

Exploring the Polar

© Derek Ruddock Southern Cross Gliding Club, Sydney November 2009

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Introduction

If we measure the sink rate of a glider at various airspeeds, and plot the results on a graph, the result is known as a polar curve, as in the picture below

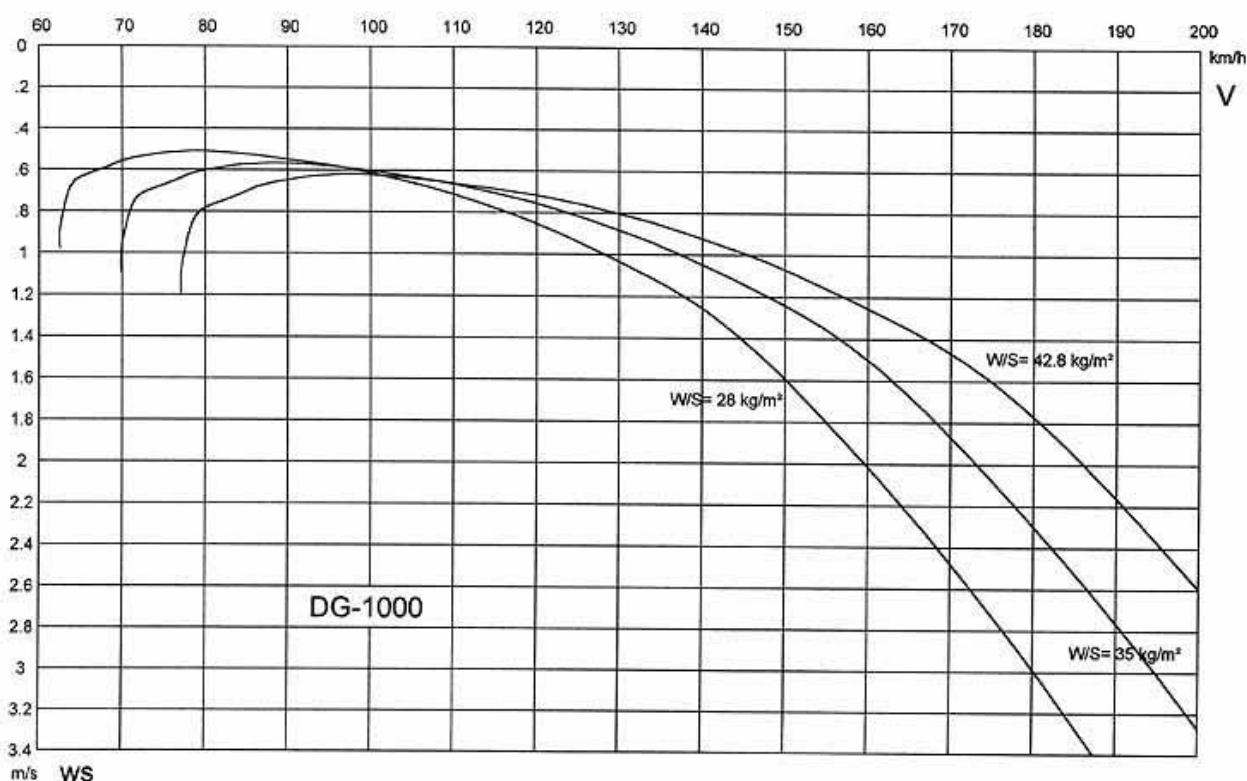


Figure 1 Sink Polars for DG1000

Note in figure 1 that there are 3 polars shown for the DG1000, corresponding to 3 wing loadings: flown with a single pilot, flown 2 up, and flown at maximum take off weight of 750kg.

There are a number of books that describe in detail how you can use the polar to determine, for example the best speed to fly given a particular wind strength, however this requires a lot of work combining the various lift or sink strengths with head or tail wind. Fortunately Jim Rennie, of the Central Coast Gliding Club has done all the work for us in his excellent spreadsheet POLAR10.XLS. This can be downloaded from a number of sources including from our club web site. The version on our web site has a number of changes from the original, such as the addition of the polars for the DG1000, the extension of the speed ranges, and a couple of minor error corrections.

Introduction to Polar10.

The spreadsheet has a number of tabs along the bottom edge, each opens a different sheet which I shall describe in turn. If the tabs are not visible, go to Tools/Options/view, and ensure that Sheet tabs in the bottom right hand corner is checked.

Contents

This page contains Jim's contact details, and shows the list of tabs. There are 2 dropdown listboxes, from which you may select any of the dozens of gliders in the database.

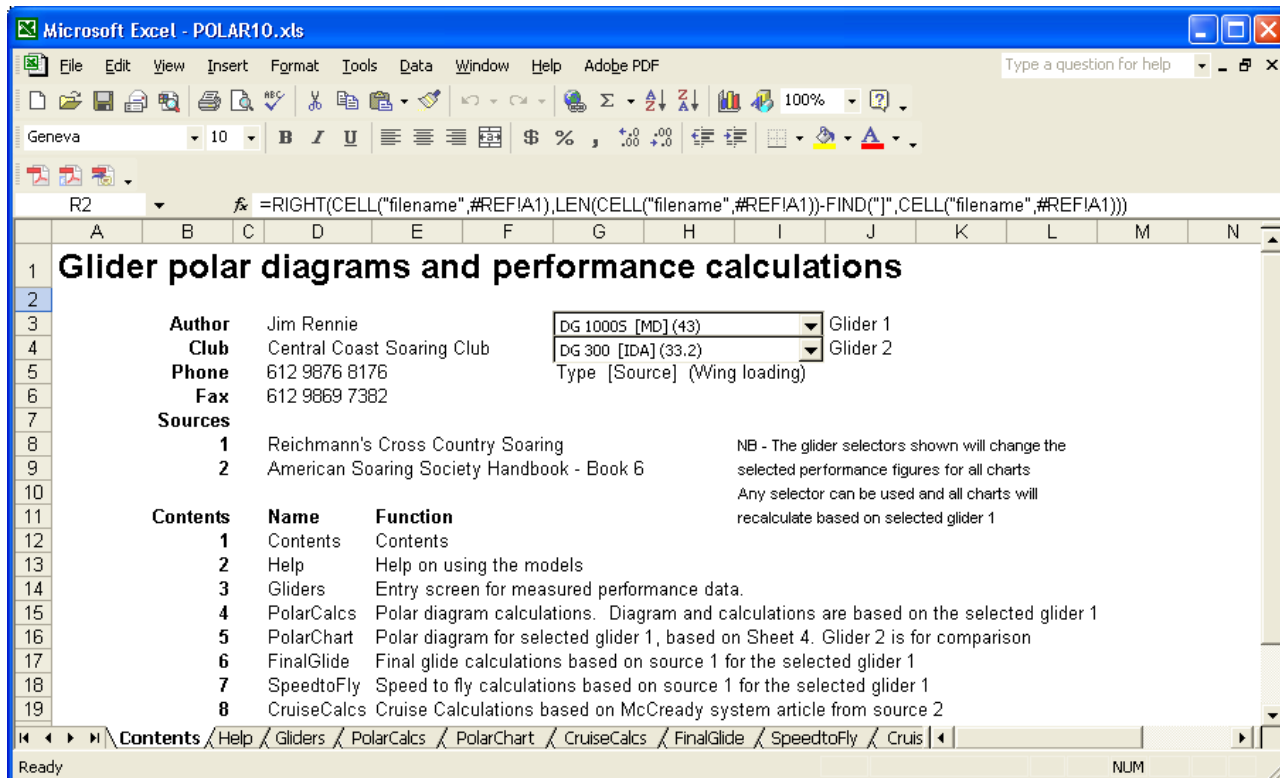


Figure 2 The Contents page

Help

This sheet describes how to add a new glider polar to the database.

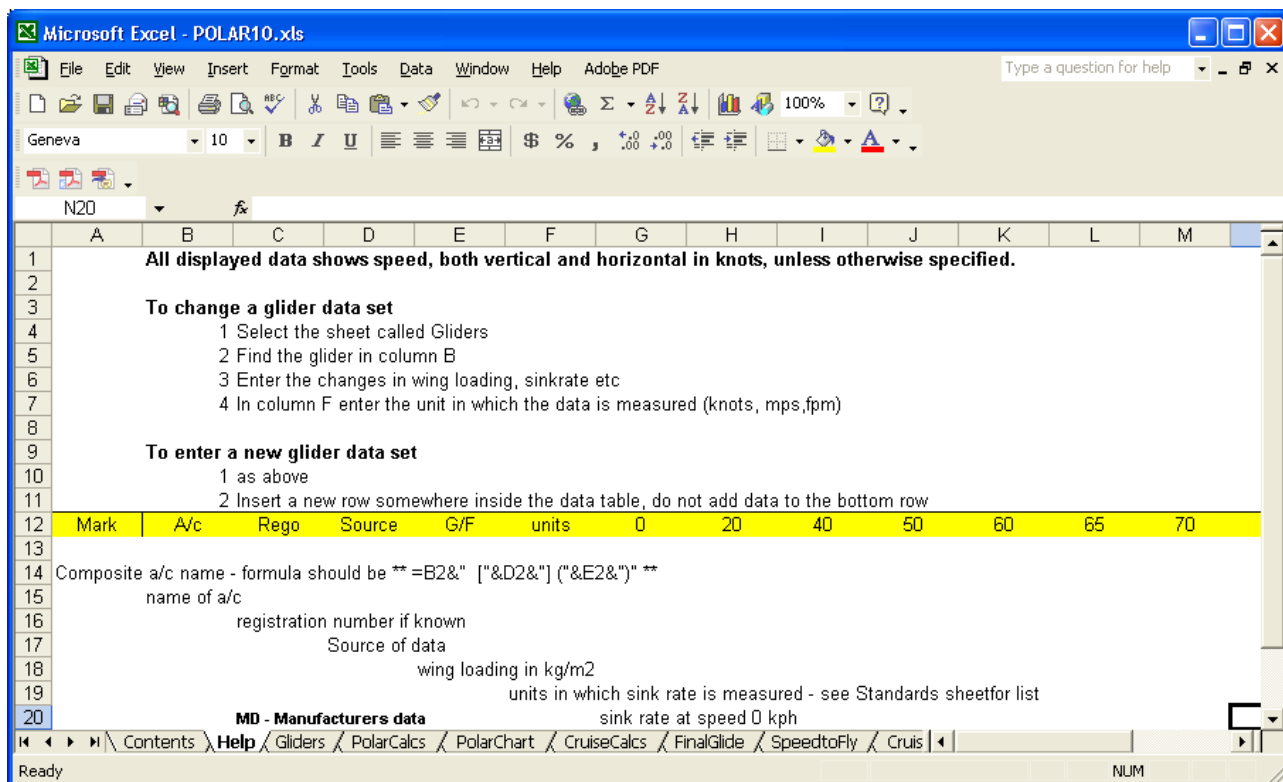


Figure 3 The Help page

Gliders

This sheet contains the polar data, as described in the Help section. The 'Mark' column (column A) contains a composite of the aircraft type (column B), the source (Column C, usually MD for Manufacturer's Data, but may contain any other value), and the wing loading (column E).

If the glider of interest is not in the glider list, then get hold of a polar and insert the values yourself, as I have done for eth DG1000.

Note. As explained in the Help page, it is important when adding data to insert lines within the existing data. Adding data to the end of the list will not work, as it will be outside the named range.

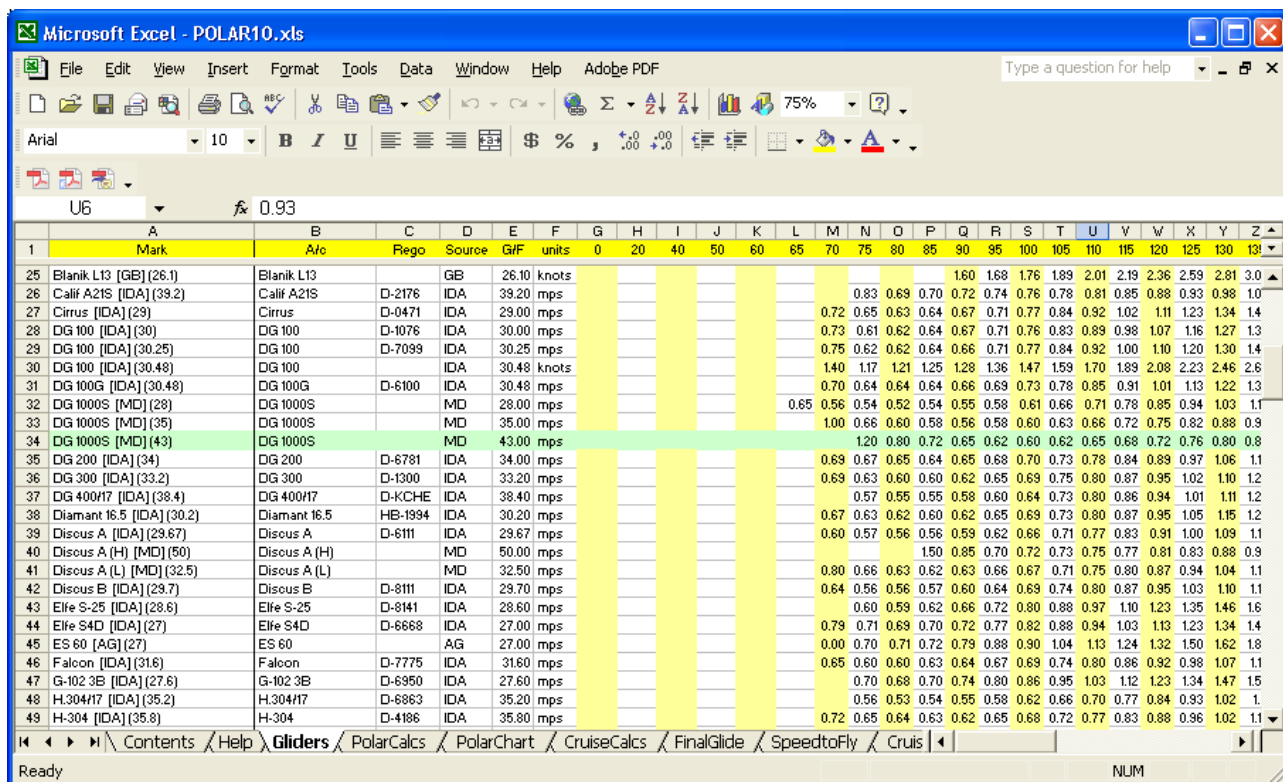


Figure 4 The Gliders page

PolarCalcs

On this page, you can select the glider that you are interested in. In addition a second glider, or a different wing loading for the same glider, may be selected for comparison purposes, the DG1000 at 43kg/m² vs the DG1000 at 35kg/m² in the figure. The sink speeds are transcribed depending on the selected glider.

Jim has used calculations from Helmut Reichmann's classic 'Cross Country Soaring' to calculate a number of values, including the L/D ratio, the speed to fly for best L/d and the minimum sink speed, in addition to calculating the L/D at various speeds.

Unless you have a head for figures, this page may be of limited use directly; however the calculated values are used in the following sheets and are much easier to understand.

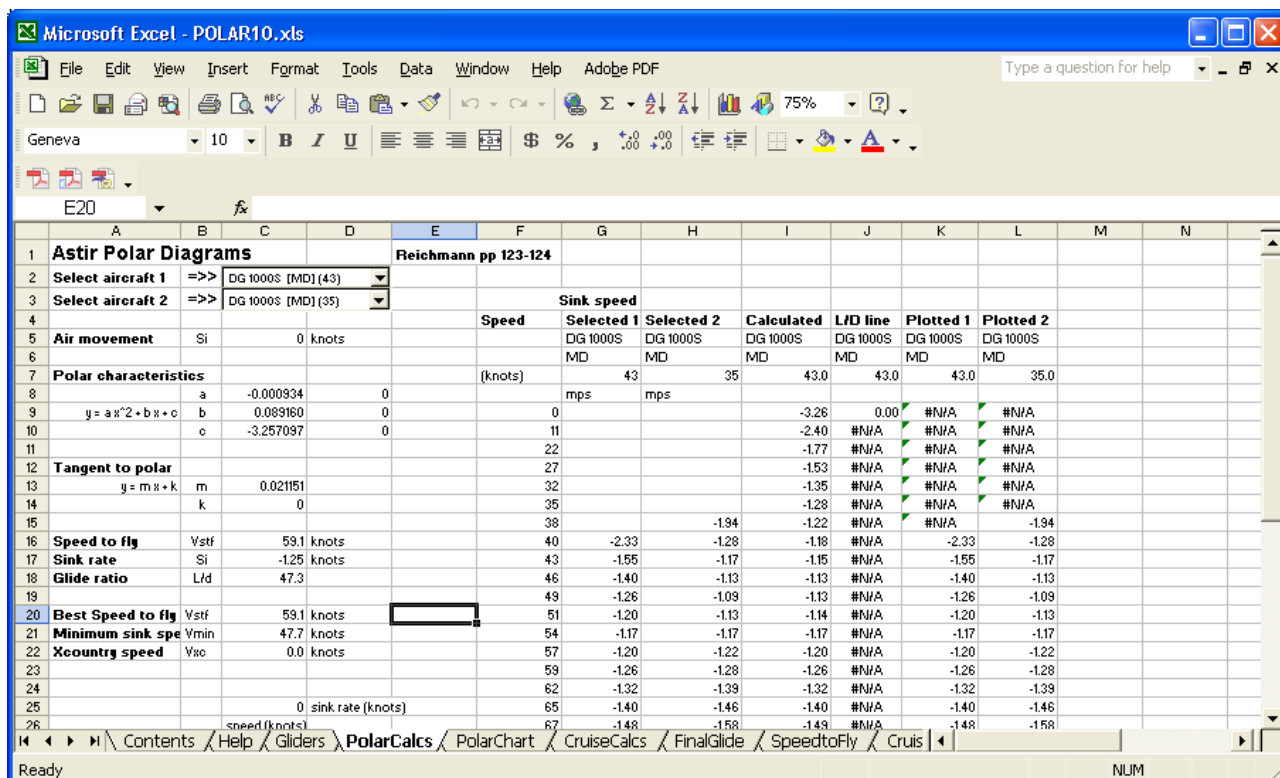


Figure 5 The PolarCalcs page

PolarChart

This is the first of the graphical tabs, and displays the data calculated on the PolarCalcs page.

The graph plots the values of the sink rates of the gliders at varying speeds, and is thus a polar chart.

The 2 glider selection boxes are also displayed on this page, enabling the selection and comparison of different gliders without the need to leave the page.

In addition to the plotted polar curves, the graph displays the calculated best glide ratio, and the corresponding speed to fly.

The calculation uses a quadratic equation to match the plotted polar. If the calculated curve does not closely follow the plotted values, it can be adjusted slightly with the Curve Adjuster up and down arrows until the best fit is obtained.

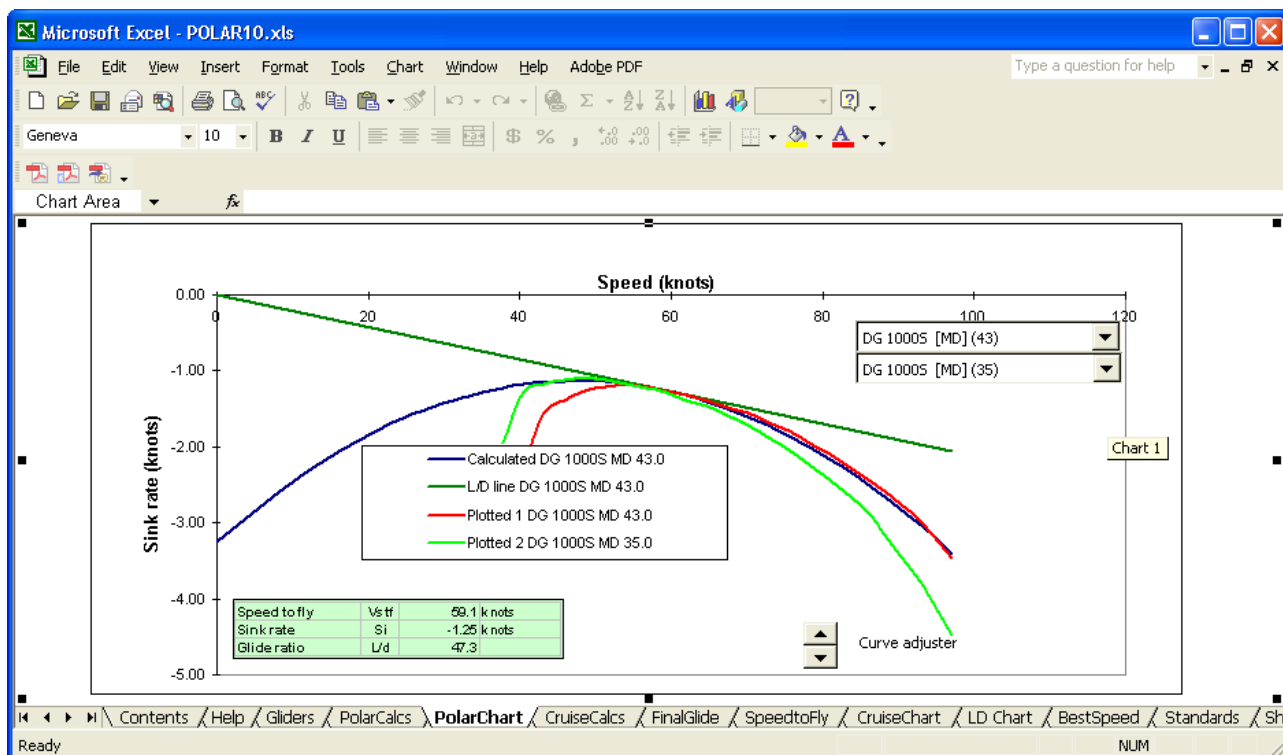


Figure 6 The PolarChart page

CruiseCalcs

This page again uses calculations from Reichmann to calculate the expected cross country speeds for given climb rates.

The first column in the table (B11:B43) is a range of speeds. The second column (C11:C43) shows the sink rate at that speed in knots.

Columns D to I show the calculated cross country speeds in kph that will be achieved if the glider flies at the speed in column B

For example, cell E26 (highlighted in green) shows that at an average thermal strength of 1 knot (as shown in E10: ignore the leading minus sign), the average cross country speed will be 69kph, if the speed flown between thermals is 62 knots. If you decide to fly at 89 knots for some reason, your average cross country speed will only increase to 71kph, as shown in cell E36, highlighted in red.

By the same token, if the average thermal strength is 8 knots, and your interthermal speed is 100 knots, your calculated cross country speed will be 125kph (cell H40, highlighted purple)

The sink factor between thermal can be set with the 'Select sink factor' arrows. By changing the sink factor, the effect on the cruise speeds can be determined.

These tables are portrayed graphically on the CruiseChart tab.

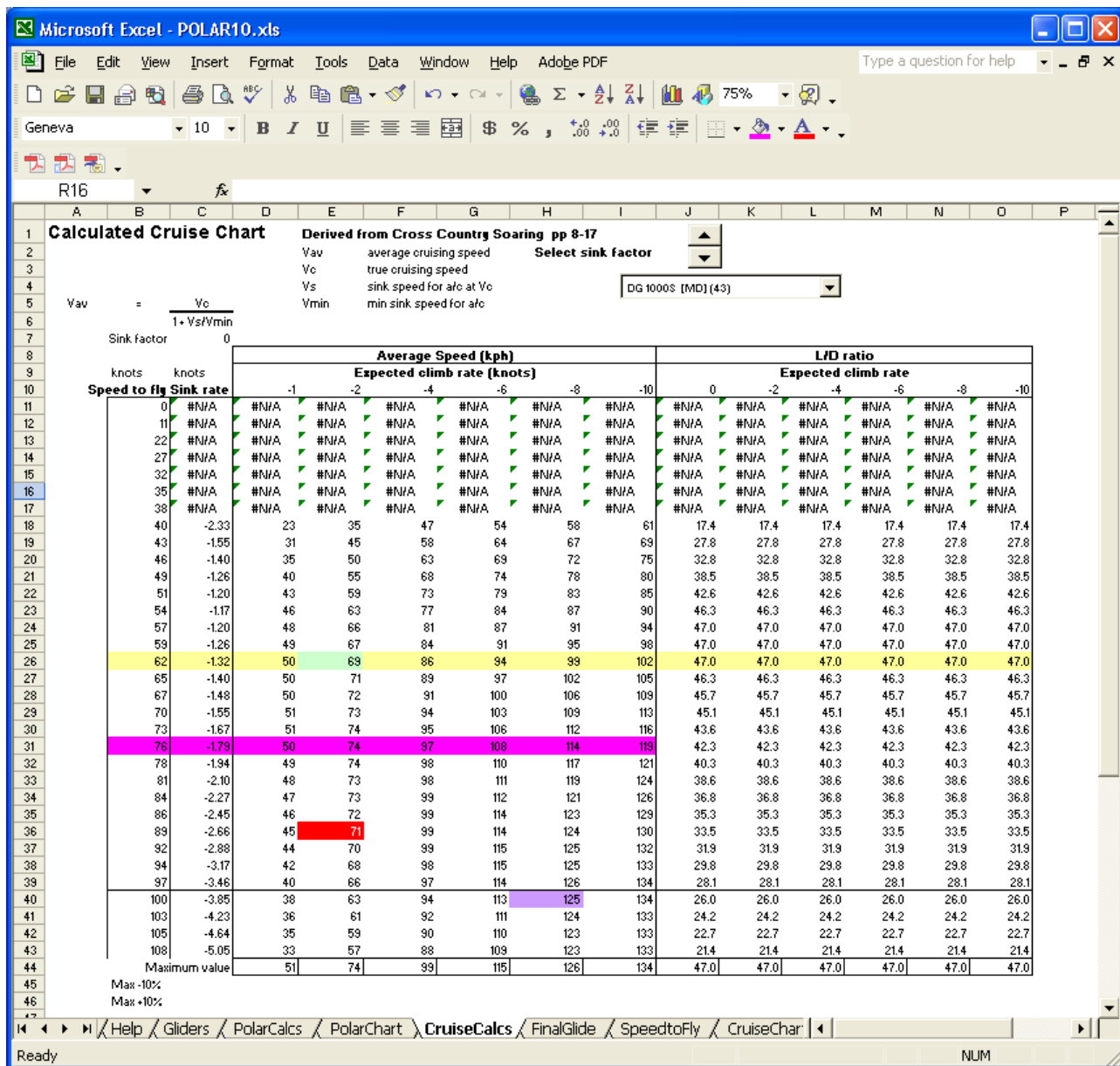


Figure 7 The CruiseCalcs page

FinalGlide

Arguably of reduced benefit in these days of glide computers, this page displays the calculations that can be used to determine the final glide for the selected Glider 1, at a distance of 50km.

In the example (highlighted in yellow), for a lift strength of six knots in nil wind, The final glide for the DG1000 should be started at 6000 feet, at a speed of 100 knots. Note that as the lift strength increases, the required height increases, as the glider is flying faster. Note also that there is no allowance made in these calculations for a circuit, and therefore 1000 feet should be added to all the displayed figures.

The top table of calculations shows the groundspeed, ie the airspeed less a headwind or plus a tailwind.

The middle table shows the height that will be consumed over 50km flying at the speed in column B, for the various head and tail winds. For a 6 knot thermal, the final glide should be at 100 knots for the DG1000. The calculation is (distance in feet*sink rate)/groundspeed: the final glide distance of 50,000m (50km) is multiplied by the number of feet in a metre to give the distance. This is then divided by the groundspeed to give the time taken to cover the distance. The time, when multiplied by the sink rate gives the height required, ie the height that will be lost in that time.

The final table shows the calculated l/d for the various speeds at the selected wind strengths.

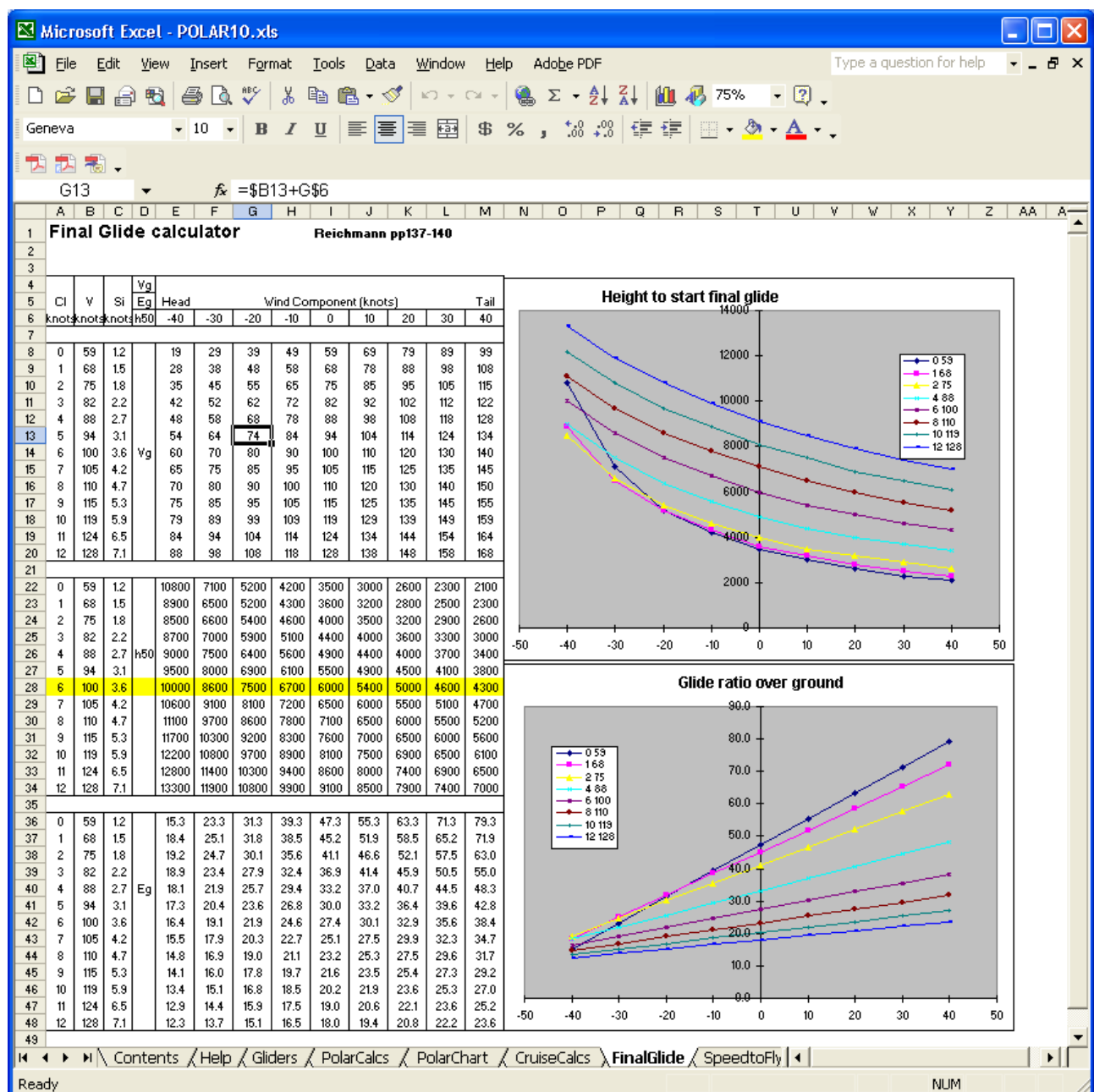


Figure 8 The FinalGlide page

SpeedtoFly

Probably one of the more useful pages, this sheet plots the speed to fly (left axis) against the expected average lift strength (bottom axis), and the resultant achieved cross country speed (in kph) on the right hand line.

Some interesting observations can be made from this graph, for example, from 6 knots on the achieved cross country speed line is almost linear, and if the average lift strength for the flight doubles from 6 knots to 12 knots, the average cross country speed only rises from 130 to 150kph. At strengths of less than 6 knots, the curve is steeper, and therefore the effect on the achieved cross country speed is more marked.

Note that these calculations are a model: they do not take into account the life cycles of thermals: In real life, a glider flying towards the minimum of the speed range would arrive at the thermal too late to connect with the lift. Conversely a glider flying at the highest speed would probably end up too low to connect with the lift due to the higher sink rate.

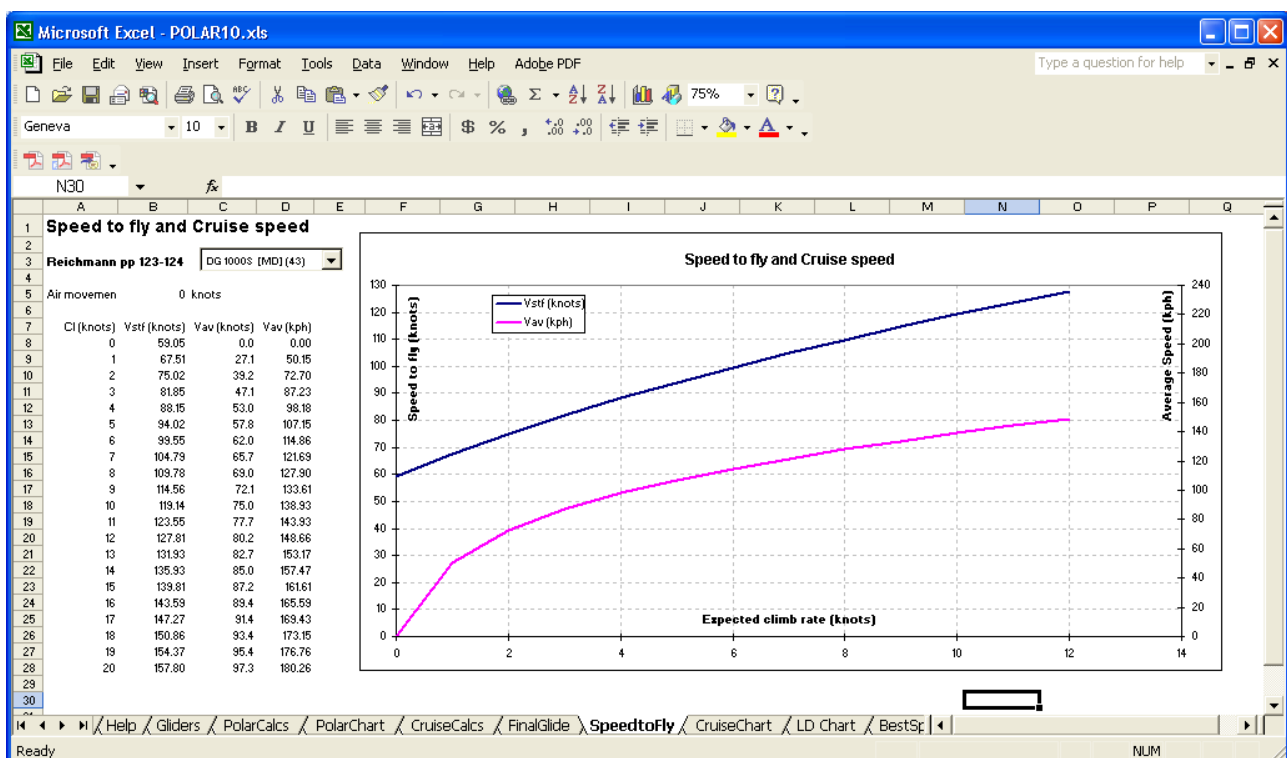


Figure 9 The SpeedtoFly page

CruiseChart

This chart plots the expected average cross country speeds against various lift strengths, and is a graphical representation of the data on the CruiseCalcs page.

In some ways, this is perhaps the most significant of the pages in this spreadsheet as it shows the result on the achieved cross country speed of flying at a MacCready setting higher or lower than optimum.

Take the pink line as an example. This shows that, for an average lift strength of 2 knots, the best speed to fly between thermals is 76 knots for an achieved cross country speed of 74kph; (the actual value can be verified using the table on the CruiseCals page, highlighted in pink), however, as can be seen, the penalty in achieved speed by flying 10 knots faster, or 10 knots slower is only 2kph, or less than 3%. (Note figures are for a DG1000 at max weight)

For a 4 knot thermal the optimum interthermal speed is about 88 knots for an achieved speed of 99kph, and the penalty is even less.

What does this mean in practice? As noted in the section on CruiseCalcs, this is a model and makes no allowance for the behaviour of thermals, and therefore your likelihood of contacting the next thermal.

What it shows is that, for average lift strength of 4 knots or less, that the penalty for flying more slowly than the MacCready setting would indicate is not going to make much difference to your average speed. The biggest issue is, what MacCready Reading should you use? Glider pilots are like anglers, and inclined to use the peak reading of the vario when lying about the flight in the bar afterwards, however it is important to note that these calculations rely on the average figure, taking into account the time spent trying to centre the thermal initially, and the time wasted remaining in the thermal after the strength of the lift has reduced. Generally speaking the average lift strength is around two thirds to three quarters of the best steady (not peak) reading.

Flying faster than the optimum reduces your cross country speed, and due to the higher sink rate, will probably see you ahead of the pack, but grovelling down in the weeds, looking for a low save.

Flying a few knots slower than the optimum however will only marginally affect your speed, but will increase your range and increase your chance of contacting the next thermal.

In practice what the graphs are showing is that, for weak thermals, setting the MacCready setting to a more conservative value has little effect on your cross country speeds, but increases your chance of finding and connecting with the next thermal., or, to look at it from a different viewpoint, flying much faster than optimum (eg 20knots) only diminishes your cross country speed, and will probably result in an outlanding.

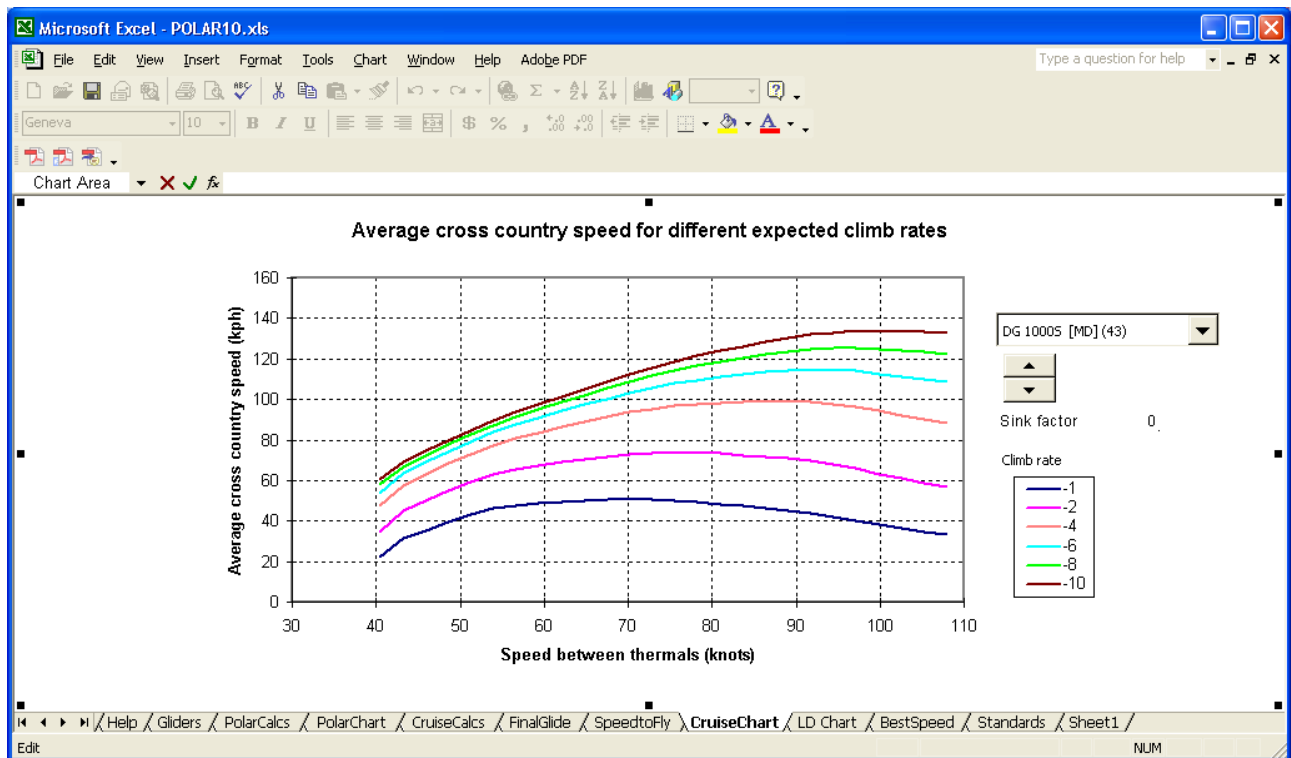


Figure 10 The CruiseChart page

LD Chart

This chart plots the L/D ratio at various speeds: for the selected glider, and again is a graphical representation of the data from the CruiseCalcs page. This shows that for the DG1000, the max L/D is around 47 at 60 knots and is still 35:1 at 85 knots.

Data for all the lift strengths are plotted, but, as the L/D is not affected by the lift, the curves are superimposed.

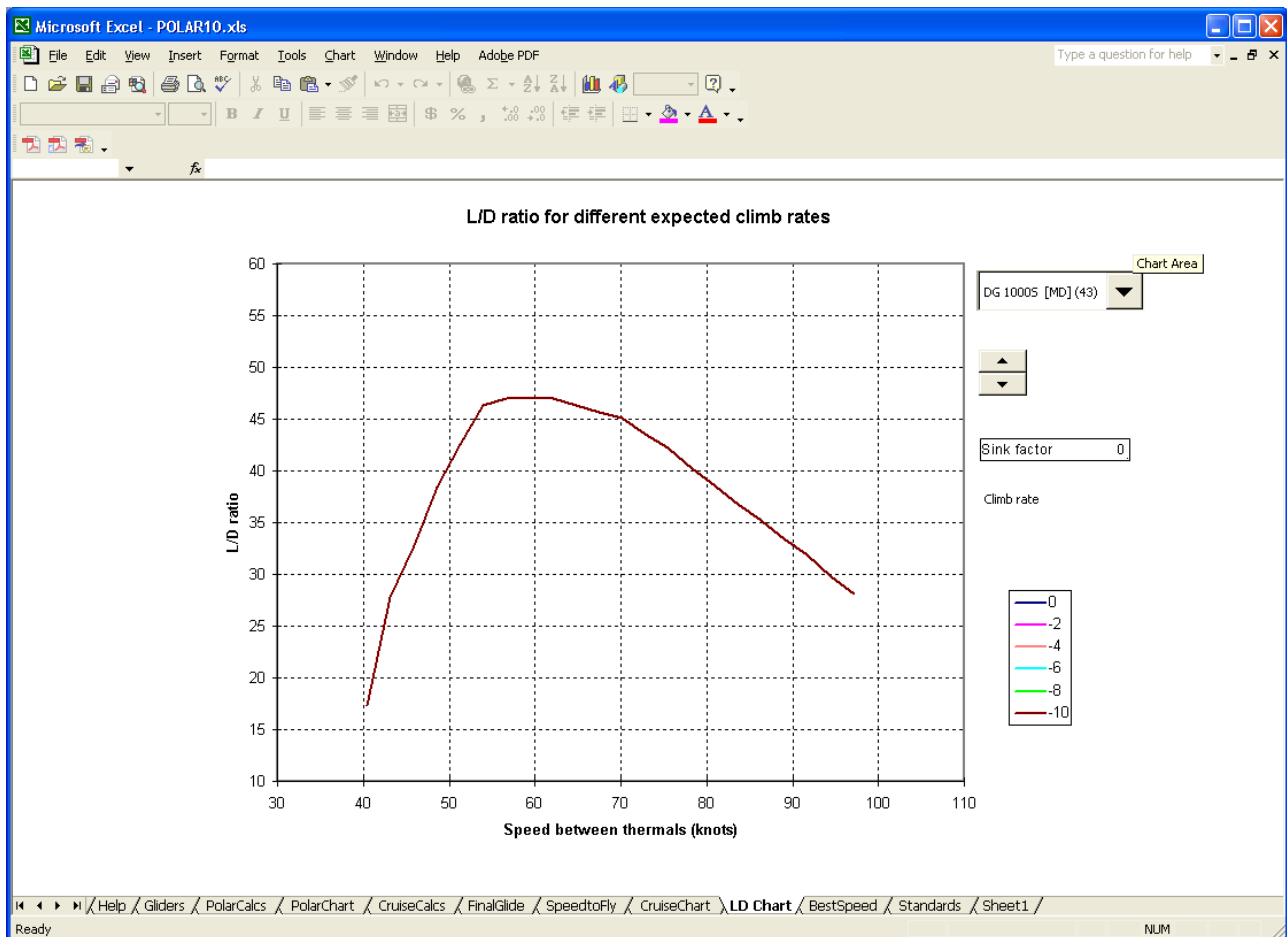


Figure 11 The LD Chart page

BestSpeed

Another useful page, this page enable you to perform ‘what if’ scenarios with various lift and thermal separation combinations, and calculates the optimum speed to fly between thermals.

Again, no allowance is made for the actual behaviour of thermals: flying too fast could result in the glider arriving too low to contact the next thermal, and flying too slowly could mean that the thermal had gone by the time the glider arrived.

To use this sheet, the glider should be selected from the drop[down box, as in al the other sheets. In the yellow box in the left, the average thermal strength can be entered (in this case 4 knots), the bottom of the working lift band (3000 feet) and the cloudbase (8000 feet). In the example the convection goes up to 12000 feet (ie there are Cu’s 4000 feet in depth). For a blue day, the convection height would equal the cloudbase. The thermal distance factor is used in conjunction with the convection height to calculate the distance between thermals.

Whenever any of these factors are changed the spreadsheet recalculates the figures. The optimum speed to fly for the glider under those conditions is then indicated by the XXX in line 21 (90 knots in this case)

This sheet shows the effect of flying to slowly and too quickly: it calculates the distance travelled and the corresponding height lost for all the airspeeds in the range 50 to 110 knots, and displays the results graphically for ease of understanding.

In the chart on the left, the blue lines show the time to fly the distance between thermals figure in cell B18: as the speed increases this time obviously decreases.

The burgundy lines show the time required to climb from the calculated arrival height to cloudbase: as the glider flies faster, the rate of sink increases, therefore the height at which the glider arrives at the next thermal decreases, and the height required, and thus the time, increases accordingly.

The 2 figures below show exactly the same parameters, at 2 knots and at 8 knots. Note the burgundy bars are much lower for the 8 knot graph: the penalty for flying fast when the lift is strong is much reduced. The combined result, ie the top of the blue+burgundy column, shows another interesting result: whereas for the 2 knot graph there is a minimum at around 75 knots, for the 8 knot graph this is not present, in other words as the speed increases, the time taken decreases, showing that as the lift strength increases, there comes a point at which it pays to fly faster. This is demonstrated graphically by the light blue line in the graph on the right.

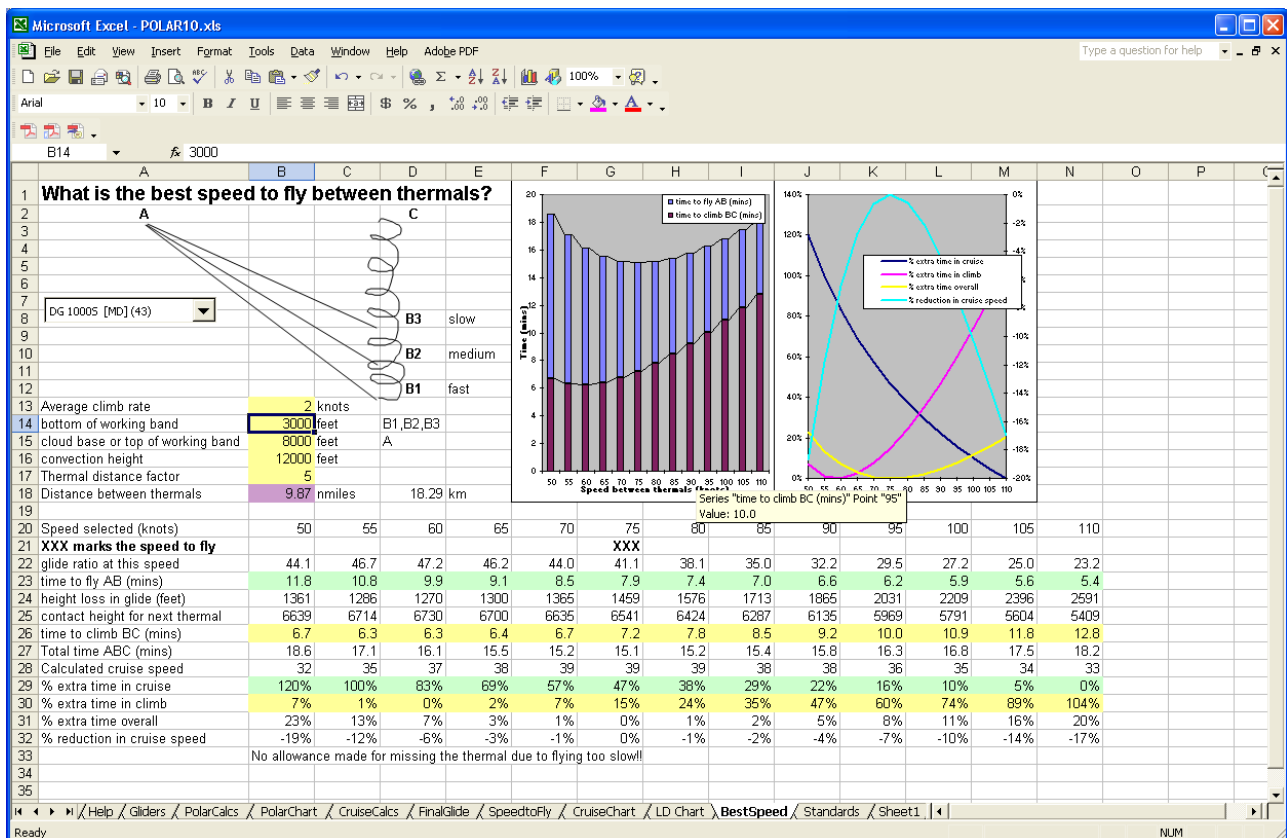


Figure 12 The BestSpeed page – 2 knots

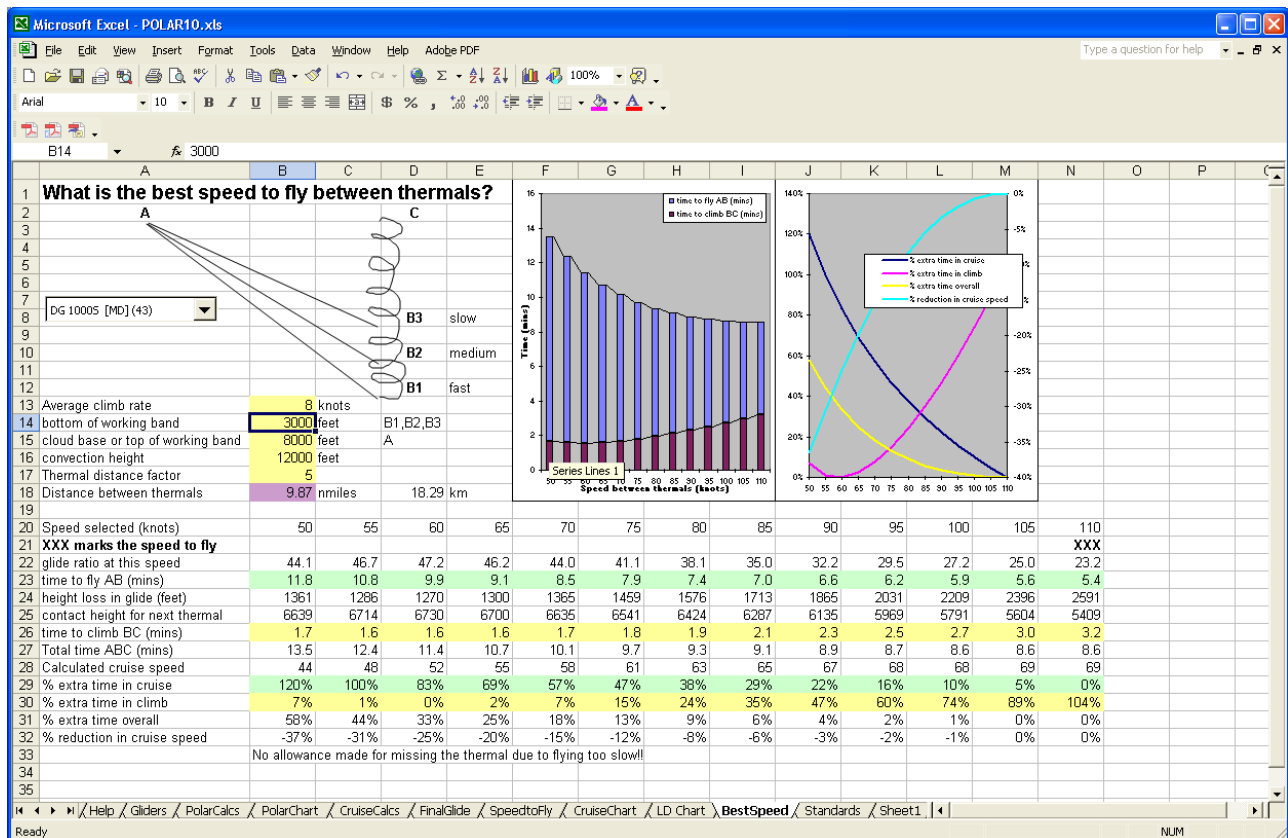


Figure 13 The BestSpeed page - 8 knots

Standards

The final page contains the constants and conversion factors used in the preceding sheets.