WARWICK J. HOOD AO

DATE: 3 September 1999

MEMO TO: Sen. Const. David Upston

FROM: Warwick Hood

SUBJECT: **"Business Post Naiad" - Removal of Internal Ballast**

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1. Three (3) consecutive certificates up to that of 28/7/97 inclusive (issue dates) show displacement (measured) of 6020 kilograms.

2. Certificate issued 28/7/97 was for yacht measured on 11/3/97.

3. Certificate issued 28/9/98 was for yacht measured on 18/9/98.

4. Elapsed time between measurement dates of 2 & 3 above is 18 months. This may be the "some 18 months ago" to which Steve Walker refers in his fax to David Lyons.

5. Colin Boyle is certain there was no other internal ballast except that glassed in and that under the (old) engine.

6. It would be reasonable, in my view, that, having just bought a new yacht you would remove the loose ballast under the companionway because it's dangerous to have loose ballast.

7. In my report I suggested that a reasonable view of the ballast removal was that the inside loose ballast (as in 6 above) was removed by the owner as soon as he got the boat and the rest removed - all the glassed-in internal ballast, sometimes within the 18 months between the '97 and '98 measurings.

8. This does not fit with all of Steve Walker's recollections but it does satisfy good yachting practice and Walker's recollection about time.

Hope this helps.

Warwick Hood

Warwick

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WARWICK J. HOOD AO

THE YACHT "BUSINESS POST NAIAD"

AND THE

1998 SYDNEY - HOBART YACHT RACE

A Report on Investigations into Stability & Measurement Certificates

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1.0 INTRODUCTION

1.1 During the course of the 1998 Sydney to Hobart Yacht race, a competing yacht, "Business Post Naiad" was rolled over in a severe storm. The yacht's mast was broken but the wreckage was secured on deck by the crew.

1.2 The yacht, while under power to a safe haven, was rolled over again and remained inverted for a considerable time. During this second event, two crew members died.

1.3 The February 1999 issue of the Australian yachting magazine "Sailing" elaborates on this in an article headed "Bombed" and with a sub-heading "How storm-force winds took out the middle of the fleet and how six men died."

1.4 On page 20, the writer commences his description of the events leading to the death of two men from "Business Post Naiad". He describes how the yacht under "bare poles" (no sail set at all) was rolled right over - presumably through 360°, breaking the mast in two places and causing major structural damage. Even though some of the crew were overboard secured by their harnesses, they were brought back on board. The broken mast and rigging were secured on board and the yacht then began motoring towards Gabo Island, away to the north west.

1.5 Later, the yacht was rolled again, this time to 180° and stayed inverted for four or five minutes. It was at this stage when one crew member was drowned, trapped in his harness.

1.6 Then the yacht was righted by another wave, the yacht having about a metre of water in it. Another crew member fell into this water and, upon getting up, died of a heart attack.

1.7 On the assumption that this description of the events leading to the death of two men is correct - and the author writes with some authority, then the report of investigations which this writer has carried out into the subject yacht's stability may help in an understanding of the events.

1.8 In the course of these investigations several other matters came to light, particularly the validity of its measurement certificate. This report also describes investigations into these matters and provides conclusions.

2.0 SUMMARY OF FINDINGS

2.1 The measurements taken from the yacht's hull using the IMS instrument are adequate to describe the hull shape for computing purposes at large heel angles.

2.2 At 180° heel, the yacht included its damaged mast and rigging is very stable.

2.3 There is serious doubt about the validity of the measurement certificate which covered the yacht's participation in the race. In particular, the measured displacement was incorrect and the limit of positive stability (LPS) was also incorrect.

3.0 INVESTIGATIONS

3.1 The basic information supplied was:

(a) a full set of designer's drawings for a yacht of the Farr 40 type.

(b) a modification drawing prepared by the designer for a different keel to the standard, fitted to the actual yacht.

(c) a quantity of measurement certificates and measurement documents and correspondence.

(d) a copy of a letter from Mr David Lyons to the Cruising Yacht Club of Australia.

3.2 In addition to the above the writer has obtained a tabulation of machine measured offsets for the yacht from Mr Tony Mooney at Australian Yachting Federation.

3.3 The writer has also had numerous discussions with Sen. Const. David Upston of Sydney Water Police, who supplied a copy of a facsimile from Mr Steve Walker of Wynyard, Tasmania, to Mr David Lyons.

3.4 Mr Colin Boyle, the previous owner, during an interview supplied valuable information about the yacht's internal ballast.

3.5 Following the receipt of the drawings, a file of offsets was compiled, working from the lines plan. This was not easy because the drawing is a little distorted and some of the offsets given on the drawing are inaccurate. It is believed, however, that the hull offsets file, totalling more than 50 Kb is adequately representative of the shape of hull shown by the lines plan.

3.6 Utilising the "Nautilus" computer programme - the same as that embedded in the IMS programme, and other data taken from the yacht's documents, particularly freeboards and vertical centres of gravity position, the file was processed.

3.7 It is to be borne in mind that the computer programme is simply a means of performing classical naval architecture calculations which are riddled with small approximations. So it was not to be expected that the results from the yacht measurement and the plan "measurement" would be exactly the same. The writer is, however, surprised at some of the differences.

3.8 While the displacements - 7161 Kg from the yacht and 7155 from the plan, are so close as to be in the "too good to be true" class, the calculated limit of positive stability is 107.8° from the plans and 104.7° from the yacht. It is in the righting arm area ratio where there is a much greater difference. From the yacht it is 1.296 and from the plan it is 1.770.

3.9 Subsequently, a file of offsets for the hull, keel and rudder were obtained from Mr Tony Mooney at Australian Yachting Federation. These had been developed from raw data from the hull measurement on 10 January 1990, using the measuring "machine".

These offsets were used to compile a new file for the computer and using the previous vertical centre of gravity and freeboards, the program was run. The displacement was calculated to be 6864 kilograms, the limit of positive stability 109.2° and the righting arm area ratio 1.5957.

3.10 Mr David Lyons has commented (see 3.1 (a) hereof) on the measurement file in that he considers that an inadequate number of positions on the hull were measured.

3.11 Exhibit 1 hereto shows a plot of the offsets for station 6 on the Sections & Offsets Plan No. 138/2A Station 6 is located 6.544 abaft the head of the stem and is the biggest station in terms of breadth of the waterline. Station 7 is a little bigger above the waterline.

3.12 Shown as dots only are the intersections of the yacht measurer's vertical and horizontal measurements taken from the file of offsets supplied by Mr Mooney for a station 6.403 metres abaft the head of the stem. This station is 143 millimetres forward of station 6 above.

3.13 The measurer's station is a little forward of the designer's station 6 and it should be a little smaller, as is indeed shown by the exhibit. The two sections shown have a good similarity.

3.14 The drawing indicates a number of other things as well. Note that:

(a) the hull is slightly shallower than designed, and

(b) the measurer recognising that the bottom is designed to be flat from the centreline out to beyond the 420 butlock, has taken three measurements in this area.

3.15 It may also be noted that in defining this section near the designer's section 6, the measurer has taken 18 spots in comparison with the 21 provided by the designer. This is not, in a seriously deficient number. The writer is confident that the number given adequately describes the hull shape in the area of the hull in question to the computer.

3.16 Because the inverted (180° heel) stability is of importance, the writer has calculated the change in the vertical centre of gravity of the yacht with its broken mast and rigging secured on its deck - see Section 5 and with this knowledge, the stability inverted - see Section 6.

3.17 There appears various anomalies in the measurement certificates available. The writer has spent some time in the examination of these certificates, especially in connection with the yacht's internal ballast. These are detailed in Section 7 hereof.

4.0 VERTICAL CENTRE OF GRAVITY OF DAMAGED YACHT

4.1 During the first capsize, the yacht's mast was broken in two places. Photographs and the designer's sail plan no 138-1/21A were used to calculate the resulting change in the vertical centre of gravity.

4.2 From examination of photographs, it appears that no parts of the mast and rigging were lost after the mast broke. The crew secured the wreckage on board.

4.3 The height of the yacht's vertical centre of gravity is reduced as a result of the mast breaking and the securing of the wreckage on board. The following unit weights of the various components of the rig have been used in the calculation;

Mast Section Zapspar 170		Kg/Metre 5.7
Rods Navtec No.	3	.07
	4	.119
	8	.210
	10	.250
	12	.320
	17	.440

together with catalogue weights for terminals, cordage and other fittings.

4.4 The mast broke at the top end of its internal stiffening, just below the lowest set of spreaders. The piece of mast remaining in the yacht, supported by the lowest set of shrouds has been estimated to weigh 43.0 Kg with a vertical centre of gravity 2.45 above the measurement trim waterline shown on the "Hobart '98" certificate, dated 15/10/98.

4.5 The total weight of the mast (MWT) is given on this certificate as 212 Kg and its vertical centre of gravity as 4.675 metres above the datum given in the Rules. This is equal to a height of 7.595 above the measurement trim waterline above.

4.6 This weight (MWT) does not include any halyards but the mast is otherwise complete. The halyards were typical high strength cordage and 5 kilograms has been allowed for these. The total mast weight is therefore 217 kilograms.

4.7 The total weight of the broken piece of mast is 174 kilograms.

4.8 This piece, however, also broke into two pieces. One piece, consisting of a section of unstiffened extrusion 3.7 metres long with one pair of spreaders and rigging lay diagonally, suspended by the halyards at the aft top end. This piece of mast is estimated to weigh 27.0 kilograms and to have a vertical centre of gravity of 2.9 metres above the measurement trim waterline.

4.9 The remainder of the mast, relatively undamaged, was lashed down on the deck on the starboard side, the top pointing aft. This piece of mast is estimated to weigh 147 kilograms and to have a final vertical centre of gravity of 1.50 metres above the measurement trim waterline.

4.10 During the first roll over, the aft end of the mainsail boom became bent down to deck level. It appears that the bottom of the boom buckled in way of the top end of the vang. The boom, including all its fittings and gear, for example reefing fittings and mainsheet blocks, is estimated to weigh 30 kilograms and, undamaged, a VCG of 2.65 metres.

A component of the undamaged yacht's weight and VCG is the mainsail. From the certificate dated 15/10/98, the mainsail weight is given as 30.9 Kg. The vertical centre of gravity is calculated from clause 719 of the IMS rules and is 7.96 metres above the measurement waterline.

After the damage, the vertical centre of gravity of both boom and mainsail is estimated to be 2.30 metres above the measurement waterline.

4.11 The final vertical centre of gravity of the damaged yacht may be estimated as follows:

ITEM		Weight Kg	VCG (1)	Moment
(i)	Undamaged yacht	7161	0.241	1725.8
(ii)	Subtract mast (see 4 above)	-217	7.595	-1648.1
(iii)	Subtract boom (see 6 above)	-30	2.65	-79.5
(iv)	subtract mainsail (see 6 above)	-31	7.96	-246.8
(v)	add mast stump (see 4 above)	+43	2.45	+105.4
(vi)	add "diagonal" piece (see 5 above)	+27	2.90	+78.3
(vii)	add remainder (see 5 above)	+147	1.50	+220.5
(viii)	add boom mainsail (see 6 above)	+61	2.30	+140.3
Damaged yacht		7161	+0.041	+295.3

(1) Above measurement trim waterline
(2) From rating certificate

As a result of the breaking of the mast, the vertical centre of gravity of the whole yacht is lowered by 0.200 metres.

5.0 STABILITY INVERTED

5.1 Evidence shows that upon the yacht being rolled over a second time, it remained at 180° keel, i.e. completely inverted, for a considerable time, said to be five or six minutes. The yacht had been damaged in a previous roll and the estimated vertical centre of gravity of the yacht at the second roll is given in Section 4 above.

5.2 Assuming that the weight of the yacht had not changed i.e. there was no water inside, which is unlikely to be true, but the assumption allows a starting point, a waterline was found when the yacht floating upside down including the deck camber, cockpit and cabin house, has a displacement equal to 7161 kilograms. This waterline is at about 0.955 metres above the designer's DWL.

5.3 This waterplane, making allowance for the cockpit continuous through the transom and not as shown on the plans, has a transverse inertia of about 25.8 metres to the fourth. The volume of displacement in salt water is 6.986 metres cubed. The height of the metacentre above the centre of buoyancy is therefore 3.69 metres.

5.4 In Section 4 the vertical centre of gravity of the damaged yacht was shown to be 0.041 above the measurement waterline. The distance between the upside down (180° heel) centre of buoyancy and this centre of gravity is about 1.13 metres. Therefore, the upside down metacentric height is about 2.56 metres; or in other words, upside down, this yacht is very stable when damaged as described.

5.5 It has been assumed that there is no water inside. This is probably a false assumption and a small amount of water would be in the cabin house, lowering the centre of gravity and creating a small free surface correction.

5.6 As further water gained access - and this is difficult because the upside down hull is airtight, it would fill the cabin house, creating a greater free surface until the yacht became unstable inverted. It might then right itself.

5.7 The effect of the wind and sea state is difficult to assess. There is evidence of yachts having similar characteristics including high inverted stability remaining upside down for days in very rough seas.

6.0 CORRECTNESS OF MEASUREMENT CERTIFICATES

6.1 It needs to be stated at the beginning of this section that the "as designed" freeboards and displacement at the nominated "DWL" are:

Freeboard Forward FF	=	1.257 m
Freeboard Aft FA	=	1.039 m
Corresponding displacement	=	5890 Kg

6.2 The following is a tabulation of forward and aft freeboards and displacements shown on the various rating certificates supplied to the writer.

No	Date	Freeboards		Measured Displacement Kg	Remarks
		FM	AM		
1	2-1-90	1.151	1.125	Not given but approx. 5690	10R certificate
2	19-10-95	1.160	1.132	5461.7	10R certificate
3	27-10-95	1.160	1.132	5869	IMS certificate
4	30-11-95	1.198	1.088	6020	IMS certificate
5	30-7-96	1.198	1.088	6020	IMS certificate
6	28-7-97	1.198	1.088	6020	IMS certificate
7	29-9-98	1.322	1.037	5546	IMS certificate - inside ballast removed
8	15-10-98	1.232	1.037	6287	IMS certificate - rethink of freeboard forward

6.3 The last 10R certificate issued to the yacht gave the displacement as 5461.7. Shortly after, the first IMS certificate was issued giving a displacement of 5869 only 21 kilograms short of the designer's displacement. This certificate must, however, be considered flawed as the VCG height was shown as -0.975, an impossible distance below the waterline.

6.4 The certificate issued on 30-11-95 (see table, item no.4) resulted from a redistribution of weight and the addition of weight, the displacement now being 6020. The increase in displacement is 151 kilograms, the bow freeboard is greater and the stern less.

6.5 Examination of the certificates numbered 4,5 and 6 in the table above shows that the freeboards and displacements are exactly the same while the stability information changes. Further examination of the certificates shows that all the inclining experiment information is the same, that is, the weights used, the distance weights were shifted, the pendulum length and the pendulum deflections are all the same. This information in association with the displacement must give exactly the same height of the vertical centre of gravity. Yet, it does not. Between the 30-11-95 and 30-7-96 certificates, the centre of gravity is shown as having risen by 0.178 metres. This is hard to believe. If the sailing trim displacement of 6959 kilograms is used, then the rise in the height of the vertical centre of gravity is equivalent to the raising of 100 kilograms of the yacht's mass through nearly 3.4 metres.

6.6 This problem has been discussed with Mr Tony Mooney of Australian Yachting Federation (AYF) who could offer no explanation. In the writer's opinion, it should be discussed further with Mr Richard Fisher, the yacht's measurer over the period under examination.

6.7 The writer now draws attention to the certificates dated 29 September 1998 and 15 October 1998. The latter may be referred to as the "'98 Hobart Race" certificate.

On or about 18 July 1998, the yacht was re-measured consequent upon the owner removing the remaining inside ballast from it. The usual measurement condition checklist and inventory was prepared and signed by both owner and measurer. In addition to these, the measurer supplied to AYF a sheet of paper dated 18-7-98 showing the inclining experiment details and the freeboards. There are two sets of forward freeboards shown, one set marked "subsequent check".

6.8 AYF calculated and issued a certificate dated 29 September 1998 using not the forward freeboards marked "subsequent check" but the first set. That is, the freeboards used for this calculation were - forward 1.322 and aft 1.037. The resulting displacement was 5546 kilograms which is consistent with ballast weight having been removed from a yacht which prior to this removal had a displacement of 6020 kilograms (see 28 July 1997 certificate). It should also be especially noted that the calculated limit of positive stability was 109.5°.

6.9 In facsimiles dated 6 and 15 October 1998 Mr Fisher advised AYF of problems with the freeboard measurements. The measurement given in the 15 October fax were 1.231 and 1.037, forward and aft respectively and it is these freeboards which are shown on the 15 October 1998 certificate, the "'98 Hobart Race" certificate.

On this certificate, the displacement is given as 6287 kilograms and the angle as 104.7°.

6.10 The writer finds this latter displacement impossible to reconcile with weight having been removed from the yacht. In 1997 the displacement was 6020 kilograms. In 1998 weight having been removed, the displacement must be less, not more.

6.11 It seems likely therefore that the 29 September certificate is correct, showing, as it does, a limiting stability angle of 109.5°, very close to the screening value of 110°.

6.12 The writer being not entirely satisfied, made more investigations and now adds further information to the above.

6.13 Mr Colin Boyle advised that shortly before the yacht was sold to the late Mr Bruce Guy it was re-engined and that a small quantity of loose ballast - his estimate about 80 kilograms, was removed from the engine space as the new engine had a deeper sump. Mr Boyle does not know what happened to this ballast but it may be that loose ballast later removed from under the companionway to which Mr Steve Walker refers.

6.14 Mr Boyle further noted that all the internal ballast was located under the main cabin sole each side of the centre line. Via a hand hole in the cabin sole, it was possible not only to mop out any water but also to feel the lead ingots through the fibreglass holding it in position.

6.15 Mr Steve Walker sent a fax to Mr David Lyons of 20 January 1999 describing his recollection of the inside ballast removal. He appears to suggest that the first tranche of internal ballast - that is ballast glassed in as referred to in .7 above was removed when Mr Guy first owned the yacht and the remainder prior to re-measurement in 1998.

6.16 Mr Boyle further advised that the yacht had no other internal ballast near or under the engine. Its outside keel was as shown on the designer's drawing no. 138/1/25 and was estimated to weigh as follows:

bronze top	238.1 kg
lead fin	1884
total	**2122.1 kg**

6.17 This total weight compares with the original lead fin keel of 1782 kg as shown on drawing no. 138/3A. This drawing also showed internal ballast under and each side of the engine totalling 1250 kg.

6.18 It is interesting to note that drawing no. 138/1/5 of the new keel shows no internal ballast, although a position is shown for it.

6.19 After considerable thought, the writer believes this to be incorrect and proposes the following:

(1) the small quantity of internal ballast removed from under the engine (see .13 above) was placed loose under the companionway. Mr Walker refers to this and I believe that this was the first and only amount of ballast removed at that time.

(2) prior to re-measurement in 1998, <u>all</u> the inside ballast was removed. The writer agrees with Mr Walker that the ingots described, clean, would weigh about 680 kg.

(3) The total weight of the yacht at the time of re-measurement in 1998 was therefore 6020 - 680 = 5340 kg.

It is to be remembered that prior to 1998, three consecutive certificates showed the measured displacement as 6020 kg.

6.20 On the other hand, the above value for displacement is hardly satisfactory when compared with the value - 5546 kg shown on the 29 September 1998 certificate. The difference, 206 kg, can hardly be explained away by errors in measurement and/or calculating.

6.21 The writer does not understand the conclusion which arises from the above. If the difference in displacement from the 29 September 1998 certificate was ±100 kg, it is believed that this cold be ascribed to measuring or calculation errors and the writer would then be prepared to say that the certificate issued to the yacht on 15-10-98 - the "Hobart"

certificate, was wrong and that the previous certificate of 29-9-98 was actually correct. But the writer cannot do this.

6.22 Clearly, the question of the yacht's stability may not be answered until this basic question of the displacement is first settled. The following investigations will help:

(1) when the yacht was destroyed after the race, was there <u>any</u> inside ballast?

(2) Mr Walker's recollections of the ballast removed on each of the occasions to which he refers, and

(3) of course, the freeboards.

7.0 ACCURACY

7.1 It is to be noted that the computer calculations are based on the measuring of the freeboards at two locations, one each near the bow and stern. It is not possible, using ordinary methods, to obtain these freeboards with high precision.

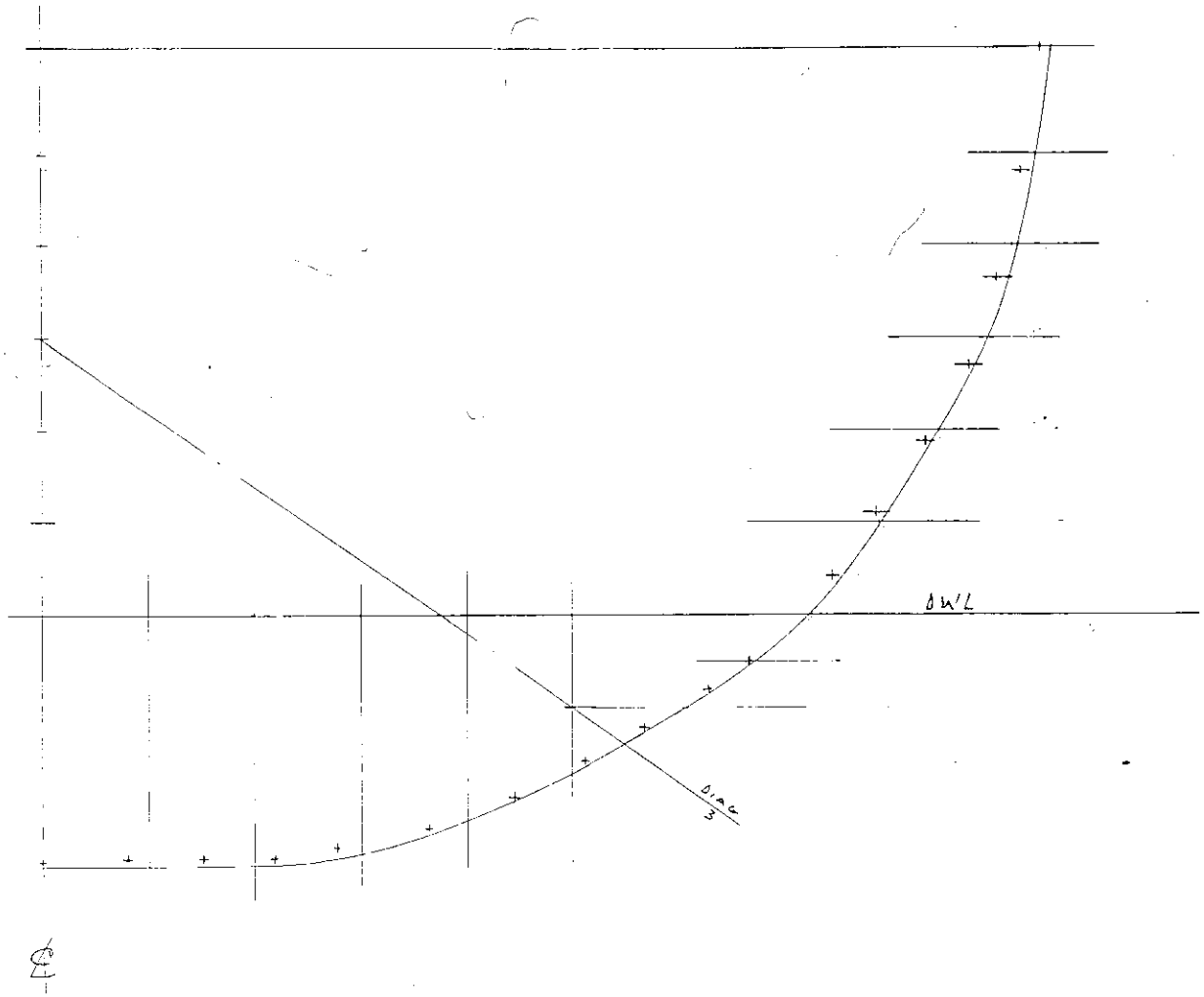
Even a slight wind will create ripples on the surface. The ripples will have a height of up to 20 mm in two knots of wind. The accuracy of the freeboard measurements is unlikely to be better than ±5 millimetres.

7.2 At a typical measurement waterplane for the yacht in question, the weight required to sink the yacht 10 mm is approximately 200 kilograms, so the accuracy of the displacement calculation is about ±100 kilograms.

7.3 The writer however, cannot understand that on the measuring occasions which led to the issue of certificates dated 30-11-95, 30-7-96 and 28-7-97, the measurer was able to record exactly the same forward and aft freeboards - 1.198m and 1.088m. This appears to indicate that over a period of about 20 months, not one thing at all was changed or moved.

If these certificates were not correct, particularly that of 28-7-97, it is impossible to have much confidence in the writer's calculations above. If, on the other hand, the displacement given on the 28-7-97 certificate was correct or nearly so, then the "Hobart" certificate was not correct.

7.4 In addition, traditional naval architecture calculations of displacement, stability etc. are based on assumptions about the curves from which vessel hulls are drawn up so that there is no absolute accuracy in these calculations. The availability of computers and programs does not alter the accuracy, it just speeds the work.



SOLID LINE FROM DESIGNER'S LINES PLAN

+ FROM MEASURER'S FILE

EXHIBIT 1