

# *Sink-Rate Flight Testing With Your Flight Data Recorder*

*If you haven't spoken a number, you haven't said anything at all. <sup>(1)</sup>*



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## Forward

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A primary concern for all serious glider owners is the performance of their aircraft. For obvious reasons, we take pains to make them and keep them as aerodynamically efficient as possible. A considerable body of knowledge about modifications to improve performance has been amassed over the years. Most of it is reliable but some is questionable.

We seal our canopies and control gaps, install turbulators, add winglets and aileron fences, etc. and then we assume we have improved our gliders. We fly them in turbulent air and we swear they fly better. But we really don't know. Without quantitative information we really know nothing at all and our claims are often just wishful thinking.

My experience with turbulators is a case in point. I followed advice in a booklet that told where to place them. I was sure my glider flew better. Later I thought it would be neat to try some oil flow visualizations. I was surprised to see a hefty transition bubble way out in front of my turbulators. They were only adding to the turbulence behind the normal reattachment point. Then, after fixing the problem, I needed to remove the turbulators for drag probe measurements on the clean wing. So, of course I took measurements first with turbulators then without. I was astonished to find no significant difference at any measured airspeed. Though I was close, once again I had failed to place them forward enough to trip the flow. And, once again I was sure they were helping. Oops!

## Background

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In 2003, when I began working on the deturbulator project, I contacted Richard H. "Dick" Johnson for advice on performance testing gliders. He kindly answered all my questions and supplied me with a sample spreadsheet. I thought I could get better results using my Cambridge 302 logger than by taking data manually, as Dick did. So, I modified his methods to use IGC log data. Then, in December 2006, Dick tested my glider and I had an opportunity to compare methods. He agreed to operate my 302 while he took data his usual way. Later, I compared all 84 of Dick's measurements to the log data using my modified spreadsheet. The results are posted on the deturbulator website ([www.deturbulator.org/Progress-Johnson-Logs.asp](http://www.deturbulator.org/Progress-Johnson-Logs.asp)). They confirmed that Dick's method and mine yielded equivalent results. The differences being that my method relieved the pilot of a significant workload and eliminated a source of human error. Taking the data acquisition part of the work load out of the picture means that average pilots, like you and me, can take good data ourselves.

## Concepts

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### Methods

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In *Sailplane Flight Test Methods* (Soaring Magazine, May 1989), Dick Johnson described five ways that a sailplane's polar might be measured. The two most popular ways are taking sink rate measurements and flying parallel vs. a glider of known performance. For practical reasons, sink rate measurements have been preferred in the US while European manufacturers and the Akafleig groups in Germany prefer the parallel flight method.

Sink rate measurements require only the glider to be tested, a tow plane and two pilots; however, convection in the air must be nearly absent, so opportunities to take data are fewer and multiple flights are necessary to get enough repeated data to average out the errors.

Parallel flying only needs smooth air, but convection is not a problem since one glider is being measured vs. the known performance of another, so there are more opportunities for testing. However, two gliders must be towed to altitude and greater piloting skills and coordination are needed.

This document describes the sink rate method that Dick Johnson used successfully for many years. However, instead of visually reading gauges and manually noting the data, a flight data recorder is used to improve accuracy and relieve the work load to a level that ordinary pilots, with a little practice, can do the job. Except for this difference, the method presented here follows Johnson's time-proven method.

## Airspeeds

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You will be measuring a sink rate at each of a set of airspeeds, usually 5 kts (or mph) or 10 kph apart.

Normally, polars are plotted vs. calibrated airspeed where the calibration accounts for errors in the airspeed indicator and the Pitot/static system. Calibrating the airspeed system is difficult since special knowledge and equipment are needed. For details see the article *Sailplane Flight Test Methods* by Dick Johnson. For more information, go to [www.wikipedia.org](http://www.wikipedia.org) and search for *calibrated airspeed*.

If you want accurate L/D values and polars that can be meaningfully compared to other gliders, you will need an airspeed system calibration of your glider. However, if your concern is only to measure relative differences from modifications to your glider, then you can skip the calibration and use indicated airspeeds instead. Sink-rate plots will be distorted horizontally and L/D figures (airspeed/sink rate) will be inaccurate, but that will not matter as long as you are only interested in relative before and after comparisons.

## Measurements

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To measure a sink rate at a specific airspeed, you need at least two altitudes separated by a time period that is long enough for accurate results. You also need the mean air temperature. Dick Johnson would hold an airspeed long enough to lose 400 or 500 feet of altitude and manually note the beginning and ending altimeter readings and times. He would note the temperatures while on tow every 100 feet or so and later interpolate to the center altitude for a speed run. He would calculate the sink rate as the altitude lost divided by the time elapsed and then, using the temperature and mean altitude, correct the result to equivalent sea level performance.

With a flight data recorder taking samples every 4 seconds or so, you will have more data and better accuracy than you could achieve by reading and manually noting altimeter and timer readings while holding the airspeed steady. The spreadsheet described below uses 10 altitude samples to calculate a sink rate. It does this by fitting a line to the equally spaced altitude samples. The slope of the line is the sink rate. Fitting a line to 10 points that are automatically acquired is better than using only two data points that contain greater errors because they were taken visually by a busy pilot.

Using a flight data recorder also eliminates the need for a calibrated altimeter.

## How much trouble will it be?

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To measure a performance enhancement, you will need to measure a *baseline* polar before the alteration and another *modified* polar afterward. Plotting them together will make the differences obvious. In each case, you will need a minimum of three measurements for enough data to average out scatter from convection and piloting errors. Depending on the quality of your data, you may need additional data. Once obtained, the baseline polar does not need to be repeated.

You will need to hold each airspeed for one minute. This may eat up 6,000 to 8,000 feet in smooth, non-convecting air. If enough altitude is not available, you may have to fly two or more times to acquire all the data. This sounds like a lot of trouble, but taking multiple low-altitude flights under a dead overcast may enable you to take data without waiting for winter. Also, if your tow charges escalate with altitude, two low launches can be more economical than a single high tow.

Once acquired, all that remains is to reduce the data and plot the results. This is handled for you by the sample spreadsheet on the distribution CD. Essentially, this entails choosing which samples to use and plugging them into the spreadsheet. The plots develop automatically as you enter the data.

## What you will need

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You will need the following items:

- **Flight data recorder** – you probably already have one
- **Excel, or compatible, spreadsheet software** – you probably have this too
- **Sample Excel spreadsheet** – included on the distribution CD
- **IGC software program** – Cambridge Aero Explorer is on the distribution CD
- **Thermometer with tethered probe** – a cheap indoor/outdoor digital thermometer will do
- **Video recorder** – optional

An IGC certified **flight data recorder**, or equivalent, is sufficient for recording your altitude readings. Configure it to record samples every four seconds. At four seconds per sample, 10 altitude readings will cover 36 seconds of time. Usually, 45 seconds to a minute is enough time to ensure 36 seconds of good data. Longer may be needed until you develop your skill at setting and holding airspeeds.

A sample **Excel 97-2003** spreadsheet for reducing the data and graphing the result is supplied on the distribution CD. Make a copy for your baseline measurements then copy it for each project. That way you will start each project with a spreadsheet containing the baseline measurements.

An **IGC software program** like Cambridge Aero Explorer is needed for viewing your altitude samples graphically and for displaying the numbers to plug into the spreadsheet. Inspecting the data graphically lets you see the quality of your data. The program must display the individual altitude samples for you to enter into the spreadsheet. Cambridge Aero Explorer was written to accept only files created by Cambridge instruments. If you wish to use this program with non-Cambridge files, you can edit them to make them acceptable. (See **Hints for Using Cambridge Aero Explorer** below.)

A battery operated **thermometer** with a tethered probe is needed for reading the outside air temperature. Secure the probe in the air vent inlet where it will be shaded from direct sunlight.

Finally, a **video recorder** trained on your panel, although not essential, may be helpful. Nobody is perfect and you will certainly forget to note something important while flying. The ability to review your flight instruments in the comfort of your living room will supply missing information and help you pick out the best parts of your data.

## Weather conditions

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Since you will be measuring sink rates, it is important to fly in air that has a minimum of vertical motion, whether general lifting/sinking of the air mass or turbulence or shear wave action. Wind is not a problem as long as it is horizontal and there is no significant shear wave action. Finding good days for testing will be your greatest challenge. Besides general forecasts, you will need to consult a soaring forecast for height of the inversion level and forecasts of winds aloft to estimate the likelihood of shear waves.

For fiberglass ships, 6,000 to 8,000 feet of good air are enough to measure 14 airspeeds. So, if the inversion is around 3000 feet agl, a 10,000 foot tow should be adequate for a full set of measurements. Using your flight data recorder, you will want to fly each speed for at least 45 seconds to a minute. Additional time may be needed if you have trouble setting the airspeed.

Sink rate measurements are normally attempted only in the winter months when the inversion level is often low. However, acceptable conditions occur occasionally in the spring, summer and fall months. For instance, a solid overcast may produce dead air beneath and mild winds over level ground with no appreciable shear. Also, days when the afternoon conditions are unacceptable may be ok early in the morning. One caution here, take care to anticipate the possibility of condensation on the canopy upon takeoff if the humidity is high. You may find yourself flying IFR on tow.

Try as you may, there will be scatter in your data. This comes from two sources: turbulence or convection and your inability to hold airspeeds precisely. The first cause can be minimized by reading the weather conditions carefully. You will get better with experience. The second cause too will improve with experience, though some pilots have no problem from their first flights. You may have to throw out your first attempt because of either or both of these problems. Normal data scatter is illustrated in Fig. 1. When averaged together, three to six flights like this are sufficient for a good measurement (dashed black curves). Dick Johnson typically got maximum deviations of sink rates from a 2<sup>nd</sup> degree polynomial curve fit to the data of 20 fpm for speeds up to say 60 or 70 kts, and more at higher speeds. If you

are seeing 30-40 fpm deviations, then you have likely been bitten by bad weather. More readings of that quality will be needed to give smooth results that are correct.

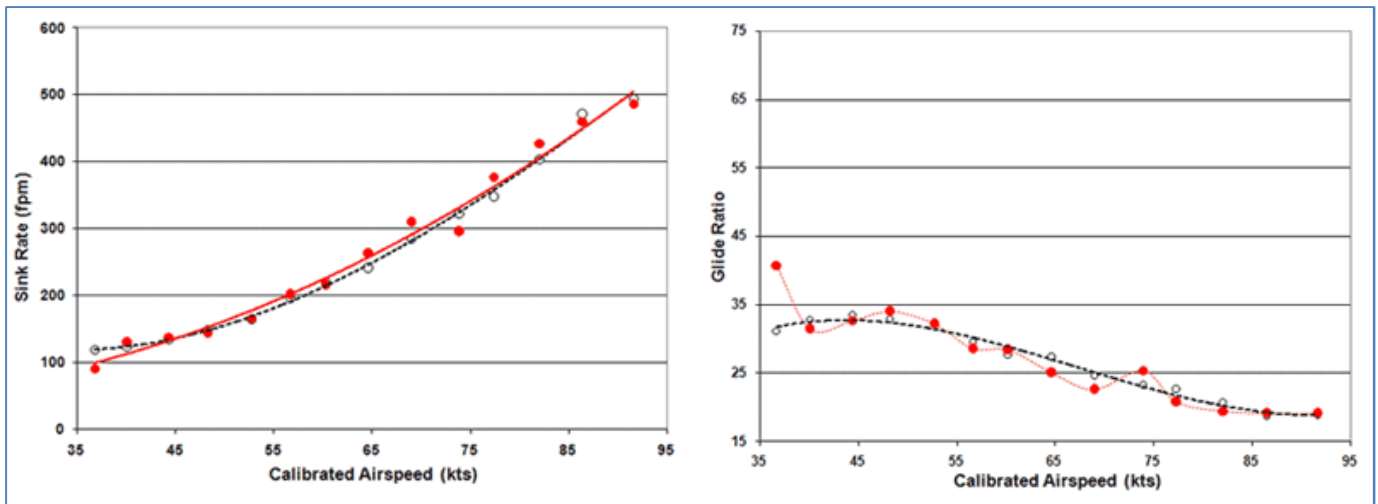


Figure 1 - Normal Data Scatter

## Taking data

### Preparation

Take a **note pad** and **pen** for documenting the sequence of your speed runs, the outside air temperature between runs and comments. Don't depend on your memory, since you will not necessarily fly every speed in sequence and you will occasionally repeat some speeds.

Anticipate the amount of data you will be able to take in the altitude available and write the speeds you intend to fly in the note pad.

Set your logger to record at 4 second intervals and plan to hold your speed runs for 45 seconds to 1 minute each. That should give you 10 clean altitude readings for each speed. That's the way the spreadsheet is set up. However, if for any speed you have fewer points, you can modify the spreadsheet to use what you have. If you extend a speed run long enough, you can decimate (skip) every other point and modify the spreadsheet to use 8 second periods. That can help when your data is not as straight as it might have been. If your logger cannot not log that fast, then use the fastest setting and modify the spreadsheet to work with fewer samples.

If you have a small video recorder, mount it to focus on your ASI, altimeter and thermometer. The recording will come in handy when you forget to jot down a note and your memory fails you. It is also handy for verbally noting the phases of your flight, the temperature readings and comments. Finally, if you have trouble setting and holding an airspeed, replaying the flight can help you find the part of a speed run where you nailed the speed, or where you came closest.

One suggestion that may save you the cost and trouble of a high altitude flight is to check an old IGC log from the logger that you will be using for flight testing. Some loggers and GPS receivers do not have the resolution needed to get reliable sink rates from speed runs as short as 45 seconds. Cambridge Aero Explorer is good for this purpose, as it displays the individual altitude samples in both GPS and pressure altitudes. You should see smooth traces from both sources that track each other very closely except for a DC offset. If the traces are jagged with runs of three or more samples at the same value, then the resolution of the logger/GPS receiver is not up to the task and a better logger is needed.

### Fly the low speeds first

Fly the low speeds first and progress towards the high speeds as you descend. This is because you will encounter rougher air at the low altitudes and you want those errors to be a smaller part of value being measured.

## Notch the barograph between speed runs

You need a way to distinguish which segments of the log were flown at which airspeeds. For that, *notch the barograph* before each speed run. Before the lowest speeds, dip the nose for several seconds then pull it up again. For higher speeds, pull up to slow down, and then set the airspeed. If you notch your altitudes, it will be perfectly obvious where your data is when you look at an altitude vs. time plot. You only need to consult your note pad for the sequence of the speeds you flew. Your data will be in the smooth, straight segments between notches. Fig. 2 is a notched altitude profile. The airspeeds are annotated for illustration. The blue data are GPS altitudes and the red are pressure altitudes. You can see that they follow one another closely.

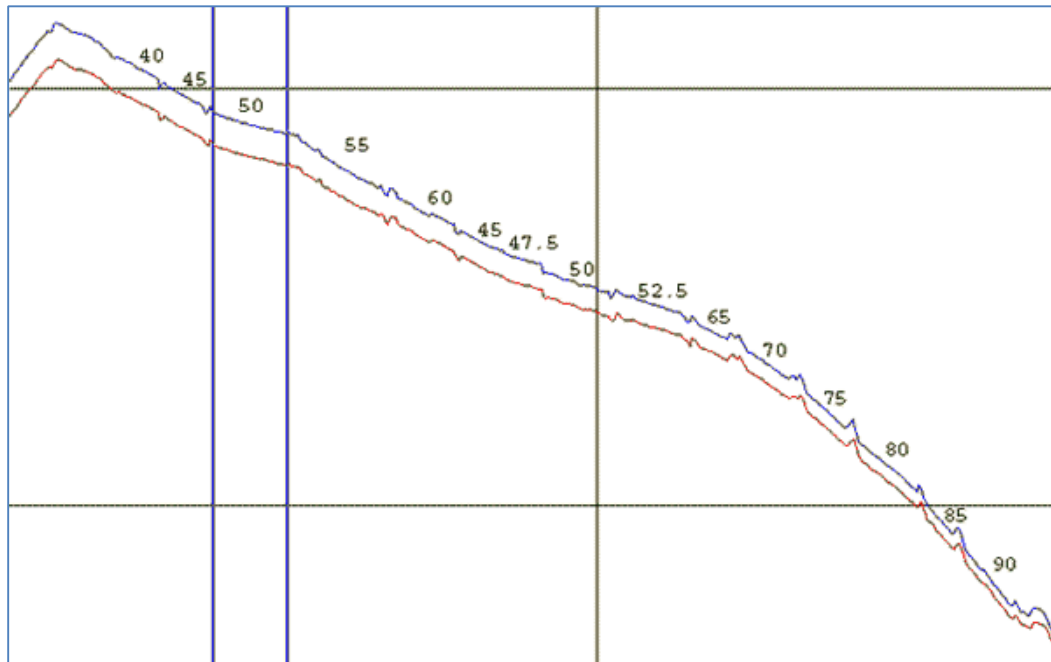


Figure 2 - Notched Altitude Profile

When you are notching the barograph, it is a good time to note the speed flown and the thermometer reading in your note pad.

## Setting and holding airspeeds

After notching the barograph, you will then push the nose down or pull it up to your next airspeed. As you approach it, ease back or forward as necessary to level out with the ASI needle directly over the hash mark. If you overshoot, you will waste altitude hunting the speed. Some hunting is inevitable, but, with practice, you will gain proficiency.

Then, having set the speed, you will begin counting down the seconds as you hold it without deviation. You will need to make minute corrections as the needle drifts off the hash mark. Again, with practice, when the air is smooth and without shear waves, you may surprise yourself at how perfectly you can hold the speed. This is the most critical skill for good results and it requires absolute concentration.

A brief deviation is okay if it is corrected. But, sustained deviations in a single direction will bias the result. If you find yourself drifting significantly, jot a note on your pad, correct the error and restart your count. Or, you may prefer to notch the barograph again and make a second run at the same speed. Just be sure to note it on your pad so there will be no confusion later.

## Reducing the data

### Selecting the data

After transferring your IGC log file to your computer in your usual manner, you will be ready to begin selecting the data and entering it into the spreadsheet. First, make a copy of **Performance.xls**, or a version of that spreadsheet containing your baseline data, to a name that identifies your test series; e.g., **Winglets.xls**. Tab to the **Baseline** or **Modified** worksheet to enter your altitude samples.

Then, with the spreadsheet running, launch your IGC program, open your log file and display your altitude profile graphically. You should be familiar with this procedure. (See **Hints for Using Cambridge Aero Explorer** below.)

Next, expand the altitude graph so that the part of the flight when data was taken fills the pane. You should see something like Fig. 3 below. If you notched your data before each speed run and if you noted the sequence of your speed runs on a pad, you should be able to easily identify the segments containing the samples from each speed run. For instance, in Fig. 3 below, there are nine segments and according to the in-flight notes the order is 37, 40, 45, 51, 50, 52, 60, 65 and 70 kts.

In this display from Cambridge Aero Explorer, the blue curve shows GPS altitudes and the red shows pressure altitudes. GPS altitudes are much maligned for their inaccuracy, and indeed their quality may depend on the particular GPS receiver in your data logger and the geometry of the satellites when the data was acquired, but I seldom see any practical difference between them. Some IGC software, like SeeYou, will only display pressure altitudes. Cambridge Aero Explorer, on the other hand, will display both. I like to compare the two and choose one or the other if it looks markedly better. The spreadsheet doesn't care which you use and you can change from one speed point to another.

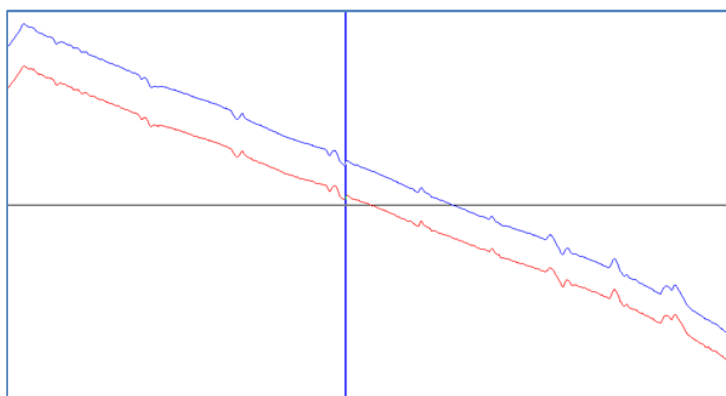


Figure 3 - Typical Altitude Profile

The linearity of a data segment reflects the quality of the data. If you had trouble holding a speed consistently, it will show up as waviness or as a trend in the segment. However, if you consistently flew a little too slow or too fast, that will not show up in the altitude data and when graphed as a sink rate or L/D point, it will be displaced up or down according to the change in performance at the biased airspeed. Most of the segments in Fig. 3 look good. Segment 1 looks rough at the beginning and settles down toward the end. In that case, you would take 10 samples from the end of the run. It would not matter much if you took every other sample and used the full period of the run. Decimating samples that way requires that you modify the spreadsheet for that data point so that it will not assume the wrong sample period and calculate a bogus sink rate. More will be said on this later.

Segment 3 is bowed downward. That probably indicates that the airspeed drifted consistently. In that case, it is important to know which part of the run was closest to the correct speed. For that, an in-flight notation, or a video recording of the panel would come in handy. Consulting either of these, you could choose to take data from either end or the middle or across the full span of the segment, decimating samples as necessary. This highlights the need for good notes and/or a video recording.

The last segment looks pretty rough. It was taken at 70 kts at the lowest altitude. The roughness was due to difficulty holding the high airspeed precisely and the presence of turbulence at low altitudes. This illustrates why flying the high speeds last is a good practice. If you have a certain error in your data, better that it's part of a larger sink rate than a smaller one.



### Entering the data

The performance spreadsheet contains worksheets for **Baseline** and **Modified** measurements. The two worksheets are similar, except that the **Modified** performance plots contain the averaged **Baseline** curve as a reference. The top left corner of **Modified** worksheet is shown in Fig. 4 below. Cells that are highlighted in yellow are for manual input. Other cells contain calculations or labels.

Cells **A2** through **A5** of each worksheet contain mnemonics that set the units for input data and plotting as well as the number of seconds in the sink-rate reporting units; i.e., **60** for reporting in feet per minute and **1** in meters per second. The specific mnemonics that are recognized are shown in parentheses. Cells **A6** and **A7** contain calculated conversion factors. Do not alter those cells.

Each worksheet provides for six sets of speed points, one for each of six flights. For each flight, each speed that is measured has a vertical block of cells labeled from **35** to **100 (kts)** or **60** to **190 (kph)** depending on what you have specified in cell **A5**.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1	<b>Baseline</b>																					
2	<b>60</b>	seconds per sink-rate time unit - (60, 1)																				
3	<b>F</b>	temperature units - (F, C)																				
4	<b>ft</b>	altitude units - (ft, m)																				
5	<b>kts</b>	speed units - (kph, kts, mph)																				
6	1.000000	speed conversion to kts																				
7	0.009875	sink rate conversion to kts																				
8																						
9	<b>Flight</b>	<b>12</b>	<b>35</b>		<b>16</b>	<b>40</b>		<b>4</b>	<b>45</b>		<b>4</b>	<b>50</b>		<b>4</b>	<b>55</b>		<b>4</b>	<b>60</b>		<b>4</b>	<b>65</b>	
10	<b>1</b>	Sec	Alt	Err	Sec	Alt	Err	Sec	Alt	Err	Sec	Alt	Err	Sec	Alt	Err	Sec	Alt	Err	Sec	Alt	Err
11		0	6286	44.8	0	9229	0.3	0	6056	11.6	0	100	0.0	0	100	0.0	0	100	0.0	0	100	0.0
12		12	6243	1.9	16	9189	1.2	8	6040	1.2	4	100	0.0	4	100	0.0	4	100	0.0	4	100	0.0
13		24	6210	36.9	32	9153	1.5	12	6026	6.9	8	99	0.0	8	99	0.0	8	99	0.0	8	99	0.0
14		36	6158	67.8	48	9120	42.6	16	6023	21.5	12	99	0.0	12	99	0.0	12	99	0.0	12	99	0.0
15		48	6115	183.5	64	9068	51.2	20	6010	3.6	16	98	0.0	16	98	0.0	16	98	0.0	16	98	0.0
16		60	6092	1.3	80	9035	3.4	24	6000	4.6	20	98	0.0	20	98	0.0	20	98	0.0	20	98	0.0
17		72	6049	17.3	96	8996	6.4	28	5987	0.3	24	97	0.0	24	97	0.0	24	97	0.0	24	97	0.0
18		84	6020	20.5	112	8963	7.8	32	5977	0.1	28	97	0.0	28	97	0.0	28	97	0.0	28	97	0.0
19		96	5980	4.9	128	8923	1.2	36	5967	0.0	32	96	0.0	32	96	0.0	32	96	0.0	32	96	0.0
20		108	5944	15.3	144	8884	0.2	40	5954	7.9	36	96	0.0	36	96	0.0	36	96	0.0	36	96	0.0
21		Vs	188	6.3	Vs	144	3.4	Vs	154	2.4	Vs	8	0.0	Vs	8	0.0	Vs	8	0.0	Vs	8	0.0
22		MAIt	6110	2%	MAIt	9056	1%	MAIt	6004	2%	MAIt	98	0%	MAIt	98	0%	MAIt	98	0%	MAIt	98	0%
23		Tmp	75		Tmp	63		Tmp	59		Tmp	0		Tmp	0		Tmp	0		Tmp	0	
24		Ra	536		Ra	524		Ra	520		Ra	461		Ra	461		Ra	461		Ra	461	
25		Corr	0.95		Corr	0.90		Corr	0.93		Corr	0.94		Corr	0.94		Corr	0.94		Corr	0.94	
26		Vso	179		Vso	130		Vso	144		Vso	7		Vso	7		Vso	7		Vso	7	
27																						
28	<b>Flight</b>	<b>4</b>	<b>35</b>		<b>4</b>	<b>40</b>		<b>4</b>	<b>45</b>		<b>4</b>	<b>50</b>		<b>4</b>	<b>55</b>		<b>4</b>	<b>60</b>		<b>4</b>	<b>65</b>	
29	<b>2</b>	Sec	Alt	Err	Sec	Alt	Err	Sec	Alt	Err	Sec	Alt	Err	Sec	Alt	Err	Sec	Alt	Err	Sec	Alt	Err
30		0	100	0.0	0	100	0.0	0	100	0.0	0	100	0.0	0	100	0.0	0	100	0.0	0	100	0.0
31		4	99	0.0	4	99	0.0	4	99	0.0	4	99	0.0	4	99	0.0	4	99	0.0	4	99	0.0
32		8	98	0.0	8	98	0.0	8	98	0.0	8	98	0.0	8	98	0.0	8	98	0.0	8	98	0.0

Figure 4 - Spreadsheet Data Entry Cells

The **Sec** column in each speed block designates the relative times of the altitude samples in seconds. The default period for each speed block is specified above the **Sec** label. If a particular speed uses different timing, then the default value for that block can be altered without affecting other speed blocks on the worksheet. On occasion, you will extend a speed run to several minutes if you feel that you did not have precise control of the speed. In such cases, your best results will come from using as many of the samples as possible. For instance, if you held a speed for two minutes, you should change the sample period from 4 to 8 and skip every other sample in the data, extending the duration of the data to include most of the measurement period. The longer a speed is held, the better the quality of the data. However, altitude is limited, so you must compromise to get measurements at enough speeds for your purpose.

The relative times in the **Sec** column start at zero and each following cell is calculated by adding the default sample period to the time in the preceding cell. This arrangement makes it easy to handle a situation where your logger drops a sample. You may find that the spacing between two samples is twice the normal sample period, or more. That does not spoil the speed run. All you need to do is override the calculated time of the next sample by manually entering the correct relative time. The following times will be correctly adjusted from that point down. It is a good idea to highlight the background of manually overridden time cells so that it will be obvious in the future. This was done in the cell at **H12** in Fig. 4 above. Notice that it follows the prior cell by **8** seconds, whereas the following samples follow it in **4** second intervals.

The **Alt** column is highlighted in yellow to indicate the cells where you will enter altitude sample values. The altitude units you use are designated in cell **A4**. Dummy values are in these cells by default. These serve to eliminate errors in calculated fields.

The **Err** column indicates the quality of your data. An **Err** value is the square of the deviation of the altitude sample from the linear curve fit. An erroneous altitude entry produces a large deviation, suggesting that you should check your data. At the bottom of the **Err** column, in bold font, is the square root of the average of the deviations (RMS). Finally, as an overall quality indicator, the RMS error is calculated as a percentage of the altitude consumed in the speed run. This makes it relatively independent of airspeed. You should see 1% to 3%. Larger numbers signal poor quality data. Very large values indicate a data entry error.

The speed blocks in Fig. 4 that are highlighted by a heavy outline have been filled in with real data. Notice the orange highlighted **8** in cell **H12**. This constant was entered to override the value **4** to account for a dropped sample resulting in an **8** second period between the prior sample (6056) the current one (6040). Notice that below that point, the times resume in normal **4** second intervals as specified in cell **H9** above.

At the bottom of each speed block is a series of cells that calculate the raw sink rate and then correct it to sea level equivalent so that it is independent of the altitude at which the measurement was taken. These cells are labeled as described below:

- **Vs** is the raw sink rate. It is calculated as the slope of a line fit to the altitude samples (**Alt**) versus the relative times (**Sec**).
- **MAIt** is the mean altitude for the measurement. It is used in the sea level correction factor.
- **Tmp** is where you enter the temperature that you measured for the speed run. Enter it in the units that you specified in cell **A3**. The temperature has a small effect on the sea level correction factor. Large swings in the temperature change the corrected sink rate by only a few feet per minute. So, you will have no problems if you enter the temperature reading preceding or following each speed run. This lets you read and note the temperature between speed runs while you are notching the barograph. A purist would interpolate to the mid-point between the temperatures that bracket the speed run, but it is not worth the effort. Also, if you fail to collect the temperature, you can guess or you may use archival data as an estimate and still get usable results.
- **Ra** is the temperature converted into Rankine units for the correction factor calculation below.
- **Corr** multiplies the raw sink rate to produce the sea level corrected sink rate.
- **Vso** is the sea level corrected sink rate.

## The Summary Block

To the right of the speed blocks is a group of cells where the sink rates are brought together and averaged for calculating the glide ratios and for graphing.

	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC
1												
2				Flight	Flight	Flight	Flight	Flight	Flight	1	Flights	
3				1	2	3	4	5	6	Avg	Avg	
4		IAS	CAS	Vso	Vso	Vso	Vso	Vso	Vso	Vso	L/D	
5		35.0	35.0	179	14	21	28	35	42	179	19.8	
6		40.0	40.0	130	14	21	28	35	42	130	31.2	
7		45.0	45.0	135	14	21	28	35	42	135	33.7	
8		50.0	50.0	7	14	21	28	35	42	7	717.2	
9		55.0	55.0	7	14	21	28	35	42	7	788.9	
10		60.0	60.0	7	14	21	28	35	42	7	860.6	
11		65.0	65.0	7	14	21	28	35	42	7	932.3	
12		70.0	70.0	7	14	21	28	35	42	7	1004.0	
13		75.0	75.0	7	14	21	28	35	42	7	1075.8	
14		80.0	80.0	7	14	21	28	35	42	7	1147.5	
15		85.0	85.0	7	14	21	28	35	42	7	1219.2	
16		90.0	90.0	7	14	21	28	35	42	7	1290.9	
17		95.0	95.0	7	14	21	28	35	42	7	1362.6	
18		100.0	100.0	7	14	21	28	35	42	7	1434.3	
19												

Figure 5 – Sink Rate Averaging and Glide Ratio Calculations

Fig. 5 shows this block. Average sink rates for one to six flights are calculated in column **BA** and glide ratios are calculated from the average sink rates in column **BB**.

Above the **Avg Vso** column, in cell **BA2**, is an integer indicating the number of flights to average. By default this number is **1**, so that the first flight will plot correctly as your average to date. When a second flight has been added, change **BA2** to **2** and so on for the remaining flights. Usually, three or four flights will be enough for a smooth average.

In Fig. 4, three speeds for the first flight have been entered. You have just left your computer for a cup of coffee. These three speeds are clearly evident as they stand out from the default values and have popped out from the default values in the graphs (Fig. 6 below).

The **Vso** values for each flight in the summary block have distinct font colors. These agree with the colors of the data points that are plotted in the sink rate polar (Fig. 6 below).

You may wish to economize by omitting every other airspeed above say 60 kts. In that case, you can delete the rows in the summary block for the omitted speeds. This will leave gaps in the plotted performance curves. But those may be closed by dragging the lower rows up to close the gaps.

## The performance curves

Fig. 6 is an example of the two plots on the **Baseline** worksheet. On the left is a sink rate polar and on the right is the glide ratio plot. No units are given since they depend on your choice of units at the top left corner of the worksheet. You can edit the axis labels to show units if you wish.

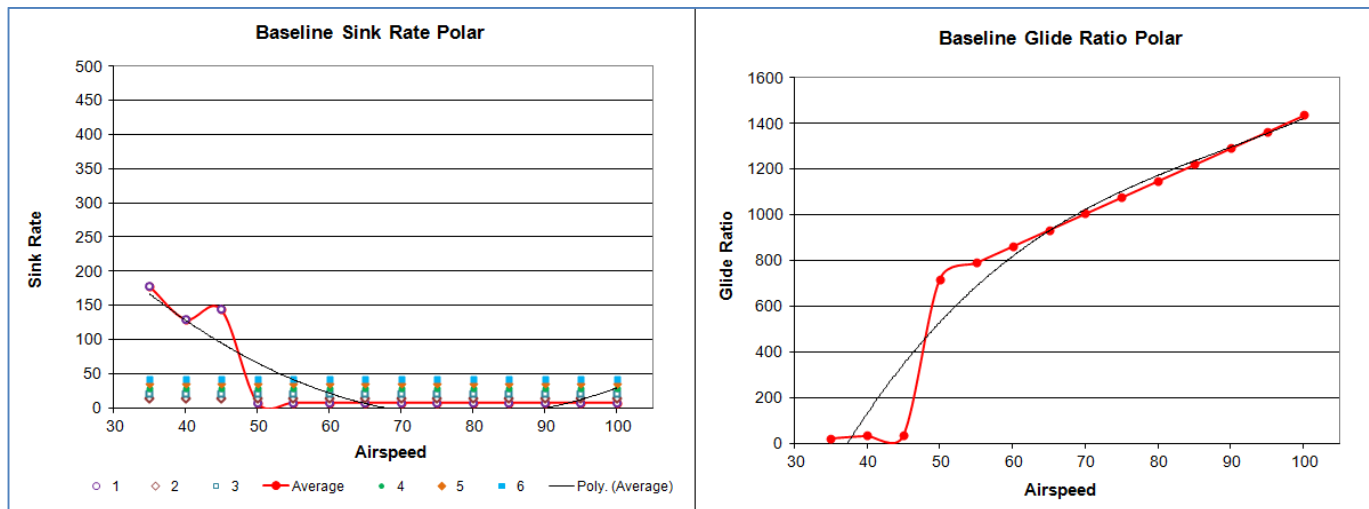


Figure 6 – Baseline Sink Rate and Glide Ratio Plots

The sink rate plot shows data points for all six flights plus the average of the flights for which data was taken plus a polynomial fit to the average. The glide ratio plot shows only the average L/D and a polynomial fit. On the **Modified** worksheet, the plots are the same, but add the average baseline from this the **Baseline** worksheet.

## Baseline measurements

Configure your glider in its simplest standard form for your baseline measurements. If you have wing extensions and/or winglets, remove them. That way, you can measure their effects later. If you have flaps, set them to zero and treat non-zero settings as modifications.

If you want to measure the effects of control gap seals, then start with the factory configuration.

If you don't have a current weight and balance, now is the time to take one.

Document everything about the configuration, especially things that affect weight and balance. How much do you weigh? Are you flying with a parachute? How much does it weigh? Is an oxygen bottle installed? How much does it weigh and where is its CG relative to the datum point? Treat changes in these things as modifications, or at least be aware that they changed when you interpret future results.

Make a complete list of everything about the baseline configuration. There should be no question in the future about the baseline configuration.

## Modified measurements

For each modified measurement, you must be sure to document all changes from the baseline. You will probably accumulate changes and measure their combined effects as you go. If you do this incrementally, you will still see the effect of each one. But, if you make multiple changes between tests, then you will obscure the effects of the individual changes. If you see an improvement, for instance, you will not know the contribution of the individual mods or whether one of them is actually hurting performance and should be removed. It's tempting to save time and expense by making multiple changes, but it often backfires and costs more in the long run.

## Safety considerations

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If you are mixing it up with commercial air traffic, remember that you will be flying with your head in the cockpit, fixated on the ASI. If you have a transponder it will add to your safety by showing up on the TCAS indicators of commercial traffic sharing your airspace. You could also use VFR flight following services from your ATC center. However, the problem with that is the distraction of communicating with the ATC when you are concentrating 100% on your job. But, if you are accustomed to ATC communications, it may work for you.

You also share the skies with other gliders and general aviation. Above the inversion level, these are usually not much of a problem. Nevertheless, you should take a clearing turn between speed runs as you notch the barograph. Also, it is wise to let others who routinely fly in your air space know that you will be taking measurements.

## Hints for Using Cambridge Aero Explorer

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### Using Cambridge Aero Explorer with non-Cambridge logs

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Cambridge Aero Explorer (CAE) is a great program for graphing your altitude data and for acquiring specific samples for entry into the worksheets. I find it easier to use than more advanced software. It has the best altitude plot for examining the individual altitude samples in an IGC file.

In CAE, pressure altitudes are displayed in red and GPS in blue. You can click on a sample and the window header will display both numerical values along with the time. The right and left arrow keys can be used to move to the next sample right or left. This lets you check the sample timing. If the logger drops samples, because it cannot keep up, you will see the gap visually and can verify it in the window header.

When CAE opens a log, it shows the altitude traces at the top of the window and the ground track at the bottom. Drag the border between these down to the bottom to stretch the altitude display vertically. To expand the data horizontally, right click on the window, select ZOOM and drag the cursor across a section you want to expand.

The first thing to do is to examine the quality of the data. You may find that your logger is not up to the quality standard needed for good measurements in the time available for each speed run. If you see smooth curves then the logger is probably ok. But if it regularly holds the same altitude value for more than say 4 seconds, resulting in a stair stepped trace, then it lacks the resolution needed. Occasional repetitions of the same value are normal because the air always has some vertical movement and you cannot hold a speed precisely.

Some mobile glider software has logging capabilities. When they receive only GPS data, they duplicate it into the pressure altitude field of the "B" records. Conventional wisdom says that GPS altitude data is unreliable. That is not necessarily true. It does have less accuracy than lat/long data, but it is not necessarily unusable for our purposes. DC offset errors do not matter since we use the slope of the data, not the absolute values. The data only needs to follow altitude changes with sufficient resolution and with consistent accuracy.

CAE will not accept non-Cambridge IGC files. You can get around this limitation by editing the header lines at the top of your log files. For this, you will need a simple ASCII text editor, like **Notepad**, copy and paste the Cambridge header over foreign header (all lines before the first "B" line). Be sure to make a copy of the original file for this purpose. Following is a dummy Cambridge header that will make foreign IGC files acceptable to CAE.

```
ACAM3R2
HFDTE111008
HFFXA050
HFDTM100GPSDATUM:
HFRFWFIRMWAREVERSION:F2.6
HFRHWHARDWAREVERSION:300 Series Version 2
HFFTYFRTYPE:CAMBRIDGE AERO INSTRUMENTS, 302+
```

## Items on the distribution CD

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The distribution CD contains the following files:

- **MeasuringGliderPerformance.pdf** – This manual.
- **SailplaneFlightTestMethods.pdf** – Dick Johnson’s article, *Sailplane Flight Test Methods*, from the May 1989 issue of *Soaring*.
- **Performance.xls** – The sample spreadsheet. Make a copy for your baseline measurements, then copy that file for each modification you test.
- **InstallAeroExplorer-1.10.exe** – Execute this file to install Cambridge Aero Explorer on your Windows computer.
- Dummy Cambridge header code.

## Credits

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I wish to acknowledge my debt to Dick Johnson, who’s many years of dedicated service to the soaring community paved the way for this document. We are all standing on his shoulders.

The Dallas Glider Association (DGA) must be acknowledged for their dedicated service in financially supporting the Johnson flight test evaluation project over the years.

I wish also to acknowledge the tow pilots at Memphis Soaring whose question, “How high do you want to go?” took on a whole new meaning.

Finally, my dear friend, Ralph Luebke is the person who encouraged me to document my testing methods in hopes that the soaring community at large might benefit.

## References

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1. Paraphrased from Lord Kelvin: *I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the state of Science, whatever the matter may be.*
2. Richard H. Johnson, *Sailplane Performance Flight Test Methods*, *Soaring*, May 1989, ([www.oxaero.com/SailplanePerformanceFlightTestMethods.pdf](http://www.oxaero.com/SailplanePerformanceFlightTestMethods.pdf)).