A PROGRAM TO ASSIST IN THE CONSTRUCTION OF A STÖCKER HANDHELD FINAL GLIDE CALCULATOR

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Abstract

Helmut Reichmann's book *Cross-Country Soaring* brought to popular attention a form of final glide calculator which Reichmann termed the "Stöcker" final glide calculator. The key feature of this calculator lies in its use of an underlying map to assist the pilot in determining his distance from the goal. The Stöcker calculator is a form of circular nomogram, this paper will explain the geometrical relationships between the various parameters in this form. The author has written a computer program, in BASIC, to plot the required overlay.

1. Introduction

With the advent of the computer controlled final glide instruments, the once familiar hand-held final glide calculator has gradually disappeared. This is unfortunate, since the hand-held final glide calculator is at once both useful and instructive, not to mention much cheaper than the more modern electronic final glide computers.

The final glide calculator described here is a form which has been known for many years. In his book on *Cross-Country Soaring*[1] Helmut Reichmann presented a final glide calculator of this form as a "Stöcker" calculator. Reichmann's instructions as to how to duplicate this calculator, while complete, were lacking in detail. The author has developed a program, written in Microsoft QuickBasic, to do the required calculations and produce a plot suitable for use as an overlay in constructing a Stöcker-type glide

72

TECHNICAL SOARING

calculator.

2. Theory

The basic theory underlying the final glide calculator is mostly simply geometry, how high must the sailplane be in order to glide a known distance to the goal. Typically a final glide calculator also includes a speed-to-fly section which tells the pilot when the lift strength in the final thermal has dropped off sufficiently to malce initiating the final glide the optimum solution. This speed-to-fly section also tells the pilot the impact of head or tail winds on his achieved glide angle, and thus required altitude for final glide.

The Stöcker calculator is a form of circular nomogram. The basic relationship is between the achieved glide angle (L/D) and the rotational angle around the calculator, θ. On one half of the front side of the calculator, the effect of lift strength and winds are related to glide angle, that is, rotational angle on the calculator. On the other half of the same side of the calculator, glide angle is related to achievable distance over the ground. This functional relationship can be chosen to be almost any function, but most commonly a linear relationship is chosen.

Figure 1 shows the basic relationships between rotational angle, L/D, and distance for the circular glide calculator. For the required height section of the calculator, the relationship to L/D is given by the basic relationship,

$$L/D = \frac{distance}{height}$$

where height is the required altitude to cover the specified distance.

The speed-to-fly can be similarly related to L/D by,

$$L/D = \frac{V_{stf} + W_k}{V_{sink}}$$

where, V_{stf} = the computed speed-to-fly.

W_k = the component of the wind in the direction of fliight.

V_{sink} = the polar derived sink rate at V_{stf}.

The key to generating the calculator is the relationship of both required height and speed-to-fly to the achieved L/D.

2.1 Speed-to-Fly

Basic speed-to-tly theory has been known for many years. In the U.S., Paul MacCready pioneered the use of speed-to-fly theory, and introduced his unique contribution, the "speed ring".

This paper will not go into any detail regarding determination of the speed-to-fly numbers. In general, the easiest method is the geometrical technique of drawing tangent lines to the polar curve. Reichmann's book, among others, is an excellent reference on this subject.

3. Calculator

The circular calculator described here is a simple device for computing the height required to achieve an optimum

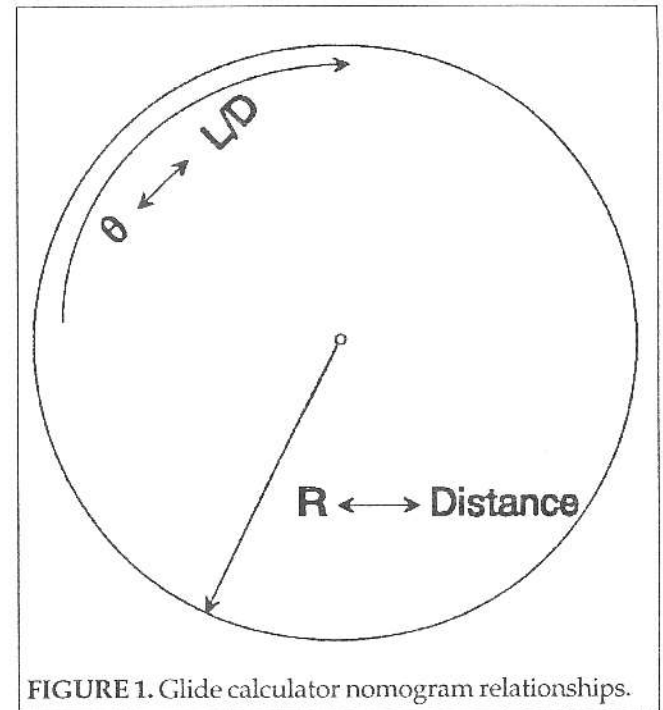final glide for various wind and lift conditions.

FIGURE 1. Glide calculator nomogram relationships.

3.1 Usage

The glide calculator is inherentiy easy to use, integrated as it is with an underlying map. While climbing in a thermal which might be his last climb before beginning final glide, the pilot wishes to know how high he must climb to achieve maximum speed to his home field. Using the Stöcker final glide calculator, the pilot takes the following steps,

1. Estimate the current lift strength (in the thermal in which he is climbing), and estimate the strength of the headwind or tailwind component.

2. The rotating cursor is placed over the intersection of the lift line and the wind line (see Figure 2). If desired, the resulting L/D can be read from the circumference of the calculator. In the example shown in Figure 2, the wind has been chosen as zero and the lift has also been chosen as zero. The resultant L/D is 38:1.

3. The entire overlay is now rotated as a whole (including the cursor) until the pilot's current location is underneath the cursor on the height required side of the caiculator. The distance to the home field can be read from the cursor, if desired.

4. The required height is read by interpolating from the height spirals. For example, again referring to Figure 2, if the pilot is 15 nautical miles from home field, the calculator shows just under 2500 feet as being required for the final glide. As a check, 15nm is 91200 feet, divided by 38:1 L/D. this equals 2400 feet.
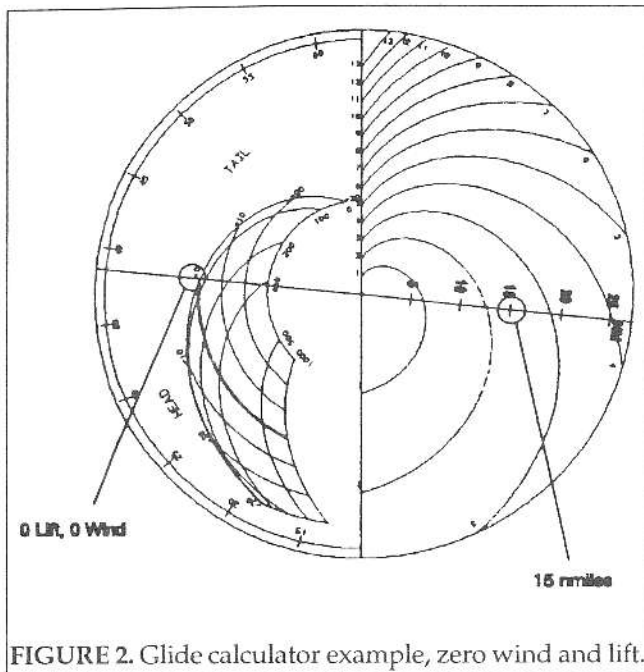
FIGURE 2. Glide calculator example, zero wind and lift.

If wind and lift conditions are non-zero, the pilot merely places the cursor appropriately and reads off the required distance. Using Figure 3 as an example, if the pilot has 10 knots of headwind and is climbing at 400 ft/min, the cursor is placed over the intersection of the 10 knot headwind and 400 ft/min lift lines. At the same 15 nm, the required height is now 3700 ft at an indicated L/D of just under 25:1.
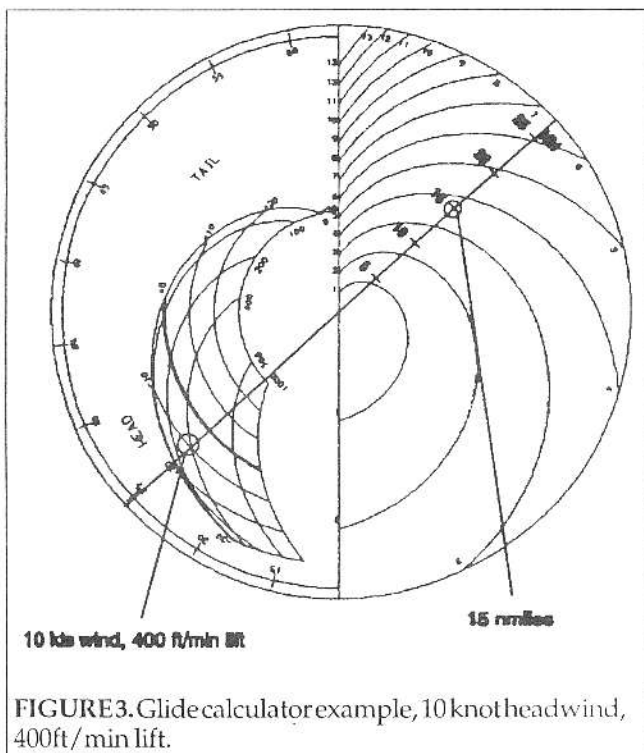

FIGURE 3. Glide calculator example, 10 knot headwind, 400ft/min lift.

The margin the pilot adds to the calculated height is a matter of personal preference and tactics. In my flying, I add 20% to the computed height plus a field height margin. In normal flying the field height margin I use is 1000 ft, while in competition, I use a 200 ft field height margin. For example, if the computer says 3500 ft is required, I add 700 ft plus the field height margin, say 1000 ft. Thus, a final glide can be initiated when a height above the rleld elevation of 5200 ft is achieved. The 20% is for unexpected sink encountered and can be flown off with higher airspeeds if the sink is not encountered.

Progress along the final glide flight path can be easily compared with required height by consulting the final glide computer during the course of the final glide.

4. Program Description

The program used to generate the overlays is written in Microsoft Quick Basic. The code listing for this program is too lengthy for reproduction here, but may be obtained from the author (see 4.3.1).

4.1 Circular Nomogram

The basis of the Stöcker final glide calculator is a circular nomogram. Rotation of a cursor around a circular disk is directly related to the L/D achieved by the glider under the specified conditions. Figure 1 shows this relationship symbolically. The relation between angle and L/D can be any chosen function, for example, linear, exponential, or hyperbolic.

Based on experience, I have chosen a linear form for the functional relationship between angle around the calculator and L/D.

The equation used in the program relating L/D and angle θ around the calculator are,

$$L/D(\theta) = C \bullet (180-\theta) + B \quad (3)$$

$$\theta(L/D) = (L/D - B)/C \quad (4)$$

where, B = the minimum L/D, C = the range in L/D, $(L/D_{max} - L/D_{min})$ divided by the angle range, 180°.

The additional 180 term in equation (1) is due to a quirk in the programing algorithm that introduces a 180 phase shift that I never had the time to correct.

Figure 4 shows an example of the overlay using this linear form. This is a plot exactly as it is produced by the program. The linear cursor is plotted below the circular portion. It is cut out and used on the separate cursor which rotates about the center of the circular portion of the calculator.

Figure 5 shows the form of the overlay if an exponential relationship is chosen.

The equations used for the exponential relationship are,

$$L/D(\theta) = \exp\left[\frac{180 - \theta}{C}\right] + B \quad (5)$$

$$\theta(L/D) = \ln(L/D - B) \bullet C \quad (6)$$

where, B = the minimum L/D minimum 1 (L/D_{min} - 1), C = 180 divided by the log of the range in L/D, (180/ ln(L/D_{max} - L/D_{min}).

In the back of his book Reichmann shows a template for use with a Stöcker-type calculator. It appears that he used a hyperbolic expression relating L/D to the constructional θ. This is an equation of the form,

$$L/D(\theta) = \frac{1}{a_1\theta + a_o} \qquad (7)$$

where, in this case, a_o = 0.078928 and a_1 = -0.000447.

Again, the equation relating L/D and angle is completely arbitrary, I have chosen the linear relationship based on experimentation and over 10 years of flight experience with this calculator.
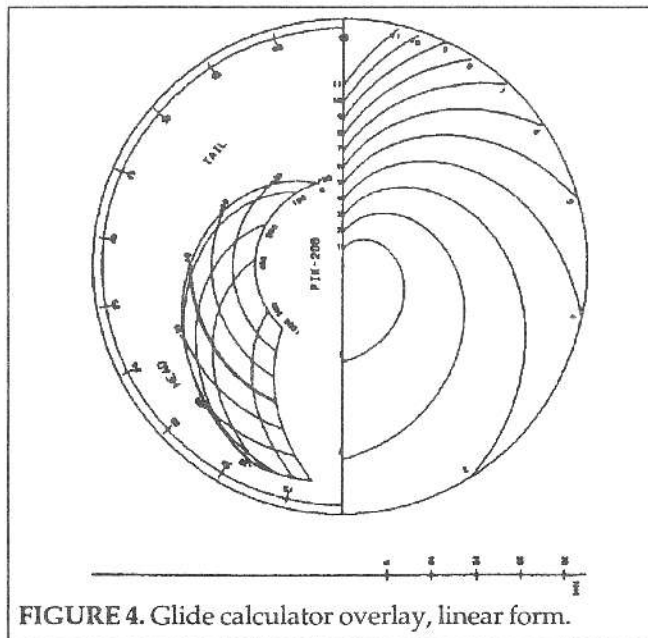

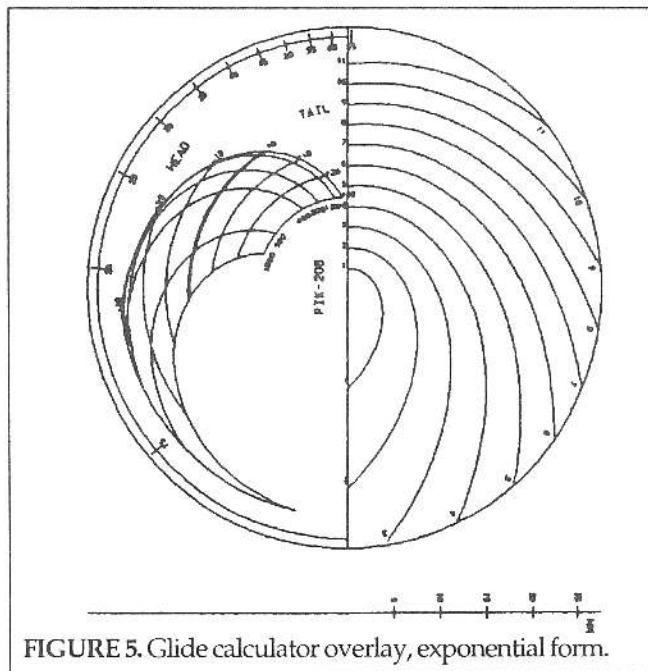FIGURE 4. Glide calculator overlay, linear form.

FIGURE 5. Glide calculator overlay, exponential form.

4.2 Program Usage

The program is written in Basic for use with Microsoft Quick Basic version 4.5. The programming style was purposely kept simple so that other Basic compilers might be able to run the program code. However, I have only tried the code with Microsoft QuickBasic, Version 4.5.

Before running the program, several parameters might have to be changed by the user. Typically, the specific speed-to-fly and polar data will be entered by the user. Four examples of data entry are given in the program listing, a PIK-20, a K-6E, a Nimbus II, and an ASW-15, this latter entered in metric coordinates. Along wih the polar data, the user specifies maximum and minimum L/D, number of polar points, sailplane label, and whether the data is metric.

Additionai paramaters subject to change are the display type, altitude starting value and step sizes, map scale, and maximum and minimum wind values. The program uses a graphics display (if available) to give the user a rough idea of the overlay shape.

4.21 HPGL Plotting

As noted in the previous section, the program's output file is in the form of HPGL plotter commands. This is a widely disseminated vector command language. While the HPGL language has some sophisticated variants, only the simplest command set was used here to achieve the widest utility.

If the user has access to a pen plotter capable of interpreting HPGL plotter commands, this is the easiest method. The output data file can be simply copied to the printer. Assuming the printer is attached to the parallel port 1.

copy hpgl.dat Iptl

If the user does not have access to a plotter, excellent results can be obtained with a shareware program called PrintGL. This program is written and distributed by Ravitz Software of Lexington, Kentucky. This program will translate HPGL code into any of a number of other printer codes. Included in the output capabilities of PrintGL are Postscript and Laserjet laser printers, Epson dot matrix printers, even Digital Research.IMG and ZSoft.PCX bitmap files. Additionally, PrintGL can output directly to the display in a graphics mode of CGA, EGA, and a number of modes of VGA. This allows the user to inspect the output before committing to a hardcopy plot.

The plots I use are produced on a standard 8.5" x 11" Postscript laser printer. I use PrintGL with the following command.

printgl hpgl.dat /fs /ml /If8.5,11.0,0.0,0.0

The "/fs" directs Postscript output, "/mI" directs unity magnification, and the final "/lf" command slightly adjusts the borders to enable the 8" wide printout to fit on the laser-printed page.

4.3 Availability

The code is entered in the public domain as copyrighted freeware. That is, it may be freely distributed, and no charge may be placed on the distribution of the program,

and it may not be used in any commercial program. The program code is available in several methods:

1.) the listing may be re-entered line by line;

2.) a stamped, self-addressed disk mailer envelope to the author, with the desired disk included, will be loaded and returned; and

3.) The program has been loaded onto the Compuserve network on the AVSIG Forum. I have also loaded the PrintGL utility up to this Forum.

4.3.1 Mail Requests

Mail requests may be made to the author at the following address. Please inchde either a 5 1/4" or 3 1/2" disk (only about 100K is required) and a suitable disk mailer, self-addressed and stamped for the return postage.

R.C.Gibbons

709 Parkview Cr.

Riichardson, Texas, USA 75080

4.3.2 Compuserve Availability

A compressed archive of the program has been uploaded to Library 13 (Computer Programs) of the AVSIG Forum (CIS:AVSIG). The program has been compressed with the PKZIP program and PKUNZIP can be downloaded from this same forum. The program name is GLIDE 11 ZIP and is approximately 30K bytes in size. Note that the numeric ending will change with the version number (you may find GLIDE12.ZIP). Also uploaded is a compressed version of the shareware program PrintGL. Compuserve is accessible worldwide. My Compuserve ID is [76244,1125].

4.4 Construction

Any number of methods may be used to construct the calculator. The method I prefer is shown in Figure 6. An
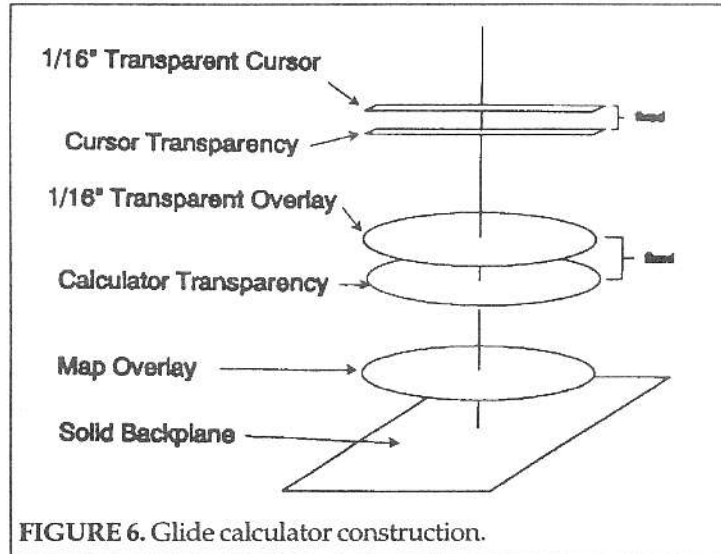

FIGURE 6. Glide calculator construction.

aeronautical map of the desired area is fastened to an opaque base slightly larger than the calculator size. I simply use double-sided tape. On top of this opaque base is a rotatable transparent plastic disk (approximately 1/16" thick) matching the map in diameter. I have found plastic fabrication shops that will make such a disk for $5-$10, including the material.

On the bottom side of this transparent disk, the overlay is fastened, again with clear double-sided tape. Finally, the linear cursor is fabricated from transparent plastic (same thickness as disk) and fastened to the top of the clear disk. I simply scribe and snap the straight line plastic cursor. The cursor overlay is fastened to the bottom side of this plastic strip. A small machine screw holds all three units together while allowing them to independently rotate.

The overlays can be made transparent either by using transparent medium in the plotter or printer, or by using a copy machine with transparent medium. I usually use the latter method. However, most of the new laser printers will readily accept transparent medium.

5. Acknowledgements

I would like to thank Dallas Gliding Association for support during the development of this program, and Skip Epp for assistance with the construction of the glide calculators.

References

1. Reichmann, Helmut, *Cross-Country Soaring*, Thomson Publications, 1978.