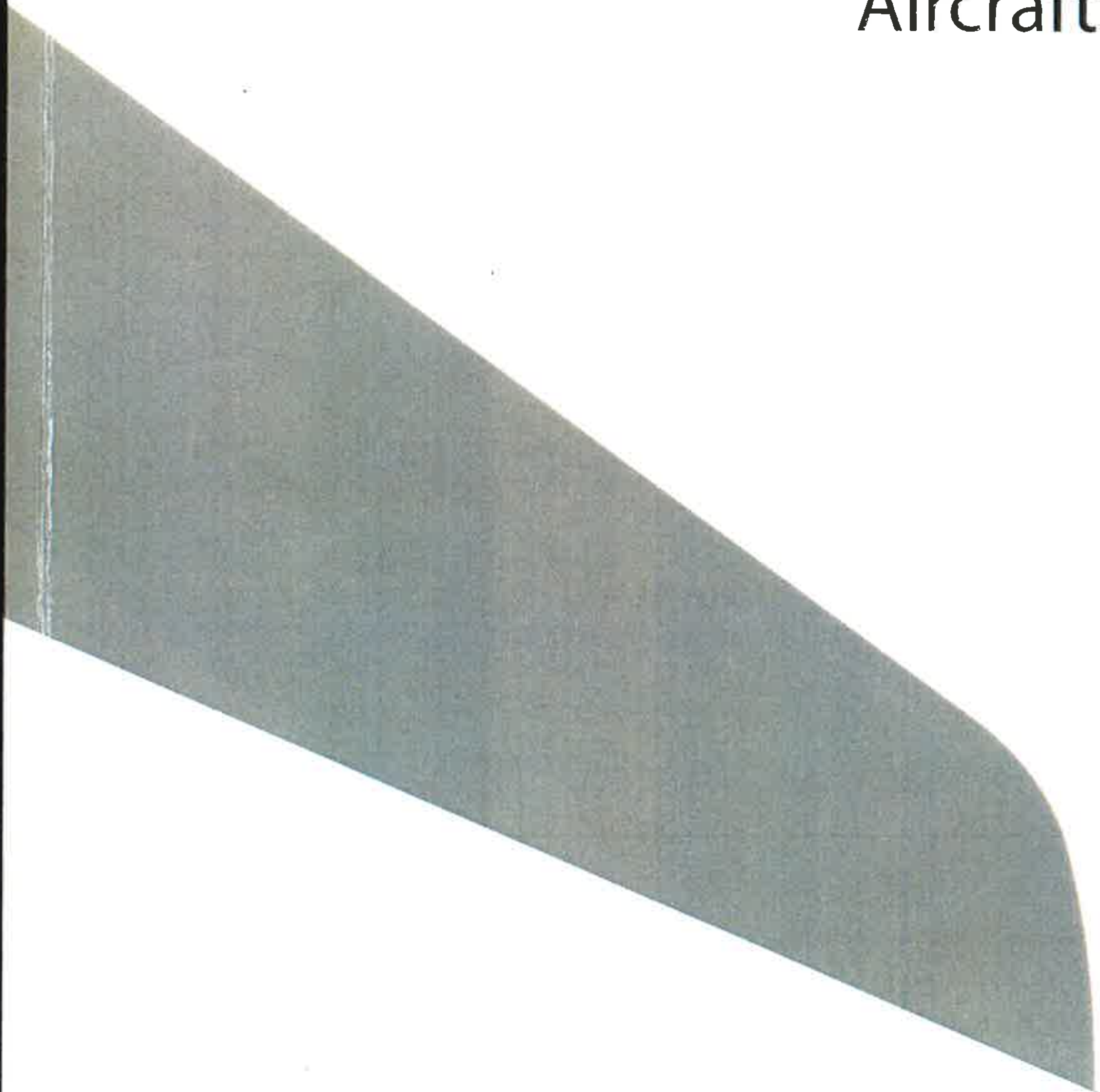
Lesson 18 part 2
Directional Stability

Aerodynamic Design of Transport Aircraft



Ed Obert

The newest generation of large transport aircraft has irreversible control systems and no aerodynamic balance on the control surfaces (except the Boeing 737 family) to minimise drag. However for small propeller aircraft, business jets and the new class of Very Light Jets (VLJ's) manual control systems with aerodynamic balance on the control surfaces will still remain attractive.

The type of aerodynamic balance on control surfaces has a large effect on the linearity of the hinge moment coefficient vs. angle-of-attack and vs. control surface deflection.

$$C_h = C_{h_0} + \frac{\partial C_h}{\partial \alpha}\alpha + \frac{\partial C_h}{\partial \delta}\delta \qquad \text{(seldom applies at large angles)}$$

Linearity of the hinge-moment relations is particularly important for rudders because the rudder may be deflected to its maximum angle both to the weather side (during flight with a failed engine) and to the lee side (during side slips and cross-wing take-offs and landings). Non-linearities in hinge moment coefficients may cause large variations in control forces.

Large overhang balances also limit the maximum control surface deflections. If the leading edge of the balance nose protrudes outside the section contour overbalance and control lock may occur.

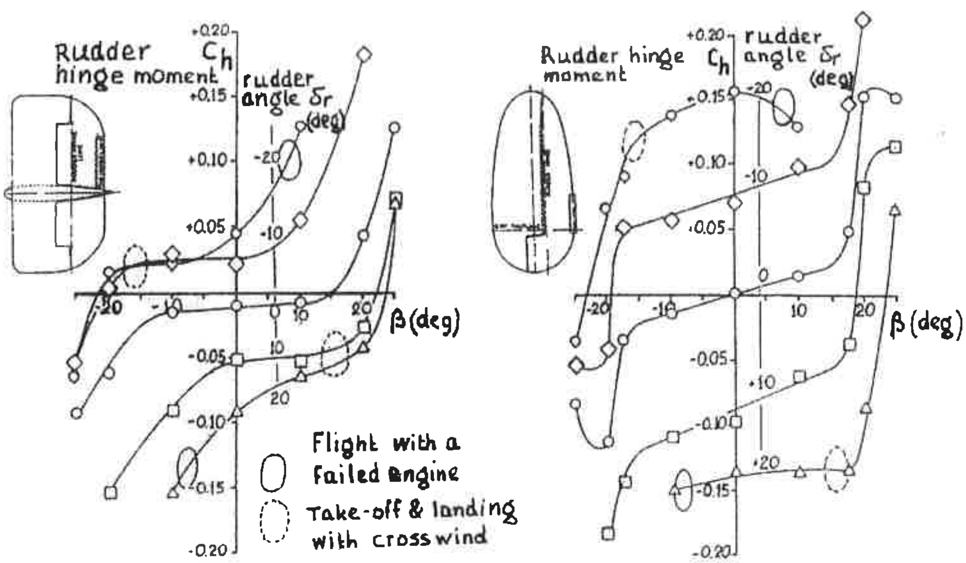


Figure 33.3 - The effect of two types of rudder balancing over the range of rudder hinge moments. Left: Handley-Page Halifax, Right: Avro Lancaster. Source: ARC R&M 2479

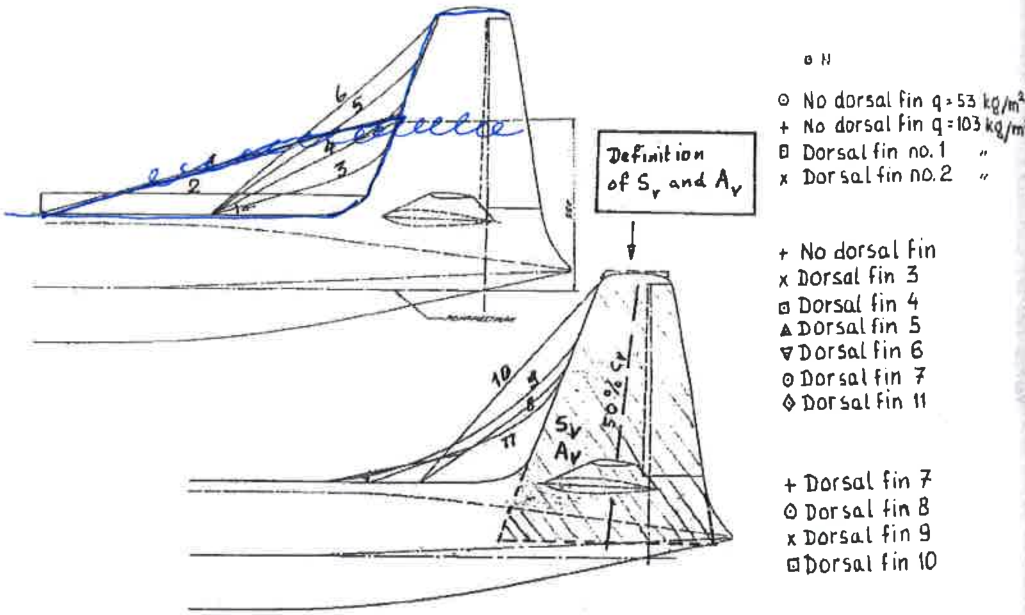


Figure 32.6 - Different dorsal fins. Source: NLL Report A-1374

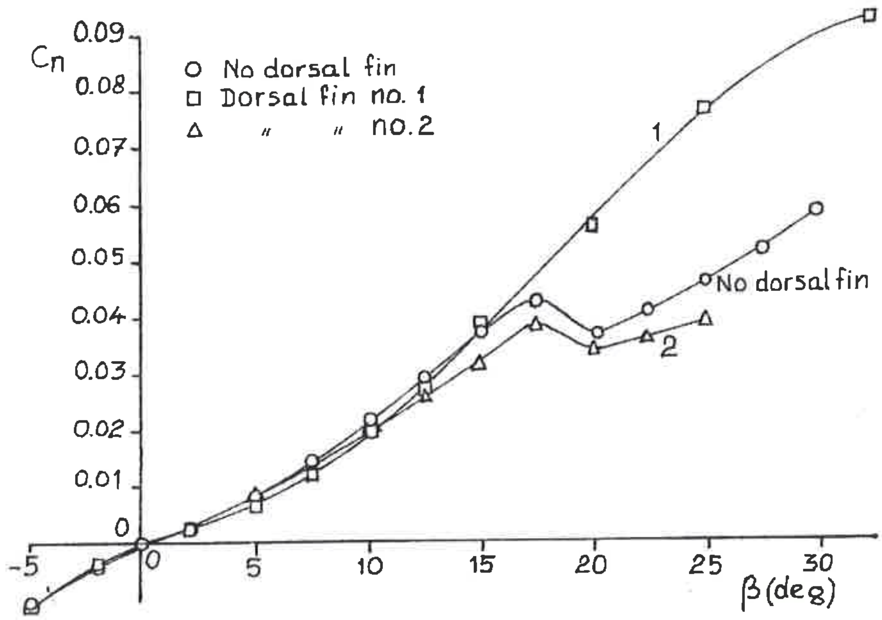


Figure 32.7 - Effect of a dorsal fin on the yawing moment coefficient (1). Source: NLL Report A-1374

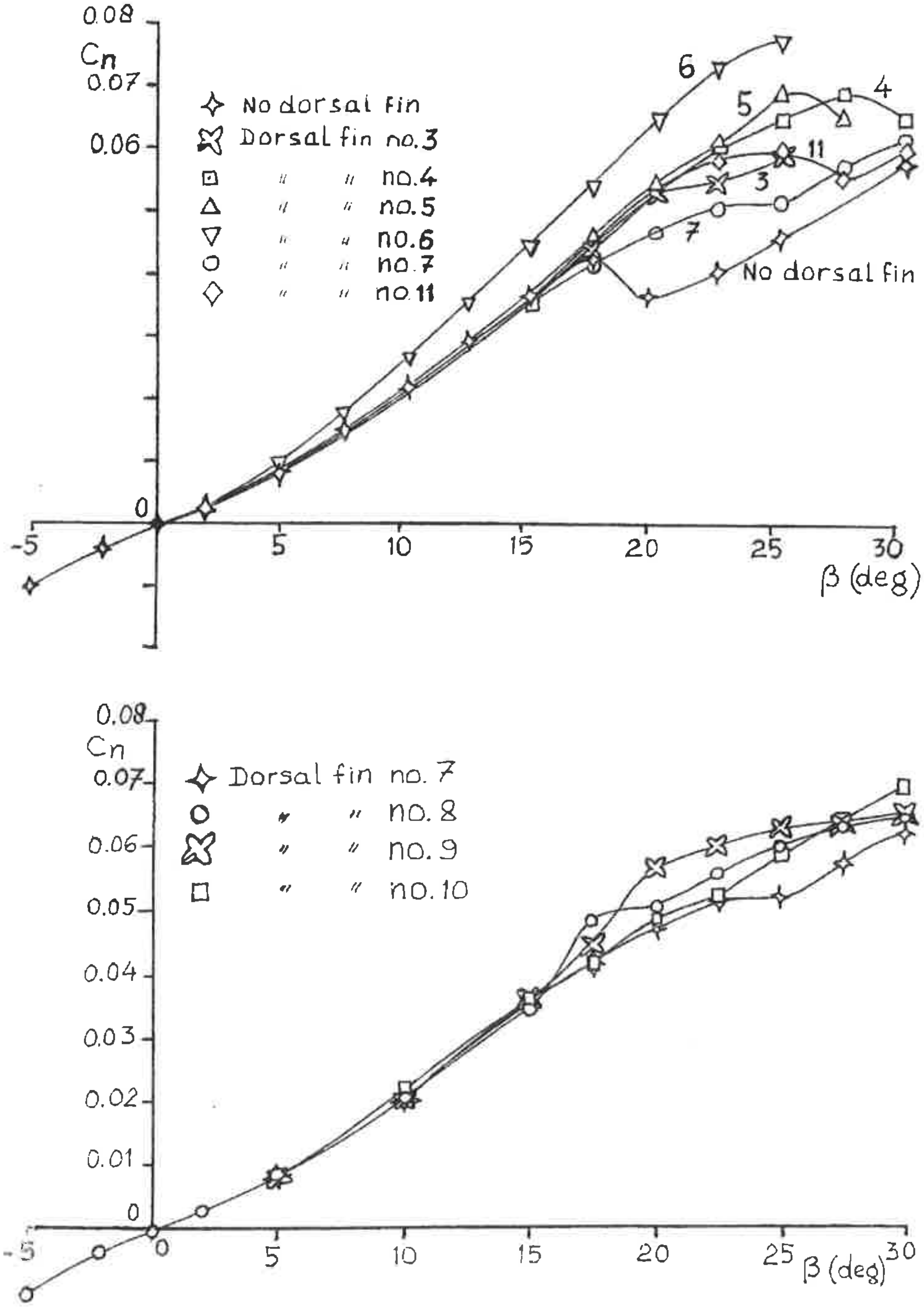
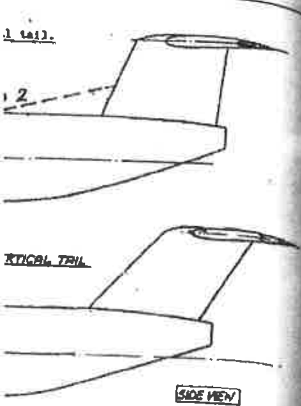


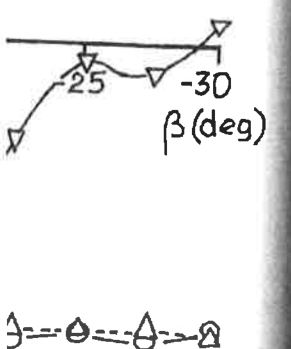
Figure 32.8 - Effect of a dorsal fin on the yawing moment coefficient (2). Source: NLL Report A-1374



...l fin investigated during

...n with a dorsal fin also a ... may produce favourable ...ed by fin no.6 in figure ...hich show test results of ...e differences in leading- ...f the Fokker F-28.

...) angle is presented for ...ns tested. For the linear ...r side-slip angles above ...ng fin sweep or adding a ... yawing moment curve.



NLR Report A-1582

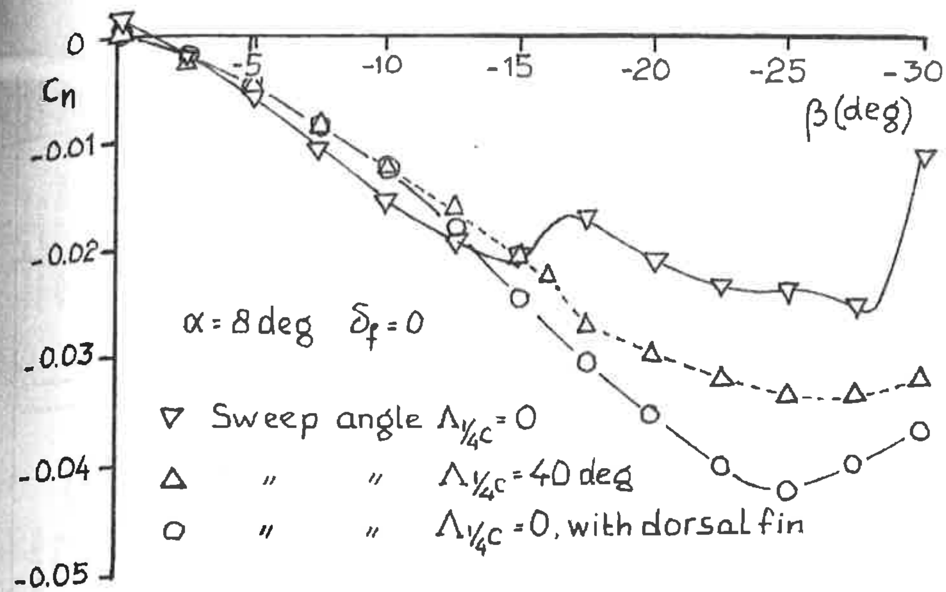


Figure 32.11 - Effect of sweep angle on vertical tailplane lift curve. Source: NLR Report A-1582

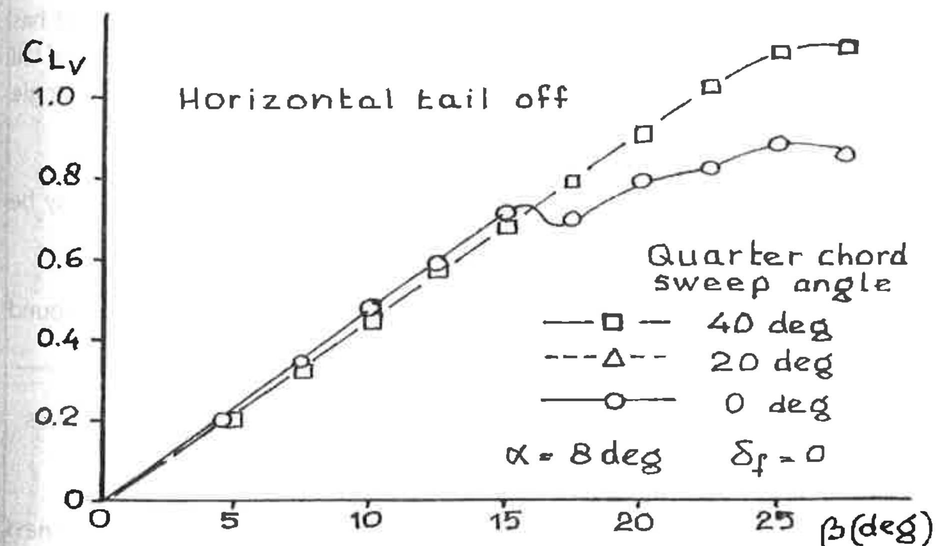


Figure 32.12 - Effect of the sweep angle and of the horizontal tail plane on the lift (side force) of the vertical tailplane in sideslip. Source NLR Report A-1582

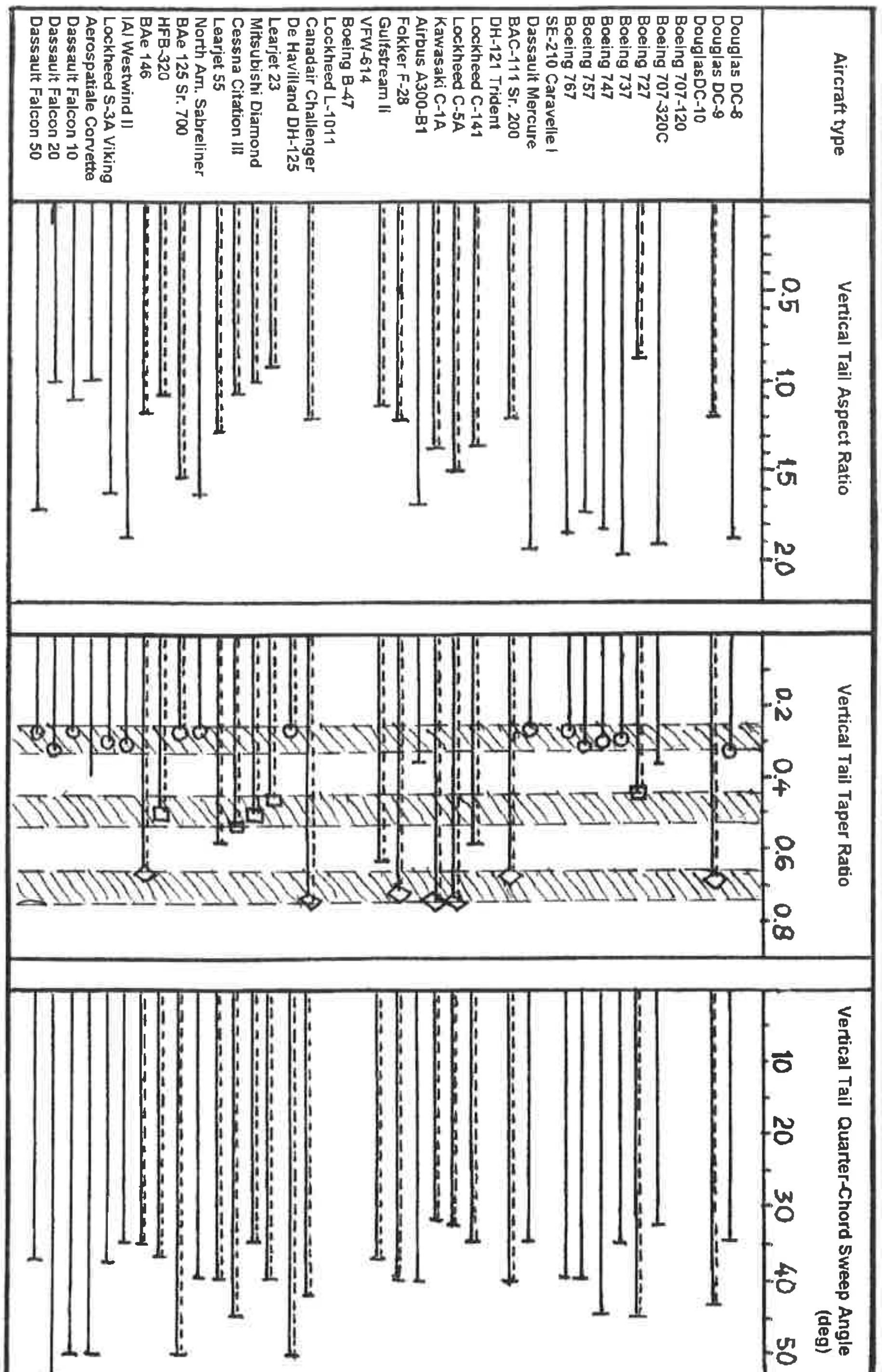


Figure 32.15 - Vertical tailplane data of jet aircraft

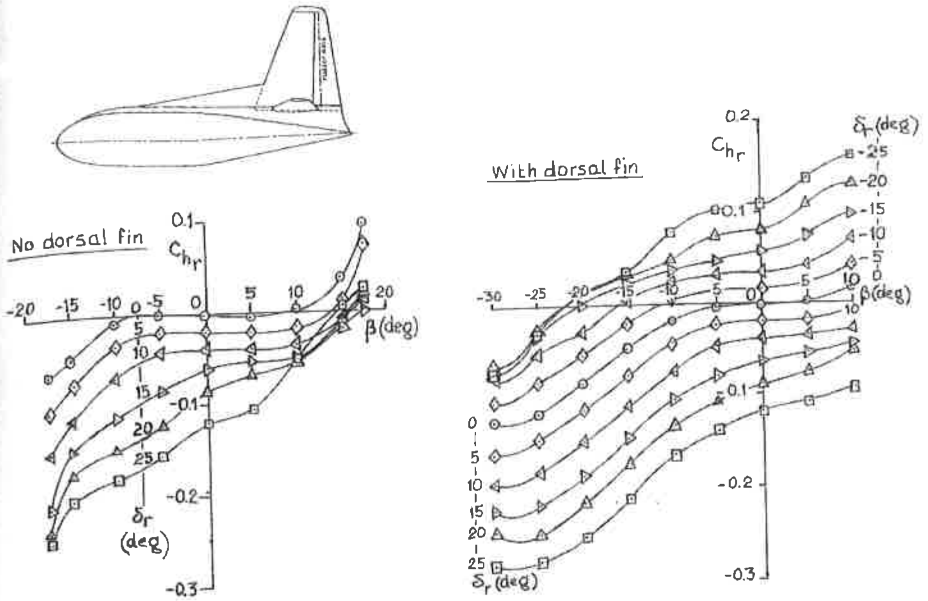


Figure 33.5 - Effect of a dorsal fin on the rudder hinge moment - Fokker F-27. Source: NLL Report A - 1394

Some significant characteristics of elevators were already discussed in chapter 31. Also on horizontal tail surfaces large variations occur in angle-of-attack and control deflection. In particular when some ice accretion is taken into consideration this may heavily influence the choice of primary design parameters for the horizontal tailplane and may also effect the elevator control force characteristics.

Contrary to elevator and rudder, which are attitude controls, ailerons are primarily rate controls. Therefore their effect increases linearly with speed unless compressibility effects or aeroelastic deformation causes a decrease in achievable roll rates. This is illustrated in figures 33.6 and 33.7 where peak roll rates for aileron-alone roll manoeuvres are presented for the Fokker F-28 Mk 1000.

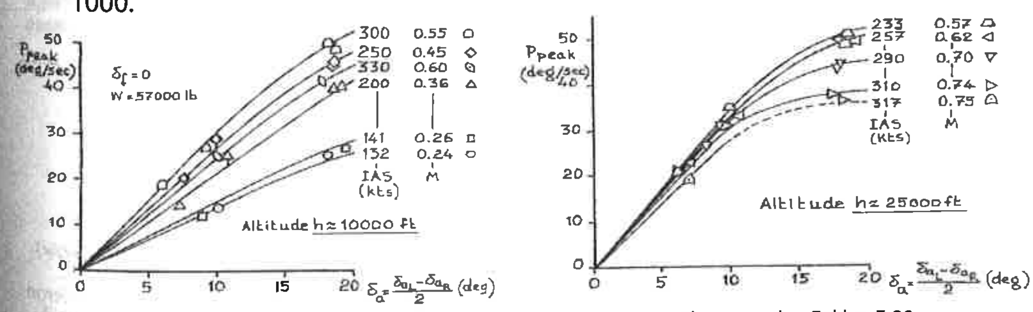
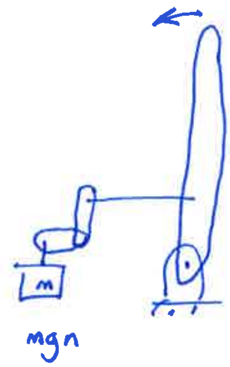
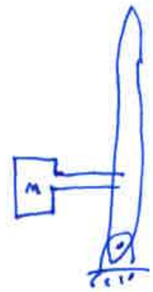


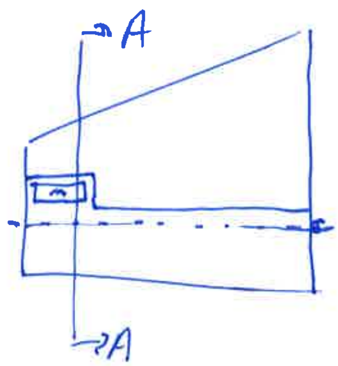
Figure 33.6 - Peak roll rates in aileron-alone roll manoeuvres vs. aileron angle - Fokker F-28. Source: Fokker Report V - 28 – 75.

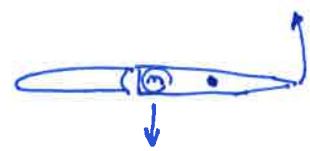
HW 24th

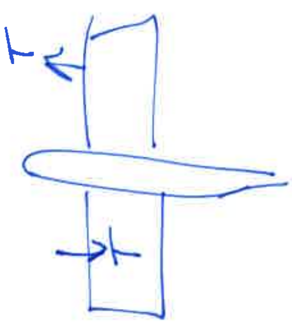
Exm 27th n 29th

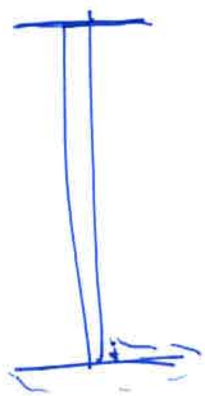


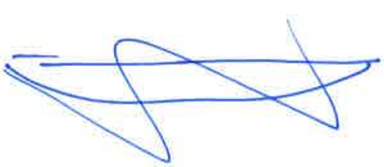


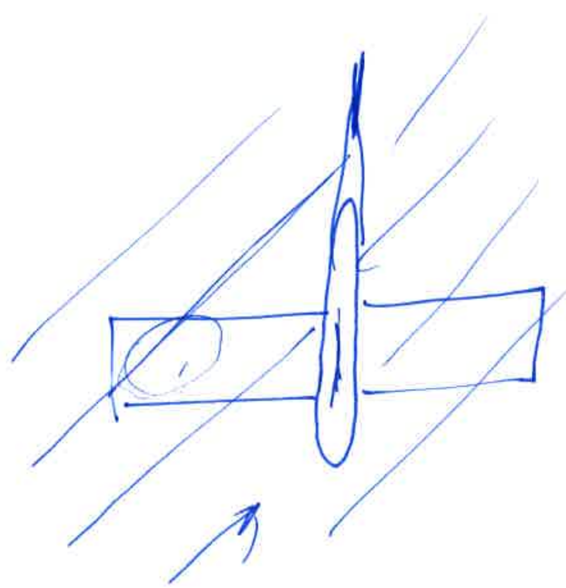




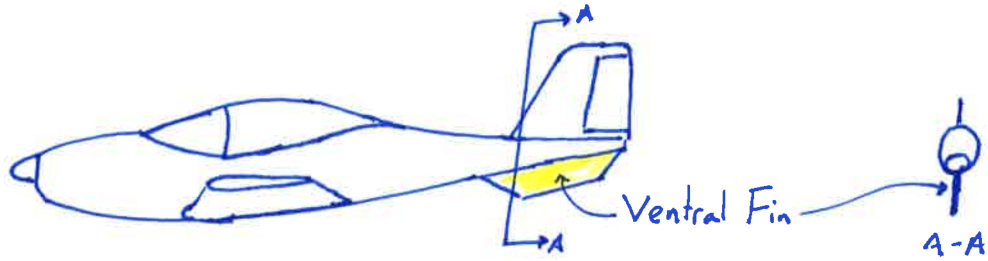








Ventral Fin

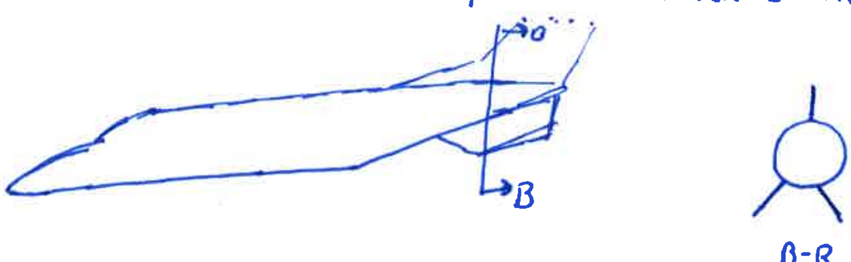


A vertical fin (or two) often seen on the underside of high performance aircraft. Usually the fin appears as a "plate" and is usually not controlled.

The ventral fin is particularly useful for maintaining directional stability at high AOA, when the vertical may be in stalled unsteady wakes. The ventral sticks down into undisturbed air.

Ventral Fins are often limited by tail strike angles on takeoff + landing.
↑ or even integrated into!

The Learjet 60 has an example of twin ventral fins ("Delta fins").



At high AOA, the twin ventrals provide both directional and long' stability.

Servo Tabs

Q: How can a single pilot of a Boeing KC-135 provide enough force to control the 322500 lbf aircraft? Only the rudder has a powered surface!

A: Servo Tabs.

We know that control surfaces are particularly good at generating a hinge moment.

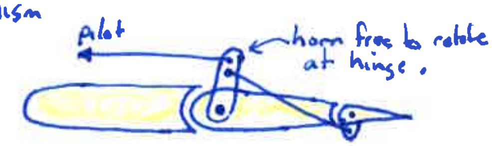
So, the strategy is to add a control tab to the control surface.

The pilot moves the tab, which helps moves the surface.

but area of tab is much smaller than area of control surface

Think of servo tabs as amplifiers.

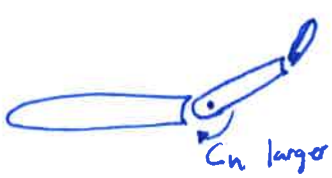
Mechanism



Anti-Servo tabs

Often, the control forces on small aircraft are too small.

An anti-servo tab is added to increase the effective hinge moment.



Mechanism

piper cherokee.

by adjusting this length, the tab acts as both an anti servo tab and a trim tab. Ingenious!