THE CHALLENGE OF FLYING WING DESIGN

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The intent of this paper is to review the state-of-the-art in flying wing glider design, by comparing two prominent types: the Horten IV and the BKB-1, both of which the author has personally flown and evaluated. Based on the experience gained with these models, some thoughts are put forth concerning new designs which could lead to further advances in achieving the long standing promise of the flying wing concept: the ultimate in flight efficiency.

OUTLINE

The main topics of the paper are the following:

- Comparison of design features and technical data of the Horten IV and BKB-1.
- Summary of aerodynamic evaluation of the Horten IV including description of the measurement techniques applied.
- Comments on the performance characteristics of the BKB-1.
- Comparison of flying qualities of the Horten IV and BKB-1.
- Concluding remarks on what future designs may derive from the experience gained with the Horten IV and BKB-1.

CONFIGURATION DESCRIPTION

This section describes the design features of the Horten IV and BKB-1 and includes the following:

1. Comparison of technical data and general layout of several tailless gliders (see Figure 1).

$C_{L_{max}}$ decreased from 1.17 to 1.12

e decreased from 63% to 53%

$(L/D)_{max}$ decreased from 31.5 to 29.5

- The probable reasons for the discrepancies between the DFS and MSU test results are possible differences in the CG locations and surface conditions of the planes tested.

- The major causes of the lower than expected performance were identified as (see Figure 10):

  a) high wing section profile drag which was due to the adverse effects of the control surfaces and rather early transition of the boundary layer (Figure 11)

  b) additional induced drag that resulted from distorted load distributions due to deflection of control surfaces to achieve trim (Figure 12)

  c) flow separation of the back of the canopy (Figure 13)

  d) relatively low $C_{L_{max}}$ of about 1.15

- The aerodynamic efficiency of the Horten IV was apparently severely compromised to achieve good handling characteristics. The static longitudinal stability measurements (see Figures 14 and 15) indicated excessive static margin which resulted in large elevator deflections for trimming. Moving the CG forward improved the handling characteristics but spoiled performance (~~see Figure 14~~). Flying with more aft CG location, however, compromised the directional stability.

PERFORMANCE CHARACTERISTICS OF THE BKB-1

Only estimated performance data are available at this time

COMPARISON OF FLYING QUALITIES

- Both the Horten IV and the BKB-1 are more sensitive to longitudinal control than conventional sailplanes because of the low inertia about the pitch axis inherent with the tailless concept. Between the two, however, the Horten has a less abrupt response to elevator movements.

- Both types experience pitch oscillations under gusty conditions but these are quickly damped and require no corrective action by the pilot.

- Also, both types demonstrate extremely good natured stall characteristics. The Hörten has a slight tendency for phugoid motion near the minimum speed due to the rather high static longitudinal stability margin. Stalling in tight turns is virtually impossible with both planes because of limitation of elevator power.

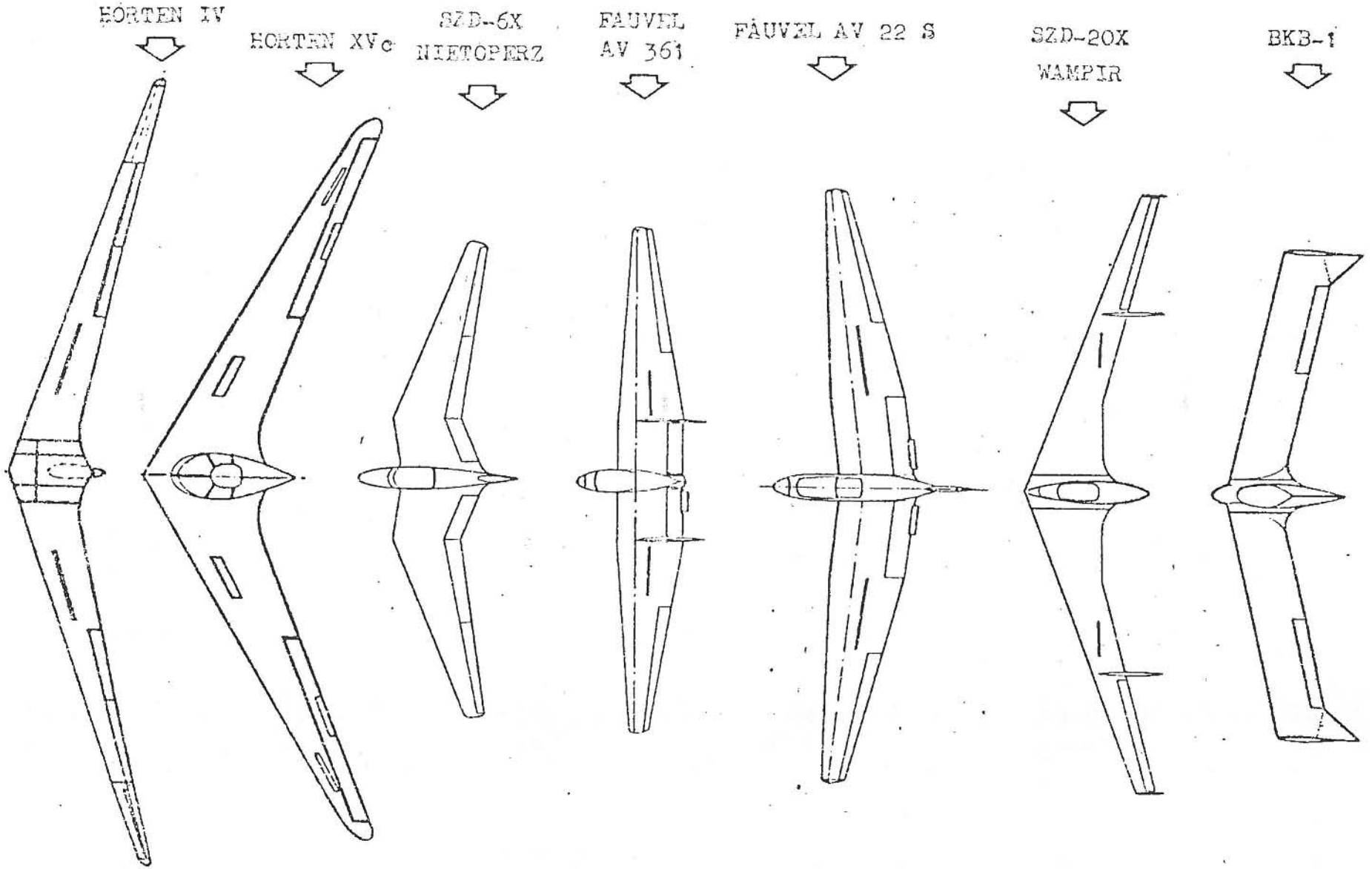
- The lateral-directional control characteristics of the two planes are drastically different. In the case of the Horten IV, the elevon does all. Drag rudders are provided at the wing tip but their use is limited to such occasions when very abrupt changes in flight direction are required. The operation of the rudder is accompanied with a nose down pitch that could be rather unpleasant at take off or landing although it can be corrected by appropriate movement of the elevator. The lateral directional control of the BKB-1, on the other hand, must be done entirely by the wing tip rudder. Deflection of the aileron results in an adverse yawing moment which, particularly in airplane tow, tends to induce lateral-

(sweep-camber-twist) and structurally (aero-isoclinic construction).

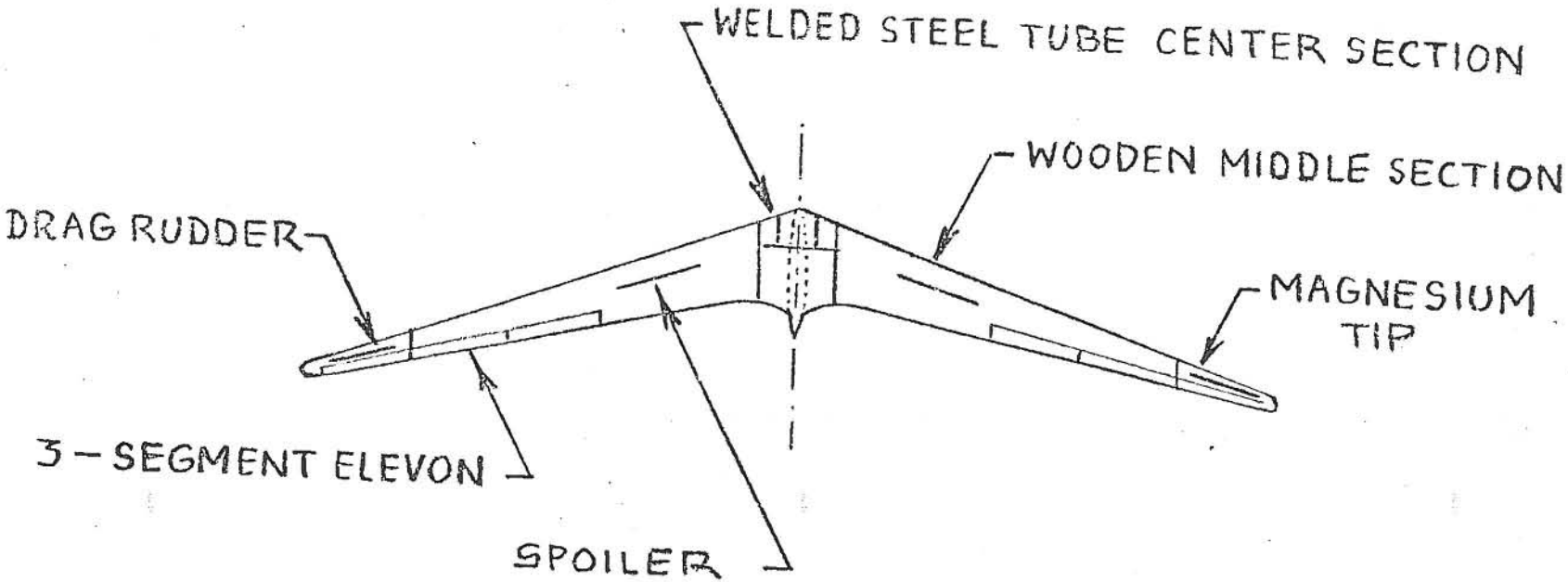
3) Variable sweep to provide trim instead of deflecting the elevon surfaces. Although this may present a difficult design problem, an acceptable solution which is simple, reliable and lightweight, is not out of sight.

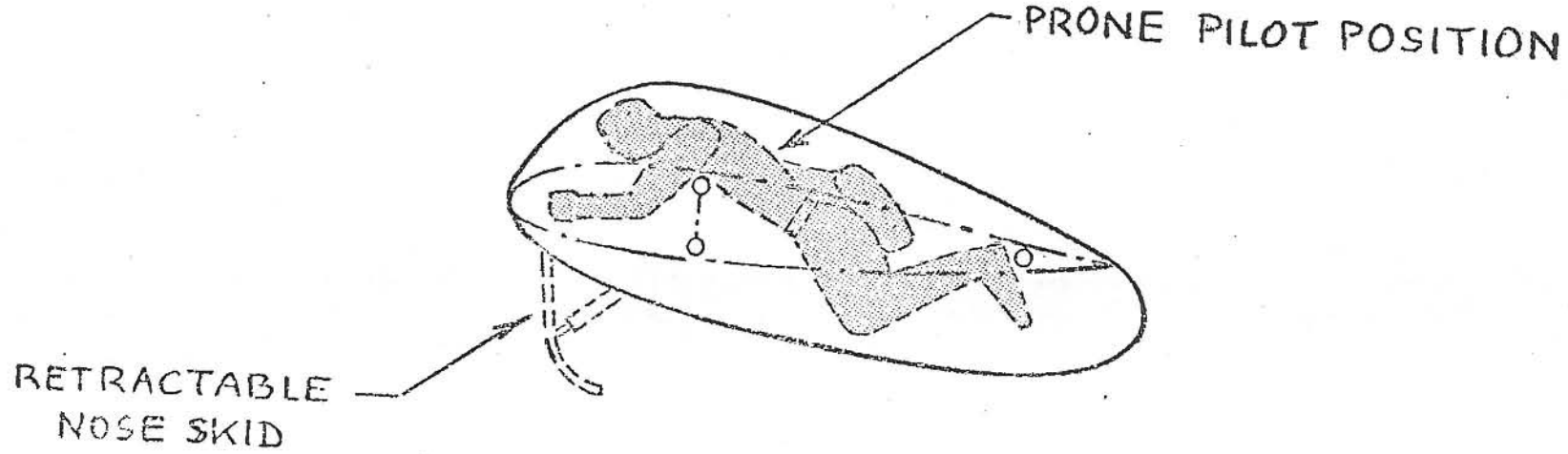
The closing section of the paper will be devoted to discussing such possible future designs in more detail.

TAILLESS GLIDER DESIGNS



HORTEN IV. - DESIGN FEATURES





HORTEN IV. FLIGHT CONTROLS

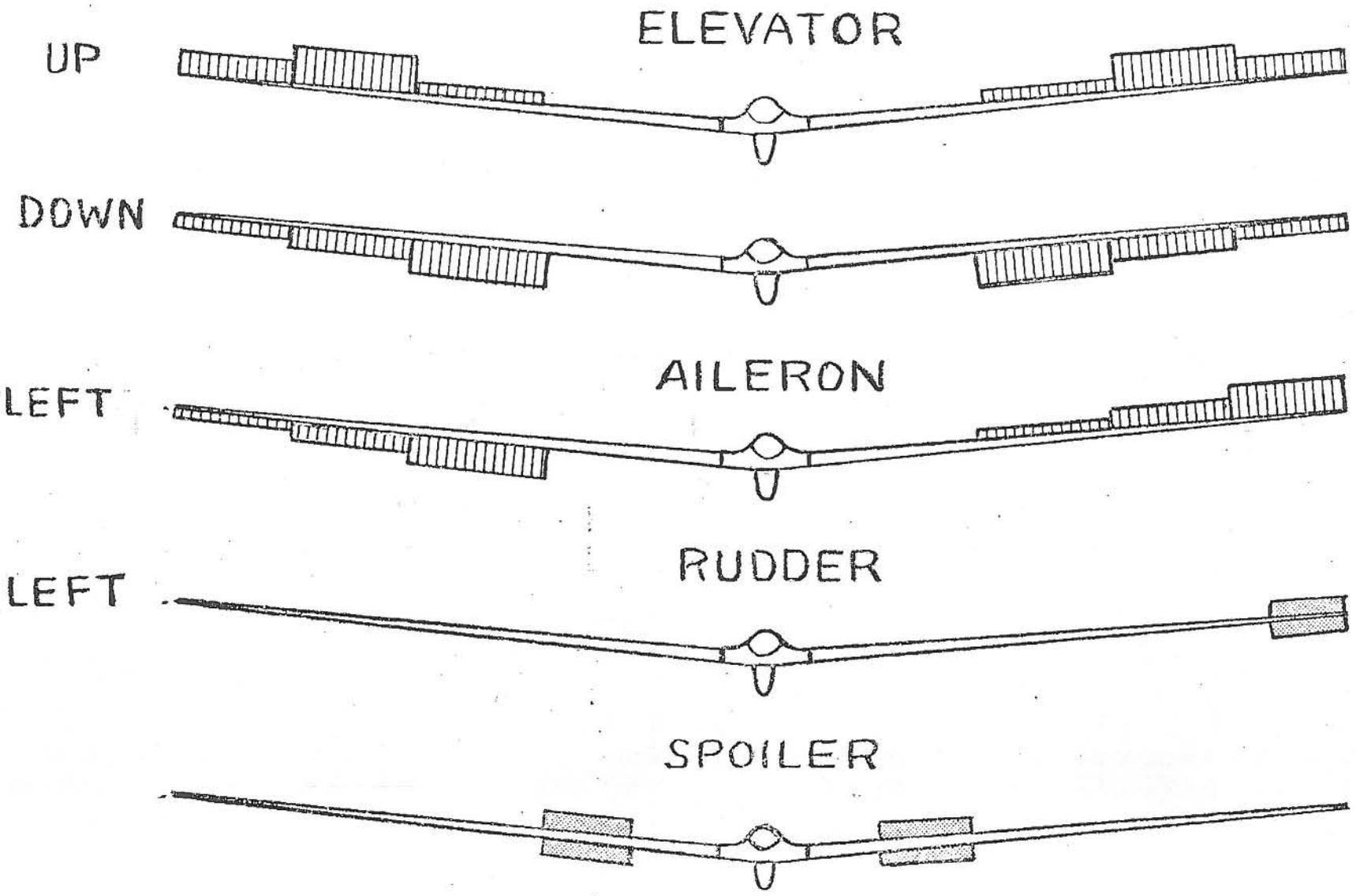
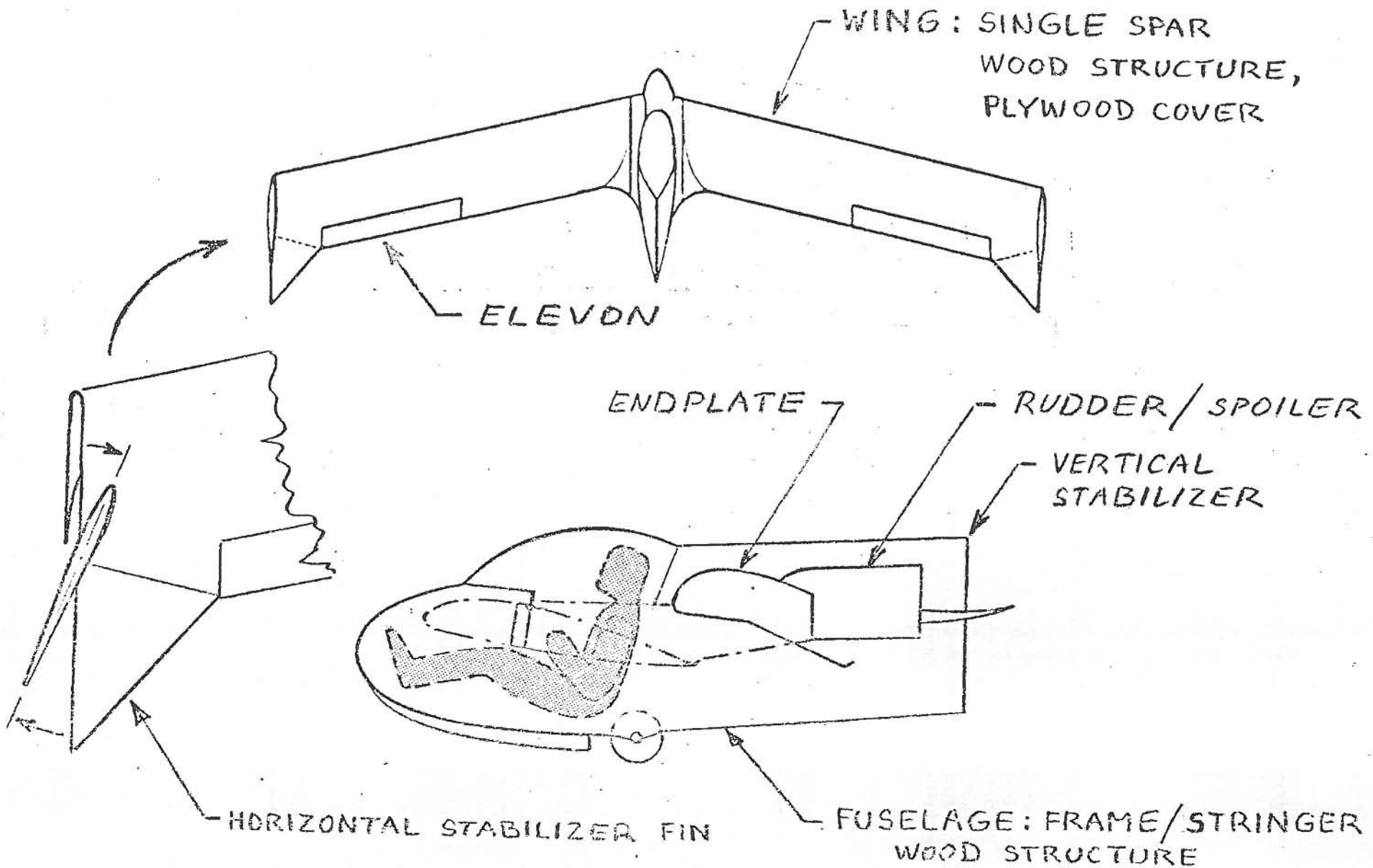
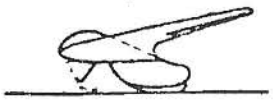


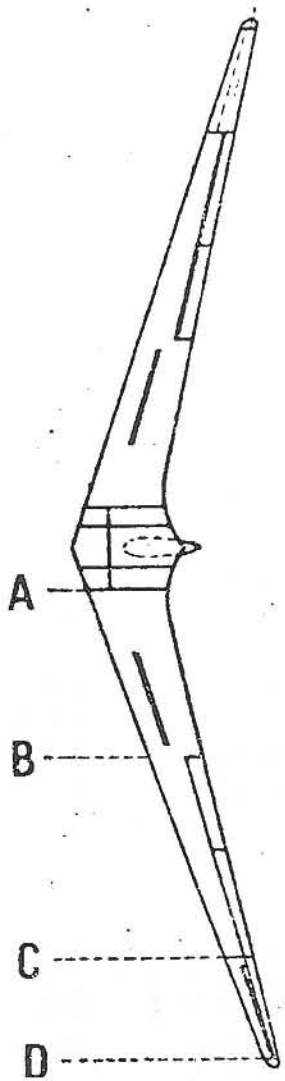
Figure 3

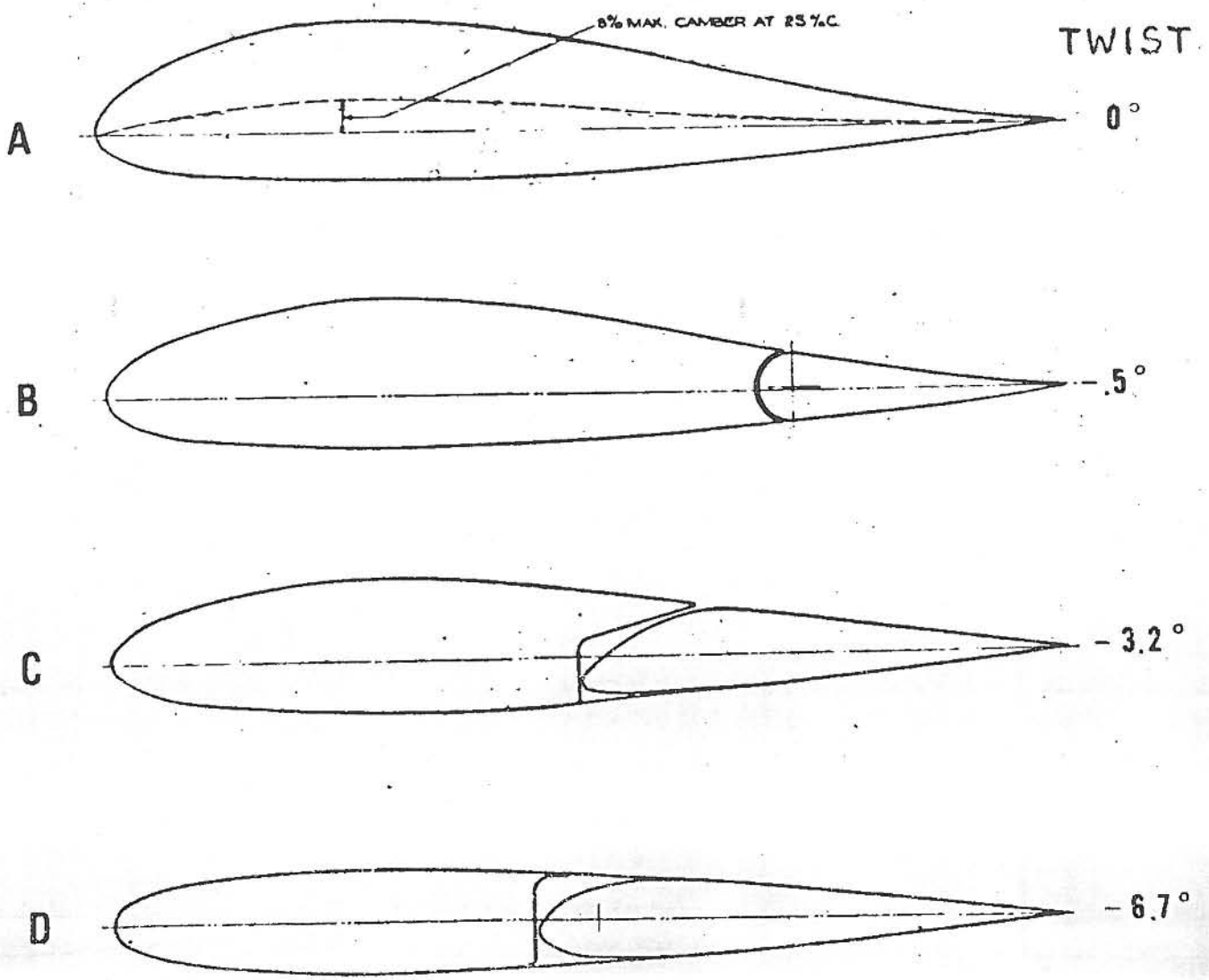
BKB-1 DESIGN FEATURES



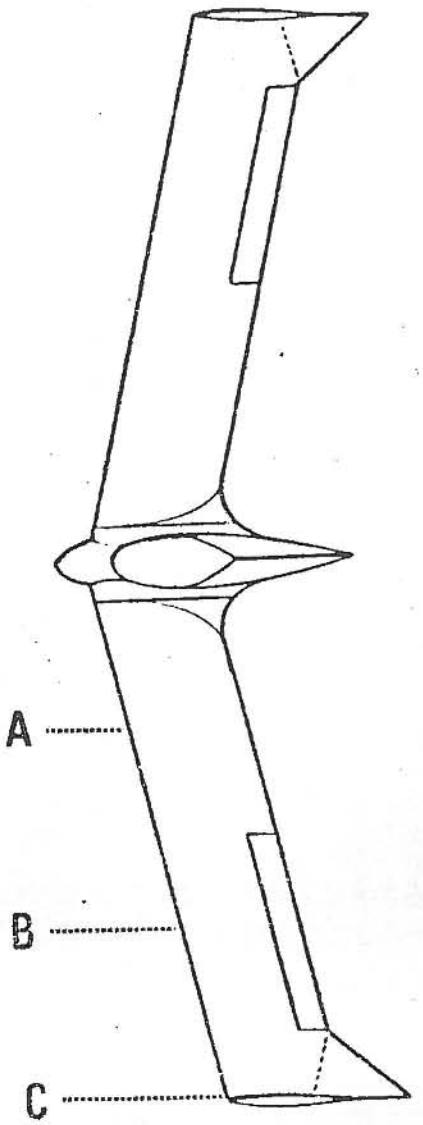
HORTEN IV. WING SECTIONS

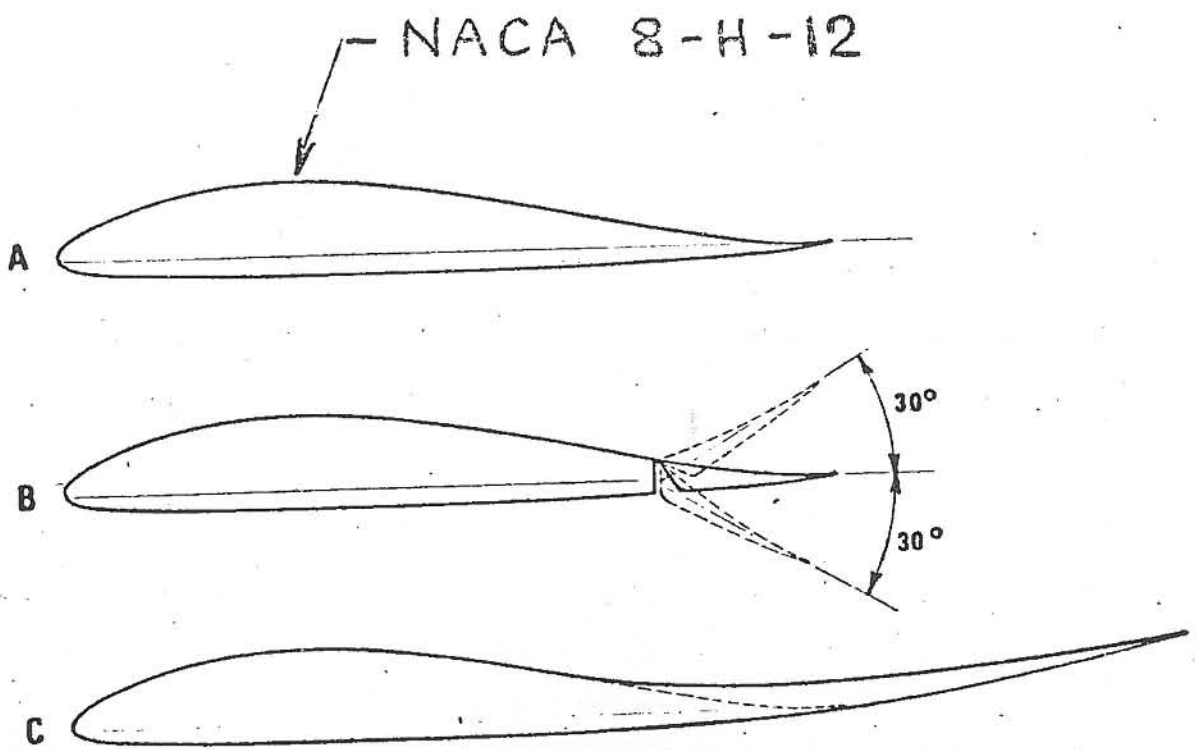






BKB-1 WING SECTIONS





Figu

COMPUTED AIRFOIL SECTION PRESSURE DISTRIBUTIONS

ITERATIVE POTENTIAL/VISCOUS FLOW COMPUTATION

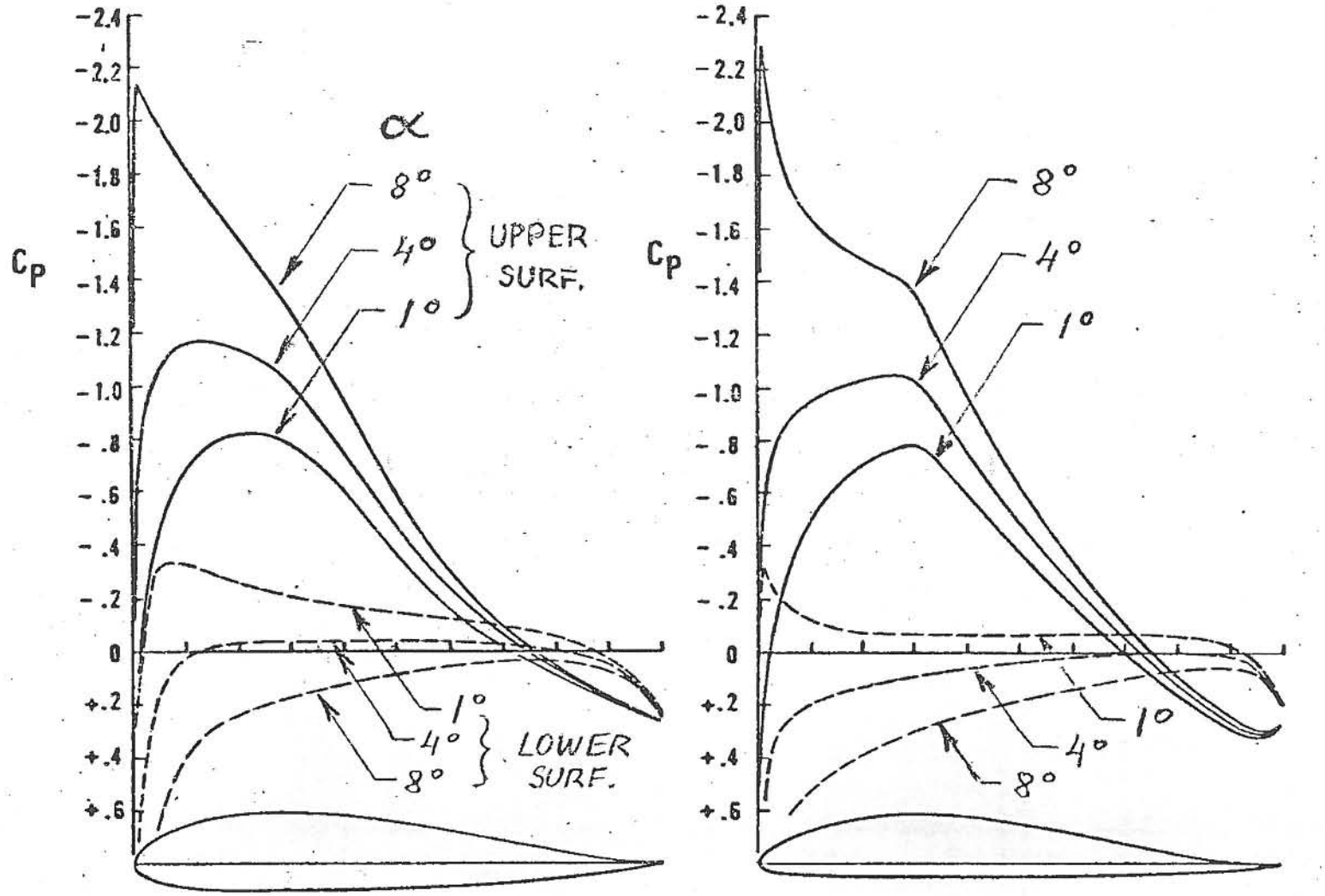
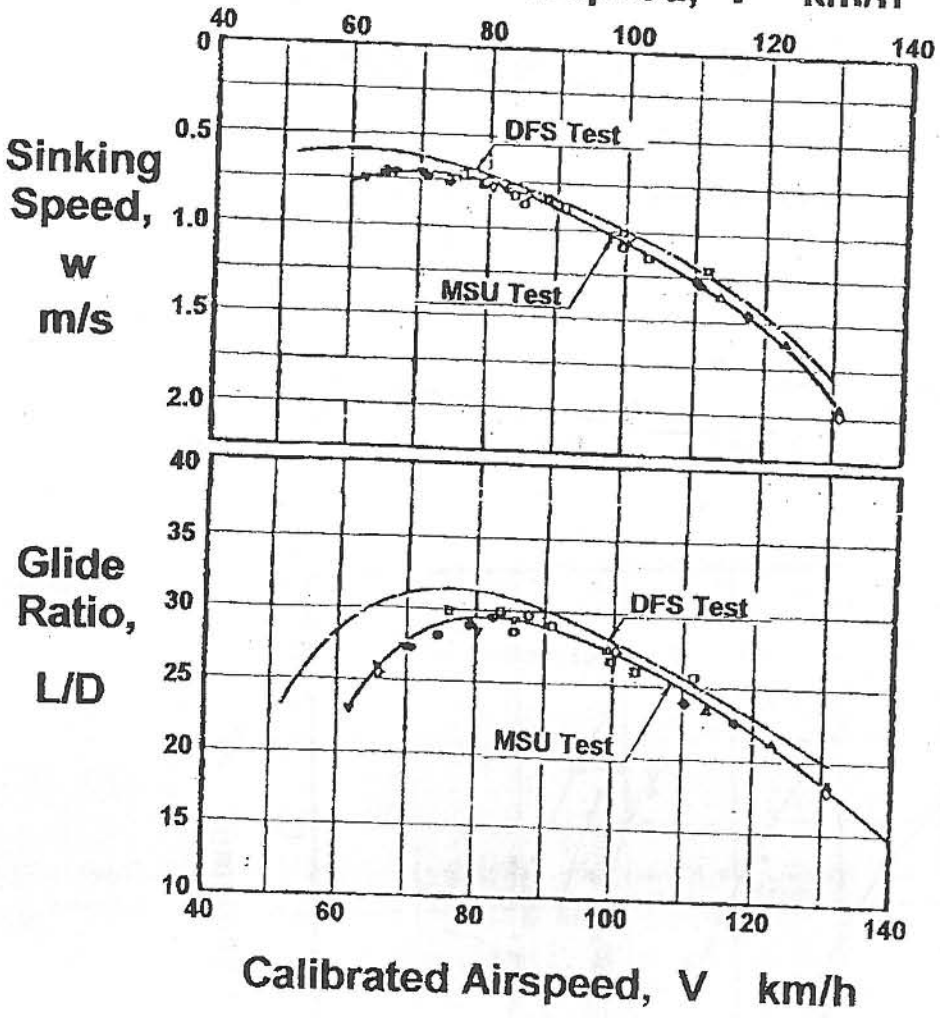
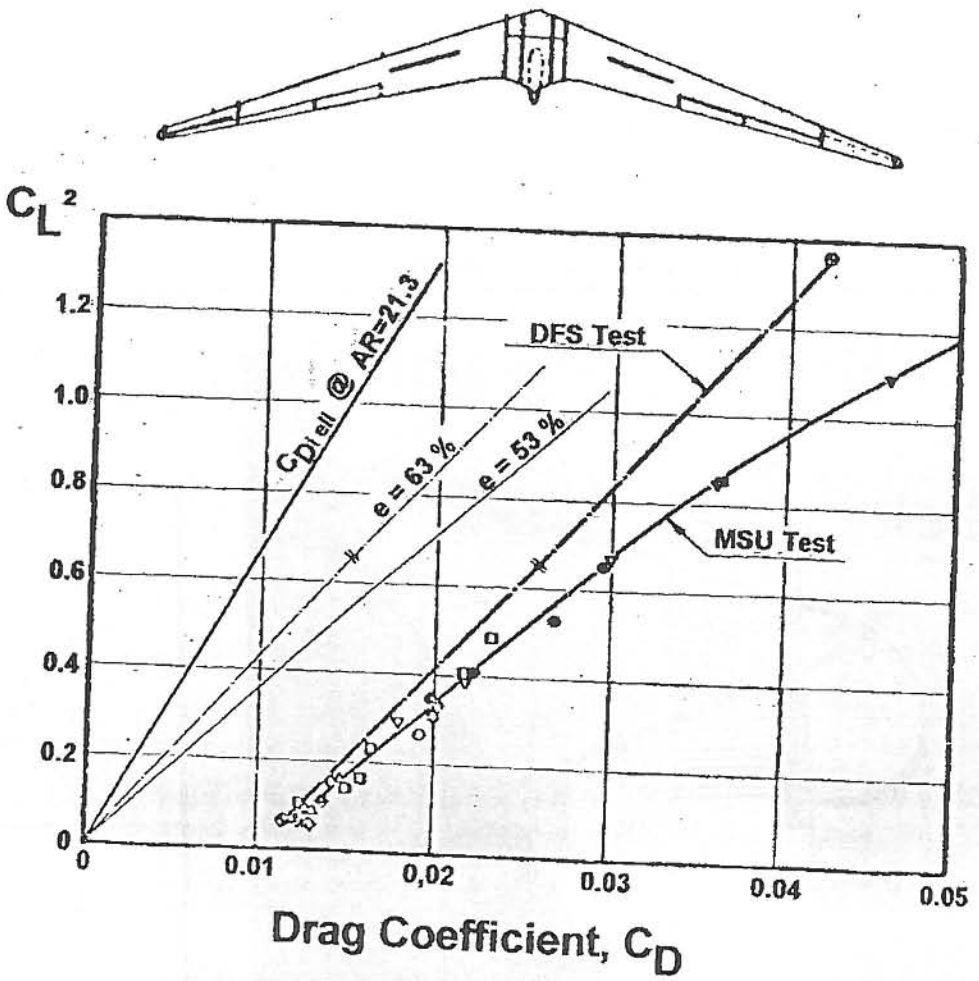


Figure 7

MEASURED PERFORMANCE OF THE HORTEN IV

Gross Weight: 810 lb (366 kg) **Wing Loading: 4.0 lb/ft² (19.5 kg/m²)**



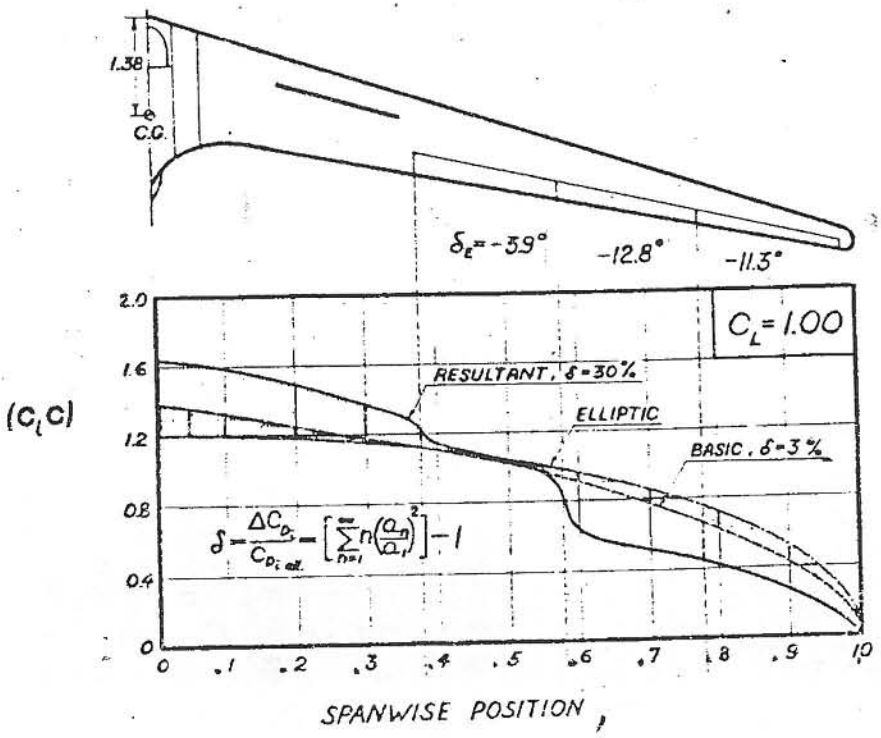


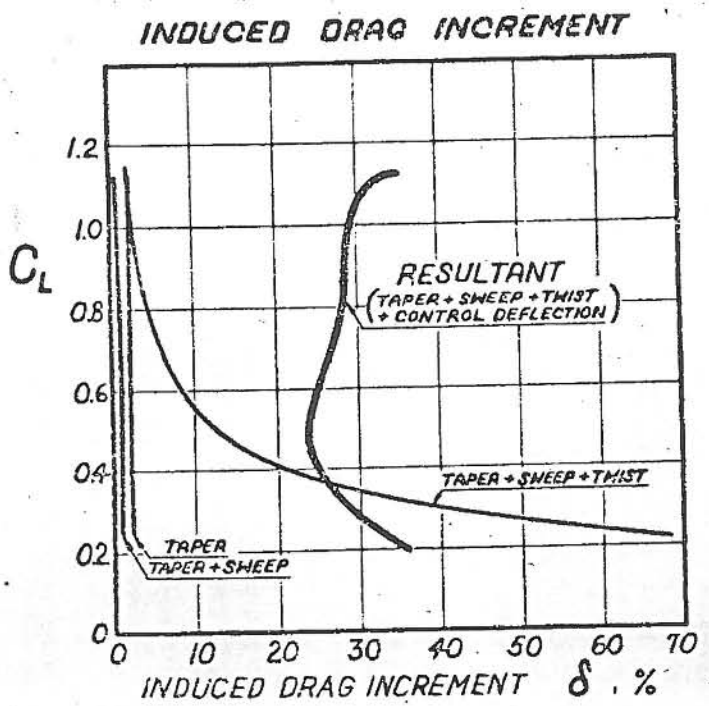
Note: DFS Data Converted to MSU Test Weight of 810 lb

Section Profile Drag Coefficient $c_{d_{pr}}$

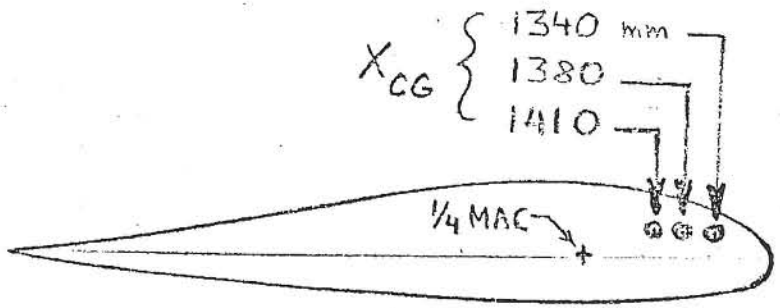
CALCULATED SPANWISE LIFT DISTRIBUTION AND INDUCED DRAG INCREMENT FOR THE HORTEN IV.

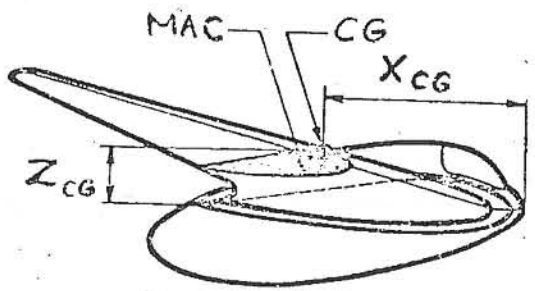
$$C_{D_I} = \frac{C_L^2}{\pi AR}(1+\delta)$$





MEASUREMENT OF STATIC LONGITUDINAL STABILITY ON THE HORTEN IV.

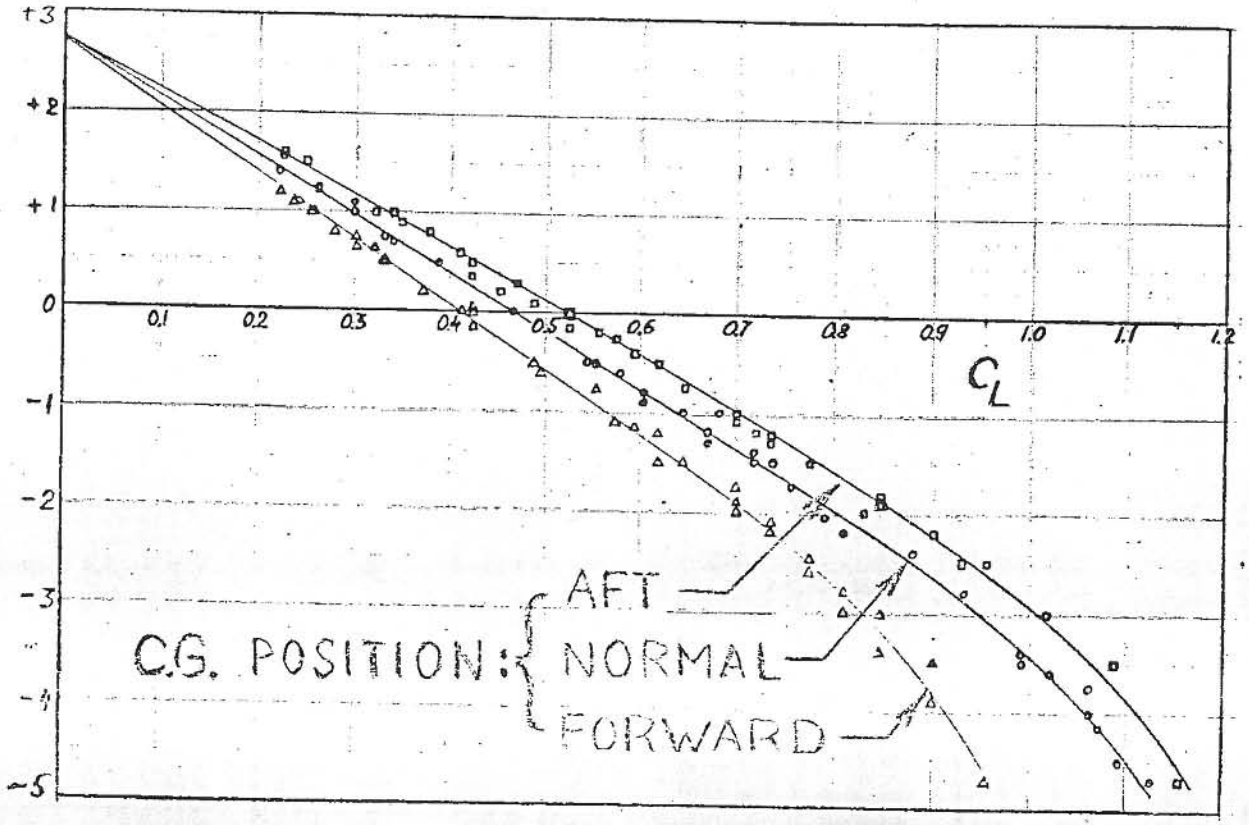




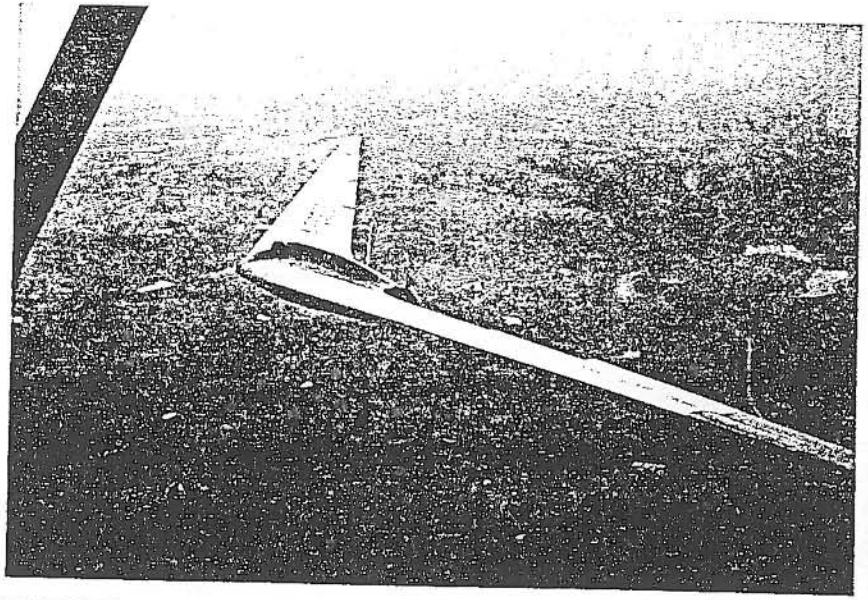
ELEVATOR CONTROL MOVEMENT

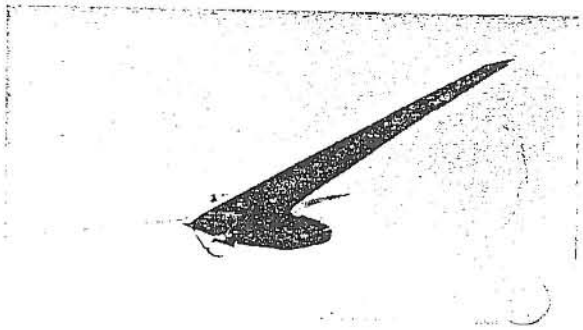
X_E

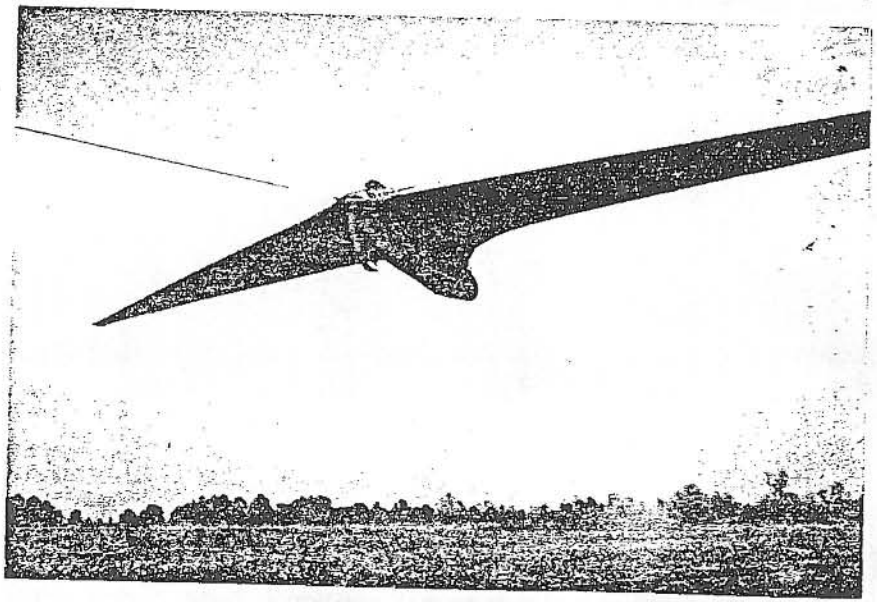
(inches)

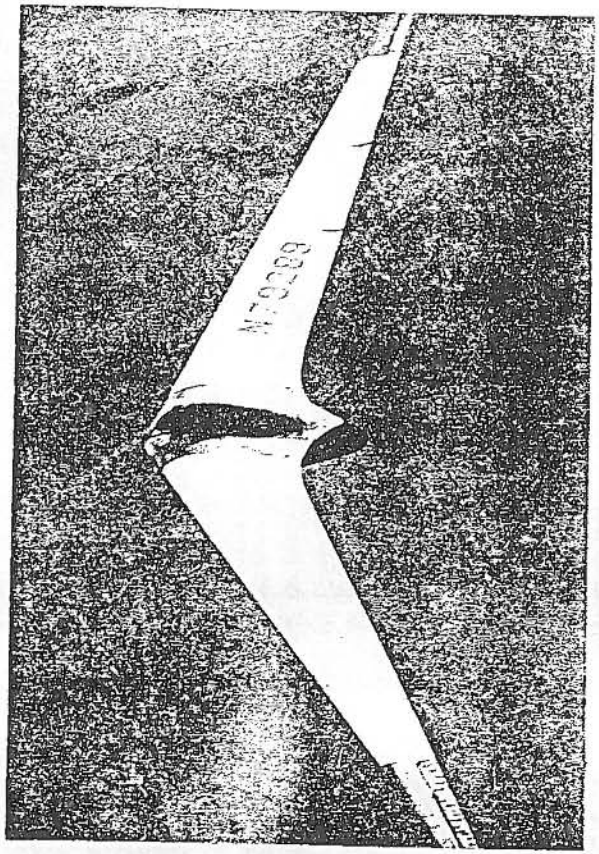


THE HORTEN IV FLYING WING SAILPLANE









ESTIMATED PERFORMANCE OF THE BKB - 1

$W_G = 260$ kg (573 lb) $\quad W_G/S = 18.0$ kg/m² (3.68 lb/ft²)