = 1.19$
$C_T = 0.39$
$C_T = 0.15$

Propellers off

Calculated

- Windtunnel test data

(See Page IX-10)
Fokker 50 (DNW)

$\delta_p = 16.5 \text{ deg}$

$V_o = 40/38 \text{ m/sec}$

$C_{LT}$ and $C_{MT}$

NOT included

-- D-- W.T. Test

Calculated

(See Page IX-15)

$C_{LT} = 0.815$

$C_T = 0.326$

Propellers off
Appendix XVI

A comparison between the tail-on pitching moment curves of the aircraft configuration from Report NASA TN D-25 as calculated and as derived from windtunnel test data.

The tail-on pitching moment can be written as:

$$ C_M = C_{M_{tail-off}} + (\Delta C_M)_H, \text{ where} $$

$$ (\Delta C_M)_{H} = -C_{\infty} \frac{V_H}{q} \left( \alpha - \phi + i_h \right) \frac{q_{\infty}}{q} $$

with:

$$ C_{\infty} = 0.052/\text{deg} \quad \frac{V_H}{q} = 1.047 $$

$$ i_h = +4.3 \text{ deg} \quad \left( \frac{L_{\alpha}}{c} = 3.76 \right) $$

$$ \frac{S}{S_w} = 0.275 \quad A_H = 4.55 $$

For the cruise configuration ($\delta_t = 0$) the calculation of $C_M$, both without and with tail are presented in Table X and in the figures on page XVI-5 to XIV-7.

For the landing configuration ($\delta_t = 60$ deg, $\delta_t = 30$ deg) the calculated tail-off data are presented in Table IV and in the figure on page IX-9. The tail-on data are presented in Table X and in the figures on page XIV-8.

The windtunnel test data both without and with tail surfaces are also presented in Tables IV and X and on pages IX-9, XVI-5 to XIV-8.
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**Table X: Downwash Characteristics**
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**Table X** Downwash Characteristics (Continued)
Appendix XVII

The effect of the ratio between the vertical distance between propeller axis and wing section chord and propeller diameter on lift due to propeller slipstream.

In the analysis of the effect of propeller slipstream on the aerodynamic characteristics of an aircraft as presented in the main body of this report the vertical location of the propeller axis relative to the wing has not been considered an important parameter because on most practical aircraft configurations this distance is small.

Also limited available test data suggested that this parameter only becomes important when this vertical distance with the propeller axis below the wing is of the order of 70% of half the propeller diameter or above (fig. 18 and ref. 5).

Recent test data show however that this relation between the vertical slipstream position and the wing is less unambiguous than thought before.

A first illustration of this statement is presented on pages XVII-3 and XVII-4. The figures on page XVII-3, show the test set-up for an experiment performed recently in the Low-Speed Tunnel of the Aerospace Faculty of the Delft University of Technology. A wing half model, equipped with a 5-component balance at the root was investigated with a separately mounted propeller in front of the half model. This powered propeller was located at various vertical positions and operated at a thrust coefficient $C_t = 0.71$. When the wing angle of attack was varied the position of the propeller in the test section was changed accordingly keeping the distance $Z_v$ constant. On page XVII-4 test data are shown for the lift curve without propeller and the increase in lift due to slipstream at varying angle of attack for different values of the vertical distance $Z_v$.

The test data show a regular pattern with variations in $\Delta C_{l_{10}}$ around $\alpha = 0$ and $Z_v = 0$ of the same order as at large $\alpha$'s and large values of $Z_v$. Note however that over the greater part of the range of $\alpha$'s and $Z_v$'s the increase in lift due to slipstream $\Delta C_{l_{10}}$ with increasing $\alpha$ is more or less constant, in particular for negative $Z_v$ values. This is in accordance with figure 18.

A second illustration is presented in the figures on pages XVII-5 to XVII-7 which show the test set-up and some test data from an experiment performed in the '70's at the National Aerospace Laboratory, NLR in the Netherlands. A half model was constructed which was densely covered with pressure tappings allowing the determination of detailed pressure distributions, spanwise lift distributions and the overall lift. In front of the wing half model two blowing nacelles were mounted producing a simulated slipstream at $C_t = 0.71$ and 2.42. The test data show trends which compare well with the data from page XVII-4. A downward shift of the slipstream of 0.50 D/2 decreases the lift by $\Delta(\Delta C_{l_{10}}) = 0.15$ when $C_t = 0.81$ but the increase in lift with increasing angle of attack is hardly altered, both without and with flap deflected.

A third illustration is presented on pages XVII-8 to XVII-16. As indicated this example is taken from NASA TM 4541, dated April 1994. This test again concerns a half model, however with a powered nacelle with propeller mounted integrally with the wing half model. In the example presented the propeller axis is positioned at 0.83 D/2 below the wing reference plane. In the clean configuration the lift at $\alpha = 0$ decreases by $\Delta \alpha = 0.25$ when the propeller thrust is increased from windmilling to $C_t = 1.10$. At $\alpha = 12$ deg the lift increases by $\Delta C_{l} = 0.40$ when $C_t = 1.10$. This is in reasonable agreement with the previous examples. When the flaps are deflected to $\delta = 60$ deg however, the increase in lift is much larger than expected with the low thrust line position investigated. Apparently the low flap trailing edge position strongly affects the Kutta-Joukowski boundary-condition.

The conclusion of the present analysis must be that although with flaps retracted the effect of the vertical thrust line position seems reasonable clear, with flaps deflected this effect deserves further study.
6 component balance

Airfoil section : NACA64A015
A_w : 5.33
D : 0.236 m

Test set up for APROPOS tests (APROPOS = Adaptive PROpeller POsitioning System).
From:
NLR TR 277... C
w.r.t. test data

$\Delta f = 30 \text{ deg}$

$\Delta V = 1$
$\Delta V = 2$

$C_T = 0.81$
$C_T = 2.42$

$D_2$
$D_{1/2}$

$z_h = 0$
$z_h = 0.50$

$\delta f = 30 \text{ deg}$
$\delta f = 30 \text{ deg}$

$\Delta (C_l)_{\Delta V/\overline{V}}$

$\Delta (C_l)_{\Delta V/\overline{V}}$

$\kappa_{R(\text{deg})}$

$\kappa_{R(\text{deg})}$

XVII-6
The 1-ft-diameter, eight-bladed propeller was a scale model of the SR-7L propeller designed and developed jointly by Hamilton Standard Propellers and NASA Lewis Research Center (ref. 9). The air motor that was used to power the propeller was a compact, high power-to-weight ratio, four-stage turbine designed to deliver approximately 150 hp at 19,000 rpm and was housed in the 5-in-diameter nacelle. The drive air was exhausted through a nozzle at the nacelle exit directly in the nacelle axial direction.

Experiments were conducted at a free-stream dynamic pressure of 15 lb/ft² (66.5 knots), which yielded a Reynolds number of 0.88 x 10⁶ based on the wing reference chord of 20 in. Wing angle of attack was varied within the stall boundaries from -30° to 40°. The dynamic pressure and the propeller speeds of 11,000 and 14,000 rpm were selected to simulate highly loaded blade configurations.

April 1994

Figure 3. Schematic of propeller-nacelle position.
(a) Three-view sketch of semispan high-lift wing with propeller-nacelle assembly.

\[ \beta_{0.75} = 40 \, \text{deg} \]

(b) High-lift configuration.

(c) Cruise configuration.

Figure 2. Schematics of test model. All dimensions are in inches.
If it is assumed that the thrust is constant between $V=0$ and 66.5 kts, then:
At 11000 rpm $T=61$ lb and $C_T = \frac{61}{15 \times 960/144} = 0.61$
At 14000 rpm $T=110$ lb and $C_T = \frac{110}{15 \times 960/144} = 1.10$
(a) Windmill conditions.

Effect of nacelle inclination on aerodynamic characteristics for $q = 15$ lb/ft$^2$, $x/c = 0.60$, $z/c = 0.25$, and $\delta_f = 0^\circ$.
(c) Propeller speed = 14,000 rpm.

Figure 4. Concluded.
Figure 9. Effect of nacelle inclination on aerodynamic characteristics for $q = 15$ lb/ft$^2$, $x/c = 0.60$, $z/c = 0.30$, and $\theta_f = 60^\circ$. 

(a) Windmill conditions.
Effect of nacelle inclination on thrust-removed aerodynamic characteristics for $q = 15 \text{ lb/ft}^2$, $\beta_f = 60^\circ$, $x/c = 0.60$, and $z/c = 0.25$.
Figure 17. Propeller thrust and slipstream effects on wing aerodynamic characteristics with propeller blades on, and core pressure ratio matched to blades-off configuration for $q = 15 \text{ lb/ft}^2$, $x/c = 0.60$, $z/c = 0.30$, $\delta_f = 60^\circ$, and Propeller speed = 11 000 rpm.
Figure 18. Effect of propeller rotational speed on wing aerodynamic performance for $q = 15\ \text{lb/ft}^2$, $x/c = 0.60$, $z/c = 0.30$, $\delta_f = 60^\circ$, and $i_{inc} = 0^\circ$. 

Propeller speed, rpm

- C
- 11 000
- 14 000
- 11 000 thrust removed
- 14 000 thrust removed
Appendix XVIII

The effect of the ratio between propeller diameter and wing chord on lift due to slipstream.

Already Smelt and Davies investigated in ref. 6 whether the increase in lift due to the slipstream of a given propeller at a certain thrust coefficient depends on the ratio between the average chord of the wing part submerged in the slipstream and the diameter of the (fully contracted) propeller slipstream.

Their conclusion was that for single propellers on clean wings with propeller-diameter-to-wing-chord ratios as low as $D'/c_s = 0.58$ this ratio did not affect the lift due to slipstream. However when several propellers were mounted in front of the wing sufficiently close to each other so that their slipstreams merged the increase in lift due to slipstream approached double the increase in lift found with a single propeller at equal thrust.

Jameson, in ref. 31, analysed this question on a theoretical basis, albeit on a simplified mathematical model with a slipstream with square cross-sections. His conclusions agreed in general with those of Smelt and Davies.

He furthermore indicated that also when the slipstream of multiple propellers did not merge this configuration produced more lift than a single propeller at equal thrust. This was attributed to the smaller slipstream height-to-wing chord ratio.

In the present report the slipstream is considered as comparable to the flow around low-aspect-ratio wings as formulated by Jones (ref. 42) and De Young (ref. 43). As mentioned already in chapter 6.1 of the main body of this report the theory of refs. 42 and 43 states that the circulation on a wing with aspect-ratio approaching zero is exclusively determined by the flow angle of the trailing edge independent of the slope of the camber line. For all configurations analysed a better agreement between calculated and windtunnel test data were found however when the angle of attack of the wing part submerged in the slipstream was measured relative to the equivalent flat plate zero-lift angle.

For all cases however the ratio $D'/c_s > 0.6$ except for the configuration from report NLR TR 77...C presented on page VI-10. On this 'four-engined' configuration $D'/c_s = 0.533$ with the flap extended and deflected to 30 deg.

On pages XVIII-3 and XVIII-4 lift curves both as calculated and as obtained from windtunnel tests are presented for this configuration for three slipstream-to-freestream velocity ratios. The calculations were performed both according to the standard procedure where the slipstream downwash angle is related to the zero-lift angle and to a procedure related to the flap deflection angle. Note that the test data lie halfway between the two sets of theoretical curves.

On pages XVIII-5 to XVIII-7 the increase in lift due to slipstream is presented for the configuration shown on page XVIII-7 as calculated according to the standard procedure and as derived from windtunnel tests. The two-engined model was tested with flaps retracted and at flapsettings of 20 and 40 degrees.

At the highest thrust coefficient investigated $D'/c_s = 0.63$. Good agreement is shown between calculated and test data.

The data analysed in this appendix suggest that the procedure adopted for the determination of lift due to slipstream with flaps deflected is valid for $D'/c_s > 0.60$.

For lower values of $D'/c_s$ the slipstream seems to resemble the flow over low-aspect-ratio wings even more. However a more detailed investigation into this subject seems justified before more definite conclusions can be drawn.
From: NLR TR 77...

\[ \delta_f = 30 \text{ deg} \]
\[ i_f = 0 \]

FOUR (simulated) propellers
(Two "propellers"
on half-model)

\[ D^*/C_s = 0.533 \]

\[ \kappa_R \text{(deg)} \]

\[ \xi_z = \kappa_0 + \xi_z^* + \xi \]

\[ \xi_z^* = \xi_0 + \xi_z^* \xi_f + \xi \]
From:
NLR TR 77-001 C

$\delta_f = 30\,\text{deg}$

$L_{jet} = 10\,\text{deg}$

FOUR (simulated) propellers
(Two "propellers"
on half model)

$D/c_s = 0.533$
Flaps retracted

\[
\alpha_w = 10.5 \text{ deg} \\
\alpha_r = \alpha_w - 4.3 \text{ deg}
\]
Flaps at 20 deg

\[ \alpha_w = 10.6 \text{ deg} \]

\[ \alpha_R - \alpha_w = 4.3 \text{ deg} \]
Flaps at 40 deg

\[ \alpha_w = 10.1 \, \text{deg} \]

\[ \alpha_r = \alpha_w - 4.3 \, \text{deg} \]
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The method makes possible the determination of slipstream effects on wing lift-off pitching moment and flow conditions at the horizontal tail.