Fleet Longitudinal Stability Analysis Summary

A brief analysis of the longitudinal stability of the Fleet Biplane was conducted using the "equivalent monoplane wing" approach as proposed in textbooks of that era (Von Mises, Warner, Millikan, etc.). In this approach, the airplane is treated as a monoplane, with the wing mean chord and location, aspect ratio, etc. determined by methods outlined in these references. The mean aerodynamic chord was determined as 44.1 in. with the leading edge 12.6 in. forward of the datum (lower wing LE). The aerodynamic center is taken as 23% of the MAC, or 2.5 in. forward of the datum. According to Fleet data, the CG varies from 1.8 in. to 3.1 in. aft of the datum. Dimensions for the tail were somewhat obscure, but measured from the drawings included in the Fleet data. Some error could be introduced from the scaling, but the dimensions should be reasonably accurate.

A balance of forces and moments, using the weight as the value of lift on the wing (neglects additional + or - tail load), was used to determine the necessary load on the tail to trim out the airplane in level flight. Results showed that, at 70 mph, the horizontal tail has a download of 6.5# at aft CG or 19.5# at forward CG. However, when the airplane is slowed down to 50 mph, the tail actually has a positive (upward) load of 24.7# at aft CG, and 11.3# at foreward CG. This result may explain why the horizontal tail has a positively cambered airfoil. It may have been considered more important to improve efficiency at the lower speeds.

The longitudinal static stability was then investigated, using the moment coefficient derivative as the measure of relative stability (change in pitching moment coefficient with angle of attack, or Cm/alpha). A number of approximations were again used in this analysis to determine the terms included in the standard Cm/alpha equation. The results were as follows;

Cm/alpha = -.355 (aft CG)
-.496 (fwd CG)

To compare, values of Cm/alpha at normal loading CG for other aircraft are as follows:

Cherokee 180:	-.828
Cessna 182:	-.900
Learjet:	-.630
F-4 fighter:	-.100

In general, the more negative this number, the more stable the airplane. Usually, the less stable the airplane (less negative value), the more maneuverable it is. Hence, the Fleet is about half as stable as a Cherokee or single-engine Cessna, but four times more than a jet fighter. This is about the result one would expect of an aerobatic biplane.

HCS, 1 May 2004

FLEET LONGITUDINAL STABILITY - REVISED APR 2004

$W_{GROSS} = 1675\#$

$MAC = 44.1''$

$ac = 0.23\ MAC$

$C_{Mac} = -.09$

CG RANGE: $+1.8'' \rightarrow 3.1''$ AFT DATUM

$S_1 = S_2 = 105\ FT^2$

$S_{TOT} = 210\ FT^2$

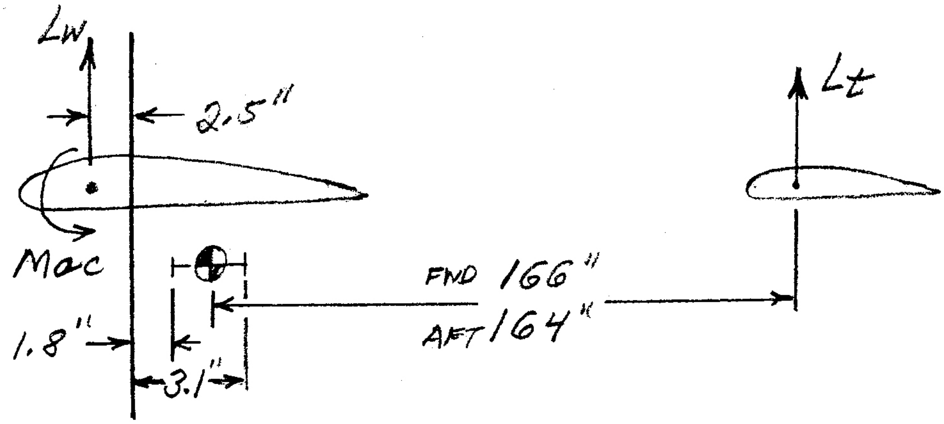
$b_1 = b_2 = 28'$

$AR_{1,2} = 7.5$

$AR_{eq} = 6.0$

$S_t = 24\ FT^2$

USING EQUIVALENT MONOPLANE WING:



TAIL LOAD (L_t)

$$M_{ac} = C_{M_{ac}}\, q\, S\, \bar{c}$$
$$= -.09(210)\,3.675'\, q$$
$$= -69.46\, q \text{ FT\#} = -833.52\, q \text{ IN\#}$$

$$q = \tfrac{1}{2}\rho V^2 = \tfrac{1}{2}(.002377)\left[70(1.467)\right]^2$$
$$= 12.53\ \#/\text{FT}^2 \quad 70\ \text{MPH}$$
$$= 6.39\ \#/\text{FT}^2 \quad 50\ \text{MPH}$$

SUMMING MOMENTS:

$$\Sigma\, MOM_{CG} = L_w(ARM_w) + M_{ac} - L_t(ARM_t)$$

$$L_t = \frac{L_w(ARM) + M_{ac}}{ARM_t}$$

<u>AT AFT CG:</u>

70 MPH: $$L_t = \frac{1675(5.6) - 833.52(12.53)}{164}$$
$$= -\underline{6.5}\ \# \ (\text{DOWN})$$

50 MPH: $$L_t = \frac{1675(5.6) - 833.52(6.39)}{164}$$
$$= \underline{+24.7}\ \# \ (\text{UP})$$

<u>AT FWD CG:</u>

70 MPH: $$L_t = \frac{1675(4.3) - 833.52(12.53)}{166}$$
$$= -\underline{19.53}\ (\text{DOWN})$$

50 MPH: $$L_t = \frac{1675(4.3) - 833.52(6.39)}{166}$$
$$= \underline{+11.3}\ \# \ (\text{UP})$$

LONGITUDINAL STATIC STABILITY

TAIL VOLUME COEFF.:

$b_{TAIL} = 113.5'' = 9.46'$

$S_t = 24\ FT^2 \quad S = 210\ FT^2$

$l_t = 164''$ (AFT CG) $= 166''$ (FWD CG)

$$V_H = \frac{l_t}{\bar{c}}\frac{S_t}{S} = \frac{164}{44.1}\frac{24}{210} = .425 \text{ (AFT)}$$

$$= .430 \text{ (FWD)}$$

LIFT CURVE SLOPE:

$$\left.\begin{aligned} AR_{EQUIV} &= 5.02 \text{ METH 1} \\ &= 6.95 \text{ METH 2} \end{aligned}\right\} = 6.0 \text{ AVER.}$$

$$a_{0_{WING}} = 0.106 \quad a_W = \frac{6}{6+2} a_0 = 0.0795$$

$$a_{0_{TAIL}} = 0.100 \quad AR_t \cong 3.5 \quad a_t = \frac{3.5}{3.5+2} a_{0_t} = 0.0636$$

DOWNWASH FACTOR:

ASSUME MEAN CHORD OF WING IN PLANE OF TAIL

$$l_{ac} = 164 + 3.1 + 2.5 = 169.6 \quad \frac{l_{ac}}{b/2} = \frac{169.6}{14(12)} = 1.01$$

FROM CHART, $\frac{\partial \epsilon}{\partial \alpha} = .40$

SLOPE OF MOMENT VS. ANGLE OF ATTACK:

$$C_{M_\alpha} = a_W(h - h_{ac}) - a_t\left(1 - \frac{\partial \epsilon}{\partial \alpha}\right)V_H$$

$$= .0795\left(\frac{15.74}{44.1} - .23\right) - .0636(1 - .4)(.425)$$

$$= 0.01 - 0.0162 = -.0062/\text{DEGREE}$$

$$= \underline{-.355}/\text{RADIAN}$$

(AFT CG)

$$C_{M\alpha(FWD\ CG)} = a_w(h - h_{ac}) - a_t\left(1 - \frac{\partial\epsilon}{\partial\alpha}\right)V_H$$

$$= .0795\left(\frac{14.44}{44.1} - .23\right) - .0636(1-.4)(.430)$$

$$= .00775 - 0.0164 = -.00866\ /\text{DEG.}$$

$$= \underline{\underline{-.496}}\ /\text{RAD.}$$

$C_{M\alpha}$ RANGE: $-.496 \rightarrow -.355$

TYPICAL $C_{M\alpha}$ AT NORMAL CG:

PA-28: $-.828$

C-182: $-.900$

LEARJET: $-.630$

F-4 : $-.100$