Yacht Design Related Safety Issues and the 1998 Sydney to Hobart Yacht Race

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INTRODUCTION

The 1998 Sydney to Hobart yacht race was truly a tragic event for the sport of offshore yacht racing. Sporting endeavours, especially those where man is pitted against the elements of nature, are potentially dangerous. It is the job of those providing the equipment and those involved in setting out the rules to do all that is possible to reduce that level of risk. Studying and learning from a tragic event such as the Sydney to Hobart race just past forms an integral part of the process of reducing that risk.

In the process of studying and learning from an event it is vitally important to do so in the framework of the facts in regard to the boats involved and the events that took place. In the months following last year's tragedy there has been considerable criticism of the modern ocean racing fleet, almost all of which has been without any reference to the facts. Most all of this criticism has focused on two issues; light displacement boats that dominate the present racing fleet, and the level of stability of these boats. It is a shame that so much energy has been spent on two arguments neither of which shows any merit in light of the facts of the event. This is highlighted by the knockdown and sinking of the *Winston Churchill*, which lead to perhaps the greatest tragedy of the event; the *Winston Churchill* was one of the oldest and heaviest boats in the fleet.

The facts of the event indicate other areas of concern. Based on first hand interviews of those involved in the race, in particular the owners and crews of the 12 Murray, Burns & Dovell designed boats participating, and from what has been published to date on the incident, all considered in the frame work of the design parameters of the boats involved, the main lessons to be learned are:

- Deck structural scantlings need to be increased to reflect the dynamics associated with a severe knockdown.
- Personal harness need to be reviewed both in terms of design and use.
- Life rafts also need to be reviewed both in terms of design and use.
- The race category and general safety standards applied to the Sydney to Hobart race need to be re-evaluated.

In this review I will limit myself to those safety issues, indicated by fact or implicated by "experts", that pertain to design of the boats, namely structural integrity, stability, and the issue of relative lightness of modern boats.

THE RULES AND REGULATIONS OF THE SYDNEY TO HOBART YACHT RACE.

The Cruising Yacht Club of Australia runs the Sydney to Hobart Yacht Race, (SHYR), in accordance with the Australian Yachting Federation's Racing Rules of Sailing for 1997 - 2000. Associated relevant documents include:

- Notice of Race
- Race Instructions
- AYF Special Regulations
- The International Measurement Rule
- The Channel Handicap Rule

Of these the most pertinent to safety issues is the AYF Special Regulations. The IMS rule also plays a very important support role in that it provides objectively determined design parameters referred to in the Special Regulations.

The International Measurement System

The IMS or International Measurement System, originally drafted in the late 1970's, has been the dominant format for offshore yacht racing world wide for the past 10 years or so. The IMS rule undertakes to assess a yacht's speed potential based on a massive array of design parameters including length, beam, displacement, righting moment, sail area, etc. Each and every boat racing under the IMS must be subject to a lines lift, done on shore and termed the "hull

measurement", and a flotation and righting moment test, termed the "in water measurement". It is no doubt a complicated system, and the sailors will argue about its fairness until they win a race. Fairness aside, one of the outstanding features of the IMS rule is that it provides race organisers with an accurate and objectively determined set of design parameters from which a yacht's general safety levels can be assessed in accordance with the well established standards set down by the ORC in its special regulations (discussed in the next section of this report). In particular the values of displacement, righting moment, and the limit of positive stability are accurately determined as part of the IMS measuring process - critical parameters in determining the seaworthiness of a yacht.

No other racing rule past or present includes this scientific, and objective assessment of stability. Any rule that is to be seriously considered as a replacement for the IMS rule must incorporate this feature.

It is of note that the 60' yachts raced singlehandedly around the world are assessed in terms of stability by designer's declaration. Given the frequency with which these yachts invert and remain inverted, highlights the importance of an accurate and objective assessment of stability.

The AYF Special Regulations

These regulations are based on the Offshore Racing Council's Special Regulations and set forth standards for structural features, general yacht safety equipment, and personal safety equipment. Eight categories of race types are defined according to the level of exposure to weather and proximity to shore. The SHYR is specified by the CYCA as a Category 1 event, which is defined as follows:

> "Category 1: Races of long distance and well offshore, where boats must be self-sufficient for extended periods of time, capable of withstanding heavy storms and prepared to meet serious emergencies without the expectation of outside assistance."

Stability Standards

For a Category 1 event the ORC Special Regulations specify the competing yachts are required to have a limit of positive stability greater than 115°. The CYCA's Notice of Race modifies this requirement with a grandfathering clause that exempts yachts that have competed in a previous Sydney to Hobart to have an LPS of 110°.

It is of note that the stability requirements specified in the ORC Special Regulations are the result of ongoing study of the subject of intact stability and have been put in place as a direct result of the research done on the matter in response to the 1979 Fastnet Race tragedy. This research has proven a very strong correlation between the Limit of Positive Stability and the amount of time a yacht can expect to remain inverted if rolled. This work is based on tank testing experiments and has been verified with experience. A review of this work is presented in Jan O. de Kat's paper "Causes of Yacht Capsizing in Heavy Seas" presented as part of this workshop. It is of note that the boats rolled in the 1998 Sydney to Hobart race also behaved as predicted by this research.

Structural Standards

For Category 1 and 2 events the AYF Special Regulations specify that yachts are to be built to plans approved by the American Bureau of Shipping, (ABS), Guide to Building and Classing Offshore Boats.

Subsequent to the publication of the AYF's 1997 - 2000 Rules of Sailing, (in which the Special Regulations are contained as an Addendum), The ABS stopped providing the service of plan approval for offshore boats. The ORC are presently awaiting the publication of a new structural standard being drafted by the International Standards Organisation which will be adopted on its release as the new structural standard for offshore racing yachts. The interim policy is that a yacht's designer must file a letter with the AYF that the yacht in question has been designed in accordance with the ABS Guide.

It is my opinion as a professional yacht designer that this status of self evaluation is a dangerous situation as the ABS Guide, (like any regulation), is subject to interpretation, and therefore needs to be administered by an independent body. In addition as time goes on yacht design continues to develop, while the structural rules remain stagnant; the result is that the rules are quickly becoming outdated. I encourage the ORC to move on this issue as a matter of urgency.

THE EVENT AND THE DAMAGE

I will in this section focus on the design aspects of what happened to the fleet during the severe weather of the event, including structural integrity, stability, and displacement to length ratio, (a measure of a yacht's relative lightness)

First I think it is important to point out that the damage to the boats themselves was limited considering the conditions; this fact is pointed out clearly by the Chief Executive Officer of Club Marine in his editorial column of the January 1999 issue of the company magazine, Club Marine Magazine:

> "Final figures are still not available, and won't be until the CYCA finalises its inquiry, but in my opinion the criticism of the yacht designers and the mast manufacturers is also not justified. The often quoted 1984 event saw 69% of the starters retire, whilst in 1998, 65% retired. Very similar figures, but after analysis, it is shown that 26% of retirements in 1984 were as a direct result of rig failures. So far for 1998, the failure of rigs is around 10%. In 1984, 16% withdrew due to hull failure. Once again, so far tor 1998 this figure is looking to be around 5%.
>
> So at this stage, it would appear that the biggest cause for boat withdrawal was sound seamanship and not inadequate hull design or construction. In fact, I am of the belief that the fleet which started the race on Boxing Day, was probably one of the best prepared fleets to ever compete in the event."

All of the facts surrounding the various incidents are still not all at hand, but based on what information I have been able to collect first hand through interviews and from what has been published to date, the following is a brief summary of the boats rolled and or severely knocked down.

Six yachts were rolled to or past 180 deg after being hit by extreme breaking waves, These yachts were:

1. *Business Post Naiad*
   1984 40' IOR racing yacht
   Twice rolled through 360°, remaining inverted for approx 4 min. during the second roll. Dismasted during the first roll.

2. *VC Offshore Stand Aside*
   1990 41' NZ built light displacement racer
   Rolled 360°, dismasted, severe deck damage

3. *Sword of Orion*
   1993 42' custom built IMS racing yacht
   Rolled, dismasted, severe deck damage

4. *Midnight Special*
   1995 42' IMS cruiser / racer
   Twice rolled through 360°

5. *B52*
   1994 41' IMS cruiser / racer
   Rolled to 180°, remained inverted for approx. 4 minutes, then righted itself. Dismasted with significant deck damage.

6. *Loki*
   1997 44' Swan built performance cruiser
   Rolled to 180°

Several other boats were severely knocked down by similar waves, these boats include:

1. *Winston Churchill*
   1942 racing yacht
   Severe knockdown resulting in hull damage that eventually sank the boat.

2. *Kinngurra*
   1972 built Joubert designed heavy displacement racing yacht.
   Severe knockdown. Significant deck and deck equipment damage

3. *Solo Globe Challenger*
   1970 43' heavy displacement yacht

4. *Team Jaguar*
   1989 65' medium displacement IMS cruiser / racer
   Near pitchpoled after dismasting. Severe deck damage

5. *Miintinta*
   1976 42' heavy displacement cruising yacht

This list is lacking in detail and is likely far from complete. It will take some time still for all of the facts of the various incidences to come out, certainly much more will be known when the CYCA publishes its report on the event.

FLEET FACTS AND FIGURES

115 yachts started the 1998 Sydney to Hobart Race. 57 were entered in the IMS division, 12 in the CHS division, and the remaining 46 were entered in the PHRF division.

This study focuses on the IMS division as this is where the greatest number of yachts compete and is the division with the greatest percentage of modern yachts, about which the most is known due to the nature of the IMS rule as outlined above. Where available, boats entered in the CHS or PHRF division

have been included in this study if they also held a valid IMS certificate at the time of the race. Only one of the boats that was knocked down has been left out of this data set as no IMS certificate was available for this boat, that boat was *Miintinta*,

Every boat racing in the IMS division is required to have an IMS certificate, these documents are publicly available. A typical IMS certificate is presented in Table 1. An IMS certificate contains an abundance of information about a yacht both in terms of its design parameters, and its rating data for every wind direction and strength. Hidden amongst all of this is the yacht's length, displacement, and limit of positive stability; these values are highlighted in the example given in Table 1. Table 2 is a summary table of the design parameters pertinent to safety as taken from each of the participating yacht's certificate.

The relative lightness or heaviness of a yacht is best defined by its displacement to length ratio. This is typically calculated as displacement in cubic metres divided by length cubed and multiplied by 1000 to make the number of reasonable magnitude. The value of length used in this study is an average of the IMS calculated length and length overall. Chart 1 is a graph of displacement to length as a function of length for the entire SHYR fleet. Typical values for purpose built racing yachts designed in the last 5 years are indicated and form a cluster in the lower third of the graph indicating that these yachts are indeed lighter than their predecessors. Older yachts and heavier displacement cruising yachts have higher displacement / length values, a few noteworthy examples are pointed out. Those yachts that reported being rolled and those that were severely knocked down have been individually identified.

Chart 2 is a graph of the limit of positive stability as a function of length for the fleet, and again those yachts that were rolled or severely knocked down are noted. A cross section of the modern racing boats have been pointed out; several examples of older heavier designs have been highlighted as well. Unlike the trend shown in Chart 1 for the modern boats to show as a cluster, in the case of the limit of positive stability the modern boats are scattered fairly evenly through the fleet.

CONCLUSIONS

Light vs. Heavy Displacement

From Chart 1 it is clear that there is no correlation between a yacht's relative lightness and its susceptibility to being rolled or severely knocked down in extreme conditions. In fact the boats rolled or severely knocked down have displacement to length ratios scattered right across the range of this variable from the extreme of light to the extreme of heavy.

Stability

From Chart 2 it is clear that there is no correlation between a yachts positive limit of stability and its susceptibility to being rolled or severely knocked down in extreme conditions.

It is noteworthy that the time spent inverted by each of the yachts rolled was in line with the correlation established by USYRU in 1989, and none of the boats report being kept upside down for more that 4 minutes, which is the expected value for a yacht with a limit of positive stability of 115deg.

About the only correlation that can be formed from the two graphs of displacement to length and limit of positive stability is that most of the trouble was experienced by boats between 11 and 13m in length. I would suggest that this is due primarily to the weather pattern, which hit this part of the fleet hardest.

Structure

Of all of the yachts rolled, all report being violently thrown down, rather than rolled, and in some cases yachtsmen report a sustained feeling of free-falling a significant distance before impacting on the topsides or deck. All of these yachts sustained some level of deck damage, and in the case of *VC Offshore Stand Aside* and *Sword of Orion*, the deck damage appears to be the primary reason for requiring rescue as the yachts were in imminent danger of being swamped. Even *Kinngurra*, one of the heaviest boats in the fleet, and probably one of the most stoutly built, reported deck damage from being thrown by a breaking sea

Clearly deck structures built to the present structural standard, The American Bureau of Shipping's Guide to Building and Classing Offshore Boats, are not strong enough to handle the extreme conditions encountered by this fleet. The design pressures for deck panels specified by ABS for the boats in question is approx. 2.5m of head. Clearly this is not a high enough design pressure in light of the violent slamming loads experienced by these decks.

RECOMMENDATIONS

It is apparent that when subject to hurricane level weather such as that encountered in the recent SHYR,

yachts are going to occasionally encounter massively powerful breaking waves, waves significantly larger than those in the adjacent wave field. When this happens, it matters not what the design parameters of the yacht are, it will likely be thrown on its side or deck. Accepting this fact and working around it is the key to surviving such conditions. Having accepted this, the focus of work must turn to structural integrity, getting the boat back upright within an acceptable amount of time, and to keeping the crew safely aboard the yachts.

I have not discussed the matter of personal safety gear in this review, nor have I discussed liferafts, but it is clear from the incident reports that personal harnesses and life raft design and use need review. I understand that this work is already under way.

One of the most important considerations that must be kept in mind in directing the efforts in the follow on studies is that resources for yacht research are very limited. It is therefore important to identify the topics of research that will yield the greatest improvements in yachting safety for the given effort and expenditure. Below is a prioritised list of design issues that impact on safety that I would put forward as a useful course of action given the recent SHYR experience:

1. The ORC must resolve the issue of structural standards for offshore racing yachts as soon as possible.

2. Whatever classification society is selected for this job, an immediate review of the design pressures specified for deck structures needs to be undertaken to account for the significant difference between the present design heads and the significant slamming loads experienced by the decks in the 1998 SHYR.

3. Given the fairly high probability of severe weather on the SHYR course, consideration should be given to increasing the category of the race to Category 0, or perhaps adapting parts of that classification.

4. Given the close correlation between a yacht's limit of positive stability and the amount of time it will remain inverted before being righted, there is little impetus to take this research any further. It may however be useful to study the implications of the amount of time a yacht is inverted once rolled in terms of its ability to remain self sufficient once back upright. This study may have bearing on the limit of positive stability set for future Sydney to Hobart Yacht Races.

End

IMS RATING CERTIFICATE No. 208100
Based on: FULL MEASUREMENT (Metric)

NOT VALID AFTER 30/06/99

GPH 533.0

IMS AMENDED TO JANUARY 1998
Offshore Racing Council
Ariadne House, Southampton UK
Copyright 1998

IMS AMENDED TO JANUARY 1998 VPP: 08/DEC/98 13:51:39
Cert No 208100 2081.DAT 08/DEC/98 13:48:32
OFF Meas'd: 30/JUN/96 RAGS96.OFF 01/JUL/96 21:10:36

— YACHT DESCRIPTION —

Name:	RAGAMUFFIN		
Sail No:	70		
Class:			
LOA:	15.500m	Beam(MB)	4.407m
Designer:	FARR		
Builder:	McCONAUGHY BOATS		
Carb Rig:	FRACTIONAL SLOOP 143% Jib		
Keel/CB:	FIXED KEEL		
PropInst:	STRUT DRIVE FOLDING		
FwdAccom:	NO	SPIN:	SYMMETRIC
HullCnst:	CARBON	RudCnst:	CARBON
Forestay:	ADJST AFT	BoomMtl:	LIGHT
Spreadrs:	3 Sets	InrFsty:	NONE
Runners:	2 Sets	Jumpers:	YES
Dates:	AGE:7/1996		

COMMENTS
UPDATED THIS CERTIFICATE WITH INFORM

RATING OFFICE:
Issued: AUSTRALIAN YACHTING FED.
08/DEC/98 LOCKED BAG 806,
Measured: MILSON'S POINT,
07/DEC/98 N.S.W. 2061

Revalidation Authority: AYF
Measurer: WILLIAMS/ANDERSON

"I CERTIFY THAT I UNDERSTAND MY RESPONSIBILITIES UNDER THE IMS."

OWNER:.....
SYDNEY FISCHER
99 ELIZABETH STREET
SYDNEY
NSW 2000
ATION TAKEN FROM US CERT NO 30724

LENGTH OVERALL

— LIMITS AND REGULATIONS —

Limit of Positive Stability:	MEETS REQ	Measurement Inventory:	21/NOV/97
Minimum Displacem't 5971kg:	MEETS REQ	Accommodation Length:	14.323m
Maximum Crew Weight:	1005 kg.	Accom Certificate:	RACING
Stability Index:	138.1	Plan Approval:	YES

NOTE TO OWNER: The range available to revise crew weight is 663-1223 kg.

— TIME ALLOWANCES IN SEC/MI BY TRUE WIND VELOCITY & ANGLE —

Wind Velocity:	6kt	8kt	10kt	12kt	14kt	16kt	20kt	
BEAT ANGLES:	43.7°	41.9°	40.3°	39.2°	38.6°	38.6°	39.0°	CHECKSUM (281.3)
BEAT VMG:	854.0	730.4	671.1	640.1	623.5	614.9	609.0	(4743.0)
52°:	551.5	481.1	452.4	438.4	430.7	425.6	420.4	(3200.1)
R 60°:	513.5	453.8	431.8	420.7	413.8	408.9	403.1	(3045.6)
E 75°:	482.0	429.0	409.1	398.9	391.8	386.1	378.2	(2875.1)
A 90°:	482.3	426.6	401.2	385.2	374.8	367.9	357.2	(2795.2)
C 110°:	498.5	428.5	399.4	381.1	368.7	359.3	341.8	(2777.3)
H 120°:	530.6	444.2	408.3	385.1	366.6	350.3	325.2	(2810.3)
135°:	639.2	509.7	442.2	407.8	383.6	362.7	319.3	(3064.5)
150°:	780.7	616.1	518.6	456.8	418.7	393.1	350.3	(3534.3)
RUN VMG:	901.5	711.4	598.8	527.3	471.7	432.7	383.4	(4026.8)
GYBE ANGLES:	137.5°	140.7°	144.5°	151.2°	164.1°	169.1°	172.0°	(1079.1)

NOTE: To convert any time allowance above to speed in knots: Kt = 3600/TA

Performance Line Scoring -- Time Factor: 0.876 Distance Factor: 64.8

— TIME ALLOWANCES FOR SELECTED COURSES —

Wnd/Lwd VMG	955.2	766.5	662.8	600.0	559.6	532.2	498.0	(4574.3)
Olympic 6-leg	887.2	718.3	628.0	575.4	542.7	520.9	492.6	(4365.1)
Circular Rndm	723.9	589.4	518.0	476.6	450.7	433.2	409.7	(3601.5)
Non-Spinnaker	802.1	644.0	557.6	506.0	473.3	451.5	424.4	(3858.9)
Ocean for PCS	837.5	656.4	554.0	490.1	447.3	416.6	373.3	(3775.2)

For Time-on-time method TMF = 1.1276 ILC Weighted Avg: 598.6

— CENTERBOARD AND DRAFT —

ECM	0.000	CBRC	0.000	CBMC	0.000	CBTC	0.000
WCBA	0.0	CBDA	0.000	KCDA	0.000	ECE	0.000
WCBB	0.0	CBDB	0.000	ENDPLATE ADJ (KEDA)			0.000

— PROPELLER AND INSTALLATION —

PRD 0.540 ST1 0.048 ST4 0.103 ST5 0.395 EDL 1.325

PIPA 0.0052

— FLOTATION DATA —

FFPS	1.547	AFPS	1.254	SFFP	0.500	SAFP	14.560
FFM	1.550	FAM	1.274	FFPV	0.000	AFPV	0.000
FF	1.550	FA	1.274			SG	1.025

— INCLINING TESTS —

W1	34.000	PD1	41.000	PLM	1510.000	PL	1505.437
W2	68.000	PD2	82.000	GSA	19.400	RSA	6400.0
W3	102.000	PD3	124.000	SMB	9.754	WD	15.930
W4	136.000	PD4	165.000	RM	345.5	RMC	345.5
RM2	357.5	RM20	321.5	RM40	265.7	RM60	203.0
RM90	115.0			CREW ARM (CRA)			1.801

CALCULATED LIMIT OF POSITIVE STABILITY: 136.0 DEGREES ← LIMIT OF POSITIVE STABILITY

RATIO STABILITY CURVE AREAS, POSITIVE/NEGATIVE 7.617

— HYDROSTATICS —	— MEASUREMENT TRIM —		— SAILING TRIM —
KEEL DRAFT	(DHKO) 3.154	(DHKA)	3.201
2ND MOMENT LENGTH	(LSMO) 13.081	(LSM1)	13.354
DISPLACEMENT (WEIGHT)	(DSPM) 9564	(DSPS)	10952
WETTED SURFACE	(WSM) 40.74	(WSS)	42.93
VCG FROM OFFSETS DATUM (For CLUB RM)		(VCGD)	-0.439
VCG FROM MEASUREMENT TRIM WATERLINE		(VCGM)	-0.426
INTEGRATED BEAM ATTENUATED WITH DEPTH		(B)	3.468
MAXIMUM SECTION AREA		(AMS1)	1.638
BEAM/DEPTH RATIO		(BTR)	4.907
EFFECTIVE DRAFT		(D)	2.848
2° HEEL (LSM2) 13.373	25° HEEL	(LSM3)	13.616
SUNK (LSM4) 15.946	AVG LENGTH (L)		13.630
TRIM: 1mm/18.380m-kg	SINK:		1mm/29.768kg

DISPLACEMENT (LIGHT SHIP)

IMS "L"

SAIL AREA: MAIN + FORETRIANGLE + MIZZEN (SA) 136.47
MAIN: 84.63 SPIN: 177.29 GENOA: 77.48 MIZ'N: 0.00

— FORETRIANGLE —				— MAIN & SPARS —			
IG	18.540	SPL	5.667	HB	0.220	TL	3.250
MW	0.315	J	5.557	MGT	1.50	MDT1	0.155
GO	0.350	LPG	7.89	MGU	2.69	MDL1	0.315
ISP	18.630	FSP	0.070	MGM	4.65	MDT2	0.085
IM	18.658	LP	7.96	MGL	6.03	MDL2	0.125
HBI	1.403	SFJ	0.125	MSW	33.6	MWT	300.0
MSL	18.47	MSMW	10.20	P	19.770	MCG	6.625
SL	18.49	SMW	10.20	E	7.240	BD	0.332
SPS	5.788	LPIS	0.00	EC	7.240	CPW	2.560
TH	NO	JR	0.00	BAS	2.200	BAL	0.150

— MIZZEN —							
IY	0.000	PY	0.000	HBY	0.000	TLY	0.000
EB	0.000	EY	0.000	MGTY	0.000	MDT1Y	0.000
YSD	0.00	ECY	0.000	MGUY	0.000	MDL1Y	0.000
YSF	0.00	BASY	0.000	MGMY	0.000	MDT2Y	0.000
YSMG	0.00	BALY	0.000	MGLY	0.000	MDL2Y	0.000
		HBIY	0.000	BDY	0.000		

TABLE 1

1998 Sydney to Hobart Fleet Data Pertaining to Safety

Boat Name	LOA (metres)	IMS "L" (metres)	Length (metres)	Displacement (kilograms)	Displ/L	LPS (degrees)
Zeus 11	9.254	7.619	8.437	4134	6.717	120.4
Bin Rouge	9.500	8.731	9.116	2588	3.333	116.2
Boomaroo Morse Fans	10.089	7.886	8.988	5683	7.637	132.6
Misty	10.089	7.925	9.007	5821	7.772	130.3
Morning Tide	10.089	7.813	8.951	5394	7.338	132
Solandra	10.140	7.851	8.996	4901	6.569	130.3
Forzado	10.345	9.373	9.859	4456	4.537	117.1
Not Negotiable	10.465	8.492	9.479	5582	6.395	119.1
Southerly	10.575	8.291	9.433	7239	8.414	136
Speakeasy	11.010	9.623	10.317	5264	4.677	117.2
Chutzpah	11.051	9.933	10.492	3750	3.168	121.6
Canon Maris	11.150	8.241	9.696	8154	8.728	130.2
Trust Bank Hummingbird	11.370	9.347	10.359	5772	5.067	115.4
Pippin	11.400	9.450	10.425	6001	5.167	115.3
King Billy	11.500	9.988	10.744	7547	5.937	118.7
New Morning II	11.620	10.524	11.072	6293	4.523	116.8
Veto	11.720	9.058	10.389	6965	6.060	122.2
Komatsu Blue Lady	11.740	10.360	11.050	9014	6.518	114.5
Mark Twain	11.774	9.337	10.556	8554	7.096	128
Assassin	12.150	11.227	11.689	5948	3.634	122
Midnight Special	**12.170**	**11.056**	**11.613**	**5262**	**3.278**	**123.5**
Rapscallion	12.172	11.417	11.795	5301	3.152	119.9
Red jacket	12.200	12.133	12.167	5778	3.130	127.3
Aurora	12.237	10.101	11.169	6295	4.408	115.1
Inner Circle	12.237	10.007	11.122	5806	4.117	116.3
Hy Flyer	12.391	11.265	11.828	5562	3.279	124.2
Ocean Designs	12.460	11.472	11.966	6412	3.651	121.6
Hawke 5	12.470	11.136	11.803	5298	3.143	115.1
Sledgehammer	12.470	11.108	11.789	5229	3.114	114.7
Terra Firma	12.512	11.076	11.794	5826	3.465	117.4
Renegade	12.600	10.767	11.684	7992	4.889	119.8
She's Apples Two	12.730	11.101	11.916	9124	5.262	115.4
Secret Mens Business	12.750	11.245	11.998	5601	3.164	119.1
B-52	**12.765**	**11.516**	**12.141**	**6694**	**3.650**	**119**
Mercedes IV	12.771	10.582	11.677	8981	5.504	122.2
Magleri Wines	12.800	11.364	12.082	6384	3.531	132
Tilting at Windmills	12.825	10.888	11.857	8651	5.064	125.3
Atara	13.000	11.514	12.257	6027	3.193	118.5
Valheru	13.055	12.193	12.624	6637	3.219	124.6
Wild Oats	13.115	10.619	11.867	7119	4.156	115.7
Kingurra	**13.117**	**10.899**	**12.008**	**12465**	**7.024**	**125.4**
Polaris	**13.245**	**10.611**	**11.928**	**9781**	**5.623**	**127.9**
Ruff n Tumble	13.245	10.404	11.825	9040	5.335	139
Bacardi	13.341	11.231	12.286	11339	5.965	118
Loki	**13.380**	**11.380**	**12.380**	**11331**	**5.826**	**114.8**
Sword of Orion	**13.550**	**12.086**	**12.818**	**7071**	**3.276**	**128.8**
Quest	14.210	12.378	13.294	8180	3.397	128.1
Mirrabooka	14.240	11.672	12.956	11554	5.183	122
Ninety Seven	14.285	12.366	13.326	7545	3.111	112.79
ABN AMRO Challenge	14.290	12.782	13.536	8304	3.267	123.9
Ausmaid	14.472	12.631	13.552	7524	2.950	135.4
Margaret Rintoul II	14.780	11.942	13.361	16979	6.945	137.7
Cyclone	15.200	12.532	13.866	9335	3.416	127.1
Ragamuffin	15.500	13.630	14.565	9564	3.020	136
Winston Churchill	**15.500**	**13.057**	**14.279**	**21415**	**7.177**	**123.6**
Yendys	15.760	14.176	14.968	14526	4.226	106.2
Antipodes - Aust	17.000	14.872	15.936	25939	6.253	119.8
Sydney	18.150	16.577	17.364	16807	3.132	130.7
Team Jaguar	**19.720**	**16.929**	**18.325**	**15389**	**2.440**	**123.6**
Wild Thing	21.246	19.118	20.182	18282	2.170	119
Brindabella	22.850	20.117	21.484	23259	2.289	133.3

Table 2

Displacement to Length Ratio Data for 1998 Sydney to Hobart Fleet

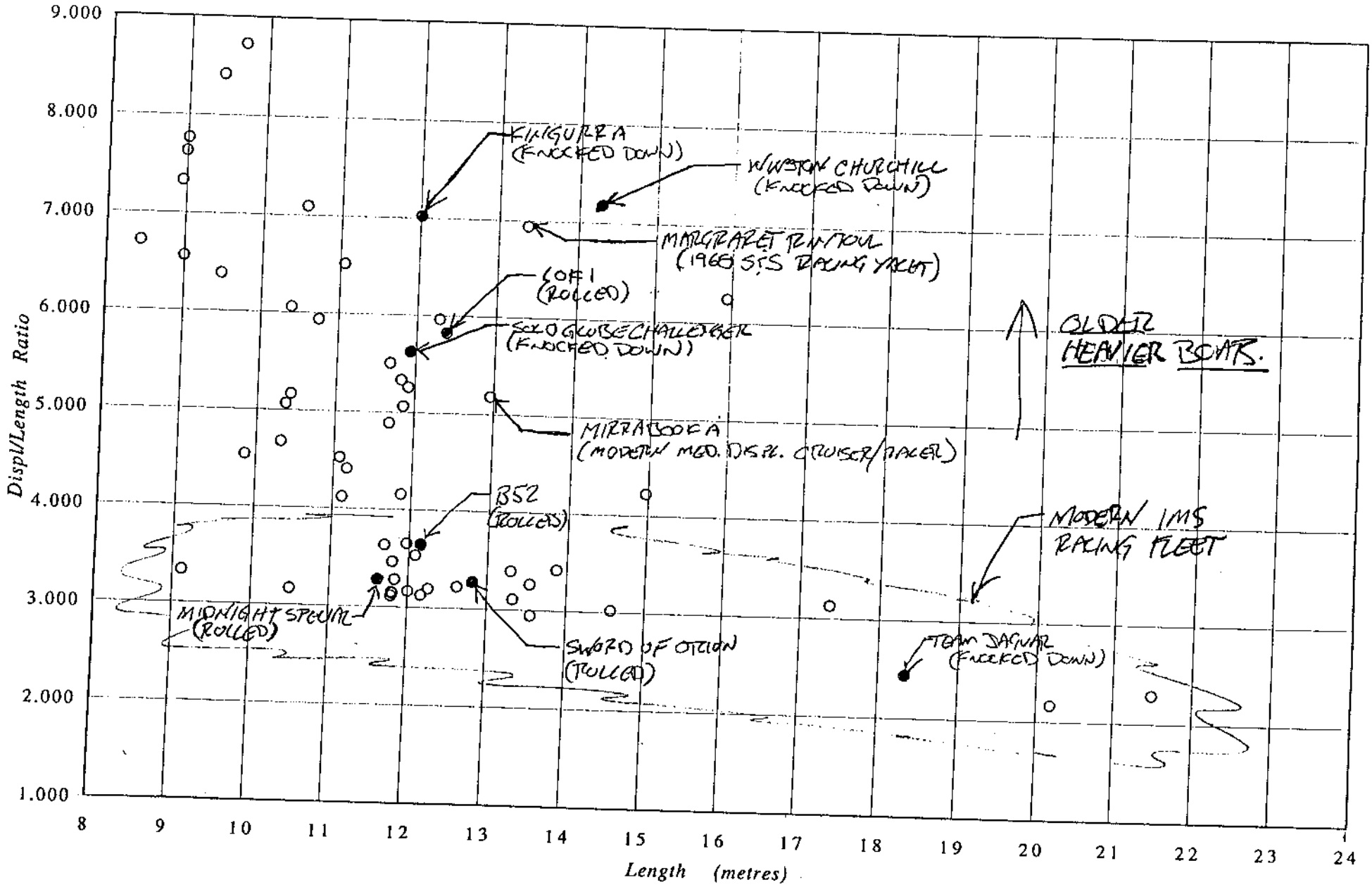

CHART 1

Limit of Positive Stability Data for the 1998 Sydney to Hobart Fleet

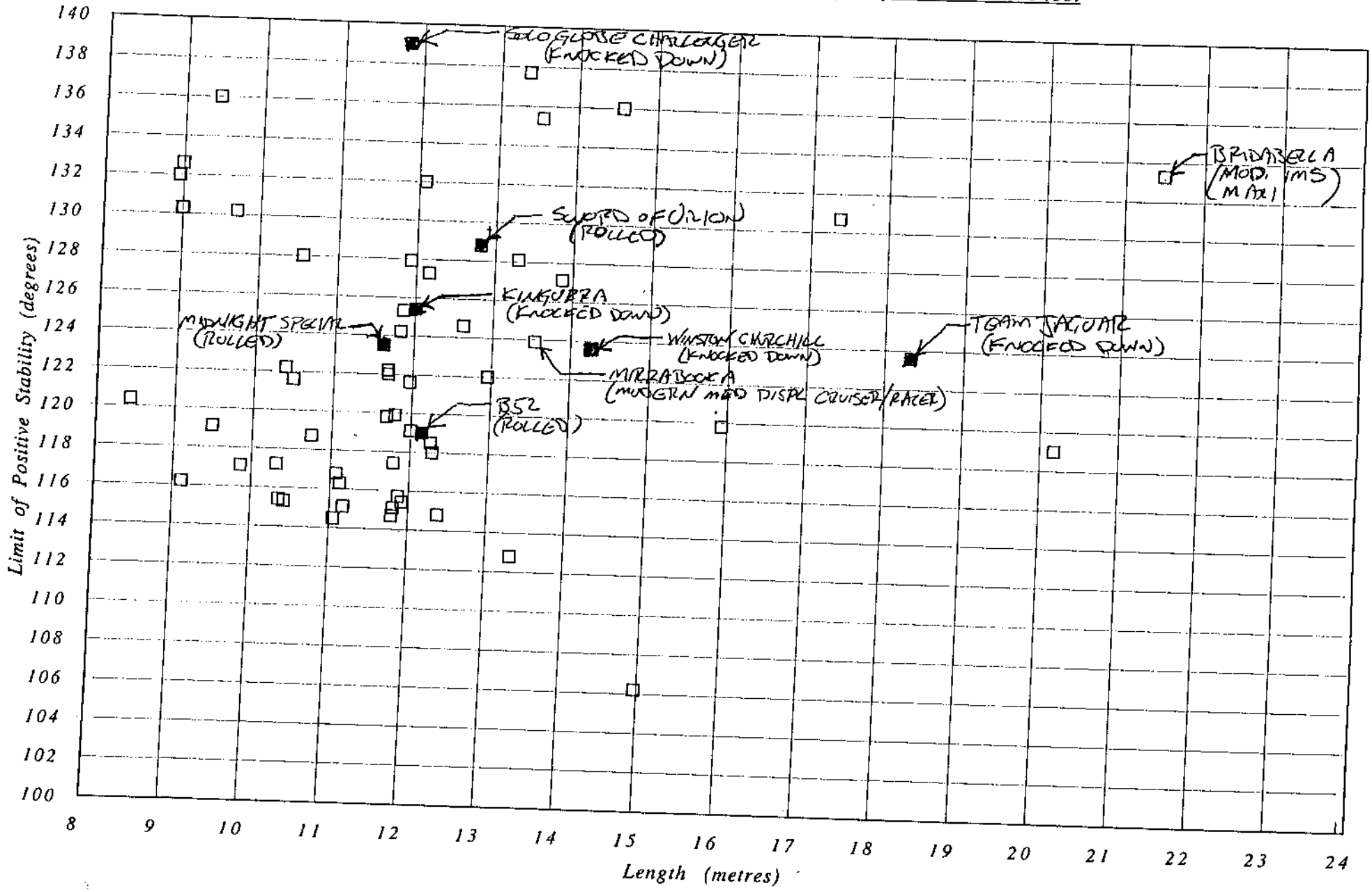

CHART 2

Andrew C. Dovell

Professional

Murray, Burns, & Dovell Pty Ltd
Senior Naval Architect
1989 - Present

From the company's inception in 1989 Andrew has worked as the principal naval architect for the firm. During this time the office has turned out over 40 complete racing yacht designs ranging in length from 30' to 80'. MBD designed racing yachts have won almost every grand prix offshore event on offer world wide including:

1st Overall Sydney to Hobart Yacht Race, Australia 1994
1st Overall Sydney to Hobart Yacht Race, Australia 1995
1st Overall Cowes Week Regatta, England 1995
1st Overall Melbourne to Osaka, Australia - Japan 1995
1st Commodore's Cup, England 1996
1st Copa Del Rey Regatta, Spain 1997
1st Principe de Asturias, Spain 1997
1st Kings Cup, Thiland 1998
1st Telstra Cup, Australia 1998
1st St. Marteen Regatta, British Virgin Islands 1999
1st Sydney to Mooloolooba Race, Australia 1999

Six MBD designed racing yachts are produced as production boats by Bashford International, including the Sydney 40, recently chosen by the RORC to serve as the middle sized yacht for the 1999 Admirals Cup. Bashford International has to date built over 4000 ft of racing yachts to MBD designs.

In 1994 and 1995 Andrew served as Designer of Record along side John Richael and Iain Murray for the OneAustralia challenge for the 1995 America's Cup.

In 1991 and 1992 Andrew worked as Designer of Record along side Iain Murray for the Spirit of Australia challenge for the 1992 America's Cup.

Fresh Ink Pty Ltd
Designer of Record for the Aloha Racing Challenge for the America's Cup 2000
1997 - Present

At present two Fresh Ink designed Amecica's Cup Class yachts are in construction in Hawaii and will be ready for shipment to NZ for the start of the America's Cup Challenger elimination series in October 1999.

Design work for this project included a 12 model towing tank program, a 6 model wind tunnel program; the results of both have been tied into a race model to predict win loss ratios for various candidate designs. Development work on the appendages will continue right through until the racing begins.

Education

Master of Engineering, Naval Architecture and Offshore Engineering
University of California at Berkeley 1981 - 1983

Batchelor of Science, Mechanics and Material Science
The Johns Hopkins University, 1978 - 1981