Flying Dutchman Keel line and stem

Some thoughts on millimeter twaddle:
The difference between a gold medal or just a place somewhere in the fleet?

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Introduction:

On making an inventory of the Cle Jeltes FD archive we came across the measurement forms of all the competitors of the Olympics in 1972 and the WC of 1980 and 1984. One of the questions asked was; is there a difference in keel lines and do these differences influence the ultimate results. Secondly; were the boats build by one builder identical, do differences exist between builders and thirdly; the boat from Rodney Pattisson intrigued us because in the (Dutch) FD book on the history of the FD the story goes that for the Olympic games of 1972 Pattisson had a new boat built by Bob Hoare. This boat was built on a new plug since the former plug showed signs of deterioration. This new boat did not “fly” and another new one was built on the old plug and the results were “as previously” with the gold medal at the end of the games in 1972. Was this just tittle-tattle or was there really an explanation based on differences in hull lines?

Methods:

Flying Dutchman keel line “H” measurements of a selection of classic FDs from the 1970s and some contemporary FD’s, including Leonhard Mader, KD, Hans Mader, Bogumil, Bianchi and Lindsay together with the Bob Hoare K263 sailed by Rodney Pattisson were put in graph. Furthermore the measurement procedure is explained in detail. Also eventual race results of the various boats are reported. This exercise should be considered against the background that new initiatives in the class could possibly benefit from these older data.

Jarek Plaszczyca together with the technical committee is developing a digital model of the original FD lines before all the original Mylar plans are lost, and so we are also looking at the keel line. Furthermore Luca Ungaro is building a new PlanaTech FD, which has been optimised using CFD codes, and wanted to confirm that his keel line conforms to the class rules. This stimulated us to upgrade class rule 29 to clarify its interpretation, and in the process the basis of this rule was checked.

The design FD keel line:

The FD class rules include a table of offsets which define the keel line at the transom and stations 0 to 10 as well as the stem profile, relative to the design water line, DWL. However, class rule 29 specifies a set of “H” measurements at stations 0 to 9 which are measured from a “base line” specified to be from 100 mm below the keel line at the transom to 120 mm below the keel line at station 9 see figure 1. This baseline is not parallel to the DWL and in the coordinate system of the hull, see figure 1, the vertical position z_b of the baseline is:

$$z_b = \left(z_{tr} - 100\right) + \frac{(z_9 - z_{tr} - 20)}{5130} x$$

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Which for the design values of z_{tr} = 11 mm and z_9 = -97 mm is z_b = -89 - 0.02495x mm

So the keel line coordinate z in terms of the "H" value is:

$$z = z_b + H = \left(H + z_{tr} - 100\right) + \frac{(z_9 - z_{tr} - 20)}{5130}x$$

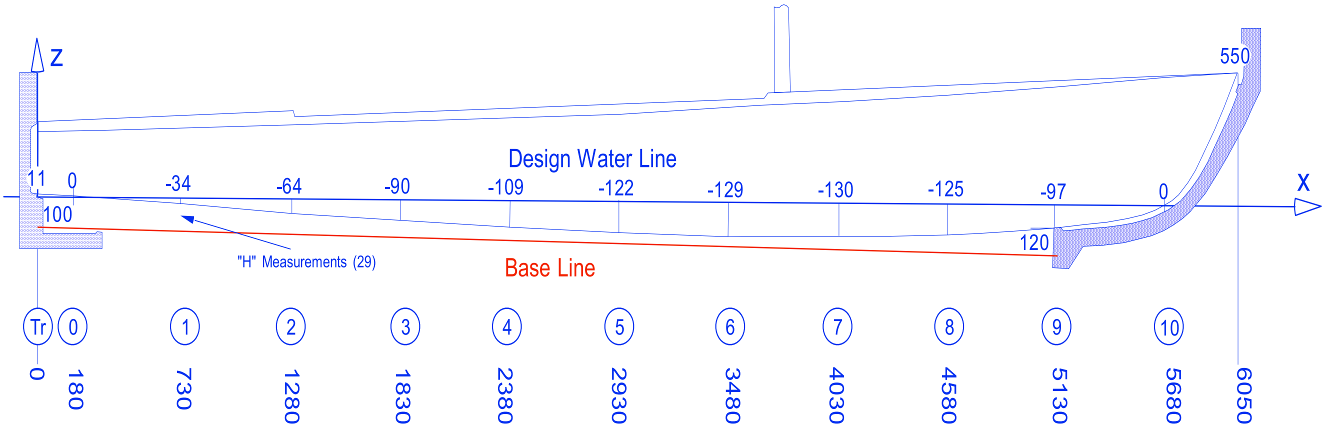

Figure 1 *The base line and design waterline together with the keel line as specified by the table of offsets.*

The 2010 Class rule 29 specifies the distances "H" from the baseline to the keel line:

29. Keel line measurements

The shape of the keel line shall be checked by measuring the minimum distance to the baseline, which is the line drawn from a point 100 mm under the keel at the transom to a point 120 mm under the keel at station 9. These minimum distances, H measurements, must be taken at each station:

Station	1	2	3	4	5	6	7	8
"H"	72	56	45	40	40	46	59	80

Tolerance: The absolute value of the algebraic difference of the greatest positive and greatest negative deviations must not exceed 12.5 mm.

This wording does not make the interpretation absolutely clear in the case where all the differences are positive (or all negative) so it is proposed to add the station 9 "H" value of 120 mm to rectify this ambiguity.

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The proposed 2012 Class rule 29 is then:

29. Keel line measurements

The shape of the keel line shall be checked by measuring the minimum distance to the baseline, which is the line drawn from a point 100 mm under the keel at the transom to a point 120 mm under the keel at station 9. These minimum distances, H measurements, must be taken at each station:

Station	1	2	3	4	5	6	7	8	9
"H"	72	56	45	40	40	46	59	80	120

Tolerance: The absolute value of the algebraic difference between the maximum and minimum deviations including zero at station 9 must not exceed 12.5 mm.

The first thing to check is the consistency of the offset data with the class rule 29 "H" values, see table 1 and figure 2 which shows the difference between the "H" values and the keel line as specified by the offsets. Although the agreement is not within the quoted precision or round off of ±0.5 mm, the algebraic sum of the differences is well within the tolerance of 12.5 mm specified by rule 29, so there is no compelling reason to change the "H" values.

Station	Position	Keel line Z	Base Line Z	Keel line to baseline	Rule 29 "H"	Deviation
Transom	0	11	-89.00	-100.0	100	0.0
0	180	0	-93.49	-93.5		
1	730	-34	-107.21	-73.2	72	-1.2
2	1280	-64	-120.94	-56.9	56	-0.9
3	1830	-90	-134.66	-44.7	45	0.3
4	2380	-109	-148.38	-39.4	40	0.6
5	2930	-122	-162.11	-40.1	40	-0.1
6	3480	-129	-175.83	-46.8	46	-0.8
7	4030	-130	-189.55	-59.6	59	-0.6
8	4580	-125	-203.28	-78.3	80	1.7
9	5130	-97	-217.00	-120.0	120	0.0
10	5680	0	-230.72	-230.7		
				Max-Min=	12.5	2.9

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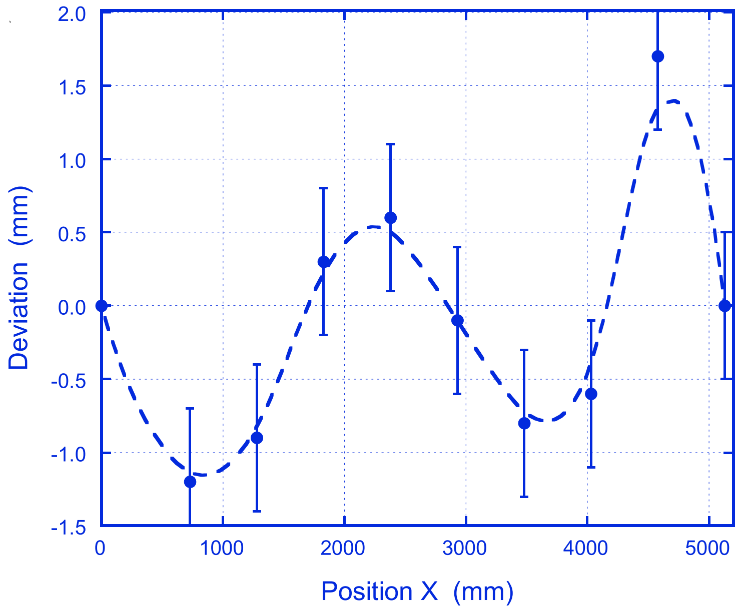

Figure 2 *The deviation of rule 29 "H" values from the table of Offsets keel line. Note these deviations seem to oscillate with amplitude of ~1 mm.*

The stem profile, as specified in the table of offsets, extends the keel line to the bow and a plot of this data, together with points interpolated by Jarek using spline fits is shown in figure 3.

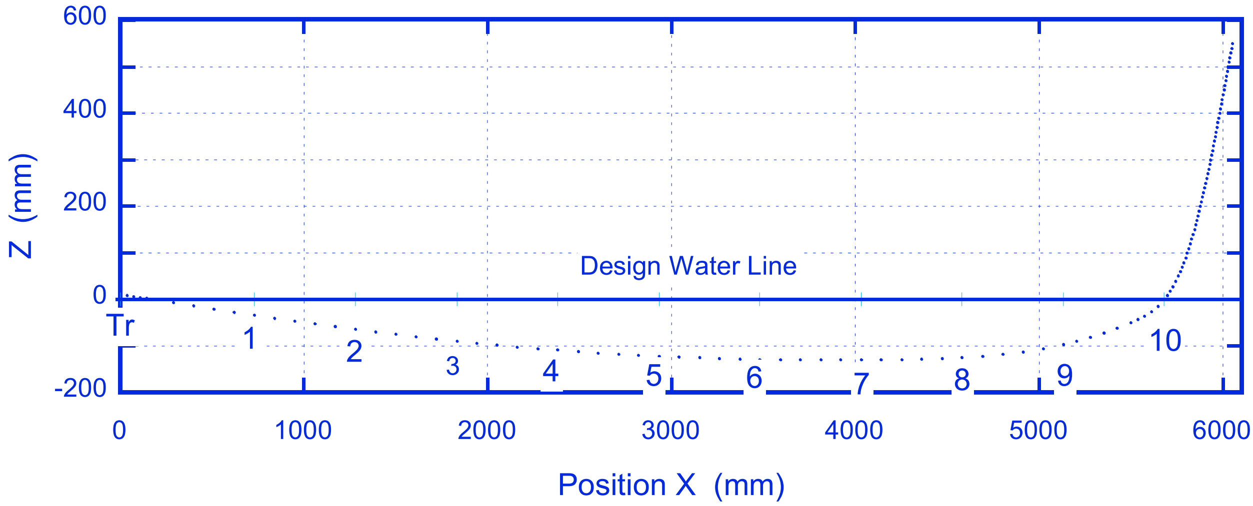

Figure 3 *The FD keel line and stem data from the table of offsets, plus spline interpolation points.*

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Keel lines derived fro “H” measurements

Class rule 29 allows some tolerance on the keel line and this has been exploited in order to build faster FD hulls. During hull fundamental measurement the “H” values are recorded and it is of great interest to investigate the variations in keel rocker between different class legal hulls and correlate this with their performance on the race course. For a preliminary investigation it is easy to plot the “H” values versus station number including the values of 100 mm at the transom and 120 mm at station 9. However, there are some caveats on the interpretation of such plots.

It should be noted that the base line is determined by the keel line at the transom and at station 9, while the DWL is defined at stations 0 and 10. Thus it is possible to move the baseline relative to the DWL by modifying the height of the HDP above the DWL from the design value of 11 mm, or by changing the depth at station 9 from the nominal 97 mm. Lowering the HDP, relative the keel line between stations 1 and 9, would require an inflection in the keel line and that is forbidden by class rule 21, however, although hardly advantageous, it is possible to raise the HDP, which would have the effect of reducing the “H” measurements. The class rules do not require an “H” measurement at stations 0 so no such data exists. Raising just the HDP will reduce the “H” measurements at the after stations without in fact changing the keel rocker below the DWL.

The stem template can be moved ±2.5 mm vertically relative to the DWL, i.e. the station 10 keel line point, due to the ±3 mm stem shape tolerance, and can also rotate about the y axis. As the stem template is rotated the deck reference line rises and the stem and station 9 lugs go up or down by ±3.5 mm at which point the ±6 mm limit of rule 34 is reached. Thus it is possible to move the station 9 keel line point by ±2.5 ± 3.5 = ±6 mm relative to the DWL, i.e. the distance below the DWL between 91 mm and 103 mm. This would significantly change both the keel rocker and the position of the base line and hence the “H” values.

Figure 4 Paul Hemker making keel line measurements at the 1976 Olympics in Kingston and 35 years later in Malcesine.

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When measuring the "H" values a taut line is rigged between the stem and the transom templates, see figure 4. In the case of moulded hulls the measurer has to decide if the keel band is uniform, in which case the templates can be placed on the keel band, or if it is necessary to estimate where the hull surface begins and then both locate the templates on it and measure to it. Thus there is an uncertainty of ±0.5 mm at the ends of the base line. The measurements are made with a ruler which at best is graduated to 0.5 mm and the string is usually 0.5 mm diameter so the measurements are at best within ±0.5 mm and probably only ±1 mm at stations 4 and 5, i.e. at the C/B slot. The measurements on NED 341 look as if no allowance for the extension of the hull skin to the centerline were made at station 4 and 5, see figure 5. Thus the measurements are at best only within ±0.5 mm and this is indicated in figure 6.

Table 2

Station	Position X	NED 27	NED 262	K 263	NED 230	NED 341	NED 340	DEN 17	GRE 22	NED 26	F 136
Year		1976	1972	1972	1972	1991	1991	1972	1971	2010	
Builder		van Dusseldorp		Hoare	Hoare	KD	Mader	Hein	Hein	Bogumil	Bianchi
Transom	0	100	100	100	100	100	100	100	100	100	100
1	730	76	76	66	70	76	76	73	72	74	73
2	1280	58	57	50	54	60	60	57	56	62	57
3	1830	44	44	38	41	46	47	48	43	50	46
4	2380	39	37	36	32	48	41	43.5	34	47	40
5	2930	39	37	36	36	48	41	46	36	45	41
6	3480	43	42	43	43	47	43	51.5	43	45	45
7	4030	53	54	53	54	57	57	65	58	60	55
8	4580	75	74	72	74	79	81	85.5	85	78	72
9	5130	120	120	120	120	120	120	120	120	120	120
	Δ	10	10	8	8	10	7	6	11	9	9

Table 3

Flying Dutchman ($H-H_{0ffset}$)

Station	Position X	NED 27	NED 262	K 263	NED 230	NED 341	NED 340	DEN 17	GRE 22	NED 26	F 136
Transom	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	730	2.8	2.8	-7.2	-3.2	2.8	2.8	-0.2	-1.2	0.8	-0.2
2	1280	1.1	0.1	-6.9	-2.9	3.1	3.1	0.1	-0.9	5.1	0.1
3	1830	-0.7	-0.7	-6.7	-3.7	1.3	2.3	3.3	-1.7	5.3	1.3
4	2380	-0.4	-2.4	-3.4	-7.4	8.6	1.6	4.1	-5.4	7.6	0.6
5	2930	-1.1	-3.1	-4.1	-4.1	7.9	0.9	5.9	-4.1	4.9	0.9
6	3480	-3.8	-4.8	-3.8	-3.8	0.2	-3.8	4.7	-3.8	-1.8	-1.8
7	4030	-6.6	-5.6	-6.6	-5.6	-2.6	-2.6	5.4	-1.6	0.4	-4.6
8	4580	-3.3	-4.3	-6.3	-4.3	0.7	2.7	7.2	6.7	-0.3	-6.3
9	5130	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

FLYING DUTCHMAN KEEL LINE AND STEM

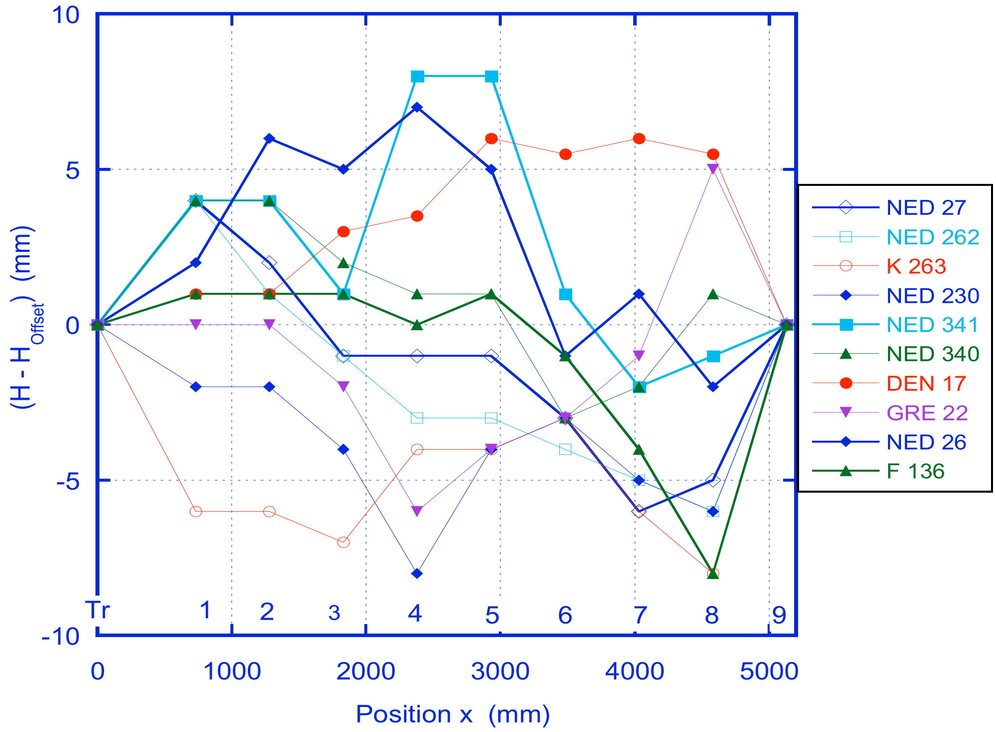

Figure 5 Deviations from the design keel line as specified by the table of offsets, derived from the "H" measurements.

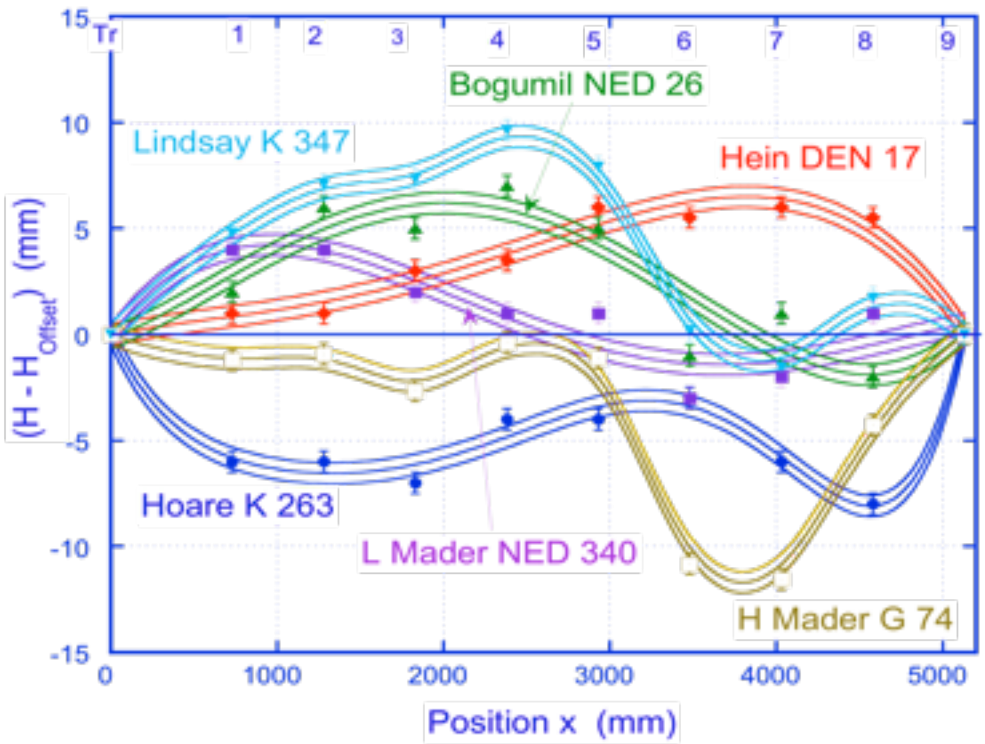

Figure 6 *Deviations from the design keel line as specified by the table of offsets, derived from the "H" measurements for different builders.*

Flying Dutchman Keel line and stem

From a naval architecture point of view it would be preferable to study the keel line relative to the DWL as the latter is determined by the buoyancy of the immersed section of the hull and due to the large water plane will only marginally change with changes in the keel line. However, due to the fact that the "H" measurements at station 0 and 10 are not recorded it is not possible to accurately relate the "H" measurement data to the DWL. So the best one can do is study the data relative to the base line remembering that the base line differs from hull to hull.

The "H" data for ten classic FD hulls is presented in table 2 together with the max. – Min value of the difference $\Delta = (H - H_{29})$ as specified in rule 29. In order to more clearly see the differences between the hulls the deviations $\Delta = (H - H_{Offset})$ are listed in table 3 and plotted in figures 5 and 6. It is rather difficult, even in this expanded plot to follow the 10 different hulls so the data for K 263 and DEN 17, which are extreme cases, are plotted separately in figure 6 together with the ±0.5 mm error regions. The curves are polynomial fits and indicate a rather complex shape for K 263 so a spline fit would be more appropriate.

At the 1972 Olympics K 263 won the gold medal. Den 17 (Hans Fogh) ranked 7th and F136 (Yves Pajot), a nearly nominal boat won the silver medal. The other Hein boat the GRE 22 is not identical with the Den 17 and was found in the tail of the final results.
The NED 26 a recent Bogumil which won the bronze medal at the WC in Malcesine.

Some data from the 1984 Worlds is listed in Tables 4 and 5, with some data presented in **figure 7**.

Table 4

	BL49	D21	DDR21	E51	D23	F181	F194	G88	G82	G67	G74	K348	K347
Year	1984	1984	1983	1983	1983	1983	1983	1984	1983	1983	1983	1984	1983
Builder	Mader	Mader	FES	Mader	Mader	Bianchi	Mader	Mader	Mader	H Mader	H Mader	Hoare	Lindsay
Result Posn	39	4	29	12	6	2	3	14	10	43	1	31	9
X													
0	100	100	100	100	100	100	100	100	100	100	100	100	100
730	76	74	77	74	78	76	76	75	75	72	72	78	78
1280	60	58	58	58	64	65	62	59	66	55	56	56	64
1830	48	48	45	47	52	54	49	48	55	41	42	45	52
2380	45	45	38	45	47	48	49	45	48	41	39	46	49
2930	47	43	42	45	48	49	49	45	47	39	39	44	48
3480	48	45	45	46	50	51	49	47	47	38	36	47	47
4030	58	57	57	57	58	60	60	57	69	49	48	57	58
4580	80	80	78	80	81	78	81	80	82	74	74	82	80
5130	120	120	120	120	120	120	120	120	120	120	120	120	120

Flying Dutchman Keel line and stem

Table 5

Posn	BL49	D21	DDR21	E51	D23	F181	F194	G88	G82	G67	G74	K348	K347
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
730	2.79	0.79	3.79	0.79	4.79	2.79	2.79	1.79	1.79	-1.21	-1.21	4.79	4.79
1280	3.06	1.06	1.06	1.06	7.06	8.06	5.06	2.06	9.06	-1.94	-0.94	-0.94	7.06
1830	3.34	3.34	0.34	2.34	7.34	9.34	4.34	3.34	10.34	-3.66	-2.66	0.34	7.34
2380	5.62	5.62	-1.38	5.62	7.62	8.62	9.62	5.62	8.62	1.62	-0.38	6.62	9.62
2930	6.89	2.89	1.89	4.89	7.89	8.89	8.89	4.89	6.89	-1.11	-1.11	3.89	7.89
3480	1.17	-1.83	-1.83	-0.83	3.17	4.17	2.17	0.17	0.17	-8.83	-10.83	0.17	0.17
4030	-1.55	-2.55	-2.55	-2.55	-1.55	0.45	0.45	-2.55	9.45	-10.55	-11.55	-2.55	-1.55
4580	1.72	1.72	-0.28	1.72	2.72	-0.28	2.72	1.72	3.72	-4.28	-4.28	3.72	1.72
5130	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

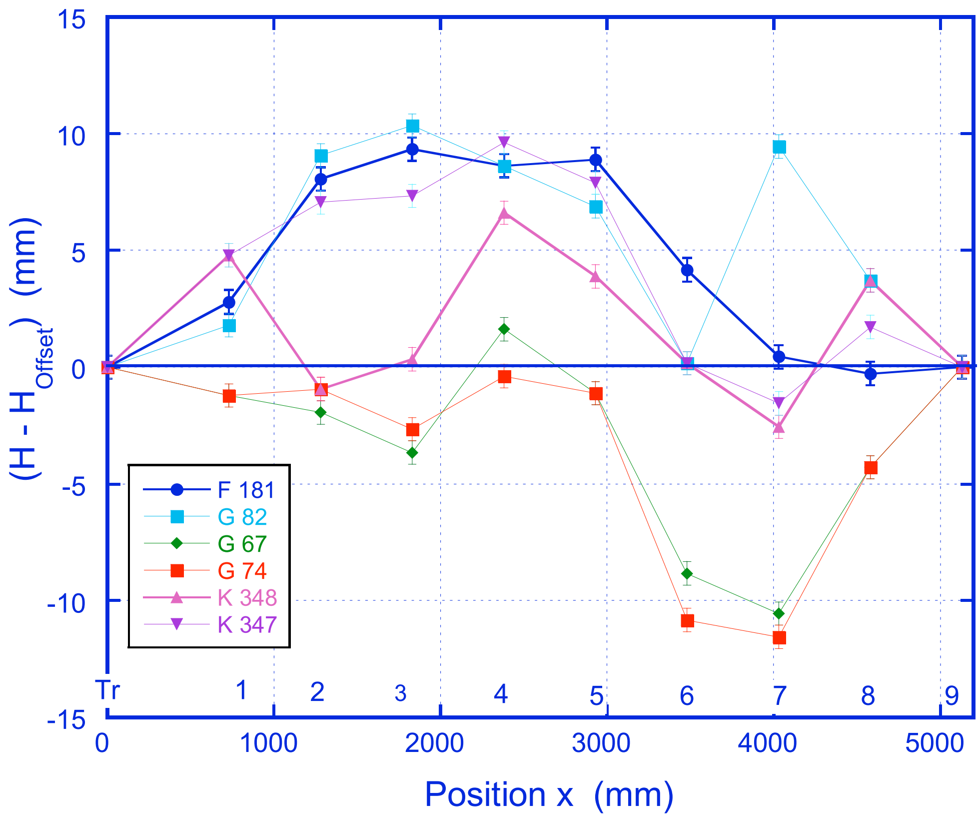

Figure 7 *Deviations from the design keel line as specified by the table of offsets, derived from the "H" measurements for some Hulls at the 1984 Worlds.*

Flying Dutchman Keel line and stem

Conclusions

What can we conclude from all this?

Firstly; boats from different builders are different,

Secondly; boats from the same builder can be different, but sometimes the FD's are identical (Hans Mader).

Thirdly; the Rodney Pattisson boat is complex in its shape and most other Hoare FDs do differ from K 263.

Fourthly: medals can (could ?) be won with different keel rockers lines.

Fifthly; tolerances from the nominal data are much smaller compared to the tolerances of another former Olympic class: the Int. 12 foot dinghy.

Sixthly: newer FD's tend to be flat but the flattest one does not often win.

Seventh; large keel rocker will reduce wetted surface and so is good in light airs, but a flat run is better for planing in heavier wind.

One should however be aware that in the early 1970s the hull was measured with half templates and there was a beam measurement with the usual 12.5 mm tolerance. This meant that by making the beam maximum width the templates could be rotated and the station made flatter, or vice versa. The story goes that Rodney took his two FDs to Spain for the summer, together with a large container of micro balloons for changing the shape within the then existing tolerances, and conducting two boat trials to find the optimum legal FD hull shape. When the present full templates with tie bars were introduced his hull no longer met the new tolerances, which were therefore adjusted so that all previous FDs remained legal. This I believe is the reason for the difference in the tolerance at station 9 compared with the other stations. We add these remarks to indicate that not only the keel rocker was different but also the hull sections of K 263 were in all probability also modified.

It is also well known that modern FDs have maximum buoyancy at the bow, i.e. maximum width at station 9, so again there have been changes to the lines of the FD hull, not just to the keel rocker. For an interesting case study of the effects of keel rocker and buoyancy in the bow go to
http://www.vikingeskibsmuseet.dk/en/boatyard/present-projects/the-oseberg-ship/
about the Viking Oseberg ship which even preceded the mythical Flying Dutchman.

We are looking forward to the advent of the new PlanaTech FD which has been designed using CFD to optimize the performance. It will be interesting to see if modern computer techniques are better than the two boat testing of the 70s when it comes to defining a faster Flying Dutchman

Durk and Peter 12 February 2012