RUDDER SIDEFORCE, YAWING MOMENT AND ROLLING MOMENT CONTROL DERIVATIVES AT LOW SPEEDS: Y_ζ, N_ζ AND L_ζ

1. NOTATION AND UNITS (see Sketches 1.1 to 1.3)

		SI	British
a_{1F}	lift-curve slope of straight-tapered wing of aspect ratio A_F, quarter-chord sweep $\Lambda_{1/4F}$ and taper ratio c_{tF}/c_{rF}	rad^{-1}	rad^{-1}
A_F	aspect ratio of fin, taken as $2h_F^2/S_F$		
A_{Feq}	equivalent aspect ratio of fin with lift-curve slope equal to $-(Y_v)_{FR}(S_W/S_F)$ and half-chord sweep $\Lambda_{1/2F}$		
b	wing span	m	ft
b_T	tailplane span	m	ft
c_F	fin chord at mid-span of rudder	m	ft
c_R	rudder chord aft of hinge line at mid-span of rudder	m	ft
c_{rF}	fin root chord	m	ft
c_{tF}	fin tip chord	m	ft
d_{BF}	body width at fin root quarter-chord station	m	ft
d_{BR}	body width at station defined by inboard end of rudder hinge-line	m	ft
h_{BF}	body height at fin root quarter-chord station	m	ft
h_{BR}	body height at station defined by inboard end of rudder hinge-line	m	ft
h_F	height of exposed fin measured from body surface at fin root quarter chord station	m	ft
h_{FR}	height of exposed fin measured from body surface at station defined by inboard end of rudder hinge-line	m	ft
h_R	spanwise extent of rudder	m	ft
h_{Ri}	height of inboard end of rudder hinge-line above longitudinal body axis passing through moment reference point	m	ft

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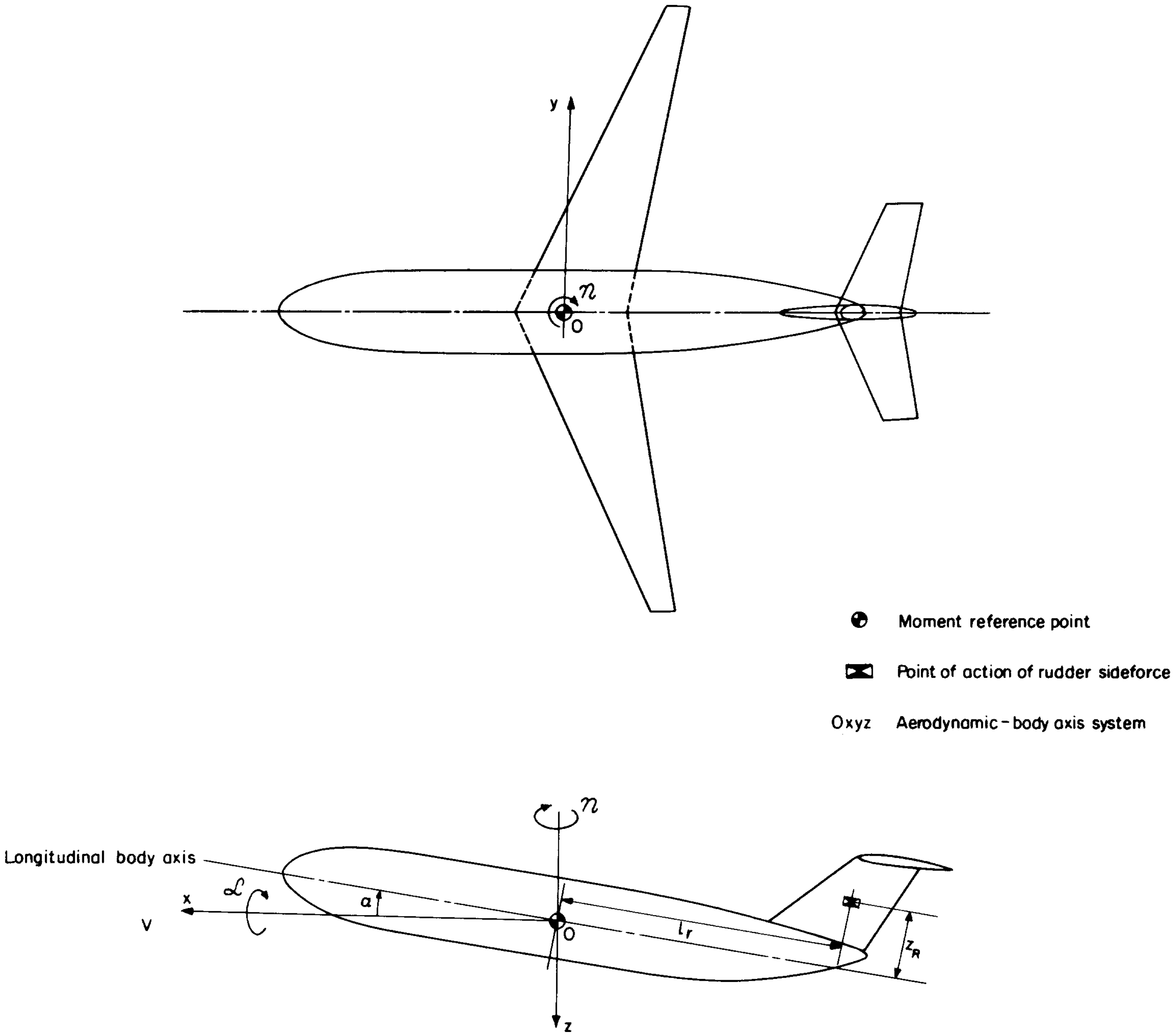
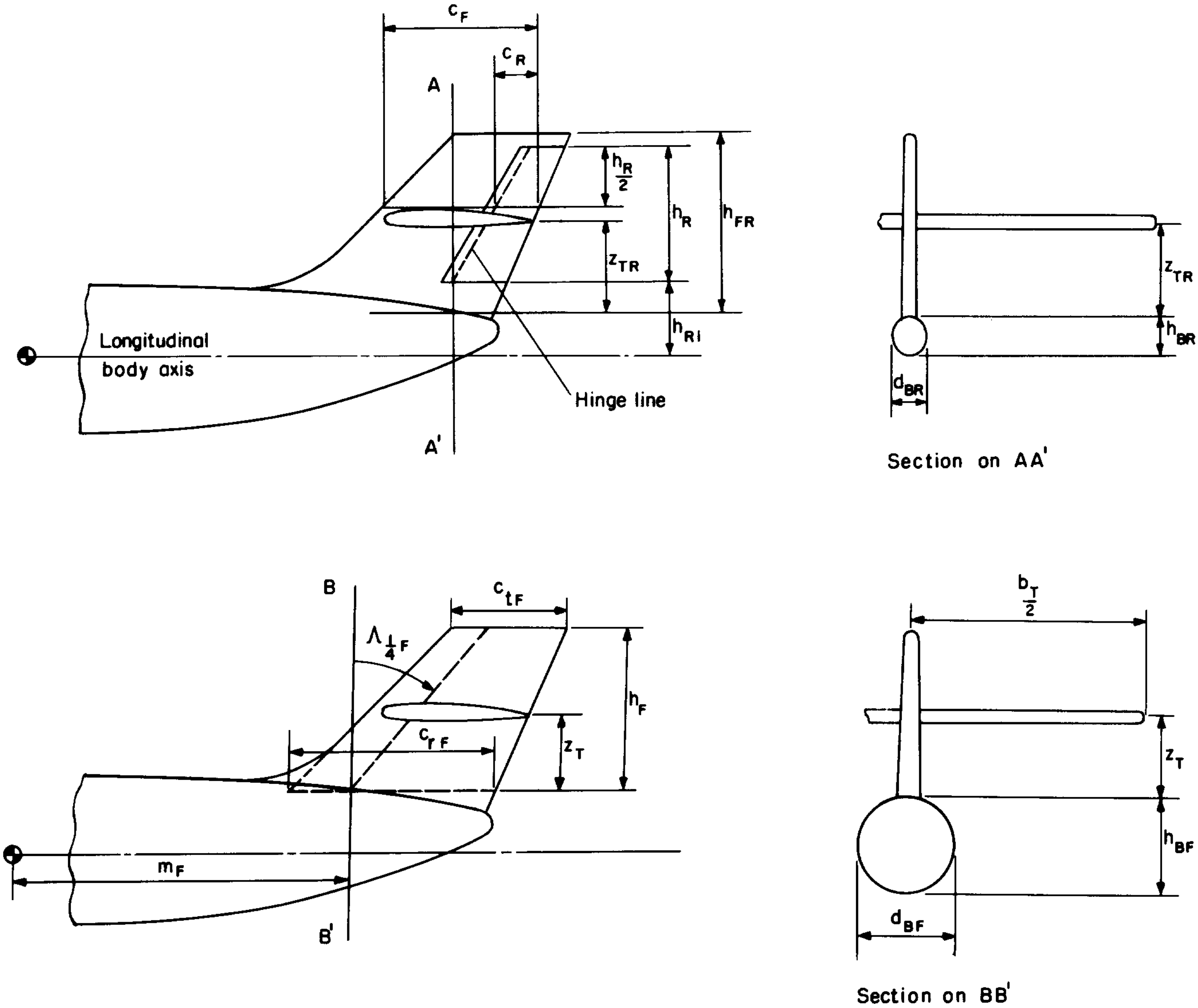
J_B, J_T, J_W	factors, defined in Item No.82010 (Derivation 8), applied to a_{1F} when calculating $(Y_v)_F$ to allow for presence of body, tailplane and wing, respectively		
J_R	body interference factor in calculation of rudder control derivatives		
J_{Ro}	basic value of body interference factor J_R		
k_1, k_2	correction factors for section thickness and Reynolds number in calculation of α_δ, see Equation (3.6)		
$\mathscr{L}$	rolling moment	N m	lbf ft
L_ζ	rolling moment derivative due to rudder deflection, $(\partial \mathscr{L}/\partial\zeta)/\frac{1}{2}\rho V^2 S_W b$	rad $^{-1}$	rad $^{-1}$
l_R	moment arm of sideforce due to rudder measured parallel to longitudinal body axis	m	ft
m_F	distance from moment reference point to fin root quarter-chord point measured parallel to longitudinal body axis	m	ft
$\mathscr{N}$	yawing moment	N m	lbf ft
N_ζ	yawing moment derivative due to rudder deflection, $(\partial \mathscr{N}/\partial\zeta)/\frac{1}{2}\rho V^2 S_W b$	rad $^{-1}$	rad $^{-1}$
R_F	Reynolds number based on c_F		
S_F	fin reference area, $h_F(c_{rF} + c_{tF})/2$	m^2	ft^2
S_W	wing planform (reference) area	m^2	ft^2
$(t/c)_F$	thickness to chord ratio of fin section at mid-span of rudder		
v	sideslip velocity	m/s	ft/s
V	velocity of aircraft relative to air	m/s	ft/s
Y	sideforce, positive to starboard	N	lbf
$(Y_v)_F$	fin sideforce derivative due to sideslip, $(\partial Y/\partial v)/\frac{1}{2}\rho V S_W$		
$(Y_v)_{FR}$	modified fin sideforce derivative due to sideslip, defined by Equation (3.2)		
Y_ζ	sideforce derivative due to rudder deflection, $(\partial Y/\partial\zeta)/\frac{1}{2}\rho V^2 S_W$	rad $^{-1}$	rad $^{-1}$

$\bar{z}_F$	parameter, defined in Item No. 82010 (Derivation 8), allowing for influence of tailplane position on location of centre of pressure of fin load due to sideslip	m	ft
z_R	moment arm of sideforce due to rudder measured normal to longitudinal body axis through moment reference point	m	ft
z_T	height of tailplane above fin root-chord	m	ft
z_{TR}	distance of tailplane above body surface at station defined by inboard end of rudder hinge-line	m	ft
α	angle of attack, see Sketch 1.1	degree	degree
α_δ	control effectiveness parameter, ratio of lift-curve slope due to control deflection to lift-curve slope due to angle of attack, see Section 3.2		
$(\alpha_\delta)_{th}$	theoretical value of α_δ		
β	angle of sideslip	degree	degree
ζ	rudder deflection angle, positive deflection trailing edge to port, measured in streamwise plane, $\approx \zeta' \cos \Lambda_h$	radian	radian
ζ'	rudder deflection angle, positive deflection trailing edge to port, measured in plane normal to hinge line	radian	radian
η_i , η_o	dimensionless inboard and outboard limits of rudder, see Section 3.3		
$\Lambda_{1/4 F}$	fin quarter-chord sweep angle	degree	degree
$\Lambda_{1/2 F}$	fin half-chord sweep angle	degree	degree
Λ_h	rudder hinge-line sweep angle	degree	degree
Λ_F	fin taper ratio, c_{tF}/c_{rF}		
ρ	density of air	kg/m^3	slug/ft^3
τ_F	trailing-edge angle of fin section at mid-span of rudder	degree	degree
Φ_1 , Φ_2	part-span correction functions		
$\Delta\Phi$	part-span correction factor		



Sketch 1.1 Axis system and moment arms

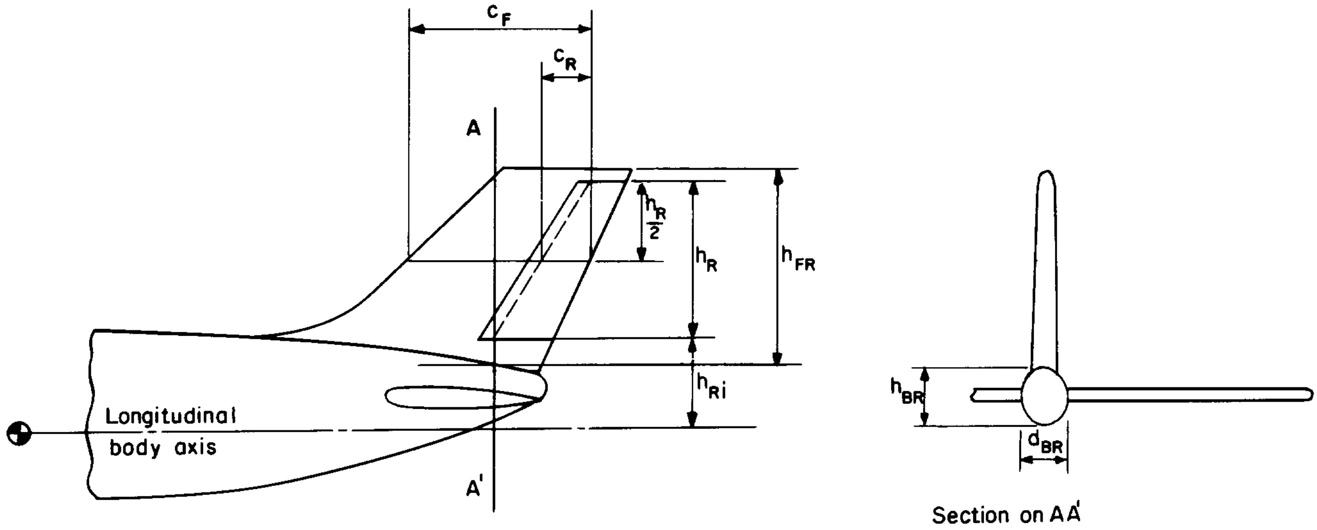


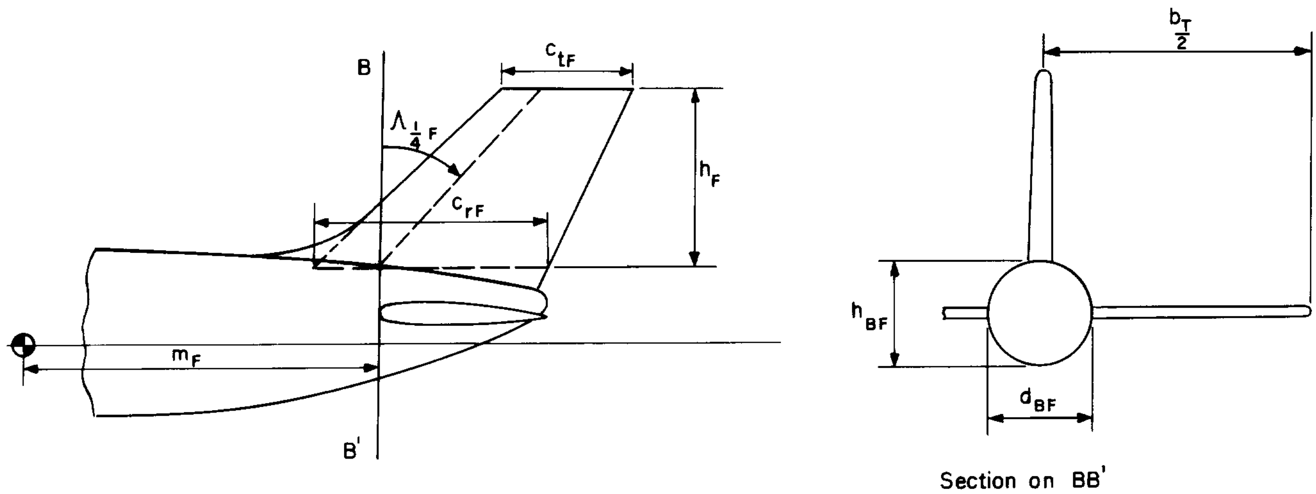
Moment reference point

AA' indicates the longitudinal station defined by the plane normal to the longitudinal body axis that passes through the inboard end of the rudder hinge-line.

BB' indicates the fin root quarter-chord station defined by the plane normal to the longitudinal axis that passes through the point at which the fin quarter-chord sweep line intersects the body surface.

Sketch 1.2 Geometry for fin-mounted tailplanes





See note on Sketch 1.2 for definition of sections AA', BB'

Sketch 1.3 Geometry for body-mounted tailplanes

2. INTRODUCTION

This Item provides a method for predicting the rudder control derivatives Y_ζ, N_ζ and L_ζ, for aircraft at low speeds.* The method treats the rudder as a plain control with no control gap and makes use of the results for such controls fitted to a wing to obtain the control effectiveness parameter α_δ. The control derivatives are then obtained by combining α_δ with a modified fin sideforce derivative due to sideslip, $(Y_v)_{FR}$, appropriate moment arms, l_R and z_R, and a part-span correction factor, $\Delta\Phi$. The empirical factors used to modify the fin sideforce derivative have been obtained from an analysis of the wind-tunnel data contained in Derivations 9 to 15. The aircraft geometries covered by the method are those where a single fin is located on top of the aircraft rear-body, and in the plane of symmetry, with the tailplane mounted either on the fin itself or on the rear-body.

This Item is complementary to Item No. 82010 (Derivation 8) which contains a method for predicting fin sideforce, yawing moment and rolling moment derivatives due to sideslip. The method in this Item makes use of some of the data from Item No. 82010, but where necessary these have been repeated in sufficient detail to allow the present Item to be used independently. The definitions of the fin geometric parameters are consistent in the two Items, although the prediction of the control derivatives naturally requires additional parameters that are associated with the rudder geometry. In Sketches 1.2 and 1.3 the upper diagrams show the additional dimensions needed, while the lower diagrams show the dimensions that are common to both Items.

3. METHOD

The rudder control derivatives are expressed in terms of the set of aerodynamic-body axes Oxyz defined in Sketch 1.1.

The rudder sideforce derivative† is given by

$$Y_\zeta = -(Y_v)_{FR}\,\alpha_\delta\,\Delta\Phi \tag{3.1}$$

where

$$(Y_v)_{FR} = -J_R J_T a_{1F} S_F / S_W . \tag{3.2}$$

The equations for the yawing moment and rolling moment derivatives† are

$$N_\zeta = -Y_\zeta (l_R \cos\alpha + z_R \sin\alpha)/b \tag{3.3}$$

and

$$L_\zeta = Y_\zeta (z_R \cos\alpha - l_R \sin\alpha)/b . \tag{3.4}$$

3.1 Modified Fin Sideforce Derivative $(Y_v)_{FR}$

The derivative $(Y_v)_{FR}$ is obtained as a modified form of the basic fin sideforce derivative $(Y_v)_F$ that is estimated in Item No. 82010 (Derivation 8) as

$$(Y_v)_F = -J_B J_T J_W a_{1F} S_F / S_W . \tag{3.5}$$

* Appendix A describes a FORTRAN computer program, ESDUpac A8708, that has been written for the method of this Item.

† The derivatives with respect to the rudder angle ζ' measured in a plane normal to the rudder hinge-line are $Y_{\zeta'} = Y_\zeta \cos\Lambda_h$, $N_{\zeta'} = N_\zeta \cos\Lambda_h$ and $L_{\zeta'} = L_\zeta \cos\Lambda_h$.

Here a_{1F} is the lift-curve slope of a straight-tapered wing of aspect ratio $A_F = 2h_F^2/S_F$, sweep $\Lambda_{¼F}$ and taper ratio c_{tF}/c_{rF} and can be estimated from Item No. 70011 (Derivation 5), which gives a_{1F}/A_F in terms of the parameters $A_F \tan\Lambda_{½F}$, λ_F and A_F. The factors J_B, J_T and J_W are empirical correction factors and it is through changes to J_B and J_W that the sideforce derivative is modified.

In Item No. 82010 the factor J_B allows for body interference and depends on the fin-body geometry at the fin root quarter-chord station. It is a function of $h_{BF}/(h_{BF} + h_F)$ and A_F, with the body cross-section inherently assumed to be circular, *i.e.* $h_{BF} = d_{BF}$. For estimating $(Y_v)_{FR}$ in this Item the factor J_B is replaced by the factor J_R. This is expressed in terms of a basic value J_{Ro}, which is closely related to J_B, and an empirically determined correction factor to allow for tailplane position. Figure 1 shows J_{Ro} which has an identical form to J_B except that it is expressed as a function of the fin-body geometry at the station defined by the inboard end of the rudder hinge-line via the geometric parameter $(h_{BR} + \mathrm{d}_{BR})/(h_{BR} + \mathrm{d}_{BR} + 2h_{FR})$, see Sketches 1.2 and 1.3. This produces a factor that is smaller than J_B because of the tapering of the rear fuselage and allows for the possibility of a non-circular body cross-section in the way suggested in Item No. 82010. For T-tails, $z_{TR} = h_{FR}$, the correction factor for tailplane position is 1.05, for body-mounted tailplanes it is 0.80 and for tailplanes at a general height z_{TR} on the fin a linear variation is assumed between those two extremes. These results are summarised in Figure 1.

The factor J_T is used in Item No. 82010 to allow for the increase in fin effectiveness due to a tailplane. For aircraft with tailplanes mounted on the fin it is given as a function of tailplane height on the fin, z_T/h_F, and the ratio of tailplane span to fin height, b_T/h_F. For tailplanes that are mounted on the body it is given as a function of b_T/h_F and $h_{BF}/(h_{BF} + h_F)$. For estimating $(Y_v)_{FR}$ the data for J_T are used unaltered in this Item, and for convenience they are reproduced as Figures 2a and 2b.

In Item No. 82010 the factor J_W, which is a function of wing height, is used to allow for wing wake and body sidewash. As these do not affect rudder power, J_W is set equal to unity and does not appear in Equation (3.2).

3.2 Control Effectiveness α_δ

A method for estimating the effectiveness of plain controls on wings is contained in Item No. 74011 (Derivation 6) and for low speeds it gives α_δ in terms of wing aspect ratio, Reynolds number, control chord to wing chord ratio, and wing section thickness to chord ratio, the final two parameters being assumed constant across the wing span. To use this method to calculate α_δ, for the rudder it is therefore necessary to define an equivalent aspect ratio for the fin, A_{Feq}, to use in conjunction with the rudder to fin chord ratio and fin section geometry. This is achieved by finding the aspect ratio of a wing that, with a half-chord sweep of $\Lambda_{½F}$, has a lift-curve slope equal to $-(Y_v)_{FR}S_W/S_F$ rad^{-1}. Figure 3 presents $1/A_{Feq}$ in terms of $\Lambda_{½F}$ and $-(Y_v)_{FR}S_W/S_F$, together with the modified lifting-line formula that has been assumed for generating these data. (For the fin geometries that have been studied this simple approximate formula agrees to within about ±5 % with the more accurate data that could be found iteratively from Item No. 70011, Derivation 5.) The rudder to fin chord ratio is often constant across the rudder span but, in any case, the ratio c_R/c_F at the mid-span of the rudder may be used. Similarly the fin thickness to chord ratio at rudder mid-span, $(t/c)_F$, may be taken as constant over the rudder span.

The method in Item No. 74011 presents α_δ (in a different notation) in a form equivalent to

$$\alpha_\delta = (\alpha_\delta)_{th}\,[1 - k_1 k_2]\,, \tag{3.6}$$

where $(\alpha_\delta)_{th}$ is a theoretical value based on lifting-surface calculations and $[1 - k_1k_2]$ is a correction that allows for section geometry and Reynolds number. For convenience, and to provide a consistent notation, the relevant data are reproduced in this Item as Figure 4a, which gives $(\alpha_\delta)_{th}$ in terms of $1/A_{Feq}$ and c_R/c_F, Figure 4c which gives k_1 in terms of $(t/c)_F \sec \Lambda_{½F}$ and c_R/c_F, and Figure 4c which gives k_2 in terms of $\log_{10}R_F$ and c_R/c_F.

The basic method of Item No. 74011 contains the simplifying restriction on section geometry that the trailing-edge angle in degrees, τ_F, is equal to $100(t/c)_F$. Most practical geometries satisfy this assumption sufficiently well for there to be no significant error in the prediction of α_δ. In the unlikely case of extreme departures, the viscous effects that are dependent on the trailing-edge angle can be more accurately allowed for by the additional use of Item Nos Aero W.01.01.05 and Aero C.01.01.03 (Derivations 3 and 4) to calculate an appropriate factor to replace $[1 - k_1k_2]$, as described in Item No. 74011.

3.3 Part-span Factor $\Delta\Phi$

If the rudder does not extend across the complete span of the fin it is necessary to calculate a part-span factor $\Delta\Phi$.

For a T-tail, as shown in diagram (i) in Figure 5a, the rudder is contained between the tailplane and the body and if the spanwise loading across the fin is assumed to be fairly uniform, then $\Delta\Phi$ can be taken simply as the ratio of rudder span to fin span, h_R/h_{FR}. If there is a fin extension above the tailplane, as shown in diagram (ii), then the function Φ_1, which represents the proportion of the load carried by the fin below the tailplane, multiplies h_R/z_{TR}. The function Φ_1 depends on the tailplane height, z_{TR}, and is based on calculations made for a rectangular fin and tailplane of typical span using the trailing horseshoe vortex model of Derivation 2 with an ad hoc allowance for the presence of the body; it only provides a simple approximation to the division of the fin load but one that should be adequate for the purposes of estimating rudder control derivatives.

If the tailplane is mounted on the body, or if the tailplane is low on the fin so that the rudder is completely above the tailplane or extends continuously on either side of it, as shown in diagrams (iii), (iv) and (v) in Figure 5b, then use is made of the method in Item No. 74012 (Derivation 7). That method was designed for application to wings with part-span controls and evaluates $\Delta\Phi$ as $\Phi_2(\eta_o) - \Phi_2(\eta_i)$, where Φ_2 is a function calculated from lifting-surface theory that depends on wing planform geometry, and η_o and η_i denote the dimensionless outboard and inboard limits of the control. For estimating rudder control derivatives, η_o and η_i are taken as fractions of the fin span h_{FR} as shown in Figure 5b. The numerical data in the Figure have been reproduced directly from Item No. 74012, but are expressed in terms of the fin parameters A_{Feq}, $\Lambda_{½F}$ and λ_F.

3.4 Moment Arms l_R, z_R

The moment arm l_R is measured parallel to the body longitudinal axis and is obtained by adding a quarter of the fin chord at rudder mid-span to the semi-empirical moment arm calculated in Item No. 82010 for the fin sideforce due to sideslip, so that

$$l_R = (m_F + 0.7\bar{z}_F \tan\Lambda_{¼F}) + 0.25c_F\,. \tag{3.7}$$

The bracketed expression is the moment arm from Item No. 82010. The distance m_F is measured from the moment reference point to the fin root quarter-chord station (see Sketches 1.2 and 1.3), and the parameter $\bar{z}_F$ which is a function of tailplane height z_T is given in Figure 6 which has been reproduced directly from Item No. 82010.

The moment arm z_R is measured normal to the longitudinal body axis. For a rudder contained between the tailplane and the body, as in diagrams (i) and (ii) on Figure 5a, z_R is measured to the rudder mid-span, so

$$z_R = h_{Ri} + 0.5h_R , \tag{3.8}$$

where h_{Ri} is the distance of the inboard end of the rudder hinge-line above the moment reference point and h_R is the rudder span.

If the tailplane is body-mounted or if the tailplane is low on the fin so that the rudder is completely above the tailplane or extends on either side of it, as shown in diagrams (iii), (iv) and (v) in Figure 5b, then z_R is measured to 40% of the rudder span, so

$$z_R = h_{Ri} + 0.4h_R , \tag{3.9}$$

where the 0.4 factor has been determined empirically.

4. ACCURACY AND APPLICABILITY

Predicted and experimental values of the rudder control derivatives are compared in Sketches 4.1 to 4.3. In general, Y_ζ is predicted to within ± 0.04, N_ζ to within ± 0.02 and L_ζ to within ± 0.01; the data shown are all for zero angle of attack. The error bands are half those associated with the prediction of the fin derivatives due to sideslip in Item No. 82010, which is a consistent reflection of the possible uncertainty introduced via the estimate of $(Y_v)_{FR}$.

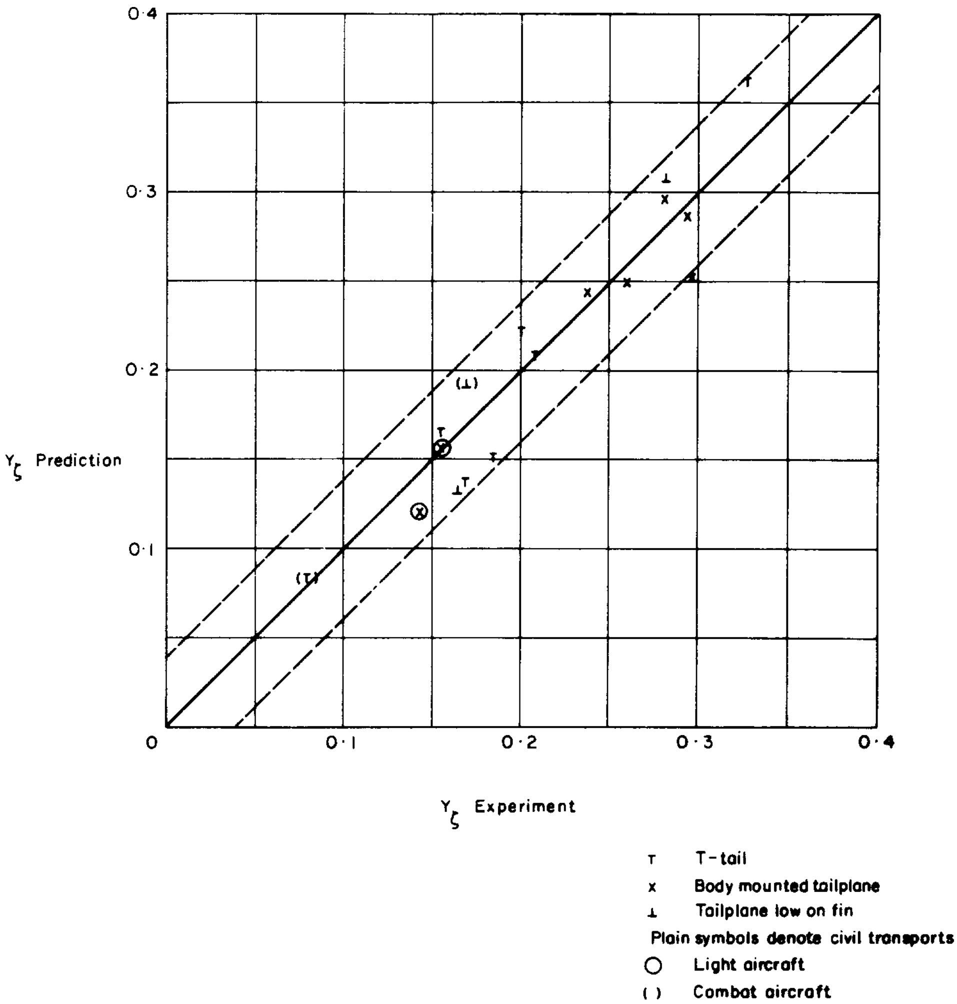
The method has been based mainly on analysis of data for civil transport aircraft, where the fin is reasonably well aft of the wing. Some additional data for light aircraft and combat aircraft have also been utilised to support the analysis. Attention has been restricted to low speeds and angles of attack, sideslip and rudder deflection for which the rudder sideforce and moments vary linearly with ζ, typically $0 \le \alpha \le 10°$, $|\beta| \le 10°$ and $|\zeta| \le 10°$. For some configurations Y_ζ decreases by about 10% or so as α increases from 0 to 10°, with a consequent influence on the variation of N_ζ and L_ζ with α. In most cases the rudder characteristics depart only slowly from the linear as ζ increases from 10° to 20° or so. The extent of the linear range depends on the control nose shape. It has been assumed that there is no load on the tailplane, and the data are restricted to conventional controls with a sharp trailing-edge.

The control gap between rudder and fin has been assumed to be insignificant in terms of its effect on rudder control derivatives. Some information on the effect of significant gaps on control effectiveness is contained in Item No. Aero C.01.01.04 (Derivation 1).

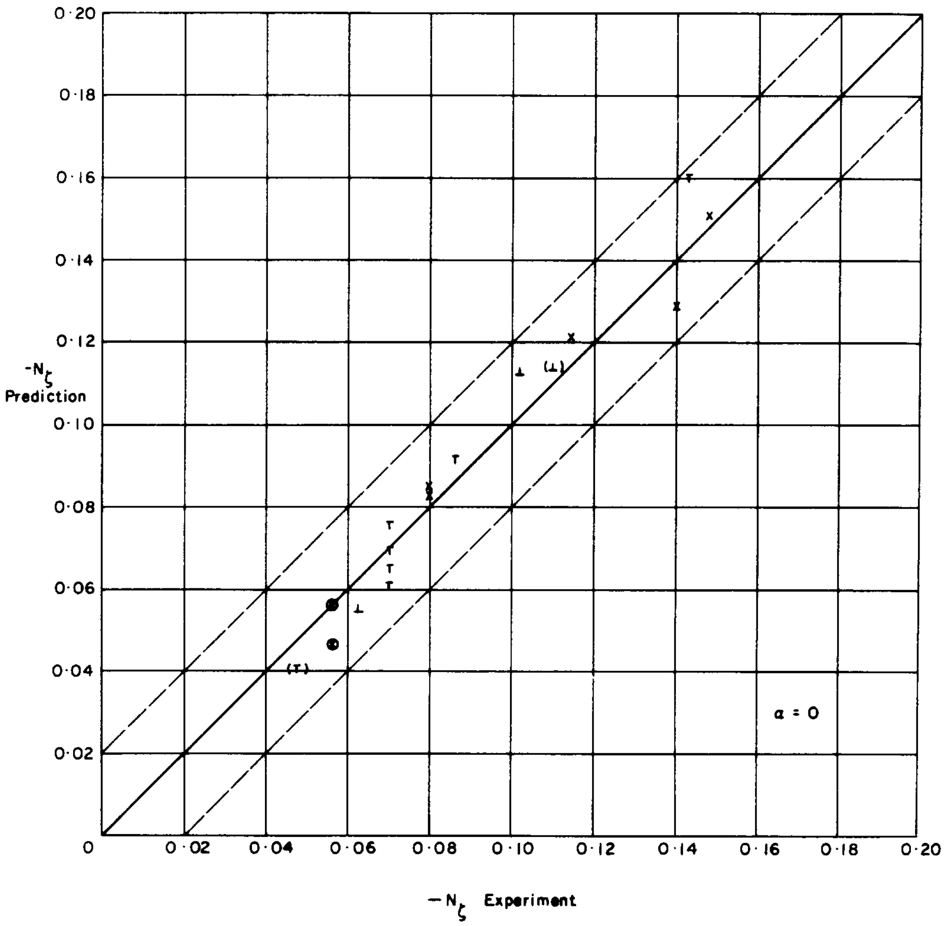
Table 4.1 summarises the ranges of parameters covered by the experimental data. The method should only be used with caution for configurations with geometries that are significantly different from those listed. The different types of fin and rudder geometries that have been studied are illustrated in the diagrams in Figures 5a and 5b.

TABLE 4.1

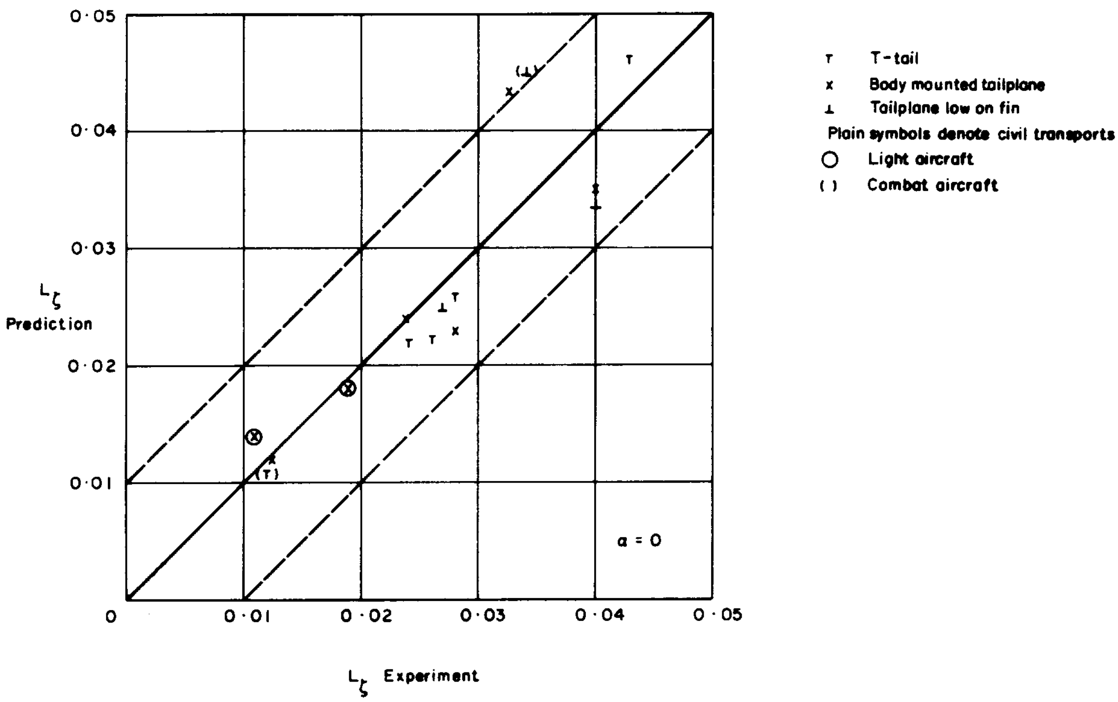
	T-tail	*Tailplane on body or low on fin*
A_F	1.0 to 2.5	2.4 to 3.7
λ_F	0.4 to 0.8	0.25 to 0.5
$\Lambda_{½F}$	20° to 55°	7° to 40°
m_R/b	0.30 to 0.47	0.33 to 0.48
S_F/S_W	0.08 to 0.18	0.07 to 0.20
c_R/c_F	0.20 to 0.40	0.25 to 0.40
h_R/h_{FR}	0.70 to 1.0	0.64 to 1.0
$\tau_F/(t/c)_F$	0.8 to 1.25	
R_F	10^6 to 5×10^6	



Sketch 4.1 Comparison of predicted and experimental values of Y_ζ



Sketch 4.2 Comparison of predicted and experimental values of N_ζ



Sketch 4.3 Comparison of predicted and experimental values of L_ζ

5. DERIVATION

The Derivation lists selected sources of information that have assisted in the preparation of this Item.

1.	ESDU	Effect of gap on slope of lift curve and slope of lift increment curve due to control surface deflection. Engineering Sciences Data Unit, London, Item No. Aero C.01.01.04, June, 1949.
2.	QUEIJO, M.J. RILEY, D.R.	Calculated subsonic span loads and resulting stability derivatives of unswept and 45° sweptback tail surfaces in sideslip and steady roll. NACA tech. Note 3245, 1954.
3.	ESDU	Slope of lift curve for two-dimensional flow. Engineering Sciences Data Unit, London, Item No. Aero W.01.01.05, January, 1955.
4.	ESDU	Rate of change of lift coefficient with control deflection in incompressible two-dimensional flow, $(a_2)_0$. Engineering Sciences Data Unit, London, Item No. Aero C.01.01.03 May, 1956.
5.	ESDU	Lift-curve slope and aerodynamic centre position of wings in inviscid subsonic flow. Engineering Sciences Data Unit, London, Item No. 70011, July, 1970.
6.	ESDU	Rate of change of lift coefficient with control deflection for full-span plain controls. Engineering Sciences Data Unit, London, Item No. 74011, July, 1974.
7.	ESDU	Conversion of lift coefficient increment due to flaps from full span to part span. Engineering Sciences Data Unit, London, Item No. 74012, February, 1974.
8.	ESDU	Contribution of fin to sideforce, yawing moment and rolling moment derivatives due to sideslip, $(Y_v)_F$, $(N_v)_F$, $(L_v)_F$, in the presence of body, wing and tailplane. Engineering Sciences Data Unit, London, Item No. 82010, October, 1982.

Experimental Data

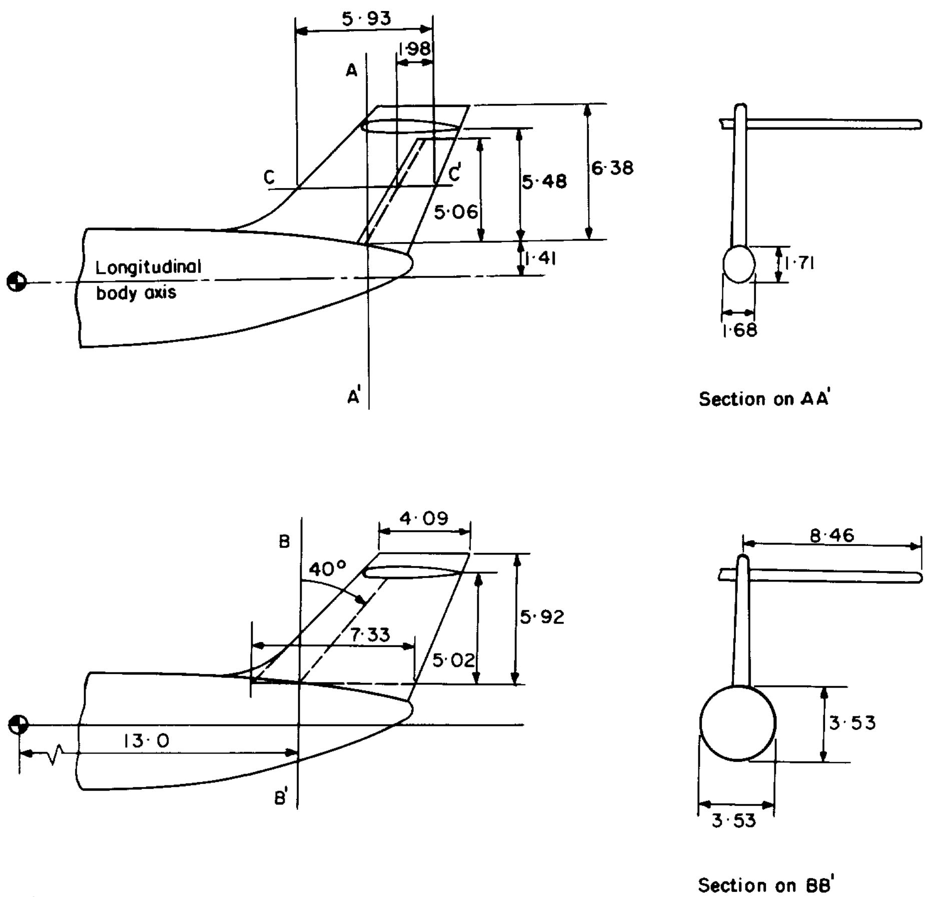
9.	KIRBY, D.A. HOLFORD, J.F.	Low speed tunnel tests on a 1/5th scale model of a single-jet fighter with a 40° sweptback wing (Hawker F.3/48). RAE Rep Aero. 2386, 1950.
10.	TEPER, G.L.	Aircraft stability and control data. Systems Technology Inc. STI tech. Rep. 176-1, 1969.
11.	SHIVERS, J.P. FINK, M.P. WARE, G.M.	Full-scale wind tunnel investigation of the static longitudinal and lateral characteristics of a light single-engine low-wing airplane. NASA tech. Note D-5857, 1970.
12.	FINK, M.P. FREEMAN, D.C. GREER, H.D.	Full-scale wind-tunnel investigation of the static longitudinal and lateral characteristics of a light single-engine airplane. NASA tech. Note D-5700, 1970.
13.	SODERMAN, P.T. AIKEN, T.N.	Full-scale wind-tunnel tests of a small unpowered jet aircraft with a T-tail. NASA tech. Note D-6573, 1971.

14.	FINK, M.P. SHIVERS, J.P. SMITH, C.C.	A wind-tunnel investigation of static longitudinal and lateral characteristics of a full-scale mock up of a light twin-engine airplane. NASA tech. Note D-6238. 1971.
15.	BAe	Unpublished wind-tunnel data from BAe Weybridge, Woodford and Hatfield.

6. EXAMPLES

6.1 Example 1

Calculate the low speed rudder control derivatives for the configuration shown in Sketch 6.1 for an angle of attack $\alpha = 2°$. For the fin section geometry it may be assumed that $(t/c)_F = 0.10$ and $\tau_F = 10°$. The Reynolds number R_F based on c_F can be taken as 10^7.



AA' is station defined by inboard end of rudder hinge-line

BB' is fin root quarter – chord station

CC' is rudder mid – span

Dimensions in metres

$S_W = 200{\cdot}0 \ m^2$

$b = 40{\cdot}0 \ m$

Sketch 6.1

(i) Calculate a_{1F}

By definition the fin reference area is

$$S_F = h_F(c_{rF} + c_{tF})/2$$

$$= 5.92(7.33 + 4.09)/2 = 33.8 \ \text{m}^2$$

and the associated aspect ratio is

$$A_F = 2h_F^2/S_F$$

$$= 2 \times 5.92^2/33.8 = 2.07.$$

The taper ratio is

$$\lambda_F = c_{tF}/c_{rF}$$

$$= 4.09/7.33 = 0.558$$

and the quarter-chord sweep is

$$\Lambda_{¼F} = 40°.$$

These values give the half-chord sweep parameter

$$A_F \tan\Lambda_{½F} = A_F \tan\Lambda_{¼F} - \frac{1-\lambda_F}{1+\lambda_F}$$

$$= 1.453,$$

so $\Lambda_{½F} = 35.1°$

From Item No. 70011, with $A_F \tan\Lambda_{½F} = 1.453$, $\lambda_F = 0.558$ and $A_F = 2.07$,

$$a_{1F}/A_F = 1.21$$

so the lift-curve slope is

$$a_{1F} = 1.21 \times 2.07 = 2.50 \ \text{rad}^{-1}.$$

(ii) **Calculate J_R, J_T**

From Figure 1, for

$$(h_{BR} + d_{BR})/(h_{BR} + d_{BR} + 2h_{FR}) = (1.71 + 1.68)/(1.71 + 1.68 + 2 \times 6.38) = 0.210$$

and $A_F = 2.07$,

$J_{Ro} = 0.855$.

The tailplane is located on the fin at a height

$$z_{TR}/h_{FR} = 5.48/6.38 = 0.859,$$

so from the equation given in Figure 1, the body interference factor is

$$\begin{aligned} J_R &= [0.80 + 0.25(z_{TR}/h_{FR})]J_{Ro} \\ &= [0.80 + 0.25 \times 0.855]0.855 = 0.868. \end{aligned}$$

From Figure 2a, for

$$(z_T/h_F)^2 = (5.02/5.92)^2 = 0.719$$

and $b_T/h_F = 2 \times 8.46/5.92 = 2.86$,

the tailplane interference factor is

$$J_T = 1.12.$$

(iii) **Calculate $(Y_v)_{FR}$, A_{Feq}**

From Equation (3.2) the modified derivative for the sideforce due to sideslip is

$$\begin{aligned} (Y_v)_{FR} &= -J_R J_T\, a_{1F} S_F/S_W \\ &= -0.868 \times 1.12 \times 2.50 \times 33.8/200.0 = -0.411. \end{aligned}$$

Figure 3 is used to obtain A_{Feq}. With

$$-(Y_v)_{FR} S_W/S_F = 0.868 \times 1.12 \times 2.50 = 2.43,$$

and $\Lambda_{½F} = 35.1°$,

$1/A_{Feq} = 0.502$.

and so the equivalent aspect ratio of the fin is

$$A_{Feq} = 1.992.$$

(iv) Calculate α_δ

From Figure 4a, with

$$c_R/c_F = 1.98/5.93 = 0.334$$

and $$1/A_{Feq} = 0.502,$$

$$(\alpha_\delta)_{th} = 0.782.$$

From Figure 4c, with

$$c_R/c_F = 0.334$$

and $$(t/c)_F \sec \Lambda_{½F} = 0.10 \sec 35.1° = 0.122,$$

$$k_1 = 0.140.$$

From Figure 4c, with

$$c_R/c_F = 0.334$$

and $$\log_{10} R_F = \log_{10} 10^7 = 7.0,$$

$$k_2 = 0.445.$$

Therefore, using Equation (3.6), the control effectiveness parameter is

$$\alpha_\delta = (\alpha_\delta)_{th}[1 - k_1 k_2]$$
$$= 0.782[1 - 0.140 \times 0.445] = 0.733.$$

(v) Calculate $\Delta\Phi$

From Figure 5a, with

$$z_{TR}/h_{FR} = 5.48/6.38 = 0.859,$$

$$\Phi_1 = 0.965$$

From the equation given for diagram (ii) on the figure the part-span correcton factor is

$$\begin{aligned}\Delta\Phi &= (h_R/z_{TR})\Phi_1\\ &= (5.06/548)0.965 = 0.891.\end{aligned}$$

(vi) Calculate l_R, z_R

From Equation (3.7) the longitudinal moment arm is

$$l_R = (m_F + 0.7\bar{z}_F \tan\Lambda_{1/4F}) + 0.25c_F.$$

From Figure 6, for a fin-mounted tailplane with

$$\begin{aligned}z_T/h_F &= 5.02/5.92 = 0.848,\\ \bar{z}_F/h_F &= 0.559,\end{aligned}$$

so $\bar{z}_F = 0.559 \times 5.92 = 3.31$ m.

Therefore $l_R = 13.0 + 0.7 \times 3.31 \tan 40° + 0.25 \times 5.93$

$= 13.0 + 1.94 + 1.48 = 16.42$ m,

so $l_R/b = 16.42/42.0 = 0.411.$

For a configuration of the type shown in Sketch 6.1, the moment arm z_R is calculated from Equation (3.8)

$$\begin{aligned}z_R &= h_{Ri} + 0.5h_R\\ &= 1.41 + 0.5 \times 5.06 = 3.94 \text{ m}\end{aligned}$$

so $z_R/b = 3.94/40.0 = 0.099.$

(vii) Calculate Y_ζ, N_ζ and L_ζ

From Equation (3.1), substituting previously calculated values, the sideforce derivative* due to rudder deflection is

$$\begin{aligned} Y_\zeta &= -(Y_v)_{FR}\alpha_\delta\Delta\Phi \\ &= -(-0.411) \times 0.733 \times 0.891 \;=\; 0.268. \end{aligned}$$

For $\alpha = 2°$, Equations (3.3) and (3.4) give the corresponding yawing moment derivative*

$$\begin{aligned} N_\zeta &= -Y_\zeta(l_R\cos\,\alpha + z_R\sin\,\alpha)/b \\ &= -0.268(0.411\cos\,2 + 0.099\sin\,2) \;=\; -0.111, \end{aligned}$$

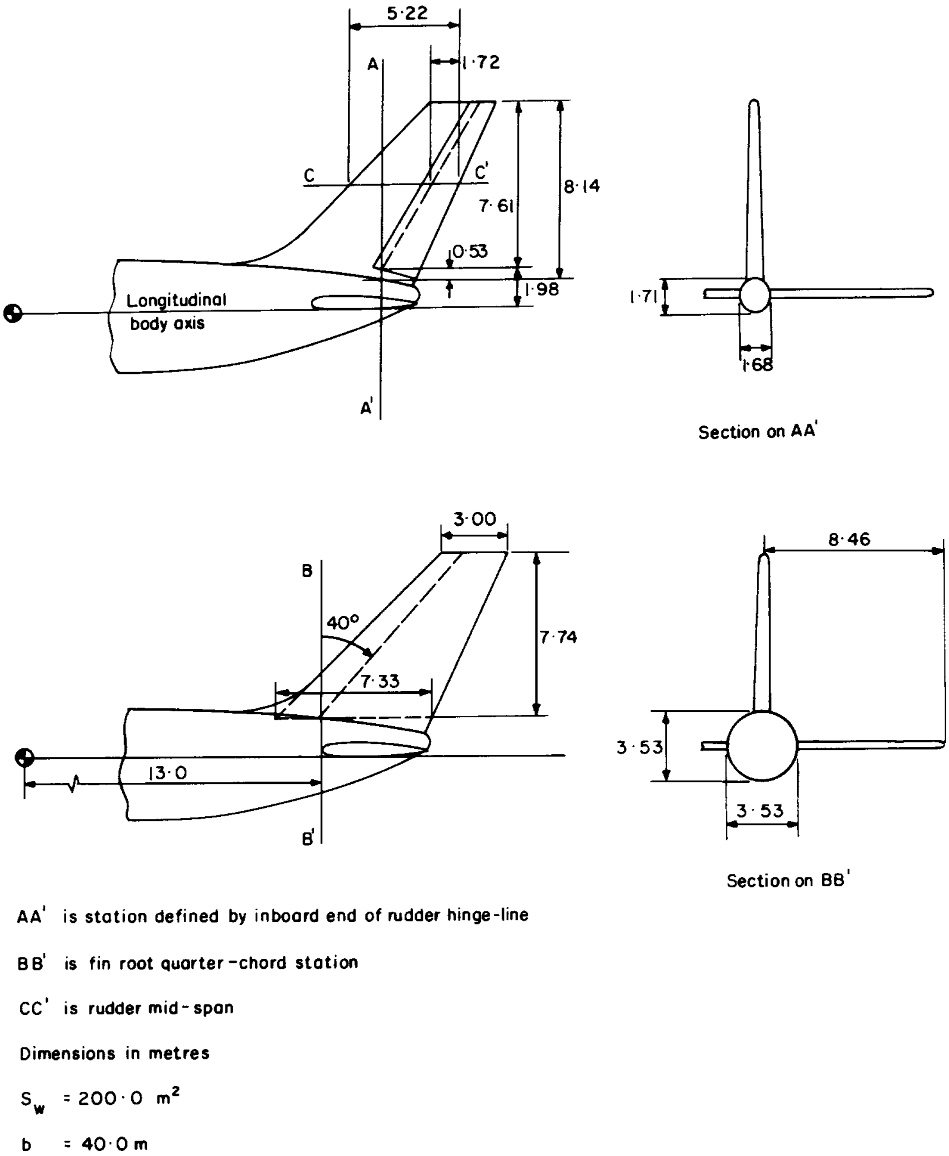
and rolling moment derivative*

$$\begin{aligned} L_\zeta &= Y_\zeta(z_R\cos\,\alpha - l_R\sin\,\alpha)/b \\ &= 0.268(0.099\cos\,2 - 0.411\sin\,2) \;=\; 0.023. \end{aligned}$$

6.2 Example 2

Calculate the low speed rudder control derivatives for the configuration shown in Sketch 6.2 for an angle of attack $\alpha = 2°$. For the fin section geometry it may be assumed that $(t/c)_F = 0.10$ and $\tau_F = 10°$. The Reynolds number R_F based on c_F can be taken as 10^7.

* The derivatives with respect to the rudder angle ζ' measured in a plane normal to the rudder hinge-line are $Y_{\zeta'} = Y_\zeta\cos\Lambda_h$, $N_{\zeta'} = N_\zeta\cos\Lambda_h$ and $L_{\zeta'} = L_\zeta\cos\Lambda_h$.



Sketch 6.2

(i) Calculate a_{1F}

By definition the fin reference area is

$$S_F = h_F (c_{rF} + c_{tF})/2$$

$$= 7.74(7.33 + 3.00)/2 = 40.0 \text{ m}^2$$

and the associated aspect ratio is

$$A_F = 2h_F^2/S_F = 2 \times 7.74^2/40.0 = 3.00 .$$

The taper ratio is

$$\lambda_F = c_{tF}/c_{rF}$$

$$= 3.00/7.33 = 0.409$$

and the quarter-chord sweep is

$$\Lambda_{¼F} = 40° .$$

These values give the half-chord sweep parameter

$$A_F \tan\Lambda_{½F} = A_F \tan\Lambda_{¼F} - \frac{1-\lambda_F}{1+\lambda_F}$$

$$= 2.098,$$

so $\Lambda_{½F} = 35.0°$.

From Item No. 70011, with $A_F \tan\Lambda_{½F} = 2.098$, $\lambda_F = 0.409$ and $A_F = 3.00$,

$$a_{1F}/A_F = 1.00$$

so the lift-curve slope is

$$a_{1F} = 1.00 \times 3.00 = 3.00 \text{ rad}^{-1} .$$

(ii) Calculate J_R , J_T

From Figure 1, for

$$(h_{BR} + d_{BR})/(h_{BR} + d_{BR} + 2h_{FR}) = (1.71 + 1.68)/(1.71 + 1.68 + 2 \times 8.14) = 0.172$$

and $A_F = 3.00$,

$$J_{Ro} = 0.840.$$

The tailplane is body-mounted so the body interference factor is

$$J_R = 0.80\, J_{Ro}$$

$$= 0.80 \times 0.840 = 0.672.$$

From Figure 2b, for

$$h_{BF}/(h_{BF} + h_F) = 3.53/(3.53 + 7.74) = 0.313$$

and $$b_T/h_F = 2 \times 8.46/7.74 = 2.19,$$

the tailplane interference factor is

$$J_T = 1.10.$$

(iii) Calculate $(Y_v)_{FR}$, A_{Feq}

From Equation (3.2) the modified derivative for the sideforce due to sideslip is

$$(Y_v)_{FR} = -J_R J_T a_{1F} S_F / S_W$$

$$= -0.672 \times 1.10 \times 3.00 \times 40.0/200.0 = -0.444.$$

Figure 3 is used to obtain A_{Feq}. With

$$-(Y_v)_{FR} S_W/S_F = 0.672 \times 1.10 \times 3.00 = 2.22$$

$$\Lambda_{½F} = 35.0°,$$

$$1/A_{Feq} = 0.576,$$

and so the equivalent aspect ratio of the fin is

$$A_{Feq} = 1.736.$$

(iv) Calculate α_δ

From Figure 4a, with

$$c_R/c_F = 1.72/5.22 = 0.330$$

and $$1/A_{Feq} = 0.576,$$

$$(\alpha_\delta)_{th} = 0.788.$$

From Figure 4c, with

$$c_R/c_F = 0.330$$

and $$(t/c)_F \sec \Lambda_{½F} = 0.10 \sec 35.0° = 0.122,$$

$$k_1 = 0.141.$$

From Figure 4c, with

$$c_R/c_F = 0.330$$

and $\log_{10}R_F = \log_{10}10^7 = 7.0$,

$$k_2 = 0.450.$$

Therefore, using Equation (3.6), the control effectiveness parameter is

$$\alpha_\delta = (\alpha_\delta)_{th}[1 - k_1 k_2]$$

$$= 0.788\,[1 - 0.141 \times 0.450] = 0.738.$$

(v) Calculate $\Delta\Phi$

From Figure 5b, with the inboard and outboard limits of the rudder expressed as fractions of h_{FR},

$$\eta_i = 0.53/8.14 = 0.065$$

$$\eta_o = 8.14/8.14 = 1,$$

and with the planform parameter

$$A_{Feq}\tan\Lambda_{\frac{1}{2}F} - 8\lambda_F = 1.736\ \tan 35.0° - 8 \times 0.409 = -2.06,$$

the part-span correction factor is

$$\Delta\Phi = \Phi_2(1) - \Phi_2(0.065) = 1 - 0.090 = 0.910.$$

(vi) Calculate l_R, z_R

From Equation (3.7) the longitudinal moment arm is

$$l_R = (m_F + 0.7\bar{z}_F\tan\Lambda_{\frac{1}{4}F}) + 0.25c_F.$$

From Figure 6, for a body-mounted tailplane,

$$\bar{z}_F/h_F = 0.4$$

so $\bar{z}_F = 0.4 \times 7.74 = 3.10\ \text{m}.$

Therefore $l_R = 13.0 + 0.7 \times 3.10\tan 40° + 0.25 \times 5.22$

$$= 13.0 + 1.82 + 1.31 = 16.13\ \text{m},$$

so $\quad l_R/b = 16.13/40.0 = 0.403.$

For a configuration of the type shown in Sketch 6.2, the moment arm z_R is calculated from Equation (3.9)

$$z_R = h_{Ri} + 0.4\ h_R$$

$$= 1.98 + 0.4 + 7.61 = 5.02 \text{ m},$$

so $\quad z_R/b = 5.02/40.0 = 0.126.$

(vii) Calculate Y_ζ, N_ζ and L_ζ

From Equation (3.1), substituting previously calculated values, the sideforce derivative* due to rudder deflection is

$$Y_\zeta = -(Y_v)_{FR}\alpha_\delta\Delta\Phi$$

$$= -(-0.444) \times 0.738 \times 0.910 = 0.298.$$

For $\alpha = 2°$, Equations (3.3) and (3.4) give the corresponding yawing moment derivative*

$$N_\zeta = -Y_\zeta(l_R\cos\alpha + z_R\sin\alpha)/b$$

$$= -0.298(0.403\cos 2 + 0.126\sin 2) = -0.121,$$

and rolling moment derivative*

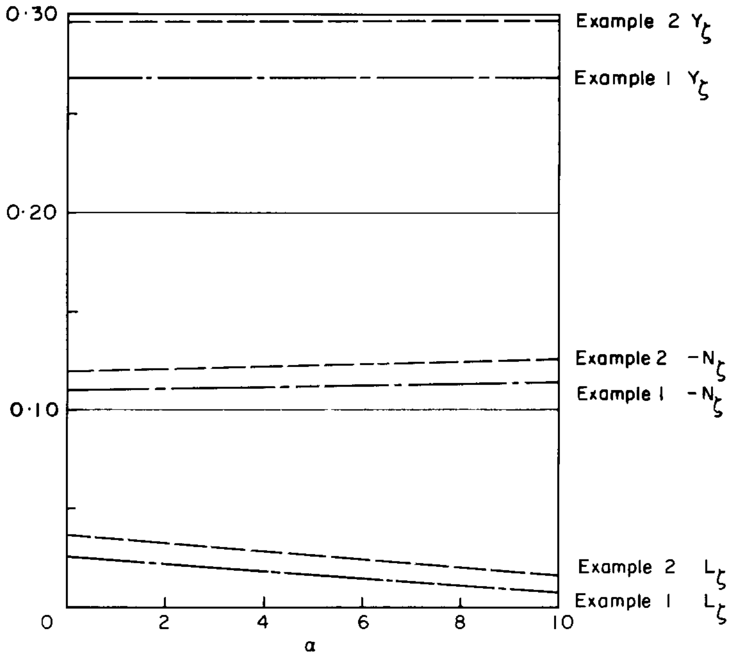
$$L_\zeta = Y_\zeta(z_R\cos\alpha - l_R\sin\alpha)/b$$

$$= 0.298 \times (0.126\cos 2 - 0.403\sin 2) = 0.033\ .$$

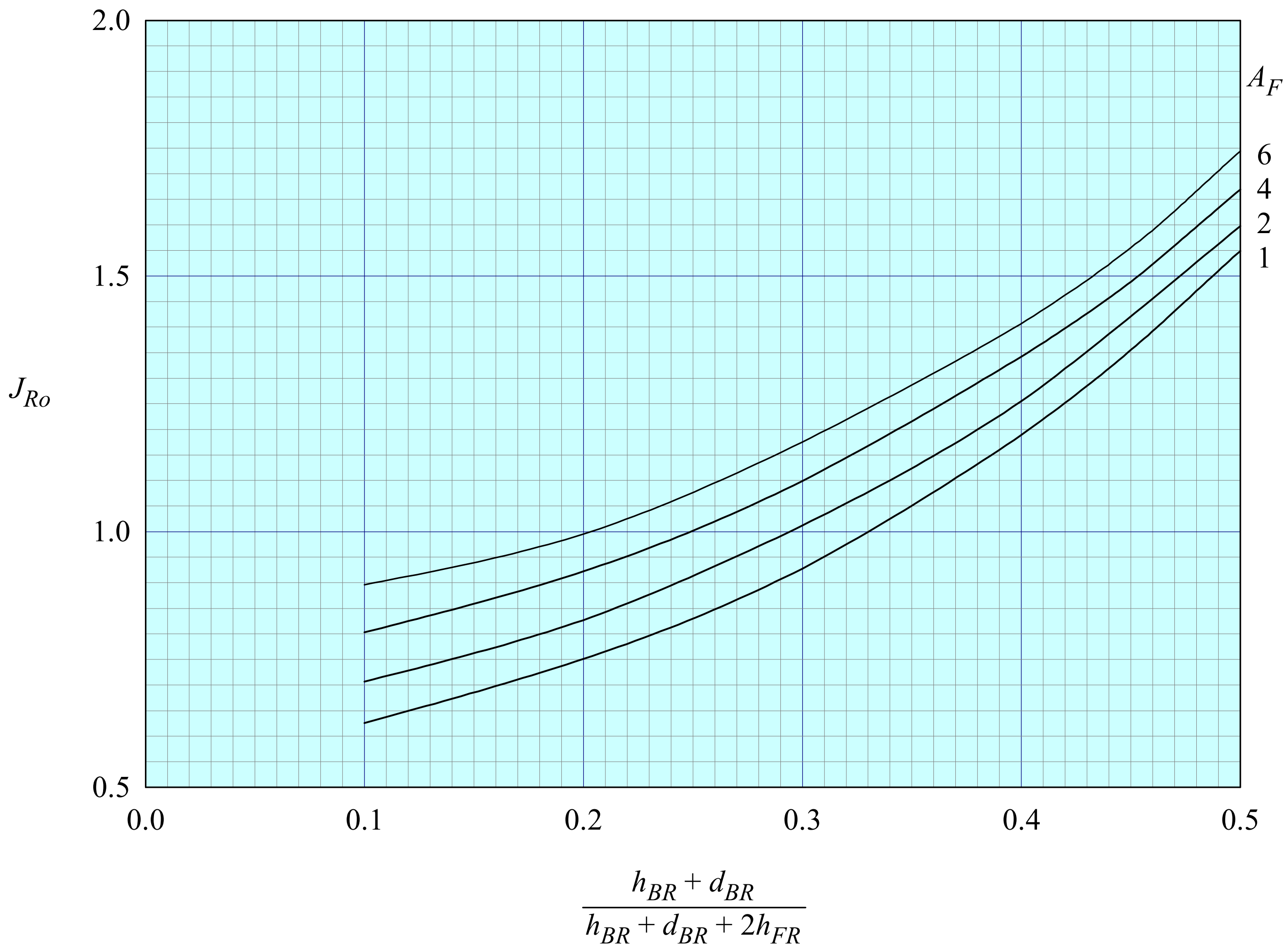
* The derivatives with respect to the rudder angle ζ' measured in a plane normal to the rudder hinge-line are $Y_{\zeta'} = Y_\zeta\cos\Lambda_h$, $N_{\zeta'} = N_\zeta\cos\Lambda_h$ $L_{\zeta'} = L_\zeta\cos\Lambda_h$.

6.3 Comparison of Results

Sketch 6.3 shows the results for Examples 1 and 2 plotted against α.

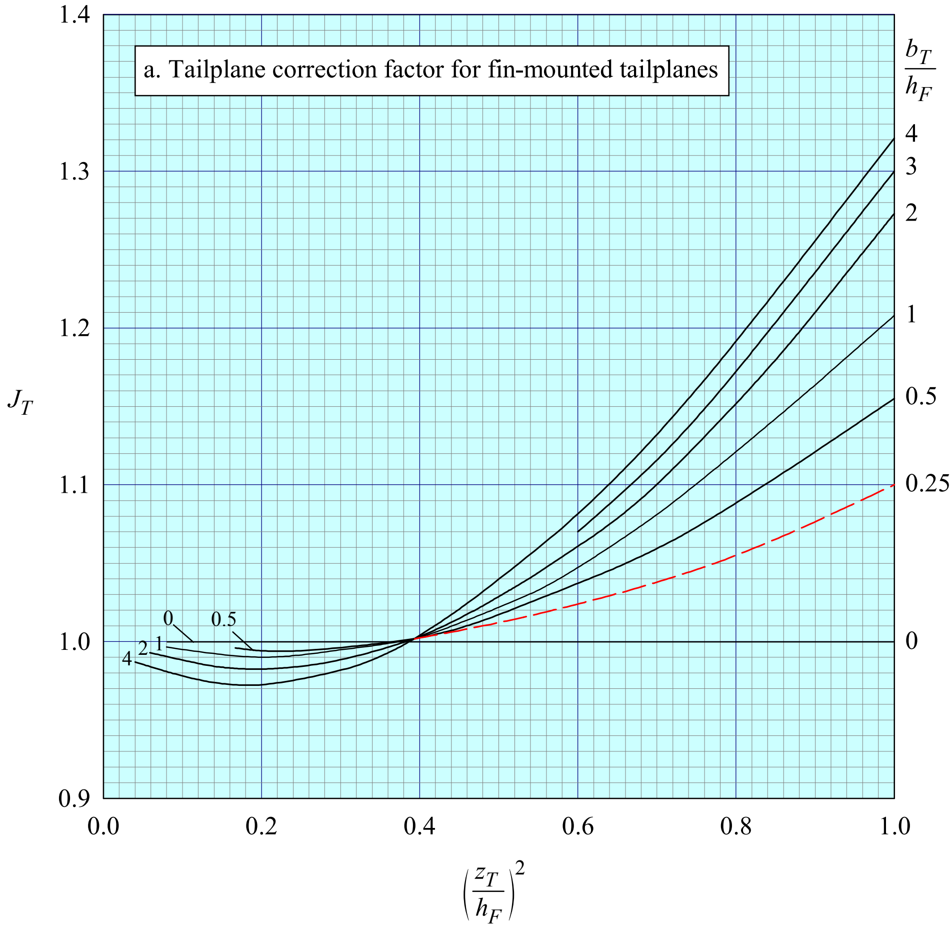


Sketch 6.3 Comparison of results from Examples 1 and 2



T - tails , $z_{TR} = h_{FR}$	$J_R = 1.05\ J_{Ro}$
Tailplane at height z_{TR} on fin	$J_R = [0.80 + 0.25(z_{TR}/h_{FR})]J_{Ro}$
Tailplane on body	$J_R = 0.80\ J_{Ro}$

FIGURE 1 BODY CORRECTION FACTOR



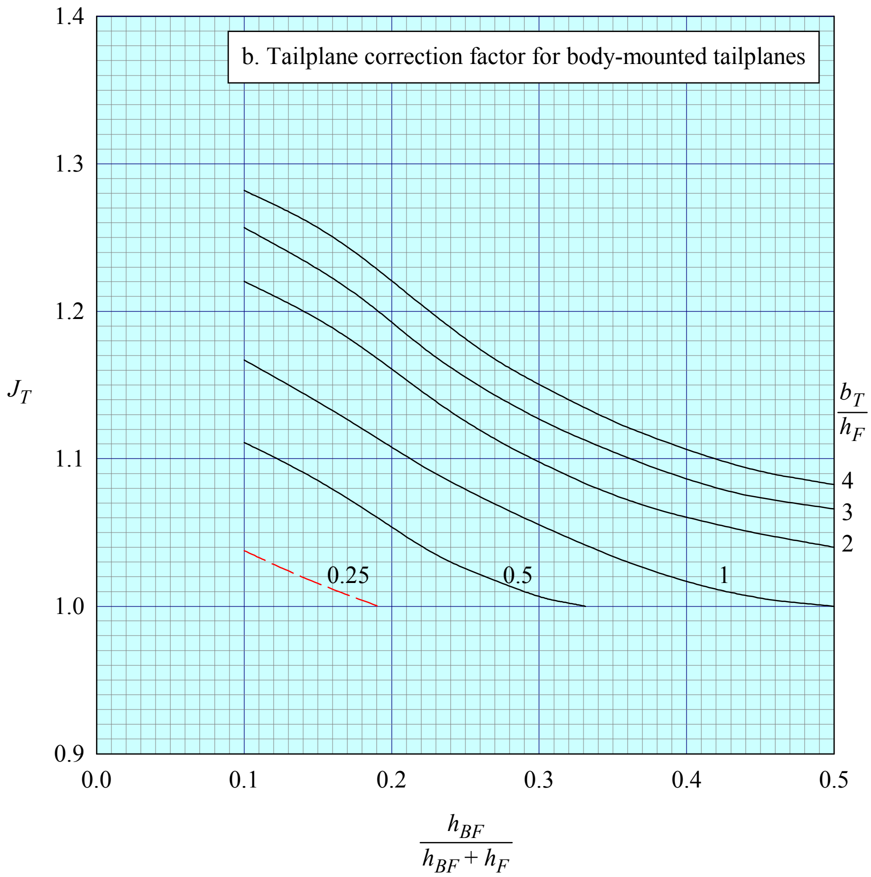
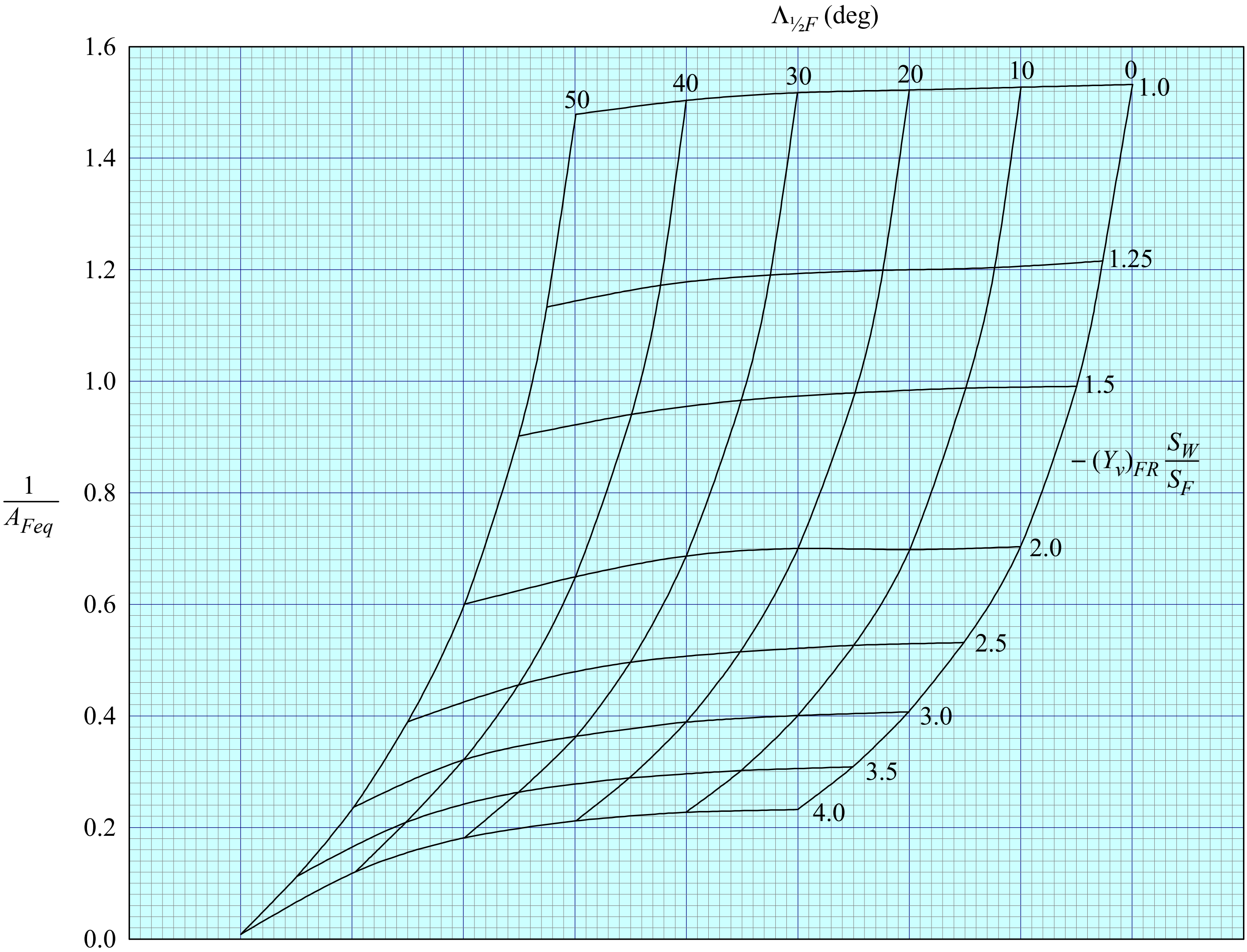


FIGURE 2 TAILPLANE CORRECTION FACTOR



$$\frac{1}{A_{Feq}} = \frac{-\pi}{2(Y_v)_{FR}(S_W/S_F)}\left[1-\left(\frac{(Y_v)_{FR}(S_W/S_F)}{2\pi\cos\Lambda_{½F}}\right)^2\right]$$

FIGURE 3 EQUIVALENT FIN ASPECT RATIO

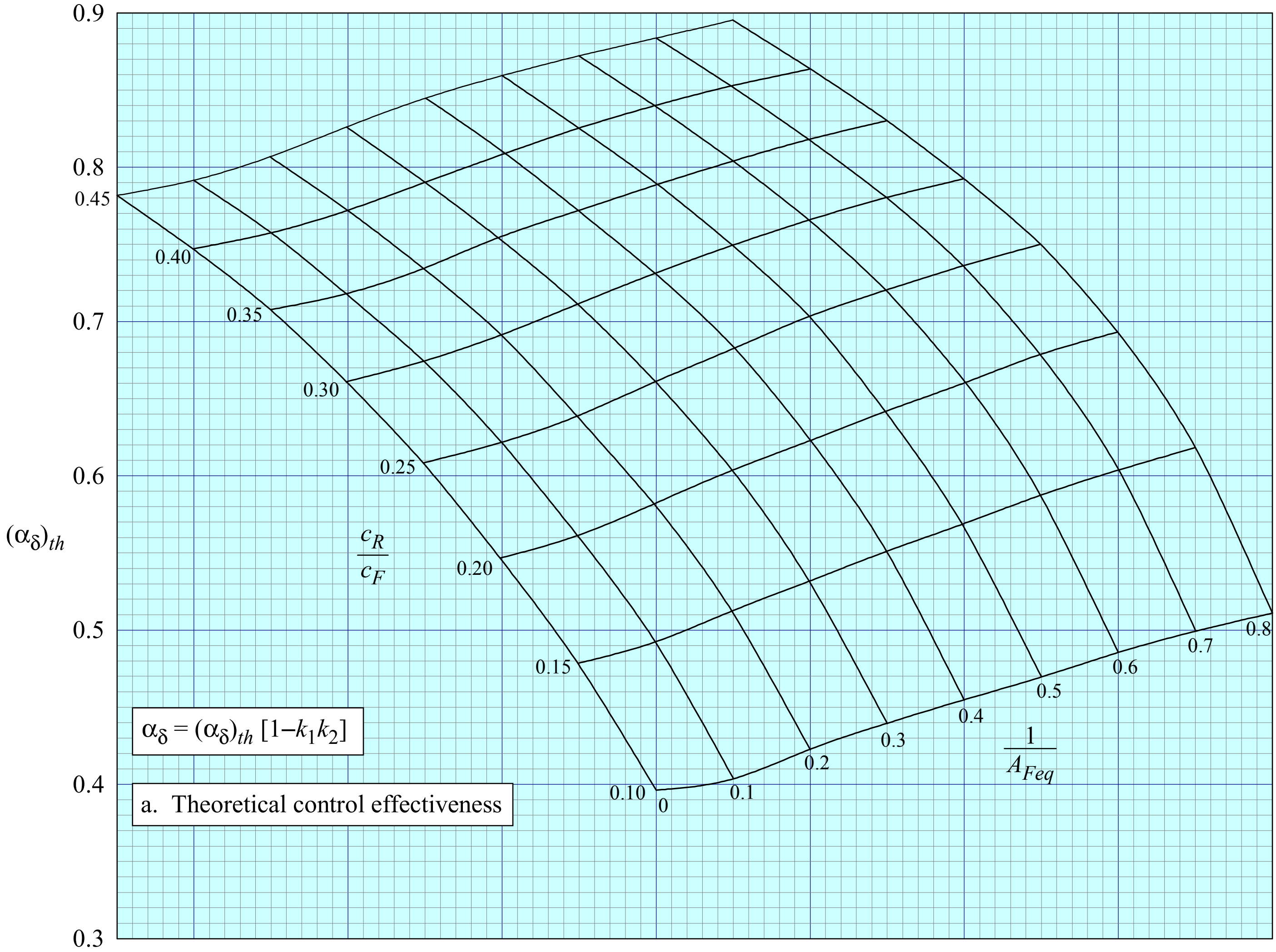


FIGURE 4a CONTROL EFFECTIVENESS

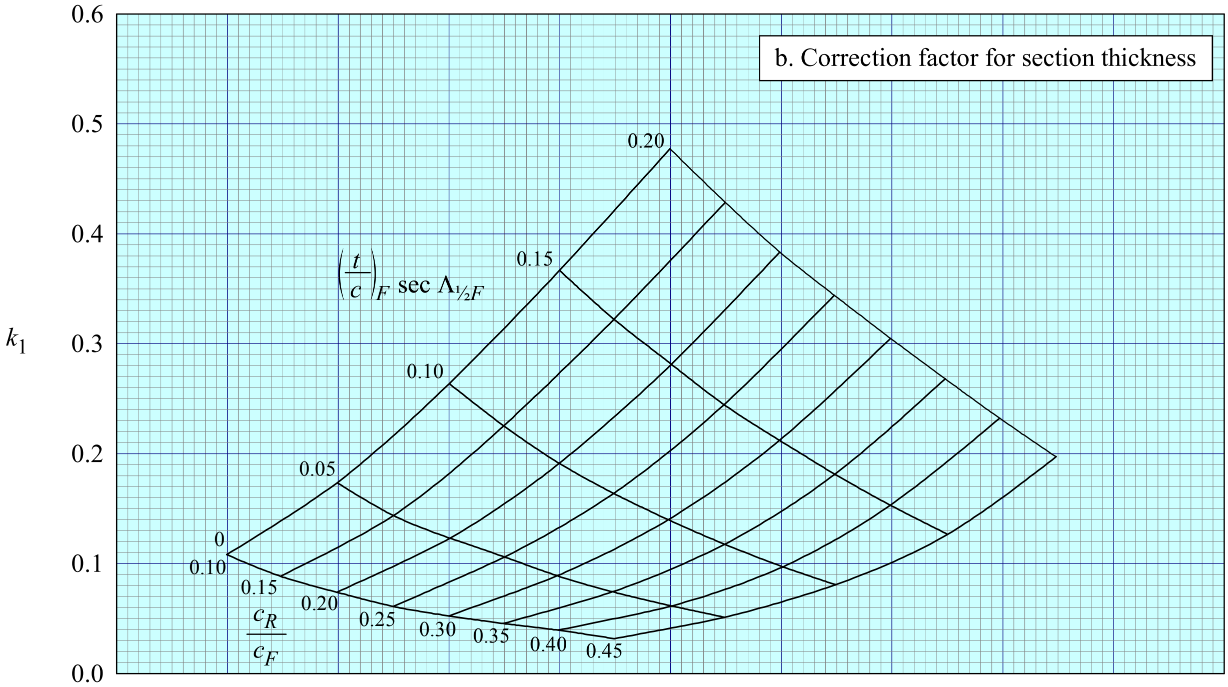


FIGURE 4b

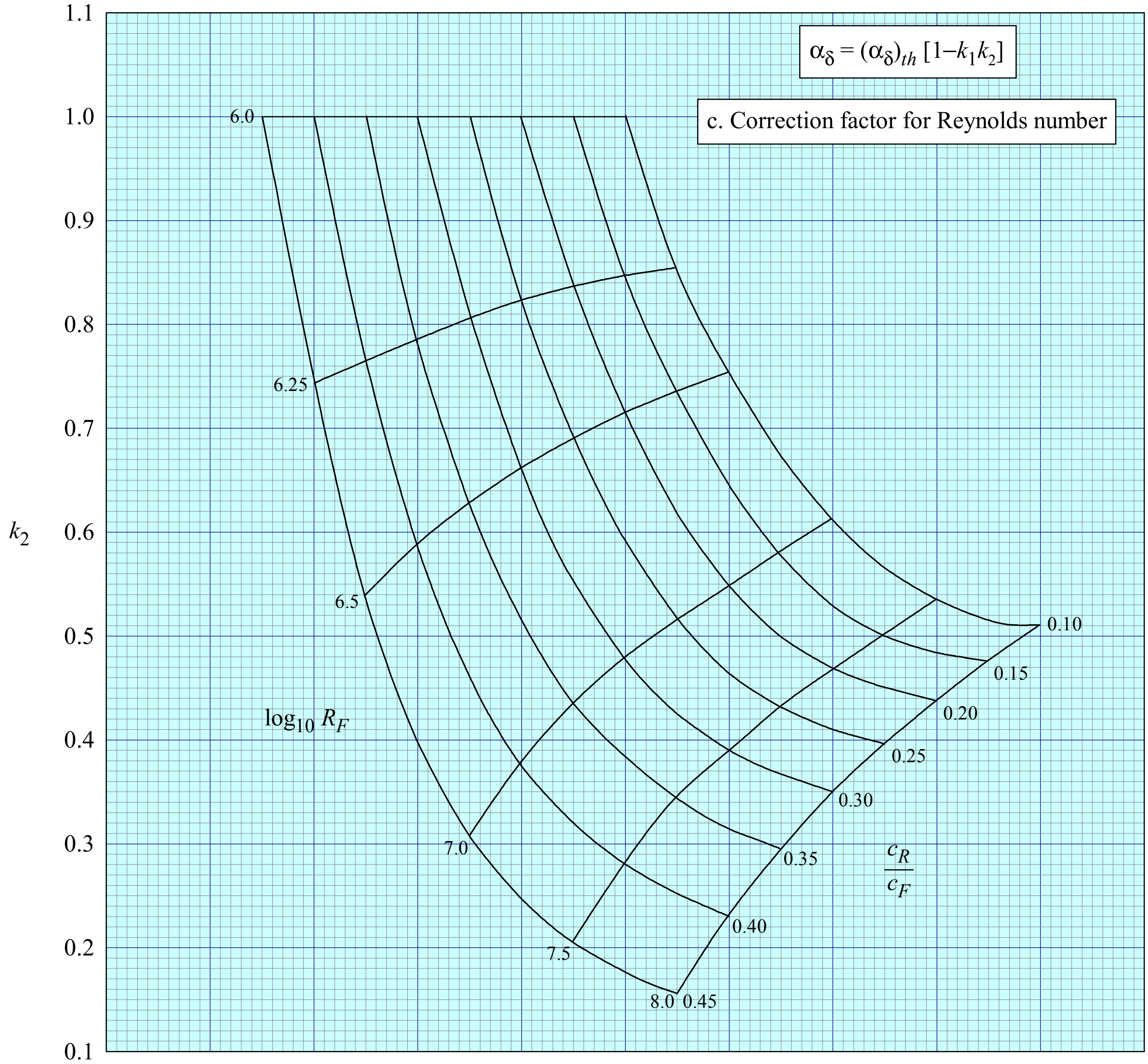
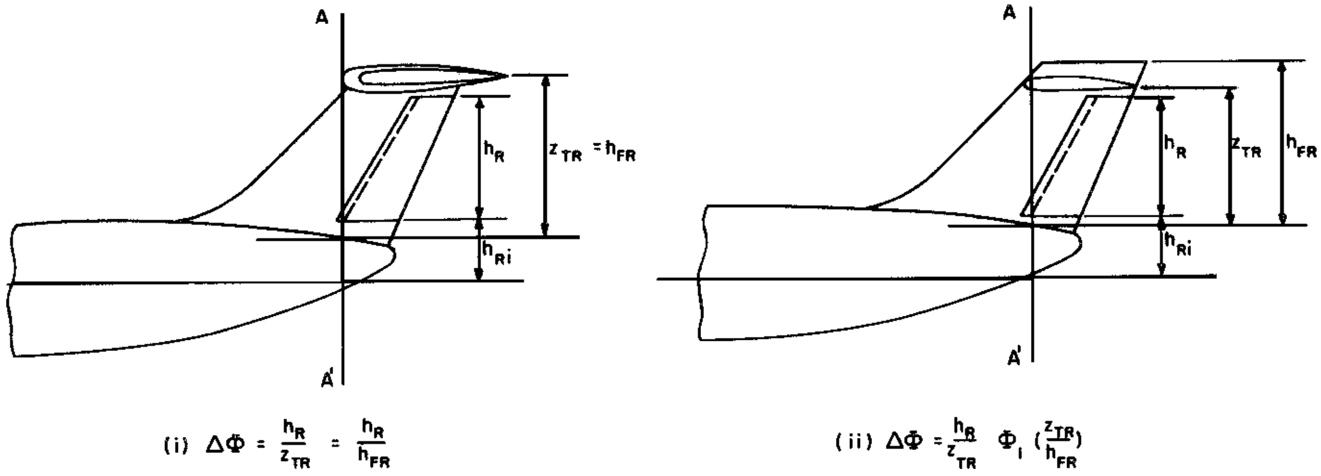


FIGURE 4c



AA' is station defined by inboard end of hinge line

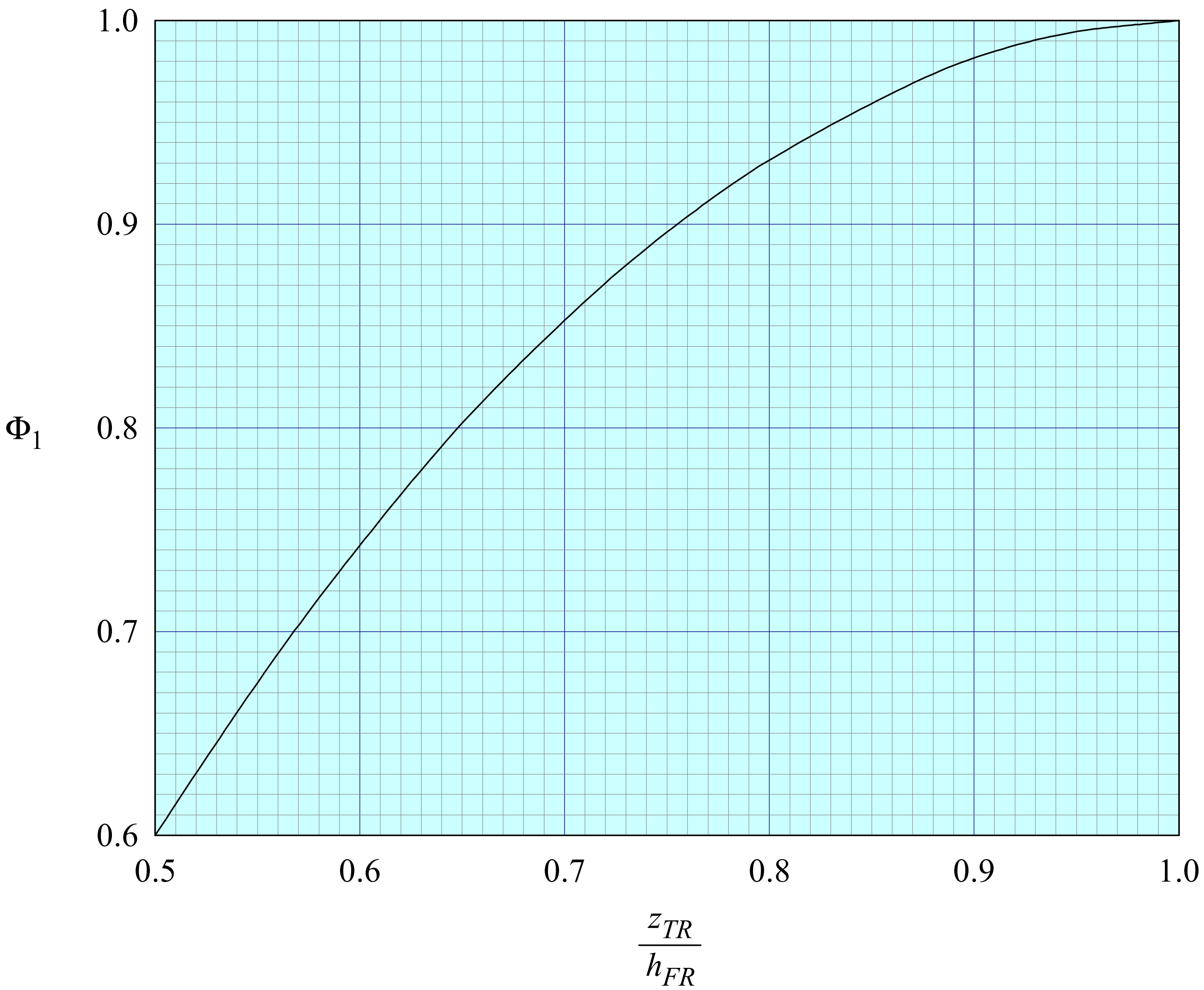
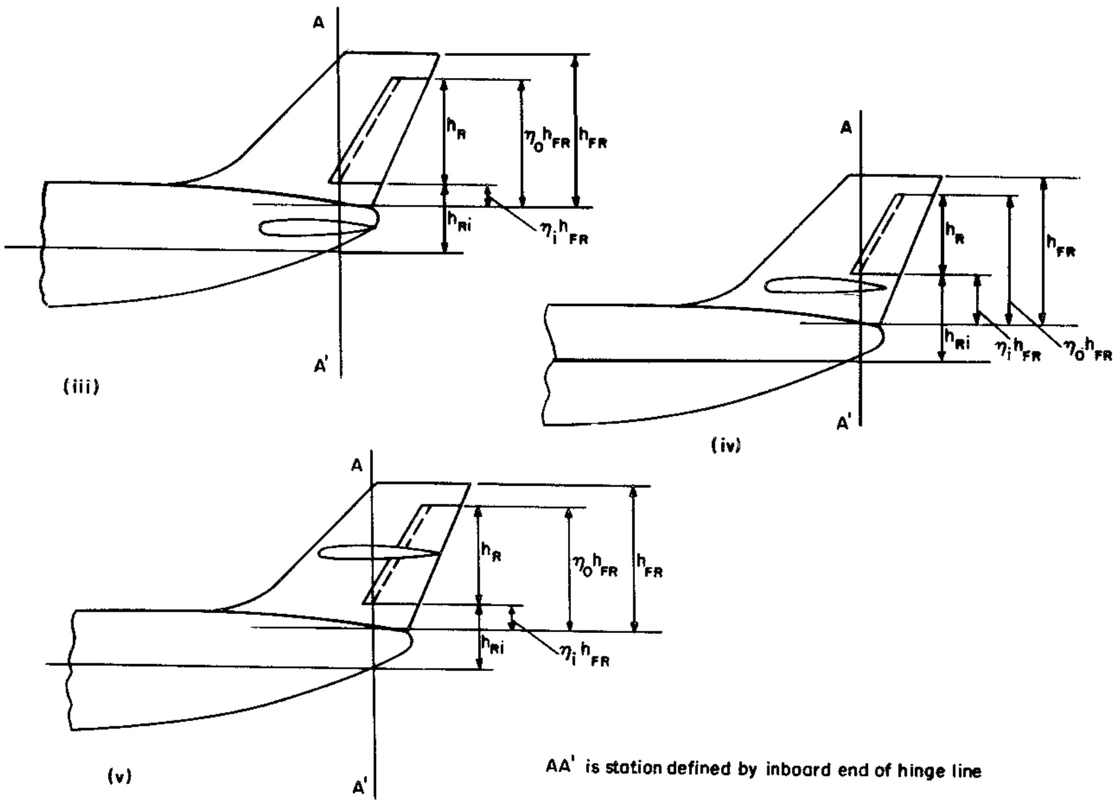


FIGURE 5a PART-SPAN CORRECTION FACTOR $\Delta\Phi$



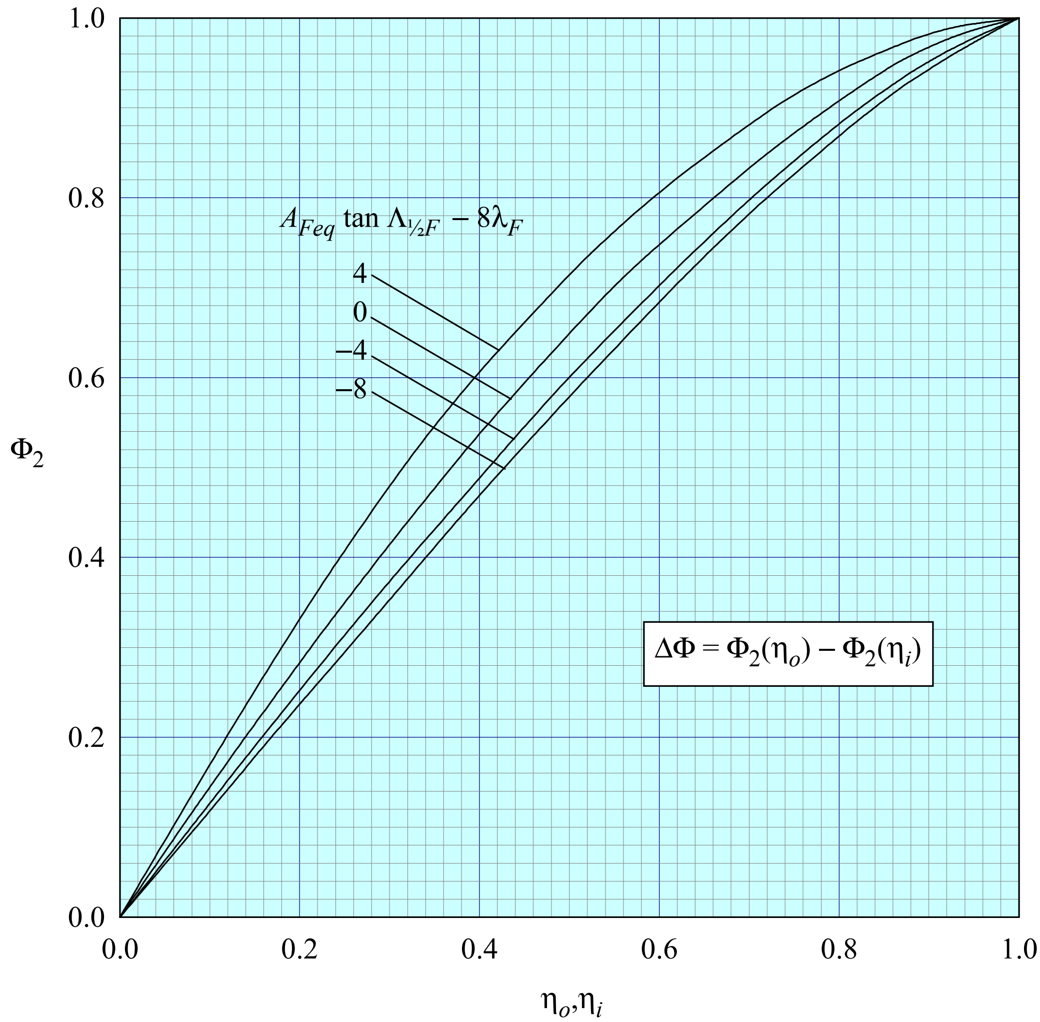
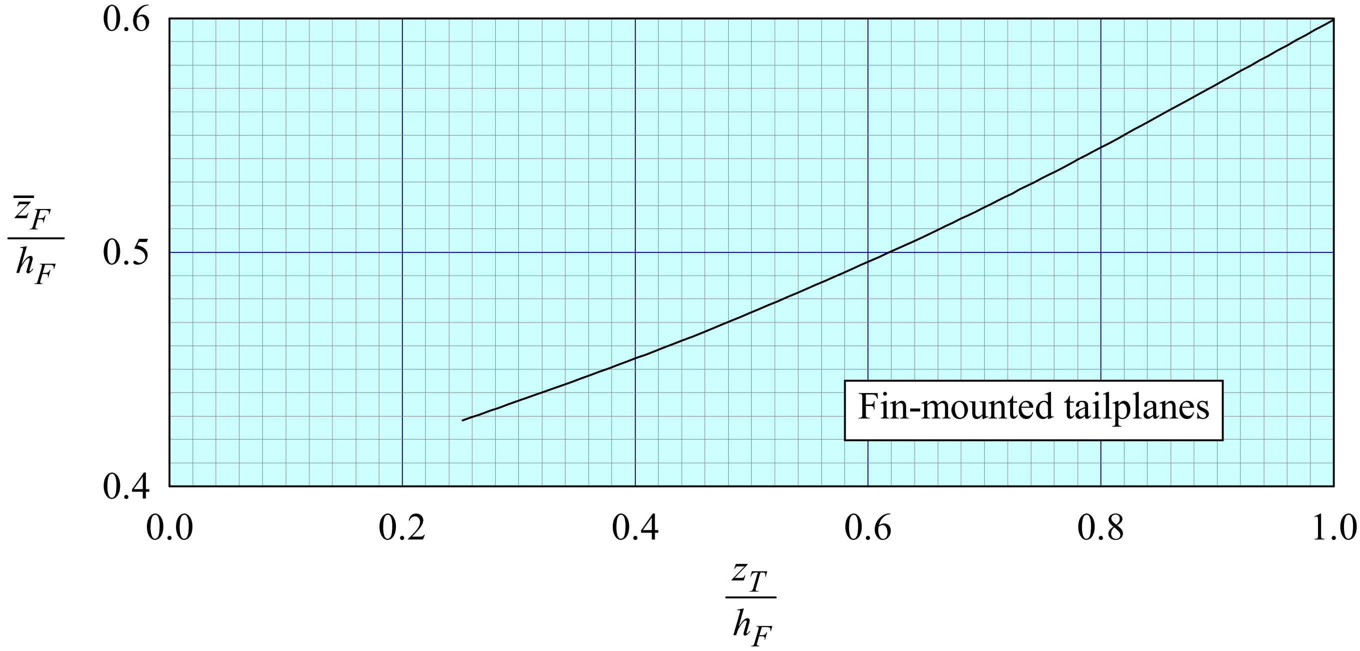


FIGURE 5b PART-SPAN CORRECTION FACTOR ΔΦ



$\frac{\bar{z}_F}{h_F} = 0.4$ for body-mounted tailplanes

FIGURE 6 PARAMETER ALLOWING FOR INFLUENCE OF TAILPLANE POSITION ON LOCATION OF CENTRE OF PRESSURE OF FIN LOAD DUE TO SIDESLIP

APPENDIX A PROGRAM FOR CALCULATION OF RUDDER SIDEFORCE, YAWING MOMENT AND ROLLING MOMENT CONTROL DERIVATIVES AT LOW SPEEDS

The program has been written in "STRICT" Microsoft FORTRAN 77 for use on machines using PC/MS DOS. A diskette containing files for the source code, worked examples and an information file is provided in the Aerodynamics Software Volume. Guidance on copying, compilation and running the program is given in the "Introduction to ESDUpacs" in that volume. However, if any difficulty experienced in using the program please contact ESDU International and we will do all we can to assist in overcoming the problem. The software is also available on CD Rom.

Every reasonable effort has been made to ensure that the program performs the intended calculations satisfactorily. However, in common with all providers of software, ESDU International cannot guarantee the suitability or fitness of the program for any particular purpose and no liability for any loss occasioned by any person as a direct or indirect result of use of the program, whether arising from negligence or otherwise, can be accepted. In no event shall ESDU International or any individuals associated with the development of the program be liable for any damage, including loss of profit or consequential loss, arising out of or in connection with the program.

A1. INTRODUCTION

A computer program, called ESDUpac A8708, has been written by the Computer Products Group of ESDU International to determine rudder sideforce, yawing moment and rolling moment control derivatives at low speeds. The program simply follows the method of Item No. 87008, with the graphical data held in digitised form.

A2. INPUT

Table A2.1 lists the input parameters for the program. It gives their program name, their notation in the Item (unless they are control variables of integer type in the program), and where appropriate refers to the relevant sketches to identify geometric dimensions.

The first three lines of the input allow the user to input text to describe a particular run. The next entry chooses the system of units to be used (British or SI). An entry to identify the tail type follows. This is determined by consulting the diagrams on Figures 5a and 5b to select type (i), (ii), (iii), (iv) or (v). The remaining entries specify the aircraft geometric dimensions, the Reynolds number for the fin, and the angles of attack that are required.

A value must be entered for every variable in Table A2.1, but for each tail type one or more of the variables may not be called up within the program. For example the parameters that define the tailplane height on the fin, z_{TR} and z_T , are unnecessary in the calculation routines for tail type (iii) because the tailplane is mounted on the body. In such cases dummy values (zero for convenience) should be entered at the appropriate places in the input list, as indicated in Table A2.1. If of interest, calculations with the tailplane off can be made by specifying tail type (iii) and entering b_T as zero.

Section A3 gives examples of input files that correspond to the worked examples of Sections 6.1 and 6.2. The outputs that result are shown in Section A4.

TABLE A2.1 *

Variable name in program	*Notation in Item (or integer in program)*	*Comments*	*Variable required yes/no if no, enter zero* — *Tail type*				
			(i)	(ii)	(iii)	(iv)	(v)
CHAR 1		Three lines of text to describe run†	YES	YES	YES	YES	YES
CHAR 2	–		YES	YES	YES	YES	YES
CHAR 3	–		YES	YES	YES	YES	YES
UNITS	(INTEGER)	Enter 1, for British units (ft, slug, s) or 2 for SI units (m, kg, s)	YES	YES	YES	YES	YES
TAIL	(INTEGER)	Enter 1, 2, 3, 4 or 5 according to tail type (i), (ii), (iii), (iv) or (v) shown in Figures 5a and 5b	YES	YES	YES	YES	YES
SW	S_w	Aircraft reference dimensions	YES	YES	YES	YES	YES
B	b		YES	YES	YES	YES	YES
CF	c_F	See Sketch 1.2 for geometry of fin-mounted tailplanes (tail types (i), (ii), (iv) and (v)) or Sketch 1.3 for geometry of body-mounted tailplanes (tail type (iii)). Note that the program requires $50(t/c)_F \le \tau_F \le 150(t/c)_F$, see Section 3.2.	YES	YES	YES	YES	YES
CR	c_R		YES	YES	YES	YES	YES
TCF	$(t/c)_F$		YES	YES	YES	YES	YES
TAUF	τ_F		YES	YES	YES	YES	YES
RF	R_F		YES	YES	YES	YES	YES
HR	h_R		YES	YES	YES	YES	YES
HRI	h_{Ri}		YES	YES	YES	YES	YES
HFR	h_{FR}		YES	YES	YES	YES	YES
HBR	h_{BR}		YES	YES	YES	YES	YES
DBR	d_{BR}		YES	YES	YES	YES	YES
ZTR	z_{TR}		YES	YES	NO	YES	YES
MF	m_F		YES	YES	YES	YES	YES
CRF	c_{rF}		YES	YES	YES	YES	YES
CTF	c_{tF}		YES	YES	YES	YES	YES
LQF	$\Lambda_{1/4F}$		YES	YES	YES	YES	YES
HF	h_F		YES	YES	YES	YES	YES
HBF	h_{BF}		NO	NO	YES	NO	NO
ZT	z_T		YES	YES	NO	YES	YES
BT	b_T		YES	YES	YES	YES	YES
EIHFR	$\eta_i h_{FR}$	See Figure 5b	NO	NO	YES	YES	YES
EOHFR	$\eta_o h_{FR}$		NO	NO	YES	YES	YES
IANG	(INTEGER)	Number of angles of attack, up to a maximum of 20	YES	YES	YES	YES	YES
ALPHA (1)	a	Values of angles (degrees)	YES	YES	YES	YES	YES
:	:		:	:	:	:	:
ALPHA (N)	a		YES	YES	YES	YES	YES

* Formerly Table A.1, and error messages from the program will use the earlier table number.

† Each line may contain 72 characters and must end with a carriage return. The text is written on the output file. A blank line must be entered if no text is available.

A3. EXAMPLES OF INPUT

(i) INPUT FOR EXAMPLE 1 IN SECTION 6.1

```
EXAMPLE 1 IN APPENDIX A, ( INPUT FILE I01A8708, OUTPUT FILE R01A8708 )
DATA FOR INPUT IN EXAMPLE 1 OF SECTION 6.1 OF ITEM No. 87008

2
2
200.0
40.0
5.93
1.98
0.10
10
1e7
5.06
1.41
6.38
1.71
1.68
5.48
13.0
7.33
4.09
40.0
5.92
0.0
5.02
16.92
0.0
0.0
1
2.0
```

(ii) INPUT FOR EXAMPLE 2 IN SECTION 6.2

```
EXAMPLE 2 IN APPENDIX A, ( INPUT FILE I02A8708, OUTPUT FILE R02A8708 )
DATA FOR INPUT IN EXAMPLE 2 OF SECTION 6.2 OF ITEM No. 87008

2
3
200.0
40.0
5.22
1.72
0.10
10
1e7
7.61
1.98
8.14
1.71
1.68
0.0
13.0
7.33
3.0
40.0
7.74
3.53
```

```
0.0
16.92
0.53
8.14
1
2.0
```

A4. EXAMPLES OF OUTPUT

(i) OUTPUT FOR EXAMPLE 1 IN SECTION 6.1

```
---------------------------------------------------------------------------
ESDU International Plc

PROGRAM A8708

ESDUpac Number:   A8708
ESDUpac Title:    Rudder sideforce, yawing moment and rolling moment
                  control derivatives at low speeds
Data Item Number: 87008
Data Item Title:  Rudder sideforce, yawing moment and rolling moment
                  control derivatives at low speeds : YZETA, NZETA and LZETA
ESDUpac Version:  1.2 October 1992 -- Data Item Amendment E
(See Data Item for full input/output specification and interpretation)
---------------------------------------------------------------------------

EXAMPLE 1 IN APPENDIX A, ( INPUT FILE I01A8708, OUTPUT FILE R01A8708 )
DATA FOR INPUT IN EXAMPLE 1 OF SECTION 6.1 OF ITEM No. 87008




FOR EXPLANATION OF INPUT SEE APPENDIX A OF DATA ITEM NO. 87008

S.I. UNITS (m, kg, s) ARE USED

TAIL IS OF TYPE SHOWN IN Fig 5(ii)

WING PLANFORM AREA............................SW = .200E+03
TOTAL WING SPAN................................B = .400E+02
FIN CHORD AT MID-SPAN OF RUDDER...............CF = .593E+01
RUDDER CHORD AFT OF HINGE LINE AT
MID-SPAN OF RUDDER............................CR = .198E+01
THICKNESS TO CHORD RATIO OF FIN SECTION AT
MID SPAN OF RUDDER...........................TCF = .100E+00
TRAILING EDGE ANGLE OF FIN/RUDDER SECTION...TAUF =   10.000
REYNOLDS NUMBER BASED ON CF...................RF = .100E+08
SPANWISE EXTENT OF RUDDER.....................HR = .506E+01
HEIGHT OF INBOARD END OF RUDDER HINGE LINE
ABOVE LONGITUDINAL BODY AXIS PASSING
THROUGH MOMENT REFERENCE POINT...............HRI = .141E+01
HEIGHT OF EXPOSED FIN MEASURED FROM BODY
SURFACE AT STATION AA'.......................HFR = .638E+01
BODY HEIGHT AT STATION AA'...................HBR = .171E+01
BODY WIDTH AT STATION AA'....................DBR = .168E+01
DISTANCE OF TAILPLANE ABOVE BODY SURFACE AT
STATION AA'..................................ZTR = .548E+01
DISTANCE FROM MOMENT REFERENCE POINT TO FIN
ROOT QUARTER CHORD POINT MEASURED PARALLEL
TO LONGITUDINAL BODY AXIS.....................MF = .130E+02
```

```
FIN ROOT CHORD..............................CRF = .733E+01
FIN TIP CHORD...............................CTF = .409E+01
FIN QUARTER CHORD SWEEP ANGLE.........Lambda1/4F = .400E+02
HEIGHT OF EXPOSED FIN MEASURED FROM BODY
SURFACE AT STATION BB'.......................HF = .592E+01
HEIGHT OF TAILPLANE ABOVE FIN ROOT-CHORD......ZT = .502E+01
TOTAL TAILPLANE SPAN.........................BT = .169E+02
----------------------------------------------------------------------------

ANGLE OF ATTACK                           ALPHA = .200E+01 DEG

SIDEFORCE DERIVATIVE DUE TO RUDDER DEFLECTION
                                          YZETA = .261E+00 RAD-1
YAWING MOMENT DERIVATIVE DUE TO RUDDER DEFLECTION
                                          NZETA =-.108E+00 RAD-1
ROLLING MOMENT DERIVATIVE DUE TO RUDDER DEFLECTION
                                          LZETA = .219E-01 RAD-1
----------------------------------------------------------------------------
```

(ii) OUTPUT FOR EXAMPLE 2 IN SECTION 6.2

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ESDU International Plc

PROGRAM A8708

ESDUpac Number:   A8708
ESDUpac Title:    Rudder sideforce, yawing moment and rolling moment
                  control derivatives at low speeds
Data Item Number: 87008
Data Item Title:  Rudder sideforce, yawing moment and rolling moment
                  control derivatives at low speeds : YZETA, NZETA and LZETA
ESDUpac Version:  1.2 October 1992 -- Data Item Amendment E
(See Data Item for full input/output specification and interpretation)
----------------------------------------------------------------------------

EXAMPLE 2 IN APPENDIX A, ( INPUT FILE I02A8708, OUTPUT FILE R02A8708 )
DATA FOR INPUT IN EXAMPLE 2 OF SECTION 6.2 OF ITEM No. 87008




FOR EXPLANATION OF INPUT SEE APPENDIX A OF DATA ITEM NO. 87008

S.I. UNITS (m, kg, s) ARE USED

TAIL IS OF TYPE SHOWN IN Fig 5(iii)

WING PLANFORM AREA...........................SW = .200E+03
TOTAL WING SPAN...............................B = .400E+02
FIN CHORD AT MID-SPAN OF RUDDER..............CF = .522E+01
RUDDER CHORD AFT OF HINGE LINE AT
MID-SPAN OF RUDDER...........................CR = .172E+01
THICKNESS TO CHORD RATIO OF FIN SECTION AT
MID SPAN OF RUDDER..........................TCF = .100E+00
TRAILING EDGE ANGLE OF FIN/RUDDER SECTION...TAUF =   10.000
REYNOLDS NUMBER BASED ON CF..................RF = .100E+08
SPANWISE EXTENT OF RUDDER....................HR = .761E+01
HEIGHT OF INBOARD END OF RUDDER HINGE LINE
ABOVE LONGITUDINAL BODY AXIS PASSING
THROUGH MOMENT REFERENCE POINT..............HRI = .198E+01
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HEIGHT OF EXPOSED FIN MEASURED FROM BODY
SURFACE AT STATION AA'.......................HFR = .814E+01
BODY HEIGHT AT STATION AA'...................HBR = .171E+01
BODY WIDTH AT STATION AA'....................DBR = .168E+01
DISTANCE FROM MOMENT REFERENCE POINT TO FIN
ROOT QUARTER CHORD POINT MEASURED PARALLEL
TO LONGITUDINAL BODY AXIS.....................MF = .130E+02
FIN ROOT CHORD...............................CRF = .733E+01
FIN TIP CHORD................................CTF = .300E+01
FIN QUARTER CHORD SWEEP ANGLE.........Lambda1/4F = .400E+02
HEIGHT OF EXPOSED FIN MEASURED FROM BODY
SURFACE AT STATION BB'........................HF = .774E+01
BODY HEIGHT AT STATION BB'...................HBF = .353E+01
TOTAL TAILPLANE SPAN..........................BT = .169E+02
INBOARD LIMIT OF RUDDER.....................EIHFR = .530E+00
OUTBOARD LIMIT OF RUDDER...................EOHFR = .814E+01
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ANGLE OF ATTACK                           ALPHA = .200E+01 DEG

SIDEFORCE DERIVATIVE DUE TO RUDDER DEFLECTION
                                          YZETA = .294E+00 RAD-1
YAWING MOMENT DERIVATIVE DUE TO RUDDER DEFLECTION
                                          NZETA =-.120E+00 RAD-1
ROLLING MOMENT DERIVATIVE DUE TO RUDDER DEFLECTION
                                          LZETA = .328E-01 RAD-1
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THE PREPARATION OF THIS DATA ITEM

The work on this particular Item was monitored and guided by the Aerodynamics Committee which first met in 1942 and now has the following membership:

Chairman
Mr H.C. Garner – Independent

Vice-Chairman
Mr P.K. Jones – British Aerospace Regional Aircraft Ltd, Woodford

Members
Mr G.E. Bean* – Boeing Aerospace Company, Seattle, Wash., USA
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Mr A.E. Sewell* – McDonnell Douglas, Long Beach, Calif., USA
Mr M.R. Smith – British Aerospace Airbus Ltd, Bristol
Miss J. Willaume – Aérospatiale, Toulouse, France.

* Corresponding Member

The technical work in the assessment of the available information and the construction and subsequent development of the Data Item was carried out by

Mr R.W. Gilbey – Senior Engineer.