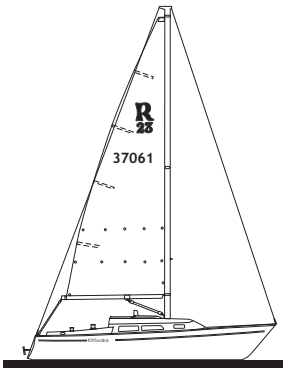


Ranger 23 Boatspeed Polars

What they are and how to use them

Arvel Gentry

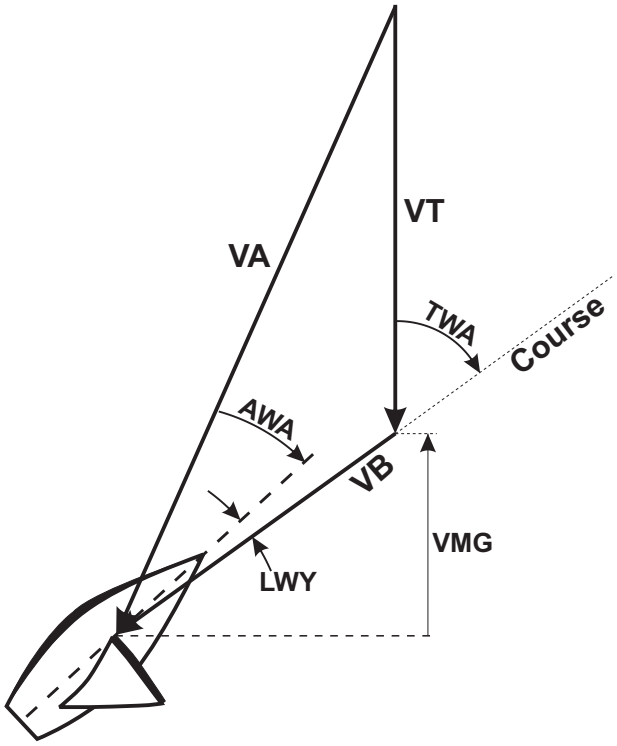
The Ranger 23 Polars

Selecting the right sail combination and planning a course requires knowledge of the true wind direction and velocity and what the boatspeed will be. Even the owner of a Ranger 23 planning a trip to the Island can use knowledge of boat performance to get there with efficiency and with the nice feeling that the game with the water and wind was played well. It's also a lot of fun to see if you can match the boatspeeds predicted by speed polars.

The R-23 tall-rig speed polar data presented here was calculated for me by Peter T. Schwenn in 1995 using his Velocity Prediction Program (VPP) called *FAST YACHT*. The input to the program includes measurements of the boat (hull, sails, weight, etc.), plus the sailing conditions to be calculated (true wind angle and true wind speed). Program output includes boatspeed, leeway angle, heel angle, apparent wind speed, and apparent wind angle.

How does the VPP do this? Well, it's a rather complicated matter. The mathematics in the computer must somehow represent the actual sailing conditions of the boat. This is a real art as we actually sail our boat, but it is even a blacker art when you try to do it with a computer. When we sail our boat, we adjust our sails to the course and sailing conditions. The computer somehow has to do the same thing. It has to balance the forces on the sails and the rig against the underwater forces on the hull, keel, and rudder. As the wind increases in velocity we flatten our mainsails and maybe change to a smaller genoa. The computer program has to do the same thing. As we change course, we adjust the sails or even put up a spinnaker and set the pole and sheet trim to match the conditions. To be realistic, the computer must do that also.

All of this means that the computer program must include a great amount of empirical data in order to accurately represent our boat. Some of it may be very good and some not so good. We, therefore, must take the program output with a grain of salt (or sand). However, one thing going for the computer data is that it covers a wide range of conditions in great detail, and it forms a good starting point for understanding our boat. As we gather data about the performance of our boat, we can adjust the calculated polars accordingly. Anyone interested in the



Terminology

- VT True wind speed
- VB Boatspeed
- VA Apparent wind speed
- TWA True wind angle (the angle between the true wind vector and the course of the boat)
- AWA Apparent wind angle (the angle between the centerline of the boat and the apparent wind speed vector). This does not include the upwash term.
- LWY Leeway angle (the angle between the centerline of the boat and the actual path of the boat through the water)
- VMG Velocity made good to windward (the

component of the boatspeed vector, VS, that is directly into the true wind)

It is important to note that the apparent wind angle, AWA, as shown in the diagram, must still be corrected for a sail upwash term to give the apparent wind angle that you would normally see on a wind direction instrument on the boat. The apparent wind angle tabulations in the Ranger 23 polar data have an empirical upwash correction included in the results. The same is also true of the apparent wind speed values. If you are mathematically inclined, you can prove this by picking a true wind speed and angle condition from the tabulated data and solve for the AWA and VA values as shown in the diagram above. You will find that the answers do not agree with the AWA and VA numbers in the data listing. The values in the listings include upwash and heel angle corrections to give values closer to what you would measure with a wind speed/direction instrument mounted at the top of the mast.

Also, some of the other terms are not quite what you might think. If you go sailing and measure the wind speed at the deck and then again at the top of the mast, you will get two different answers. The deck reading will be lower than the masthead reading. This difference in wind speeds is called the wind gradient. The R-23 polar calculations assume that the true wind measurement height was 10 meters above the water (32.8 feet). *Kittiwake's* wind instruments are about 34 feet from the water so I can use the polars about as they are.

To get an idea of the true wind speed with a handheld speed indicator, I would first take down the genoa and head the boat into the wind until the boatspeed drops to zero. I would stand at the headstay and hold the device as high as I could to take the reading. To correct this reading taken at about 10 feet off the water to the 10 meter polar-data height, I would have to multiply it by a factor of about 1.2. With a 7 knot reading on the deck, I would use an 8.4 knot polar curve to read boatspeed data.

But what if you don't have a way of measuring the true wind speed? You can get a rough idea of the wind speed by using the famous Beaufort Scale shown in the tabulation on the next page. This may not be very accurate from the engineering standpoint, but it's better than nothing. In this tabulation I have left off the higher wind scales (they go up to force 12 hurricane strength) since under those conditions you'll probably be more concerned with things other than speed polars and boatspeed performance.

Boatspeed can be another problem. If you have a knotmeter, how good is it? Have you calibrated it over a measured mile? Did you do it under sail and with the boat heeled? If you have your knotmeter sensor on the side, say in the locker under the sink, then you should

Beaufort Scale of Wind Force

Beaufort scale	Wind Speed knots	Descriptive	Sea Conditions
0	0-1	Calm	Sea smooth and mirror-like.
1	1-3	Light air	Scale-like ripples without foam crests.
2	4-6	Light breeze	Small, short wavelets; crests have a glassy appearance and do not break.
3	7-10	Gentle breeze	Large wavelets; some crests begin to break; foam of glassy appearance. Occasional white foam crests.
4	11-16	Moderate breeze	Small waves, becoming longer; fairly frequent white foam crests.
5	17-21	Fresh breeze	Moderate waves, taking a more pronounced long form; many white foam crests; there may be some spray.
6	22-27	Strong breeze	Large waves begin to form; white foam crests are more extensive everywhere; there may be some spray.
7	28-33	Near gale	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind.

The Data Formats

The Ranger 23 speed data includes four types of information: Speed Polars, Optimum Upwind Performance Plots, Optimum Downwind Performance Plots, and the Tabulation of Calculated Data.

The Speed Polars plot is a convenient way of viewing and understanding a great deal of information. In the polar plot, the true wind is blowing down the vertical axis as indicated by the large arrow up near the 6 knot label. The concentric circles are the boatspeed scales. The radial lines are the true wind angle scales. The red curves are the windward boatspeed curves. The blue curves are the downwind boatspeed curves.

If you are unfamiliar with speed polars, try the following simple example. Assume that you are sailing at a 60 degree angle to the true wind and that the true wind speed is 6 knots. Follow along the 60 degree radial true wind angle line until it crosses the 6 knot true wind speed line. This point lies between the 4 and 5 knot boatspeed circles and gives an interpolated value of about 4.6 knots. Tracing a line horizontally to the left, we see that the speed made good into the wind, VMG, is about 2.3 knots. If we look at the tabulation on page 8 for these conditions, we see that the VPP predicts a boat speed of 4.646 knots and a VMG of 2.323 knots. If we traced the 6 knot true wind speed curve up to about 45 degrees true wind angle, we would be sailing at about 4 knots and a VMG of 2.7 knots.

The optimum windward conditions are marked with a triangle (maximum VMG). The optimum jibing condition points are marked with a square symbol (optimum downwind VMG conditions). The points where the windward and downward curves cross indicates where you should switch from the genoa to the spinnaker (diamond

symbols).

The optimum upwind data plots on page 6 show how the key windward parameters vary with the true wind speed. Page 7 gives the optimum downwind data under spinnaker. All of these data are presented as a function of

How Good Is The Data?

In general, the polars do a pretty good job of representing the speed characteristics of a tall rig Ranger 23. But before looking at the polars in detail, here are some general observations.

The VPP that produced these data assumed that the water was smooth at the lower wind conditions and that the water roughness increased at the higher wind speeds. The VPP roughness may or may not represent what you would experience in actual sailing. If you have some left-over chop in light winds, your optimum windward speed may be up to a half knot slower than the polar data. Also, as is typical of most windward VPP codes, they do not show quite the reduction of boatspeed that we have as the boat is pinched closer to the wind from the optimum VMG condition. The VPP codes may be assuming that the genoa is somehow made flatter or trimmed closer than we can achieve with real sails.

I also have a problem with the VPP assumptions made at the low wind speeds. If you look at the heel angle plots and the tabulated data, you will see that at 3 knots wind speed the boat is standing almost upright. Under real sailing conditions we would be intentionally heeling the boat in a bow-down condition by placing the crew to leeward and forward. This is done to let the sails sag into a better aerodynamic shape and to reduce the hull drag. The VPP does not do this. *Kittiwake* does a bit better than the windward calculated data at the low wind speeds.

How good is the downwind data? The VPP data shows the typical characteristics as wind speed increases. At the low wind speeds, the optimum apparent wind angle is about 110 degrees with jibing angles of about 78 degrees (see page 7). In the light winds, we move the pole forward and reach to build boatspeed, but as a result have to sail a longer distance to go downwind. The VPP data shows an improvement in downwind VMG using the optimum reaching path instead of a straight downwind path.

At the highest wind speed, the VPP polar data says that you go almost dead downwind, and I agree with that. Note that the Polar Plot on page 5 does not include the 28 and 32 knot data from the data listings (page 11). If you have the spinnaker up under the 28 or 32 knot wind condition and at true wind angles less than 135 degrees, you will certainly have your hands full controlling the boat. However, *Kittiwake* has verified the spinnaker polar data boatspeed at a true wind speed of 31 knots before we wiped out!

If you look at the tabulated data for wind speeds above 10 knots, you will see that for some wind angles, the Sail Flatness and Mainsail Reef factors are less than 1.00. This means, that for these conditions the sails are flattened and/or the mainsail reefed. For example, at 20 knots of wind and a wind angle of 41.6 degrees (the windward optimum), the Reef Factor is 0.86. Squaring the Reef Factor gives the relative change in mainsail area. That means that the mainsail has been reefed down so that its area is 74% of its full hoist size (0.86x0.86=0.74). The Flatness Factor is interpreted in the same manner as the Reef Factor, and represents either a flattening of the sails, or an actual change in headsails. In other words, all of the polar data assumes that you always have the proper sails up for the particular wind speed and sailing angle and that they are always trimmed perfectly.

The tabulated data says that for beating conditions you would flatten the sails or go to a smaller genoa at the

Using the Polar Data

The obvious use of the polar data is to let you know just what your boat is capable of. Check the true wind speed; then for the course that you are sailing try to achieve the speed shown by the VPP data. If you can't quite get your boat up to that speed with changes in sail trim, then you may have other problems. Your knotmeter might be off. Your sails could be old and tired. Or, the speed polars might be off for the conditions that you are sailing in (sea roughness, wind shear, etc.).

Or maybe you are trying to use the tall rig polar data for your short rig boat. If you do have a short rig you, can still make some use of the polar data. For the lower wind speeds you should expect to have boatspeeds that are up to a half knot slower than the polar data. At the higher wind speeds you should come pretty close to the 5+ knot boatspeed windward condition shown by the polar data. However, the tall rig boat will reach the 5+ knot optimum windward VMG condition at about 2 knots true wind speed before the short rig boat.

If you are achieving boatspeeds that are significantly higher than shown by this data, then I suspect several possibilities: your knotmeter is not calibrated, you are not sailing at the same true wind angles, the wind is blowing harder than you think it is, etc., etc., etc....

There are also some not so obvious aspects to the speed polar data. As has been pointed out by Jim Marshall in several *Sailing World* magazine articles, the polar

data can help you handle changing wind conditions and also in selecting the best course when under reaching conditions.

The Optimum Upwind Performance plots show that the boatspeed curve is very steep until the true wind speed gets up to 10 knots. Above 10 knots, the boatspeed curve flattens out as it approaches the hull speed limit. If you are sailing in the lower wind range and the wind speed increases by about two knots, what do you do? The increase in wind speed will cause the apparent wind to shift aft a little. The telltales on the lee side of the genoa may start to twirl indicating that you should head up as you seem to have been lifted. However, the higher wind speed indicates that your boatspeed should be higher than before. What is the best way to get up to that new speed?

As soon as you see that you are apparently lifted, the tendency is to head the boat up. However, as Marshall points out, heading the boat up will mean that it will take the boat longer to get up to the new and higher target boatspeed. The best procedure is to hold the boat to the same course, let the genoa out slightly, and let the boat accelerate up to the new speed. As the boatspeed builds up, the apparent wind speed will shift back forward slightly. You can then re-trim the sails and get back into an optimum upwind groove at the new and higher boatspeed.

If you are sailing in the lower speed wind range and the wind decreases, what do you do? A decrease in the wind will cause the apparent wind to shift forward and the sails may even luff. The natural tendency, if you are just following your telltales, is to bear off or trim the genoa in tighter. Marshall says that this is wrong. He says that "Sailing by target (boat) speeds tells us to head up if we're going too fast. The conservative response is to steer straight -- but don't bear off to follow the telltales! The most efficient way to shift boatspeeds with the wind speed drop is to turn that excess speed into valuable distance upwind. As the boatspeed starts to near the (new) target, capture that target (speed) at a close-hauled course."

When the true wind speed is above 10 knots and you are already sailing at 5 knots or better, then you should follow your natural tendencies and head the boat up when the wind speed increases. Holding the same course, as you should do when sailing in the lower speed range, won't gain you much speed. The boatspeed curve is too flat. Just take advantage of the apparent wind lift and gain additional distance to windward. Also, in the higher wind-speed range, the boat changes speed very quickly when the wind speed changes. Just steer the boat by feel and the heel angle of the boat. I have found that one good way to learn this is to practice steering the boat with your eyes closed when sailing in the higher wind speed region. You will soon get the hang of maintaining a constant heel angle just by the feel of the boat.

The polars can also be used to plan a course under reaching conditions. If you don't expect the wind to change direction, then just pick the radial wind angle line to get you to your destination. However, if you expect the wind to shift, you might want to consider sailing at a different angle to increase the speed made good in the target direction and then change your path when the wind shifts. You'll get there quicker.

To improve your downwind performance under spinnaker, study the Speed Polars plot on page 5 and the Optimum Downwind Performance data on page 7. Note that for light winds up to 6 knots true, the optimum true wind angle is about 140 degrees and the apparent wind angle of 110 degrees. In this wind range, the correct sailing angle changes hardly at all. You will be jibing through about 80 degrees.

Bill Gladstone's book, *Performance Racing Tactics* (North U. Performance Racing Seminars), covers downwind sailing very well. He says that, "In these light air conditions the *off in the puffs, up in the lulls* adage we advocated for reaching does not apply. Our sailing angle remains steady through puffs and lulls in light air running."

Gladstone emphasized this by repeating, "The proper response to a puff depends on which segment of the performance curve you are in. Remember, off in the puffs is wrong in light air."

Between 6 to 12 knots of wind, the optimum downwind sailing angle changes very rapidly. The apparent wind angle changes from about 110 degrees to 160 degrees by the time the wind is up to 12 knots. Gladstone says that, "*Off in the puffs, up in the lulls is very much a part of moderate air running*."

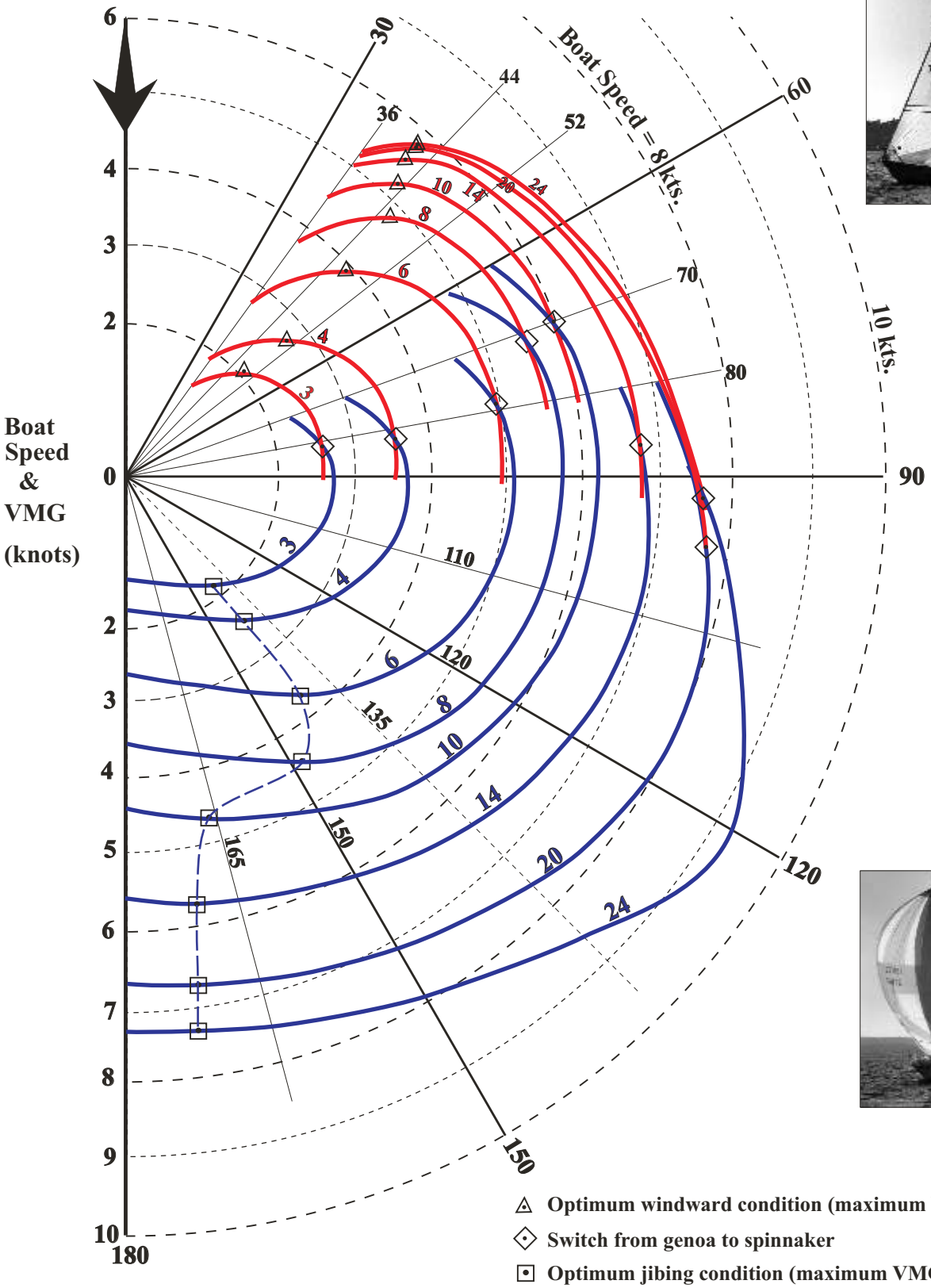
In true winds above 12 knots, we sail almost straight downwind. Note that the polar curves in the heavy air region are rather flat giving you a lot of tolerance in sailing angle. In this region go straight for the mark!

At the higher wind speeds you will have problems controlling the R-23 under reaching conditions. I can't imagine flying a full spinnaker on the R-23 with 32 knots true wind speed and a 150 degree true wind angle. The data on page 11 says that the boatspeed would be 11.255 knots with a heel angle of 7.1 degrees. I've tried that and the heel angle was more like 50+ degrees!

This set of polars that I obtained from Peter Schwenn in 1995 greatly improved the way we sail *Kittiwake* downwind. Prior to that time we were following the old guide-

Ranger 23 Tall Rig
Speed Polars

Data produced by *FAST Yacht*, Peter T. Schwenn, Dec. 5, 1995



△ Optimum windward condition (maximum VMG)

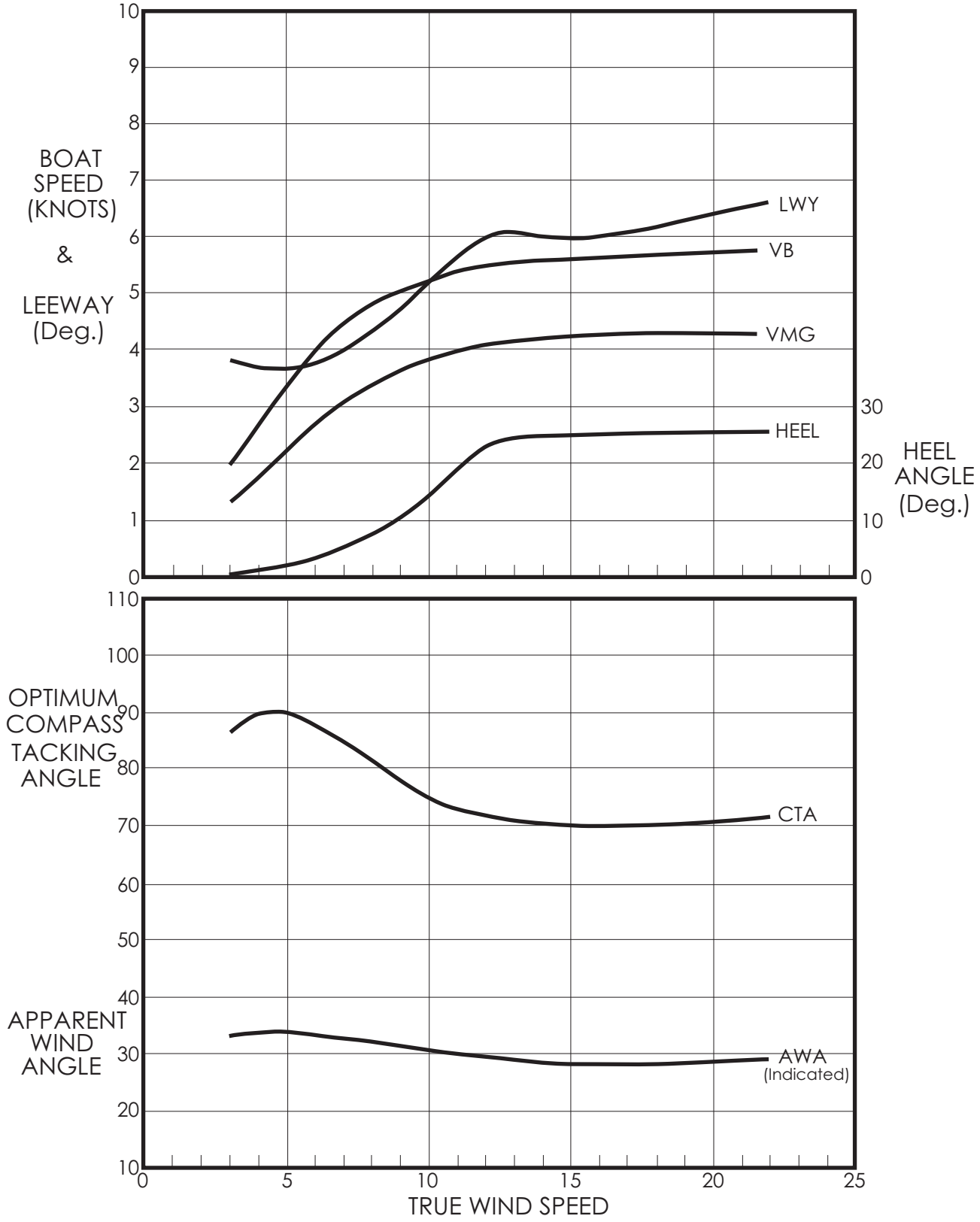
◇ Switch from genoa to spinnaker

⊡ Optimum jibing condition (maximum VMG)

Arvel Gentry 4/20/05

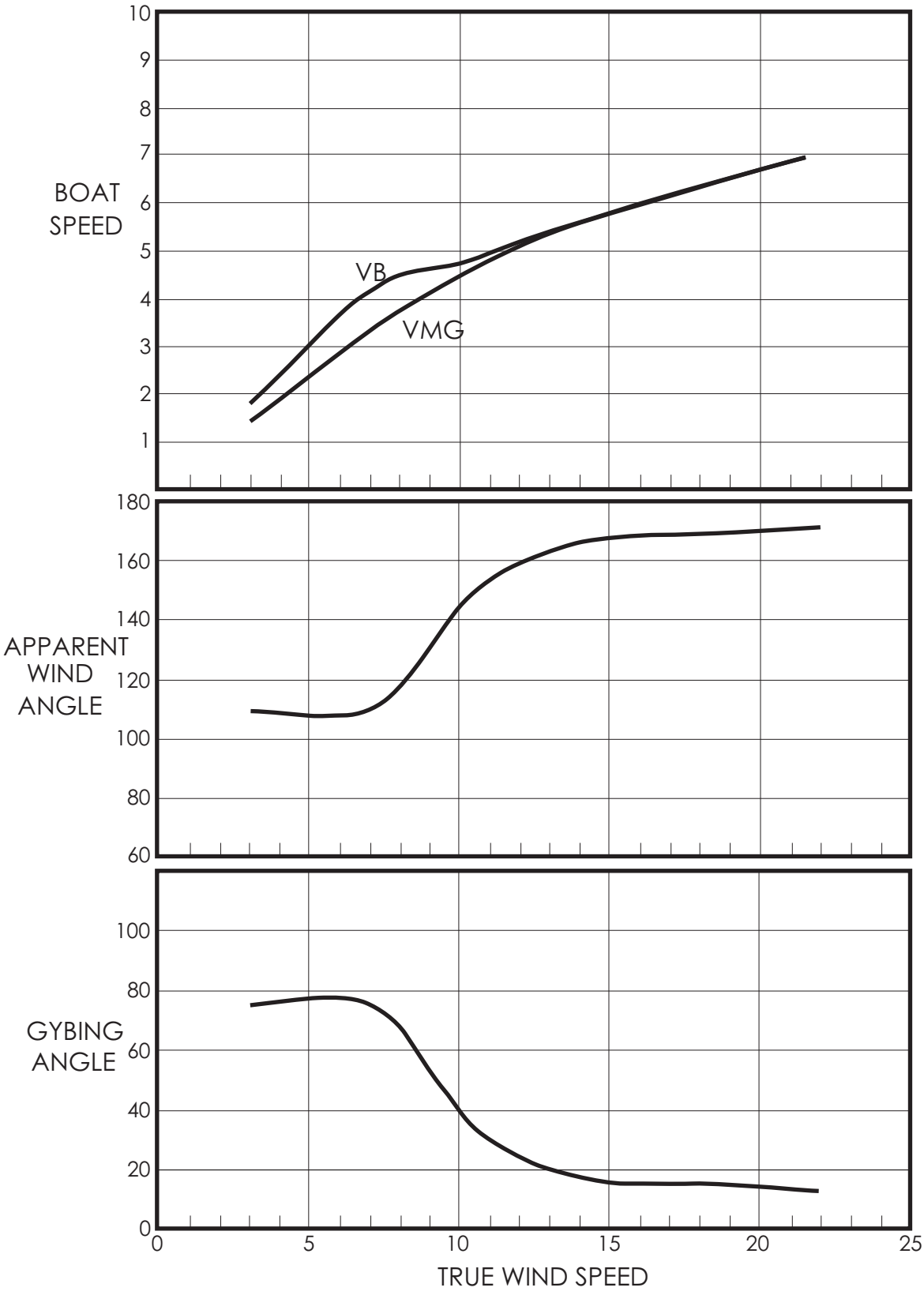
Ranger 23 Tall Rig

Optimum Windward Performance



Ranger 23 Tall Rig

Optimum Downwind Performance



Ranger 23 Predicted Boat Speed Data Tall Rig

Data Source: *FAST* Yacht, Peter t. Schwenn, Dec.. 5, 1995

True Wind Angle	Apparent Wind Speed	Apparent Wind Angle	Boat Speed	VMG	Heel Angle	Leeway Angle	Sail Flatness Factor	Mainsail Reef Factor
3.0 knots true wind speed ----------								
36.0	4.3	26.7	1.461	1.182	0.7	5.97	1.00	1.00
44.0	4.5	31.5	1.855	1.334	0.8	4.24	1.00	1.00
Optimum 47.1	4.6	33.1	1.978	1.346	0.8	3.85	1.00	1.00
52.0	4.6	35.5	2.146	1.321	0.8	3.37	1.00	1.00
60.0	4.7	39.3	2.365	1.182	0.8	2.80	1.00	1.00
70.0	4.5	44.1	2.542	0.869	0.8	2.31	1.00	1.00
80.0	4.3	49.3	2.614	0.454	0.7	1.95	1.00	1.00
81.3	----------		^ Genoa	/ Spinnaker	v	----------		
90.0	4.1	54.2	2.733	0.000	0.8	1.63	1.00	1.00
105.0	3.4	63.9	2.632	-0.681	0.5	1.21	1.00	1.00
120.0	2.7	77.8	2.351	-1.175	0.3	0.82	1.00	1.00
135.0	2.1	97.6	1.996	-1.412	0.1	0.45	1.00	1.00
Optimum142.3	1.9	109.6	1.829	-1.447	0.1	0.30	1.00	1.00
150.0	1.8	123.8	1.653	-1.432	0.0	0.21	1.00	1.00
165.0	1.7	152.0	1.441	-1.392	0.0	0.13	1.00	1.00
180.0	1.7	179.9	1.339	-1.339	0.0	0.05	1.00	1.00
4.00 knots true wind speed----------								
36.0	5.6	26.7	1.898	1.535	1.2	6.18	1.00	1.00
44.0	6.0	31.6	2.423	1.743	1.4	4.35	1.00	1.00
Optimum 48.7	6.1	34.0	2.684	1.772	1.4	3.72	1.00	1.00
52.0	6.2	35.5	2.855	1.757	1.5	3.38	1.00	1.00
60.0	6.2	39.1	3.199	1.600	1.5	2.76	1.00	1.00
70.0	6.1	43.7	3.467	1.186	1.4	2.26	1.00	1.00
80.0	5.8	48.7	3.571	0.620	1.3	1.90	1.00	1.00
82.7	----------		^ Genoa	/ Spinnaker	v	----------		
90.0	5.5	53.6	3.712	0.000	1.4	1.59	1.00	1.00
105.0	4.6	63.2	3.586	-0.928	1.0	1.19	1.00	1.00
120.0	3.7	77.2	3.173	-1.587	0.5	0.81	1.00	1.00
135.0	2.8	98.1	2.632	-1.861	0.2	0.46	1.00	1.00
Optimum141.6	2.6	109.1	2.420	-1.896	0.1	0.32	1.00	1.00
150.0	2.4	124.5	2.164	-1.874	0.1	0.22	1.00	1.00
165.0	2.2	152.3	1.894	-1.829	0.0	0.13	1.00	1.00
180.0	2.2	179.9	1.762	-1.762	0.0	0.05	1.00	1.00
6.0 knots true wind speed----------								
36.0	8.4	26.7	2.801	2.266	2.7	6.31	1.00	1.00
44.0	9.0	31.5	3.711	2.670	3.3	4.24	1.00	1.00
Optimum 47.6	9.2	33.3	4.007	2.701	3.5	3.77	1.00	1.00
52.0	9.3	35.5	4.289	2.641	3.6	3.37	1.00	1.00
60.0	9.2	39.5	4.646	2.323	3.6	2.85	1.00	1.00
70.0	8.9	44.8	4.872	1.666	3.3	2.41	1.00	1.00
79.0	----------		^ Genoa	/ Spinnaker	v	----------		
80.0	8.4	50.2	4.984	0.865	3.5	2.00	1.00	1.00
90.0	7.9	56.0	5.090	0.000	3.2	1.76	1.00	1.00
105.0	6.7	65.8	4.981	-1.289	2.1	1.27	1.00	1.00
120.0	5.4	78.4	4.629	-2.315	1.2	0.83	1.00	1.00
135.0	4.2	97.4	4.006	-2.833	0.5	0.45	1.00	1.00
Optimum141.2	3.9	107.7	3.708	-2.891	0.3	0.32	1.00	1.00
150.0	3.6	124.3	3.268	-2.830	0.1	0.22	1.00	1.00
165.0	3.4	152.5	2.817	-2.721	0.1	0.13	1.00	1.00
180.0	3.4	179.9	2.608	-2.608	0.0	0.06	1.00	1.00

	True Wind Angle	Apparent Wind Speed	Apparent Wind Angle	Boat Speed	VMG	Heel Angle	Leeway Angle	Sail Flatness Factor	Mainsail Reef Factor
8.0 knots true wind speed----------									
	36.0	11.3	26.6	3.793	3.069	6.0	6.17	1.00	1.00
	44.0	11.8	31.6	4.729	3.402	7.7	4.46	1.00	1.00
Optimum	45.1	11.9	32.2	4.814	3.398	7.8	4.33	1.00	1.00
	52.0	11.9	36.2	5.183	3.191	7.9	3.75	1.00	1.00
	60.0	11.7	41.0	5.410	2.705	7.3	3.31	1.00	1.00
	70.0	11.2	47.2	5.550	1.898	6.1	2.86	1.00	1.00
	73.9	----------	^ Genoa	/	Spinnaker	v	----------		
	80.0	10.6	53.4	5.708	0.991	7.6	2.48	1.00	1.00
	90.0	9.8	60.1	5.746	0.000	5.5	2.07	1.00	1.00
	105.0	8.5	70.8	5.665	-1.466	3.3	1.46	1.00	1.00
	120.0	7.1	83.6	5.431	-2.715	1.8	0.91	1.00	1.00
	135.0	5.7	100.4	5.010	-3.543	0.8	0.47	1.00	1.00
Optimum	146.0	4.9	117.5	4.523	-3.752	0.3	0.26	1.00	1.00
	150.0	4.8	124.6	4.323	-3.744	0.3	0.22	1.00	1.00
	165.0	4.4	152.3	3.792	-3.663	0.1	0.13	1.00	1.00
	180.0	4.5	179.9	3.514	-3.514	0.0	0.05	1.00	1.00
10.0 knots true wind speed ----------									
	36.0	13.9	26.2	4.542	3.675	12.8	6.46	1.00	1.00
Optimum	42.6	14.2	30.6	5.230	3.851	14.4	5.18	1.00	1.00
	44.0	14.2	31.5	5.316	3.824	14.5	5.02	1.00	1.00
	52.0	14.1	36.8	5.657	3.483	14.2	4.36	1.00	1.00
	60.0	13.7	42.1	5.850	2.925	13.1	3.87	1.00	1.00
	69.7	----------	^ Genoa	/	Spinnaker	v	----------		
	70.0	13.1	48.6	5.998	2.052	14.5	3.23	1.00	1.00
	80.0	12.4	55.7	6.165	1.071	13.4	2.89	1.00	1.00
	90.0	11.6	63.1	6.219	0.000	9.9	2.39	1.00	1.00
	105.0	10.3	74.9	6.156	-1.593	4.9	1.67	1.00	1.00
	120.0	8.7	88.4	5.940	-2.970	2.5	1.03	1.00	1.00
	135.0	7.2	105.0	5.603	-3.962	1.1	0.52	1.00	1.00
	150.0	6.1	126.7	5.109	-4.424	0.4	0.25	1.00	1.00
Optimum	160.6	5.7	144.8	4.767	-4.496	0.2	0.17	1.00	1.00
	165.0	5.6	152.7	4.645	-4.486	0.2	0.14	1.00	1.00
	180.0	5.6	179.9	4.353	-4.353	0.1	0.06	1.00	1.00
12.0 knots true wind speed ----------									
	36.0	16.1	25.4	4.979	4.028	19.5	6.75	0.94	1.00
Optimum	41.8	16.2	29.3	5.489	4.092	23.0	6.01	1.00	1.00
	44.0	16.2	30.9	5.613	4.037	23.0	5.74	1.00	1.00
	52.0	16.0	36.6	5.941	3.658	22.0	4.99	1.00	1.00
	60.0	15.6	42.4	6.153	3.076	20.0	4.43	1.00	1.00
	70.0	15.0	49.9	6.319	2.161	17.1	3.84	1.00	1.00
	77.0	----------	^ Genoa	/	Spinnaker	v	----------		
	80.0	14.1	57.2	6.466	1.123	19.3	3.22	0.99	1.00
	90.0	13.3	65.2	6.610	0.000	15.1	2.68	1.00	1.00
	105.0	12.0	77.8	6.590	-1.706	8.0	1.88	1.00	1.00
	120.0	10.4	91.9	6.382	-3.191	3.4	1.16	1.00	1.00
	135.0	8.8	108.8	6.054	-4.281	1.4	0.59	1.00	1.00
	150.0	7.7	129.4	5.625	-4.872	0.6	0.30	1.00	1.00
	165.0	7.0	153.8	5.282	-5.102	0.3	0.16	1.00	1.00
Optimum	167.9	7.0	158.9	5.224	-5.109	0.2	0.14	1.00	1.00
	180.0	7.0	179.9	5.042	-5.042	0.1	0.06	1.00	1.00

	True Wind Angle	Apparent Wind Speed	Apparent Wind Angle	Boat Speed	VMG	Heel Angle	Leeway Angle	Sail Flatness Factor	Mainsail Reef Factor
14.0 knots true wind speed ----------									
	36.0	18.1	24.6	5.173	4.185	23.4	6.84	0.82	1.00
Optimum	41.1	18.2	28.3	5.589	4.209	24.8	6.02	0.83	1.00
	44.0	18.1	30.4	5.743	4.131	25.0	5.73	0.84	1.00
	52.0	17.8	36.3	6.069	3.736	25.2	5.12	0.88	1.00
	60.0	17.2	42.3	6.309	3.154	25.3	4.75	0.94	1.00
	70.0	16.5	50.1	6.560	2.244	24.0	4.26	1.00	1.00
	80.0	15.9	58.5	6.715	1.166	19.5	3.64	1.00	1.00
	86.9	----------	^ Genoa	/	Spinnaker		v ----------		
	90.0	14.9	66.9	6.846	0.000	19.2	2.89	1.00	0.98
	105.0	13.7	80.1	6.974	-1.805	11.8	2.07	1.00	1.00
	120.0	12.1	94.6	6.798	-3.399	4.5	1.28	1.00	1.00
	135.0	10.5	111.5	6.461	-4.569	1.8	0.66	1.00	1.00
	150.0	9.3	131.7	6.044	-5.234	0.8	0.36	1.00	1.00
	165.0	8.6	155.0	5.740	-5.545	0.4	0.20	1.00	1.00
Optimum	171.5	8.5	165.8	5.636	-5.574	0.3	0.14	1.00	1.00
	180.0	8.5	179.9	5.536	-5.536	0.2	0.08	1.00	1.00
16.0 knots true wind speed ----------									
	36.0	20.1	24.0	5.254	4.250	24.8	6.84	0.69	1.00
Optimum	40.8	20.1	27.8	5.632	4.262	25.2	6.01	0.70	0.99
	44.0	20.0	30.3	5.803	4.175	25.2	5.73	0.75	0.97
	52.0	19.6	36.5	6.133	3.776	25.3	5.25	0.87	0.94
	60.0	19.1	42.7	6.398	3.199	25.5	4.88	0.97	0.92
	70.0	18.2	50.7	6.657	2.277	25.4	4.41	1.00	0.95
	80.0	17.2	59.0	6.902	1.198	25.3	3.94	1.00	1.00
	90.0	16.6	68.1	7.054	0.000	20.1	3.34	1.00	1.00
	93.6	----------	^ Genoa	/	Spinnaker		v ----------		
	105.0	15.1	81.9	7.309	-1.892	15.9	2.23	1.00	1.00
	120.0	13.8	96.6	7.190	-3.595	6.4	1.40	1.00	1.00
	135.0	12.2	113.6	6.846	-4.841	2.4	0.74	1.00	1.00
	150.0	10.9	133.4	6.429	-5.568	1.1	0.43	1.00	1.00
	165.0	10.2	155.9	6.133	-5.924	0.6	0.24	1.00	1.00
Optimum	172.6	10.1	168.0	6.017	-5.966	0.4	0.16	1.00	1.00
	180.0	10.1	179.9	5.933	-5.933	0.2	0.10	1.00	1.00
20.0 knots true wind speed ----------									
	36.0	23.9	23.5	5.240	4.239	24.9	7.39	0.66	0.89
Optimum	41.6	23.9	28.3	5.719	4.274	25.3	6.40	0.75	0.86
	44.0	23.8	30.3	5.855	4.211	25.4	6.16	0.79	0.85
	52.0	23.4	36.8	6.209	3.823	25.5	5.59	0.91	0.81
	60.0	22.7	43.4	6.499	3.249	25.6	5.14	1.00	0.80
	70.0	21.8	51.9	6.790	2.322	25.4	4.57	1.00	0.83
	80.0	20.7	60.7	7.067	1.227	25.4	4.06	1.00	0.88
	90.0	19.5	69.9	7.339	0.000	25.5	3.60	1.00	0.94
	99.8	----------	^ Genoa	/	Spinnaker		v ----------		
	105.0	18.4	84.8	7.682	-1.988	19.4	2.36	1.00	0.93
	120.0	17.1	99.6	7.957	-3.979	11.9	1.58	1.00	1.00
	135.0	15.6	116.5	7.580	-5.360	3.8	0.91	1.00	1.00
	150.0	14.3	135.7	7.154	-6.196	1.9	0.56	1.00	1.00
	165.0	13.5	157.2	6.851	-6.617	1.0	0.33	1.00	1.00
Optimum	173.1	13.4	169.4	6.721	-6.672	0.7	0.22	1.00	1.00
	180.0	13.4	179.9	6.637	-6.637	0.4	0.14	1.00	1.00

	True Wind Angle	Apparent Wind Speed	Apparent Wind Angle	Boat Speed	VMG	Heel Angle	Leeway Angle	Sail Flatness Factor	Mainsail Reef Factor
24.0 knots true wind speed									
	36.0	27.6	22.8	5.101	4.127	25.0	8.35	0.68	0.80
Optimum	42.8	27.6	29.2	5.775	4.237	25.5	6.77	0.79	0.76
	44.0	27.6	30.2	5.849	4.207	25.6	6.63	0.81	0.75
	52.0	27.1	37.1	6.237	3.840	25.6	5.94	0.93	0.72
	60.0	26.4	43.9	6.552	3.276	25.7	5.38	1.00	0.72
	70.0	25.3	52.8	6.879	2.353	25.6	4.74	1.00	0.75
	80.0	24.2	62.0	7.183	1.247	25.5	4.19	1.00	0.79
	90.0	22.9	71.5	7.485	0.000	25.6	3.70	1.00	0.84
	102.6	----------	^ Genoa	/	Spinnaker	v	----------		
	105.0	21.9	86.9	7.950	-2.058	19.5	2.37	1.00	0.84
	120.0	19.8	100.5	9.304	-4.652	19.3	1.51	1.00	1.00
	135.0	18.8	117.6	8.637	-6.108	6.6	0.98	1.00	1.00
	150.0	17.6	137.1	7.879	-6.824	3.0	0.69	1.00	1.00
	165.0	16.8	158.0	7.522	-7.265	1.5	0.42	1.00	1.00
Optimum	173.1	16.7	169.8	7.378	-7.325	1.0	0.29	1.00	1.00
	180.0	16.7	179.8	7.286	-7.286	0.7	0.19	1.00	1.00
28 knots true wind speed									
	36.0	31.1	21.2	4.682	3.788	25.3	10.42	0.67	0.74
	44.0	31.3	30.0	5.792	4.166	25.8	7.16	0.83	0.68
Optimum	44.1	31.3	30.1	5.798	4.164	25.8	7.15	0.83	0.68
	52.0	30.7	37.2	6.224	3.832	25.8	6.31	0.95	0.65
	60.0	30.0	44.3	6.567	3.284	25.9	5.63	1.00	0.65
	70.0	28.9	53.5	6.930	2.370	25.8	4.91	1.00	0.68
	80.0	27.6	63.0	7.277	1.264	25.8	4.31	1.00	0.71
	90.0	26.3	72.8	7.593	0.000	25.8	3.79	1.00	0.76
	99.6	----------	^ Genoa	/	Spinnaker	v	----------		
	105.0	25.5	88.5	8.215	-2.126	19.6	2.36	1.00	0.76
	120.0	23.2	101.7	10.048	-5.024	19.6	1.39	1.00	0.90
	135.0	21.4	116.6	10.751	-7.602	12.2	0.84	1.00	1.00
	150.0	20.5	137.1	9.259	-8.019	4.4	0.68	1.00	1.00
Optimum	164.2	20.1	157.3	8.387	-8.070	2.3	0.48	1.00	1.00
	165.0	20.0	158.4	8.355	-8.070	2.2	0.47	1.00	1.00
	180.0	20.0	179.8	7.961	-7.961	1.0	0.23	1.00	1.00
32 knots true wind speed									
	36.0	34.8	21.4	4.443	3.595	25.3	9.92	0.59	0.64
	44.0	34.9	29.6	5.655	4.068	26.0	7.86	0.84	0.62
Optimum	44.5	34.9	30.1	5.697	4.061	26.0	7.76	0.85	0.62
	52.0	34.4	37.2	6.150	3.786	26.1	6.75	0.97	0.59
	60.0	33.6	44.6	6.527	3.264	26.1	5.93	1.00	0.59
	70.0	32.4	54.1	6.924	2.368	26.0	5.12	1.00	0.61
	80.0	31.1	63.9	7.297	1.267	26.0	4.46	1.00	0.65
	90.0	29.8	73.9	7.644	0.000	25.9	3.91	1.00	0.69
	97.4	----------	^ Genoa	/	Spinnaker	v	----------		
	105.0	29.1	89.7	8.457	-2.189	19.8	2.35	1.00	0.69
	120.0	26.6	102.9	10.637	-5.319	19.7	1.30	1.00	0.82
	135.0	23.7	116.6	12.637	-8.936	18.4	0.75	1.00	1.00
	150.0	22.9	136.2	11.255	-9.747	7.1	0.58	1.00	1.00
Optimum	155.1	22.6	143.5	10.799	-9.796	5.0	0.53	1.00	1.00
	165.0	22.5	158.1	10.015	-9.674	3.0	0.42	1.00	1.00
	180.0	22.8	179.8	9.194	-9.194	1.3	0.22	1.00	1.00