

Safety Glides
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Draft 8/27/2012

“I don’t get it,” said the pilot as his crew was picking him out of the field. “The glide computer said I could make it home with 100 meters to spare! This stupid thing must be busted.”

“No,” his crew answered, “you set the MacCready to zero. You were guaranteed not to make it.”

“Huh?” said the pilot, “I set the MacCready to zero to maximize my glide.”

Crew explained: “If you had found lift, you wouldn’t have landed. If you’re not in lift, you’re in sink. So the only way you will land is if you find sink and no lift. By using a zero Mc setting you are guaranteeing that if you land, it won’t be at the airport.”

“So how am I supposed to use this bloody thing?” Good question. Read on

Our glide computers are wondrous devices, but you have to know how to interpret their calculations. They are designed to maximize speed in a contest. They tell you how far you can go on average, if lift or sink cancel out.

They can also help you to assess the safety of a glide, what if lift and sink don’t cancel out. But to get that help, you have to learn to speak its language and interpret its numbers.

Lesson 1: Learn to speak MacCready

Many pilots think in of glides in terms of glide angles, or meters lost per kilometer. The computer speaks MacCready values.

	Dry ASW 27				Wet ASW 27			
Mc	Speed	Avg	L/D	m/km	Speed	Avg	L/D	m/km
0	103	0	48	21	125	0	48	21
1	135	71	41	25	164	79	41	24
2	160	96	32	31	195	110	34	30
3	183	113	26	38	222	130	28	35
4	202	126	22	45	246	147	24	41

[TABLE CAPTION. KEEP WITH TABLE] Table 1. MacCready table for ASW27. Mc gives the MacCready setting in m/s. Speed gives the still air speed-to-fly, in km/h. Avg gives the cross-country average speed, in km/h, assuming still air between thermals. L/D gives the still-air glide angle and m/km gives meters lost per kilometer.

Table 1 gives MacCready values for an ASW27. (I used the polar from the flight manual, which is a little optimistic.) For example, in 2 m/s thermals, (Mc 2) you fly 160 kph dry and 195 (yes) kph wet. You achieve a 32:1-34:1 glide, through still air. Your average speed is 96 kph mph dry, and 110 kph wet, if you glide through still air.

These translations are helpful for thinking about MacCready values. If you think you will achieve about 100 kph (excluding the final glide), then input Mc 2 on the task planning page of your computer. If you want the glide computer to tell you to fly 160 kph in still air, but adjust for lift and sink, then input Mc 2.

And the translations are helpful for telling the computer what you want. If you want the computer to calculate a 33:1 glide or leave 30 meters per km, then input Mc 2. (The MacCready input page of flight computers should include these numbers!)

Though the table advertises translation, I think it's better to learn to speak MacCready. Learn to express daring vs. caution, and codify your experience, in terms of a "MacCready zero" glide, a "MacCready 2" glide and a "MacCready 4 glide" instead of glide angle (30:1) or meters per km.

Why? L/D and meters per km are drastically affected by wind. The computer takes care of that for you, so a MacCready 2 glide is the same thing upwind or downwind. MacCready numbers transfer readily from glider to glider, while the other numbers depend on the glider's performance. A "MacCready 2 glide" in a Nimbus 4 is about the same level of aggressiveness as in a Discus, but the L/D and m/km are wildly different. And *everything* in cross-country soaring is keyed to MacCready values, from what thermals to take, how fast to fly, how aggressively to take upwind turnpoints, how big course deviations to take and so on.

Lesson 2: Decouple the glide computer and the speed director

Suppose that, studying the above table (or its equivalent in your computer), you input MacCready 2, dry. The computer will now calculate a 32:1 glide to the chosen point, adjusting for wind.

The computer will also tell you to fly at 160 km/h knots dry or 195 km/h wet. It presumed you asked the contest final glide question: "How fast do I go through still air to use up this altitude?" But that's not your question. You want to maintain the 32:1 profile for safety, in case you run in to sink. You want to fly much slower. Yet you want to adapt to lift and sink along the way. If you just set Mc 2, your speed director will be screaming its sink tone, "speed up," and giving you no useful information about lift and sink along the way.

(You *are* flying with an audio speed-to-fly-vario, right? Every glider needs one, even the club ASK21. How else can you maximize glide through lift and sink, or even know about gentle lift and sink when you're gliding?)

What to do? Answer: *decouple the vario (speed director) MacCready setting from the glide computer's MacCready setting.* While flying in Northern Illinois, for example, I typically set the speed director (vario) to Mc 1 and the glide computer to Mc 2. As I descend towards the safety altitude, I'll lower the speed director towards Mc 0.5 and then Mc 0, stretching my glide and helping me to slow down and milk lift. I keep the glide computer on Mc 2, where I make my decisions about whether to go on or divert to an airport.

Our instrument makers should do this for us. Glide solutions to alternates or the "ring" displayed by Clearnav and Xcsoar should use a separate "safety" MacCready value that is unaffected by changes in the "speed" MacCready value.

Lesson 3: You may have to use much higher values than you think

Table 1 gives surprisingly high MacCready settings when used for safety glides. 30:1 is even a daring safety glide angle. We don't often cruise at MacCready 2.5! The standard safety recommendation in the Alps is 20:1 plus a reserve. You need to set MacCready 5 to see that glide angle.

Get used to it. For safety-related glide calculations, you may use MacCready values that are much, much, larger than those you would use for speed, thermal, or other considerations.

The reason for high MacCready values is that our gliders are so good. They sink so little in still air, that even small amounts of sink has a disastrous effect on glide angle.

Table 2 presents the numbers. I assume the pilot is desperate, flying at the MacCready zero setting. How bad is his glide in sink? The answer is: terrible. If you fly through steady 0.5 m/s sink, your speed director will tell you to speed up to 120 kph dry and 146 wet. You will achieve a L/D of 27. Yes, 27. If you fly through steady 1 m/s sink, your speed director will say to speed up to 135-164, and you will achieve a 19:1 – 21:1 glide.

Netto	Dry ASW 27				Wet ASW 27			
	Sink	Speed	L/D	m/km	Vario	Speed	L/D	m/km
0	103	47	21	0.55	125	47	21	0.7
0.5	120	27	37	1.2	146	29	35	1.4
1	135	19	52	1.9	164	21	47	2.0
1.5	148	15	65	2.7	180	17	58	2.8
2.5	172	11	88	4.1	209	23	77	4.3

[TABLE CAPTION KEEP WITH THE TABLE] Table 2. Effect of sustained sink on achieved glide. The pilot flies through steady sink as given in the first column, in m/s. He follows the Mc 0 speed to fly given in the second column, in kph. L/D gives the achieved glide angle. m/km is meters lost per km. Vario is the sink rate of the glider in m/s.

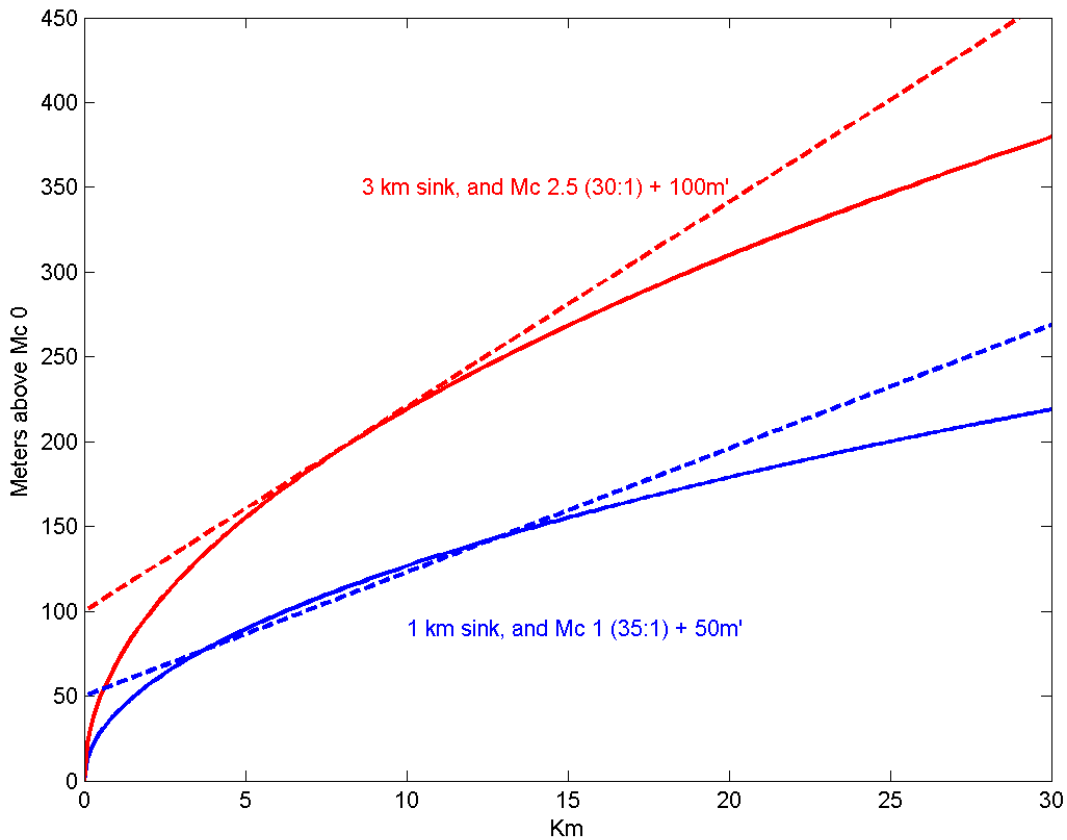
So, if you want to protect yourself against steady 1 m/s sink all the way to your landing, Table 2 says that's a 19:1 glide, not a 47:1 glide! How do you tell your computer to do that? Table 1 says that to compute a 19:1 glide you have to set the MacCready value to 5. *Five!* Even just to protect yourself against 0.5 m/s sink all the way to landing, Table 2 says 27:1 glide, and Table 1 gives a MacCready setting of 3!

Lesson 4: Angle plus reserve and the square root rule.

These seem like huge MacCready settings to most contest pilots. Most of us have spent decades flying Mc 1-2 final glides, and though they don't always work out, blowing a final glide once a decade on Mc 1.5 doesn't suggest we need Mc 3 or 5 to stay safe.

That experience is correct – most of the time. In fact, steady sink all the way to the landing is rare. Almost always, you will experience some sink, but then it will end.

If you want to make absolutely sure, you have to use these huge numbers. The realistic question is, how much altitude must we leave to control the *probability* of a landout? The answer is a square root of the distance to go.



[FIGURE CAPTION KEEP WITH FIGURE] Figure 1. Safety glides, with 2% chance of not making it.

Figure 1 illustrates the square root rule. To calculate the solid blue line, I assume that in each km you fly, there is a 33% chance of losing 20 m or more and a 2% chance of losing 40 m or more. The vertical axis shows how many meters over the Mc 0 glide you need in order to keep a constant 2% chance of landing out in these conditions.

At 1 km out, you need 40 extra meters (two standard deviations). At 10 km out you don't need $10 \times 40\text{m} = 400\text{m}$. You need the *square root* of 10, times 40m, or about 125m. At 20 km out, you don't need $20 \times 40\text{m} = 800\text{m}$, you need the square root of 20, times 40m, or about 180m.

Why? The chance of losing 40m in one km is 2% (by assumption). But the chance of losing 40m *in every single km* on the way home is next to nothing – that's the chance of a coin coming up tails 10 times in a row.

(Techies: I assume that height loss in each km is normally distributed with a standard deviation of 20m. I'm finding the lower two-standard deviation risk band. The standard deviation of a sum of T independent random variables is the square root of T times their individual standard deviations.)

A square root is hard to keep in your head, and our glide computers don't program square root profiles. (They should!) But they do program higher glide angles and margins, and we can use those to approximate the square root rule. The dashed blue line in Figure 1 shows that a 50m margin and Mc 1 (35:1) glide nicely approximates the square root pattern. Now you know why we use both higher glide angles and reserves to control the probability of landouts.

What can go wrong here? Rivers of sink. (If you don't know about these, follow me sometime.) I assumed that each km was a new coin flip, so if you're in sink there is a good chance of getting out of it in the next km. This is really the diametrically opposite calculation from Table 2, which assumes that sink, once found, lasts all the way home. Reality is in between, and depends on the day.

To illustrate, the red line in Figure 2 keeps everything the same, but now any lift or sink lasts for three km before you get to roll the dice again with the lift gods. To blow it from 9 km out, now you need only 3 coin flips to come up all tails, which is much more likely than 9 coin flips to do so. The result is still a square root rule, but you need more altitude at every step of the way. It is better approximated in the last 10 miles by MacCready 2.5 (30:1) plus 100m.

In the red line, I did not make the sink any stronger. I just made it last longer. How persistent the sink is, before you have a chance of finding still air or lift is really what counts for glides, not how strong the sink is.

In both cases, when you're further out, you use a flatter glide with a larger margin. When you're closer in, you need a steeper glide but less reserve. There is a lot of debate about reserve vs. steeper angle in planning safety glides. The right answer depends how far out you are.

If you want a lower probability of not making it, the curves all shift up. If you can accept a greater probability of not making it, the curves shift down.

Lesson 5: The Real World

What values should you use in the real world? That depends.

First, it depends on the cost of not making it to your desired landing spot, and consequently what probability of not making it you can accept. If you're flying over good fields, the cost of a landout vs. making it to an airport is only inconvenience.

On a final glide over good terrain, the cost is rather severe loss of contest points. In halfway decent conditions, the speed MacCready of 2 or so will be enough. In weak 0.5-1 m/s lift, it's worth building up a bit more margin, maybe flying the final glide at Mc 1.5-2 rather than the Mc 1 of the last thermal.

In rougher terrain, the cost of landing out can be glider damage, but not personal injury. This argues for a good deal higher values, in the Mc 3 region.

Sometimes you're crossing totally unlandable terrain, where failing to make your goal will mean injury or worse. That argues for a very high probability standard. When the instructor in the French Alps tells you to use 20:1 plus reserve, he is not kidding. That means MacCready 5, plus reserve, a value you may not know that your instrument can use. If you use values like that, you will routinely get to your goal with gobs of extra altitude. Once in a lifetime you will barely make it. That's the point.

Second, what value to use depends on the weather. We're not thinking about what the day is like on average. We need to think about how bad the worst-case scenario can be.

No lift is good news. Where there is no lift there is no sink! When the wind dies, the cirrus clamp comes in, and the smoke all goes horizontal, you know that the chance of finding unexpected sink is very small. Now you can consider those long Mc0.5 or Mc1 glides, even over somewhat rough terrain.

By contrast, paradoxically, booming days require more caution. Where there is lift, there is sink. It's not so much the strength of sink that matters, it's how long the sink can last. Punchy sink you can get out of is not so bad. Organized rivers of sink that go on for miles are the real danger.

Streeting puts joy in a pilots' heart. Streets of lift mean streets of sink, though. And, as you descend to the lower levels, staying connected to the clouds is harder and the chance of hitting one of those rivers is greater. If it's blue, or a goal that is cross wind add to the danger. Wave suppression and high winds also signal rivers of sink.

In sum, the worse the terrain the more cautious you need to be (obvious), and the better the soaring weather the more cautious you need to be (less obvious).

What next? I really would like to get some traces and quantify how bad sink can get, how variable glides really are, in different weather conditions and parts of the country. What, really, is the worst that a 10 km glide can be? That's a big project; perhaps this article will inspire someone else to do the programming. In my dreams, my glide computer will give me a quantitative assessment of just how bad the sink can be, based on sampling the air for the last hour or so, and give a quantitative guide to picking these safety margins.

Of course, the way I have described to input safety glides, by tricking the glide computer with a high Mc value and reserve, can be improved by our instrument manufacturers. Being able to input worst-case sink – or some lift for final glide calculations – in the manner of Table 2 would be useful. Calculating square-root type safety profiles, calibrated to lift/sink on a given day and an input probability of landout, would be even better.