In 1989 we travelled to Madison Wisconsin to attend our first MARCS Symposium. As several previous Symposia had featured Ken Bates speaking about his numerous flying wing experiments, we were hoping that the 1989 gathering would be no different. Prior to the event, we learned that Dr. Walter Panknin was on the Symposium agenda, scheduled to speak about his "Flying Rainbow" design.

A brief description of Dr. Panknin’s presentation at the Symposium appeared in “On the ’Wing...,” and a complete transcript of Walter’s presentation is available from the Madison Area Radio Control Society. Walter did not focus on any particular aspect of his Flying Rainbow, but rather provided a generalized overview of swept wing tailless design.

It took several years of friends’ prodding to convince Walter to build his first “flying wing.” Günther Koech, an aircraft designer employed by Lippisch during WWII, was a proponent of the idea, along with Hansjörg Ackerman, a pioneer in building tailless models. But it was a paper by Helmut Schenk, “Determination of the Longitudinal Moment for the Flying Wing Model,” which served as motivation for Walter to build his first ’wing. Schenk’s paper explained how the moment coefficients and zero lift angles of the airfoils worked in conjunction with wing twist, sweepback, and other variables so as to achieve a pitch stable aircraft.

A fundamental formula which Schenk provided in his paper served to integrate these important variables, and while it looks intimidating, it is actually relatively simple. A low-cost scientific calculator makes quick work of evaluating a single design, and computer programs have been written which allow iterative processes and user manipulation of one or several variables.

The Schenk formula is:

$$\alpha_{\text{total}} = \frac{(K_1 \cdot C_{\text{Mi}} + K_2 \cdot C_{\text{Ma}}) \cdot C_L}{1.4 \cdot 10^{-5} \cdot \lambda \cdot 1.43 \cdot \Lambda} \cdot St$$

where

- $b$ = wing span
- $t_i$ = root chord
- $t_a$ = tip chord
- $t_m = (t_a + t_i)/2$
- $l$ = aspect ratio, $b/t_m$
- $L$ = angle of sweepback, measured at 25% chord
- $C_{\text{Mi}}$ = moment coefficient, root section
- $C_{\text{Ma}}$ = moment coefficient, tip section
- $C_L$ = design coefficient of lift, $C_{\text{Lcruise}}$
- $St$ = stability value (static margin)
- $t$ = taper ratio, $t_a/t_i$
\[ K_1 = \frac{1}{4} \cdot (3 + 2t + t^2)/(1 + t + t^2) \]
\[ K_2 = 1 - K_1 \]

and

\[ \alpha_{\text{geo}} = \alpha_{\text{total}} - \left( \alpha_{0L_{\text{root}}} - \alpha_{0L_{\text{tip}}} \right) \]

where
- \( \alpha_{\text{geo}} \) = geometric twist, used when cutting cores
- \( \alpha_{0L_{\text{root}}} \) = zero lift angle, root section
- \( \alpha_{0L_{\text{tip}}} \) = zero lift angle, tip section
- \( \alpha_{\text{total}} \) = total wing twist, aerodynamic

To use the Schenk formula, the designer must always begin with knowledge of the pitching moment, \( C_{M0} \), and zero lift angle, \( \alpha_{L=0} \), of the airfoil(s) used at the wing root and tip. Changing airfoils, taper ratio, aspect ratio, sweepback and static margin gives the designer wide latitude so far as final design. A comprehensive examination of the dynamics of the Schenk formula was published in *RC Soaring Digest* a few years ago.
Wingspan 3.20 meters
Aspect Ratio 9.4
Root Chord 400 mm
Tip Chord 280 mm
Keel Length 505 mm; extends from trailing edge to act as hand hold
Wing Area 109 dm$^2$
Sweep; LE, t/4 20.6, 19.6 deg
Wing Loading 33 g/dm$^2$
Geometric Twist -2.5 deg
Fin Root 230 mm
Fin Tip 130 mm
Winglet Area 2 * 93 in$^2$
Winglet Height 300 mm
Profiles E222, E226, E230
Elevons 65 mm x 700 mm, outer end 60 mm from wing tip

DR. WALTER PANKNIN’S “FLYING RAINBOW”
The planform of Walter’s "Flying Rainbow" was determined using Schenk’s formula. We’ve spent some time at the computer and have been able to work backward from the final design to determine some of the initial parameters. This "Flying Rainbow" uses the Eppler 222 at the root and the E 230 at the tip. The zero lift angles are $\alpha_{0L_{\text{root}}} = -3.65$ and $\alpha_{0L_{\text{tip}}} = +1.73$, respectively. Plugging the latter values into the second formula,

$$\begin{align*}
-2.5 &= \alpha_{\text{total}} - (-3.65 - 1.73) \\
\alpha_{\text{total}} &= -2.5 + (-3.65 - 1.73) \\
\alpha_{\text{total}} &= -7.88 \text{ degrees}
\end{align*}$$

For Walter’s Flying Rainbow, we also know the following information:

- $b = 3200 \text{ mm}, 126.3^\circ$
- $t_i = 400 \text{ mm}, 15.8^\circ$
- $t_a = 280 \text{ mm}, 11.0^\circ$
- $t_m = (280 \text{ mm} + 400 \text{ mm})/2 = 340 \text{ mm}$
- $l = 3200 \text{ mm}/340 \text{ mm} = 9.4$
- $L = 19.6$
- $C_{Mi} = -0.097$
- $C_{Ma} = +0.025^*$
- $t = 280 \text{ mm}/400 \text{ mm} = 0.7$
- $K_1 = 1/4 \cdot (3 + 1.4 + 0.49)/(1 + 0.7 + 0.49) = 1/4 \cdot (4.89)/(2.19) = 0.5582$
- $K_2 = 1.0 - 0.5582 = 0.4418$

* This value was derived by Dr. Panknin based on practical experience and a formula utilizing the camber line leading edge and trailing edge angles.

The primary formula, once appropriate values are inserted, becomes:

$$\begin{align*}
-7.88 &= \frac{(0.5582 \cdot -0.097 + 0.4418 \cdot 0.025) - (\overline{C_L} \cdot \text{St})}{1.4 \cdot 10^{-5} \cdot 9.4^{1.43} \cdot 19.6} \\
-7.88 &= \frac{(-0.043) - (\overline{C_L} \cdot \text{St})}{0.0068} \\
(-7.88 \cdot 0.0068) + 0.043 &= -(\overline{C_L} \cdot \text{St}) \\
\overline{C_L} &= \frac{0.0106}{\text{St}}
\end{align*}$$
Based on planform geometry and actual CG location, and using the iterative abilities of our computer program, we set $St = 0.075$ and find:

$$
\overline{C_L} = \frac{0.0106}{0.075}
$$

$$
\overline{C_L} \equiv 0.14
$$

The elevons should be set for no deflection during cruise. That is, the elevons should be set such that they are in trail. This setting will produce the lowest drag. Additionally, when trimmed in this way, the aircraft should be operating at $L/D_{\text{max}}$. $\overline{C_L} = \sim 0.14$ is, therefore, not an unreasonably low value.

From a structural point of view, Walter’s “Flying Rainbow” included some rather unique solutions to the inherent difficulties of swept wings. The spar, for instance, is built around a 5/8” by 5/8” O.D. square aluminum extrusion. The spar caps are made by laying 0.125” by 5/8” spruce strips on top of and under the aluminum box. To minimize the effect of the transition from the aluminum to the balsa sheer web, one of two methods have been used. (1) The sheer web between the spruce strips is balsa with 1/16” plywood sides transitioning to balsa near the end. (2) The use of carbon fiber over the spruce cap strips can be used to reduce the stress riser at the end of the aluminum tube without the use of 1/16” plywood and balsa. The spar runs to the leading edge of the cores near the end of the center panels. The joiner rod can be 0.5” steel, aluminum, fiberglass or carbon fiber rod.

Further reinforcement is required if balsa sheeting is to be used as the wing skin. For purposes of torsional stiffness, some glass cloth should be placed on the core at a 45 degree angle. An alternative would be to use carbon fiber veil to increase the torsional stiffness.

Winglets are made from blue foam with a balsa base. The installation of wood blocks for mounting the winglets should be considered before sheeting. The objective is to keep them light. Walter used pressure sensitive plastic film (vinyl shelf lining paper) to cover them, and this worked out very nicely. The weight of the winglet should not exceed 35 grams or 1.2 ounces. This weight requirement can also be met by using blue foam with 2 oz. cloth vacuumed bagged onto it.

Walter used a third servo mounted in the wing root to control a flap which was hinged at about 50% of the 3” flap chord. The flaps were about 10” long on each side. This setup serves as more of a speed brake than a flap, and no pitching results from its use.

The "Flying Rainbow" is an extremely successful design. It builds rapidly, can be winch launched, is stable, and performs well both over flat land and on the slope. Interestingly, it seems to do better in turbulent conditions.

Walter’s presentation at the MARCS Symposium was not only exciting, it provided the motivation for us to begin construction of our own series of swept wing tailless sailplanes — Project Penumbra. Walter visited us in April 1991, and we spent a day at 60 Acres testing and
trimming one of the later versions. His death in November 1992 affected us deeply, and we
dedicated “On the ’Wing... the book” to his memory.

References:

Dr. Walter Panknin at the MARCS Symposium. “On the ’Wing...,” *RC Soaring Digest*,


’Wing... the book, Volume 2,” pp. 73 - 93,

Panknin.bas is available in Applesoft BASIC, and in QuickBASIC for both IBM-compatibles and
the Macintosh platform. Alan Halleck’s Razer1 and Dr. Panknin’s Twist Formulae, “On the

Schenk, Helmut. Laengsmomentum-Rechnung Beim Nurflugel-Modell. Self-published,
Pforzheim Germany.