Laser 28 PERFORMANCE PREDICTION TABLES

TOP SECRET

Virtually all of the information produced by the Performance Prediction Program is presented in these tables. A complete understanding of this tabular form of the data will ensure that you achieve maximum utilization of this package.

Tabular values of your yacht's predicted performance as a function of true wind speed and heading are contained in these tables. For each true wind strength, a number of standard wind angles are computed. In addition, both upwind and downwind optimum tacking (gybing) angles are computed. These conditions appear boxed in the output. Specifically, for each true wind strength, the output down to the first boxed condition represents sailing your yacht with the spinnaker set, ending with the optimum gybing angle. Next the true wind angle is backed up to 120 degrees, and the output down to the next boxed condition represents sailing with the genoa jib set, ending with the optimum upwind tacking angle. Note that for the true wind angles between 120 and 60 degrees predictions are given twice. The first time each angle is run, the spinnaker is assumed to be flying; the second time the genoa is set.

There are ten variables in each line of these tables. As is the case throughout this package, velocities are in knots and angles in degrees. The first two columns contain the true wind strength and heading. Because of the assumed wind gradient and the desire to be able to compare boats with different height rigs, a standard height of 10 meters above the water is used to define the true wind.

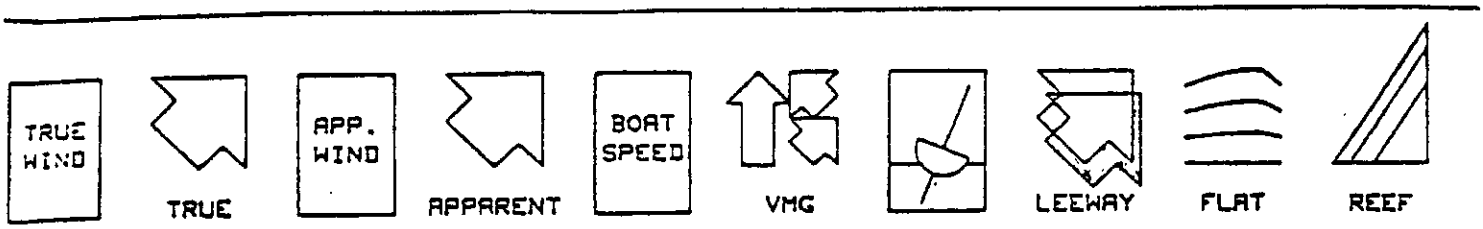
The next two columns contain the indicated apparent wind strength and direction. Here, unlike the case for the true wind, it is most appropriate to present these variables at the masthead, so as to approximate the readings on the onboard instruments. This involves corrections not only for height, but also heel angle, leeway and upwash.

The two succeeding variables presented are boat speed and speed-made-good to weather. (VMG) This latter quantity is simply the component of boat speed in the direction of the true wind. A negative sign on the VMG implies downwind sailing. Notice that VMG is the quantity that has been maximized (minimized) in the boxed optimum sailing conditions.

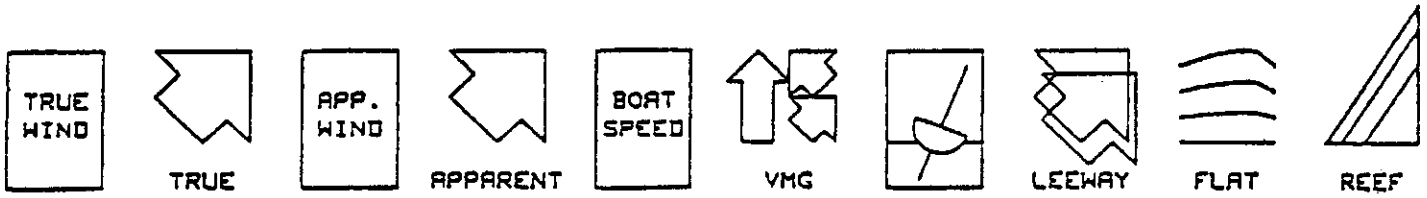
The next column contains the predicted heel angle. Two things should be noted in connection with this variable. First, the crew is assumed to all be sitting on the rail by the time the boat is heeled more than 5 degrees. This agressive attitude on the part of the assumed crew, tends to produce lower heel angles in light air than most sailors find advantageous in real world sailing. However, the computer's math model is such that the lower heel angles produce more accurate estimates of boat speed. The second point of interest involves heavy weather sailing. The computer helmsman does not have to contend with boats that tend to broach when pressed. Thus if your boat loses its controlability at high heel angles, clearly you should avoid broaching in an attempt to match the predicted heel angles.

Leeway is the next variable. This is the angle by which the boat's track through the water differs from the heading. It is a natural consequence of the underbody's need for an angle of attack through the water to produce sideforce in opposition to load on the rig.

The last two columns contain parameters that describe the sail trim required to achieve maximum boat speed, namely FLAT and REEF. Both variables apply to the entire rig, making precise definitions in terms of individual sails difficult or impossible. "FLAT" is the fraction of the maximum attainable lift (sideforce) that is required for optimum performance, ie. a value less than 1 indicates a reduction in sideforce. Onboard this might be accomplished by changing to a shorter LP full-hoist jib, or by reducing drive on the mainsail by flattening and easing the traveller to leeward. Values of REEF less than 1, like FLAT, imply a reduction of force on the sails, but unlike FLAT, this reduction is accompanied by a diminished height of the center of effort. Center of effort height is assumed to vary directly with REEF, while sail area is assumed to vary as REEF squared. For example, a REEF value of .9 implies a sail area reduced to 81% of it's original value, while the center of effort is lowered by 10%. Note that with this interpretation of REEF, twisting off the top of a large mainsail is more closely approximated as "REEF"-ing than as "FLAT"-tening. Note that FLAT applies to however much sail area is left as a result of REEF.



	TRUE WIND	TRUE	APP. WIND	APPARENT	BOAT SPEED	VMG		LEEWAY	FLAT	REEF
DOWNWIND	3.0	180.0	1.6	179.9	1.452	-1.452	0.0	0.1	1.00	1.00
	3.0	165.0	1.6	150.6	1.555	-1.502	0.1	0.1	1.00	1.00
	3.0	150.0	1.9	119.3	1.799	-1.558	0.1	0.2	1.00	1.00
	3.0	135.0	2.2	89.6	2.239	-1.583	0.4	0.4	1.00	1.00
	3.0	120.0	2.9	67.9	2.711	-1.356	0.8	0.7	1.00	1.00
	3.0	105.0	3.7	54.4	3.053	-0.790	1.2	1.0	1.00	1.00
	3.0	90.0	4.4	45.7	3.137	0.000	1.5	1.4	1.00	1.00
	3.0	80.0	4.6	41.9	2.946	0.512	1.5	1.5	1.00	1.00
	3.0	70.0	4.7	38.7	2.604	0.890	1.3	1.6	1.00	1.00
	3.0	60.0	4.5	35.6	2.147	1.073	1.1	1.8	1.00	1.00
optimum	3.0	140.6	2.0	100.0	2.065	-1.595	0.2	0.3	1.00	1.00
	3.0	120.0	2.8	72.0	2.464	-1.232	0.6	0.7	1.00	1.00
	3.0	105.0	3.6	57.1	2.816	-0.729	0.9	1.0	1.00	1.00
	3.0	90.0	4.3	46.7	3.012	0.000	1.3	1.3	1.00	1.00
	3.0	80.0	4.7	41.2	3.049	0.529	1.5	1.6	1.00	1.00
	3.0	70.0	5.0	36.3	2.991	1.023	1.6	1.9	1.00	1.00
	3.0	60.0	5.1	31.8	2.823	1.411	1.6	2.2	1.00	1.00
	3.0	52.0	5.1	28.4	2.597	1.599	1.6	2.6	1.00	1.00
	3.0	44.0	5.0	24.9	2.281	1.641	1.6	3.2	1.00	1.00
	3.0	36.0	4.7	21.0	1.860	1.505	1.4	4.3	1.00	1.00
optimum	3.0	45.9	5.0	25.7	2.365	1.646	1.6	3.1	1.00	1.00
UPWIND	6.0	180.0	3.3	179.9	2.858	-2.858	0.1	0.1	1.00	1.00
	6.0	165.0	3.3	151.2	3.041	-2.938	0.2	0.1	1.00	1.00
	6.0	150.0	3.6	121.9	3.438	-2.978	0.4	0.2	1.00	1.00
	6.0	135.0	4.3	94.3	4.102	-2.900	0.9	0.4	1.00	1.00
	6.0	120.0	5.6	73.3	4.817	-2.408	1.8	0.8	1.00	1.00
	6.0	105.0	7.0	58.8	5.387	-1.394	2.8	1.1	1.00	1.00
	6.0	90.0	8.3	48.8	5.606	0.000	3.8	1.6	1.00	1.00
	6.0	80.0	8.9	43.7	5.435	0.944	4.0	1.8	1.00	1.00
	6.0	70.0	9.0	39.8	4.875	1.667	3.5	1.9	1.00	1.00
	6.0	60.0	8.9	36.3	4.077	2.038	2.9	2.1	1.00	1.00
optimum	6.0	144.9	3.8	111.9	3.656	-2.990	0.5	0.2	1.00	1.00
	6.0	120.0	5.5	77.0	4.398	-2.199	1.5	0.8	1.00	1.00
	6.0	105.0	6.8	61.5	4.960	-1.284	2.2	1.1	1.00	1.00
	6.0	90.0	8.1	50.2	5.284	0.000	3.0	1.5	1.00	1.00
	6.0	80.0	8.8	44.1	5.345	0.928	3.5	1.8	1.00	1.00
	6.0	70.0	9.3	38.5	5.264	1.800	3.9	2.1	1.00	1.00
	6.0	60.0	9.6	33.5	4.992	2.496	4.2	2.5	1.00	1.00
	6.0	52.0	9.7	29.6	4.619	2.844	4.2	3.0	1.00	1.00
	6.0	44.0	9.5	25.6	4.122	2.965	4.1	3.6	1.00	1.00
	6.0	36.0	9.2	21.2	3.475	2.812	3.8	4.7	1.00	1.00
optimum	6.0	44.0	9.5	25.6	4.122	2.965	4.1	3.6	1.00	1.00

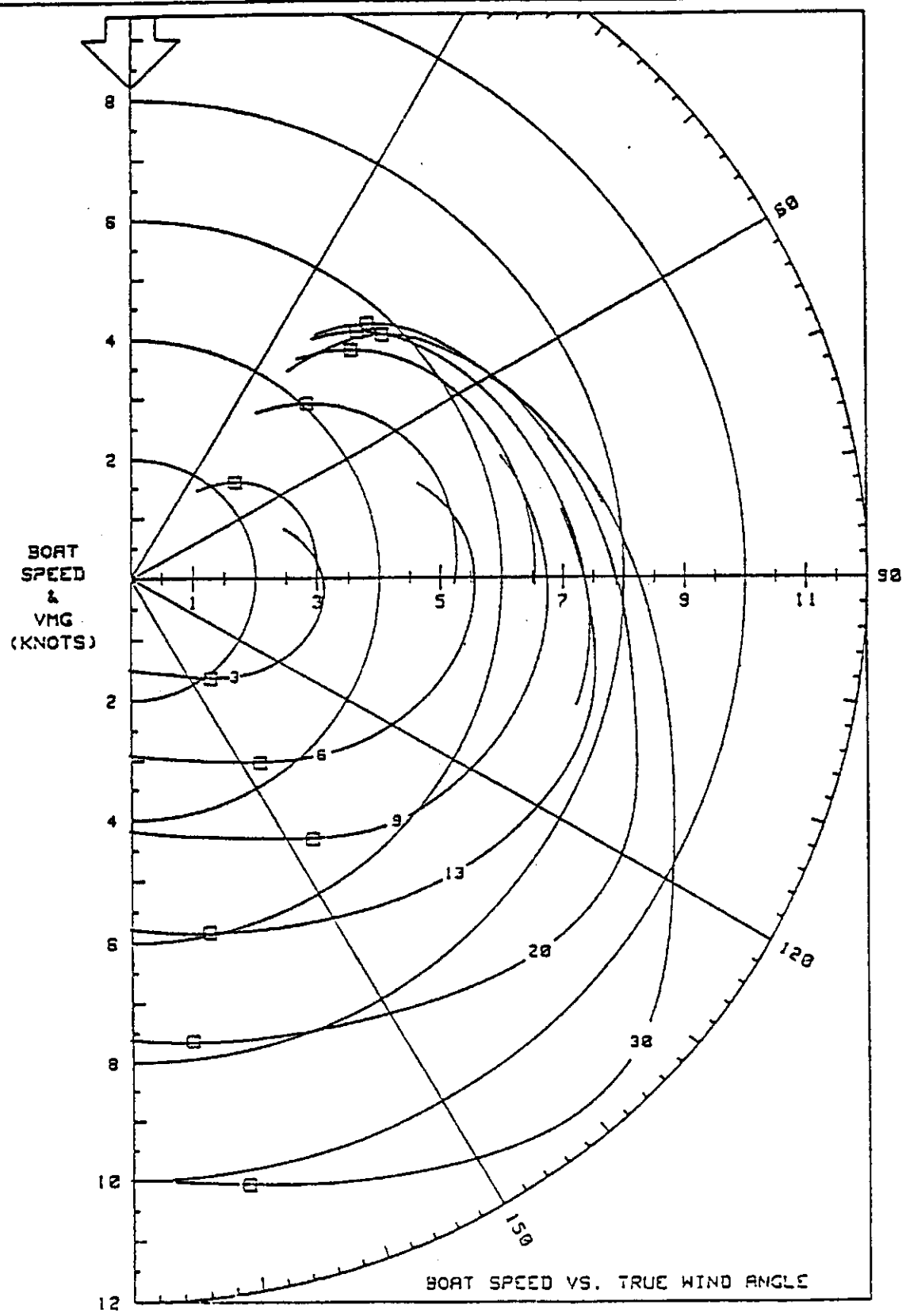


TRUE WIND	TRUE	APP. WIND	APPARENT	BOAT SPEED	VMG		LEEWAY	FLAT	REEF
9.0	180.0	5.1	179.9	4.126	-4.126	0.2	0.1	1.00	1.00
9.0	165.0	5.1	152.1	4.375	-4.226	0.4	0.1	1.00	1.00
9.0	150.0	5.5	124.0	4.912	-4.254	0.3	0.2	1.00	1.00
9.0	135.0	6.6	97.7	5.755	-4.070	1.6	0.4	1.00	1.00
9.0	120.0	8.1	79.1	6.326	-3.163	2.3	0.8	1.00	1.00
9.0	105.0	9.9	65.2	6.696	-1.733	4.6	1.3	1.00	1.00
9.0	90.0	11.2	53.7	6.790	0.000	12.4	1.9	1.00	1.00
9.0	80.0	11.9	46.6	6.634	1.152	18.8	2.2	1.00	1.00
9.0	70.0	12.6	41.0	6.344	2.170	16.9	2.4	1.00	1.00
9.0	60.0	13.0	36.7	5.766	2.883	8.6	2.4	1.00	1.00
9.0	145.3	5.8	115.1	5.186	-4.265	-0.9	0.2	1.00	1.00
9.0	120.0	8.1	81.0	5.984	-2.992	2.4	0.8	1.00	1.00
9.0	105.0	9.7	66.5	6.388	-1.653	3.6	1.3	1.00	1.00
9.0	90.0	11.3	54.9	6.586	0.000	5.5	1.8	1.00	1.00
9.0	80.0	12.1	47.8	6.575	1.142	10.1	2.2	1.00	1.00
9.0	70.0	12.7	41.0	6.452	2.207	14.9	2.5	1.00	1.00
9.0	60.0	13.1	34.5	6.196	3.098	19.2	3.0	1.00	1.00
9.0	52.0	13.3	29.8	5.873	3.615	19.6	3.4	0.97	1.00
9.0	44.0	13.4	25.4	5.383	3.872	18.4	4.0	0.96	1.00
9.0	36.0	13.1	20.7	4.604	3.725	15.9	5.3	0.98	1.00
9.0	42.7	13.4	24.7	5.277	3.878	18.0	4.1	0.96	1.00
13.0	180.0	7.6	179.9	5.736	-5.736	0.5	0.1	1.00	1.00
13.0	165.0	7.7	153.2	5.995	-5.791	0.8	0.2	1.00	1.00
13.0	150.0	8.4	127.7	6.427	-5.566	1.3	0.3	1.00	1.00
13.0	135.0	9.7	104.8	7.045	-4.982	2.3	0.5	1.00	1.00
13.0	120.0	11.5	86.2	7.589	-3.794	4.3	1.0	1.00	1.00
13.0	105.0	13.0	71.1	7.781	-2.014	16.3	1.5	1.00	1.00
13.0	90.0	14.3	59.2	7.393	0.000	21.1	2.0	1.00	0.91
13.0	80.0	15.3	52.0	7.098	1.232	21.1	2.2	1.00	0.85
13.0	70.0	16.1	45.0	6.775	2.317	21.1	2.5	0.95	0.93
13.0	60.0	16.8	38.4	6.384	3.192	20.1	2.8	1.00	0.86
13.0	167.5	7.6	157.6	5.936	-5.795	0.8	0.1	1.00	1.00
13.0	120.0	11.5	87.9	7.137	-3.568	3.6	1.0	1.00	1.00
13.0	105.0	13.3	72.3	7.550	-1.954	9.2	1.6	1.00	1.00
13.0	90.0	14.3	58.9	7.417	0.000	21.6	2.1	1.00	0.99
13.0	80.0	15.3	51.6	7.150	1.242	21.5	2.4	1.00	0.92
13.0	70.0	16.2	44.6	6.863	2.347	21.8	2.7	1.00	0.88
13.0	60.0	16.9	37.8	6.542	3.271	21.5	3.1	1.00	0.85
13.0	52.0	17.3	32.5	6.219	3.829	21.0	3.4	0.98	0.84
13.0	44.0	17.5	27.2	5.771	4.151	20.5	3.9	0.88	0.86
13.0	36.0	17.3	21.6	5.014	4.056	19.8	5.1	0.80	0.90
13.0	41.3	17.5	25.4	5.565	4.179	20.3	4.2	0.86	0.87

TRUE WIND	TRUE	APP. WIND	APPARENT	BOAT SPEED	VMG		LEEWAY	FLAT	REEF
20.0	180.0	12.9	179.9	7.577	-7.577	1.1	0.1	1.00	1.00
20.0	165.0	13.1	155.9	7.834	-7.567	1.7	0.2	1.00	1.00
20.0	150.0	13.9	132.7	8.262	-7.155	2.5	0.4	1.00	1.00
20.0	135.0	15.5	111.3	8.934	-6.317	4.0	0.6	1.00	1.00
20.0	120.0	16.5	93.7	9.204	-4.602	20.2	1.1	1.00	1.00
20.0	105.0	18.4	79.6	8.517	-2.204	22.4	1.5	1.00	0.84
20.0	90.0	20.3	66.3	7.947	0.000	22.4	1.9	1.00	0.72
20.0	80.0	21.5	57.9	7.568	1.314	22.4	2.3	1.00	0.67
20.0	70.0	22.5	49.8	7.165	2.450	22.4	2.6	1.00	0.64
20.0	60.0	23.4	42.0	6.718	3.359	22.2	3.1	0.97	0.64
20.0	172.4	12.9	167.7	7.675	-7.608	1.4	0.2	1.00	1.00
20.0	120.0	17.2	94.9	8.662	-4.331	14.1	1.3	1.00	1.00
20.0	105.0	18.2	79.7	8.367	-2.165	23.1	1.7	1.00	0.90
20.0	90.0	20.2	66.1	7.905	0.000	23.0	2.1	1.00	0.79
20.0	80.0	21.4	57.6	7.574	1.315	23.0	2.4	1.00	0.73
20.0	70.0	22.5	49.5	7.206	2.465	22.9	2.8	1.00	0.69
20.0	60.0	23.4	41.5	6.813	3.406	23.1	3.3	1.00	0.67
20.0	52.0	24.0	35.3	6.451	3.972	22.7	3.7	1.00	0.66
20.0	44.0	24.3	29.2	5.967	4.293	22.0	4.4	0.96	0.66
20.0	36.0	24.2	22.6	5.102	4.128	21.2	5.8	0.82	0.71
20.0	41.6	24.4	27.4	5.775	4.315	21.8	4.6	0.90	0.67
30.0	180.0	20.7	179.8	9.975	-9.975	2.2	0.2	1.00	1.00
30.0	165.0	20.8	157.3	10.390	-10.036	3.2	0.3	1.00	1.00
30.0	150.0	21.7	135.1	11.109	-9.621	5.3	0.5	1.00	1.00
30.0	135.0	22.1	117.1	11.386	-8.051	23.4	0.7	1.00	1.00
30.0	120.0	24.2	101.6	10.199	-5.100	25.2	1.0	1.00	0.81
30.0	105.0	26.5	86.5	9.105	-2.357	25.1	1.5	1.00	0.66
30.0	90.0	28.6	71.8	8.301	0.000	25.2	2.0	1.00	0.56
30.0	80.0	30.0	62.4	7.821	1.358	25.3	2.4	1.00	0.52
30.0	70.0	31.2	53.3	7.321	2.504	25.2	2.9	1.00	0.49
30.0	60.0	32.3	44.5	6.769	3.384	25.1	3.5	0.98	0.48
30.0	169.2	20.7	163.7	10.232	-10.052	2.8	0.3	1.00	1.00
30.0	120.0	24.4	103.0	9.304	-4.652	25.2	1.4	1.00	0.84
30.0	105.0	26.3	86.8	8.785	-2.274	25.8	1.8	1.00	0.71
30.0	90.0	28.4	71.7	8.185	0.000	25.9	2.2	1.00	0.61
30.0	80.0	29.8	62.2	7.772	1.350	25.9	2.6	1.00	0.57
30.0	70.0	31.1	53.0	7.323	2.505	25.8	3.1	1.00	0.54
30.0	60.0	32.2	44.0	6.820	3.410	25.9	3.7	1.00	0.52
30.0	52.0	33.0	37.0	6.370	3.922	25.7	4.3	1.00	0.51
30.0	44.0	33.5	30.0	5.734	4.125	24.8	5.4	0.99	0.51
30.0	36.0	33.2	20.8	4.338	3.510	23.4	9.4	0.83	0.56
30.0	44.7	33.5	30.6	5.806	4.128	25.0	5.3	0.99	0.51

POLAR SPEED PLOT

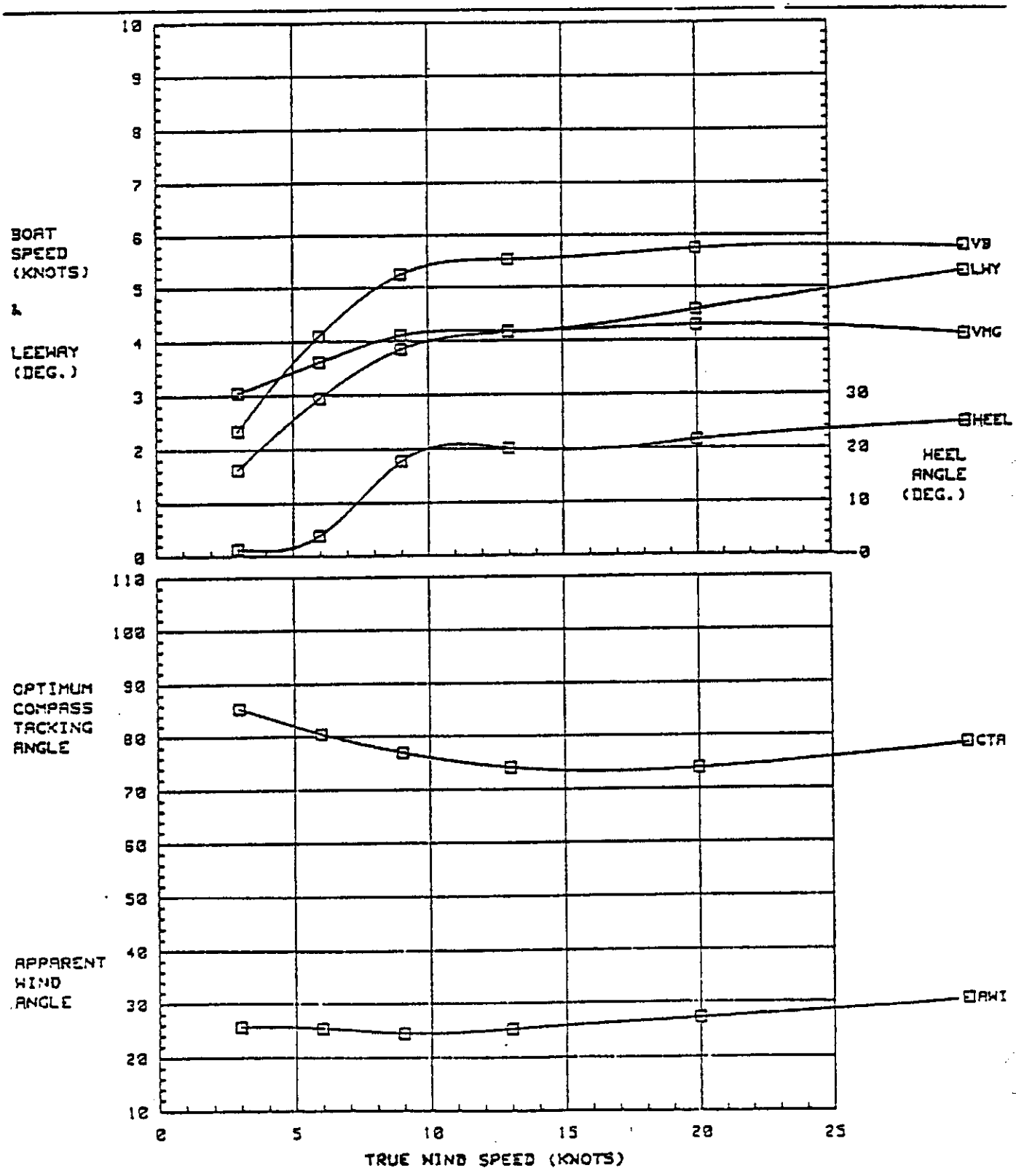
The polar speed plot is drawn to a scale of 1 knot per cm. For each *true* wind speed, there are a pair of overlapping curves (the small number embedded in each curve identifies the wind velocity). The reason for the pairs of overlapping curves is that the downwind portion has the spinnaker set, while the upwind portion has the genoa set. Clearly where the two curves cross one should change from genoa to spinnaker or vice versa. An exception to this rule is in very light air where the two curves intersect in a "dimple". One should never sail in the dimple. If the course desired is through this portion of the polar, one should tack across wind by first sailing high with genoa and then bearing off under spinnaker, or vice versa as the tactics of the situation dictate. The small boxes on the extreme upwind and downwind portions of the curve represent the optimum VMG sailing conditions to windward and leeward respectively.



UPWIND OPTIMUMS PLOT

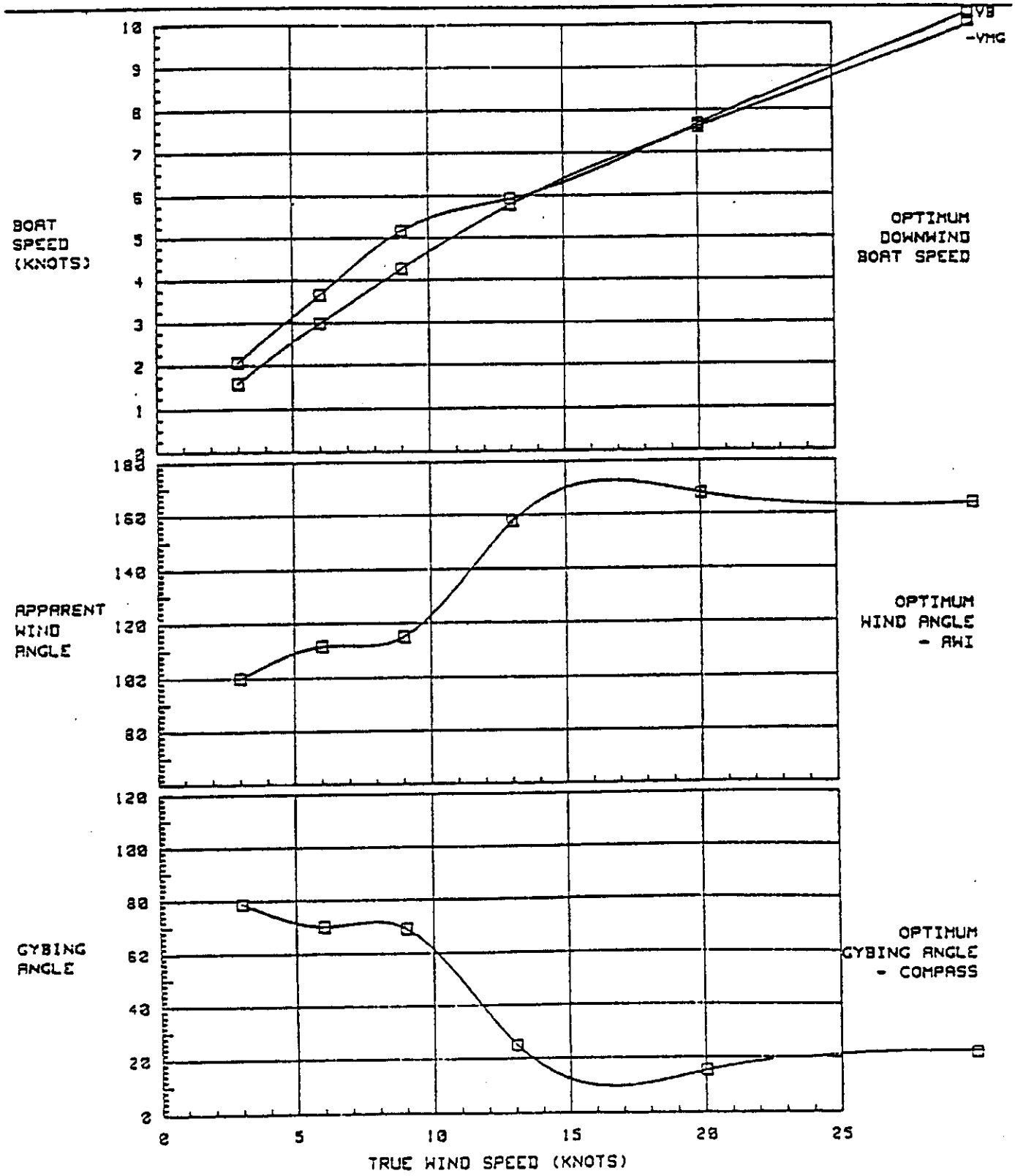
This page is a cross-plot of the optimum upwind sailing conditions. The lower graph plots optimum compass tacking angle and indicated apparent wind angle versus true wind strength. Note that the compass tacking angle is *not* the same as two times the true wind angle for optimum upwind sailing. Compass tacking angle is this latter quantity less two times the leeway angle. This is the angle that must be added or subtracted from your compass course to yield the compass course on the opposite tack.

The top graph relates boat speed, VMG, leeway and heel angle (scale for heel angle is on the right) to true wind stength for optimum upwind performance. The actual computed points are indicated by the small boxes. The interpolation is done with cubic spline curves.



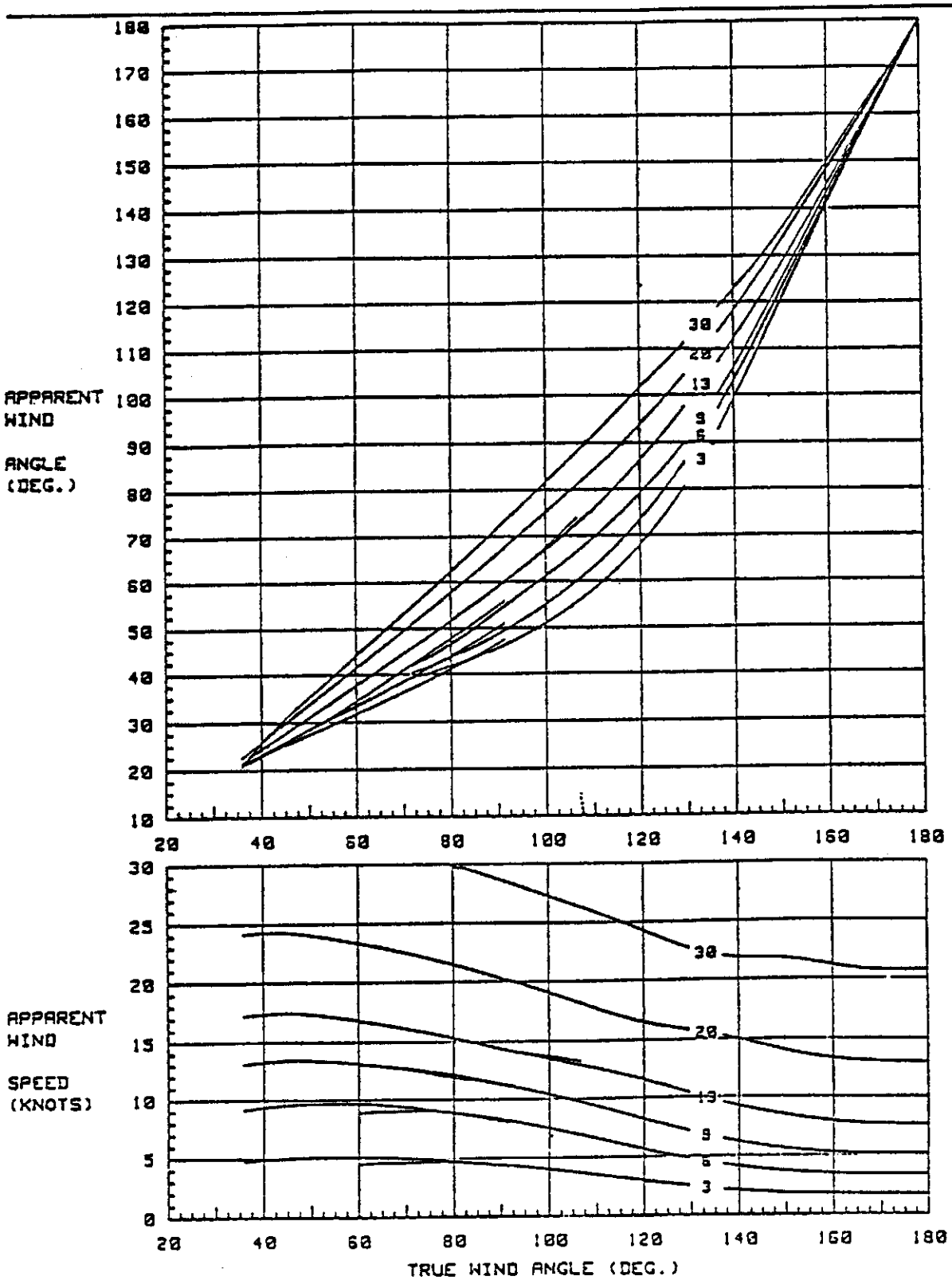
DOWNWIND OPTIMUMS PLOT

This page presents the same sort of information as on the previous page, except that the point of sail is now optimum downwind sailing. The only significant differences between the format of this page and the previous one is the omission of leeway and heel angle from the top figure, since these variables lose their importance on this point of sail. In addition, since compass tacking (gybing) angle and indicated apparent wind angle are at opposite ends of the scale, each has been given its own figure.



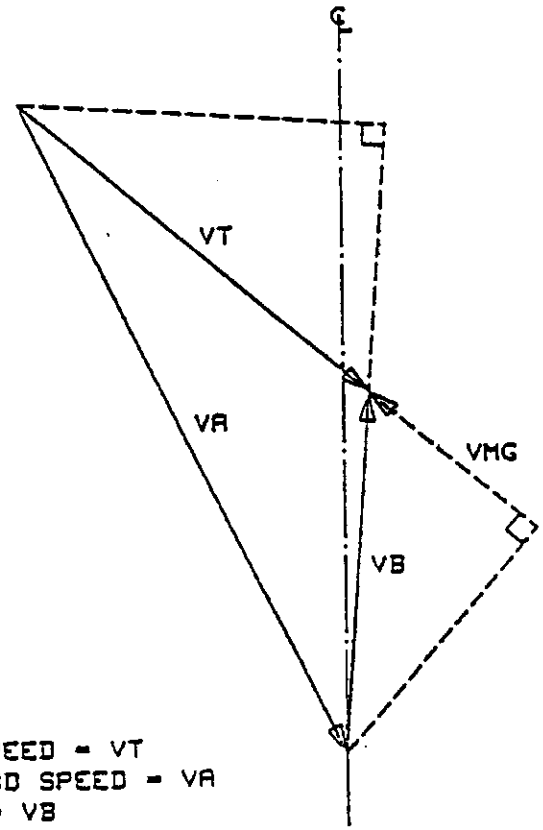
TRUE TO APPARENT WIND PLOT

This plot is intended to allow your navigator to determine the apparent wind speed and angle as a function of the true wind angle and strength. There is one graph for each relationship. Note that each graph has the same number of curves on it as there are true wind strengths in the tables. Like the speed polar, the true wind strength for each curve is indicated by the number imbedded in the curve. The overlapping portions are where the predictions with spinnaker and genoa cross.



TRUE/APPARENT WIND TRIANGLE

As you have no doubt noticed by now, true wind stength and direction are used as the variables against which nearly everything is plotted. This is unfortunately necessary as apparent wind angle and strength are insufficient information alone to determine the sailing condition of the yacht. This figure is included to allow the navigator/tactician to compute the true wind angle and speed if he knows the boat speed, apparent wind speed and angle and the heel angle. A correction for REEF and FLAT is also included to improve the accuracy of the approximating formulae. The eight equations at the bottom of the page can be executed by hand on a pocket calculator, or even better on a programmable calculator. Either way, the equations have been "custom tailored" to your boat so as to produce the best possible approximation of the true wind conditions. Note that the first equation produces an estimate of leeway angle, while the second equation computes the approximate upwash angle at the masthead. The final equation accounts for the wind gradient, since all of the tabulated values of true wind speed are taken to be at a 10 meter height above the water, while the instruments are taking measurements at the masthead.



TRUE WIND SPEED = VT
APPARENT WIND SPEED = VA
BOAT SPEED = VB
TRUE WIND ANGLE = G
APPARENT WIND ANGLE = B
LEEWAY ANGLE = L
UPWASH ANGLE = E
HEEL ANGLE = H

THE SYMBOL ^ INDICATES EXPONENTIATION.
THE SYMBOL * INDICATES MULTIPLICATION.
THE LETTER m INDICATES A MEASURED QUANTITY.
THE LETTERS mh INDICATE A VALUE TAKEN AT THE MASTHEAD.

```
L =   38.37 * H/[VB]^3
E =    2.68 * SIN[(180-Bm)/1.6671^2.5 * REEF^2 * FLAT
B = Bm + L - E
VBAUG = COS(B) * VAm
VTMCG = VBAUG - VB

G = ArcTAN (TAN(B) * VBAUG/[COS(H) * VTMCG])
VTmh = VTMCG/COS(G)
VT = VTmh/(.15055 * COS(H) + 0.873)
```

UPWIND

True Wind Speed	Target Speed	Apparent Wind	Talking Angle
3	2.37	26	85
4	3.25	26	84
5	3.62	26	83
6	4.12	26	81
7	4.57	25	79
8	4.97	25	78
9	5.28	25	77
10	5.44	25	76
11	5.54	25	75
12	5.56	25	74
13	5.57	25	74
14	5.60	26	74
15	5.63	26	74
16	5.66	26	74
17	5.69	27	74
18	5.72	27	74
19	5.75	27	74
20	5.78	27	74
21	5.79	28	74
22	5.80	28	75
23	5.81	28	75
24	5.81	29	75
25	5.81	29	76

DOWNWIND

True Wind Speed	Target Speed	Apparent Wind	Sailing Angle off Dead Downwind
3	2.37	100°	39°
4	2.76	105°	37°
5	3.15	110°	36°
6	3.66	112°	35°
7	4.21	113°	35°
8	4.76	114°	35°
9	5.19	115°	35°
10	5.50	124°	31°
11	5.69	134°	25°
12	5.80	146°	18°
13	5.94	158°	13°
14	6.22	164°	9°
15	6.30	166°	8°
16	6.55	166°	8°
17	6.81	167°	8°
18	7.28	167°	8°
19	7.38	167°	8°
20	7.68	168°	8°
21	7.89	168°	8°
22	8.28	167°	8°
23	8.43	166°	8°
24	8.68	166°	9°
25	9.00	165°	10°