

Polar Explorer

Version 2.2

Short Guide

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About the Short Guide

This Short Guide is designed to be used together with the online tutorial to help you get Polar Explorer up and running before the proper User's Manual becomes available. This booklet contains an introduction to Polar Explorer, the instructions on how to install and run the program and the online tutorial, the contents of the tutorial, and a reference to the glider library supplied with Polar Explorer. We have also included a section explaining what you should keep in mind when analyzing any particular polar, since polars are the focal point of this program.

The comprehensive online tutorial contains all necessary instructions on how to use Polar Explorer. It also includes many practical examples that illustrate the influence of various parameters on different aspects of glider performance.

We are currently working on a printed manual, which will contain in-depth information on the program and on the theory behind it. We sincerely apologize for not having this manual available at this time. The main reason is that we have severely underestimated the amount of work required to produce this program, together with all necessary support files and printed documentation. However, as soon as the proper User's Manual comes out of print, we will send it to you at no extra charge.

About Polar Explorer

General Notes

Polar Explorer is a highly specialized computer program designed for analyzing both theoretical and practical aspects of glider performance in any conditions. As far as we know, it is the only program of this kind available on the market today.

Polar Explorer was made with glider pilots in mind, but it can also be used by hang glider pilots, contest task setters, glider designers and the people who make speed command and final glide instruments. Among glider pilots, the ones who fly cross-country, or intend to do so, should benefit the most from using this program. Whether you are a student pilot, or a seasoned veteran, you should find Polar Explorer to be a source of valuable information for years to come.

Polar Explorer comes with a library of over 150 (mostly measured) polars, so you can start using it right away. In case the glider you are interested in is not included in this library, you can easily enter its polar and the few additional parameters yourself, or you can modify any existing polar from the library. After that, you can analyze the performance of *your* glider and compare it to any other glider from the library. In fact, you can compare up to five different gliders (or one glider in five different settings) at a time. We tried to make Polar Explorer as complete as possible. In doing so, we realized that the classic (MacCready) speed-to-fly theory couldn't be used in case of stationary and semi-stationary updrafts (e.g. lee waves). This led to the development of a generalized speed-to-fly theory, which has been applied in writing the program.

What Can Polar Explorer be Used For?

Polar Explorer is designed to answer many specific questions about various aspects of glider performance. As a result, you can use it for many different purposes. The following are a few examples:

- Complement the books and articles on glider performance and soaring tactics by working out practical examples.
- Find out the optimum circling technique for any glider, at any altitude and wing loading.
- Interactively plan and analyze cross-country flights with up to five legs in the **X-Country Calculator** spreadsheet.
- Calculate final glides in the **Final Glide Calculator** spreadsheet.
- Optimize configuration and wing loading for any meteo conditions.
- Apply generalized speed-to-fly theory to maximize cross-country performance when using ridge lift or waves.
- Compare different gliders by their circling and cross-country performances, in addition to comparing their speed-sink polars.

- Design and test speed rings and final glide computers for any wind, altitude and wing loading.
- If you are contemplating any modifications to your sailplane (for example adding winglets), you can use Polar Explorer to estimate the effects on the maximum glide ratio, circling performance, average speed on a given task, etc.

Performance Curves

Polar Explorer can take any glider polar as a starting point, and calculate different aspects of performance in a variety of conditions. It can produce the following performance curves, shown here grouped into five categories:

- **Basic performance**
 - Speed – Sink (polar)
 - Speed – Glide ratio
- **Cross-country performance**
 - Speed-to-fly – Rate of climb
 - Speed-to-fly – Rate of climb + glider sink rate (for direct use on a speed ring for the total energy variometer)
 - Rate of climb – Average cross-country speed
 - Updraft strength – Average cross-country speed
- **Climb performance**
 - Updraft strength – Rate of climb
 - Updraft strength – Optimum bank angle
 - Updraft strength – Optimum circling speed
- **Circling performance**
 - Circling radius – Circling airspeed
 - Circling radius – Sink rate
 - Circling radius – Bank angle
- **Lift coefficient versus Drag coefficient curves**
 - $C_L - C_{Dv1}$ (C_D viscous for $Re=1,000,000$)
 - $C_L - C_{Dv}$ (C_D viscous for Re that varies with C_L)
 - $C_L - C_D$ (C_D total for Re that varies with C_L)
 - $C_L - C_{Di}$ (C_D induced).

Polar Explorer can show the above performance curves on a screen diagram, or print their coordinates in a table that can be displayed on the screen, sent to a text file, or directly to the printer.

Interactive Performance Calculations

In addition to performance curves, Polar Explorer version 2.2 introduces two new functions, designed to facilitate planning and analysis of cross-country flights and final glides:

- **X-Country Calculator** is an interactive spreadsheet in which you can directly calculate cross-country performance on a given task with up to five independent legs. It can calculate the following parameters for each leg:
 - Climb rate, plus optimum circling speed and bank angle in given updrafts
 - Optimum cruising speed
 - Percentage of time spent in climb
 - Updraft relative glide ratio
 - Crab angle required to offset the crosswind component
 - Average cross-country speed
 - Elapsed time.

X-Country Calculator also shows the averages and totals for the whole flight, for example, the average rate of climb and the total time.

- **Final Glide Calculator** is an interactive spreadsheet in which you can determine the following final glide parameters:
 - Initial altitude required to complete the final glide
 - Speed-to-fly
 - Ground relative glide ratio
 - Crab angle required to offset the crosswind component
 - Duration of the final glide.

What Can be Varied in Performance Calculations?

All performance curves, cross-country flights and final glides can be calculated in user specified conditions. The following settings can be varied:

- **Glider**
 - Glider definition (aerodynamic and geometry characteristics)
 - Wing loading (ballast)
 - Surface contamination (bugs)
- **Environment**
 - Model of the atmosphere (Standard or custom)
 - Altitude (within the limits of the atmosphere model)
 - Horizontal wind speed
 - Horizontal wind angle
 - Vertical velocity of the air between updrafts
 - Coefficient of updraft drift (C_{ud}) which determines whether the updrafts drift completely with the wind, or are more or less stationary
- **Updraft (thermal)**
 - Shape of the cross section
 - Fixed or variable diameter (variable means that the updraft diameter increases with strength)
 - Diameter (when a fixed diameter is used)
 - Diameter/strength ratio (when a variable diameter is used)
- **Cross-country tactics**
 - Speed ring setting
 - User specified cruising speed (in X-Country Calculator and Final Glide Calculator)
 - Starting and ending altitudes for each leg (in X-Country Calculator).
- When analyzing **circling performance**, you can instruct Polar Explorer to calculate circling in one of the following **modes**:
 - Optimum mode which produces the minimum possible sink rate at any given radius
 - Constant lift coefficient reserve below the maximum C_L
 - Constant airspeed reserve between the circling airspeed and the minimum speed at that radius
 - Constant circling speed regardless of radius.

Getting Started

System Requirements

To be able to use Polar Explorer, you need:

- o IBM PC, XT, AT, PS/2, or compatible
- o 512 kb RAM memory
- o At least one floppy drive (double-sided, low or high density)
- o VGA graphics card
- o MS-DOS or PC-DOS version 3.0 or later or any version of Windows.

Installing Polar Explorer 2.2 on a Hard Disk

Simply unzip the contents of Polar_Explorer_22.zip file to a new folder on your hard drive and place a shortcut to the PE22.EXE file on your desktop. That should do it.

Polar Explorer's Files

Polar Explorer Version 2.2 distribution file (Polar_Explorer_22.zip) contains the following files:

PE22.EXE	Polar Explorer program file. Note that this is a MS-DOS program and it will best run in a DOS window.
TUTORIAL.BAT	Batch file that starts Polar Explorer 2.2 and invokes the 0-INTRO introductory tutorial script. It also tests if all the files needed for playing the 0-INTRO script are present on the current directory.
TUTORIAL.GL?	These three files (.GL0, .GL1 and .GL2) contain the tutorial glider library required for playing tutorial scripts.
TUTORIAL.PE?	These three files (.PE0, .PE1 and .PE2) contain the tutorial sheet library required for playing tutorial scripts.
*.{S}	Files containing tutorial scripts with around 7 hours of online instructions.
POLAR.GL?	Glider library with over 150 glider definitions, mostly based on flight test data published by Johnson and Zacher.
POLAR.PE?	Sheet library with sample data sheets.
*.SCR	Source files of tutorial scripts. You can use them to customize tutorial scripts any way you wish.
MSC.EXE	Macro Script Compiler/decompiler program used to compile .SCR source files into .{S} script files and vice versa.

Running Polar Explorer

Running Polar Explorer in a DOS Command Window

To run Polar Explorer 2.2 in a DOS command window, first change to the drive and directory set up for it. Next, type **PE22** and press [Enter].

You can also use several command line parameters with the following effects:

/M	Runs Polar Explorer in mono mode (suitable for some laptops).
/S:xxxx	Automatically starts executing a command script, where xxxx is the name of the script. Do not include the extension, it is assumed to be .{S}.
/T:yy	Sets the time delay constant ('T delay') to the value specified by yy. This parameter is normally used together with /S:xxxx. See the next chapter for details on 'T delay'.

Running Polar Explorer Directly from Windows

To run Polar Explorer 2.2 directly from Windows, simply double-click on PE22.EXE in the Windows explorer, or double-click on the shortcut to PE22.EXE on your desktop.

Online Tutorial

Polar Explorer's online tutorial consists of 11 tutorial scripts, each covering a number of related topics. The tutorial, with a total estimated playing time of around 7 hours, contains a detailed description of all Polar Explorer's functions, and the instructions on how to use the program.

A script is a collection of commands and text messages stored in a script file (with the extension `.{S}`). Script files are not ASCII text files, so they cannot be edited or listed with the DOS TYPE command. Instead, we have provided the source files for all tutorial scripts, which can be printed out and edited. If you wish, you can modify any of the tutorial scripts by editing its source file (`.SCR`), and then compiling it with the Macro Script Compiler program (`MSC.EXE`).

Playing Tutorial Scripts

There are several ways of activating the Polar Explorer's online tutorial. The easiest one is by typing **TUTORIAL** at the DOS prompt and pressing [Enter]. This will start the TUTORIAL.BAT batch file which will first check if all necessary files are present, and if they are, start Polar Explorer and instruct it to play the 0-INTRO introductory script. As already mentioned, you can invoke a script and adjust the time delay constant by using the `/S:` and `/T:` command line parameters when starting Polar Explorer. For example, if you type the following at the DOS prompt:

POLAR /S:1-BASIC /T:-0.5 (and press [Enter])

the program will automatically start playing the 1-BASIC script and the time delay constant will be set to -0.5.

The '**Play script**' function in the '**File**' menu can be used to start playing a tutorial script from within Polar Explorer. After activating '**Play script**', you will be asked to supply the name of the script file you wish to play. That can be done in two ways:

- By typing the name of the script into the dialogue box (do not include the extension, it is assumed to be `.{S}`).
- You can also enter an empty string, or supply the path to the directory containing script files. After that, you will be prompted to select one of the available scripts from a bar menu.

WARNING: The majority of tutorial scripts rely on using the 'TUTORIAL' glider and sheet libraries. The following files, containing the two libraries, should be present on your current directory:

- TUTORIAL.GL? (`.GL0`, `.GL1`, `.GL2`) – Glider library
- TUTORIAL.PE? (`.PE0`, `.PE1`, `.PE2`) – Sheet library

If you make any changes to these two libraries, or delete any of these files, some tutorial scripts may not play properly!

Playing Speed and 'T delay'

The overall script playing speed can be adjusted by modifying the time delay constant ('**T delay**') located in the '**File**' menu. A lower value causes a shorter delay (i.e. faster playing), and vice versa. Normal 'T delay' is 1; 'T delay' of 0.5 roughly doubles the playing speed, while 'T delay' of 2 cuts it in half.

'T delay' constant can be both positive and negative. When it is positive, the message windows displayed by a script are kept on the screen for a certain length of time, determined by the size of the window and the value of 'T delay'. This way, the entire script can be played without any input from the user.

When 'T delay' is negative, the program automatically pauses after issuing a messages window, which is kept on the screen until you press a key or click a mouse button.

Playing speed of regular program commands (e.g. moving the cursor and typing in the numbers) is not affected by the sign of 'T delay'.

The original setting of 'T delay' is -1, which is well suited for viewing the tutorial scripts. If the playing appears too fast or too slow, you can change this value, and you can also save the new 'T delay' as default by using the '**Options/save current options**' function.

Note: At certain points, tutorial scripts have to adjust various options and settings in order to proceed with playing. This is usually done rather quickly, so that minimum time is wasted. Therefore, if something is happening too fast for you to follow, don't worry, you aren't missing anything important.

Script Commands

- When a tutorial script is playing, it takes full control over program execution, and only allows you to use the following commands:
- Press [Esc], or click the right mouse button to move immediately to the next command or message window.
- Hold down the [Esc] key, or the right mouse button to perform a fast-forward. Generally, the right mouse button advances through the script much faster than the [Esc] key.
- Press any key except [Esc] once, or click either left or middle mouse button, to interrupt (pause) playing.
- When the playing is paused, press any key or click any mouse button to resume it. Note that when 'T delay' is negative, the script automatically pauses after issuing a message window.
- Press [Alt]-[=] (hold down the [Alt] key while pressing the [=] key) to terminate playing. This will leave you in the environment that was set up by the script. You can use this method to try out things on your own.
- Press [Alt]+[topic number] to jump directly to any of the topics listed in the script's table of contents. For example, to jump to topic number 5, press [Alt]-[5]. If a topic has a two digit number, for example 22, then hold down the [Alt] key while pressing the [2] key twice. For this purpose, use only the numeric keys on the main alphanumeric keypad.
- You can press [Alt]-[0] (zero) at any point to jump directly to the end of the script. This will also reset the data sheet and bring you back to the '**Play script**' menu, where you can start playing another script.

Polar Explorer's scripts can only be played forward. This also means that you cannot use the [Alt]+[topic number] command to jump to a topic that has already passed. If you wish to go back, you must follow these steps:

1. Press [Alt]-[0] to jump to the end of the script, or use [Alt]-[=] to terminate playing.
2. Restart the same script by using the '**File/Play script**' function.
3. Advance to the desired point, usually with the [Alt]+[topic number] command.

Contents of Tutorial Scripts

This chapter lists short descriptions and the tables of contents of all 11 tutorial scripts. It can serve as a reference when using the online tutorial. A similar list is given in the -- INDEX script.

0-INTRO

Introduces the Polar Explorer program and explains how to use the tutorial scripts. Estimated playing time: 34 minutes.

No	Topic
1	How to use tutorial scripts; List of commands
2	Playing speed and auto pause for message windows
3	Starting scripts
4	General notes on Polar Explorer; Licence agreement
5	List of files provided with the program
6	New things in Polar Explorer Version 2.1
7	A quick tour through Polar Explorer:
8	1-BASIC Basic, cross-country and climb performance
9	2-CIRCL Circling performance
11	3-CL-CD Lift coef.-Drag coef. (C_L - C_D) performance
22	4-SHEET Sheet mode and the contents of data sheet
33	5-GRAPH Graph mode and its commands
44	6-FUNC Main menu and program functions
55	7-EDIT Entering and editing glider definitions
66	8-XC-CAL X-Country Calculator
77	9-FG-CAL Final Glide Calculator
88	ADVANCED Exploring different glider modifications

1-BASIC

Introduces basic, cross-country and climb performance curves (Basic/XC/Climb).
Estimated playing time: 29 minutes.

No	Topic
1	General notes
2	Basic performance curves
3	Curve #1: $V^{rel,air} - W^{abs,sink}$
4	Curve #2: $V^{air} - L/D \text{ rel } (E)$
5	XC (Cross-country) performance curves
6	Curve #3: $V^{stf} - W^{climb}$
7	Speed-to-fly and irregular polars
8	Curve #4: $V^{stf} - W^{climb} + W^{sink}$
9	Curve #5: $W^{climb} - V_{xc} \text{ average}$
11	Curve #6: $W^{updraft} - V_{xc} \text{ average}$
22	Climb performance curves
33	Curve #7: $W^{updraft} - \text{Bank angle } (\Phi)$
44	Curve #8: $W^{updraft} - V^{circling}$
55	Curve #9: $W^{updraft} - W^{climb}$

2-CIRCL

Introduces circling performance curves. Also explains different circling modes and the concept of optimum circling. Estimated playing time: 19 minutes.

No	Topic
1	About circling performance curves
2	Circling Settings and circling Mode
3	Curve #1: Radius - $V^{circling}$
4	Optimum circling airspeed
5	Curve #2: Radius - W^{sink}
6	Curve #3: Radius - Bank angle (Φ)
7	Direct correlation between circling airspeed, sink rate and bank angle
8	Sink rate comparison between Optimum mode and circling with a

constant C_L

3-CL-CD

Introduces four different types of lift coefficient - drag coefficient (C_L-C_D) curves. Estimated playing time: 15 minutes.

No	Topic
1	About C_L-C_D performance curves
2	Lift-Drag Settings
3	Curve #1: C_L-C_{Dv1} (C_D visc.; $MRe=1$)
4	Curve #2: C_L-C_{Dv} (C_D visc.; Re varies)
5	Curve #3: C_L-C_D (C_D total; Re varies)
6	Curve #4: C_L-C_{Di} (C_D induced)
7	Comparing C_L-C_D curves

4-SHEET

Takes you on a tour through the data sheet. Explains Sheet mode commands and the roles of various data fields. Shows the effects of different settings on some of the basic and cross-country performance curves. Also introduces the coefficient of updraft drift (C_{ud}) and some basic concepts regarding generalized speed-to-fly theory. Estimated playing time: 61 minutes.

No	Topic
1	Using the mouse; Main menu; Help bar; Main data sheet; The rest of data sheet; Moving around the data sheet
2	Types of data fields; Editing data fields;
3	Sheet; Precision: (Calc.; Graph); Print step
4	Sho & Co fields for curves and glider cells
5	Low-hi limits for diagrams and tables

6	V equivalent and W equivalent (V^{\wedge} and W^{\wedge})
7	Wcl max; Updraft definition (Updr.Dia ÷ Variable Dia)
8	Settings in the bottom table; Glider; Alt. (P, T, Ro, u)
9	Underlying different settings; Using the [=] key
11	Bug
22	W/S; Ball.
33	Mc
44	Wind: (B; Hor.V; Ver.W)
55	Cud; Generalized speed-to-fly theory
66	Negative Mc setting
77	Output Atmosphere

5-GRAPH

Takes you through Polar Explorer's Graph mode and explains the Graph mode commands. Estimated playing time: 43 minutes.

No	Topic
1	About Graph mode; Display graph
2	Mouse; Cursor; Diagram elements
3	Basic graph mode commands
4	Win; Last; Out; Pan; All; Exit
5	X= ; Y= ; Dist
6	Annotating commands
7	Line; Rect; Circ
8	Text; Eras; Wipe
9	Hide; Xor
11	Edit Graph; Polar editing commands
22	Move; Drag
33	Ins; Rem
44	Shift; sScale
55	Undo; Grab

6-FUNC

Takes you through Polar Explorer's menu tree and describes the program functions. Also shows how to use glider and sheet libraries. Estimated playing time: 54 minutes.

No	Topic
1	Menu structure and program functions
2	Glider
3	Glider and sheet libraries
4	Sheet
5	Basic/XC/Climb
6	Circling
7	Lift-Drag
8	Options; Sheet lib; Glider lib
9	Units
11	Printing options;
22	Colors; Zero suppress chr
33	Warning sound; [Enter] advance; Input checking; sAve current options
44	Various diagram options
55	File; Exit to DOS; DOS shell; About
66	Play script; T delay; Record script

7-EDIT

Explains Polar Explorer's glider definitions. Also demonstrates how to enter a new polar, and how to remove any unwanted polar curve irregularities (waviness). Estimated playing time: 33 minutes.

No	Topic
1	Glider definition; Polar type; Input Atmosphere
2	Entering a glider definition; Glider; Alt.; V^{\wedge} ; W^{\wedge}
3	Wing span; Wing area; Dry mass (weight); W/S; Ball.
4	Wing planform; Aspect ratio correction factor

5	Reynolds number exponent
6	1000xCD bugs
7	Smallest irregularity
8	Second derivative: (Scale, Show, Color); Edit polar
9	Entering polar points
11	Polar waviness; Second derivative (SD) lines
22	Rules for smoothing the polar curve
33	Saving a new glider definition

8-XC-CAL

Introduces X-Country Calculator that has been added to Polar Explorer in Version 2.1.
Estimated playing time: 64 minutes.

No	Topic
1	About X-Country Calculator; Loading a glider
2	Customizing the atmosphere model
3	Defining a special thermal (updraft) model
4	Entering a task (example of a 400 mile triangle); Dist; $W^{(u)}$; Alt.1; Alt.2
5	General settings: Wind; Flying Tactics; Glider condition;
6	Alt.; Free and fixed altitude modes
7	Recalculate; Working altitude
8	$W^{(cl)}$; $V^{(stf)}$; V^A ; W^A
9	Results for each leg: $V^{(ci)}$; Bank; T cl; L/D rel Crab; V xc; T total
11	Summary results for the whole task; !! symbol
22	Advanced use of X-Country Calculator
33	Comparing cross-country performance - method A
44	Comparing cross-country performance - method B
55	Special cases that cannot be calculated; Optimize $V^{(stf)}$

9-FG-CAL

Introduces Final Glide Calculator that has been added to Polar Explorer in Version 2.1.
Estimated playing time: 27 minutes.

No	Topic
1	About Final Glide Calculator
2	Atmosphere model
3	Alt.; Free and fixed altitude modes
4	General settings
5	Final glide parameters: Alt.2; Dist; $W^{(cl)}$
6	Recalculate; Working altitude
7	$W^{(cl)}$; $V^{(stf)}$; V^A ; W^A
8	Calculated results: Alt.1; L/D grnd; Crab; V grnd; T glide
9	Influence of different factors on a final glide

ADVANCED

Demonstrates Polar Explorer's advanced polar editing capabilities and shows how to explore the consequences of different glider modifications. Estimated playing time: 42 minutes.

No	Topic
1	About glider modifications
2	Increasing the wing span
3	- Sink rate and L/D comparison
4	- C_L - C_D analysis
5	- Circling performance comparison
6	Adding winglets
7	- Sink rate and L/D comparison
8	- C_L - C_D analysis
9	- Circling performance comparison
11	Reducing the parasite drag
22	- Sink rate and L/D comparison
33	- C_L - C_D analysis
44	- Circling performance comparison

About Glider Polars

All Polar Explorer's performance calculations are based on a glider definition, which normally includes a speed-sink polar as its central part. The quality of the obtained results, therefore, largely depends on the accuracy of the polar being used.

The question of polar accuracy is quite intricate, and must be evaluated separately for each particular case. For example, it is very likely that the polars of two gliders of a same type will be noticeably different if they come from different sources, even when reduced to the same wing loading. In a case like that, it is important to figure out whether the polars are different because of calculation or measurement errors, or because the two gliders actually have different performance.

In this chapter, we will try to give you some general guidelines on how to assess polar accuracy, and also some insight into why gliders of the same type may exhibit different performance. We will start by analyzing the influence of the polar source (i.e. whether it has been derived by calculations or in-flight performance measurements) on its accuracy.

Calculated Polars

Calculated polars are usually produced by sailplane designers and/or manufacturers, and published in glider flight manuals, advertising brochures, or magazine ads.

Up until recently, the calculated polars were mostly based on simplified theoretical and semi-empirical methods, which relied on published airfoil data. However, numerous comparisons between calculated and measured polars reveal that those methods often tend to overestimate the performance, sometimes by more than 10%. The following are some possible reasons for the discrepancy:

- It is very difficult to accurately calculate the interference drag, such as the one caused by the wing-fuselage connection.
- Most published airfoil data pertain to very smooth wing surfaces. However, the real world gliders, especially the older wooden and metal ones, do not attain the desired surface quality, even when brand new.
- It is impossible to manufacture wings with the perfect airfoil shape with any of the classic glider manufacturing techniques, be it in wood, metal or composite materials. The actually produced airfoils usually exhibit a lower maximum lift coefficient and higher drag coefficient, when compared to the theoretical ones.
- Many sources of parasite drag are difficult to account for. These include things like imperfect fit of the canopy, dive brakes or landing gear doors, as well as various points where air leaks can occur.
- The laminar separation bubble, which is difficult to predict, can appear at certain angles of attack. Whenever it forms, it substantially increases the profile drag, and consequently the sink rate.
- Last but not least, the calculated polar is in many cases a powerful marketing tool, so the glider designer may be under considerable pressure to make a few optimistic assumptions when doing the calculations. However, such practice can easily become counter productive if the glider manufacturer becomes notorious for publishing polars that are regularly too optimistic.

In recent years, the accuracy of the calculated polars has improved quite dramatically. The new computerized methods have made the aerodynamic calculations easier and more precise. Also, the theoretical and experimental research has produced more reliable data and some glider designers are now using the wind tunnel tests as a part of the design process. As a result, the calculated polars of some of the latest types of gliders are fairly close to their actual performance.

Measured Polars

Measured polars are usually not supplied by glider manufacturers. The tedious flight testing and data processing has been done by soaring enthusiasts such as Paul Bikle, Richard Johnson and Hans Zacher, to name only those who should be given most credit. Their work was usually supported by institutions such as Dallas Gliding Association and German DVL (formerly DFVLR) institute.

Although glider performance measurements can be done in many different ways, only two flight testing methods were generally used: the partial glide descent timing (mostly

used by Bikle and Johnson) and the side-by-side comparison with a calibrated glider (mostly used by Germans).

- **Partial Glide Descent Timing** is a procedure in which a test pilot measures the time it takes the glider to descend from one altitude level to another, at a constant equivalent airspeed. The sink rate is then calculated from the altitude difference and the duration of descent. The procedure is repeated for different airspeeds, and even several times for the same airspeed. (The airspeed system has to be calibrated in order to compensate for its errors.) After the flight testing is done, the obtained speed-sink points are converted to the sea level conditions in the Standard atmosphere, and plotted on a diagram. At the end, the polar is drawn as the best-fit curve through the measured points.
- This method results in a considerable scatter of the measured speed-sink points, mainly because the air in the atmosphere is never perfectly still. The obtained polar is usually not very accurate, unless a large number of points is used.
- **Side-By-Side Comparison With a Calibrated Glider** is a method in which the sailplane being tested is flown side-by-side with a calibrated glider (whose polar is already known). Both gliders start from approximately the same altitude, and are flown at the same airspeed for a certain period of time. During that time, one of them usually loses more altitude than the other, which can be measured by analyzing the photographs of the two gliders taken from a chase airplane at the beginning and at the end of the glide. Since the sink rate of the calibrated glider at that airspeed is known, the sink rate of the glider being tested can be determined. The same procedure is then repeated for different airspeeds, until enough points are obtained to draw the polar.

The scatter of thus obtained speed-sink points is much less than in the descent timing method, because the effects of vertical air movement are largely cancelled out by both gliders flying in the same airmass. However, the whole measurement is based on the assumption that the polar of the calibrated glider has been precisely determined, since any error in it will be repeated in the test polar. (The performance of the calibrated glider is usually measured using the partial glide descent timing method with a very large number of points, in order to minimize the error.)

Performance Differences Between Gliders of a Same Type

So far, we can conclude that any polar, either calculated or measured, has a certain margin of error, and thus should be taken with some reserve. Maybe even more important is to realize that two gliders of a same type may exhibit a noticeable difference in performance. This can be caused by the following factors:

- Since manufacturing and finishing of composite gliders is primarily done by manual production methods, the wings that come out of a same mould are not identical, neither in mass, nor in geometry. The same applies even more to metal and wooden gliders. As a result, two brand new unmodified gliders of the same type can differ in performance, as well as in handling characteristics.
- After several years of production, the molds used for manufacturing of composite wings may become slightly deformed. If that happens, the gliders produced later in the series will most likely have inferior performance to the ones made from the new molds.
- As a glider gets older, the quality of its surfaces begins to deteriorate, resulting in loss of performance. The extent of surface degradation depends mostly on the type of glider construction and the material used for surface coating. It also depends on how well the glider surfaces have been maintained and protected from hostile elements like Sun UV rays, rain, dust, extreme temperatures, etc.
- After coming out of the factory, most gliders need some touch-up work in order to realize their full performance potential. This usually includes installing seals at places such as wing roots, dive breaks, ailerons, etc. In case of gliders equipped with blow holes for boundary layer control, some of them may be plugged and need to be cleaned. On some glider types, these simple modifications can improve the performance by several percentage points.
- As mentioned earlier, the actual airfoil of a wing coming out of a factory is usually somewhat distorted. This flaw can be corrected by filling and sending, with the help of accurate airfoil templates. Although this procedure has a potential of significantly increasing the performance, it is not widely used because it requires a huge amount of labor.

- A gliders that has been repaired after a structural damage can suffer a performance loss, especially if the damage was to the wings.

All this should be kept in mind before using any particular polar in performance calculations. Even if you have obtained a precisely measured polar of a glider that is the same type as yours, you should estimate whether your glider is in better or worse shape than the one tested. If you conclude that there is a difference, you should modify the original polar accordingly.

For example, if you assume that your glider has a 2% performance advantage over the one tested, you can use the '**sScale**' polar editing function to reduce the sink rate by 2% throughout the polar. To do that, specify the scale factor of 1 in the horizontal direction, and the factor of 0.98 in the vertical direction.

Incomplete Polars

In addition to all the uncertainties surrounding the question of polar accuracy, you may run into another problem. Namely, a relatively large number of published polars (measured ones in particular), do not cover the entire airspeed range. In some cases, that can have negative consequences on the accuracy of certain performance calculations.

- **Case 'A'**: If the high speed end of a polar is cut short, so it ends below the V_{NE} , Polar Explorer will use the cruising speeds only up to the value defined by the high speed end of the polar. This is normally not a problem because the extremely high speeds are rarely used anyway. In fact, you may intentionally cut the high speed end in order to limit the cruising speeds used by the program.
- **Case 'B'**: Many measured polars, and even some calculated ones, do not start from the minimum airspeed, but rather from a point close to the minimum sink speed. Some even don't go below the best L/D speed! While this may be acceptable for evaluating the straight flight performance (e.g. speed-to-fly), it is totally inadequate for calculating circling performance.

The low speed end of the speed-sink polar is of the foremost importance for realistic calculation of the optimum circling performance. If a portion of the low speed end is missing, the calculated circling sink rate will be unrealistically high, especially at a small radius, and the minimum radius will increase substantially. This will also degrade the calculated climb performance and the corresponding cross-country performance.

Note: Many glider definitions included in the 'POLAR' library have polars with either one both ends cut short, because these polars had been published that way, and we tried not to make any modifications to the original data. If you have to use such a polar, we suggest that you try to extend its low speed end by making it similar to the calculated polar for the same type, or to the polar of a similar glider. Otherwise, you might as well avoid any performance analysis that involves circling flight.

Glider Library Included with Polar Explorer

Sources

Polar Explorer comes with a library of glider definitions that are mostly based on measured polars published by different authors. Although we have made every effort to transfer the data as accurately as possible, we cannot guarantee that the polars included in this library are identical to the published ones. In most cases we had to scale the curves from the diagrams which were hand drawn and usually too small for accurate measurements.

The source of each polar in the Polar Explorer's library is indicated in parentheses in both the glider name and the comment. The following are the main sources that have been used:

- (J) (Johnson) *Flight Test Evaluations of...* by Richard H. Johnson published in the Soaring magazine.
- (D1) (DFVLR-1) *Flugmessungen mit 25 Segelflugzeugen* by H. Laurson and H. Zacher, DFVLR Institute, Germany, (1972)
- (D2) (DFVLR-2) *Flugmessungen an 35 Segelflugzeugen und Motorseglern* by H. Laurson and H. Zacher, DFVLR Institute, Germany, (1976)
- (D3) (DVL) *Flugmessungen mit Segelflugzeugen von 12 bis 13 M Spannweite* by Hans Zacher, DVL, München-Riem, Germany, (1965)

- (M) (FFM) *Flight performance measurements on twelve sailplanes* by H. J. Merklein and H. Zacher, Scientific Flight Research Establishment Munich (FFM), (1964).

List of Gliders in the 'POLAR' Library

The glider definitions currently included in the glider library 'POLAR' are listed in this section. The following example illustrates the meanings of different elements used in this list:

105. Mini Nimbus /N871T/#16 (J) (Johnson; Seals installed)

105. Serial number in the 'POLAR' library
 Mini Nimbus Glider type
 N871T Glider registration number
 #16 Factory serial number
 (J) Polar source
 Johnson Polar source
 Seals installed Additional comment

No.	Glider	(Source; Comment)
1.	Ahrens Delphin V2 (D3)	(DVL)
2.	AK 1 /D-KEUL (D2)	(DFVLR-2)
3.	ASH 25 /N80WK/#4 (J)	(Johnson)
4.	ASH 26E (C)	(Calculated polar)
5.	ASK 13 /D-2018 (D1)	(DFVLR-1)
6.	ASK 16 /D-KEIK (D2)	(DFVLR-2)
7.	ASK 21 /N362KS/#225 (J)	(Johnson)
8.	Astir CS /D-7290 (D2)	(DFVLR-2)
9.	ASW 15 /D-0510 (D1)	(DFVLR-1)
10.	ASW 15 /D-0791 (D1)	(DFVLR-1)
11.	ASW 17 /N45JD (J)	(Johnson)
12.	ASW 17/20m /D-1110 (D2)	(DFVLR-2)
13.	ASW 17S/21m /D-2119 (D2)	(DFVLR-2)
14.	ASW 19 /D-4525 (D2)	(DFVLR-2)
15.	ASW 19 /N19KL (J)	(Johnson)
16.	ASW 20 /N104WR/#17 (J)	(Johnson)
17.	ASW 20 [-9] /N104WR/#17 (J)	(Johnson; [Flaps -9 deg])
18.	ASW 20 [8,0] /N104WR/#17 (J)	(Johnson; [Flaps +8 & 0 deg]))
19.	ASW 22/22m /N2702J/#15 (J)	(Johnson)
20.	ASW 22/24m /N2702J/#15 (J)	(Johnson)
21.	ASW 24 (D*)	(German Test Data)
22.	ASW 27 (C)	(Calculated polar)
23.	Bergfalke II /D-1217 (M)	(FFM)
24.	Bergfalke III /D-1737 (D1)	(DFVLR-1)
25.	Bergfalke IV /D-1005 (D2)	(DFVLR-2)
26.	Blanik L-13 (F)	(Factory)
27.	Bocian /D-1578 (M)	(FFM)
28.	Calif A-21 S /D-2176 (D2)	(DFVLR-2)
29.	Cirrus /D-0471 (D1)	(DFVLR-1)
30.	Cirrus /D-0471 (D2)	(DFVLR-2)
31.	Club Libelle /D-3695 (D2)	(DFVLR-2)
32.	D-34 b Aphrodite/D-4607 (M)	(FFM)
33.	D-34 d (D3)	(DVL)
34.	D-34 d /D-4607 (M)	(FFM)
35.	D-36 V1 /D-4685 (D1)	(DFVLR-1)
36.	D-37 Artemis /D-2278 (D2)	(DFVLR-2)
37.	D-37 Artemis /D-KEDD (D2)	(DFVLR-2)
38.	D-38 /D-0938 (D2)	(DFVLR-2)
39.	DG 300 /N33HB/#E47 (J)	(Johnson; Sealed, clean holes))
40.	DG-100 /D-1076 (D2)	(DFVLR-2)
41.	DG-100 /D-7099 (D2)	(DFVLR-2)
42.	DG-101 G /N101TX/#E168 (J)	(Johnson)

No.	Glider	(Source; Comment)
43.	DG-200 /N200GA/#2-101 (J)	(Johnson)
44.	DG-600/15 /N70205 (J)	(Johnson; 15m; No winglets)
45.	DG-600/15W /N70205 (J)	(Johnson; 15m; With winglets))
46.	DG-600/17 /N70205 (J)	(Johnson; 17m)
47.	Discus A /N52XX/#33 (J)	(Johnson; sealed)
48.	Discus A [W] /N52XX/#33 (J)	(Johnson; Ballasted)
49.	Elfe S3 /HB-902 (D1)	(DFVLR-1)
50.	Elfe S4 /D-6301 (D2)	(DFVLR-2)
51.	Elfe S4 /D-6668 (D2)	(DFVLR-2)
52.	FK 3 /D-0292 (D1)	(DFVLR-1)
53.	FS 24 Phonix T /D-8385 (M)	(FFM)
54.	FS 25 Curevo /D-8141 (D1)	(DFVLR-1)
55.	FS 29-13.8m /D-2929 (D2)	(DFVLR-2)
56.	FS 29-16m /D-2929 (D2)	(DFVLR-2)
57.	FS 29-19m /D-2929 (D2)	(DFVLR-2)
58.	FS 29-all /D-2929 (D2)	(DFVLR-2)
59.	Glasflugel 604 /D-8085 (D2)	(DFVLR-2)
60.	Glasflugel 604 /N57L (J)	(Johnson)
61.	Glasflugel 604 mod./N57L (J)	(Johnson; Corrected profile)
62.	Grob 102 Club IIIb/N3981A(J)	(Johnson; /#5610 Sealed)
63.	Grob 103 Twin II /N427BG (J)	(Johnson)
64.	Grob 103 Twin II mod. (J)	(Johnson; Mod.wheel fairings))
65.	Grob 103C Twin III (J)	(Johnson; /#34107)
66.	Grob 109B /N300BG/#6390 (J)	(Johnson)
67.	H-101 Salto /D-2040 (D1)	(DFVLR-1)
68.	H-201 St.Libelle/D-0082 (D1)	(DFVLR-1)
69.	H-301 Libelle /D-9412 (D1)	(DFVLR-1)
70.	H-401 Kestrel /D-0245 (D1)	(DFVLR-1)
71.	Hi 25 Kria (D3)	(DVL)
72.	Hornet /D-7816 (D2)	(DFVLR-2)
73.	J-4 Javelin /N5TF (J)	(Johnson)
74.	Jantar 1 /N46DB (J)	(Johnson)
75.	Jantar 2A /N980 (J)	(Johnson)
76.	Jantar Std. /N51AS/#880 (J)	(Johnson)
77.	Jantar Std. /SE-TOI (D2)	(DFVLR-2)
78.	Jantar Std.2 /N45AS/#863 (J)	(Johnson)
79.	Janus /D-3111 (D2)	(DFVLR-2)
80.	Janus /N468F (J)	(Johnson)
81.	Jaskolka Z-O SZD-8ter (M)	(FFM /HB-604)
82.	K-7 /D-1800 (M)	(FFM)
83.	K-8 /D-1590 (M)	(FFM)
84.	K-8-KM 48 /D-KIBO (D1)	(DFVLR-1)
85.	Ka-6 BR/S /D-8390 (M)	(FFM)
86.	Ka-6 CR (D3)	(DVL)
87.	Ka-6 CR /D-1810 (D1)	(DFVLR-1)
88.	Ka-6 CR /D-1810 (D2)	(DFVLR-2)
89.	Ka-6 CR /D-4390 (M)	(FFM)
90.	Ka-6 E /D-3657 (D)	(DFVLR-2)
91.	Kestrel /D-0475 (D2)	(DFVLR-2)
92.	Kestrel 19(T59D)/D-5999 (D2)	(DFVLR-2)
93.	KORA 1 /D-KORT (D2)	(DFVLR-2)
94.	Kranich III /D-1398 (M)	(FFM)
95.	LCF 2 /D-6446 (D2)	(DFVLR-2)
96.	LS 1-C /D-0558 (D1)	(DFVLR-1)
97.	LS 1-F /D-3252 (D*)	(German Test Data)
98.	LS 1-F /D-3252 (D2)	(DFVLR-2)
99.	LS 3 /N45EW (J)	(Johnson)
100.	LS 4 /D-2628 (D*)	(German Test Data)
101.	LS 4 /D-2628; W/S=34.4 (D*)	(German Test Data)
102.	LS 4 /D-6680 (D*)	(German Test Data)
103.	LS 4A /N274W/#321 (J)	(Johnson)

No.	Glider	(Source; Comment)
104.	LS 4A /N430RH/#384 (J)	(Johnson)
	No. Glider	(Source; Comment)
105.	Mini Nimbus /N871T/#16 (J)	(Johnson; Seals installed)
106.	Mistral /D-4998 (D2)	(DFVLR-2)
107.	Mosquito /N46898 (J)	(Johnson)
108.	Mu 22 b /D-1848 (D1)	(DFVLR-1)
109.	Mu 26 /D-0726 {1971} (D1)	(DFVLR-1)
110.	Mu 26 /D-0726 {1972} (D1)	(DFVLR-1)
111.	Nimbus 3/22.9 /N49JD/#19 (J)	(Johnson)
112.	Nimbus 3/24.5 /N49JD/#19 (J)	(Johnson)
113.	Nimbus 3/24.5 Mod. (J)	(Johnson; Profiled wing)
114.	Nimbus II /D-0107 (D1)	(DFVLR-1)
115.	Nimbus II /D-0699 (D1)	(DFVLR-1)
116.	Nimbus II /D-2111 (D2)	(DFVLR-2)
117.	Nimbus II Smooth /N45DJ (J)	(Johnson; Smoothed wings)
118.	Phoebus C /D-0559 (D1)	(DFVLR-1)
119.	Pik 20 A /OY-XCR (D2)	(DFVLR-2)
120.	Pik 20 A.I. /N100DC/#8 (J)	(Johnson; With ail.interconn))
121.	Pik 20 B Mod. /N46JD (J)	(Johnson; Mod.w.leading edge))
122.	Pik 20 D-78 /N19YZ (J)	(Johnson)
123.	Pik 20 No AI /N100DC/#8 (J)	(Johnson; No ail. interconn.))
124.	Pilatus B4 PC11 /HB-1127(D2)	(DFVLR-2)
125.	RF 5 B Sperber /D-KOKS (D2)	(DFVLR-2)
126.	Sagitta /PH-319 (D1)	(DFVLR-1)
127.	Salto 15 mod. /D-2220 (D2)	(DFVLR-2)
128.	SB-10 /D-6085 (D2)	(DFVLR-2)
129.	SB-8 V2 /D-6085 (D1)	(DFVLR-1)
130.	SB-9 /D-6085 (D1)	(DFVLR-1)
131.	Schweizer 1-26E /N33904 (J)	(Johnson; /#634)
132.	Schweizer 1-35 /N17976 (J)	(Johnson)
133.	Schweizer 1-36 /N362IT (J)	(Johnson)
134.	SF 27 A /D-6068 (D1)	(DFVLR-1)
135.	SF 28 Tandem /D-KFAJ (D2)	(DFVLR-2)
136.	SF 30 Club Spatz /D-3697(D2)	(DFVLR-2)
137.	Skylark 3 F /RAF-146 (M)	(FFM)
138.	Std. Cirrus /D-0483 (D1)	(DFVLR-1)
139.	Std. Cirrus /D-3261 (D2)	(DFVLR-2)
140.	Std. Cirrus B /N5CC (J)	(Johnson)
141.	Std. Cirrus/16m /D-3261 (D2)	(DFVLR-2)
142.	SZD-30 Pirat /D-3660 (D1)	(DFVLR-1)
143.	SZD-55-1 /N3176T (J)	(Johnson)
144.	Vega /N3751Q/#1927 (J)	(Johnson)
145.	Ventus A /N47JD/#29 (J)	(Johnson)
146.	Ventus A/16.6 (J)	(Johnson; Original wing)
147.	Ventus A/16.6 Mod. (J)	(Johnson; Profiled wing)
148.	Ventus B /N139P (J)	(Johnson)
149.	Zuni /N14XZ/#14 (J)	(Johnson)
150.	Zuni [-8.8] /N14XZ/#14 (J)	(Johnson; [Flaps -8.8 deg])
151.	Zuni [0] /N14XZ/#14 (J)	(Johnson; [Flaps 0 deg])