Proceedings of the Workshop on Safety of Ocean Racing Yachts

The University of New South Wales
Sydney, NSW 2052, Australia

Sunday, March 28, 1999

Organized by the

School of Mechanical and
Manufacturing Engineering
(Naval Architecture Course)

in Association with

The Royal Institution of Naval Architects
(Australian Division)

and supported by the

Institute of Marine Engineers
(Sydney Branch)

and

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Preface

The recent Sydney to Hobart yacht race in December 1998 has led to considerable debate in both the yachting community and the general public in Australia. The loss of six lives, which resulted from the ferocious ocean storms, has caused many concerned persons to question a number of aspects of this event. In many ways, the nightmares of the well documented Fastnet race in England in August, 1979, have been relived and one might wonder if any lessons have been learnt during the intervening period.

From the perspective of UNSW and RINA, the objectives of the workshop include:

- Provide leadership on a subject of some importance;
- Provide a forum for the exchange of relevant ideas; and
- Make a contribution to maritime safety.

In this seminar, we will examine the various factors that might lie behind the recent tragedies. Do we need to improve the design of the yachts themselves in order to enhance their survivability in rough weather? Should the yachtspersons be required to undergo specific training and certification before being permitted to participate in such an ocean race? Should the yachts be equipped with better position-locating devices? Should we raise our ability to forecast the likely weather patterns? Should the maritime safety authorities and the ship-classification societies play an expanded role?

The Naval Architecture Course at The University of New South Wales is pleased to welcome to the campus professional naval architects, yacht sailors, and other interested persons in order to participate in a discussion of this challenging subject at an all-day seminar, which is being held in conjunction with the jubilee celebrations of UNSW and the reunion of graduates of the School.

We would like to take this opportunity to express our gratitude to the many sources of assistance, without which the planning of this event would not have proceeded so efficiently and smoothly. The main organizations which assisted with the matter of publicity included the yachting associations in each of the states of Australia, yachting magazines, the daily press, and television and radio stations. The considerable support of the committee members of The Royal Institution of Naval Architects (Australian Division) and the Naval Architecture Course at UNSW is much appreciated. This support consisted of both valuable suggestions and physical effort. A number of other individuals also assisted us and we would like them to know by this that their help is appreciated.

Further information about the workshop can be obtained from the undersigned.

Assoc. Prof. L.J. Doctors
Mr P.J. Helmore
Editors

Workshop on

Safety of Ocean Racing Yachts

Kingsford Rooms, Squarehouse, Kensington campus
The University of New South Wales
Sydney, NSW 2052, Australia

Sunday, March 28, 1999

Program

0830–0915: Registration

0915–0930: Opening Session
Chairman: Assoc. Prof. Lawrence Doctors, UNSW, Sydney

- **Welcome Address**, Professor Mark Wainwright, UNSW, Sydney
- **Opening Address**, Sir James Hardy, OBE, Vintner and Yachtsman, Sydney

0930–1030: Aspects of Yacht Racing
Chairman: Assoc. Prof. Lawrence Doctors, UNSW, Sydney

1030–1100: Morning Tea

1100–1200: Naval Architecture of Yachts and their Construction
Chairman: Mr Noel Riley, Commercial Marine Design Pty Ltd, Daley's Point

1200–1300: Design and Classification of Yachts
Chairman: Dr Prabhat Pal, UNSW, Sydney

1300–1400: Lunch

1400–1530: Viewpoint from the Boat
Chairman: Mr Phillip Helmore, UNSW, Sydney

Written Discussion

Organization of Ocean Yacht Races

Mr Mark Pryke

Cruising Yacht Club of Australia
Rushcutters Bay

International Sailing Federation
ISAF

Formally IYRU

Union of RYA and US Sailing

International Governing Body of Sport of Sailing

President
Vice Presidents
Council
Committee Members
Race Officials
Judges
Umpires
Race Officers
Measurers
MNAs
Class Associations

Funding

IOC
Classes
Advertising

Australian Yachting Federation
AYF

President
Board
Elected by States
Appointed

Sailing in General

High Performance

Olympic

Racing Rules of Sailing

Funding

MYAs
Advertising
Sailors via MYAs

MYAs

Yachting Association of NSW

YA of NSW

President

Committee
Club Representatives

Funding

Sailing members via Clubs

Cruising Yacht Club of Australia
CYCA

Commodore
Vice Commodores
Sailing Committee Offshore
Safety
Training, development Youth

Race Control

Racing is run by a Committee which is headed up by a Principal Race Officer

Rules are administered by a Jury

Handicapping Systems

IOR'	Outdated	
IMS	Current ... Course Construction ... PCS	
PHS	Historical data	Ongoing performance

CHS	
Yardstick	Small boat... Class to Class
Thames	
Arbitrary	

SAFETY

ISAF

AYF Prescriptions and Safety Regulations

ORC Offshore racing Council

Waterways

Club

Measurement/Safety
YA Officers

Safety
Handicap
Righting Moments

Other Inputs

Weather
Wind
Current

Design Control

Owners
Builders
Sailmakers
"Experts"
Pushing the Outer limits of envelope

Logistics and Information (Sydney-Hobart)

Headquarters in Sydney
Transfer to Command Post in Hobart (RYCT)

Young Endeavour

Radio relay Ship	
Tracking	Skeds
Weather Updates	Forecasts

Air and Sea Rescue Canberra

....responsibility to sail.....

Ultimate decision

747 pacific
Overrule ATC
Weather avoidance
Go or Not
Land or Not

Could we stop a Long Ocean race? ...examples

Yes. but why??

Can We Predict the Weather?

Mr Patrick Sullivan

Bureau of Meteorology

Darlinghurst

The title of this paper poses a challenging question. Is it referring to tomorrow's weather, weather over the next few days, a month ahead? Rather than answer the question directly I propose to explain the scientific practice that underpins the weather forecast and indicate its application to the forecasting of winds and ocean waves, a component theme of this workshop.

People through the ages have monitored the weather in the hope of gaining an understanding of how today's and yesterday's weather might foreshadow that of tomorrow, next week, next season and longer. The knowledge that past generations gleaned about the weather and its likely behaviour from observation was often summarised in proverbs. For instance, "red sky at night, sailor's delight; red sky in morning, sailors take warning" is code for a weather forecast. We know today that this English sailing proverb has a sound scientific basis explained by the differential scattering by air molecules of the colours that make up white light. But its use in centuries past was not based in an understanding of atmospheric physics, just its observed utility as an indicator of weather to come.

Modern meteorology might be said to have had its beginnings with the invention of the thermometer by Galileo Galilei in 1607 and Evangelista Torricelli's invention of the barometer in 1643. The ability to measure and assign numbers to two important attributes of the atmosphere was a necessary requirement for rigorously defining and comparing weather both spatially and temporally. However it would be another two centuries before Samuel Morse's invention of the telegraph enabled a synopsis of reported weather over large areas to be composited in real time. This synopsis, now popularly described as the weather map, is referred to by meteorologists as the mean sea level (msl) synoptic chart.

The analysis of weather data is the first step in the forecast process. It is done both manually by the meteorologist as well as by the computer.

The data needed by the meteorologist and the computer includes surface and upper air measurement of pressure, temperature, moisture and wind. The surface measurements are taken by people on land and at sea as well as by automatic weather stations. The upper air observations are taken by remote sensors attached to balloons and also deduced from measurements taken from satellites, both geostationary (36 000 km above the equator) and polar orbiting (900 km altitude) satellites.

The computer analysis presents the data in a regular grid array (Figure 1) on numerous levels from the surface to the stratosphere. Computers require the data

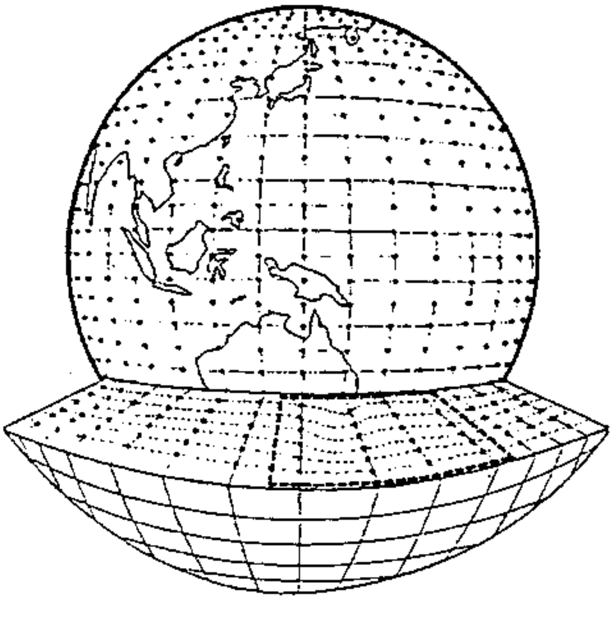


Figure 1 A schematic view of a course global grid structure for computer modeling

this way as input to the prediction models.

The manual analysis depicts the areas of high and low pressure, the fronts that separate warmer and colder air masses, and by implication, the winds. By studying a sequence of analyses, indications of a strengthening or weakening of features, as well as their direction and speed of movement, is evident. And, in some situations, a good first guess at the weather forecast for a few hours ahead, and sometimes longer, can be deduced by simple extrapolation of features.

Although there is a perception amongst some that a weather forecast can be inferred from the msl chart alone, this is not so. The atmosphere is three dimensional and many clues to its future state are hidden in the skies above. Patterns at the surface can be drastically changed in as little as 6-12 hours by complex interactions high in the atmosphere. The developments that brought storm force winds to waters in and east of Bass Strait on Sunday 27 December 1999 dramatically illustrate how rapidly weather patterns can change. Figure 2 shows the genesis of a low at 3 am Sunday 27 December just north of Tasmania's Northwest coast. Figure 3 shows the low fully developed east of Bass Strait just 12 hours later. Figure 4 is the satellite picture about that time.

Atmospheric prediction requires not only a depiction of weather patterns at the surface, but additionally, the fullest possible depiction of the distribution of winds, temperature and moisture through the total depth of that part of the atmosphere in which precipitation and clouds are confined. This part of the atmosphere is called the troposphere and extends to about 16 km at the equator and 9 km or so at the poles.

The area over which the analysis is performed depends on how far ahead we wish to predict. A prediction for 24-48 hours ahead would start with a full description of the atmosphere at the surface and through the troposphere over Australia and surrounding oceans; but for four or more days ahead, the analysis needs to be global.

Once the analysis is completed, the next step is to formulate future states of the atmosphere 24 hours to several days ahead. For much of this century this was done solely by a qualitative approach using conceptual models based in the laws of physics. However, over the past three or so decades, a quantitative approach, facilitated by supercomputers and global communication, has been gradually changing the way weather predictions are done. Computer models are now to the fore as the principal influence behind the forecast. The meteorologist's knowledge and experience are still important as a reality check on the models, and the model output still needs to be fine tuned for local effects and smaller scale influences; but increasingly, computer predictions have become the cornerstone of modern day weather prediction.

The Bureau runs a global prediction model twice daily. Additionally, meteorologists in the Bureau routinely refer to model predictions for the Australian region from the UK Meteorological Office, the USA National Weather Service, and the European Centre for Medium Range Weather Forecasting (ECMWF). These global predictions are valid out to seven days. A sequence of four charts for the Australian region from the Bureau's global prediction is published daily in most metropolitan newspapers across the country. These predictions, although broadscale, are usually a reasonably good indication of

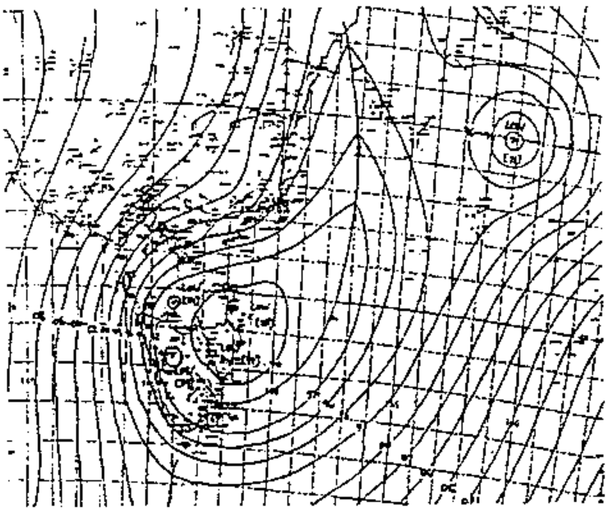


Figure 2 MSL Analysis 3 am 27-12-1998

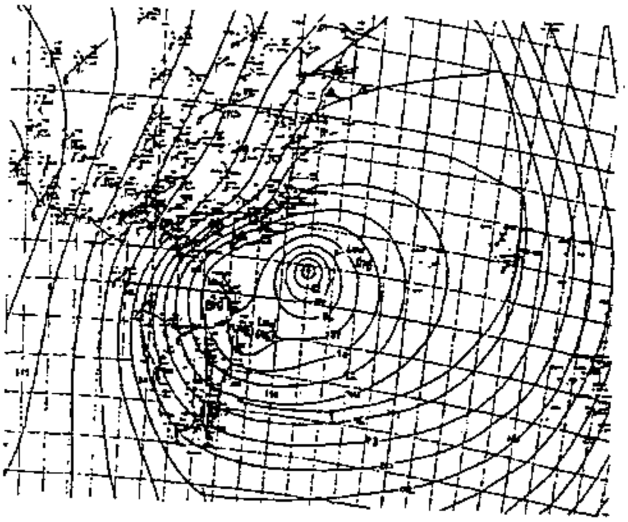


Figure 3 MSL Analysis 3 pm 27-12- 1998

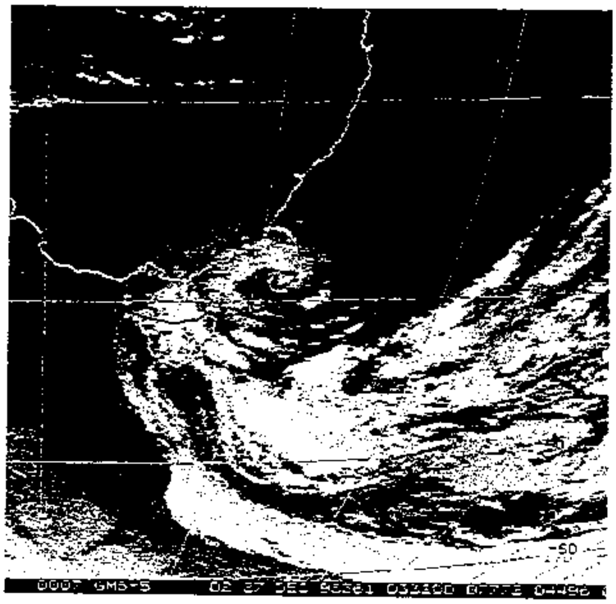


Figure 4 Satellite photo 3 pm 27-12-1998

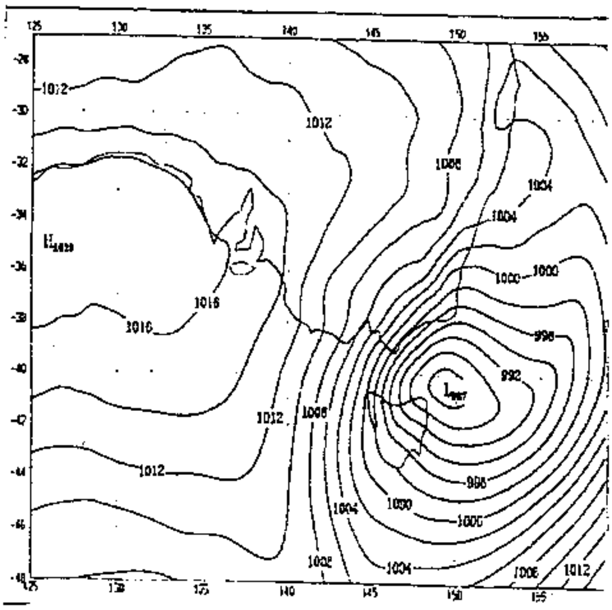


Figure 5 MSL Prediction 3pm 27-12-98

the larger weather pattern, at least out to four or so days.

In addition to the global model, the Bureau models the atmosphere on a regional scale covering Australia and on a much finer scale over southeast and southwest Australia. Finer scale models portray detail not presented by the global models. However the time frame of their prediction is limited. Currently the finest scale model run operationally by the Bureau is a 25 km resolution model. This provides a limited area prediction out to 36 hours. Models with resolution down to 5 km are being run in research mode.

A 30 hour prediction over southeast Australia by the 25 km resolution model, available early Saturday afternoon, 26 December 1998, and valid for Sunday afternoon, is at Figure 5. The computer model run of which this prediction is part was the principal influence in the decision to issue a Storm Warning soon after 2 pm Saturday, for the following afternoon, in coastal waters south of Merimbula and east of Wilsons Promontory.

Now let us return to the title of this paper: Can we predict the weather? As indicated in the opening paragraph, the Bureau's capability in this respect would take as an example the prediction of winds and ocean waves.

When a meteorologist refers to wind, the reference is to a mean wind at 10 metres above the surface, averaged over 10 minutes. This is the wind that is forecast. Being an average, it excludes the short duration gusts and the lulls that are part of the real wind. These need to be accounted for by the user noting that they can vary the wind by up to 40% from its mean value. An example of a 24 hour wind speed recording is at Figure 6. This is the wind speed recording for Sydney Airport for 7 August 1998, a day of exceptionally strong winds (and heavy rain) in Sydney. Figure 6 illustrates the great variability in wind speed from moment to moment, and the impossibility of succinctly describing its every detail other than in digital or graphical form. The international convention is to refer to the average wind over a ten minute period. Gusts are implied.

Wind forecasts derived from computer predictions are found to be a good estimate of actual winds provided the computer predictions themselves are an accurate representation of the weather patterns that occur. Clearly any large inaccuracies in the prediction of the weather pattern will incur similar inaccuracies in the wind forecast. And that statement invites the question, how good are the model predictions? This is best answered in terms of performance trends.

The trend in models' performance can be assessed in qualitative terms based on the day to day guidance they provide meteorologists forecasting the weather. Against this benchmark of performance, meteorologists would say that the models' performance is good and improving.

A quantitative measure of the trend is also available and is presented in Figure 7. The skill score used is one in which low values indicate higher accuracy. Skill score graphs are included for the Bureau's global model (GASP) as well as the global models of the United Kingdom Meteorological Office, the USA National Weather Service and the European Centre for Medium Range Weather Forecasting.

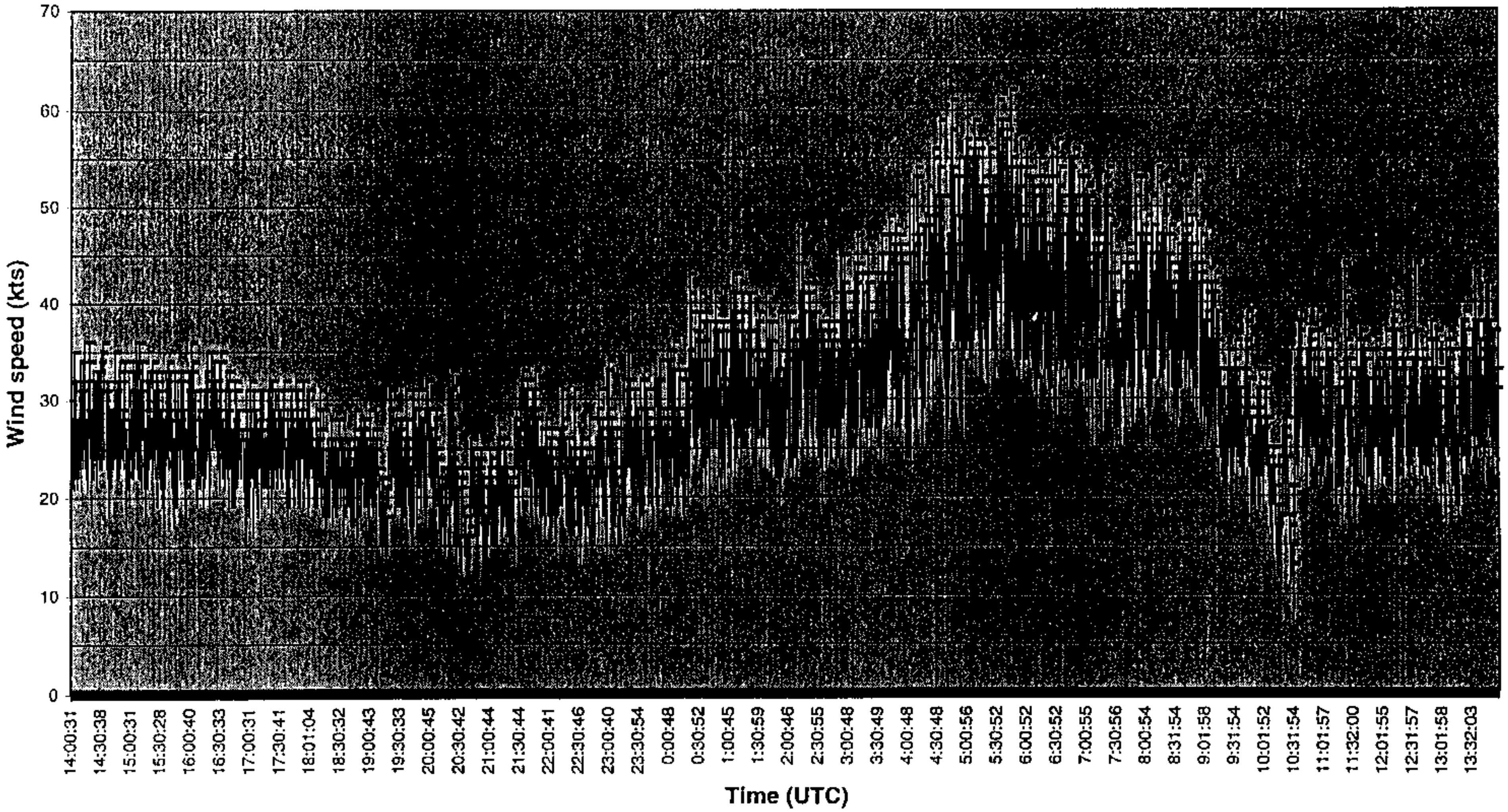


Figure 6 Wind speed recording at Mascot Airport 7 August 1998

From the downward slope of the skill score graphs for each of the models, it is clear that the overall trend is one of improvement and, over the past decade or so, improvement in skill is 25% or more for a 24 hour prediction. As the model predictions have a significant influence on wind forecasts, it is a reasonable conclusion that the meteorologists' ability to forecast the wind has shown a commensurate improvement.

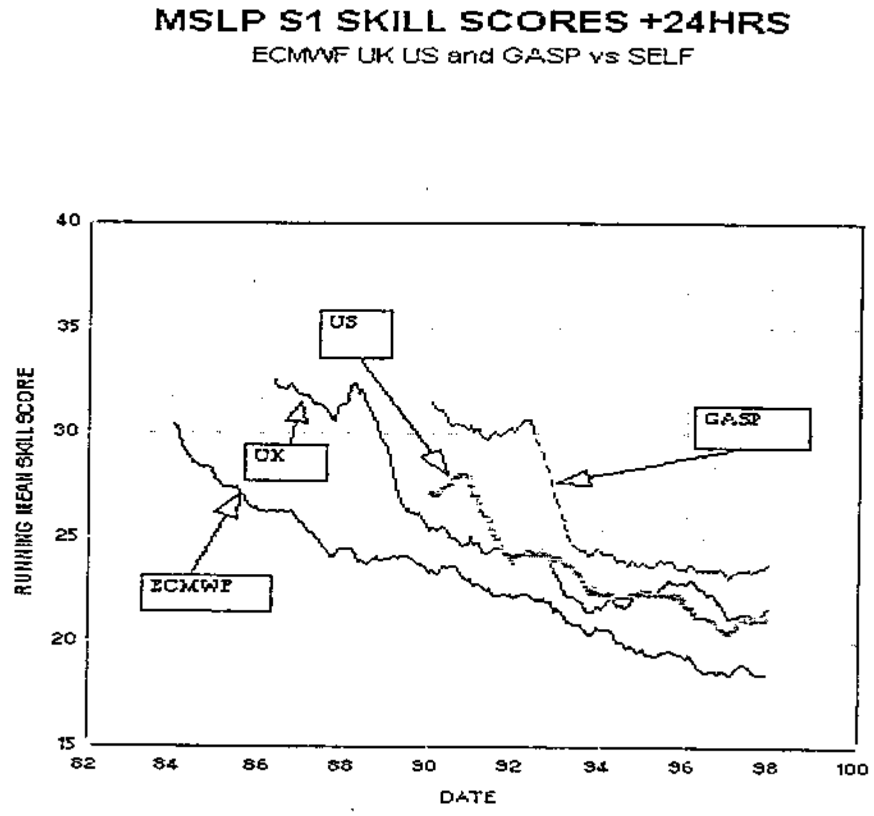


Figure 7 Model Performance 1984-1998

Wave height forecasts for both sea waves (waves generated in situ by the wind) and swell waves (waves generated distant from the locality of interest) is the significant wave height. This is the average height of the highest one-third of the waves. It has been found to approximate the average height of the waves as estimated by an experienced observer. The sea waves and swell waves interact in a complex way to produce a combined significant wave height. Because the significant wave height is an average height, waves both higher and lower than the significant wave height occur. It is estimated that in every 1000 waves, a wave up to1.86 times the significant wave height will be experienced. Thus for a significant wave height of 7 metres with a period of 7.2 seconds, a wave of 13 metres can be expected every two hours or so. Figure 8 is an example of wave rider buoy data recorded off the west coast of Tasmania. It shows the relationship between significant wave height and maximum wave height, the latter at times being virtually double the former.

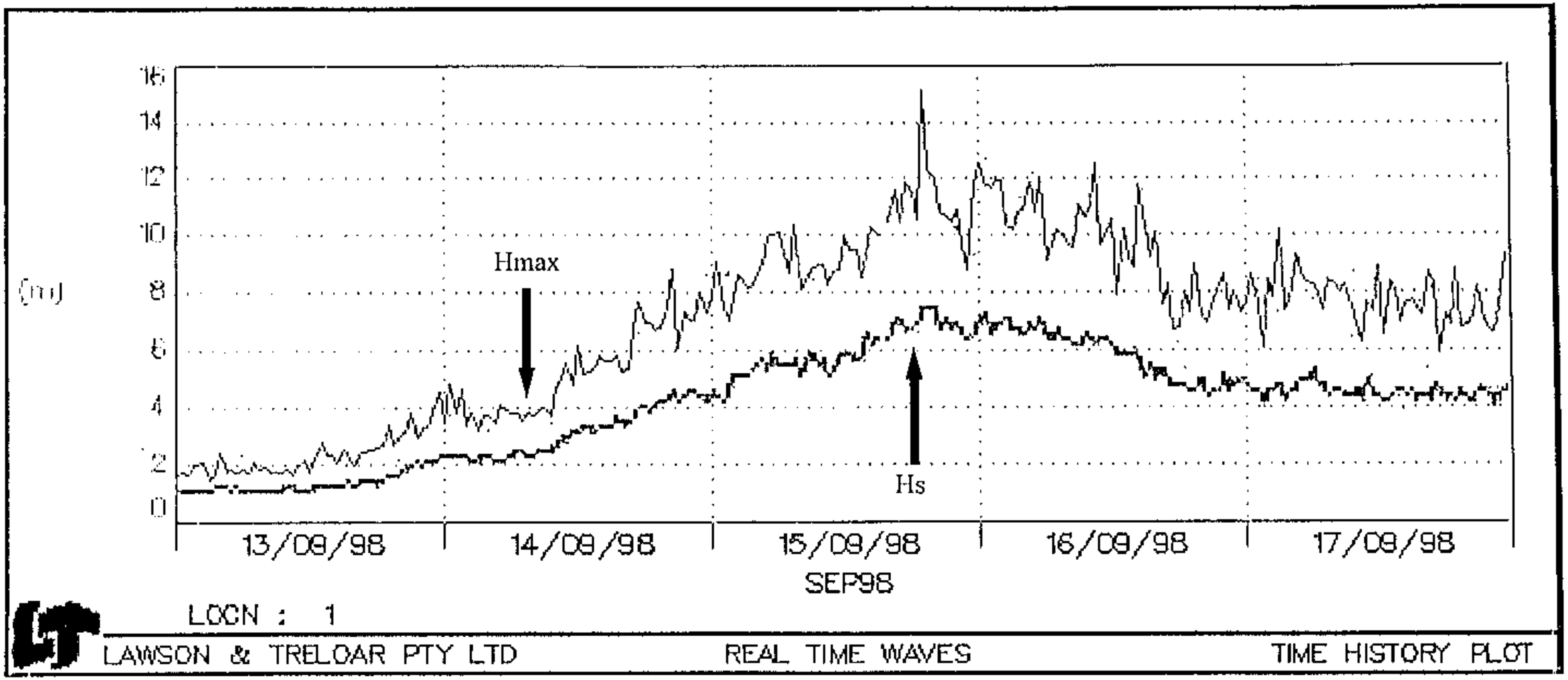


Figure 8 Wave rider buoy data (Tasmanian west coast) 13 - 17 September 1998

The computation of expected deep water wave height depends on three considerations - the wind speed, the duration of the wind and the wind fetch. Understanding how wave heights depend on these three parameters enables significant wave heights to be calculated either by use of computing algorithms utilising the wind fields output by the models, or by reference to nomograms which combine the three effects. Users must then be cognisant that wave heights will vary significantly about this value due to a complex interaction between different wave trains, both sea and swell, and the surface ocean current.

The accuracy of the wave height forecast is very much dependent on the accuracy of the wind forecast and an understanding of the way in which winds, waves and currents interact. It seems reasonable to assume that higher accuracy with respect to wind forecasts must inevitably be improving our ability to more accurately forecast significant wave height.

It can fairly be said that with respect to winds and ocean waves in particular, and the weather generally, the steady increase in the accuracy of computer model predictions of the atmosphere, on scales ranging from global to local, inevitably feeds into the forecast process in such a way that forecasts of winds and waves, and weather, are also achieving higher standards of accuracy.

In conclusion, it must be said that the question which is the title of this paper has not been answered explicitly. Yes, we can predict the weather but the claim cannot be made without qualification. There will always be a requirement for information on future states of the weather just beyond whatever our capability is at any particular time. If we predict the weather accurately to four days, then people ask what about the fifth, sixth, seventh day? Next week? Next month? And so on. The challenge of forecasting the weather is unending.

What is Wrong with Modern Ocean-Racing Yachts?

Mr Warwick Hood

Naval Architect

Blackheath

"I am sensible that this Tractate may likely incur the Censure of a superfluous piece, and myself the Blame of giving the Reader unnecessary Trouble, there having been so much so well written of this subject by the most learned men of our Time."[1]

Introduction

This paper is dedicated to the life and work of Jim Lawler. Jim was widely loved amongst the yachting fraternity of Sydney and to those of us practising naval architects, much admired for his professionalism as a surveyor for American Bureau of Shipping.

In this paper I attempt, not only to describe what I perceive as the problems of modern ocean racing yacht design and construction, but also to suggest ways of dealing with these problems In my view, it is important that a Symposium such as this one be able to present a body of ideas to the ocean racing clubs in the hope that beneficial changes can be made. If yachtsmen themselves do not act to improve the safety of their sport, the authorities <u>will</u> act to either ban or control it. I cannot imagine what yacht racing controlled by AMSA would be like.

About 40 years ago, a well-known Sydney yachtsman, Ron Robertson, was washed out of the cockpit of the big yacht, "Kurrewa IV", just after the yacht had entered the Heads. His body was never recovered. The Cruising Yacht Club of Australia immediately established a safety committee of which my then employer, Alan Payne, was a member. This committee developed a set of safety rules about life rafts and jackets, guard rails and harnesses, 2 way radios and first aid kits, flares and so on. These rules were adopted amidst howls of rage, by the Club.

Yachtsmen everywhere complained that the cost of all this new equipment would see the end of ocean racing. CYCA persisted, fortunately, and also persuaded the much larger, stronger and influential clus in USA and Britain to adopt its rules. So, it's not impossible to have an international influence.

A journalist, Bob Mills, speculating on why men and women deliberately participate in the Sydney to Hobart race, knowing of the very real dangers said:

"*The reason is that this race is a spectacular experience, sublime in the fairest of weathers and genuinely challenging in the foulest.*" And went on:

"*For the crew, this race is one of the few and precious opportunities that fairly ordinary people ever get to commit themselves to a genuine adventure.*"[2]

Simply describing what's wrong with modern ocean racing yachts would mean missing an opportunity to help to ensure that that spectacular experience can continue to be available, in greater safety and without official interference.

Mills again wrote. "*Inevitably the tragedy of loss of life and the dangers and cost necessarily associated with the massive rescue operation will raise questions about the future of the race.*"[3]

We must improve the boats and equipment ourselves to prevent tighter controls and to allow the great race to continue with much improved safety.

I don't accept that the race's weather or sea state should be taken as unusual. In an appendix to the book "Heavy Weather Sailing", Laurence Draper of the British National Institute of Oceanography describes how very large waves may suddenly occur out of a normal ocean wave system.[4] Even given the very rapid deterioration of the weather in the last Hobart race, well designed, built and maintained yachts should be able to stop racing and seek shelter or stop racing and heave to or stop racing and sail slowly away from it.

On 14th May 1873, Mr Samuel Plimsoll moved the second reading of his Shipping Survey bill, number 43 of 1873 in the House of Commons. As background he said. *"Briefly, the facts were these - 2,700 odd lives were every year lost by shipwrecks."*[5]

Eventually, after lengthy debate, Plimsoll's bill which basically proposed the application of a load line to every ship to help prevent overloading, failed to pass the vote by a margin of 173 to 170, the main argument against being that a Royal Commission on the same matter was then in progress.

My paper today may be viewed in the same light; that is, an enquiry into the last Hobart race is still in progress by the Cruising Yacht Club and a coronial enquiry is yet to commence.

I am not prepared, however, to wait as the Hobart race is held annually and the next one is only 8 months away. It might be claimed that last year's storm was a very, very rare event but it can happen any time again and even during the next race.

So What's Wrong?

In my opinion, the major problems are:

a) The currently used International Measuring System (IMS) is just that and contains no or very few design standards. Almost any yacht can be measured and provided with an IMS rating. Provided that a yacht has the requisite safety equipment, it is then considered to be suitable for ocean racing anywhere.

b) In the quest for the highest possible speed, current IMS type yachts have very low displacement, long narrow keels and rudders and very tall rigs.

c) Yachts are built of fibre reinforced plastics having high strength to weight and high stiffness to weight reinforcement such as carbon fibre.

d) Yachts are not surveyed every few years by a competent person to ensure that hull, rig and equipment are being maintained in a seaworthy condition.

A few weeks ago, on the hardstand at a Sydney yacht club, I saw a typical IMS yacht designed by a well known designer. Figure 1 shows, roughly, its profile. The underwater profile is a shallow curve meeting the nearly vertical stem at practically zero draft forward. The very short stem overhang meets the steeply forward sloping transom, "de rigeur" on this type of yacht. The very high topsides rake out towards the aft end so as to position the crew mass as far outboard as possible. The tiny cabin house is just big enough to meet IMS accommodation regulations.

The cockpit, just a trench in the deck, has no coamings. There is no protection for the crew. I have been advised that the crew members are expected to spend all their time on the rail as the performance falls off significantly without them so located.

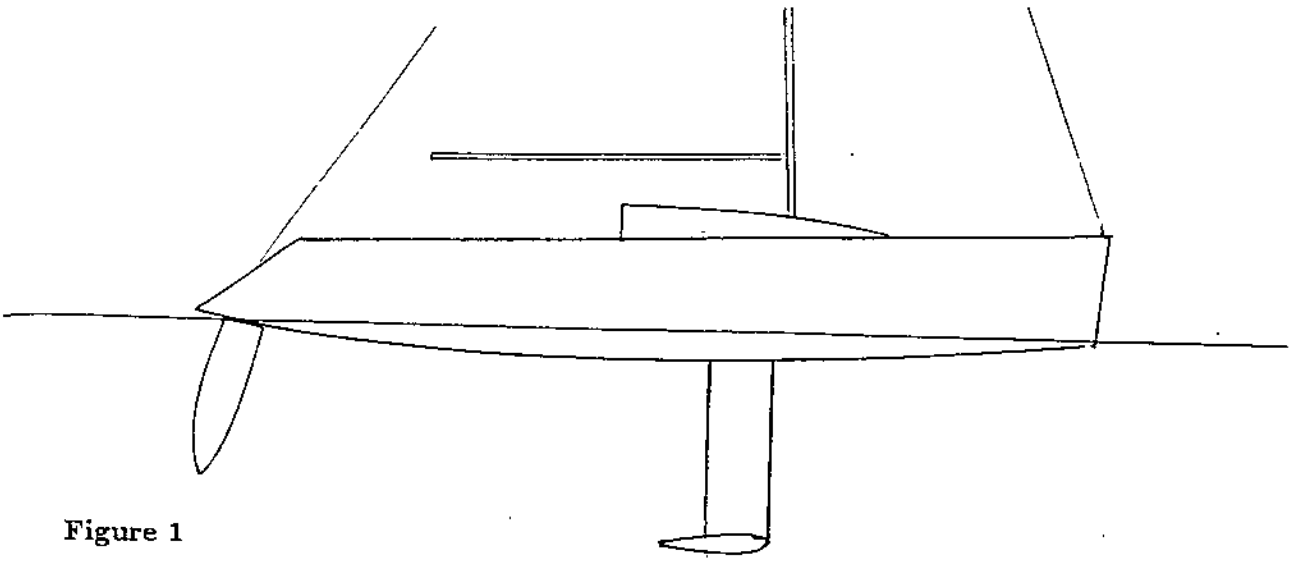


Figure 1

This yacht, like others of its type, is provided with a very tall, fragile-looking rig. The standing rigging is solid rod stainless steel with swaged terminals, running rigging and jib and main sheets are of small diameter, high strength, low stretch synthetic fibre.

This yacht is obviously very fast up and down wind and would probably plane down wind in the right conditions with a crew of "feel no fear" chaps on board. Great fun in 30 milers off Sydney but hardly suitable for Sydney to Hobart races.

Any statical stability analysis of this type of yacht which ignores the effect of crew mass on the rail is worthless because the righting lever GZ can have a value greater than zero at 0 degrees heel. This increase in the righting lever continues until that heel angle at which the crew fall off the rail - probably at about 90 degrees.

These high freeboard light displacement yachts have a huge ratio of reserve buoyancy to displacement and this ensures that they will float over just about any wave and will receive the maximum breaking wave impact. Any very high wave has also a very deep trough so while it's a long way up and if a yacht is still moving at the top, it's a long way to fall to the bottom. Impacts on the sides and the bottom are very severe. Professor Peter Joubert has shown that the impact loads are much greater than the scantling rules allow for and designers believe possible.

There is currently no satisfactory structural assessment made for new IMS yachts. In the past, the American Bureau of Shipping provided a structural check of the construction plans for new yachts but did not supervise the construction. This service has not been available for several years so yachts are new built without structural approval.

To achieve the lightness and stiffness desired, yachts are often built of carbon fibre composite construction. Inner and outer carbon fibre/resin skins are laid up over some sort of core material. This may be end-grain balsa or a man made honeycomb material. This writer considers that these so-called high modulus materials are unsuitable for building ocean racing yachts because the work of fracture is too low. There is nearly unlimited energy available in a stormy sea to break a yacht so the work of fracture and not just high specific stiffness is an important attribute of the material from which it is constructed.

The elongation of carbon fibre at fracture is about 1 ½%. A comparison of the stress/strain diagrams of mild steel and carbon fibre is shown in Figure 2. The work of fracture is represented by the area under the stress/strain line.

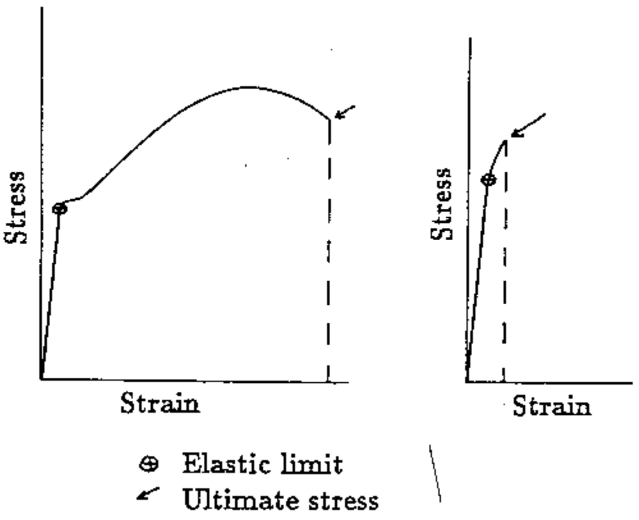


Figure 2

Designers discovered, some time ago, the importance of building the ends (bow and stern) of yachts as lightly as possible. Rudder stocks are now often fabricated in a complex fashion from carbon fibre/resin. This saves a little weight compared to, say, stainless steel. The number of broken rudders continues to rise but in spite of that, some designers continue to specify unsuitable materials such as carbon fibre. It is possible to build highly successful structures from carbon fibre. These are known as aeroplanes.

While yachts may be built to good designs and under supervision, by highly skilled builders in good premises, after they are sold they are probably never again subject to any kind of expert inspection. Similarly, older boats are only ever inspected at the time of sale to a new owner and this inspection can vary from a very thorough one to merely superficial.

When yachts were built of thoroughly reliable materials such as wood and steel and the rigging was of galvanised steel and natural fibres, the condition did not deteriorate as rapidly with age as the latest high performance materials. For example - galvanised steel wire rigging was provided with hand made eye splice terminals, easily inspected for condition. Stainless steel, on the other hand, beside being susceptible to stress corrosion cracking, is usually used in the form of rods with swaged on terminals, nearly impossible to assess for condition.

What Is To Be Done?

Having described the problems of modern ocean racing yachts, it is then necessary to attempt to prescribe a remedy.

The remedy proposed is to provide a designing rule which can incorporate those factors leading to seaworthiness.

But it is first necessary to take a step backwards and review recent past ocean yacht rating rules.

RORC Rule

This rule was developed by the RORC and was used for the Fastnet race and other tough races in the English Channel. It is an interesting rule in that the two parts attempt a balance between light and heavy displacement. It also attempted to provide a bonus for heavy construction by including a "Scantling Allowance". This allowance had the effect, in my experience, of designers and builders fitting large useless stringers around the topsides. There were other aberrations.

Neither displacement nor stability were directly measured.√BD in the first part of the rating formula was considered to be sufficiently representative of displacement and the stability allowance captured all sorts of things such as the scantling allowance, the engine weight, shallow draft, iron keel and so on.

The complete formula was

$$R = \frac{0.15L + \sqrt{S}}{\sqrt{B \times D}} + 0.2(L + \sqrt{S}) \pm \text{Stab. Allowance} - \text{Prop. Allow.} + \text{Draft Penalty} \quad (1)$$

with the factors L meaning length, B meaning beam, D meaning depth and S sail area. The calculation of some of these factors was difficult before electronic computers and minor changes in trim could lead to large changes in rating.

CCA Rule

The Cruising Club of America's rule

$$R = 0.95(L \pm B \pm D_{ra} \pm D_{isp} \pm S_{\text{A}} \pm F - I) \times \text{Bal.R} \times \text{Prop.} \quad (2)$$

was a good rule as it set standards for various factors in its formula and then provided bonuses or penalties for variations from the standards. The effect in the individual factors is shown in the table below.

Factor	*Symbol*	*Large*	*Small*
Beam	B_m	Credit	Penalty
Draft	D_{ra}	Penalty	Credit
Displacement	D_{isp}	Credit	Penalty
Sail area	S_A	Penalty	Credit
Freeboard	F	Credit	Penalty
Iron keel credit	I	Credit for boats having iron keel instead of lead keel	
Ballast ratio	Bal.R.	Penalty	Credit
Propeller factor	Prop.	More credit for large propeller, less for small	

Table 1

The base displacement was such that a yacht having no penalty or credit had sufficient displacement to permit strong construction from conventional materials like wood or steel and enough ballast to give good stability with the beam/length ratio which was common.

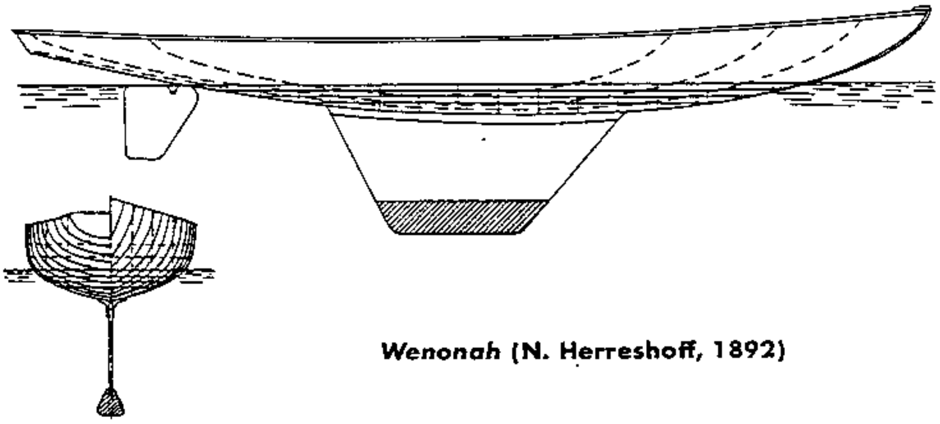
The actual displacement and the ballast ratio were certified by designer or builder.

IOR Rule (Marks I-III)

In an attempt to provide a handicapping rule which would be used on each side of the Atlantic a new rule, to some extent combining factors from each of the above rules was formulated. It went, very quickly, through various modifications but was never anything other than a compromise and produced truly awful yachts.

IMS

It was disenchantment with IOR Mk III yachts that produced IMS. This is not a design rule at all but simply a measurement system. The rating produced by this system is a quite accurate representation of a given yacht's speed. In the absence of restrictions, yachts have developed much as they did for a period about 100 years ago. The lines of Herreshoff's "Wenonah" of 1892, reproduced below, show a type not much different in basic concept from many new yachts of today, developed since the arrival of IMS.



Wenonah (N. Herreshoff, 1892)

Figure 3

100 years ago, yachts of the "Wenonah" type were called "skimming dishes" and it was said that they were light, fast - especially to windward- and <u>dangerous</u> to sail.

<u>The remedy</u> proposed is a new yacht designing rule for serious, long distance ocean racing having the rating formula:

$$R = \boxed{\frac{L + \sqrt{S}}{2}} - F \pm B \pm d \pm D + A \pm H + C - K \qquad X\, Pf$$

where L = length
S = sail area
F = freeboard
B = beam coefficient
d = draft coefficient
D = displacement coefficient
A = bow overhang coefficient
H = underwater profile coefficient
C = stern overhang coefficient
K = iron keel coefficient
Pf = propeller factor

All of the above except Pf are in linear units.

Observe the dotted box containing

$$\frac{L + \sqrt{S}}{2}$$

This is nothing other than the New York Yacht Club "linear rater" rule of the 1890s. This rule has been used early in this century on Sydney Harbour, a typical 30 rater, being about 30 feet on the waterline and having 900 square feet of measured sail area and hence

$$\frac{30 + \sqrt{900}}{2} = 30$$

This rule was, of course, easily corrupted and a typical 30 rater was 60 feet long overall and extremely lightly built. About 40 years ago I was told by a then quite old member of Royal Sydney Yacht Squadron that the wealthy who sailed this class had a new yacht every season because after 1 season's racing, the long ends drooped, the hull hogged and L became much greater than when the yacht was launched.

All of the other factors in this proposed new rule but especially D will overcome the above problem. In addition to the rating formula a regulation will include a static stability requirement.

The existing instructions to ~~measurers~~ can be used to obtain a sail area; a lines plan will yield B, d, A, H and C;and a designer's and/or builder's declaration will yield the displacement. L and F may be measured from the yacht in a specified condition.

Yachts built to this proposed rule can, of course, go through the IMS process as the IMS can rate almost any yacht. There is no problem with IMS as a measuring system but in the absence of design standards it is producing bad yachts.

It's all very well to have a new designing rule but the problems described above will not go away unless there is also an appropriate structural design rule. The development and administration - ie.plan approval and survey during construction, will be time consuming and expensive.

As a starting point, the light craft rules of the various ship classification societies might be used. This shows some promise, it is believed, because the proposed new rule ensures that the base displacement is sufficient to allow strong construction in standard materials as well as enough ballast. The penalty for less than the base displacement will be large.

Conclusion

Now it remains to the proponents of this new rule to get it into a final workable form together with the associated arrangements and then to interest a yacht club or clubs to run races for yachts rated in accordance with the rule or specially built to it. This will not be an easy task as there is a very substantial investment in the existing situation. There may be, however, a powerful ally in the insurance industry which must be hurting from its involvement in yacht insurance and the expensive consequences.

Bibliography

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3) Ibid
4) Laurence Draper, British National Institute of Oceanography, appendix to "Heavy Weather Sailing" by K Adlard Coles
5) Hansard, page no 1987 et seq, House of Commons, May 14th 1873

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.

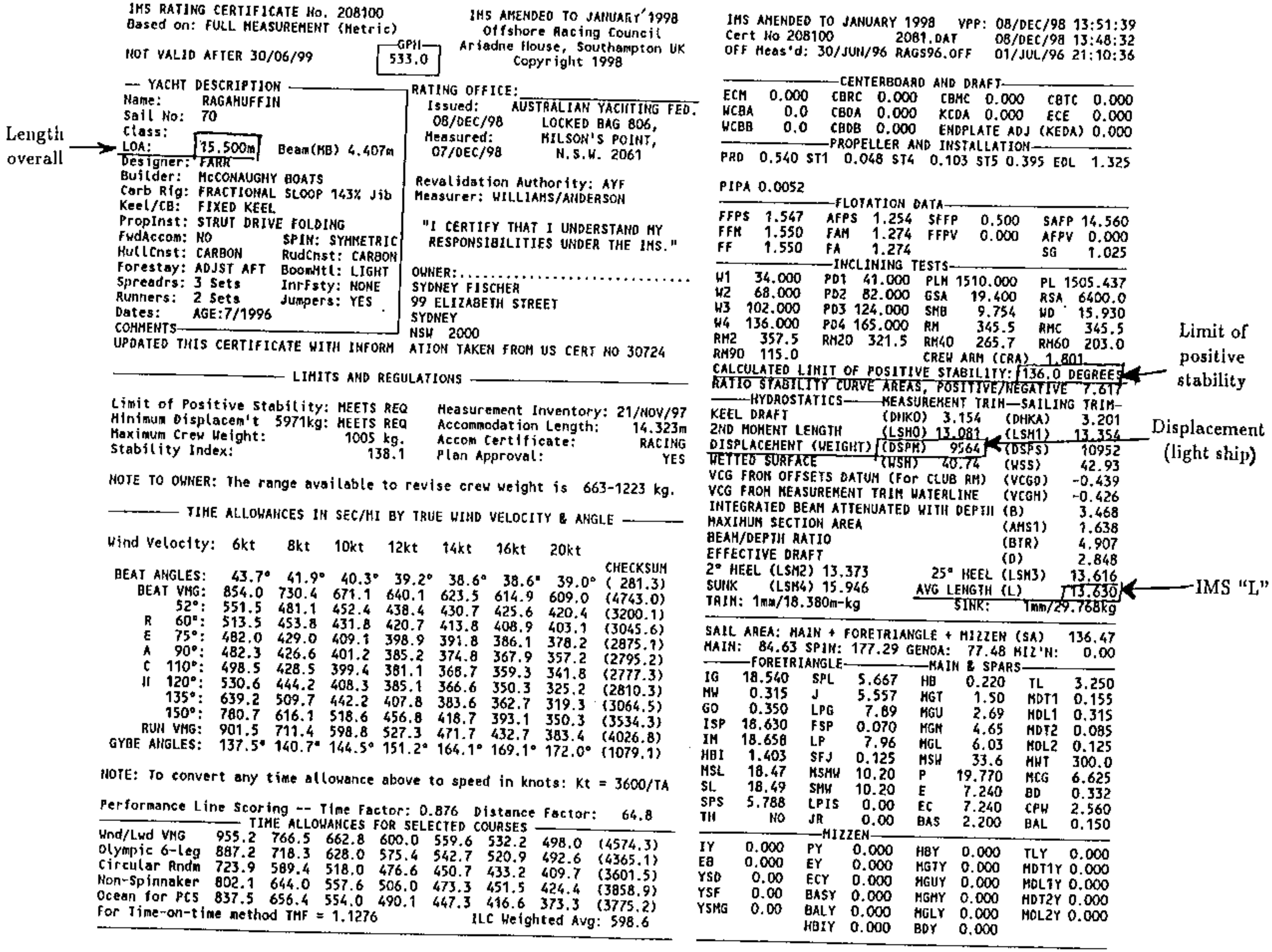
One of the most important considerations that must be kept in mind in directing the efforts in the follow on studies is that resources for yacht research are very limited. It is therefore important to identify the topics of research that will yield the greatest improvements in yachting safety for the 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.



Length overall

Limit of positive stability

Displacement (light ship)

IMS "L"

```
IMS RATING CERTIFICATE No. 208100             IMS AMENDED TO JANUARY 1998
Based on: FULL MEASUREMENT (Metric)             Offshore Racing Council
                                      -GPH-   Ariadne House, Southampton UK
NOT VALID AFTER 30/06/99              533.0       Copyright 1998

-- YACHT DESCRIPTION ------------------- RATING OFFICE:
Name:      RAGAMUFFIN                     Issued:    AUSTRALIAN YACHTING FED.
Sail No:   70                              08/DEC/98     LOCKED BAG 806,
Class:                                    Measured:      MILSON'S POINT,
LOA:       15.500m   Beam(MB) 4.407m       07/DEC/98       N.S.W. 2061
Designer:  FARR
Builder:   McCONAUGHY BOATS               Revalidation Authority: AYF
Carb Rig:  FRACTIONAL SLOOP 143% Jib      Measurer: WILLIAMS/ANDERSON
Keel/CB:   FIXED KEEL
PropInst:  STRUT DRIVE FOLDING             "I CERTIFY THAT I UNDERSTAND MY
FwdAccom:  NO          SPIN: SYMMETRIC      RESPONSIBILITIES UNDER THE IMS."
HullCnst:  CARBON      RudCnst: CARBON
Forestay:  ADJST AFT   BoomMtl: LIGHT     OWNER:..............................
Spreadrs:  3 Sets      InrFsty: NONE      SYDNEY FISCHER
Runners:   2 Sets      Jumpers: YES       99 ELIZABETH STREET
Dates:     AGE:7/1996                     SYDNEY
COMMENTS--------------------------------- NSW  2000
UPDATED THIS CERTIFICATE WITH INFORM  ATION TAKEN FROM US CERT NO 30724

------------------- 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
                                                              CHECKSUM
 BEAT ANGLES:   43.7°  41.9°  40.3°  39.2°  38.6°  38.6°  39.0° ( 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
```

```
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

-------------------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
RATIO STABILITY CURVE AREAS, POSITIVE/NEGATIVE  7.617
------HYDROSTATICS------MEASUREMENT TRIM--SAILING TRIM-
KEEL DRAFT                (DHKO)  3.154  (DHKA)     3.201
2ND MOMENT LENGTH         (LSHO) 13.081  (LSH1)    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

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

Table 1

1998 Sydney to Hobart Fleet Data Pertaining to Safety

Boat Name	LOA (metres)	IMS "L" (metres)	Length (metres)	Displacement (kilograms)	Dispi/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

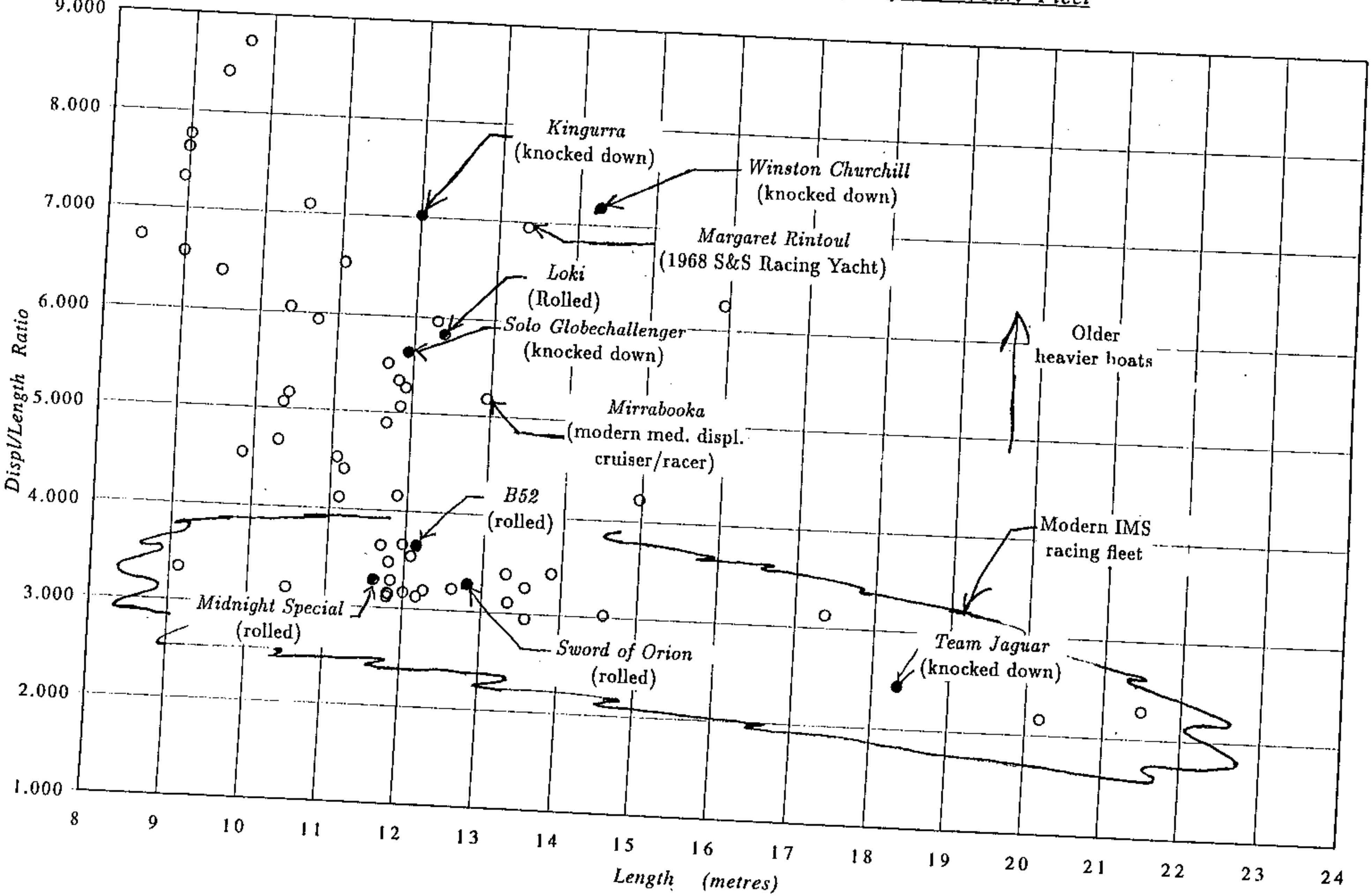


Chart 1

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

Chart 1

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

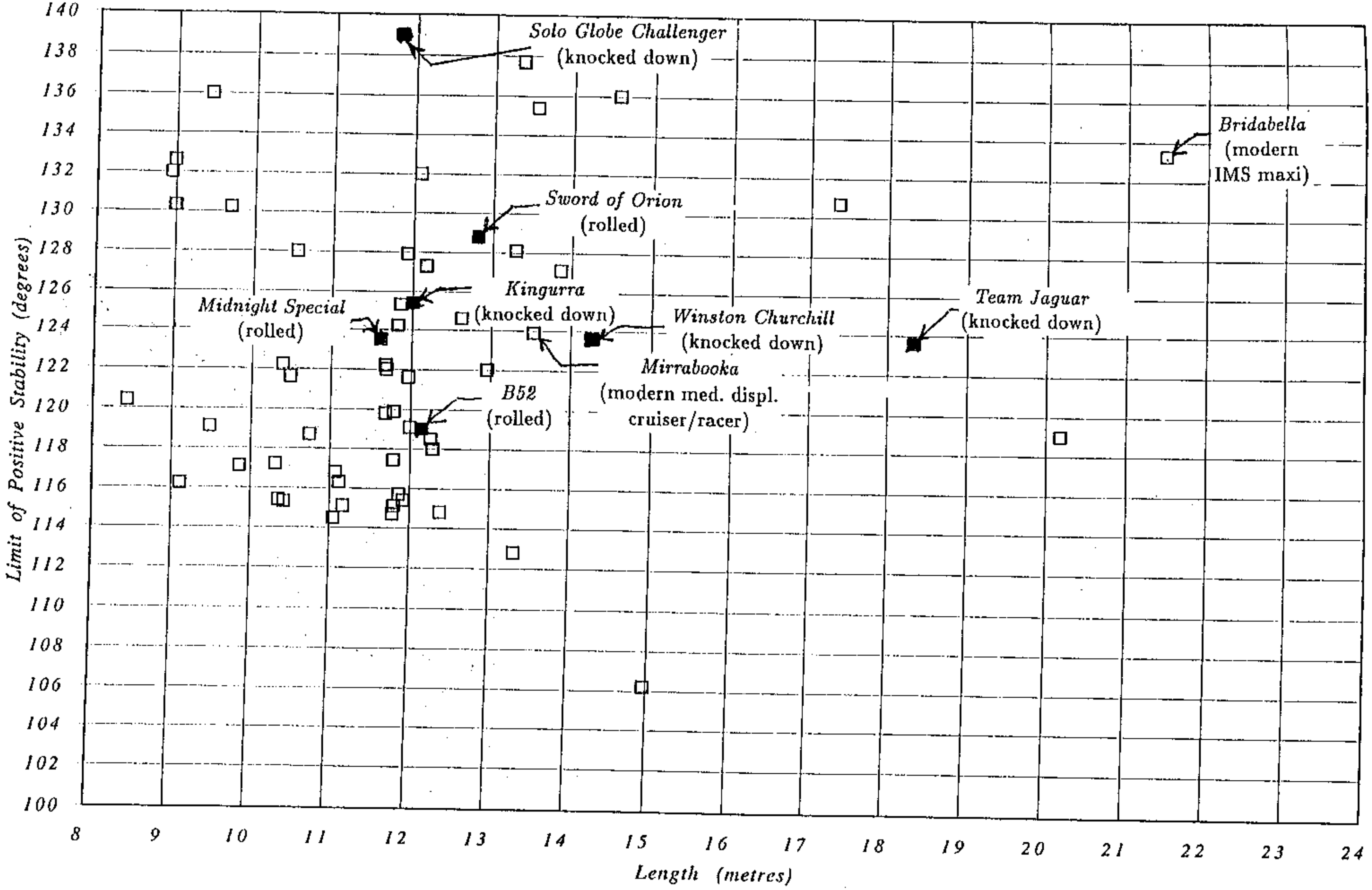


Chart 2

Yacht Stability and Seaworthiness

Mr Christopher Murman

Floating Point Designz

Mosman

Nomenclature

Δ = Mass displacement
□ = Volume of displacement
Θ = Angle of heel

B = Centre of Buoyancy
Beam = The maximum width of the vessel
BWL = The maximum width of the vessel at the waterline
BM = The distance from the centre of buoyancy to the metacentric height

Displacement/Length Ratio = $(\Delta/0.01 * LWL)^3$
DWL = Design Waterline

G = Centre of Gravity
GM = The distance from the centre of gravity to the metacentric height

GZ = Righting Lever

H = Draft. The minimum depth of water required to allow the vessel to float

H_c = Draft of hull canoe body

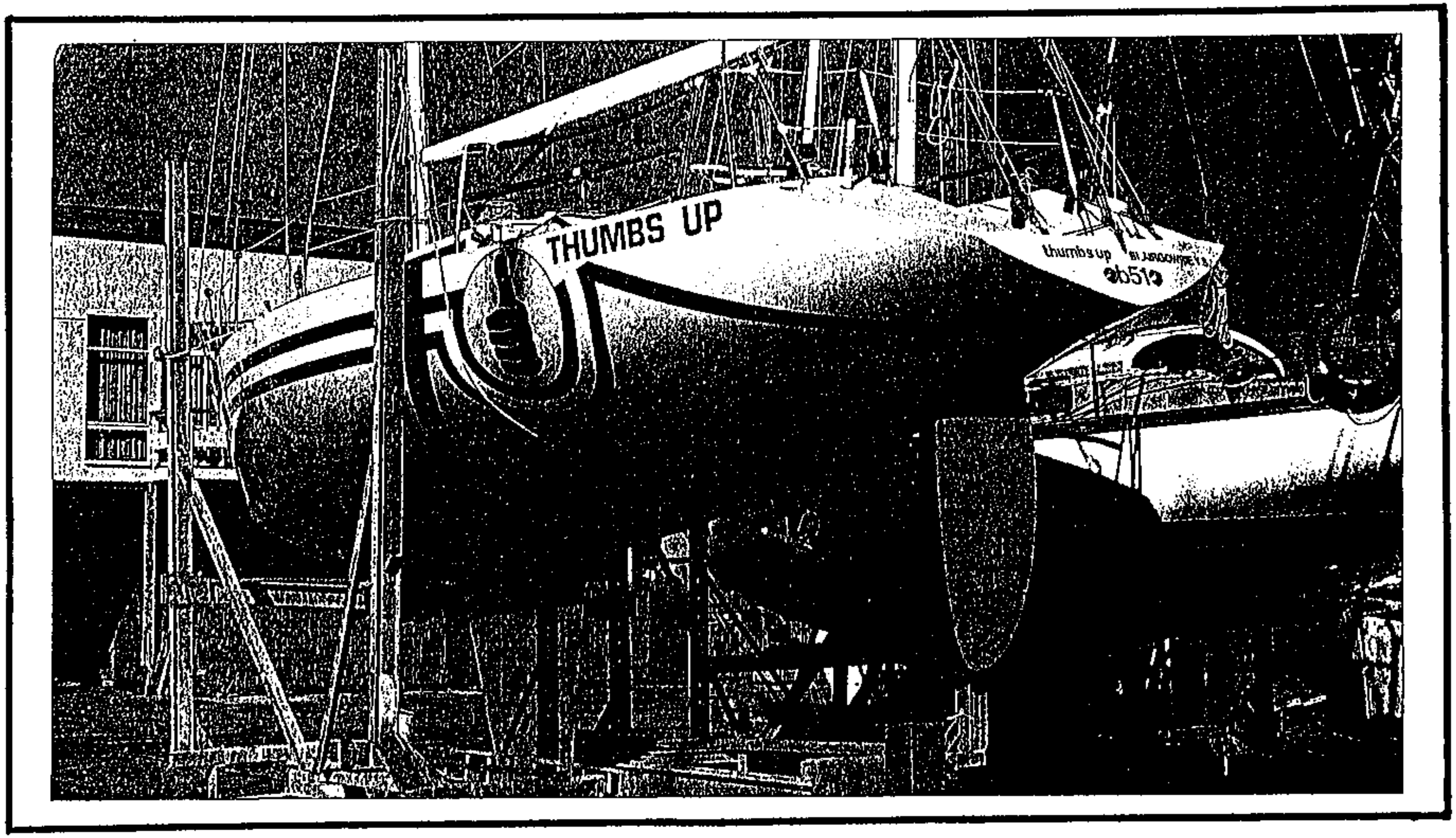
KG = Distance from the keel to the centre of gravity
KM = Distance from the keel to the metacentric height

LOA = Length Overall. The maximum length of the vessel
LWL = Load Waterline Length. The length of the vessel at the waterline

M = Metacentric Height

RM(x°) = Righting Moment (for a given angle of heel, degrees)

T = Wave period (seconds)


THUMBS UP
thumbs up
9b51

Synopsis

This paper outlines the components that make up the stability characteristics of a sailing yacht. Some comparisons are then presented to illustrate the design trends and the marked influence of the rating rules that have occurred over the years.

An analysis of these trends clearly indicates a move away from the characteristics that are crucial to a seaworthy ocean going yacht, capable of surviving the extreme weather conditions that may be found at sea.

Stability and the Effects on Safety

"Of the three rotational and three translational motions of a boat in a seaway the most important, affecting seakindliness and safety, is rolling" [1]. The heel and rolling characteristics of any vessel are an important part of the measure of seaworthy of any vessel.

Every vessel has its own unique range of stability, this is also unique for each load condition. However we may consider the load condition of a yacht to be approximately constant, unless an extended voyage is being undertaken. A vessel undertaking an extended voyage will be heavily loaded with stores, provisions and additional equipment, this will set her down on her marks.

If we assume a constant load condition, then the vessel will have only one hydrostatic stability curve. An example of a typical hydrostatic stability curve is illustrated in figure 1.0. If the centre of gravity is constant (G) (because the load condition is considered to be constant), the only stability characteristic to move as the vessel is heeled, is the centre of buoyancy (B), this will also result in the movement of the metacentric height (M), see figure 2.0.

For a given angle of heel the shape of the sectional hull form governs the movement of B and M and thus the resultant righting lever (GZ). Figure 3.0 illustrates the different values of GZ, for a given angle of heel, of two different sectional hull forms. The value of GZ may be calculated (for small angles of heel) if the height of M and the angle of heel are known, as follows:

$$\text{Righting Lever (GZ)} = GM \sin \Theta \qquad (1)$$

As can be clearly seen from figure 3.0, the beamy light displacement vessel develops large values of GZ, due to the rapid movement of B (for the same angle of heel) thus increasing the value of BM. This rapid movement of B (and the resultant increased value of BM), will make the yacht "feel" very "stiff" in light to moderate weather conditions. This can be regarded as the hull form stability characteristics of the vessel.

For small angles of heel, (ie, typically less than approximately 30 degrees) a vessel moves about the longitudinal centre line at the LWL. As stability characteristics and the resultant GZ, are a function of the location of G, the position of G in relation to the load waterline (LWL) will dictate the mass or ballast condition stability characteristics of the vessel. If G is below the LWL, then G will contribute to the overall stability characteristics of the vessel. However if G is above the LWL, then G will be detrimental to the overall stability

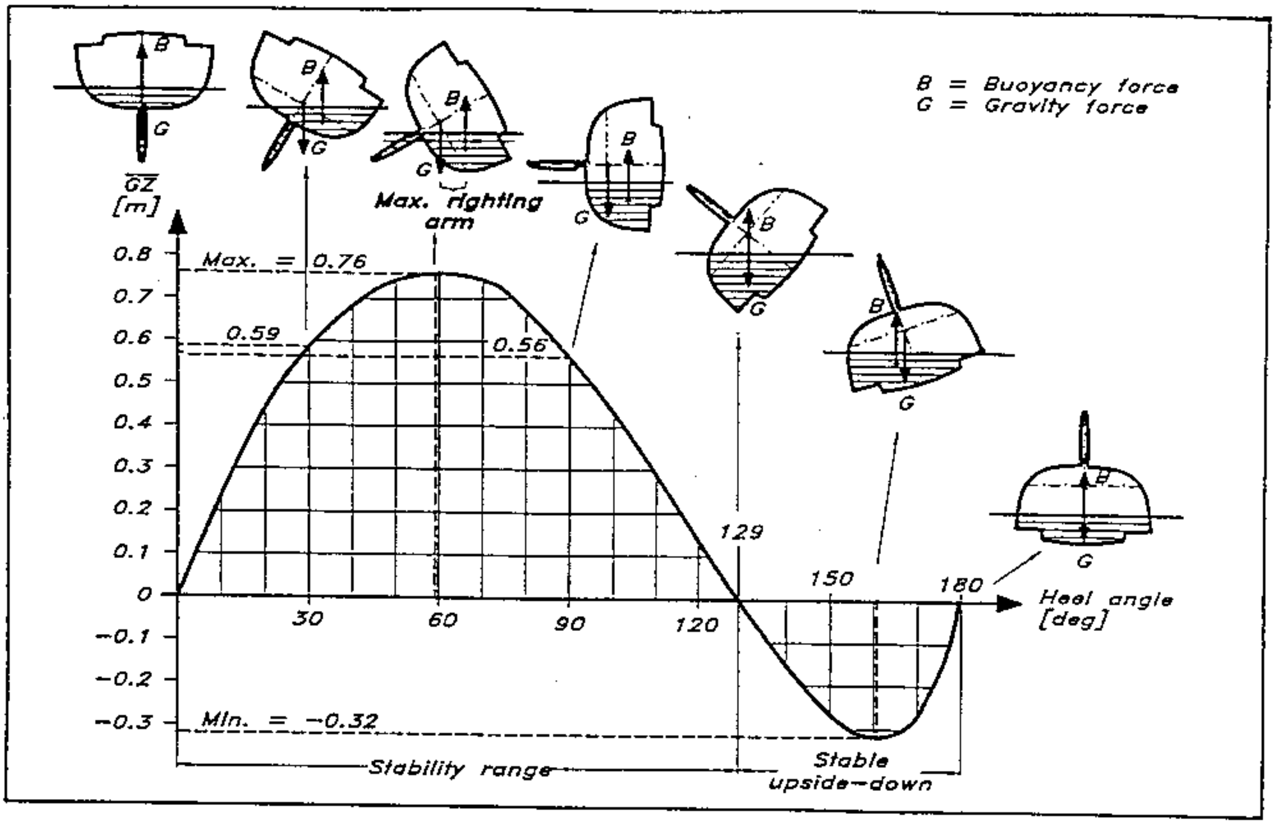
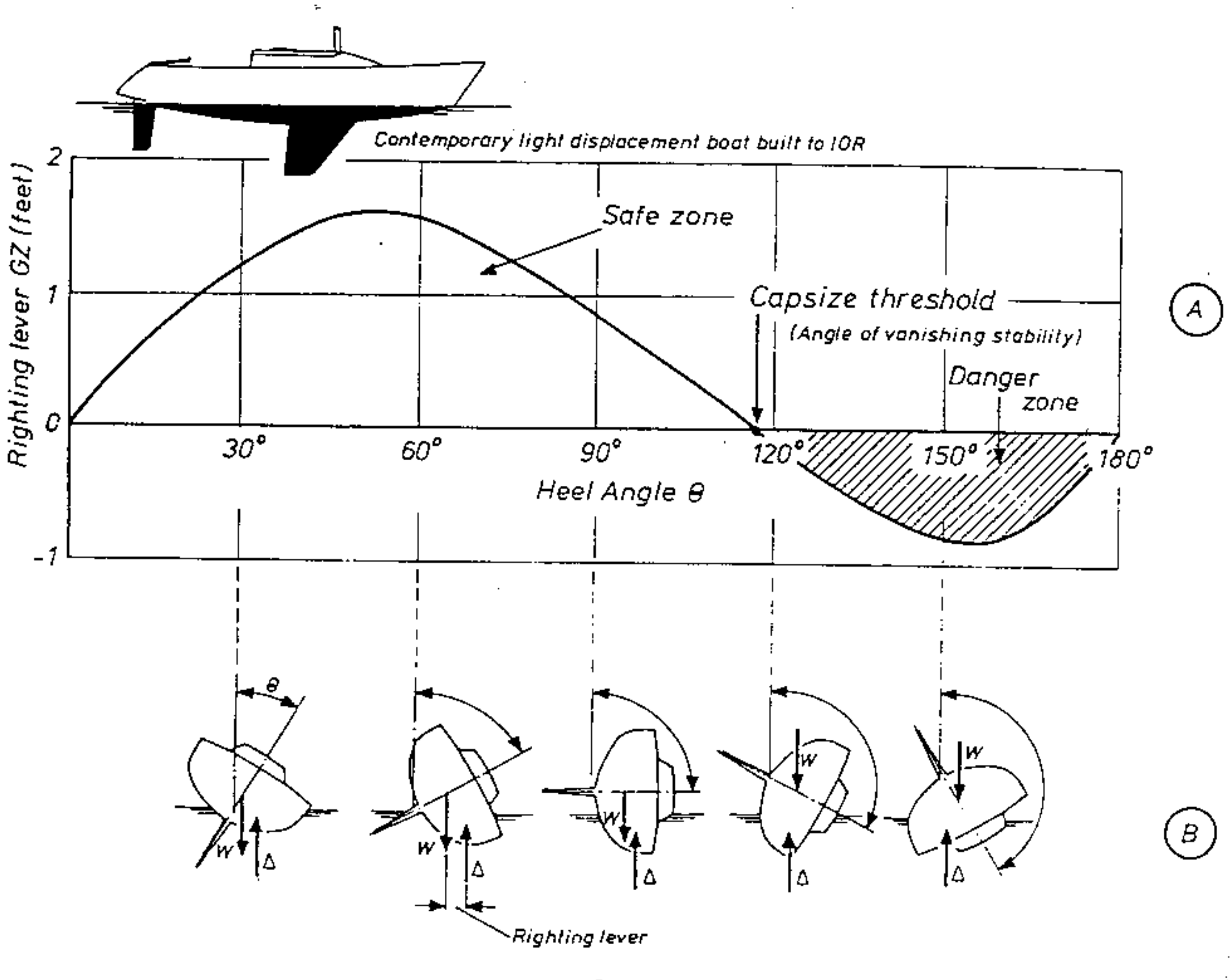
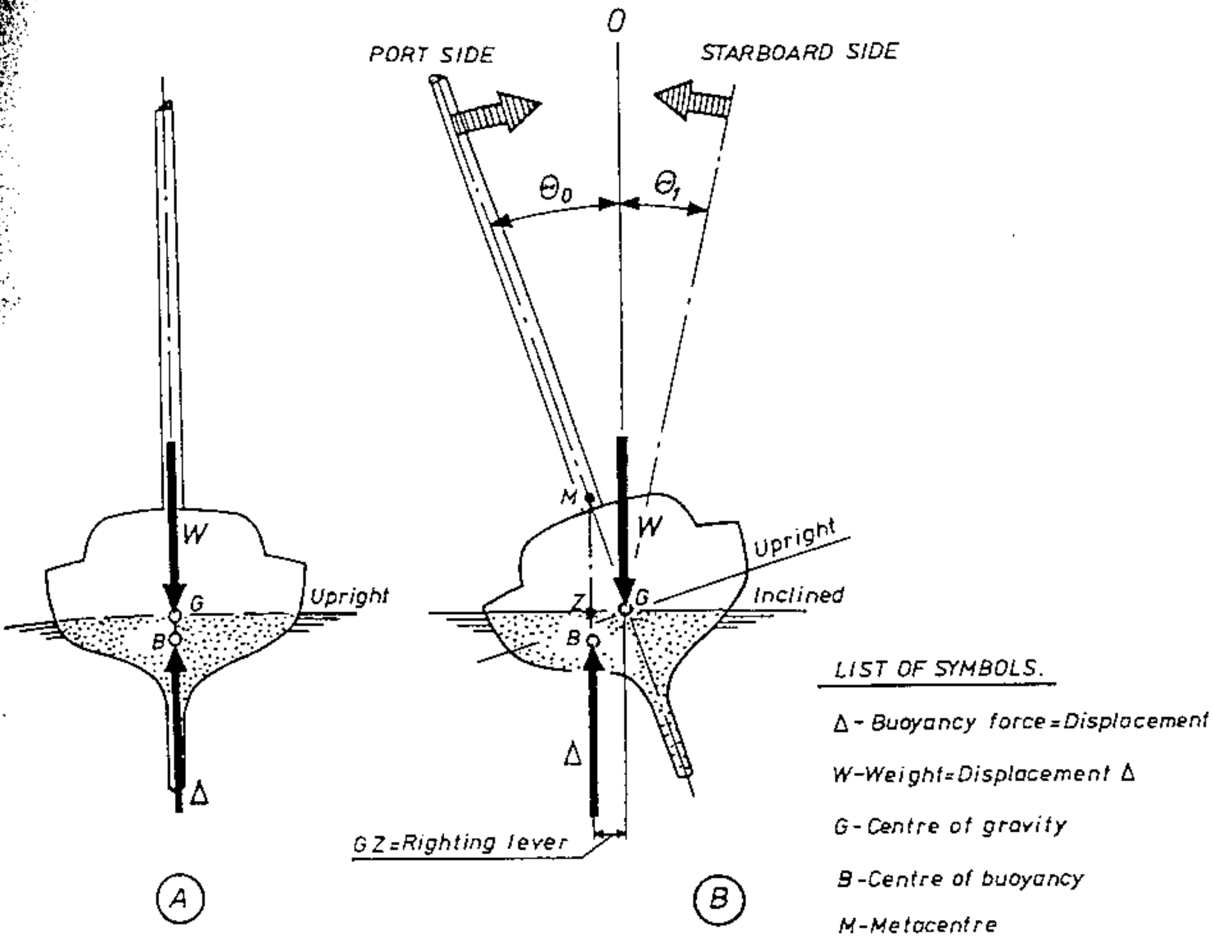


Figure 1: Typical Hydrostatic Stability Curves

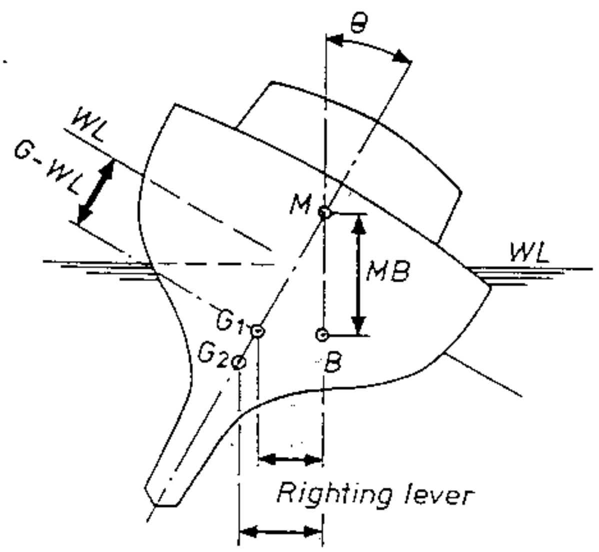


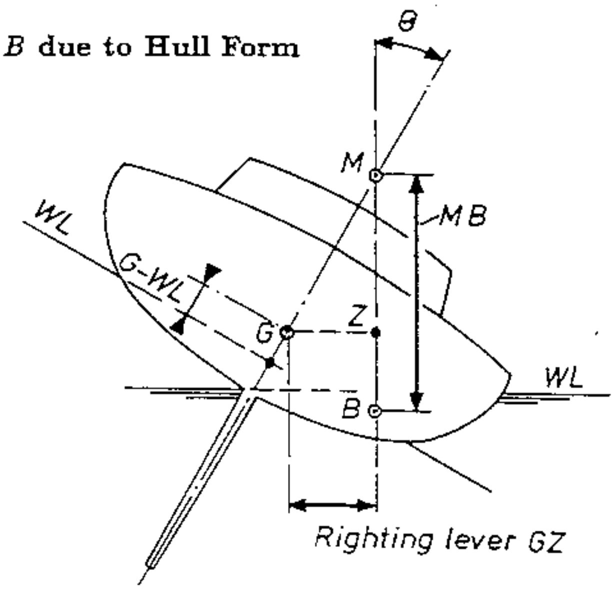


Definition of terms and forces operating in hydrostatic conditions.

Figure 2: Movement of B due to Heel

Figure 3: Movement of B due to Hull Form





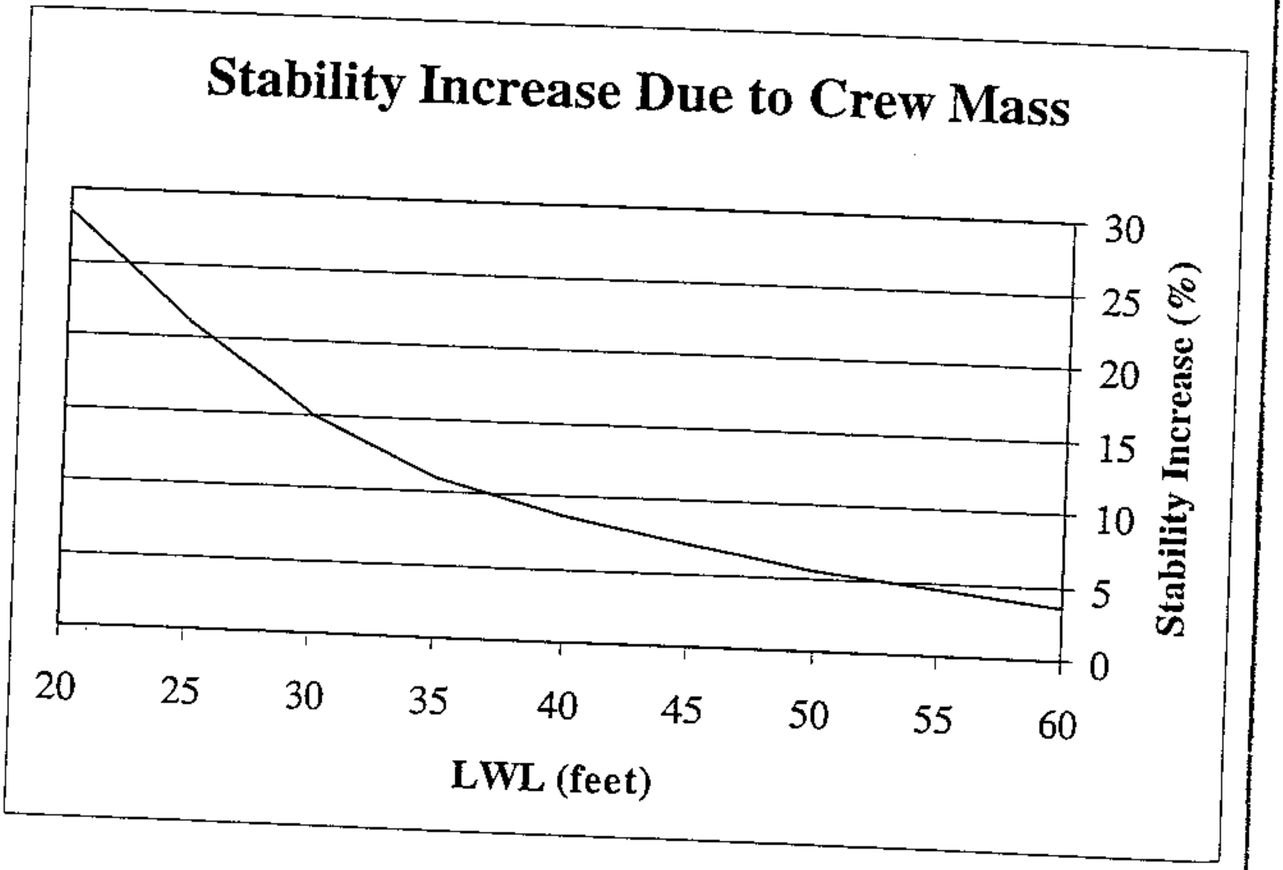
G-Centre of gravity
B-Centre of buoyancy
GM-Metacentric height
GZ-Righting lever
Distance MB-Form conditioned stability factor
Distance G-WL-Weight conditioned stability factor

M is on the centreline for θ less than approximately 10 degrees heel

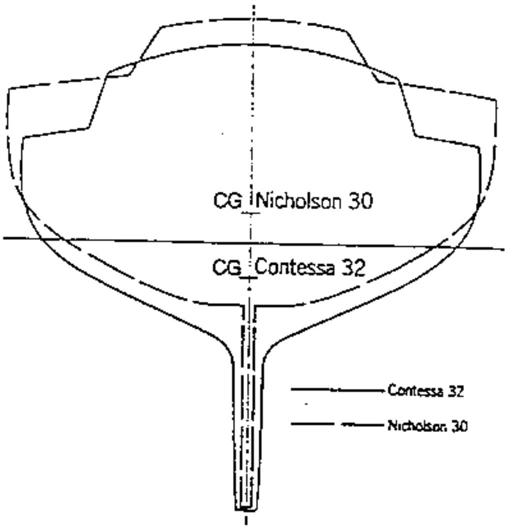
The overall hydrostatic stability characteristics of a vessel are the resultant of the hull form stability characteristics and the pendulum stability characteristics of the vessel. However one of these may dominate the overall stability characteristics of the particular vessel. For small angles of heel (ie, typically less than approximately 30 degrees) the hull form stability is the predominate factor contributing to the stability of the vessel. As heel increases, the pendulum stability becomes increasingly dominant.

Vessels with G above the LWL will typically have a smaller maximum GZ, this smaller maximum GZ, will also occur at a smaller angle of heel, when compared to vessels with G below the LWL. In addition to this, the overall range of positive stability will also be reduced, see figure 4.0.

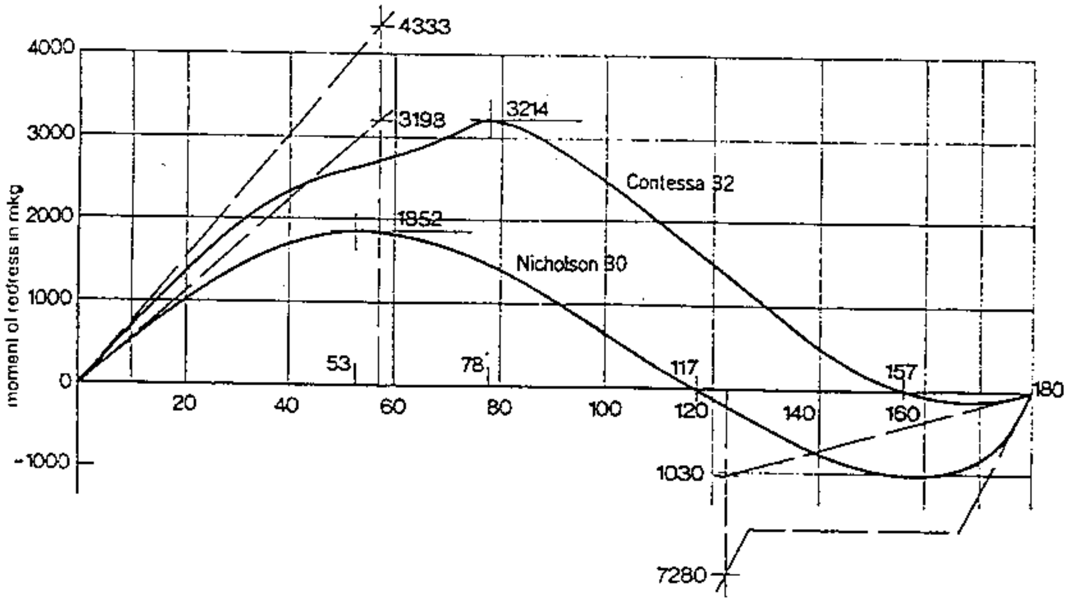
While moving crew and sometimes stores, (commonly known as stacking), to the weather side of the vessel can enhance stability characteristics of the modern light displacement yacht, the impact is dramatically diminished as the size of the vessel increases. For the typical light displacement Sydney to Hobart vessel, of approximately 12 meters, the expected stability gain would not exceed 10 percent. A typical light displacement Sydney to Hobart maxi yacht would only gain approximately 3 to 4 percent in stability. Graph 1.0 below illustrates typical values:



Graph 1 Stability Increase Due to Crew Mass



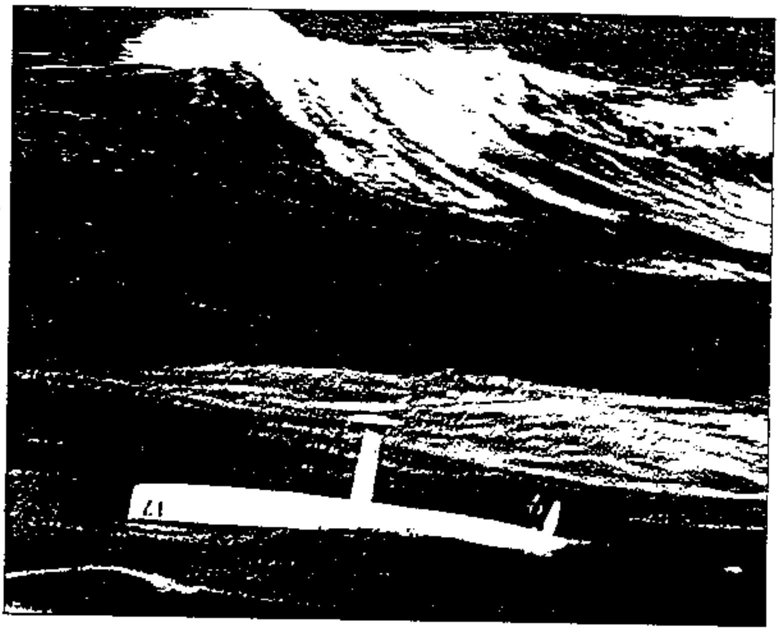
The midship sections



Righting moment curves of the Contessa 32 and Grimalkin.

Figure 4: Position of G and the Associated Range of Stability

Figure 5.0 illustrates the typical stability curve of an ultra light displacement maxi yacht. The range of positive stability is dramatically reduced when compared to the typical stability curve of a traditional yacht, see figure 6.0. The other important point to note is the maximum value of the negative GZ of both diagrams. It is clear that the ultra light displacement maxi yacht (see figure 5.0) will not only become unstable at a smaller angle of heel, (115 degrees in this example) but the vessel will have a strong tendency to remain inverted. The vessel would be required to roll 65 degrees (while inverted) before she begins to return to the upright position of her own accord, this is unlikely in a seaway. This tendency was graphically illustrated during the last Around Alone race (1995-1996) when the French yacht was overturned in the South Pacific Ocean. The photographs (by the media and the Australian Navy) clearly showed the vessel floating in the inverted position with the keel and rudder still intact and the skipper standing on the vessel waiting to be rescued.



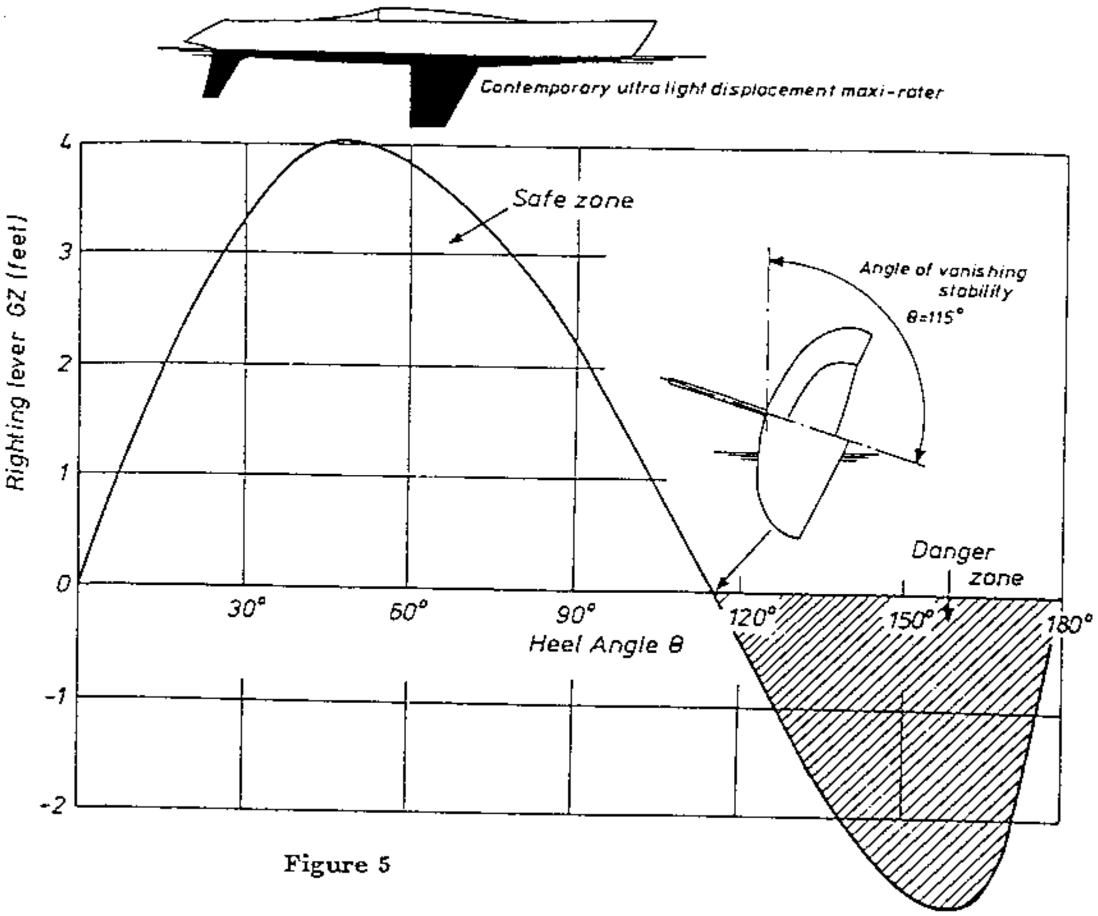


Figure 5

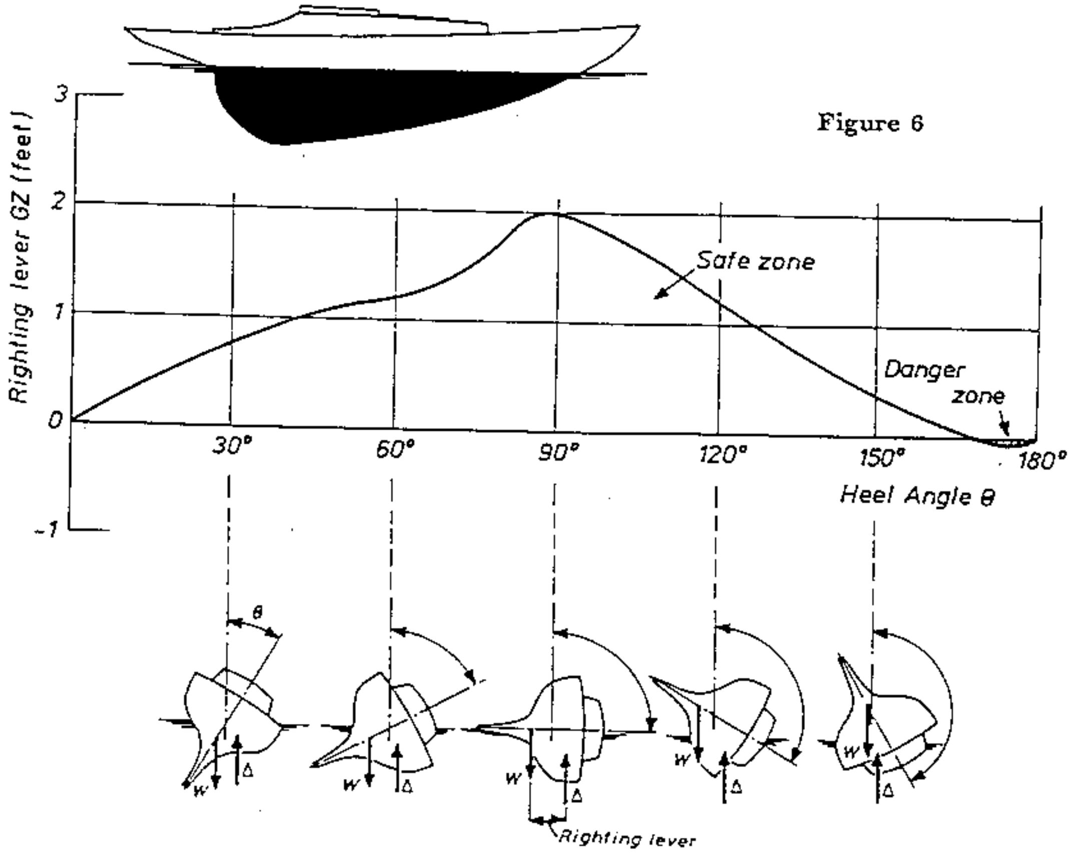


Figure 6

Figure 7.0 and 8.0 illustrate the effect of hull section and the relative positions of B and G on the hydrostatic stability. The hull sections were derived from a parent form of a Threequarter-Tonner. The basic dimensions of this vessel are as follows:

Dimension	Measure	Metric Unit	Measure	Imperial Unit
LOA	10	M	32.8	ft
LWL	8.3	M	27.25	ft
Beam (B)	3.4	M	11.25	ft
Draft (H)	1.5	M	4.9	ft
Displacement	3.0	Tons		
Displacement/Length Ratio	148.3			

The characteristics of these hull sections are as follows:

Hull	Beam/H	KG	GM	Θ	T	H_c	KM (m)
A	1.73	0.08	1.29	166	0.53	1.73	1.37
B	1.96	0.26	1.30	145	0.50	1.63	1.56
C	2.22	0.44	1.36	125	0.47	1.52	1.80
D	2.66	0.78	1.50	99	0.43	1.43	2.28

Note:

1) Θ is the angle of vanishing stability.
2) KG is the vertical distance from the baseline (as drawn) to G.

Figure 9.0 (graph A, B and C) illustrates the development of modern racing yacht design with a strong trend towards:

1) Higher tenderness ratios (larger BM/GM ratio)
2) Increased beam in relation to LOA
3) Increased beam in relation to displacement
4) Lower displacement/length ratio.

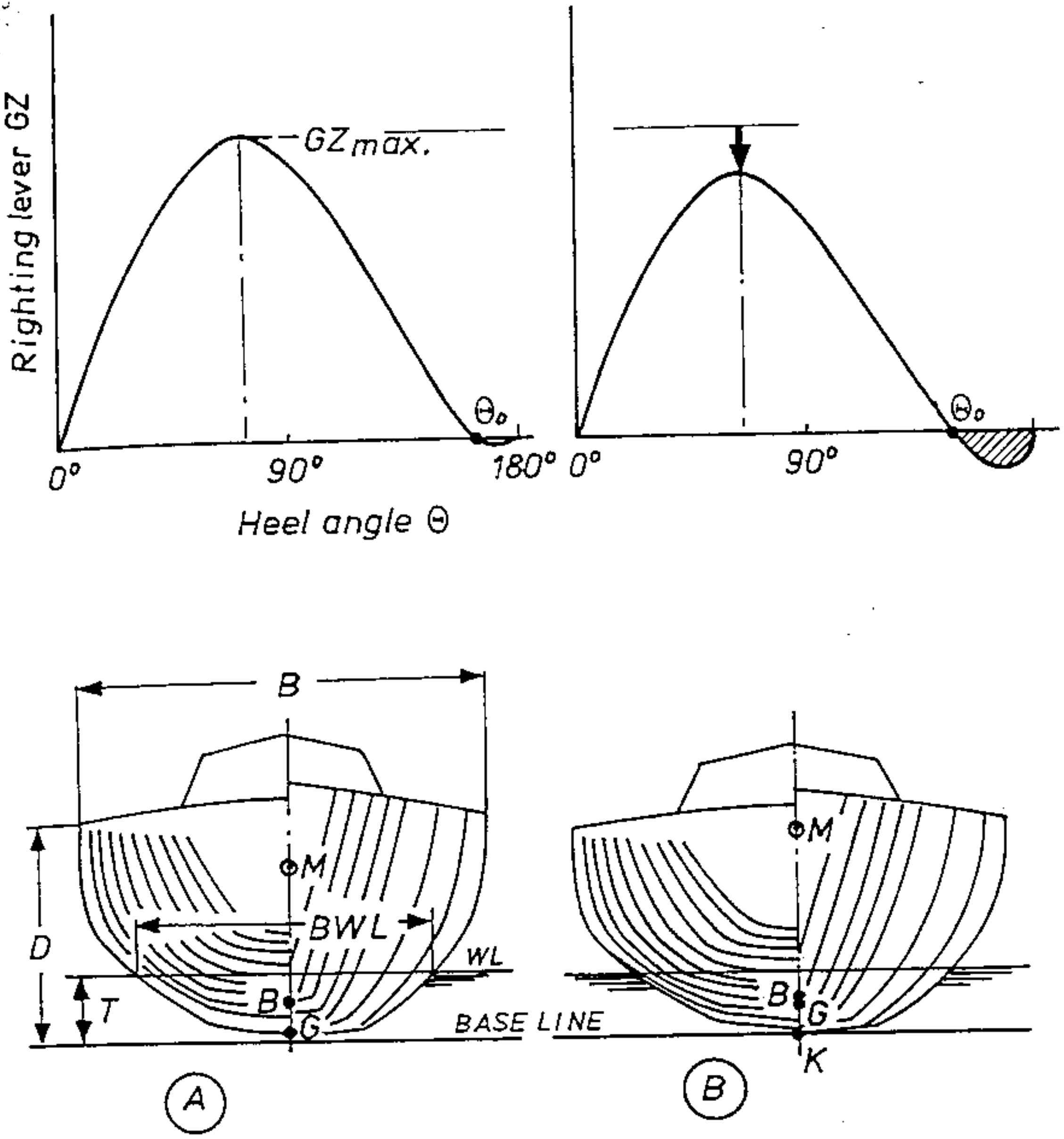

Righting lever GZ
GZ max.
Θ₀
0°
90°
180°
Heel angle Θ
0°
90°
Θ₀
B
M
BWL
WL
D
T
B
G
BASE LINE
A
M
B
G
K
B

Figure 7

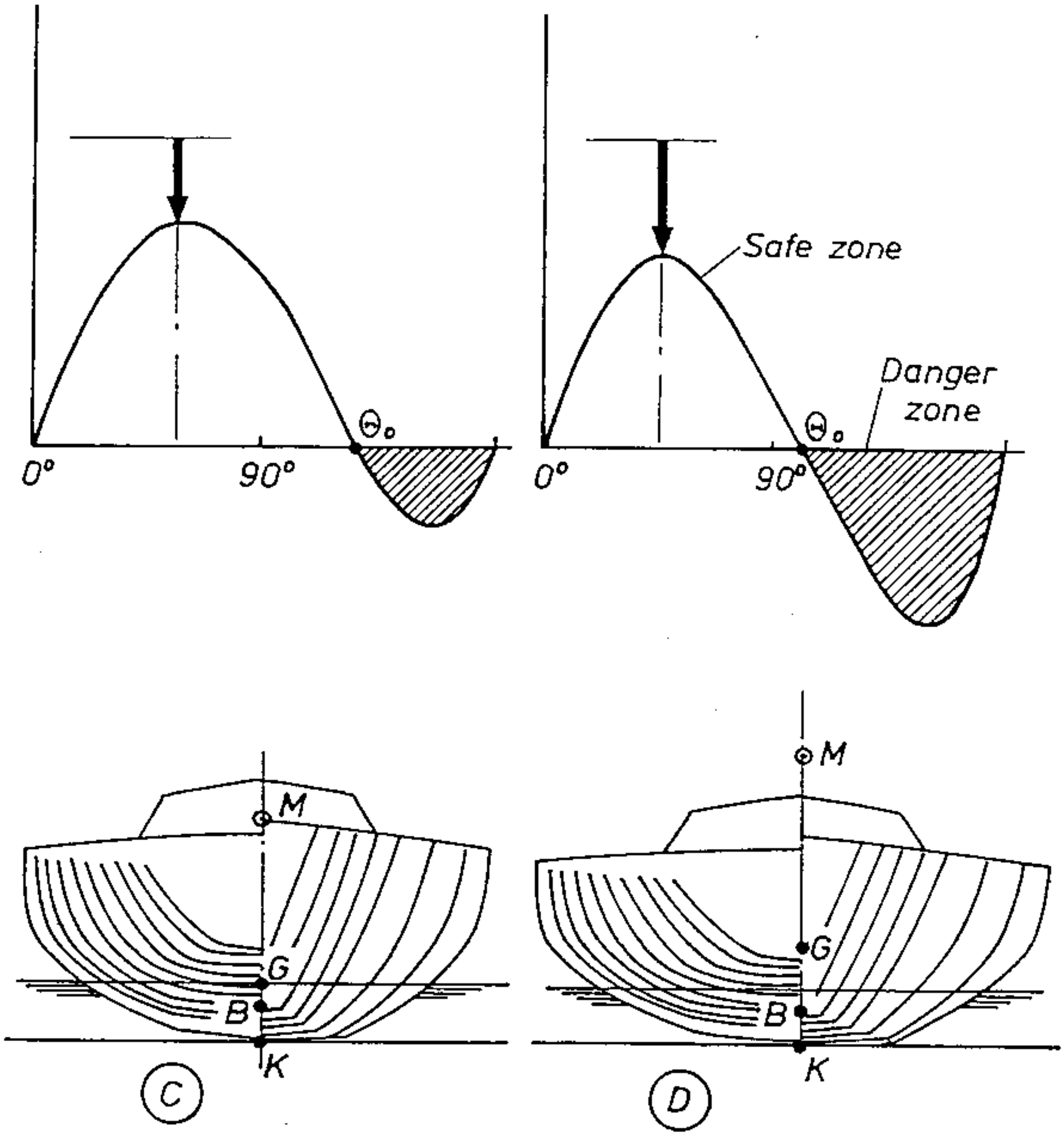


Figure 8

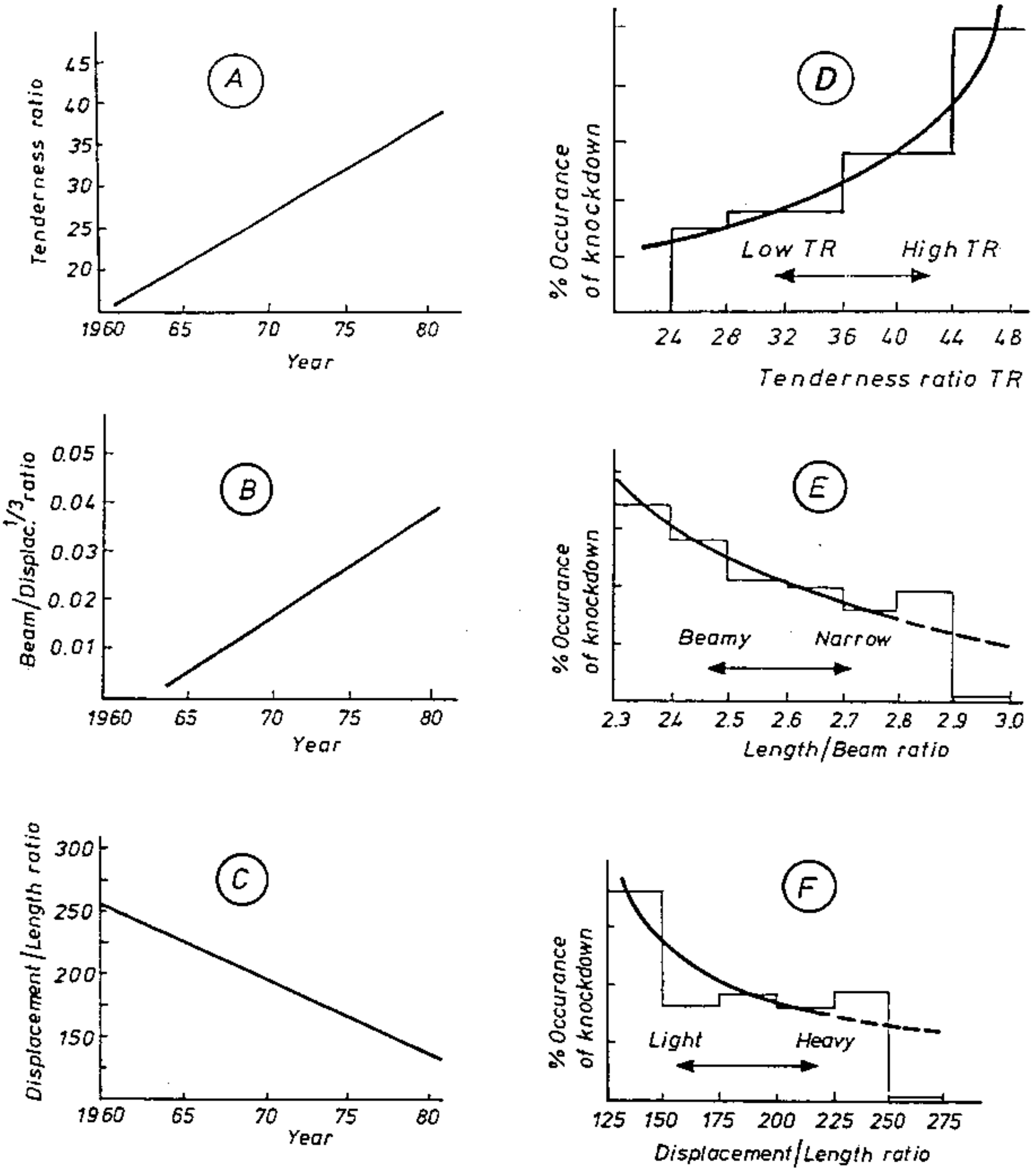

A
Tenderness ratio
45
40
35
30
25
20
1960
65
70
75
80
Year
D
% Occurance of knockdown
Low TR
High TR
24
28
32
36
40
44
48
Tenderness ratio TR
B
Beam/Displac.^1/3 ratio
0.05
0.04
0.03
0.02
0.01
1960
65
70
75
80
Year
E
% Occurance of knockdown
Beamy
Narrow
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0
Length/Beam ratio
C
Displacement/Length ratio
300
250
200
150
1960
65
70
75
80
Year
F
% Occurance of knockdown
Light
Heavy
125
150
175
200
225
250
275
Displacement/Length ratio

Figure 9

After the 1979 Fastnet Race disaster much research was carried out on the stability characteristics of yachts in breaking waves. Those who studied the data with a view to drawing some conclusions, agreed that the following design characteristics have adversely affected the safety of yachts in breaking waves:

- Large beam
- Shallow canoe body draft
- High aspect ratio keels (due to there poor directional stability characteristics)
- Light displacement
- Low coach roof volume.

Figure 9.0 (graph D, E and F) indicate the correlation of these design trends, with the probability of capsize in breaking waves, based on the Fastnet Race inquiry, - following the 1979 race.

Notes :

1) Tenderness ratio = $(0.97LOA * (BWL)^3)/RM(1^\circ) = 22.3 * (BM/GM)$.

Figure 10.0 plots Stability Range against Overall Length (LOA) and indicates the vessels that were capsized. The range of designs within this graph is extensive and includes yachts from the 1979 Fastnet Race, the 1994 New Zealand to Tonga Race and a host of other sources, over a long period of time [2].

Notes :

1. Δ Plot of a particular yacht
2. —.— Traditional cruising yachts
3. — — Contemporary racing yachts
4. O The yacht capsized but recovered, (may have been damaged)
5. O The yacht that did not survive the capsize

The following observations can be made from this graph:

1) A large number of vessels with a stability range of less than approximately 138 degrees were rolled in breaking waves.
2) Most of the vessels that capsized were contemporary cruiser-racing yachts.
3) No vessel with a stability range exceeding 138 degrees was rolled in breaking waves.
4) All of the vessels that were rolled, with a stability range of less than approximately 118 degrees, did not recover.
5) Only one vessel classified as a traditional cruising yacht, was capsized, but it did recover. The stability range of this vessel is approximately 122 degrees.

Conclusions

The modern trend towards vessels with the following characteristics:

- Large beam
- Shallow canoe body draft
- High aspect ratio keels (due to there poor directional stability characteristics)
- Light displacement
- High values of KG

Has reduced the stability characteristics and hence the safety of modern racing yachts.

Based on the design trend analysis of modern racing yachts presented in Figure 9.0, and the empirical results presented in Figure 10, the current rating rules lack sufficient focus on the design characteristics that encourage the racing yacht designer to include stability characteristics into the design of the vessel. This has lead to a trend away from the design parameters that make for a seaworthy vessel. Hence it is not prudent, in the interests of safety, to sail these yachts in races where heavy weather is likely to be encountered.

References

[1] "Seaworthiness : The forgotten factor". By C. A. Marchaj. Revised edition, 1996. Published by Adlard Coles Nautical. ISBN 0-7137-4347-1.

[2] "The Search for Stability". By Barry Deakin. University of Southampton, Wolfson Unit, Cruising Helmsman magazine, April 1997.

[3] "Principles of Yacht Design". By Lars Larsson and Rolf E Eliasson. First Edition, 1994. ISBN 0-7136-3855-9.

[4] "Ship Stability for Masters and Mates". By D. R. Derrett. Forth Edition, 1972. ISBN 0 540 01403 6

[5] "Design of Sailing Yachts". By Pierre Gutelle. Second Edition 1993 (revised 1994). ISBN 0 948646 54 3

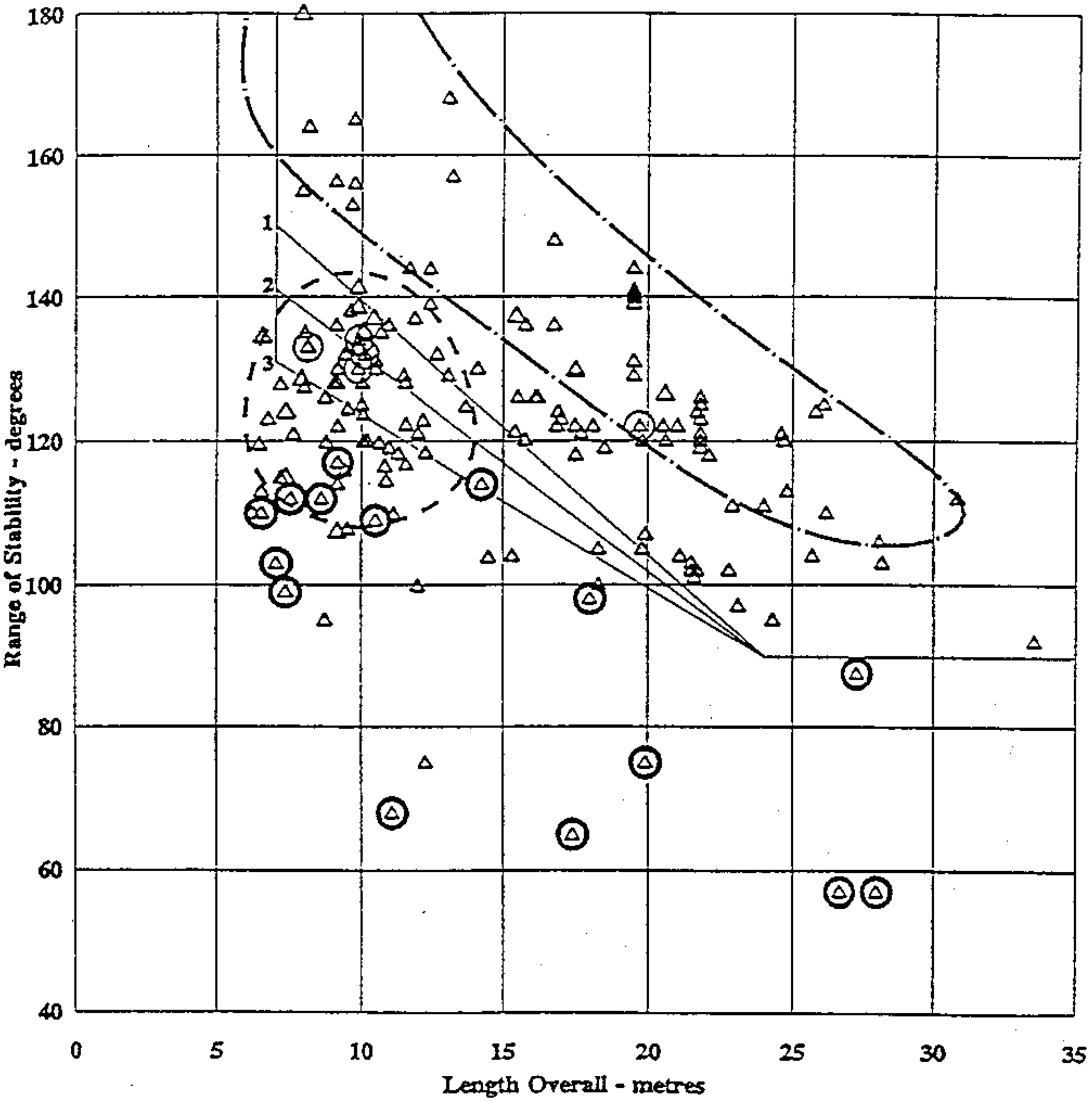

180
160
140
120
100
80
60
40
0
5
10
15
20
25
30
35
1
2
3
Range of Stability - degrees
Length Overall - metres

Figure 10

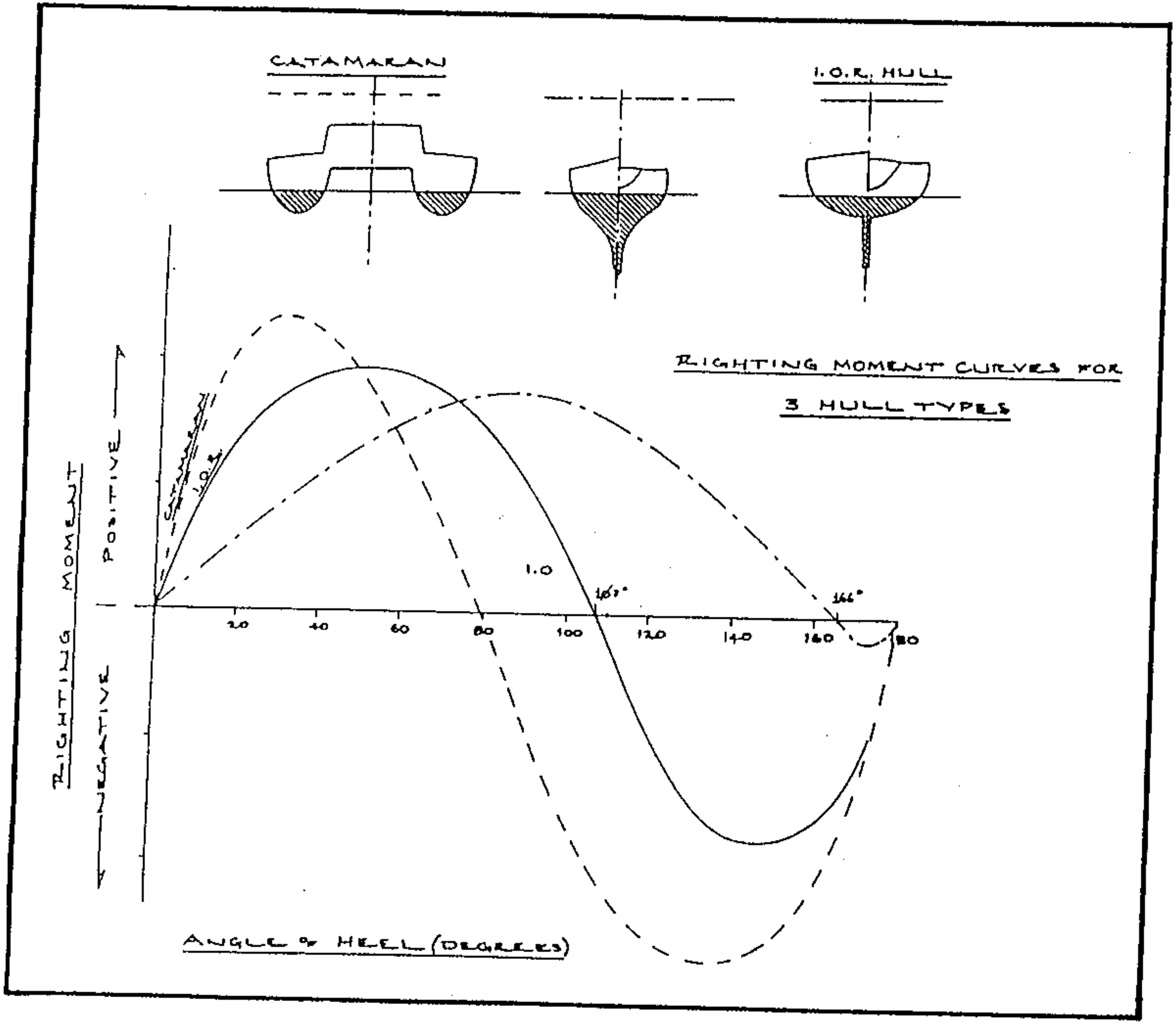
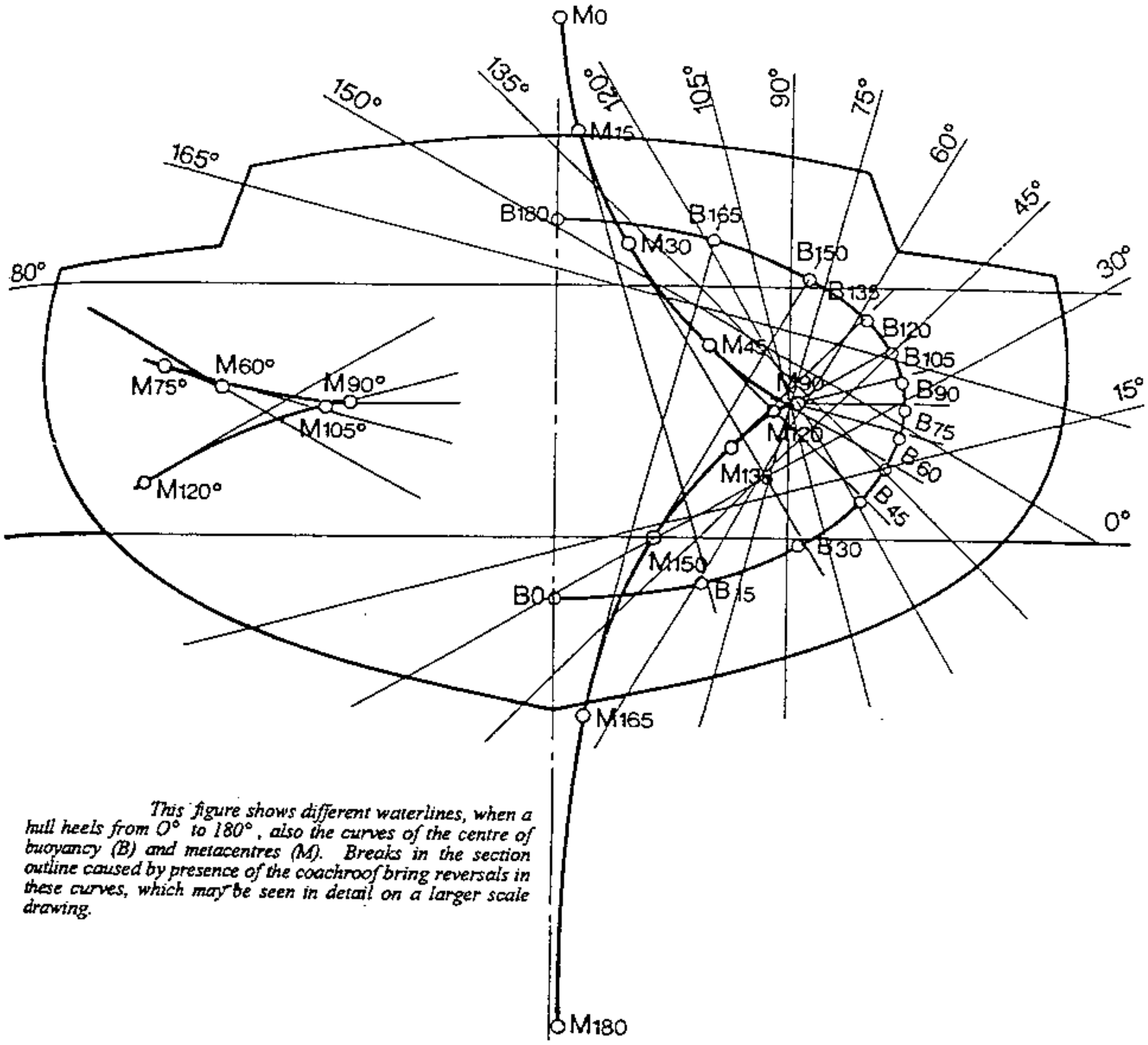

CATAMARAN
I.O.R. HULL
RIGHTING MOMENT CURVES FOR
3 HULL TYPES
RIGHTING MOMENT
POSITIVE
NEGATIVE
CATAMARAN
I.O.R.
1.0
107°
166°
20
40
60
80
100
120
140
160
180
ANGLE OF HEEL (DEGREES)

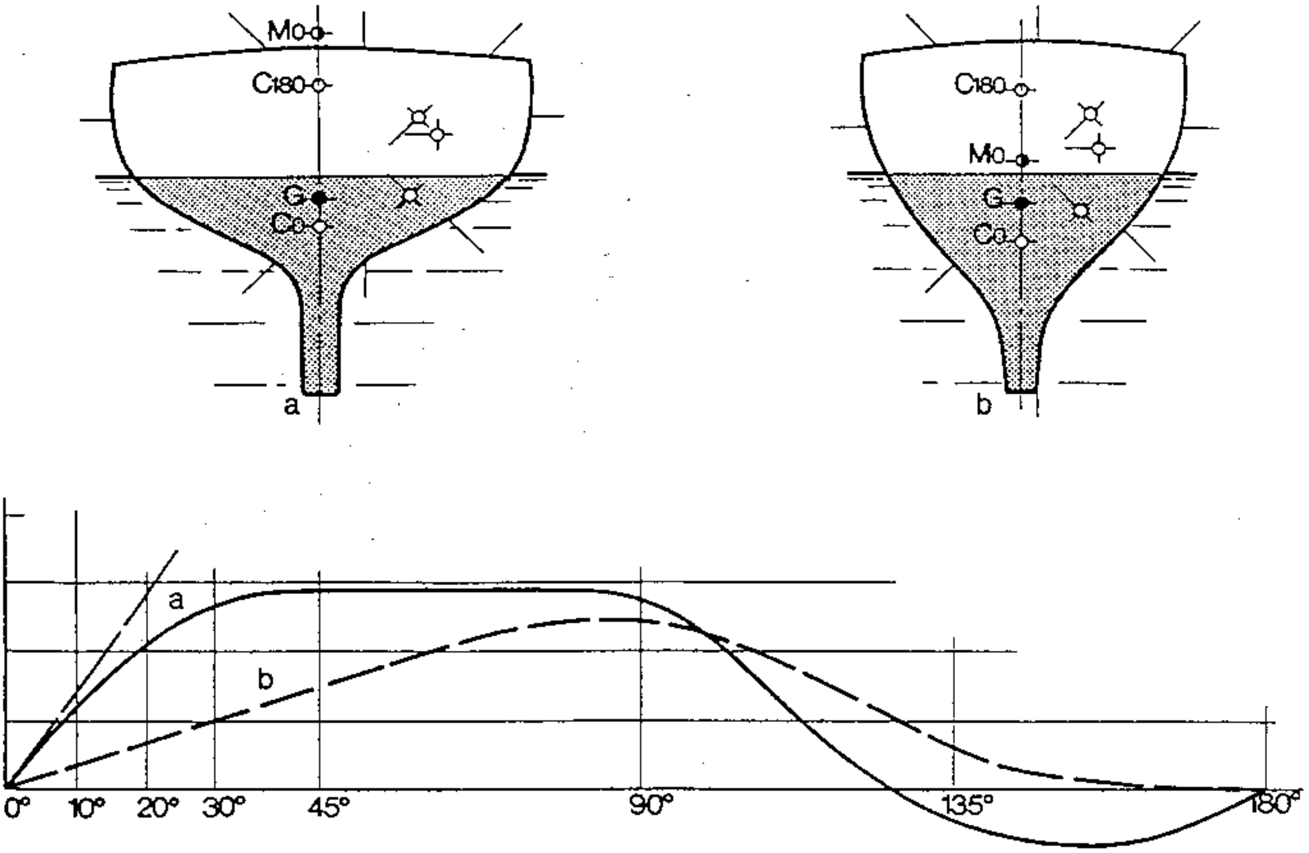
Figure 11

Figure 11



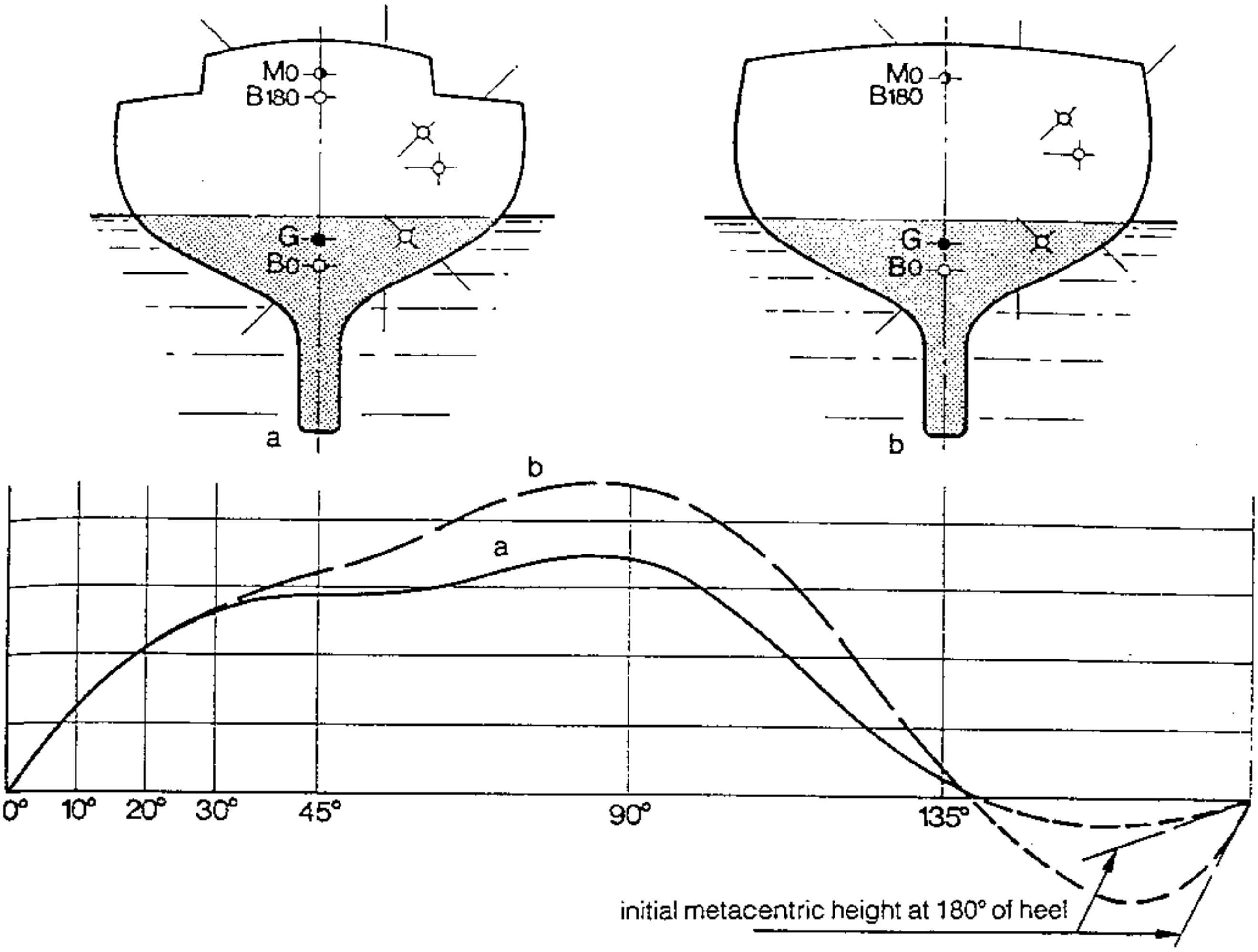
This figure shows different waterlines, when a hull heels from 0° to 180°, also the curves of the centre of buoyancy (B) and metacentres (M). Breaks in the section outline caused by presence of the coachroof bring reversals in these curves, which may be seen in detail on a larger scale drawing.

Figure 12



The effect that waterline beam has on the shape of the curve of statical stability.

Figure 13



The stability curve of the hull with a flush deck shows that its stability is greater than that of the hull with a coachroof. Every increase in volume high up increases stability at large angles of heel. On the other hand, initial stability in the inverted position is also greater.

Figure 14

Design	LWL	Disp	LWL/Disp	Ball Ratio	SA	SA/Disp
Steinman ''Flying Colours	49.0	8.0	67	*	*	*
Adams 44	37.6	9.4	178	50	973	20.5
Dufour 39	35.5	6.7	148	46	724	19.0
Lightwave 395	33.7	4.9	127	49	742	24.0
Oceanis 370	31.6	5.0	158	36	549	17.5
Moody 376	31.2	7.3	237	39	637	15.8
Gibsea 372	30.5	5.3	187	35	499	15.3
Oceanis 350	30.0	4.7	175	34	507	16.8
Dehler 36 CWS	30.0	5.5	203	42	667	20.0
Catalina 36	30.0	7.0	253	40	639	16.3
Northshore 33	29.5	4.25	165	40	512	18.2
Lexcen Eureka	29.2	2.7	108	*	450	21.7
Hallberg Rassy 36	28.6	7.5	320	44	678	16.5
Vancouver 36	28.5	9.1	395	39	767	16.0
Saltram 36	28.2	9.1	403	38	561	12.0
Jeanneau Sunrise	28.0	4.6	209	32	542	18.3
Passage 33	28.0	4.6	209	47	510	17.3
Nicholson 35	26.7	7.0	365	47	736	18.8
Adams 31	25.7	4.4	259	*	476	16.6
Beneteau 285	25.0	2.8	179	28	449	21.0
S&S 34	25.0	5.0	320	48	*	*
Vancouver 28	22.1	4.0	371	37	375	14.0
Vertue	21.5	4.2	425	47	375	13.4
*Data not available						

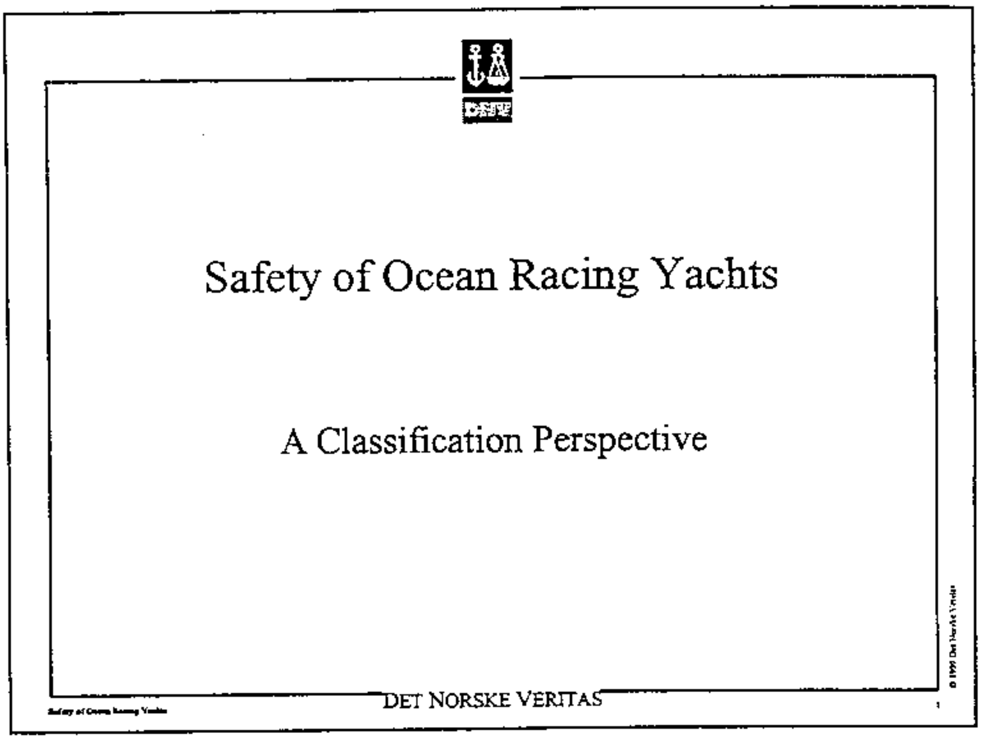
Figure 15

Aspects of Classification of Yachts

Mr John Donovan

Det Norske Veritas

North Sydney



Safety of Ocean Racing Yachts

A Classification Perspective

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Safety of Ocean Racing Yachts

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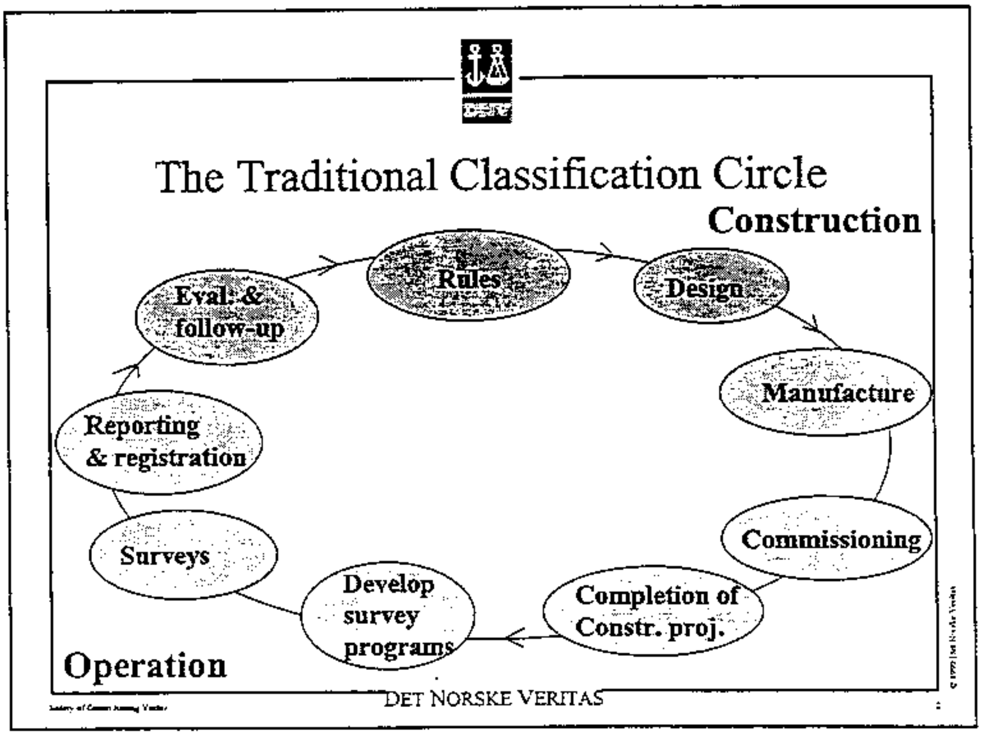

The Traditional Classification Circle

Construction

Rules

Design

Manufacture

Commissioning

Completion of Constr. proj.

Develop survey programs

Surveys

Reporting & registration

Eval. & follow-up

Operation

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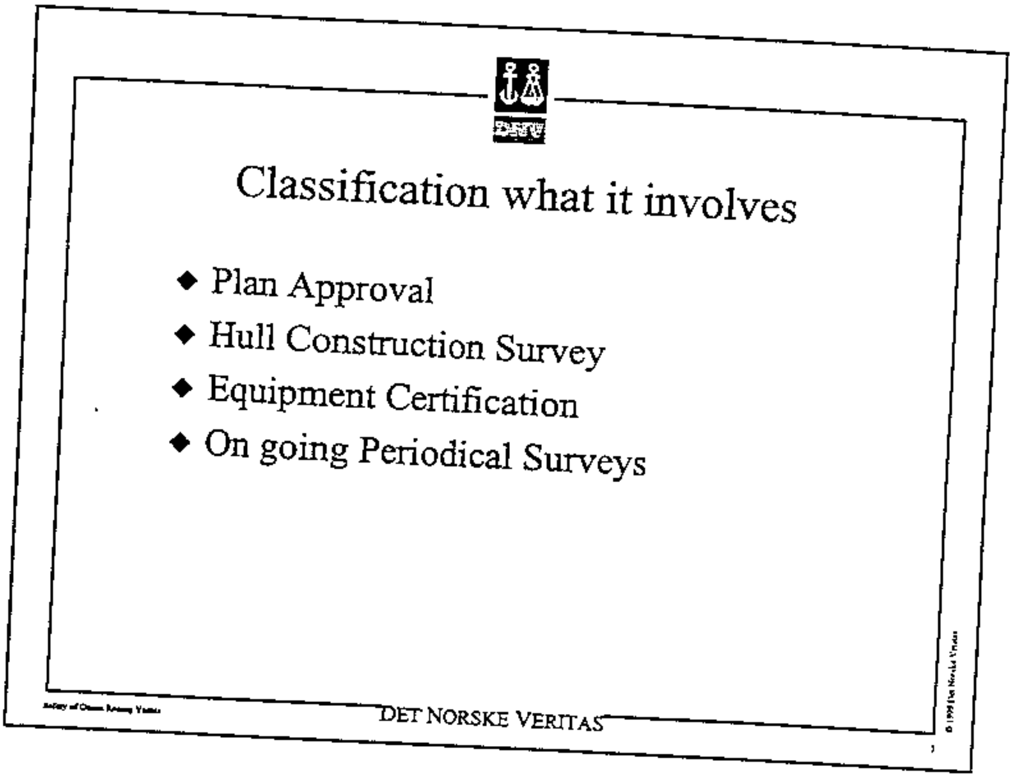

Classification what it involves

- ◆ Plan Approval
- ◆ Hull Construction Survey
- ◆ Equipment Certification
- ◆ On going Periodical Surveys

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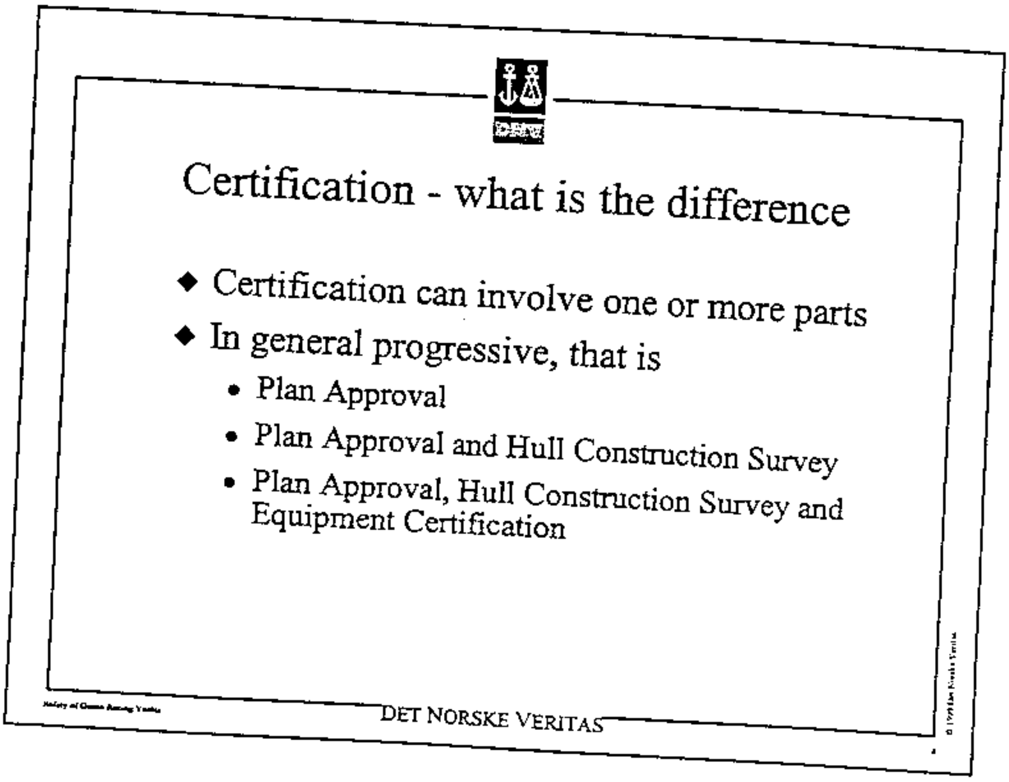

Certification - what is the difference

- ◆ Certification can involve one or more parts
- ◆ In general progressive, that is
  - Plan Approval
  - Plan Approval and Hull Construction Survey
  - Plan Approval, Hull Construction Survey and Equipment Certification

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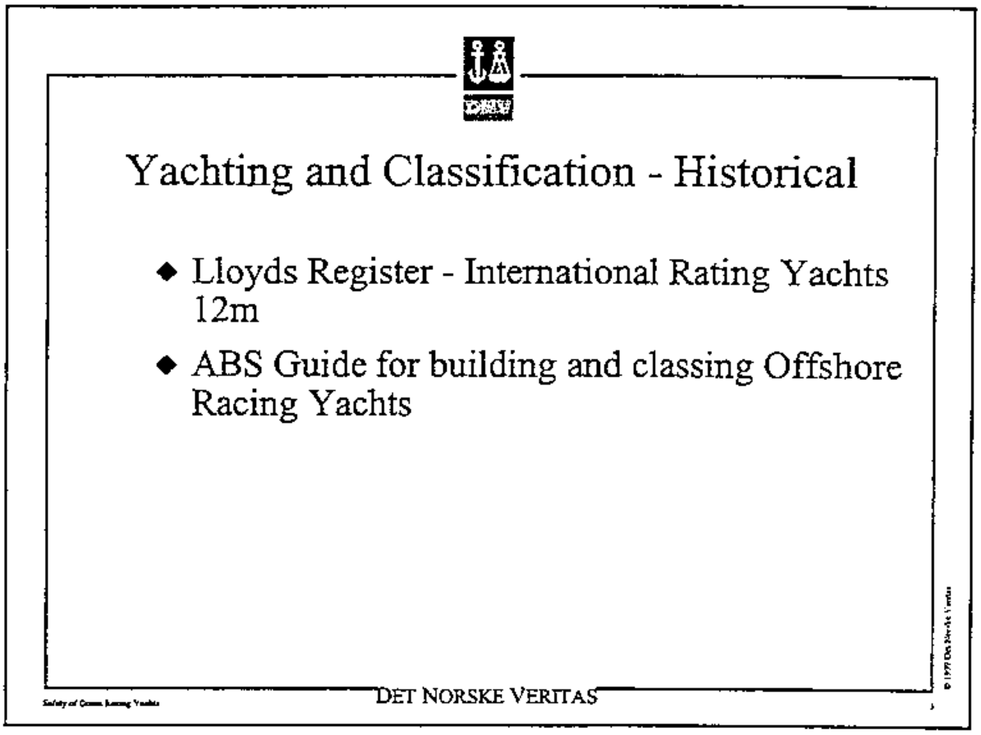

Yachting and Classification - Historical

- Lloyds Register - International Rating Yachts 12m
- ABS Guide for building and classing Offshore Racing Yachts

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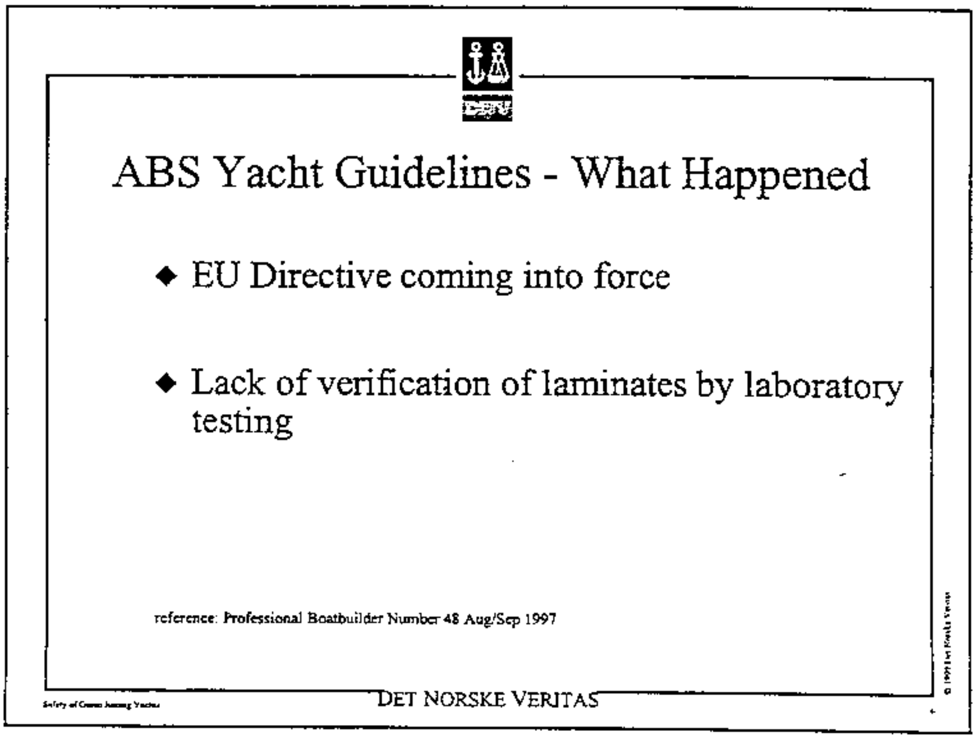

ABS Yacht Guidelines - What Happened

- EU Directive coming into force
- Lack of verification of laminates by laboratory testing

reference: Professional Boatbuilder Number 48 Aug/Sep 1997

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EU Directive for Certification

- Voluntary compliance mid 1996
- Compulsory compliance June 16 1998
- Will enforce compliance with ISO standards when they are completed

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ISO Standard - Relevance to Australia

- EU Directive enforces compliance with ISO Standard
- American Boat and Yacht Council (ABYC) publishes American Standards for boat construction
- ABYC is secretariat for US Technical advisory group to ISO
- We may see one open market with regards to requirements for Europe and America

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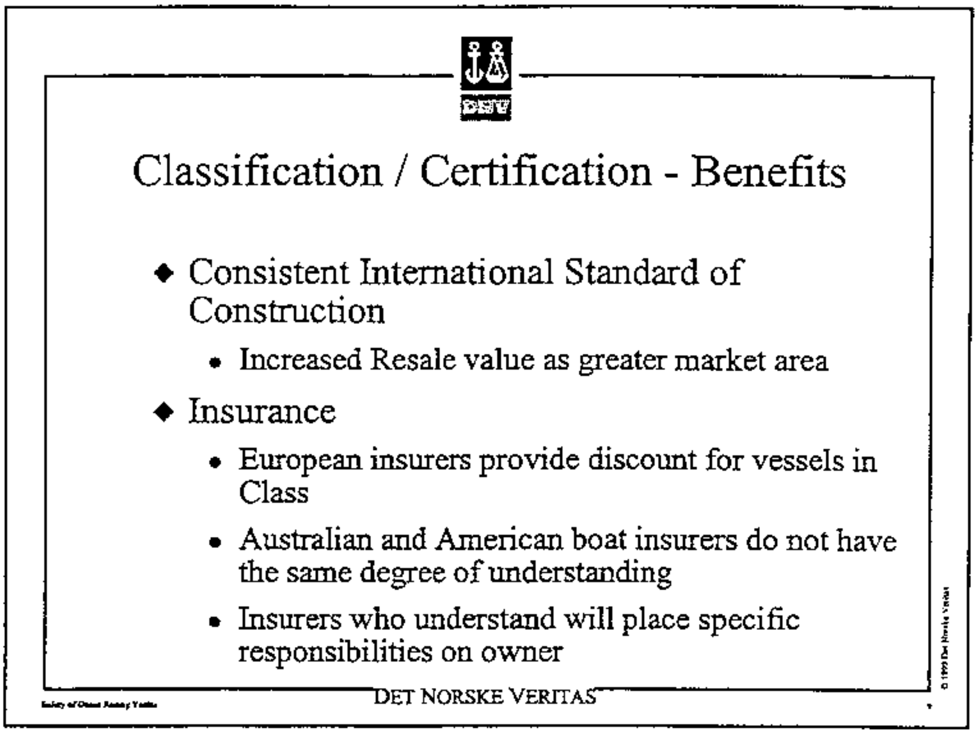

Classification / Certification - Benefits

- ◆ Consistent International Standard of Construction
  - Increased Resale value as greater market area
- ◆ Insurance
  - European insurers provide discount for vessels in Class
  - Australian and American boat insurers do not have the same degree of understanding
  - Insurers who understand will place specific responsibilities on owner

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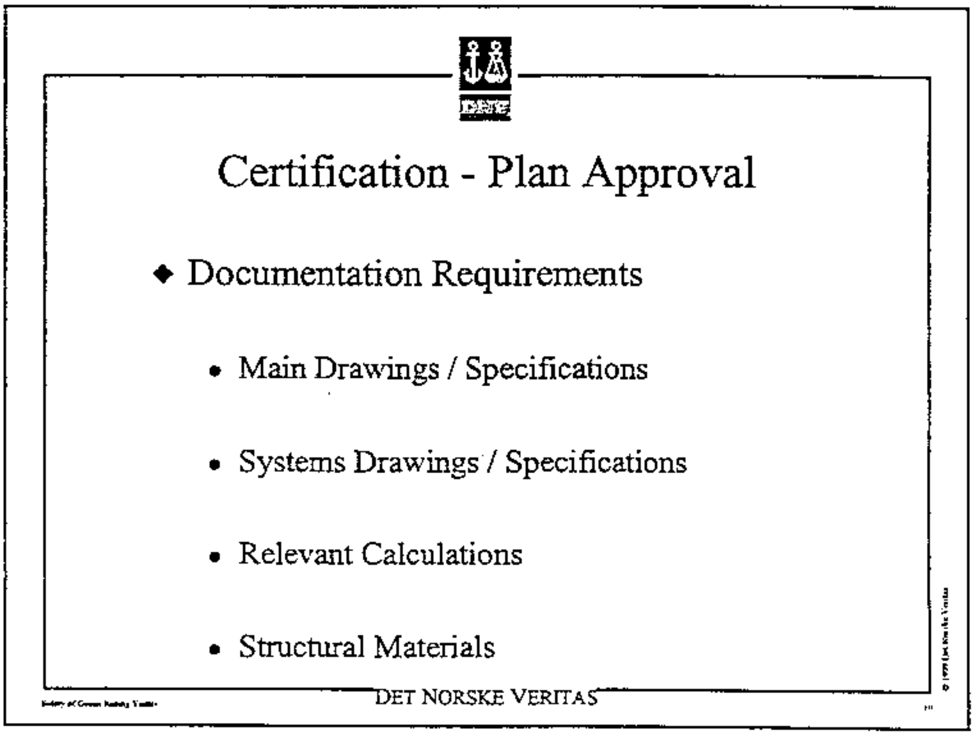

Certification - Plan Approval

- ◆ Documentation Requirements
  - Main Drawings / Specifications
  - Systems Drawings / Specifications
  - Relevant Calculations
  - Structural Materials

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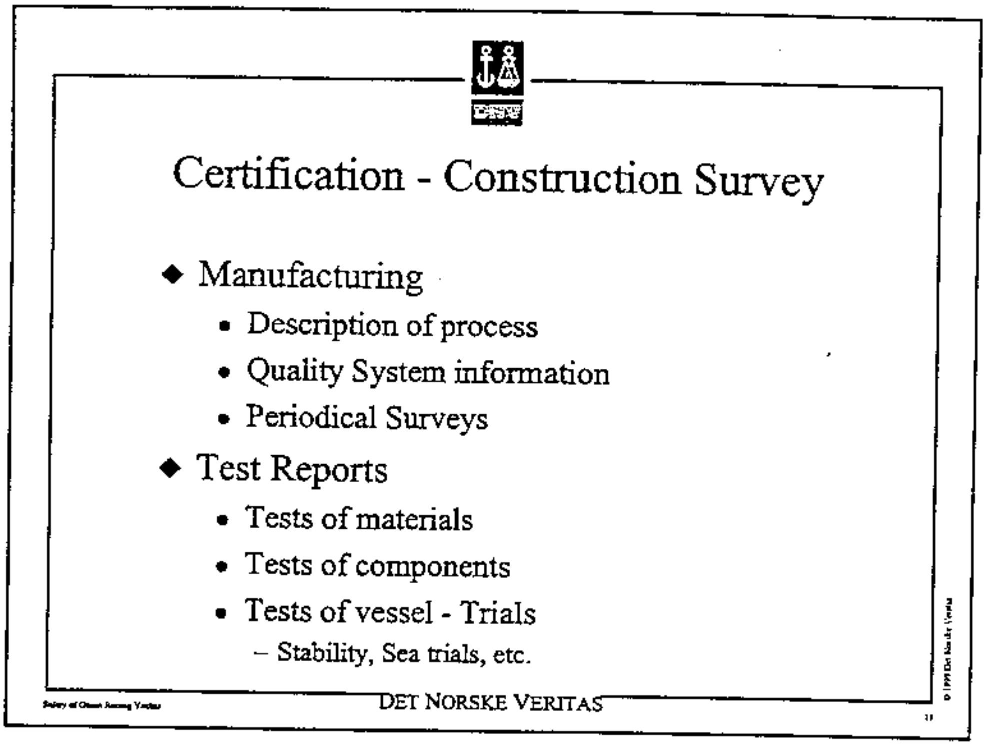

Certification - Construction Survey

- Manufacturing
  - Description of process
  - Quality System information
  - Periodical Surveys
- Test Reports
  - Tests of materials
  - Tests of components
  - Tests of vessel - Trials
    - Stability, Sea trials, etc.

Safety of Ocean Racing Yachts

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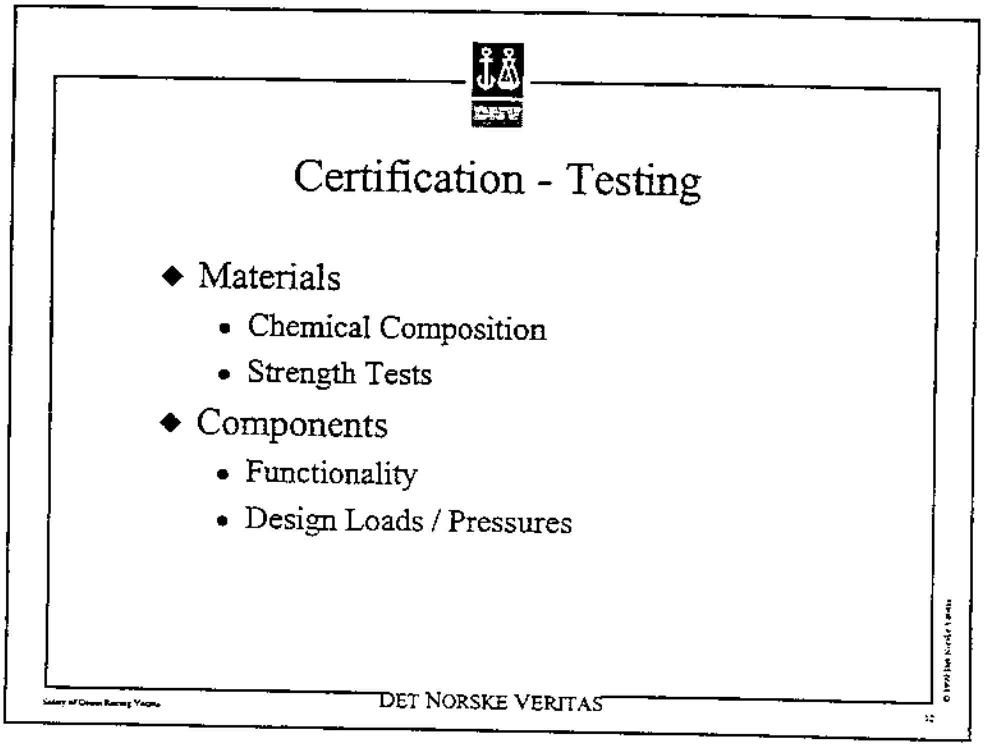

Certification - Testing

- Materials
  - Chemical Composition
  - Strength Tests
- Components
  - Functionality
  - Design Loads / Pressures

Safety of Ocean Racing Yachts

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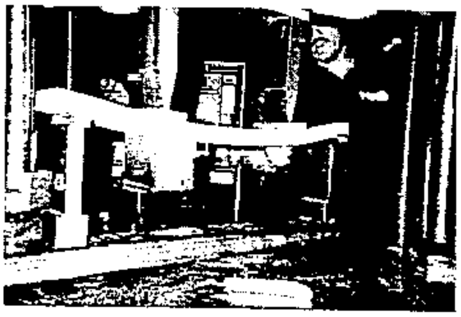
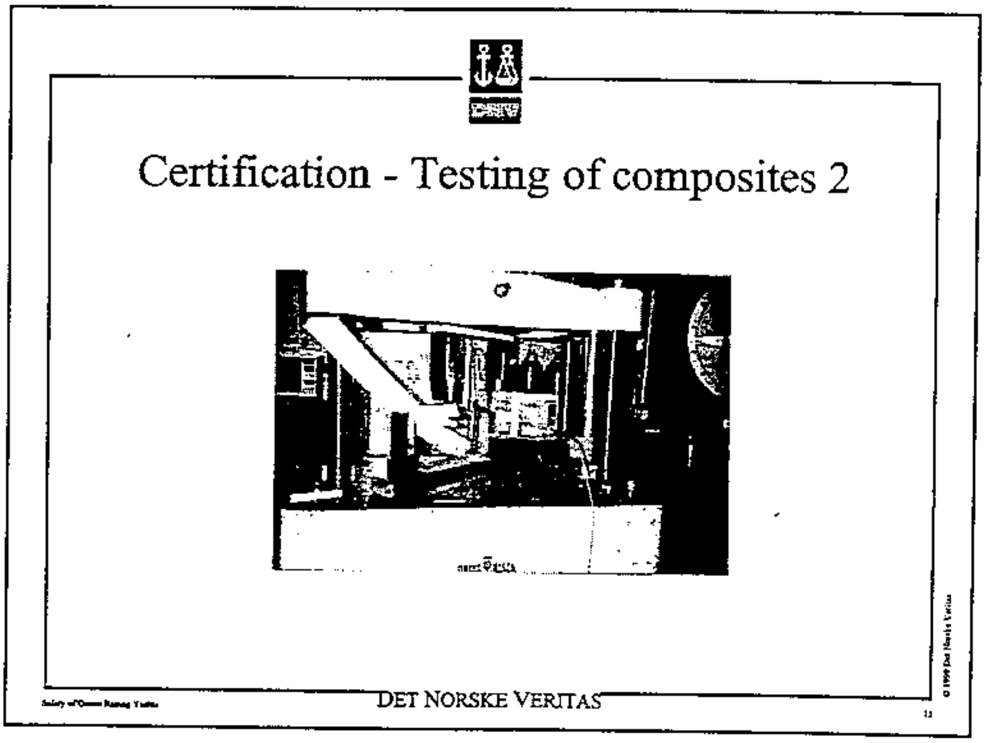
Certification - Testing of Materials

- Metals
    - Chemical
    - Isotropic tensile tests
- Composites
    - By definition many parts
    - More difficult chemical tests
    - An-isotropic
    - Test samples

Certification - Testing of composites 1





Certification - Testing of composites 2

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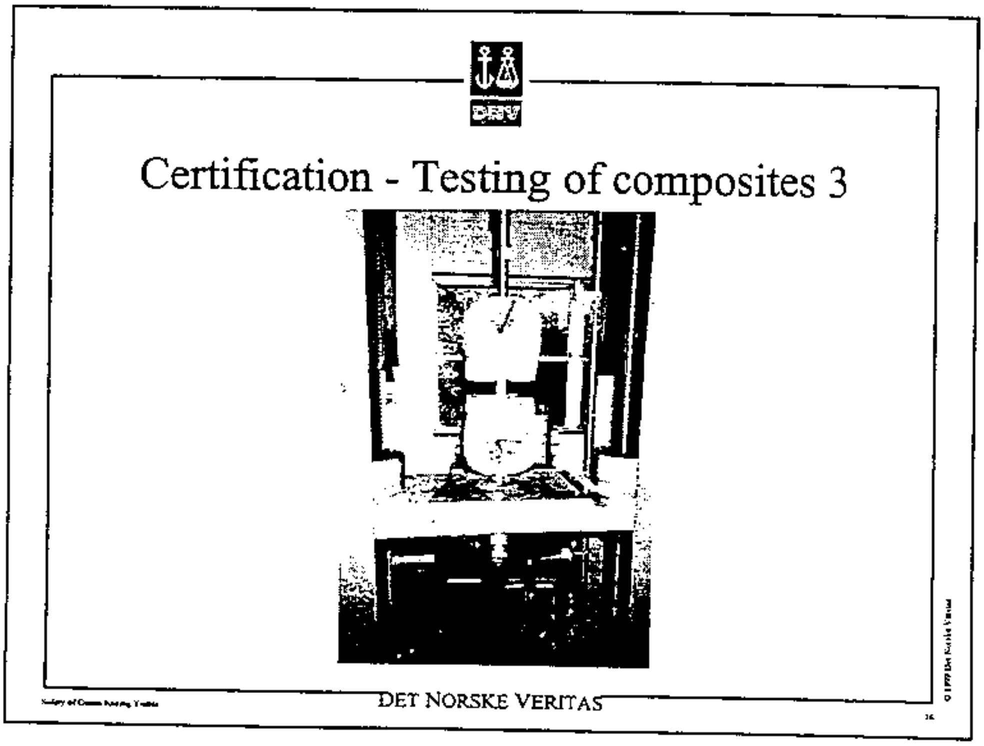

Certification - Testing of composites 3

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Classification - Approval of modifications

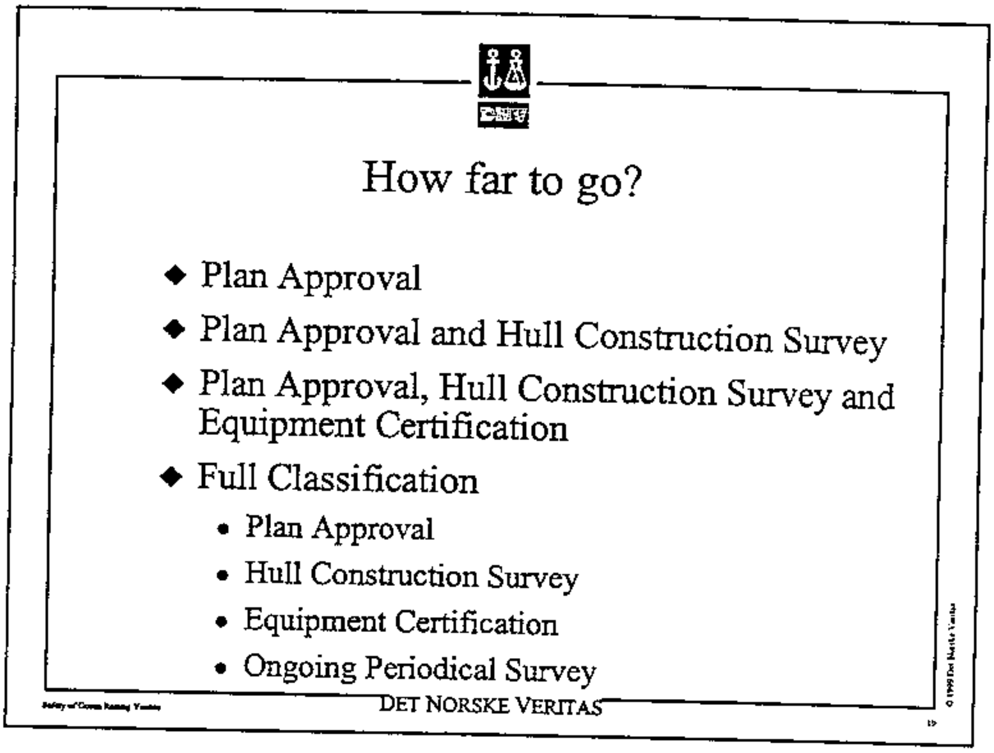
- All repairs and modifications must be approved and witnessed by the Society
- If they are not approved by the Society then vessel is no longer in Class
- Understanding Insurers will have a clause to state that if vessel is not in Class it is not insured

Where to go?

- If Certification / Classification is required
- Need to get Authority
  - Law from Federal / State Government enacting ISO standard as minimum requirement for all yachts

  or

  - Requirement for vessels to be certified before Race Committee accepts entry
- What are the implications of each choice?



How far to go?

- ◆ Plan Approval
- ◆ Plan Approval and Hull Construction Survey
- ◆ Plan Approval, Hull Construction Survey and Equipment Certification
- ◆ Full Classification
  - Plan Approval
  - Hull Construction Survey
  - Equipment Certification
  - Ongoing Periodical Survey

DET NORSKE VERITAS

Value and Quality of Experience of the Skipper and Crew

Mr Alastair Mitchell

Maritime Consultant to the Australian Yachting Federation
Sydney

INTRODUCTION.

Whatever the N.S.W. Coroner will eventually find in his report of the recent Sydney / Hobart Race, it is very clear that many, many things went right. The courage, seamanship, determination, skill, decision-making and sheer bravery of the rescuers, most participants and those rescued were extraordinary.

At the end of one of the T.V. reports on this Race, one of yachting's most experienced participants, and a participant in the Race and rescues, summarised that " we must learn from it".

So, are we going to? - No, or only comparatively few will. The value of the "cautionary tales" about the Race is inestimable but will be forgotten, indeed if ever they are properly appreciated at all, and time will soften the nightmares.

Will it happen again? - Yes, somewhere in another ocean race. Similar conditions arose at least in the 1979 Fastnet Race and the 1988 Bicentennial Round Australia Race. We have had some pretty bad Hobart races during that period too. It seems possible that these three races all suffered from a similar meteorological anomaly.

What can we do about it? Is the answer better boat design, more equipment?

Personally, I doubt it. No legislation or further regulation will solve what I believe is primarily a human and cultural problem which affects ocean racing worldwide.

In many parts of the ocean-racing world and here, regulations already are in place for the carriage of safety equipment. In none of these places is there regulation requiring anyone to know how to use any of the equipment however, or manage the boat.

The sport of ocean racing learned a lot for a while, from the 1979 Fastnet Race Report. Technical and equipment changes have been instituted as a result. The major failures seemed to stem however, from the "people failures". Only one boat was lost in that race I believe, though many lives were lost trying to escape the horrors of the storm in liferafts.

The debriefings after the Fastnet Race did much to educate the ocean racing public as have similar opportunities arising from other races, and training and experience have been regarded as the most likely effective measures for reducing loss of life and boats, even most recently in an exhaustive study on behalf of the N.Z. Maritime Safety Authority. Yet not very many seem to actually learn much from the epics which occur from time to time. Similarly some, who do learn, seem not to remember the lessons for long, and some learn the wrong answers which they repeat with great skill.

I like and often use a quotation from Joseph Conrad's writings of the sea, " ships is all right, it's the people in 'em that's the problem".

EXPERIENCE with the EQUIPMENT.

People have been going to sea for centuries in what would appear to be unsuitable boats. Joshua Slocum was one such, as was Captain Cook. Robin Knox-Johnstone and Chay Blythe rowed the North Atlantic and Bombard drifted the South Atlantic in a rubber dinghy. I doubt that any of us would regard a rubber dinghy as a suitable boat for crossing oceans, and the "Spray" and "Endeavour" would fail any self-righting test required today, and both had movable ballast.

Such is the voluntary regulation of our sport that I think it would be difficult to sneak some unsuitable vehicle into an offshore or ocean race. I would find it hard to accept that any yacht allowed to enter in any offshore or ocean race should not be there.

But, any vessel can be overwhelmed by circumstances. It is the "people in 'em" who I believe are the weak or strong link in the safety chain.

The Australian Yachting Federation publishes "Special Regulations" for Racing Boats which are based on the O.R.C. Special Regulations governing structural features, boat equipment and personal equipment. These Special Regulations are in effect lists of safety equipment, applying to various types and use of racing craft. The sort of safety equipment carried needs to conform to Categories of Events, such as for ocean racing -

- **Category O:** Trans-ocean races, where boats must be completely self-sufficient for very extended periods of time, capable of withstanding heavy storms and prepared to meet serious emergencies without the expectation of outside assistance.

- **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.

Most of the true ocean races run from Australia and through the Australian S.A.R. area (some 12% of the Earth's surface) are Category 0 or Category 1 races.

The "cultural problem" which I proposed earlier in fact becomes part of an ethos, which I might perhaps describe as the challenge, sailing in ocean races as a sort of rite of passage towards the heroism of adulthood. We share this trait afloat with many other peoples worldwide. But if one were to read the above descriptions of the categories of the events undertaken when ocean racing with one's eyes open, surely some concern should arise as to "what are we going to do if...."

I believe that the above definitions are mostly regarded as a sort of coded heading to assist one to select the required safety equipment category, equip the boat accordingly so that we may enter the ocean race, with little sense of wonder at why the regulators make us carry it all, or what it all actually does rather than looks like it does.

Ocean racing is about racing after all, going fast and preferably faster than anyone else. So we add to our equipment some expert racing crew and helmsmen/women who have honed their skill on the inshore race track in small boats, often Olympic or International Classes of dinghy.

These lessons of the inshore track are applied offshore. That is why we see so often, ocean racing yachts in storm conditions sailing triple reefed, but by inshore "jiffy reefing", with great bags of unwanted sail hanging from the boom and perfectly sited to catch any wave dumping on board, thus ripping the sail, perhaps flattening the boat and even dismasting it.

That may also be why we see boats being driven to the brink of catastrophe, leaping waves and crashing into the troughs with little thought as to the snap loadings on rigging and massive strains being put on the structure.

People fall overboard, that is outside the lifelines but remain attached to the boat by their harnesses, with luck. Some are injured by being thrown from side to side of the cockpit although wearing harnesses. Clearly they do not know how to use their harnesses and have little understanding of the force of even quite small volumes of water travelling at speed. The force of these loadings snaps harness lines and can pull apparently secure fittings from the deck.

Such is the concentration on speed, that few have researched how to slow their boats down, even heave-to. However,many boats of modern design will not heave-to or need constant attention in such a mode, something usually discovered in the wrong place at the wrong time, - when you need it. Whilst not being able to heave-to simply reduces the armoury of solutions available for use, some forethought and therefor fore-knowledge is always useful. Few of the same people would drive a car which had no brakes. Running at 20 knots or more, under bare poles, before a storm is fraught with danger, but so often I hear, as after a Hobart race in the early 80's, that the crew could not get the boat to go slower. Trailing warps or a drogue, even using a sea anchor, one never sees nowadays, yet such efforts used with skill and understanding have saved many racing boats.

"PEOPLES'" EXPERIENCE.

It seems that most ocean racing crews and some skippers may have gained what skills they have in the wrong place and in the wrong way. They have served their time in the manner of the current requirements of the commercial Uniform Shipping Laws Code of Australia, by lassoing bollards from a ferry in the harbour, so that they can one day be a master of that ferry, certificated to work up to 100 miles offshore around the Australian coast. Sea time is the thing, not the value and quality of that sea time.

The same people buy the boat they are going to use, for a variety of purposes, but mostly in the inshore arena or only occasionally, coastal. Here again, this ethos thing creeps in. Nice big windows are great for pottering round in comparatively sheltered waters, but become a major liability offshore and particularly ocean. The A.Y.F. Special Regulations used to cover this problem specifically by requiring storm covers for over-large windows, that is windows which are not necessarily very large, but beyond a certain size (0.2 sq.mtrs). I have anecdotal tales to tell of boats not fitting these in time to avoid damage and flooding, even sinking, and others which didn't carry them because their windows were very slightly smaller in area than the prescribed area limit. What we then get is a boat which has spent more than 99% of its time in sheltered water, and sailing short daylight races or cruising on sunny days, entering an ocean race because it has the right equipment on board.

The current "Special Regulations" no longer specifically mention the possible problems associated with windows and capsize. They require only "that boats shall be strongly built, watertight and, particularly with regard to hulls, decks and cabin trunks, capable of withstanding solid water and knockdowns. They must be....fully seaworthy." I wonder what all that means to many sailors. I wonder if they realise that the integrity of the deck area of a boat is equally as important as the hull. Perhaps, designers and builders should make sure that the structural strength of decks and coach roofs/cabin tops and their often all-embracing Lexan windows equals that of the hull.

EXPERIENCE of the WIND.

When commenting on the starts or participating in races, I have often heard, " we've got 30 knots across the deck here, mate..." In an ocean race, 30 knots of wind is quite common, I would say. Over the last twenty years, I would also hazard a guess that 50 knots of wind would not be uncommon during many Sydney/Hobart Races, at some stage, and average on World races. Anemometer readings are great in the bar but valueless at sea.

Admiral Beaufort did an extraordinary job in 1805 in devising his Scale. 30 knots of wind at sea level can be about 40 knots at the mast head. His Scale works on a series of ratios which are extremely practical, even today, in reflecting what is actually happening to a boat. For instance, sailing in Force 3 - 4 is fun, exhilarating with a wind speed "across the deck" of around 7 - 16 knots. In kilograms per square metre the pressure is around 1.3 - 3.2, a wide range but not uncomfortable to manage. Force 5 represents some 17 - 20 knots of wind, but the pressure against the sails and rig jumps to 6.3, twice that of Force 4. In sailing terms, when one is not reacting to digital readouts, a boat is beginning to become under stress at Force 5. Because with our magic modern materials nothing tears or breaks, doesn't mean that it will not do so shortly. Force 5 is the beginning of my scale of "rough weather" and because of the rapidly increasing pressure it does not take much of an increase in wind speed (perhaps 5 - 7 knots) to double the pressure again. 30 knots "across the deck" is not unusual, but in fact the boat is now under some considerable stress and the answering comment to such a cry should be "mate, take care" - but we don't.

I suppose that the point I wish to make here is that all this has been known since before 1805. Safety afloat is an attitude of mind, an enquiring and wondering mind. Very rarely are the boats at fault. We don't batten down for an ocean race, even ones where the race forecast is for strong winds. We simply seem to go sailing, in anticipation.

EXPERIENCE of the BOAT.

One cannot design an ocean racing yacht, unlike racing cars and many dinghies, for a predetermined track. Certainly ocean races around the World are likely to follow the course that sends them down wind as much as possible. Thus the overall shape of these boats is that of planing dinghies, with a beam of nearly one third of the boat's length, perhaps. It takes an exceptional wave, or equipment or structural failure to capsize these boats and an equally exceptional incident to right them. They all however, apparently conform to the self-righting requirements of the different races in which they are entered.

It is not a good enough excuse in my book to complain that while running in winds of around 25 knots, with the singlehanded skipper down below , the autopilot failed and the boat broached and capsized and stayed there until rescue arrived. Yet such a boat might fulfill the Category "O" requirements to the letter.

Since the epic rescues of Dubois and Bullimore a few years ago in the Southern Indian Ocean, many of these wide beam boats have fitted escape hatches in their transoms, so that extended periods can be spent (but hardly in comfort) in the hull in the not uncommon event that capsize occurs. I have heard that Autissier had to be woken up this time by a hammer being thrown at her upturned hull by her rescuer, and this some 2,000 miles from Cape Horn. She apparently exited by such a hatch.

Also, if anyone remembers the T.V. coverage of the 1996 Southern Ocean rescues, guess whose boat was a bit tender when first launched, so more weight was added to the keel.

I wonder if these practices are acceptable in terms of the O.R.C. (World Body) Category O description given above. Perhaps they are?

The self-righting capability of ocean racing yachts has been a subject of interest and concern for probably hundreds of years also. I remember there being considerable difficulty in persuading some of the R.N.L.I. Lifeboat crews to accept their new (in the 1970's) self-righting lifeboats. They viewed them as unstable, which was true when compared to their older Watson boats. More recently, at a demonstration of the most modern U.S. Coastguard lifeboats, visitors were initially appalled at how tender they appeared in calm water. Earlier in the century we went the other way and produced what are viewed nowadays as "lead mines". These comparatively narrow beamed yachts were so encumbered with huge amounts of lead on their keels to keep them upright when sailing to windward and to make them self-righting, that some of them hardly rose to any swell or waves. I suppose, the designers' art developed from carving models based on personal experience, through building models, to drawing scaled plans. Their art has produced some of the most wonderful works of mankind ever seen and some, though very few, real horrors. Design development produced boats which could both stand up to their sail area and which were sea-kindly and self-righting.

Few ocean racing boats are capsized by the wind. They are blown flat occasionally as a result of sail handling problems and sudden wind shifts and so on. But capsize at sea is really quite common as a result of wave action and course holding problems. McIntyre got it all on film during his Round the World Race, and was obviously shocked at what was an experience he had prepared for. Interestingly, his boat was able to continue and finished the race in good order.

Compromise is obviously essential in yacht design and if a designer wants the business, I suppose that they must satisfy the customer's requirements. I suspect that I know what the Dubois, Bullimore, Autissier fraternity want, - speed. It seems that it was not only speed that the Australians Adams, McIntyre, Kiernan, Gosson and others looked for. They also had to sail twice round the World in order to enter their Races. Yet, despite the spending of millions of dollars, such races are won at the eye-watering average speed of just over 8 knots, if you finish. In the 1960's the first Round the World race was won at an average speed of about 4 knots and, as the race leader refused to cross the line but went marine bush, that race was won by the second yacht some considerable way behind him.

So much money has been spent on technology in the past 40 years in achieving a 4 knot increase in speed, and the limits of prudence pushed so far that I now think that these singlehanded Round the World races have reached a fatuous stage. Very few of the Class 1 boats which started this years Around Alone Race are still in the race. Gear failure, structural failure and capsize has apparently claimed most of the others.

In less of a fantasy world, our more normal ocean racing yachts are self-righting, at least sufficiently so to be comparatively safe. Safe that is unless "the people in 'em " demand more of the boat than it was designed to take.

Yachting in general, and ocean racing as a part, have gained much from the Sydney Harbour 18 Footers. The innovations permeating through the sport from that Class are incalculable. The Rules of the Class - 18 feet long and the races start at 14.00 hours. Regulation beyond that level would have possibly killed the Class off, after time. However when one sees what is in effect, an 18 Footer setting of on a World Race, even though it may be equipped well and have survival systems, escape hatches and a fit skipper and/or crew, I wonder about the stability of those on board. I already would suspect that the boat will be stable upright or upside down.

Some regulation by the sport of the sport is probably necessary to protect us all from dare-devils. It has proved to be very difficult to achieve such regulation without stifling innovation, or worse, forcing some traditional view on others.

The business of designing and building fast ocean racing yachts is I believe similar in technology to that of the aircraft industry, to me "space age". However the designers and builders are not allowed to hide their disasters. Their prototypes appear on the public and media stage at the Start and the driver either makes it to the Finish or doesn't. Sometimes, like the old days, the model (in this case a full size model) works and becomes a legend, sometimes not.

But, make no mistake, I believe that many of the drivers of ocean racing yachts are simply technologically advantaged jockeys, with iron nerves and the reactions of a western gunfighter.

It is inevitable that when working at this level of technology, structures will break and bits will fall off. I, too, object when this happens in my back yard however and wonder if a more accessible test track could be found before entry to World races is accepted.

The EQUIPMENT.

The greatest failing of equipment aboard boats in peril offshore is a consequence of the operator's actions, abuse of the boat or the operator's understanding of what they are actually asking the boat to do, and whether it can do it without damage or, just having the right equipment on board to use.

I have already mentioned the techniques for slowing a boat down or securing it in storm conditions. Reaching off, with sufficient steerage speed, not too fast, seems to be the most anticipated proposal. If the rig is down and the engine unusable for any reason, what then - just bob around? The end result of that will be a possible further capsize. Add a man over-board to that scenario and the only thing which might keep the boat within reasonable distance of the man is possibly a sea anchor of some sort. That suggestion I have personal experience of, and running trailing warps, including the anchor-warp and chain to try to slow the boat. None of this equipment is detailed in the regulations, so I doubt if many boats carry much suitable equipment beyond the minimum, any more.

Communications are always a problem. Most yachtsmen understand a bit about radios, but it seems that not many understand the importance of a properly tuned aerial. A pre-arranged straw poll of the race entrants for an ocean race in the 1980's discovered some fantastic (and some unlicensed) radio equipment on board the yachts. On testing the aerial assemblies, many were found to be likely to degrade any signal drastically. All were mast or rigging fitted aerials and of course all had an alternative placement for the event of the mast falling off. Also of course, no one knew that they already had problems and would have more problems if the mast fell and they had to use the alternative fitting.

It really is the old story, of having to carry safety equipment, but not having to carry anyone who really knows how to use it, or who has done what we now call elementary "risk management". Epics in the past have shown that "people" don't know much about their liferaft and its limitations, about deploying their EPIRB. Hatches aren't secured. I don't remember when I last saw a strum box fitted to any bilge pump intakes.

Lifejackets are only put on when the disaster strikes, and we blame that on the opinion that most lifejackets are cumbersome and one can't work the boat in them.

I don't think any of these are "boat" problems.

IT'S ALL BEEN DONE BEFORE.

Really, it has all been done before, not usually by the same "people" each time, but nevertheless each time something goes wrong, it has also gone wrong before. We are getting better at the business of ocean racing though. Quite large numbers of entrants have learned their limitations and if possible now retire or seek shelter before the worst arrives rather than press on. Sooner or later however, given regular participation, one will encounter a storm at sea with nowhere to go, but to try solely to survive. To stand a reasonable chance, it helps to have considered the problems beforehand.

Training and the right experience are readily available and often from the participants own Clubs. Some training is recommended in the A.Y.F. Rule Book. But of course we have read all the books in "Boatbooks" including Heavy Weather Sailing, and attended that night at the Club when some survivor told us what is was like. We have also got several hundreds if not a thousand or so miles under our belts and we can cope offshore, even though our experience and focus has mostly been inshore.

Let me tell you that when it happens, most people can't cope. When the chips are down, the sheer noise of a demented wind, irrespective of whether you still have a rig or not, the slamming of the waves against the hull, the solid spray and water on board, driven by a storm that can and does strip the clothes from your body and the sense from your mind, can make fools of us all.

At the very least, if one has been trained in and rehearsed the procedures (without the noises off, although these are available at the Maritime College in Launceston), one has some hope of getting through the drills intact and to safety. The cautionary tales of those who have been there and survived are invaluable and an excellent way of learning without the traumas of bitter experience. If one hasn't got a tried plan in such circumstances one may not long have a life, as in extreme circumstances, "people" very often behave out of character and forget reason.

In over 80% of the epic rescues and survival stories that I know of, the boats have been all right after the event. Some of those which subsequently foundered probably did so as a result of being left open to the elements when they were abandoned.

But to me, it is not strange that the yacht often survives the occupants after such storms. The designer designed it to float and it usually does through the thick and thin of the storm and in spite of mishandling.

I suspect that this paper may seem like some sort of diatribe against my fellow yachtsmen and women, and to some extent it is. After around forty years in the training business and well over fifty years as an enthusiast about boats and the sea, the luck and incompetencies of my fellows and the mistakes I have made astonish me still. Nevertheless, I am still convinced that training, combined with guided experience, remains the only effective solution. Common sense ain't common enough.

As I have said, we are getting better at this business of ocean racing and many competitors seem now to realise their own limitations in good time, and before the worst happens. But you can't stop an ocean race, as one can a road race, if the conditions get dangerous.

I fear that it will continue to be the people it who get the yacht and themselves into trouble, not simply by entering, but by lack of realistic understanding of the undertaking.

Operational Decisions which the Skipper Must Make

Mr Michael Cranich

Barrister and Yachtsman

Sydney

(No written paper was prepared)

The Lucky Yachtsman

Mr John Quinn

Yachtsman and Owner

Wahroonga

My story is not new it dates back to the 1993 Hobart Race. But I guess it is similar to some of the frightening experiences we hear about from last year's race. In the 93 Hobart Race I was sailing my J35 Mem. At the time, the J35 was a competitive boat under the IMS handicap, although it was designed in 1985. Mem had been selected with Atara to form the NSW "A" team in the Southern Cross Series. Our team was leading the series going into the Hobart Race.

The race started in a good North Easter with a fair amount of East in it. A Sou'Wester came in at 20-knots at around 1700 hrs when we were just South of Coalcliff. The wind gradually increased and was gusting to above 30-knots by midnight. Generally it was W/S.W. occasionally heading us. Mem was sailing at around 8.5 knots with one reef in the main and no.4.

Throughout the next day the wind gradually headed to S.W. and increased. We lost our wind gear so the wind speeds are estimates or what others have told me. We had changed to the storm jib and put a second reef in the main by midday and Mem continued to average above 8-knots. The seas had increased so she was pounding fairly heavily.

During the radio "sched" at 1500 hrs we were well positioned. The majority of the fleet was further East of the rhumb line. Our teammate Atara was also well placed.

At around 1900 hrs we were South of Merimbula and about 50 miles East of the rhumb line. The wind had increased to over 40 knots and we were beginning to feel the impact the Bass Strait seas. We dropped the main and prepared to set the trysail. However, we found Mem was still sailing course under storm jib only at above 7-knots so we put the trysail below. While we were changing sails a large rogue wave came from the beam and broke over us. I was tempted at the time to turn, drop all sails and run for shelter. However, we were part of a team and the adrenalin was pumping.

The sea was now so rough we could no longer steer from the side deck, so the helmsman was sitting on the cockpit floor. I took over the helm at 2200 hrs when the wind was gusting at over 50-knots. In fact the crew of Atara told me later that they had gusts of over 70-knots. We were travelling at over 7-knots - on course slightly "started". The sea was now around 4 metres and little Mem was slamming fairly heavily. There was no way of slowing her more but we were steering fairly easily through the waves.

At midnight we were 45 miles ESE of Gabo Island and that's when it happened. Another rogue wave hit us on the beam and broke over us. How large we don't know; nobody saw it. It is clear that the top of the mast and the top spreaders went into the water and we suspect the lower leeward spreader as well. Peter Rothwell was tipped out of his bunk and walked along the cabin side and roof where the spinnakers ended up. The top opening icechest was emptied onto the floor.

On deck 3 of us were catapulted and washed across the leeward side of the boat and into the water.

John Marwood went around the mast and across the foredeck.

Teki Dalton was washed out of the cockpit.

I had the force of the helm thrusting to leeward and was catapulted and washed over the rails. I felt the safety harness take up and then break. I had grabbed a line as I went overboard, probably the spinnaker sheet but this was yanked out of my grip as the boat righted herself.

Jeff Starling fell off the weather rail and was suspended by his harness, hanging with his legs in the water while little Mem was on her side. The force and speed of her righting herself flicked him under the weather rail.

Four of us were in the water. Of the 5 on deck only Simon Madzair remained on board. He had been thrown over the coach house.

So I was in the water as the boat drifted away pretty quickly. The people below started the motor very quickly but they had to get all the lines out of the water before using it. I saw someone jump to the stern to get the safety gear away but the boat was 20 yards away before he got there.

Gradually the lights of Mem disappeared and I was on my own. I was in the water for 5 hours from midnight to 5am.

I am only here today because of the intervention of God in the form of the incredible navigation and seamanship of the crew of "Ampol Sarel" who drifted the giant tanker down the wind line almost on top me. And the courage of the crew of Atara who was looking for me, during the gale, in a boat that was badly damaged.

I was nearly killed, despite all my experience, because I made two basic mistakes of seamanship.

> First, I should not have entered the Sydney to Hobart in a yacht as light as the J35. They are an ideal fun, club, regatta and coastal racing yacht. Terrific for the racing I do most Saturdays. But I believe they are not safe for one Hobart in every 7.
>
> Secondly, when the first rogue wave came on board I should have realised that we were running into conditions that were likely to be beyond the limit of Mem. As the seas increased I should have turned, dropped the jib and run with warps until we could shelter, behind Green Cape.

Yet by today's standards I feel that the J35 is quite a moderate boat. I believe that a number of the new I.M.S. boats and their I.O.R predecessors are not safe boats for racing in the Tasman Sea and Bass Strait.

The history of the severe Hobart Races since 1956 tell a story: -

In 1956 - 30 boats started and 28 finished (93%)
1963 - 44 boats started and 34 finished (77%)
1970 - 61 boats started and 47 finished (77%)
And then
1977 - 131 boats started and 72 finished (55%)
1984 - 150 boats started and only 46 finished (31%)
1993 - 108 boats started and only 37 finished (34%)
1998 - 115 boats started and only 44 finished (38%)

Many of the reports coming back from the 98 Hobart are reminiscent of the 79 Fasnet, severe knock downs and boats being rolled, descriptions of boats remaining inverted for a number of minutes, rigs failing, crew being taken off by helicopter.

Over the same period we have seen yacht design change dramatically. The boats have become much lighter, the limit of positive stability is generally a smaller angle, crew is being used as ballast, cockpits and cabin structures offer little protection, the motion of the boats has become more severe. The rigs are significantly lighter and we are seeing high levels of failure.

The displacement to length ratios of boats of the 1950's, 60's and early 70's were typically between 300 and 230. By the early 1980's the ratio had dropped to around 190 and 180. The J35 is around 160, many of the newer boats have the ratio around or below 120. The displacement to length ratio has more than halved since the early 1970's.

I think the lightness of the modern boats is also influencing the tactics used in severe conditions. In the 60's we would reef the boats down to triple reefed mainsail or trysail then sail high into the wind at speeds below the normal working targets but sufficient to drive over or through the waves. The boat would virtually sail itself. However, I am not sure that this is a safe option for a light displacement boat. These days' forereaching appears to be the popular tactic. Pulling away and sailing quite fast while steering around the waves. The first technique to my mind requires far less attention from a tired helmsman and gives an easier motion and therefore is kinder to both crew and boat.

The limit of positive stability for the ocean racing boats of the 60's were generally above 125 degrees and frequently over 130 degrees. Whereas today many of the newer boats are just over the 115 degrees, required by the safety standards.

The crew is now used as ballast sitting on the rail in hard reaching and working conditions. Not only are they very vulnerable it is unlikely that they are getting sufficient sleep, food or water. One of our very experienced crewmembers holds a doctorate in pharmacology. On our return from our 93 race he was analysing his reactions in the emergency during which he had lost the sense of time and had difficulty concentrating. These symptoms, he tells me, are typical of someone who is suffering from low blood sugar that is hypoglycaemic, dehydration and/or has had insufficient sleep. This occurred despite the fact that we had continuously passed up drinks and various foods. In the old boats the crew is able to shelter in a deep cockpit, behind a dodger or coach house or below deck. Eating and drinking can take place in relative comfort. At least half the crew is normally asleep at one time in comfortable bunks that are generally below or close to the waterline where the motion is minimised. The heavier hulls with deep sections provide a far less violent motion than the modern light boat with flat sections.

The rig is the primary source of power for any yacht its loss takes away our ability to manoeuvre and therefore exposes us to greater risk and reduces the stability of the boat. It also exposes both the crew and hull to injury until it is cut away. The more violent movement of the boat plus the physical and emotional strain on the crew are sapping strength.

As a Yachtsman the thing I find crazy is that these problems plus others have been recognised for many years. After the 1979 Fastnet disaster when 15 people lost their lives considerable testing was carried out and a number of publications appeared that pointed out risks associated with the modern lightweight boat. The great Olin Stephens stated "modern racing boats and the cruisers derived from them are dangerous to their crews". C.A. Marchaj who's book "Sailing Theory and Practice" sits on many yachty's shelves wrote "Seaworthiness the forgotten factor", first published in 1986. In 1990-91 our own Alan Payne all but predicted the disaster of the 1998 Hobart race during an after dinner speech at the CYCA. Yet here we are in 1999 with a handicapping system which does little to discourage unsafe practise. I hasten to add that I know that the IMS racing boat is different to the IOR boats, which were the focus of much of the literature. However, many of the problems with the IOR boats of the 70's and 80's are common to a number of the modern IMS offshore racing boats.

In looking at the issues I believe it is vital that one considers the whole system or all the factors that effect the welfare of a yacht at sea. These are represented in the chart, which is an adaptation of one in Marchaj's book. It is important to recognise the three factors are not entirely independent of one another.

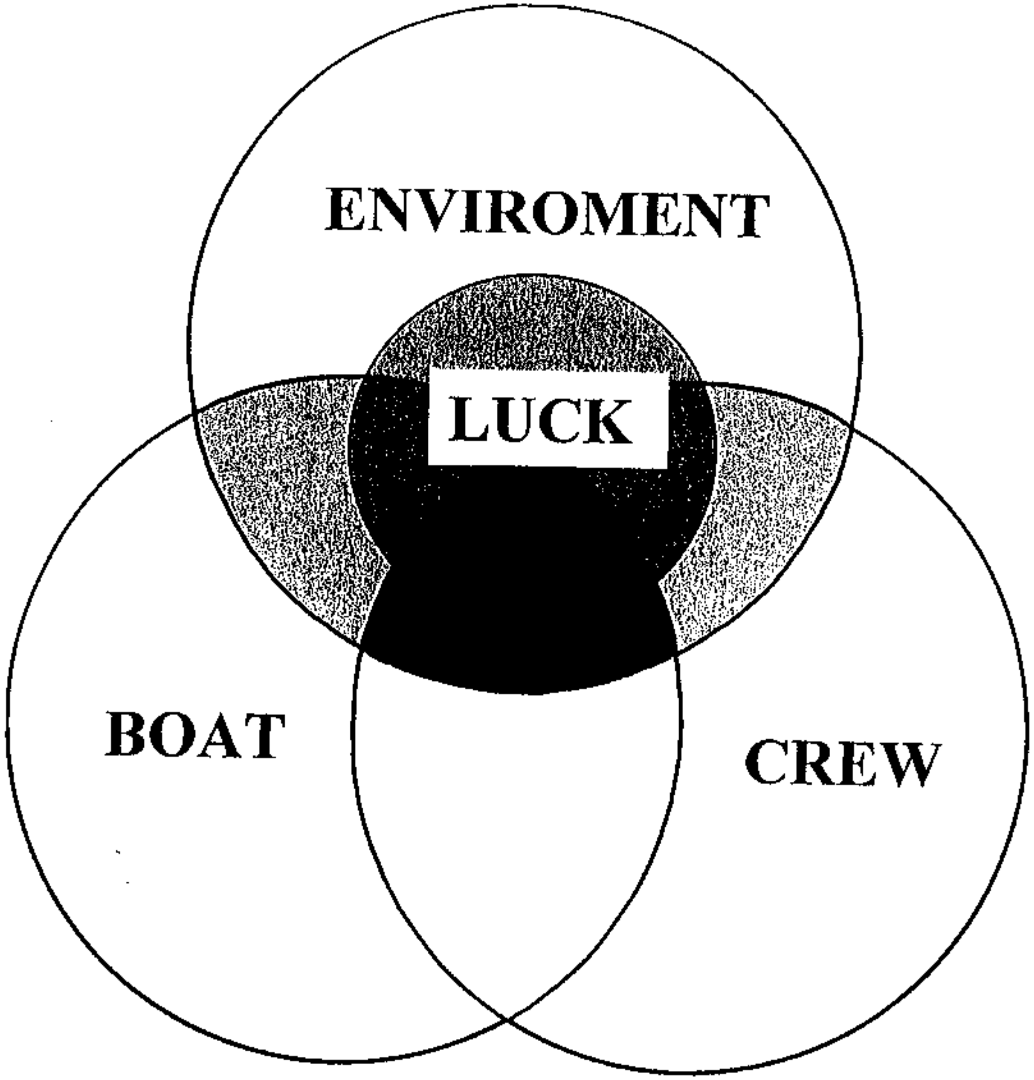
On the top is the environment , which is of course the wind and sea state. High wind speed is not necessarily a problem to a good boat and crew, it is the waves they create that is the hazard. A large wave is not itself a problem, it is the breaking wave that will knock down or capsize a yacht. A boat up wind or sufficiently down wind of the break will be unaffected. This then brings in the element of luck. No matter how good the boat and crew there can always be a storm and wave that will overwhelm them so if you're in the wrong place at the wrong time your gone. I have positioned luck on the chart where it is because I believe in the saying that a good crew in a good boat makes their own luck, to some extent. The environment is something we can't change all we can do is to predict it more accurately and avoid whenever possible the extreme conditions.

The crew is clearly critical to the boat's welfare: - their experience, fitness, condition and alertness, their preparations for the passage including all aspects of the boat. The crews choice and implementation of the tactics and their suitability for the conditions and boat are vital. The way they take care of themselves, help their fellow crewmembers and share the tasks is important for their cohesion.

Moving on to the boat the welfare of it and the crew it carries depends on its' seaworthiness. It's resistance to capsize, strength of hull, gear and rig, ability to work it's way off a lee shore in hard conditions and directional stability. Not to be forgotten is the protection it gives to the crew and the facilities it provides to allow the crew to maintain their fitness and health. The motion of the boat and availability of hand holds all play a part in crew welfare. The design of the boat will also impact the tactical options available to the crew. I believe there is considerable evidence that sailing high into the wind at reduced speed and "heaving-to" under a parachute are the safest tactics and therefore I look for a boat that is suitable for these tactics. I will accept that for fully crewed racing boats there may be alternatives. However as soon as you use the term "cruising" it must be recognised that cruising boats are typically sailed by small crews, frequently female and male partners. The boat must allow the crew to lock up and go below in severe conditions. The maximum number of tactical options must be available to the crew so they can choose the best for their circumstances. That means the boat must be suitable for heaving-to under deeply reefed mainsail, with or without jib, as well as parachute. If anybody disputes this conclusion then I refer you to "Storm Tactics" by Lin and Larry Pardy, The 1994 Pacific Storm Survey by Kim Taylor and Heavy Weather Sailing by K. Adlard Coles.

I believe that it is vital that the discussion or debate about the modern light boat must be based on sound scientific principles and consider all factors affecting the welfare of a yacht and crew. Arguments based on the experience of a small number of boats have too often been used in support of the modern boat. Small samples must be treated with caution because of the number of uncontrolled variables and the significant role of luck.

Factors affecting a yacht's welfare at sea



Is it worth it ?

How was the 20% achieved?

Av. sailing length	+ 5%
Displacement	- 46%
Working sail area	+ 14%
Beam	+ 12%
Crew weight	820Kg

Is it worth it?

Cole 43 v’s a new IMS 40 footer

True wind spd.	Predicted inc boat spd.
6 knots	16 %
12	12
20	9

- **CALL IT 20%**

Dynamics of Vessel Capsizing in Critical Wave Conditions

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Maritime Research Institute
Wageningen

ABSTRACT

This paper presents an overview of capsize modes that are relevant to intact ships and sailing yachts subjected to waves and wind. For larger size ships following and stern quartering seas tend to be most critical from a stability perspective. Sailing yachts in extreme weather conditions will be vulnerable particularly to wind-induced knowckdown and breaking impact.

The probablity of capsize of sailing yachts depends on the probability of occurrence of (possibly breaking) waves with critical height and period. For long-crested seas it is possible to derive relevant statistics based on the joint distribution of wave height and period, as is illustrated for measured storm waves. A discussion is given of design factors that influence the resistance against capsizing. Safety against complete foundering is dicussed briefly.

INTRODUCTION

Knowledge of the dynamics and physics involved in vessel capsizing should enable us to assess and improve the performance of a design in extreme weather conditions. The safety against capsizing of intact ships and yachts alike depends on the intact stability properties and on the occurrence of critical wave and wind conditions.

To illustrate the differences and similarities as regards dynamic stability between large ships and sailing yachts, this paper describes the capsize physics for both vessel types. Yachts are vulnerable to steep, breaking waves of critical height, the occurrence of which is discussed for storm wave conditions. To reduce the risk of capsizing for a yacht, a number of design parameters play an important role: displacement, righting arm curve (angle of vanishing stability and area), and moment of inertia. Adequate reserve buoyancy is a critical parameter to avoid foundering in the case of flooding of non-draining spaces through openings.

CAPSIZE MODES FOR SHIPS

The following modes are relevant to ships:

- Static loss of stability
- Dynamic loss of stability
- Broaching
- Other factors: cargo shift, water on deck, wind

Combinations of modes are possible. The above capsize modes are discussed below in some detail.

Static Loss of Stability

Loss of static stability refers to the quasi-static loss of transverse stability (associated with an excessive righting arm reduction) in the wave crest. This mode occurs typically at forward speed in regular or irregular following to stern quartering waves with low encounter frequencies. The ship can capsize when it experiences temporarily a critically reduced (possibly negative) righting arm for a sufficient amount of time, while the wave crest overtakes the ship slowly and the ship is surging or surf-riding periodically. For this mode of capsize to occur in irregular waves, one encountered wave of critical length and steepness is sufficient to cause the sudden catastrophic event. Experimental evidence can be found in Oakley et al. (1974) and Kan et al. (1990).

Dynamic Loss of Stability

A ship can lose stability dynamically in conjunction with extreme rolling motions and lack of righting energy under a variety of conditions. This major capsize mode may be associated with the following phenomena.

- *Dynamic Rolling:* This mode of motion occurs at forward speed in stern quartering seas, which can be of regular or irregular nature. Here all six degrees of freedom are coupled, where in addition to roll, surge, sway and yaw can exhibit large amplitude fluctuations. The motion is characterised by asymmetric rolling: the ship rolls heavily to the leeward side in phase with the wave crest (approximately) amidships and rolls back to the windward side in the wave trough, albeit with a shorter half-period and smaller amplitude. Due to the associated surging behaviour, the ship spends more time in the wave crest than in the trough, resulting in a periodic and longer duration reduction of the righting arm in the crest and restoring in the trough (shorter duration) of the righting arm. The roll period may exceed the natural roll period significantly. In the case of a capsize, the roll motion typically builds up over a number of wave encounters to a critical level, and the ship will usually capsize to leeward in the wave crest.

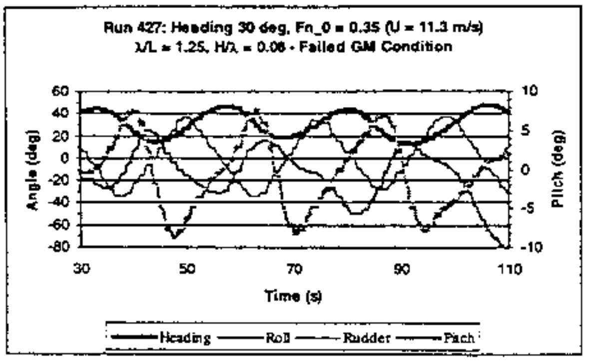

Figure 1. *Capsize: dynamic loss of stability for frigate wth low GM in stern quartering waves. Model tests with measured heading, roll, pitch and rudder angles*

Figure 1 illustrates this capsize mode in steep stern quartering waves for a frigate model with low initial stability (De Kat and Thomas, 1998); in this case the GM was such that the vessel would fail to satisfy the relevant stability criteria.

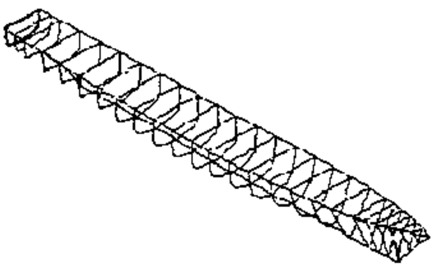

Figure 2. *Isometric sketch of frigate*

The conditions in figure 1 are as follows: mean heading is 30 degrees, calm water Froude number Fn = 0.3, wavelength to ship length ratio λ/L = 1.25, wave steepness H/λ = 0.08, scaled ship length L = 106.7 m (see figure 2 with hull form). The time series for roll, yaw (heading) and rudder angle are plotted on the left vertical axis; the heading varies between 20 and 40 degrees, rudder angle varies between +/- 40 degrees.

- *Parametric Excitation:* Parametric excitation results from the time-varying roll restoring characteristics of a ship typically found in longitudinal waves. The periodic changes in static righting arm during the repeated passage of a wave crest followed by the trough can cause large amplitude roll motions. Roll motions occurring at approximately the natural roll period and simultaneously at twice the encounter period (encounter frequency equals half of natural roll frequency) characterise this mode of motion. The roll motion is of a symmetric nature and the maximum roll angles to port and starboard occur when a wave crest passes the midship area. The wavelength must be of the order of the ship length. In such circumstances, parametric rolling - also referred to as low cycle resonance - can result in capsizing. It can occur in regular and irregular waves. It has been observed in head seas, but parametric excitation in astern seas is typically more critical in terms of capsizing (Oakley et al., 1974). In particular, when a ship travels at the mean group speed in following seas, parametric excitation can occur during the passage (in a regular fashion) of a wave group with a sufficient number of encountered waves of critical height and length.

- *Resonant Excitation:* In principle large amplitude roll motions can result when a ship is excited at or close to its natural roll frequency. Roll resonance (synchronous rolling) conditions are determined by the combination of righting arm curve characteristics, weight distribution, roll damping, heading angle (e.g., beam seas), ship speed, wavelength and height.

- *Impact Excitation:* Steep, breaking waves can cause severe roll motions and may overwhelm a vessel. The impact due to a breaking wave that hits a vessel from the side will affect the ship dynamics and may cause extreme rolling and capsizing (Dahle and Kjaerland, 1979). Possible damage to deck structures and subsequent water ingress may result as a consequence. This capsize mode is relevant especially to smaller vessels in steep seas. Experimental evidence can be found in Ishida and Takaishi (1990).

Broaching

Broaching is related to course keeping in waves. Although there is no uniformly accepted mathematical definition of a broach, it represents the wave-induced undesired, large amplitude change in heading angle. A variety of broaching modes exist in regular and irregular waves:

- Successive overtaking waves (low speed);
- Low frequency, large amplitude yaw motions;
- Broaching caused by a single wave (high speed).

The first mode has been observed to occur in steep following seas at low ship speed, where the ship is gradually forced to a beam sea condition during the passage of several steep waves. The other modes occur at higher speed, typically at a Froude number Fn > 0.3.

The third mode is usually characterised by quasi-steady surf-riding at or above wave phase speed (see e.g. figure 3) and steadily increasing yaw angle. Surfriding is particularly critical when this occurs in conjunction with bow submergence; when the bow is buried in the back slope of the preceding wave while surfriding, a strong destabilizing effect takes place as regards directional stability and a sudden, high speed broach may ensue.

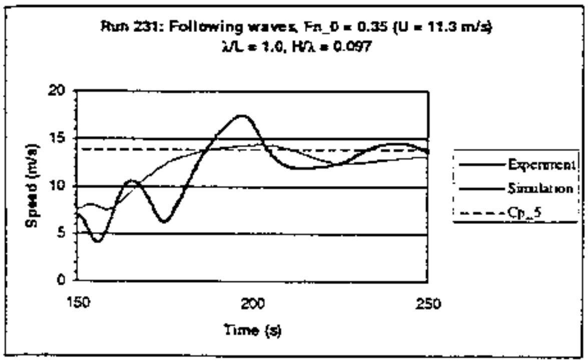

Figure 3. *Measured and predicted ship speed during surfriding events for frigate in steep following seas (De Kat and Thomas, 1998); Cp_5 is the wave phase speed.*

Figures 4a, 4b and 4c depict the occurrence of the second broaching mode for the frigate model tested in the Full Load Condition, illustrating that the ship can experience extreme roll angles in this condition (De Kat and Thomas, 1998). Figure 4b shows that the ship experiences large speed fluctuations in both longitudinal and transverse direction and that it has a significant mean negative drift velocity, i.e. it experiences a rather large drift speed to leeward while yawing. The highest transverse drift velocity occurs when the yaw angle (toward the wave) and forward speed increase while a wave crest is overtaking the ship (from aft to amidships). When the crest is in the midship area and the ship has reached its largest yaw deviation into the wave, the roll angle to leeward (negative sign) is largest; the reduction of the righting arm in the wave crest leads to asymmetric roll motions. In this case the ship experiences large roll angles, but it does not capsize. Figure 4c illustrates the amount of drift a ship can experience in steep stern quartering waves.

Other factors that influence capsizing

Water on deck can occur in conjunction with (and hence influence) the capsize modes discussed above. Large amplitude relative motions and breaking waves can result in the temporary flooding of the deck, which from a stability viewpoint is relevant especially to vessels with bulwarks, such as fishing vessels. Furthermore, deck edge submergence results in loss of waterplane area and righting arm. If a bulwark is present, its submergence will influence the forces acting on the vessel. Wind does not necessarily influence wave-induced capsizing in astern seas; in beam waves, however, it may be important. Cargo shift as a consequence of large amplitude rolling and high accelerations is a major cause for ship capsizing.

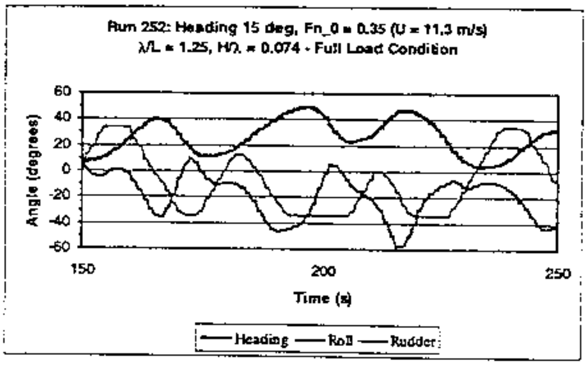

Figure 4a. *Broach mode 2: measured heading, roll and rudder angles for frigate in stern quartering waves*

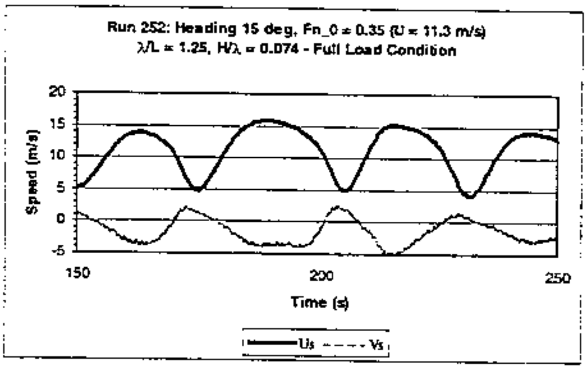

Figure 4b. *Mode 2 broach: Measured longitudinal and transverse ship speeds for run 252*

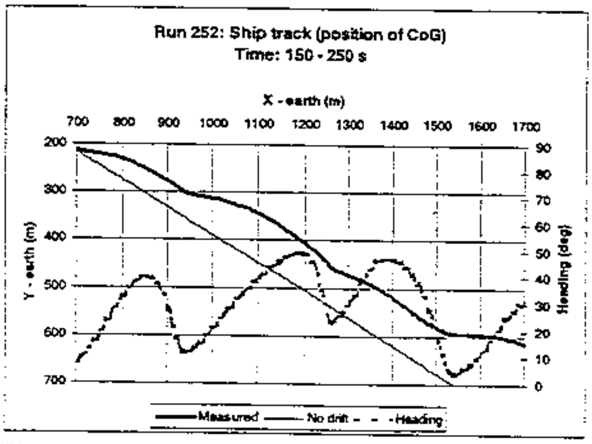

Figure 4c. *Measured ship track and heading associated with run 252 in stern quartering wave (wave direction is along x-axis)*

CAPSIZE MODES FOR SAILING YACHTS

A sailing yacht may capsize in the following modes:

- Breaking wave impact
- Knockdown under sail in heavy wind and waves
- Broaching associated with surfriding and bow submergence (loss of rudder control)
- Combination of above modes

The broaching mode associated with surfriding is similar to the mode 3 broach described for ships above. Whereas ship capsizing can be dominated by loss of stability in the wave crest, this is not the case for yachts. In extreme weather conditions, when a yacht carries as little sail as possible, capsize due to a breaking wave and knockdown in a heavy gust are particularly dangerous. Also, a yacht is vulnerable when after a knockdown it is hit by a steep or breaking wave.

Impact by steep, breaking wave

In severe weather breaking waves are critical to yacht safety, as has been reported by Stephens *et al.* (1981), among others. A wave that is about to break tends to have a steep crest front that travels at a speed that is close to the phase speed of the wave. When this crest front hits a structure or ship, the impact load can be significant (Chan, 1994). For example, the phase speed of a steep wave of height H = 12 m and period T = 9 s is 15 m/s in deep water, which is significantly higher than the crest particle velocities of a similar wave in non-breaking conditions. Figure 5 illustrates the steep face associated with a breaking wave in laboratory conditions.

Figure 5. *Breaking wave measurements in model basin (MARIN).*

At the moment of impact, an upright yacht would be subjected to the following roll moment balance:

$$(I_{44} + a_{44})\ddot{\phi} \approx \tfrac{1}{2}\rho V^2 S.r$$

where I_{44} is the roll moment of inertia in air, a_{44} is the added mass roll moment, V is the velocity of the crest front (jet), S is the projected area of impact, and r is the arm at which the impact force acts with respect to the centre of gravity of the vessel. In other words, the initial roll acceleration experienced by the yacht because of the impact is approximately proportional to the following:

$$\ddot{\phi} \approx \frac{\frac{1}{2}\rho V^2 S.r}{m\rho_{xx}^2 + a_{44}}$$

where m is the mass of the yacht and ρ_{xx} is the radius of gyration for roll.

The above equation is a very rudimentary one, but it does indicate some of the critical components. Obviously, to predict the roll response accurately, a more complete description of the equations of motion is necessary; Blume (1987) and Dahle and Kjaerland (1979) have attempted to describe the equations of motion for the case of impulsive impact due to breaking waves. Figure 6 shows the sequence of measured yacht capsize subjected to a transient breaking wave from abeam (Nimura *et al.*, 1996). This figure illustrates the occurrence of a semi-stationary knockdown stage - nos. 5, 6 and 7 - before capsize.

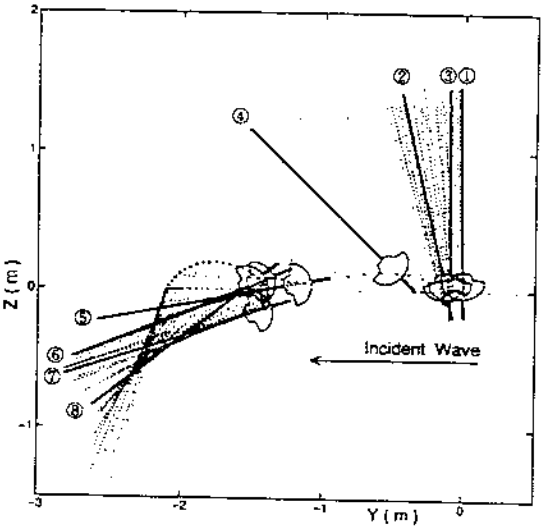

Figure 6. *Motions of capsizing yacht subjected to a transient breaking wave (model tests by Nimura et al., 1996).*

CRITICAL WAVE CONDITIONS

It is common to refer to wave conditions in terms of a reference wave height or "sea state number" (the latter especially in navy context). The reference wave height tends to be the significant wave height, which is the statistical average of one-third of the highest waves (and which corresponds approximately to the estimated wave height observed at sea). The most probable maximum wave height that can be expected in 1000 wave encounters is related to the significant height as follows:

$$H_{max} = 1.86H_S$$

where for a narrow-banded process the significant wave height is related to the area m_0 under the energy spectrum:

$$H_S = 4\sqrt{m_0}$$

Associated with the energy spectrum is a peak period:

$$T_p = 2\pi/\omega_p$$

where the peak frequency is the frequency associated with the maximum energy in the spectrum. The characteristic steepness of the sea state, s_{char}, determines the probability of occurrence of critical, steep waves:

$$s_{char} = \frac{H_s}{gT_p^2/(2\pi)}$$

The maximum steepness observed for ocean waves lies typically around $s_{char} = 0.05$; the average characteristic steepness for worst North Atlantic storm waves is approximately $s_{char} = 0.035$ (De Kat *et al.*, 1994). In terms of risk of yacht capsize, critical waves are those individual waves that are very steep: capsize risk is directly related to the probability of occurrence of almost or completely breaking waves. The same has been found to apply to the capsize risk of liferafts (Paterson *et al.*, 1996). For larger size ships, critical waves can be expressed in terms of wavelength in relation to ship length and steepness.

Although it is difficult to predict the probability of wave breaking in a sea state in deep water conditions, it is possible to make an assessment of the probability structure of individual waves based on the joint distribution of individual wave heights and periods. By applying a zero-crossing analysis of wave elevation time series, it is possible to obtain information on the characteristics of individual waves.

Let us consider as an example the properties of a steep storm sea state based on measurements in the North Atlantic, taken in deep water off the East coast of Canada. The significant wave height is 10.7 m with a peak period of 12.4 s ($s_{char} = 0.044$); to obtain statistically reliable distributions, the 20 minute time series with measured wave data were concatenated into a stationary time series of about two hours duration. Figure 7 shows the joint distribution (probability density function, or *pdf*) of the zero-crossing wave periods, T_z, and associated (crest-to-trough) wave heights, H.

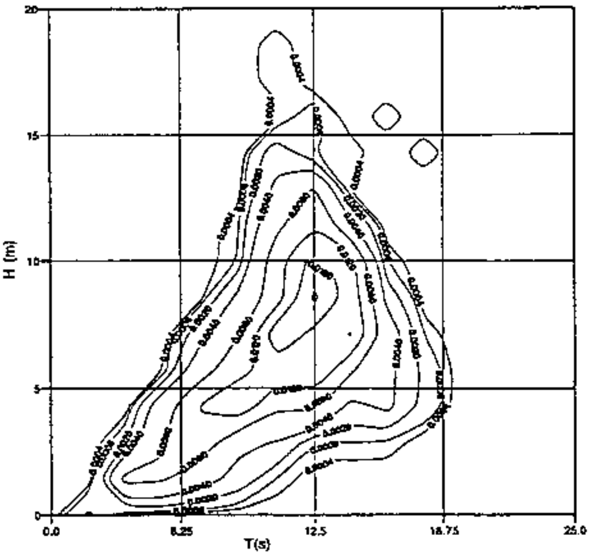

Figure 7. *Joint probability distribution function of wave period and height (full scale measurements, $H_s = 10.7$ m, $T_p = 12.4$ s).*

The outer contours represent the waves with smallest probability of occurrence; figure 7 shows that the highest observed wave has a height of about 19 m and a period of 10.7 s. The same information can be represented in terms of zero-crossing wave lengths, where the wavelength is taken to be:

$$\lambda = \frac{gT_z^2}{2\pi}$$

Figure 8 shows the resulting joint distribution of wavelength and height. It can be seen, for instance, that waves with a height of more than 15 m have lengths ranging between 170 m and 300 m.

As a last example of how such data can be presented, figure 9 shows the joint distribution of wave steepness as a function of wavelength, where the individual wave steepness is taken to be:

$$s = \frac{H}{\lambda}$$

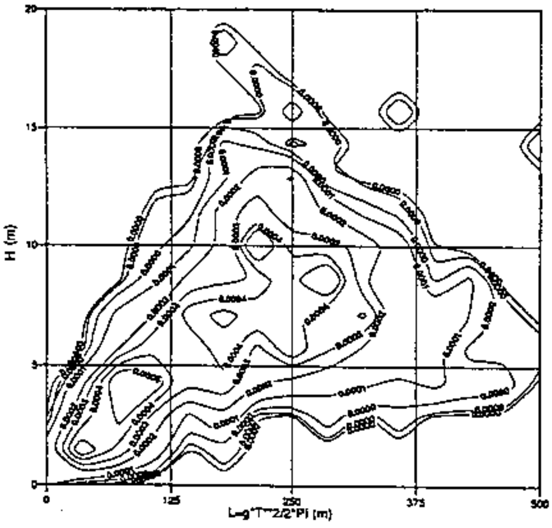

Figure 8. *Joint pdf of wavelength and height (full scale measurements, $H_s = 10.7$ m, $T_p = 12.4$ s).*

Figure 9 shows that the steepest waves have a length ranging from about 50m to 180 m; their maximum steepness is around s = 0.10, for which wave breaking could be likely (and dangerous, considering the size). Myrhaug and Kjeldsen (1987) suggest that the probability of wave breaking is linked to a crest steepness parameter, which should apply to long-crested waves. In short-crested waves, however, wave breaking is not linked strongly to wave steepness: 3D waves can break at low and high steepness with similar probability.

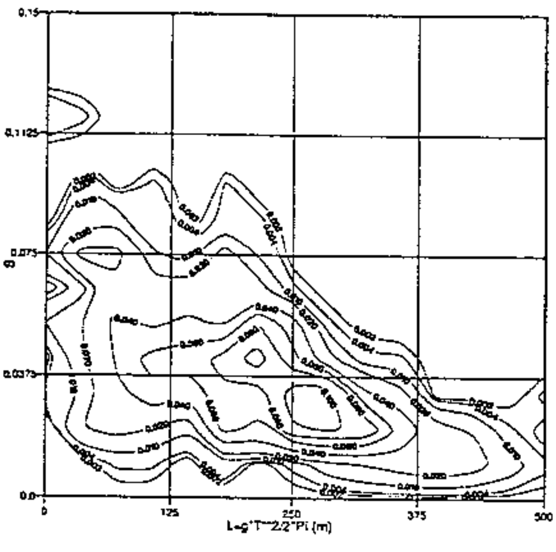

Figure 9. *Joint pdf of wavelength and steepness (full scale measurements, $H_s = 10.7$ m, $T_p = 12.4$ s).*

Nevertheless, the probabilistic description of the wave surface as discussed above provides a clear indication of the severity of a given sea state. A sea state with a realistic occurrence of high, steep waves can be considered potentially dangerous. It is possible to estimate the capsize risk due to steep waves, if one knows the critical wave height and associated steepness values in which a given vessel would capsize in e.g. beam sea conditions. The probability of capsize in a given sea state can then be obtained by integrating the joint probability density function over the critical range of wave heights and steepness values.

The presence of current may have a major influence on wave steepness. Even in the case of a weak current opposing the wave direction, experiments suggest that the particle velocities in the crest of a breaking wave can increase significantly compared with the zero-current case (Kjeldsen and Myrhaug, 1980).

Bass Strait measurements on 27 Dec. 1998

Through the courtesy of Esso Australia Ltd, data were made available for analysis as regards wind, wave and current obtained at the Kingfish-B Platform in the eastern Bass Strait during 26 through 28 December, 1998. The platform is located in 78 m water depth at 38°35.9' S and 148°11.2' E. The highest wave conditions in that period were measured on 27 December, as shown in figure 10.

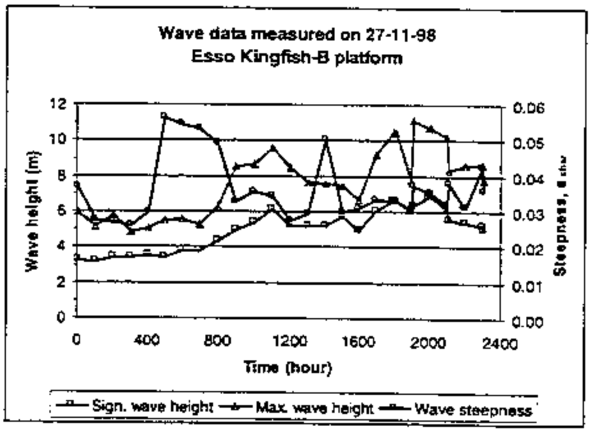

Figure 10. Wave height (significant and maximum) and direction in eastern Bass Strait.

The maximum significant wave height was around 7 m with maximum recorded wave height of around 11 m. The plotted characteristic wave steepness is defined as above. Figure 11 shows the wind data for the same period; the wind speed is an average value at a height of 44.5 m above MWL.

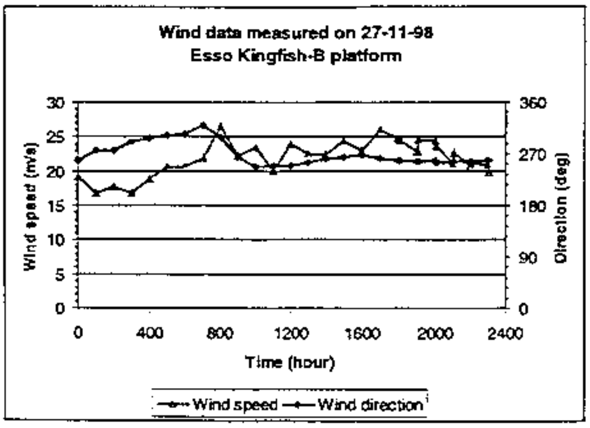

Figure 11. Wind speed and direction in Bass Strait.

Figure 12 shows the current speed and direction.

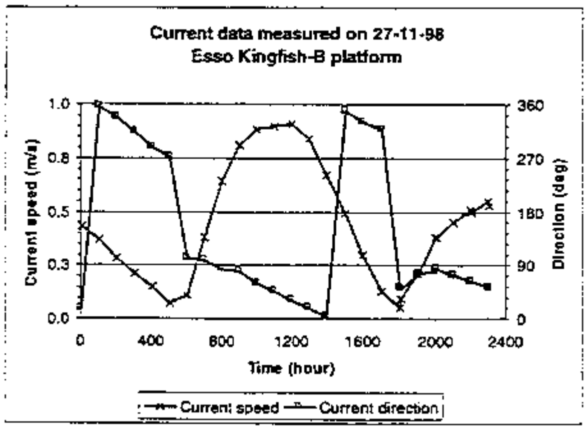

Figure 12. Current speed and direction in Bass Strait.

The figures show that as the wave height builds up between 8 and 12 a.m., the current increases from almost zero to two knots.

DESIGN FACTORS INFLUENCING CAPSIZE RISK OF YACHTS

From a design viewpoint, the following parameters will influence the resistance against capsize:

- Size (displacement)
- Range of positive stability
- Roll moment of inertia

For a yacht in survival conditions, the most relevant capsize modes are breaking wave impact and wind-induced knockdown, assuming that the yacht can be kept under reasonable control in terms of course keeping while avoiding high surfriding speeds.

The analysis in the preceding section suggests that the initial roll acceleration caused by wave impact will be smaller for a yacht with: (1) larger mass, (2) higher moment of inertia. Experience has shown that larger size yachts are at a smaller risk of capsizing. Likewise, a vessel with a higher moment of inertia has been shown less prone to capsize in breaking waves (Rousmaniere, 1987). Rigging will increase the roll moment of inertia compared with the bare hull case; evidently heavy rigging will result in a higher moment of inertia than a lightly constructed system.

Once dismasted, a yacht will be easier to capsize; also, Nimura *et al.* (1996) have observed experimentally that the rigging provides additional damping, causing the boat to attain for some time a constant large heel angle before further capsizing to the inverted condition or self-righting would take place.

Once the vessel is heeled over by wave impact or heavy wind gust, or a combination of such factors, the resistance against capsize is governed by the range of positive stability, i.e., the range of heel angles over which the vessel exhibits a positive (counter acting) restoring moment. Furthermore, the area underneath the righting arm curve over the range of positive stability is an important factor, as it determines the required energy to heel a ship. The range of stability and area of the righting arm curve depend on the underwater and above water hull form including cabin and deck camber, freeboard, cockpit, and vertical location of centre of gravity (KG).

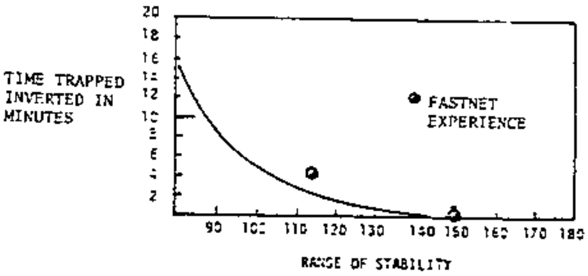

Figure 13. *Relationship between range of positive stability and time inverted after capsize (USYRU, 1985).*

The range of positive stability (RPS) determines the range of which a vessel is self-righting and to what extent a vessel is likely to remain inverted in a stable condition after capsize. Following the Fastnet disaster in 1979, capsize research (Rousmaniere, 1987, and USYRU, 1985) suggests that a yacht with RPS = 140 degrees or more will be safe from ending up inverted or stay in such a position for any significant amount of time, see figure 13. As the RPS becomes smaller (say, less than around 140 degrees), it will take a higher and steeper wave, and therefore more time, to roll a boat back to its upright position; as shown above, the probability of occurrence of waves decreases with increasing height and steepness.

Recent analysis of yacht casualties illustrates the link between safety against capsizing and the range of positive stability (Van Oossanen, 1997). In relation to this study, Figure 14 shows the angle of vanishing stability (i.e., RPS) as a function of boat length for boats that were safe and those that were stability casualties.

The significance of the range of positive stability and total area under the righting arm curve has been proven relevant for other ship types as well. For example, stability research directed at naval ships has shown that a direct relationship exists between the value of RPS and risk of capsize, and that RPS could be used as an additional design parameter in intact stability criteria for frigates (De Kat et al., 1994).

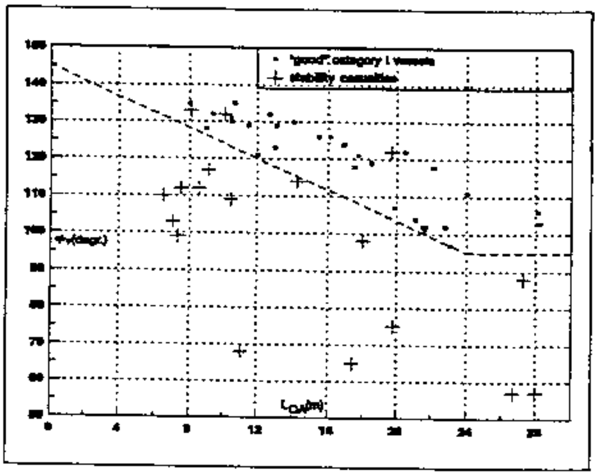

Figure 14. *Angle of vanishing stability as a function of overall boat length for stability-related casualties (+) and safe survival cases (■) obtained from casualty analysis (Van Oossanen, 1997).*

PREVENTION OF FOUNDERING

Besides stability of the intact vessel, there are several important factors that have a bearing on survivability in severe seas:

- Watertight integrity
- Structural integrity
- Reserve buoyancy

Watertight integrity implies the ability of the hull and cabin to safeguard the vessel from water ingress and downflooding into non-selfdraining areas through openings (ventilators, hatches, etc.).

Structural integrity refers to the hull, cabin, rigging and appendages being able to withstand wave and wind induced loads. Hatches with insufficient strength may not be able to withstand the pressure of a wave impact, or rigging may fail under extreme loading when a yacht is overwhelmed by a wave.

When a yacht does lose its watertight or structural integrity in severe weather conditions, it is likely to founder when there is not sufficient reserve buoyancy, as shown schematically in figure 15. While reserve buoyancy determines the floatability in damaged conditions, a damaged vessel may capsize when there is a lack of damage stability (e.g. when the range of stability is too small), but damage stability properties are more relevant to larger vessels.

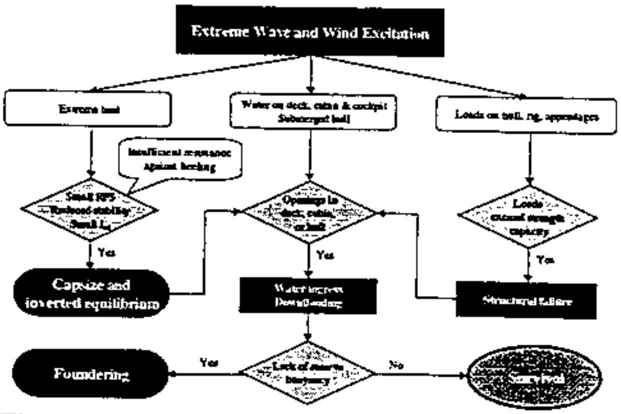

Figure 15. *Hazard identification chart for yacht subjected to extreme excitation in wind and waves*

CONCLUSIONS

This paper provides an overview of capsize modes for ships and sailing yachts. In case of the rare event of capsizing, the capsize mechanism for larger vessels will be mainly related to static of dynamic loss of stability in steep astern seas. For yachts in extreme weather the danger of impact due to steep, breaking waves and knockdown in heavy wind is most critical.

Regardless of ship type, the risk of capsizing depends largely on the probability of occurrence of critical waves. Critical waves are those individual waves that result in capsizing of a vessel with a given set of operating conditions. A methodology is described to represent the probability structure of individual (critical) waves as a function of main sea state parameters. Examples of storm wave data are given.

The paper concludes with a discussion of design factors that influence the resistance against capsizing and foundering of yachts.

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Safety of Offshore Racing — The Critical Factors

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Summary

The safety of offshore racing yachtsmen is dependent on a wide range of factors including: yacht design; safety equipment carried on board and worn; rescuer capabilities; location of the yacht; and the ability of the yachtsmen themselves.

This paper reviews the important critical factors.

It is recommended that the statical concepts used to determine a yacht's safety against capsize, and its self-righting capabilities, can be improved by using modern state-of-the-art dynamic techniques.

The application of various items of safety equipment is discussed and it is noted that the technology available is improving rapidly. Whilst the latest commercial requirements may be too expensive for amateur yachtsmen, a number of simple low cost ways of improving the safety level for competitors are discussed.

Finally, the issue of crew training - both in avoiding an accident and in surviving if an accident occurs - is discussed, and the possibility of a mandatory short course for all offshore racing yachtsmen is noted.

Introduction

Recent events such as the accidents, and consequent rescues, involving Participants in the Vendee Globe 1996-97 Single Handed Yacht Race and the Telstra 1998-99 Sydney to Hobart Yacht Race have highlighted the dangers associated with offshore yacht racing. The safety of offshore racing yachtsmen is dependent on a wide range of factors, including: yacht design; safety equipment carried on board and worn; rescuer capabilities; location of the yacht; and the ability of the yachtsmen themselves.

As an aid to improving the overall safety of competitors, each of these items is discussed, and possible improvements suggested.

Effect of hull design on capsizing tendency

A lot of work has been conducted investigating capsize mechanisms for conventional vessels, and on the appropriate minimum stability standards to prevent capsize. Although it is well recognised that capsizing is a very dynamic event, most current stability regulations are based on statical stability concepts developed many years ago.

The static righting lever in calm water, or GZ, is plotted as a function of heel angle, and the area under this curve to 30° and to 40° are calculated and compared with minimum requirement developed from vessels which have and have not capsized in the past. Only now is the scientific community starting to seriously incorporate the dynamics of vessel motion in stability regulations. Despite considerable recent advances in the simulation of ship dynamics up to and including capsize, it will be quite some time before regulations are introduced which are based on the full simulation of a vessel's motion in extreme waves.

Some of this thinking has extended to racing yachts, and GZ curves are used to assess their stability. Typical GZ curves for different racing yachts are given in figure 1. The slope of the GZ curve at small heel angles, GM, and the angle at which the GZ curve becomes negative are often used as indications of the yacht's safety against capsize.

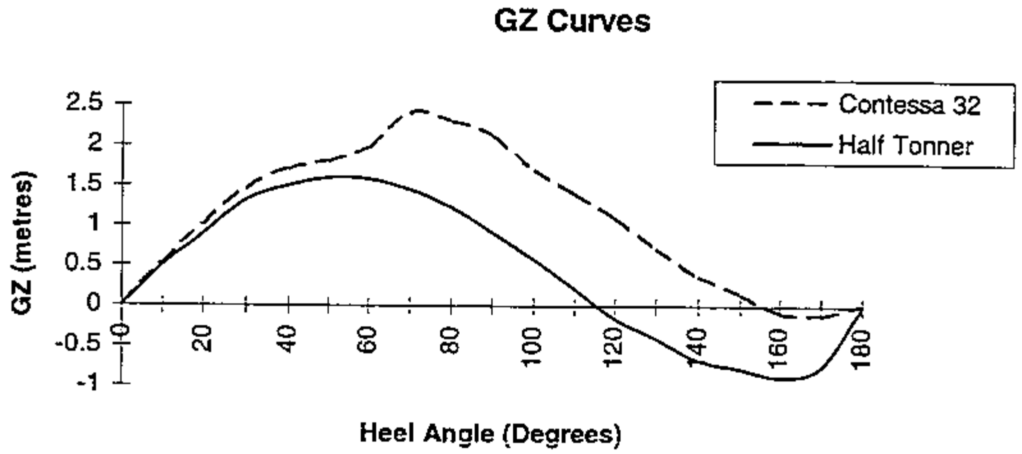


Figure 1. GZ curves for typical racing yachts - taken from Wolfson (1979)

On one hand this is appropriate as it is the balance between the heeling moment from the wind and the righting moment from the hull which will determine the angle the vessel will heel to. On the other hand, a capsize event is even more dynamic for a small vessel operating in severe waves than for a larger vessel, and of course the relative size of the wave to the vessel is much larger for a small vessel than a large one.

Some work has been conducted using small models in towing tanks with large breaking waves. (See for example Hick, 1988). The results are interesting and have shown the influence dynamic factors have on capsizing in steep breaking waves. In particular, the effect of the presence of the mast, which has a major effect on the roll moment of inertia, has been shown to have considerable influence on the likelihood of capsize in breaking waves, even when the metacentric height, GM, is held constant. The increased roll moment of inertia due to the mast significantly reduces the capsize tendency. (Figure 2)

Considerable work has been conducted into the dynamic behaviour, and capsize, of small vessels in following and quartering seas. (See for example: Renilson, 1997, Renilson and Tuite, 1997, Renilson and Hamamoto, 1998, Renilson, et al, 1996). This can, and should, be applied to offshore racing yachts to develop an understanding of the dynamics of why they capsize, and to improve the stability regulations governing them.

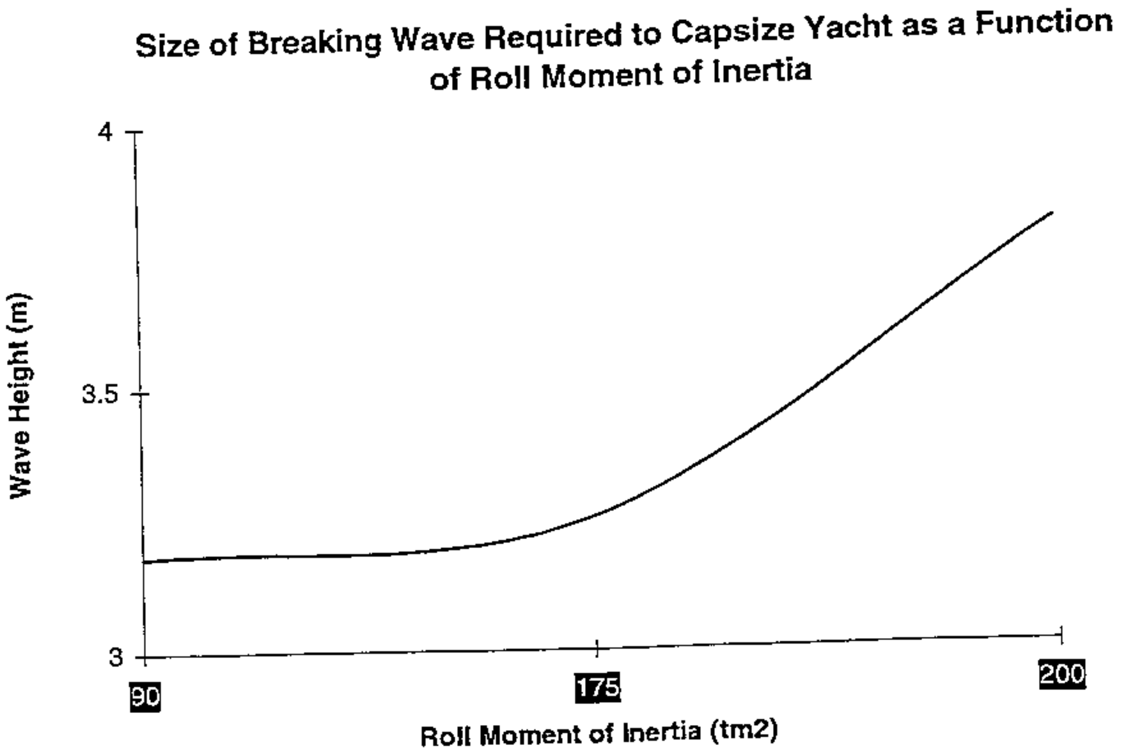


Figure 2 Effect of roll moment of inertia on capsizing tendency - taken from Hick (1988)

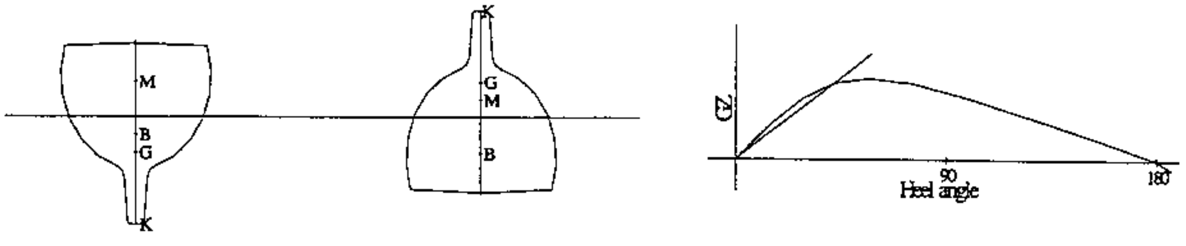
Self-righting capabilities

A modern racing yacht which is symmetrical about its centreline is very likely to be stable inverted. For it to be unstable inverted it must have a very low position of the centre of gravity when it is upright, such that when inverted the centre of gravity is above the position of the inverted metacentre.

When upright, stability at small angles is given by the fact that the centre of gravity, G, is below the metacentre, M. High stability can be achieved by a low centre of gravity and a low metacentre, or by a high centre of gravity and a high metacentre. Vessels which have a relatively small distance between the centre of buoyancy and the metacentre, BM, and rely on low centres of gravity to give them positive stability, can be designed to be unstable inverted, and will then have a strong tendency to self-right. Traditional narrow deep keeled yachts typically have these characteristics and in some cases will have positive stability right up to 180°. (Figure 3)

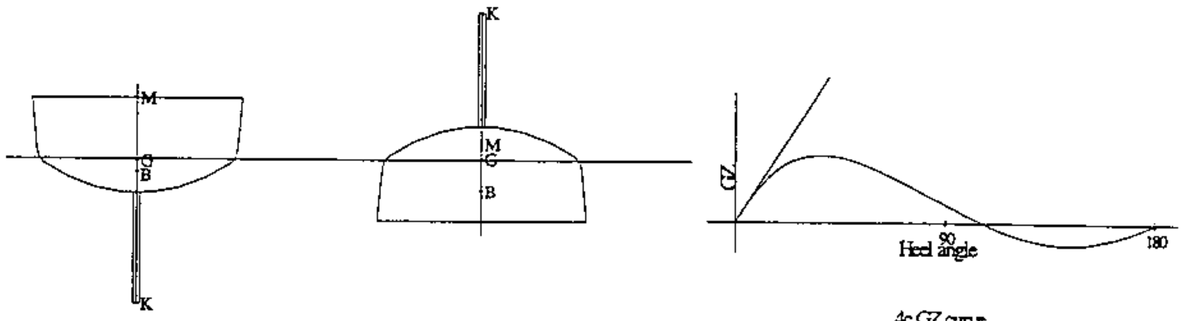
Modern racing yachts, however, along with most surface craft, tend to rely on the rise in metacentre obtained from their beam, BM, to ensure that the metacentre is above the centre of gravity. This results in a lower angle of vanishing stability and makes them much less likely to self-right. (Figure 4)

For vessels with a positive inverted GM, the range of inverted stability, and the typical roll angle the vessel will encounter when inverted, will determine whether it is likely to right itself in a reasonable period of time. The inverted roll angle will depend on the inverted GM, the roll damping, and the size of the waves. Anything that can be done to decrease the inverted GM and the inverted roll damping will make the vessel more likely to self-right. Roll damping will depend on the shape of the inverted hull, as well as the mast, rigging, and sails.



3a Upright stability 3b Inverted stability 3c GZ curve

Figure 3 Traditional sailing yacht



4a Upright stability 4b Inverted stability 4c GZ curve

Figure 4 Modern racing yacht

Both the range of positive stability and the slope of the inverted GM are influenced by the size of the coachroof, with a larger coachroof making the vessel more likely to self-right. Unfortunately, large coachroofs increase windage and hence aerodynamic drag, making the racing yacht slower. They also tend to spoil the aesthetics of the yacht! The balance is important, and must be taken seriously if yachts are to have any chance of self-righting.

Unfortunately, there has not been a lot of work done on ensuring racing yachts are self-righting. Even the definition of self-righting is not clear. As noted above, all that is required is for a roll to exceed the angle where the inverted GZ becomes negative (or the upright GZ becomes positive) and the vessel will start to self-right. Whether this will happen, and how long it will take to happen, will depend on the size of the waves as well as the dynamics of the vessel. The size of the 'negative area' of the GZ curve (*ie* when the GZ is negative), can be used in a statical sense to give a crude indication of how difficult it will be for the vessel to self-right. When this is compared to the positive area under the GZ curve a ratio sometimes known as the stability ratio, defined as follows, can be obtained:

$$\text{StabilityRatio} = \frac{\text{PositiveArea}}{\text{NegativeArea}}$$

From figure 1 it can be seen that the Contessa has a much larger Stability Ratio than the Half Tonner, whereas the Stability Ratio for the traditional yacht shown in figure 3 is infinite.

This approach is based on statical concepts and can be improved by using modern state-of-the-art dynamic techniques.

Breakages of Critical Components

There are a number of critical components, failure of which will result in the yacht being disabled. Typical recent examples include: mast; rudder and/or steering gear; keel; and the watertight integrity of the hull and/or superstructure. Failures in each of these areas may render the yacht in serious imminent danger, and as a result considerable care must be taken to reduce the likelihood of this occurring. In addition, where possible, backup arrangements should be considered, as should the effect of failure of one component on the overall system - for example mast failures can result in damage to the superstructure and/or hull.

Ideally, a complete failure tree analysis should be completed for each critical component during the design stage. Clearly this is not possible for every boat, therefore prescriptive regulations are still required. It is important to note that despite the existing prescriptive regulations, and using the latest in structural analysis and materials techniques, failures have occurred in a number of recent cases. As with many aspects of naval architecture the greatest difficulty is often in obtaining the design loads. As the load required to cause failure for each component will be known by the designer to a reasonable degree of accuracy, this can be used to assist in predicting the design load required in the future.

It is therefore vital that a comprehensive investigation be undertaken by an independent body into why each of these failures occurred, and whether a backup arrangement could have been fitted. The regulations must then be improved and properly enforced. This needs to be done on an international scale in a similar manner to aircraft accident investigation, and will require the cooperation of designers, builders and researchers. To do this properly will often require the testing to destruction of critical parts which have failed. The cost of this is not insignificant as it may require construction of these parts to the same specification as the original, and sophisticated testing under a wide range of load conditions. This is particularly true for investigations into mast failures. As with all matters of safety, the difficulties are in who should pay for these comprehensive investigations, and ensuring they are conducted by a truly independent body who is able and willing to promulgate the results to the whole community.

Other vessel design features

Access hatch

Some offshore racing sailors have remarked that the compulsory provision of an escape hatch in the hull would be very useful for getting out of an upturned yacht. This would allow deployment of safety devices such as: antennas for distress beacons; radio antennas; and pyrotechnics. If such a feature was to be incorporated it would be vital that it did not compromise the structural or watertight integrity of the hull, that it would be easy to use and that it would work even in extreme conditions after a long period without maintenance.

Bulkhead watertight integrity
In some cases watertight bulkheads have been known to have been breached by cables *etc* fitted after the vessel was first built and inspected. Apparently sort of thing tends not to be noticed by pre-race scrutineers. Clearly this is a design issue, and better liaison between the scrutineers and the designers/builders is required.

Wing masts
Modern wing masts designed to increase the power of the rig can make it difficult to handle the vessel under 'bare poles'. This can result in high speeds, even in survival mode, putting extreme strain on auto pilots, rudders, sea anchors *etc*, and can make it difficult to control the vessel in storm conditions, where the ability to heave to head to wind can be very important.

Hull visibility in extreme conditions
It is now well known that white hulls can be extremely difficult for rescuers to identify from the air in storm conditions. Brightly coloured hulls and/or day-glo stripes would create much better visibility and make the location of a yacht in distress much easier. This should also apply to liferafts, which in some cases have been known to have been made of very dark material!

Also, yachts (and liferafts) should carry large identification letters for better visual identification to avoid confusion when there are a number of yachts in the same area.

Survival equipment

Having access to the latest modern survival equipment, and its correct use, can considerably enhance a survivor's chance of living until rescued. Despite this, competitors often fit only the basic minimum equipment required by the race organisers.

The most important items of personal survival equipment are: a lifejacket; a safety harness; and an immersion suit.

Lifejacket design must allow comfort and the ability for unhindered work. For this reason the use of inflatable lifejackets incorporated into wet weather gear may be more appropriate than "solid" lifejackets. Lifejackets should be fitted with other personal survival equipment such as: strobe lights, to assist location during low light; and sea dye markers to assist location during daylight conditions. Whistles are also useful means of attracting attention in some conditions. Often these small and inexpensive, but important, items are not required by race organisers and therefore are not fitted.

Safety harnesses should also always be worn in extreme conditions. There are many incidents where they have saved lives, and a number of occasions when not wearing them has contributed to loss of life.

Immersion suits will reduce the heat loss considerably. For example, they can reduce the lowering in body temperature experienced after six hours in water at 0° Celsius to less than 2°. They should be fitted with gloves - often attached by a lanyard to the sleeves - which reduce the heat loss through the hands, and can greatly reduce the chances of frostbite. Boots should also be worn if possible and are often part of the immersion suit.

Other personal equipment which could save lives are personal pyrotechnics and personal EPIRBs. These are discussed below.

Choosing the right liferaft and its location on the boat is very important. These are often lost or inaccessible in an emergency. Equipment packs provided in the liferafts should ideally include items such as: food; drinking water; anti-seasickness medication; a first aid kit; a radar reflector or transponder; an EPIRB; a hand held waterproof VHF radio; thermal blanket aids; a torch; a repair kit/pump; a sea anchor; pyrotechnics; heliograph; bailer, sponges *etc*.

The crew should be familiar with the operation of the liferaft on their yacht and the equipment on board it. Great care should be placed on its installation such that it can be deployed under a wide range of different damaged scenarios.

Sea anchors are also important survival equipment as the ability to hold the vessel head to the sea can reduce drift and help to prevent a capsize.

Location of survivors

The first task is for the survivors to signal that a vessel has become disabled, or is in danger and requires assistance. The primary ways of doing this are by: radio; distress beacon; or pyrotechnics - each has its advantages and disadvantages.

Radio based systems
Ideally, if the radio can be operated this can be used to notify authorities or other vessels in the area that there is a distress. This has the advantage of making it possible to describe the nature of the emergency, and to confirm that it is not a false alarm.

Typical radios for small vessels operate on either the CB 27 MHz, VHF or the MF/HF frequency ranges. CB and VHF radios are easy to operate, require only small aerials and can be used to contact other ships and coast stations around Australia. Their range is limited to 30Nm. MF/HF radios, however, require larger aerials, but have a range of about 500Nm depending on the frequency. An important consideration may be that Australian shipping used to monitor the MF/HF emergency frequencies, however the mandatory requirement for this ceased on 1 February this year.

It is also possible to use the radio to contact other competitors and yacht race organisers often use the 4,483 kHz frequency, however many yachts do not monitor this frequency between skeds. It was noted that in the recent Sydney - Hobart race many yachts used this frequency instead of the international distress frequencies (2,182, 4,125, 6,215, and 8,291 kHz) which would have allowed them to communicate directly with Melbourne or Sydney Radio. This may have overloaded "Telstra Control".

To seek assistance using a radio requires a suitably trained operator, who will be fully occupied making calls. This can often be impractical in an emergency situation on a racing yacht where the survivors are busy working to save the yacht. An alternative is the use of the DSC System, costing from $3,000 - $5,000, which comes with a 'one button' distress mode. This automatically sends a signal on multiple frequencies at discrete intervals, and is monitored by shipping. The signal also includes the latest GPS position, making it easier for rescuers to locate the survivors. This is the system which has replaced Radio Telephony, or voice, as the primary distress alerting system. Voice communications are used once communication has been established.

Two other difficulties with radio based systems are the need for considerable power - usually obtained from the main batteries or the engine driven generator - and the reliance on aerials which are often placed on the mast and can be damaged if the vessel is capsized. The AYF require spare aerials, when the main aerial depends on the mast. A very useful back up is a small hand held waterproof VHF radio capable of broadcasting on channel 6.

Emergency distress beacons

A practical, low cost, alternative to a radio based method of raising the alarm is to use an emergency distress beacon, or EPIRB. These work on the principle of sending a signal to a satellite which relays the emergency to a shore based coordinating station, allowing an approximate position of the vessel to be calculated. A rescue aircraft is then dispatched with radio positioning equipment to pin point the source of the signal. EPIRBs are self contained units which require no external power and operate for a minimum of 48 hours. Once activated they require no further attention from the survivors.

Basic EPIRBs can be purchased for as little as $200. These are small portable units which operate on 121.5/243MHz and are also often fitted to liferafts. They are quite suitable for coastal operation, however are limited in their world wide range and require two passes of a satellite to obtain their position, which can take from 10 minutes to two hours. The signal gives a position correct to 10Nm, resulting in an area which has to be searched by the rescuers using radio direction finding equipment. The biggest difficulty with this type of EPIRB is that it is becoming so common that false alarms are a real danger.

This can be overcome by a more sophisticated EPIRB which operates on 406 and 121.5MHz. The signal from this EPIRB includes an identifier which the coordinating station can trace to a particular owner, making false alarms much easier to detect. Such systems cost in the range $1,500 - $3,000, and are often installed in a float free mode with a hydrostatic release. They generally only require one pass of a satellite to obtain a good position fix, which is accurate to within 3Nm.

A further system, which has not yet been approved by AMSA, is the INMAR SAT L Band EPIRB. This uses the INMAR SAT satellite system rather than the polar orbiting satellites used by the conventional EPIRBs, giving an instant alert. The signal also contains the GPS based position, giving a very accurate position immediately.

Alternative electronic based distress alerting systems

Other systems include the SART Transponder which operates on the X Band radar frequency. This sends a return signal to a radar indicating a distress, giving a very accurate position. It is a self contained unit which doesn't require external power and operates for a minimum of 96 hours. All merchant ships monitor this radar frequency.

Telephone based systems can also be used in an emergency. Although the common hand held cellular phones (analogue or digital) have limited coverage the satellite based phone system can be used worldwide.

Cost of electronic based rescue equipment

An important feature of the sophisticated electronic based rescue equipment available nowadays is its cost. Although costs are reducing for some equipment, far beyond what would have been imaginable a few years ago, it is still expensive to fully equip a vessel. The estimated cost to fit a merchant vessel with the minimum legal requirement is around $100,000 for example, and this can be a considerable deterrent to many amateurs. However, as the cost of each rescue considerably exceeds this, (it has been estimated the recent rescues during the Sydney/Hobart race cost approximately $7M) every effort must be made to ensure yachtsmen fit the best equipment possible, thereby reducing the potential cost of each rescue.

One partial solution would be for yacht clubs, or others, to own equipment which could be rented to the boats for the duration of the race. This would bring the cost to each boat down to a manageable level, and would considerably reduce the cost of each rescue. Of course, many skippers would not even rent the equipment unless it was made a regulatory requirement. Great care is required when regulating in this area, as the technology advances quickly and can easily make the regulations outdated and dangerous!

Other aids to location of survivors

Pyrotechnics can be used over short ranges. They are not generally used as the primary location device nowadays, however can be of considerable assistance in locating the survivors once the rescuers are close.

Strobe lights can be fitted to lifejackets and can make it considerably easier to locate a man overboard.

Dye and/or smoke can also be used by a man in the water to assist with location.

Assistance and rescue of survivors

Once located, the next stage in the rescue is to provide assistance to the survivors until they can be rescued. The most common way of doing this is by aerial drop from a fixed wing aircraft.

There are three different approaches to dropping supplies by air: RAAF ASRK equipment; PADS equipment; and Heli boxes.

An ASRK, or Air Sea Rescue Kit, comprises two liferafts attached by a brightly coloured 400 - 500m floating line. Two supply containers are attached to the line between the liferafts. The technique is to drop the ASRKs at right angles to the wind line directly upwind of the survivors. The liferafts inflate and the whole arrangement drifts onto the survivors who are able to grab hold of the line and pull the nearest liferaft toward them. Once on board the liferaft they can pull in the supply containers. RAAF PC-3 Orion and C-130 Hercules aircraft, and the larger civil aircraft, are capable of delivering ASRKs.

One problem associated with the ASRK delivery is the relative surface drift velocities of the deployed ASRK and the disabled yacht, or survivors in the water. Anecdotal evidence from the 1996/1997 Southern Ocean rescues suggest that a disabled yacht can drift at speeds approaching 6 knots in 60-70 knot winds, whereas recent work conducted by the Australian Maritime College (Boyle and Goodchild, 1999) has indicated that a deployed ASRK unit will drift at 1 knot in 20-25 knots of wind. Further work needs to be done on the drift rates of ASRKs and disabled ocean racing yachts in extreme conditions.

The PADS (Precision Aerial Delivery System) is a system developed for delivering a single liferaft or equipment container from a light aircraft. The payload is dropped to the water and a line is trailed from the aircraft which it drops on top of the survivors. The survivors then use the line to pull the liferaft or equipment to them. Another method of dropping a single liferaft which uses a similar principle is the Australian Maritime Safety Authority single unit drop.

A Heli Box is a box which uses a helicopter type principle to slow its rate of decent. It is dropped as close to the survivors as possible and can contain various items, including a hand held VHF radio set to channel 6 for ship to air communication.

Once located, the survivors can be rescued by either a helicopter, a ship, or another competitor in the race. It is important to realise that the maximum operational radius for a typical helicopter is only 150 Nm. Rescues further from shore than this generally have to be performed by a surface craft which will take much longer, and which may not be able to approach the disabled yacht in extreme sea states.

During this time it is very important that good communication be maintained between the rescuers and the survivors.

Finally, the increased difficulty in locating and rescuing survivors as distance from the shore base is increased must be stressed. Serious consideration should be made by race organisers to this issue and, if necessary, way points should be used to increase the safety of the competitors and rescuers.

Crew training

Crew training can be considered under two different headings: training to avoid an emergency; and survival training which will assist once the emergency has occurred.

Training to avoid an emergency
The knowledge required to avoid an emergency will include: an appreciation of the behaviour of the yacht in extreme conditions; an appreciation of the loads on the structure together with the maximum load that can be safely applied; and an appreciation of the need to maintain the critical components, the techniques to do this and the means of testing their safety.

As with most seagoing personnel there is, of course, no substitute for experience. However, yachtsmen can have many years of experience without having been in conditions which are capable of capsizing their vessel. Even the most intimate knowledge of the handling characteristics of their vessel may not prepare them for the techniques required to survive in extreme breaking waves. As noted above, however, researchers in this field have studied why vessels capsize and how to prevent capsize using physical and mathematical models. It is therefore important that this knowledge be transferred to yachtsmen who may confront these extreme conditions.

Survival training
All merchant seafarers are required to complete an approved survival training course before they are accredited to work at sea. This is true although it is very unlikely that they will end up in the water needing these skills.

Oil rig workers who are flown to oil platforms are required to complete specialist training on survival techniques required in the event of the ditching of their helicopter. Again, this is a very unlikely event.

It is noticeable, however, that yachtsmen are not required to conduct any survival training, even although they are much more likely to end up in difficulties on the water than either of the previously mentioned two groups. Of course, they are required to carry certain survival equipment - but they are not required to demonstrate their ability to use it. At least one survivor of the recent Sydney to Hobart race is quoted as having said that he had never even seen a liferaft inflated until he needed it!

Other survival issues such as: immersion suits; survival equipment; cold sea survival; use of emergency radio equipment and EPIRBs; survival rations; flares; and first-aid, are all complex issues, the knowledge of which will greatly enhance the chance of safe rescue.

Whilst there is no doubt that some serious offshore racing yachtsmen have attended survival courses, unless this is a requirement that those entering any long distance yacht race attend an appropriate course, the current situation where the group of sailors most likely to need survival skills do not have them will continue and will certainly contribute to loss of life at sea.

Finally, it should be noted that the Australian Maritime College assists the Three Peaks Race in Tasmania by running a specialist survival course for free each year, which is generally very well attended and enjoyed by all participants.

A compulsory short course for all offshore racing sailors of approximately a week duration, covering both aspects of crew training, would reduce the number of accidents, increase the chance of surviving an accident and greatly enhance the safety of offshore racing.

Concluding remarks

As noted above, the safety of offshore racing yachtsmen is dependent on a wide range of factors, which have to be considered together to make the sport of offshore racing as safe as possible.

Much is known about many of these factors, and safety could be greatly enhanced by simply applying existing knowledge to modern racing yachts, their crew and equipment.

For example, it is strongly recommended that the statical concepts used to determine a yacht's safety against capsize, and its self-righting capabilities, can be improved by using modern state-of-the-art dynamic techniques.

In addition, the safety equipment available is improving rapidly, and whilst the latest commercial requirements may be too expensive for amateur yachtsmen, a number of simple low cost ways of improving the safety level for competitors discussed in the paper should be considered.

Finally, the issue of crew training - both in avoiding an accident and in surviving if an accident occurs - is very important. It is strongly recommended that the possibility of a mandatory short course for all offshore racing yachtsmen be seriously considered.

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The assistance received from Andrew Tuite of the Australian Maritime Engineering CRC Ltd on capsizing and self-righting, and from Mike Collinson, Chairman of the RYCT Radio Communications Committee, on radio procedures was also of considerable help and is gratefully acknowledged.

Where do We Go from Here?

Mr Bryan Chapman

President RINA (Australian Division)
Melbourne

In attempting to tie together the threads of today's discussions and reach some kind of answer to the question "Where do we go from here?" I intend to focus on technical issues. While there has been considerable discussion of other aspects including weather forecasting, race organization and rescue services these are fields which are outside my area of competence. I think the RINA would generally adopt a similar position.

On the technical front the general thrust of the discussion has been that there are design problems which need to be addressed. Many of these design problems appear to arise from the measuring rules, and manifest themselves as characteristics which are unhelpful to a yacht in heavy weather conditions - high freeboard, high centre of gravity, light displacement, wide beam and low rolling moment of inertia. This implies that the measurement rules need attention from a safety perspective. It is also worth saying that this knowledge is not new. It has certainly been available since the post-Fastnet 1979 inquiries and investigations of the early 1980s.

I believe that whether we like it or not there will be some kind of regulation of recreational vessels, including ocean racing yachts, whether by legislation or on a voluntary basis. The reasons for this are:

- The current situation where the design and construction of recreational craft is completely unregulated is alarming, and can't be allowed to continue for much longer. It contrasts starkly with the situation of commercial vessels and implies that the lives of recreational sailors are less important than those of professional crews and passengers.

- The advent of the European Union Recreational Craft Directive, the likelihood of equivalent legislation in the United States and the anticipated development of relevant ISO Standards must have an influence on the design and construction of Australian manufactured vessels if they are to remain competitive in these markets.

- In many cases with recreational craft, particularly those used by weekend sailors, we are dealing with a customer base which is comparatively uninformed.

If I were a yacht designer I would pray for regulation of some kind, or at least the availability and application of some kind of guidelines. Without them it is only a matter of time before I, or somebody like me, is held to be liable for the loss of a boat or loss of life.

As to "Where to from here?", I can only speak for myself and, to some extent, for the RINA Australian Division. Within these limitations I intend to do what I can to:

- Ensure that RINA is represented at the Coroner's inquest at least in an observer role, to ensure that we understand what transpires and what recommendations may be handed down by the Coroner.

- Establish a RINA Australian Division sub-committee to review available information and develop appropriate proposals for submission to relevant bodies.

- Familiarize myself and RINA Australian Division with the requirements of the European Union Recreational Craft Directive and the development of any relevant ISO Standards and ensure that RINA Australian Division is represented on appropriate Standards Australia committees.

I noted also remarks regarding the imminent development of monitoring systems which would enable the controllers of races such as the Sydney-Hobart to monitor the conditions under which individual yachts are operating without the requirement of inputs from the crew. This would be achieved by the use of on-board sensors communicating with a central computer using the existing mobile 'phone and satellite communications systems, and I understand that similar monitoring systems are already in use by the trucking industry. Such systems appear to offer significant benefits to weather forecasters, as they would be provided with intimate details of the weather shifts encountered by individual yachts, and to rescue services, as the exact positions of any yachts in trouble could be known immediately if GPS data is one of the sensor inputs. I believe that this technology offers significant benefits in the command and control area, and intend to take the issue up personally with appropriate yachting bodies and workers in the area.

Finally I want to congratulate the organizers of this Workshop. I know that Lawry Doctors and Phil Helmore have put a lot of work into it and believe that their efforts have been well rewarded by the number of participants, the high quality of the presentations and the spirited nature of the discussion. On behalf of the Australian Division of the Royal Institution of Naval Architects I thank them for their work, and the University of New South Wales for accommodating us today.

Written Discussion

Discussion

Mr Warren Anderson

Sheerline Spars
Brookvale

I would like to make some further comments on lightweight yachts.

The IMS rule promotes reasonably light yachts, with high topsides, small cabins and low stability. These yachts are extremely fast in light weather but, as was detailed in the workshop, have problems in extreme weather.

However not all lightweight yachts are built to the IMS rule. My own yacht "Wide Load" LOA 12.19m, was designed as a two-handed yacht and therefore has to be much stiffer than an IMS yacht. We have lower topsides and a long cabin trunk but we do have a reasonably wide beam of 4.0m which is carried well aft. The yacht is also very strongly built with all the necessary bracing right throughout. It has two extra watertight bulkheads in addition to the collision bulkhead in the bow, the idea being that the yacht itself is the lifeboat.

In theHobart Race we were in the worst part of the low system (NE quadrant close to the centre) in the same general area as B52 and Sword of Orion for nine hours with estimated winds of 75 to 80 kts with higher gusts. The windspeed estimate is initially from our wind instruments and later from the behaviour of our yacht to its sail area and the appearance of the surface water.

During this time we received four knockdowns with the mast in the water. In the last knockdown a crew member was thrown against a window knocking it out. Due to the ingress of water, our radios became inoperable and we decided to turn back to the north. The knockdowns sustained were mostly caused by the boat being sailed too square to the waves as we were forced to use a spitfire jib, as our trysail was found to be too big.

While on the way back, the yacht was eventually rolled to approximately $160/170^{\circ}$ when caught in a large wave south east of Gabo. However it rolled down, stopped and immediately righted itself. The whole incident only took a few seconds. In this incident, the mast was badly damaged, both spreaders being ripped off the starboard side, but by restaying the mast we were able to proceed to Ulladulla and the yacht was sailed home from there after the spreaders were replaced.

Subsequent checks and tests have shown that there was no damage to the hull structure except for the window.

Our experiences seem to substantiate the theory that 115° positive stability is not enough - both Sword of Orion and B52 were rolled 360° in the same general vicinity, B52 staying inverted for 4 to 6 minutes. They further show that a lightweight yacht can still be built strongly enough to withstand the loads imposed by severe weather.

Discussion

Mr Don Curchod

Yacht Designer

Whale Beach

I do not feel that the "light" versus "heavy" yacht design debate will ever cease, and I do not personally feel that it is very relevant to safety.

What is very relevant and important to safety however is strength versus weakness.

1. Hence the uncontrolled present aspect of the strength and hence safety of ocean yachts is one important factor needing control.

   The overseas ISO standards will probably be the only way of implementing a strength standard, but this will only work if Australian yachting groups mandate and police their use.

2. Another important aspect is the training and qualification of skippers. It is obvious to me that the most important reason for the last Sydney–Hobart disaster was skipper incompetence. Many skippers failed to abandon the race when they should have, mainly due to not realizing that wave height and wind strength was average and required the addition of 40% to give the maximum expected. The conditions experienced during the race were as forecasted, but skippers generally did not add the required 40% and so got in over their heads.

   The only way this can be controlled is certification of passing a suitable recognized training course with race experience.

3. The weather bureau can improve this situation, as is done in some areas, by giving both the average and maximums in their standard forecasts.

Other aspects I feel are required are:

4. Mandate better life rafts.

5. Tightening of regulations regarding gear, by requiring:
   a) personal EPIRB's;
   b) double harness clips;
   c) weather faxes; and
   d) waterproof hand-held VHF radios.

Discussion

Professor Peter Joubert

The University of Melbourne

Parkville

Introduction

1. My name is Peter Numa Joubert and I reside at 14 Grosvenor Street, Brighton, Victoria. I was formerly the Professor of Mechanical Engineering at The University of Melbourne and a brief Curriculum Vitae covering some aspects relevant to these comments is attached.

2. I was a competitor in the 1998 Sydney-Hobart race, skippering my 43 feet yacht *Kingurra*, which I designed. *Kingurra* could be described as a relatively heavy (DSPM=12465 kg) yacht, beautifully built in timber by a master craftsman. It has a limit of positive stability of 125.4°. All off-watch crew sleep in warm, dry bunks, while those on-watch sit in a deep protected cockpit.

3. *Kingurra* was dumped by a large breaking wave at about 1900 hours on Sunday 27th December. The strong winds first struck about 1500 hours and until the incident the boat had been travelling in full control at about 6 knots with only a storm jib set on the inner forestay. The boat was rolled to about 145° and returned after about 10 seconds.

4. In this process, three crew members were left overboard all attached by their safety lines. Two were safely retrieved, but the third person wearing an integrated harness fitted inside his jacket slipped out of both his harness and his jacket when he raised his arms and floated off behind the yacht in his blue underwear. His inflatable buoyancy stayed in his jacket. He was later rescued by a helicopter. We gratefully acknowledge the bravery of the rescue crew. This brings me to my first comment.

Seamanship and safety harness

5. The skipper of *Bin Rouge* gave the workshop the benefit of his experience and advice on how to prepare for and sail through the hurricane, the implication being that good seamanship will save the day. I will return to this point later. One of his comments covered the wearing (at all times) of a safety harness under the waterproof jacket. He then fitted this harness over his head and arms as a demonstration and did not adjust the harness in any way.

   This was precisely the situation with the harness worn by our lost overboard crew member, John Campbell. In order to put on the harness which was permanently fitted inside his jacket, it was not tightened properly.

   The old fashioned harnesses provided on *Kingurra* are worn over the jacket and require tightening after fitting. These worked properly.

Safety responsibilities

6. The publication, "Racing Rules of Sailing for 1997–2000" by the Australian Yachting Federation, contains a number of rules dealing with safety.
   Rule 1.1 deals with helping those in danger.
   Rule 1.2 deals with life-saving equipment and personal buoyancy.
   Rule 4 states that a boat is solely responsible for deciding whether or not to start or to continue racing.
   Opposite to rule 4, rule 32 deals with shortening or abandoning after the start. Here the responsibility is on the race committee who may abandon the race or shorten the course. 32(b) states, "because of foul weather" and 32(c) for any other reason directly affecting safety.

   My comment is that safety is overriding and fundamental so the relevant aspects of rule 32 should be in the fundamental section.

   Race committees should be in a better position compared to a skipper to collect and interpret deteriorating weather information and cancel a race if, as with the 1998 Sydney-Hobart race, there was a high risk of boats being upset by the predicted storms. To argue that those on the ocean are in a better position to make a decision with regard to continuing the race does not take into account a number of facts, namely:

   (a) the desire to keep racing; no-one likes to withdraw voluntarily.

   (b) the loss of clear thinking due to being tossed about by the violent seas.

   (c) the lack of appreciation of the magnitude of the conditions in a storm by inexperienced crews.

   (d) lack of appreciation of the nature of random events (very large breaking waves).

If being out in the weather is so important, then the race director should be on *Young Endeavour*.

The attitude of the race committee in the Sydney-Hobart race is to shed responsibility on to the skipper. Mr. Cranich in his presentation referred to the possibilities of successful legal actions against responsible persons as a result of tragedies.

In many ways, good seamanship and ocean racing are contradictions. It is my opinion it is better to avoid the tragedy rather than transfer responsibility to a skipper who may let his desire to keep racing expose his crew to danger.

The weather

7. The briefing by a weather person on the 24th December made no mention of a storm in Bass Strait. There was no mention of a storm in the written information provided on the morning of 26th before the start. One hour after the start, the Bureau predicted a storm in Bass Strait for the following day, the 27th. This warning was conveyed to *Young Endeavour*. Winds of 45–55 knots were predicted. In subsequent broadcasts, *Young Endeavour* mentioned Rule 4 but gave no advice on the desirability of seeking shelter.

   At the 2pm radio schedule on 27th, a large proportion of the fleet under the influence of an intense southerly set of up to 3 knots, were entering Bass Strait. The same winds of 45–55 knots were predicted in the broadcasts.

   Sword of Orion broke the rule regarding giving advice by commenting they had winds of over 70 knots.

   Larger yachts had experienced these hurricane force winds earlier but not reported them under the rules of racing.

   It would be desirable if this kind of real information could be relayed in time to the bulk of the fleet. Many more yachts would then have turned for shelter, I feel sure.

Wind speeds

8. The Weather Bureau in a Preliminary Report dated February 1999, suggest that their forecast was accurate (45-55 knots) and that within this forecast lies a prediction that mean winds of this magnitude could be expected to produce gusts of 70–75 knots or more, on a fairly regular basis.

   This upgrading of gusts is not mentioned in any of the literature given to competitors by race officials.

   Some competitors I have spoken to claim mean winds greater than 70 knots.

   On *Kingurra* it was estimated the average wind speed during the whole of the storm was 65 knots. There were periods greater than ten minutes when the wind was in excess of 68 knots (the maximum speed on the wind gauge).

   As wind force is the quantity which affects yachts and waves, the Bureau forecast is in error by about 100 percent.

   Further, the forecast should not have been for a storm but for a hurricane according to the classification of wind strengths due to Admiral Beaufort.

Oddly enough, I understand the Bureau refuse to class winds of greater strength than that of storm.

Errors in wind speed from yachts

9. Most yachts use rotating cup anemometers to measure wind speed.

In high winds the yacht is constantly heeled to about 30° from the vertical. Photographs of yachts in the hurricane support this suggestion.

Consequently the anemometers do not measure the true wind speed but a reduced component approximately proportional to the cosine of the angle heel. Thus a wind speed measured at 70 knots gives a true speed of 80 knots.

A further complication is caused by the relative velocity and the difference between an apparent wind and true speed because of the boat's velocity at some angle to the wind direction.

Of course, all these effects may be allowed for and a modern anemometer may make such adjustments.

The question of wind speed is not simple.

Then again, the Bureau refers to a wind speed at a height of 10 meters above the ground. This measurement is even more complicated when it is referred to the violent ocean.

The waves moving with the wind at say 25 knots reduce the frictional slowing down of the wind compared to flow over a stationary surface. Thus wind speeds over the ocean at a height of 10 metres are greater than that over the land.

The datum for the standard height has even less meaning. Should it be the trough, the mean sea level or the wave crest? With roughness velocity profiles, the datum is established by a complicated analytical process and see for example, Perry and Joubert, Journal of Fluid Mechanics, Vol 17, Part 2, pages 193–211, 1963.

Grid pattern for the predicted forecast

10. In response to a question, Mr. Patrick Sullivan said the grid size used in the computer program was about 50 nautical miles but much smaller sizes were available over limited areas.

    There has been a great improvement in forecasting ability in recent years and it might be worthwhile instigating a special localised tighter grid forecast for events like the Sydney-Hobart race. This should allow better predictions of wind velocities for rapidly developing local regions of intense low pressure as occurred on 26th–27th December.

Wave size

11. The size of the waves was so great in the hurricane coupled with a probable effect from the east coast current that many of the waves were breaking. It was these large breaking waves that overturned a number of yachts which in some cases led to the loss of lives.

    The weather bureau in their preliminary report suggested that observations of wave heights at Kingfish B of 6 to 7 metres and maximum waves of 11 to 12 metres are consistent with some observations from crews near Gabo Island.

    Helicopter pilots are reported to have measured greater heights. In the article written by Mark Whittaker in the Weekend Australian Magazine of March 6–7, reference is made to the rescue crew in the Victorian police Polair helicopter. According to the article (p. 24, 3rd column) the wave height for one wave was 45 metres.

    Reference is made in an article in Seahorse magazine April 1999 (p. 10, first column) to a wave 80 feet high — probably close to 100 feet. In the second column, the overturning of the Swan 44; *Loki*, is described. They were dumped upside down by the wave.

    From the deck of a yacht it is difficult to measure the height of a wave.

    At the workshop, Professor Mike Banner of the University of NSW, outlined the manner in which a non-linear group of waves can rearrange themselves putting all their energy into one wave which may then peak and break. He has published a paper in the Journal of Fluid Mechanics on his findings.

    Stephen Salter has demonstrated to me in his laboratory in James Watt University, Edinburgh, how slightly angled waves can produce occasional double height waves which will break and overturn a vessel.

There were no wave recorders in the path of the hurricane so the only measurement which may have any validity may be that of the helicopter pilot.

Whatever the actual height of the largest breaking waves, it is certain there were a considerable number of them distributed throughout the area of the storm.

For those boats dumped by these waves it did not matter whether the boat was lighter (*Wide Load, Sword of Orion, Stand Aside*) or heavier (*Kingurra, Loki, Winston Churchill*), the waves were not survivable and I doubt that better seamanship could have avoided such waves, especially at night.

In my opinion, given equal seamanship, the question of being dumped depends on luck or probability and individual experience is no guide.

Hull strength requirements

12. From the damage to deck fittings on *Kingurra* suffered when it was dumped by the breaking wave at about 145° from the vertical and also to other yachts such as *Wide Load* (rolled five times) and *Loki*, it is clear that decks and topsides need to be built to the same strength requirements as the immersed panels.

Discussion

Mr David Lyons

Lyons Yacht Designers and Technical Consultants

Frenchs Forest

1. Scantlings

As is well known, American Bureau of Shipping (ABS) suspended their independent Plan Approval service for Offshore Racing Yachts less than 24m in 1996. Since then, the requirement of the Australian Yachting Federation (AYF) for Safety Categories 1 and 2 has been for the builder and designer to submit certification that the yacht in question has been designed and built in accordance with the *ABS Guide for Building and Classing Offshore Racing Yachts,* 1994 including *Notice No.1* effective 16 November 1995.

As a member of the Offshore Racing Council's (ORC) International Technical Committee (ITC), I can confirm that it is the policy of that body to again implement an independent scantling review system as soon as a set of rules for reference becomes available. Due to concerns about intellectual property rights, the ABS Guide will not be available. However, the International Standards Organisation (ISO) has almost finished developing the new ISO Standard 12215, which is directly applicable to such craft as those under consideration.

I am heading a sub-committee of the ORC which is comparing the scantlings of this standard with the former *ABS Guide*, and will report to the ORC as to suitability and, subsequently, a timetable for implementation of a renewed independent plan approval service based on ISO12215. This is ORC policy.

2. Stability

As a member of the Cruising Yacht Club of Australia's (CYCA) Sailing Committee, I can confirm that it has been decided to require all IMS-rated yachts to meet Stability Index minima in all future applicable races, rather than the greater of Limit of Positive Stability and Stability Index. The 1999 Sydney–Gold Coast race to be sailed in August will adopt this decision. As a result, particulars of beam, depth and size will be accounted for following research post-79 Fastnet into capsize tendency. This is in essence a more stringent requirement for most yachts, where wide, shallow, smaller yachts will require a lower VCG to meet the threshold.

3. The IMS Rule

I am concerned about comments made in letters to the *Sydney Morning Herald* in late December 1998 and early January 1999 by Bryan Chapman and Warwick Hood. In particular I take issue with the following, based on my experience as a designer and a sailor of modern offshore racing yachts:

3.1 Whilst the IMS Rule in its 1998 version has clearly encouraged low *initial* (0-30degrees) righting moment (RMC) in order to gain a handicap advantage, competitive, optimised IMS racing yachts feature a high positive/negative stability curve area ratio, and high *ultimate* stability as a result. Low-angle, as opposed to ultimate, stability should not be confused. IMS encourages moderate beam/draft ratios compared to non-IMS "skiffs with keels", and the former type is inherently quite safe to handle, assuming a competent crew is on board.

3.2 I take strong issue with any inference that modern IMS yachts are dependent for safety on crew induced righting moment. The IMS VPP assumes placement of the declared crew weight on the yacht's centreline until six degrees of heel, beyond which the full crew weight is placed at the crew righting arm to windward of the centreline. If a yacht does not do this in practice, it may be suffering a handicap disadvantage, but in my experience this is not a safety issue. Indeed, in my experience in all but ultimate storm conditions, on-deck crew prefer to sit with their legs over the side for security and comfort. In the 1998 Sydney–Hobart, most yachts sailed well with only minimal crew on deck and the majority below out of the weather, which is the safest place to be provided all movable gear is securely stowed to avoid injury. IMS actually has a disincentive against maximising crew weight, as any amount added beyond "default" is not counted when the wind is aft of the beam.

3.3 I also take issue with Mr Hood's statement that modern IMS yachts are susceptible to nose-diving as a result of rule-induced fine forward waterlines. If this feature were incorporated onto tradition older designs with correspondingly higher displacement/length ratios, then the behaviour Mr Hood describes could indeed occur. However, by virtue of modern IMS displacement/length ratios, such yachts sail at higher Froude (speed/length) ratios, and good design detailing which places adequate volume forward albeit with narrow entry, generates a dynamic component of lift which makes the yacht surf easily. Such behaviour enhances manoeuvrability in my experience. As a result, modern procedures for negotiating storm conditions are revised, and traditional methods of "lying a-hull" or "heaving to" may not be needed.

As a footnote, I would point out that the 1999 Sydney–Mooloolaba Yacht Race featured very heavy downwind sailing conditions, and none of the modern IMS hull shapes showed any susceptibility to nose-diving during conditions when it would be most expected.

3.4 In light of my earlier comments regarding scantling rules and IMS stability assessment, it is suggested that Mr Chapman should not be unduly concerned about these topics.

These were the main issues I felt the need to address immediately. The relevant committees of the ORC are taking a keen interest in the Sydney–Hobart enquiry outcome, and will incorporate any changes thought to be desirable in the interests of safety. I would contend that modern IMS yachts are the most seaworthy type for fully-crewed operation in rigorous conditions. This is based on my design and sailing experience in those conditions.

Discussion

Mr Andrew Lucas

Agent Oriented Software

Carlton

1. Introduction

The objective of this paper is to give an overview of modern satellite-based positioning and communications systems and their potential for yachting. This contribution draws upon the author's observations of a number of yacht racing emergencies over the past 20 years. It also draws on the long experience of the defence forces in surveillance and command and control; showing a practical way to improve substantially the management and safety of yacht racing. This aim can be achieved without restricting the crew's freedom to sail a race according to their wishes.

2. Background

Following the recent 1998 Sydney to Hobart yacht with the associated loss of life, the focus of public attention has been on the lessons to be learnt in respect of weather forecasting, yacht design, measurement rules, and the race management in all its respects.

However, effective race management and the achievement of a high level of safety in extreme conditions, such as those recently experienced, depend upon an accurate appreciation of the developing race situation. This, in turn, relies upon good communications and up-to-date accurate, weather forecasting and reporting.

Currently communications on racing yachts are exclusively voice based, using Very High Frequency (VHF) radio close to the coast and High/Medium Frequency (HF/MF) radio in areas such as the Tasman Sea or Bass Strait. Race organisers rely upon scheduled voice reports from the competitors for their information on yacht position and actual weather experienced. These position reports are based upon a combination of dead reckoning, celestial navigation and, more recently, satellite-based positioning. Generally the ship/shore communications are on a single voice channel, in routine circumstances radio congestion is avoided by calling yachts in turn over the period of the "sked". This system is not perfect; yachts often experience difficulty with their HF/MF communications, as HF/MF radio installation is complex and requires professional installation and regular maintenance to ensure good performance.

When emergencies occur, the limited radio channels can become congested. Radio discipline can then break down due to the competing demands of different yachts, and transmissions may become incoherent. As a result of these conditions, weaker emergency transmissions potentially can be overridden. Yachts with important information (such as the local weather they are experiencing) are sometimes reluctant to communicate over already congested channels.

Information received by coastal radio stations or radio-relay vessels must be manually passed on to other parties, such as the Australian Maritime Safety Authority (AMSA). Consequently it is hard for race authorities, radio operators, and emergency organisations to build a clear "picture" of a rapidly changing situation, absolutely vital when a major emergency develops.

As from February 1999 maritime distress communications is covered by the Global Maritime Distress and Safety System (GMDSS), compulsory for vessels over 300 tonnes. It defines a regime of radio and satellite-based emergency calling and reporting. Yachts may submit emergency reports using HF/MF or VHF voice radio. Once the emergency develops this is likely to be accompanied by the activation of one or more emergency position indicating radio beacons (EPIRB). EPIRBs (both 121.5/243 MHz or the more capable 406 MHz units) provide approximate position information to the rescue authorities; their signals can also be used as homing beacons by searching ships and aircraft. However, the simpler EPIRB signals must also be correlated manually with the many voice reports to correlate the signal with a particular vessel and to build the situation picture.

What is wanted is the ability for race organisers and rescue authorities to continuously monitor routine situations, which can sometimes rapidly develop into major emergencies. The key is to ensure that the situation picture does not have to be built in the midst of the emergency when the authorities are taken by surprise. Instead, they should have the opportunity to plan ahead. We cannot go on saying " We don't know what's going on out there!".

3. Modern Command, Control and Communications

The legendary success of the defenders in "The Battle of Britain" was due to a combination of factors, not least the bravery of the pilots. The success is often attributed to the novel use of radar to locate the attackers in time to prepare a defence. But the story is actually much more complex, success came from the integration of all the components into a single system. This is now referred to as C3, for Command, Control and Communications.

Since that time C3 has become a science studied in its own right, with a continual effort to provide timely, better quality information to military commanders, and to give them reliable communications systems to support their decisions. Defence forces around the world recognise the importance of accurate information on the situation, this has dominated US military thinking since the Gulf War. In Australia, the Defence Department, lead by the Defence Scientific and Technology Organisation in Adelaide, is developing a range of advanced surveillance and command and control systems for monitoring Australia's coastline. This C3 system, which combines over-the-horizon radar, airborne radar and other sensors, unmanned air vehicles with advanced radars, and a central control centre, promises to revolutionise surveillance of Australia's coastline in the next five years. This points to the way ahead.

3.1 Situation awareness

One of the key advances in C3 has been the recognition of the importance of "Situation Awareness" a term used to describe, for example, the race organisers' understanding of the current race situation, that is, the combination of fleet location, individual vessel problems, current weather and weather forecasts. Today, relying on periodic voice communications, information is by definition out of date, incomplete, not correlated, contradictory, or spread between several people or centres.

The objective is to design a C3 system that ensures that information is timely, correlated and drawn together into a single coherent "picture". The human brain is excellent at forming mental "pictures" of a situation, but different participants may have formed varying pictures. The system helps the human by drawing all the diverse information from various sources together into a single "situation picture" accessible to all organisers and safety-related groups.

But how can these technologies and systems benefit yacht racing? The cry will be: "But we are yachtsmen, not rocket scientists!"; or, "I'm a race official, not a general!". The answer is that it is possible using satellite-based positioning and data communications from each yacht to provide race authorities with an advanced situation display for less than the cost of a new jib for each owner. This is worth looking into.

3.2 Satellite-based positioning

In the last 10 years satellite-based positioning systems have revolutionised navigation for aircraft, ships, freight companies and, more recently, motor cars. Current systems are the US Global Positioning System (GPS) and the Russian Glonass. Both offer accurate positioning for civilian users, typically to 100 metres accuracy. Glonass currently has limited availability due to financial circumstances in Russia, making GPS the system of choice.

The US Federal Aviation Authority (FAA) has recently accepted GPS as the sole means of civil aircraft positioning in the USA, another milestone in the use of GPS.

Automated position reporting using GPS is already proven in Australia, the new advanced air traffic management system, known as TAAATS, uses GPS positions transmitted automatically via satellite from aircraft, such as QANTAS 747's, to plot a "radar like" display of aircraft across the Pacific. Air traffic controllers use this information to better manage the traffic, allowing aircraft to cruise at their optimum altitude for efficiency. The benefits, in both improved safety and reduced fuel costs, are substantial. TAAATS is an example of what can be achieved by using automated position reporting to build a situation picture.

The attractions of GPS for yachtsmen are that the service is free and receivers are cheap, reliable and provide extremely useful navigation functions. The consequence is that for yachtsmen the problem of yacht positioning is "solved", an extraordinary advance that overcomes a problem that navigators struggled with for centuries.

3.3 Satellite-based communications

The concept of satellite communications has developed from the early geostationary satellites that transmitted television pictures across the world. Currently there are a couple of hundred communications and surveillance satellites, many "geostationary" in orbits of thousands of kilometres high. Some carry international telephone conversations, others satellite-based TV to households. The weather bureaux of the world are advanced users of specialised satellites that provide, amongst other services, sensors to observe and record cloud cover, sea surface temperatures and sea states. In fact far more forecast, real-time, and historical weather information is now available from weather bureaux free over the Internet than can possibly be transmitted by low data-rate weather fax services over HF/MF or VHF radio.

But there is a new satellite revolution just beginning; Low Earth Orbit satellites, or "LEOs" which orbit much lower (only 800km above the earth's surface) than the current generation of geostationary satellites. The number of satellites to be launched over the next five years is staggering; approximately 350! Table 1 below illustrates the wide range of systems in operation or under construction. This is in addition to the existing GPS and Glonass constellations, and is more than all the satellites in orbit today. The first constellation of 66 for the Iridium mobile phone and paging system is already in orbit. Although handsets are currently expensive, as were the original GSM phones, the price will drop rapidly as the number of users increase and as competitors commence operations.

3.4 Voice and medium-rate data communications

Iridium-style global phones will provide an alternative to HF/MF radio for point-to-point voice conversations, but not for data intensive communications, such as detailed weather information including satellite photographs. The system will allow conventional voice telephone communication between a yacht and any other telephone.

3.5 The new generation of messaging and broadband data systems

The future for these constellations is illustrated by the following examples of the operational ORBCOMM and Teledesic system under development.

3.5.1 ORBCOMM

This service currently uses 28 satellites to provide global data communications via "Subscriber Communicators (SC)". The SC for mobile two-way message-based communications uses a hand-held unit, roughly the size of a GPS. Typically, the units have an alphanumeric keyboard and small display screen. Using such a lightweight, hand-held device, short messages can be sent and received via the Internet.

3.5.2 Teledesic

Teledesic is targeted to begin services in 2003. Desribed by its developers as "A Global, Broadband Internet-in-the-Sky", the Teledesic Network is a high-capacity, broadband network that combines the flexibility and robustness of the Internet, and "optic-fibre-like" communications quality. Teledesic will give low-cost access to interactive broadband communication to all areas of the Earth.

The Teledesic system is unprecedented in its scale, capability and communications capacity, dwarfing all present communications satellite systems. With 288 spacecraft the Teledesic Network is designed to support millions of simultaneous users. Most users will have two-way connections that provide up to 64 Mbps on the downlink and up to 2 Mbps on the uplink, representing access speeds up to 2,000 times faster than today's standard analogue modems.

System	*No. of satellites*	*In service*	*Roles*	*Controller & comments*
GPS (Navstar)	24 in orbit	1990-4	Positioning	US Defense Department, now guaranteed civilian access
Glonass	21 planned, approximately 14 in operation	1993 approx.	Positioning	Russian Space Force
Iridium	66 in orbit	1999	World mobile phone, paging, data	Consortium lead by Motorola. Compatible with GSM mobile phones
Globalstar	48 planned, 16 in orbit	1999	World mobile phone, paging, data	Consortium lead by Space Systems Loral. Compatible with CDMA mobile phones
Orbcomm	28 currently in service	1995-9	Data communications	Partnership of Orbital Sciences Corporation and Teleglobe Canada
ICO	10 satellites		Mobile telephone	Consortium of international telecomms. companies
Teledesic	288 planned	2003	Data communications, other services	Consortium including Boeing, Matra, supported by Bill Gates
Total satellites	**480 approx.**			

Table 1: An indicative table of satellite constellations in operation and planned

Teledesic terminals will communicate directly with the satellite network and interface with a wide range of standard network protocols, including IP (Internet), ISDN, ATM and others. Although optimised for service to fixed-site terminals, Teledesic is able to serve transportable and mobile terminals, such as those on yachts.

This extraordinary capacity to communicate with yachts at sea, and for yachts to communicate with land bases, offers enormous potential if it can be used to construct a situation picture. Already some races, such as the BT Global Challenge, are using satellite technology to monitor yacht positions. But these races are simpler to manage in many ways, with no more than a dozen competitors. This satellite technology can also provide limited data communications, but the equipment is bulky and expensive and beyond the budget or resources of a small yacht. The challenge is to monitor, manage and, if necessary assist, 200 yachts in fierce, offshore conditions.

4. C3 System for building a situation picture

Building a situation picture for 200 yachts is feasible. The situation picture, shown in the following figure, takes all the information available from diverse sources and presents it in a single coherent "situation picture". As the objective is to enhance the Situation Awareness (SA) of the race organisers, I will refer to this as an SA Display.

4.1 The participants and the sources of information

4.1.1 The competitors

Each yacht will be equipped with a data terminal, which will be act as the "hub" for the yacht's automatic communications, this will have a small antenna for communicating with the satellites. Devices, such as the yacht's GPS, will be wired to the data terminal via existing marine networking standards such as NMEA.

Under normal conditions the Race Centre's computer, programmed with the competitors' communications "addresses", will request positions automatically, say every 20 minutes. This information, which will consist of the yacht's GPS position, heading and speed made good, is then sent automatically by the yacht's data terminal as a message addressed to the Race Centre computer. In turn this information will be displayed on the SA display at the Race Centre. No human intervention is required and the message cannot be "eavesdropped" on by other yachts, unless directly addressed to them as well.

For yachts fitted with instruments possessing NMEA communications capability, information such as apparent wind strength and direction, and water temperature can also be transmitted. Combining this information from yachts spread over the race course will give a clear picture of a developing situation, for example the rate of progress of a southerly front, or the local strength of southerly currents. This information could be important in warning of extreme local wave conditions.

4.1.2 Bureau of Meteorology (BoM)

Rather than a single weather briefing, navigators can use the data terminal, potentially combined with an inexpensive lap top or printer, to receive real-time forecasts from the Bureau's web site. This could include any of the satellite images available on the web site. The speed of the communications will allow such images to be transmitted to yachts in seconds, rather than minutes.

In turn navigators could program their data terminals to transmit local conditions measured by their instruments on a periodic basis to the BoM computer, again without human intervention, other than to turn the equipment on!

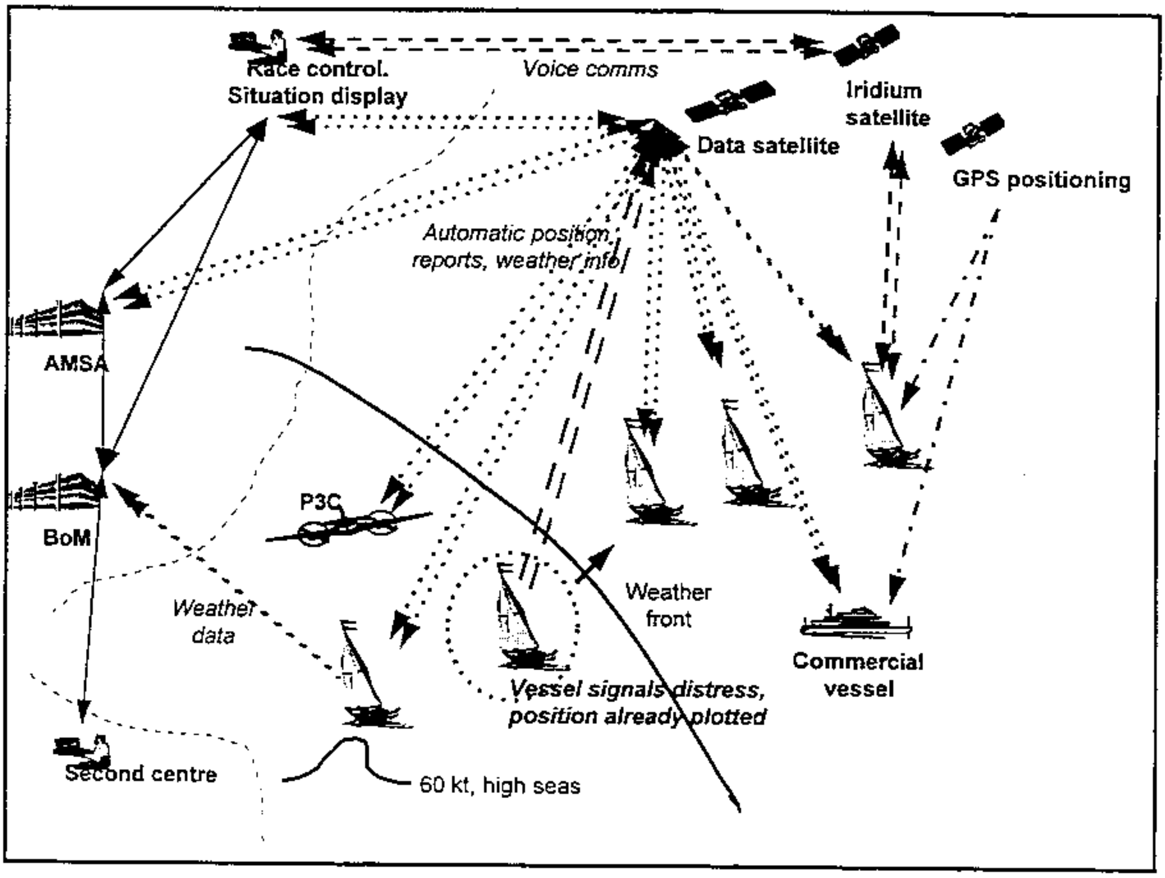


Figure 1: Building a situation picture of the race using satellite positioning and communications

4.1.3 Other information sources

There is a wide range of craft, including coast guard vessels, fishing boats, cruising yachts, ships, naval craft, aircraft and helicopters, which could be "subscribers" to this network. In the case of the Sydney/Hobart, for example, these vessels could fill in many of the blank areas of the picture with local weather information. In addition, as a precaution, their position can be communicated automatically by their data terminals to the authorities in advance of an emergency.

4.1.4 The Race Centre and AMSA

The Race Centre is the key participant as it builds the situation on its computer. This can be a relatively inexpensive PC, linked to AMSA, the Coast Guard and the satellite services by the Internet. The roles of this computer are:

- To automatically request the competitors to transmit their positions, on an "as needed" basis. If the weather is calm, information might be collected hourly. On the other hand, in extreme conditions, vessels that have already made a distress call may be monitored every 5 minutes.
- To automatically access BoM weather information, for example isobar charts or predicted sea state images. Also automatically accept messages containing new data or warnings and alert the authorities of its arrival.
- To accept information from other sources, as already described.
- Display this information as a "situation picture", plotting the competitors and other vessel positions on the electronic "chart" screen.
- Allow the instantaneous electronic communication of this situation picture via the Internet to AMSA, the coastguards, or another centre such as Hobart.
- Alert the organisers to potential emergency situations, such as when a yacht stops automatically transmitting.

In turn, AMSA can both identify its rescue resources and their positions by entering their information manually to the picture, or allowing the craft under their control to provide the information automatically. It is clearly feasible for AMSA to build a version of the situation picture for its own purposes, using the Race Centre picture as a basis. AMSA can then use this display to generate information for automatic transmission to, say, rescue helicopters. This gives them an alternative "homing" technology to radio-based EPIRB homing.

Clearly, from this description, an infrastructure is being provided for building new functions not even thought of yet. The important point is to build a C3 system that automatically provides essential race monitoring and SAR information for organisers using low-cost automatic data communications. This allows race authorities to keep in touch with developing situations, and to maintain "situation awareness" without compromising the confidentiality of information transmitted by competitors. It places AMSA in a position where it receives instant notice of an emergency, together with the necessary situation information to enable it to launch the most appropriate action.

5. Conclusions and recommendation

Yachtsmen and women are conservative. They will say: "So what for this technology, it's the skipper's choice whether to continue, or not", or, "You can't avoid accidents, they'll always happen, you can't design a boat to survive in all conditions". These sentiments will be used by some as a justification for continuing as before, "This satellite technology doesn't matter!" But it does matter: if you're skipper whose yacht is sinking and you want to give your crew the best chance of survival; or if you're the crew of a rescue helicopter operating in 60 kt. wind and 20 metre waves at 100 ft. altitude with 0.5 mile visibility in driving rain and with limited fuel you need the race and rescue authorities to have the best possible information. This information might help save a life.

Responsible use of the technology becoming available will go a long way to deflecting criticism of yachting's demands on expensive emergency services and commercial vessels. Rather than leaving it to the government to introduce a regulatory regime that will inevitably be inflexible, yachtsman should seize the initiative before this is lost to government regulation.

Yachtsmen should, in consultation with groups such as AMSA and the Coastguard, plan a strategy for the next five years. This plan should cover the provision of an integrated surveillance capability and C3 structure for major offshore yacht races. Inevitably rapid technology changes will alter the implementation in detail, but the principle requirements will remain.

As a suggest timetable, I propose:

Year 2000
- Demonstration of automated position reporting/satellite voice telephone communications from selected yachts in key races.

Years 2001-2
- Choice of manual reporting via " skeds" or automated satellite-based reporting.
- Trials of first-generation Situation Awareness display at race headquarters and AMSA.

Year 2003
- Compulsory automated position reporting.
- Proven Situation Awareness display available to authorities.
- Full two-way data communications between all centres.

Years 2004-5
- Second-generation system, including automatic weather reporting from yachts to the BoM.
- Ability for BoM to transmit updated weather reports automatically to yachts and race authorities.

6. References

As a brief guide to those interested in satellite communications, the first web site listed gives an overview of all the constellations in service or planned.

http://www.ee.surrey.ac.uk/Personal/L.Wood/constellations/overview.html#galaxy

http://www.iridium.com/

http://www.teledesic.com/overview/fastfact.html

http://www.globalstar.com

http://www.orbcomm.net/

http://www.ico.com/

Discussion

Mr David Payne

Yacht and Small Craft Designer

Mosman

> " Both men and ships live in an unstable element, are subject to subtle and powerful influences and want to have their merits understood, rather than their faults found out."
> (Joseph Conrad, " The Mirror of the Sea")

These eloquent words may have been a moment of creative inspiration for Conrad, perhaps he laboured over them. Maybe it was a bit of both. Whatever the case they do well to encapsulate our situation.

We need to encourage a balance of design factors so that as a boat experiences the range of conditions it must expect to sail in offshore, it can show off how it uses them or contends with them as the conditions dictate. For many current designs there are conditions which show off the vessel's weaknesses and torment the craft and its crew. The approach should be a measurement system with supporting rules that promote seaworthy and well prepared boats for racing. This contrasts with the current attitude of taking a craft optimised for racing and then patching it up with minimal regulations to supposedly make it seaworthy.

Taking the safety orientated approach would show a higher regard for the environment we are fortunate enough to use. The sea is no man made and managed sports field. No one has provided it with safety nets, bumpers for protection and trainers to pamper your strains. There is no half time entertainment and cheer girls. The open ocean should be appreciated and respected, not challenged aggressively and irresponsibly with an all or nothing, pushing the limits of the envelope vessel, with little or no margin for error. We should let it challenge us to find our way through its vagaries and extremes as best we can with a boat that has enough in reserve to fall back on when the going gets tough.

Conrad also wrote the following.

> " Of all the living creatures upon land and sea, it is ships alone that cannot be taken in by barren pretenses, that will not put up with bad art from their masters."

The recent record of open ocean racing has shown as false the claims that many of our boats and their crews can manage severe conditions and the consequences when things go wrong. The statistics, technical and theoretical details of why this is so are well documented but we need to be reminded of them again. Steps should be taken to improve the standards so there is considerably less " bad art".

Perhaps too, that as part of these changes we might be able to give more consideration to that other meaning of "art" in our design processes. There have been periods when a variety of design styles gathered to race against each other, but it looks like our numbers based design approach sees us all using the same numbers. Modern racing boats all look the same. Some creative inspiration and diversity on our behalf, as well as the respect already discussed, would be a complement to the environment we are so lucky to be able to use.

Discussion

Mr Dusko Spalj, Dr Swapan Dey, Mr Gary Esdaile, and Mr Glen Wilkins

Naval Architecture, Sydney Institute of Technology

Ultimo

Introduction

Following the tragic events of the 1998 Sydney to Hobart Yacht Race, the Naval Architecture Program of the School of Mechanical and Manufacturing Engineering at the University of New South Wales organised a seminar in March 1999 for naval architects, yacht designers, ocean racing yacht owners, skipper and crews, search and rescue personnel, yachting administrators, meteorology professionals, students and other interested parties.

The presentations and dramatic accounts of race participants raised a number of issues for further research, analysis and discussion.

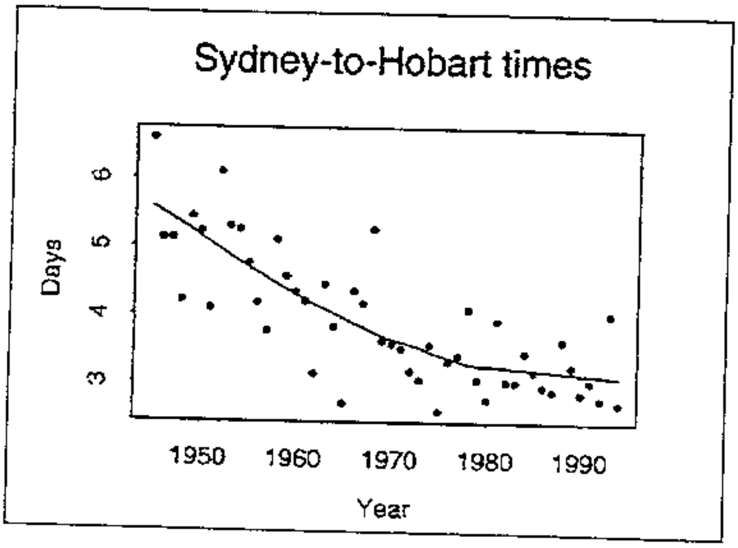
This paper addresses some of these issues and focuses on design, meteorology and marine geography, education and training of ocean racing participants, communications and race organisation.

We believe that there should be genuine positive action resulting from the analysis of the events from the recent survey conducted by the Cruising Yacht Club of Australia (CYCA) and the forthcoming Coronial inquest.

There is danger in considering 1998 as a "once in 100 years storm". However, a history of increasing incidence of heavy weather in recent years may point to global warming and "El Nino".

The fact that ocean racing yachts are becoming faster, gives rise to a higher potential disaster if the going gets really tough. Open stretches of 150 miles, such as the Bass Strait crossing, will take 12 – 24 hours depending on the size of yacht in good conditions.

This is reflected in the graph below in the reduction in race times since the beginning of the event in 1945.



Marine Geography

Those who go to sea require a full understanding of the area in which they are required to sail. Bass Strait is one of the world's most dangerous stretches of ocean. It contains the very deep Bass Canyon and may produce an influence on sea states resulting from a combination of forces above and below the ocean surface.

Bass Canyon cuts more than 2 kilometres into the seabed of Bass Strait, then drops down to an abyssal plain more than 4000 metres below sea level. Bass Strait is generally rather flat and less than 200 metres deep, with a sandy bottom. The Gippsland Oil wells are at the NW corner of the shaded map area shown below, and the Canyon which is 60 kilometres wide is located 100 kilometres SE of Lakes Entrance. (Ref: "Professional Fisherman" Magazine – August 1997, Baird Publications).

This geography could be a factor in producing dangerous sea states, similar to those experienced by the 1998 Sydney-Hobart fleet, when the effect of strong NSW southerly currents "collided" with 70 knots of storm force wind, waves and swell from Bass Strait, over a period of 6-12 hours.

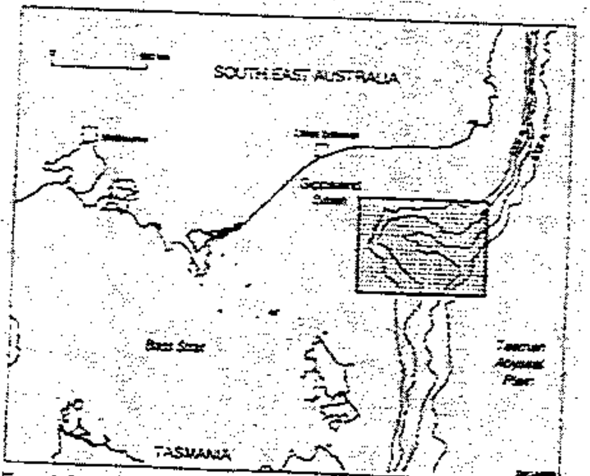


Figure 1: Location of survey area in the Gippsland Basin off Victoria, showing the Bass Canyon

Figure 2: Morphology of the Bass Canyon area showing Gippsland Basin petroleum exploration wells. The much greater detail revealed by multibeam sonar, as compared to earlier mapping based on single-beam sonar, is obvious for the area inside the dashed line on the map.

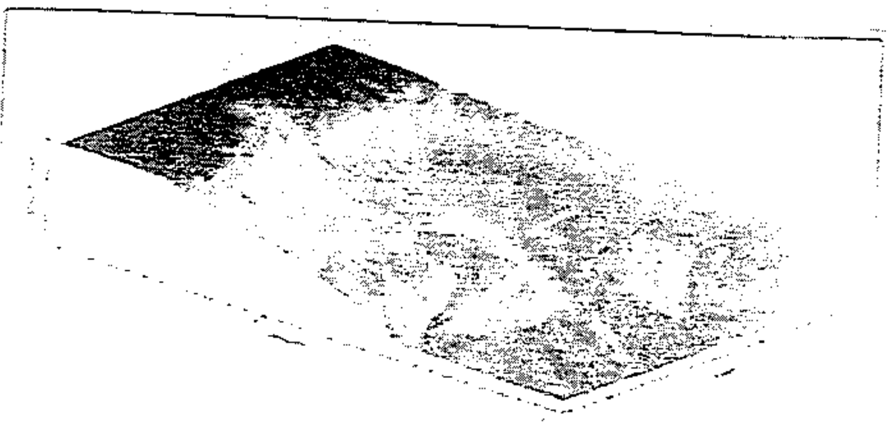


Figure 3: This 3D colour image generated from the seafloor mapping data shows the Bass Canyon, tributary canyons and the fishing ground known as 'The Horseshoe' as viewed from southeast.

The following issues have been identified as priorities for discussion. Our recommendations conclude the paper.

THE DESIGN PROBLEM

Dynamic Stability of Yachts

Some delegates were unimpressed with the presentations on static stability, and an implied criticism of wide beam, shallow hulls with fin keels and scimitar rudders. Stowage of gear or adding new equipment significantly affects the resulting righting moment (RM) and angle of diminishing stability according to location of items and weight e.g. What is the effect on RM by placing a radar unit 5m up the mast?

Virtually everything that finds its way aboard (including crew) ends up above the waterline, thus reducing stability by raising the vertical centre of gravity. e.g. books racked in shelves, instruments, cutlery, outboard motors and barbeques mounted on pushpits, furling mainsails and headsails, liferafts and/or dinghies mounted on deck.

There is an argument that designers should revert to traditional, moderate hull forms with full length keels/skeg rudders and higher displacement, as these hulls are considered to be more seaworthy. Light displacement is not necessarily considered a risky disadvantage given good construction and good seamanship. The tendency to be blown sideways due to shallow forefoots is viewed positively, as opposed to a long keel "tripping over" into the side of a steep wave. The fear of a loss in resale value of modern yachts by changes in design rules is a further factor in the argument.

Classification rules

Technological advances in sail construction and the inherent high strength of the materials used in sails and running rigging have not been matched to the structure of vessels.

Extremely high loadings are placed on the mast and standing rigging, rudders, keels, and hulls. Forty years ago when masts were over-designed, the sails disintegrated in heavy weather. The pendulum has swung too far in the opposite direction with mast design, in that failures are now quite common in moderate conditions and lumpy seas. The higher speeds generated from large sail areas on light displacement hulls also exert very high loadings on rudders and steering gear. These factors combined with racing in heavy weather, large waves and swells, increase the likelihood of structural failure around the keel and in the bow areas due to high speeds and large slamming stresses.

We are strongly of the opinion that rules for design be reinstated by the classification societies and that all vessels be designed and constructed to such rules and be surveyed.

Hull construction

Pleasure and non commercial yachts are currently not required to be built to survey, nor inspected during construction by qualified surveyors. Cost equates to displacement and increases in costs due to surveys create an added expense for manufacturers in a competitive

The following issues have been identified as priorities for discussion. Our recommendations conclude the paper.

THE DESIGN PROBLEM

Dynamic Stability of Yachts

Some delegates were unimpressed with the presentations on static stability, and an implied criticism of wide beam, shallow hulls with fin keels and scimitar rudders. Stowage of gear or adding new equipment significantly affects the resulting righting moment (RM) and angle of diminishing stability according to location of items and weight e.g. What is the effect on RM by placing a radar unit 5m up the mast?

Virtually everything that finds its way aboard (including crew) ends up above the waterline, thus reducing stability by raising the vertical centre of gravity. e.g. books racked in shelves, instruments, cutlery, outboard motors and barbeques mounted on pushpits, furling mainsails and headsails, liferafts and/or dinghies mounted on deck.

There is an argument that designers should revert to traditional, moderate hull forms with full length keels/skeg rudders and higher displacement, as these hulls are considered to be more seaworthy. Light displacement is not necessarily considered a risky disadvantage given good construction and good seamanship. The tendency to be blown sideways due to shallow forefoots is viewed positively, as opposed to a long keel "tripping over" into the side of a steep wave. The fear of a loss in resale value of modern yachts by changes in design rules is a further factor in the argument.

Classification rules

Technological advances in sail construction and the inherent high strength of the materials used in sails and running rigging have not been matched to the structure of vessels.

Extremely high loadings are placed on the mast and standing rigging, rudders, keels, and hulls. Forty years ago when masts were over-designed, the sails disintegrated in heavy weather. The pendulum has swung too far in the opposite direction with mast design, in that failures are now quite common in moderate conditions and lumpy seas. The higher speeds generated from large sail areas on light displacement hulls also exert very high loadings on rudders and steering gear. These factors combined with racing in heavy weather, large waves and swells, increase the likelihood of structural failure around the keel and in the bow areas due to high speeds and large slamming stresses.

We are strongly of the opinion that rules for design be reinstated by the classification societies and that all vessels be designed and constructed to such rules and be surveyed.

Hull construction

Pleasure and non commercial yachts are currently not required to be built to survey, nor inspected during construction by qualified surveyors. Cost equates to displacement and increases in costs due to surveys create an added expense for manufacturers in a competitive market. However, warranties could be offered if vessels were built to survey and would be an incentive for prospective buyers.

The purpose for which a pleasure yacht is intended is as important as for commercial vessels. If a vessel owner wants to race predominantly inshore, but competes in one or two ocean races annually, then in our opinion, the vessel should be classified to comply with the higher long distance offshore categories. eg corresponding to the equivalent USL Code 2A or 2B.

If classified under "USL 2C equivalent" then the vessel will be limited to short coastal races of not more than 30 miles to seaward from safe haven. It is recommended that ALL pleasure vessels be certified annually, just as motor vehicles are required to be inspected after the age of 3 years.

An independent body or duly certified inspecting stations are recommended as self regulation cannot be relied upon. We believe that insurance companies will soon demand that such be in place. There is no real objection to Government bodies controlling or policing the regulations.

Watertight/collision compartments and crew protection

As long ago as 1963 the Junior Offshore Group Special Regulations referring to JOG yachts of LWL 16' to 24' specified that hull, decks and upper works, mast rigging and fittings must be sufficiently strong to withstand the weight of a heavy sea upon them or the stresses imposed by the vessel being rolled on her side. Further, the rules stated that smaller yachts should carry sufficient reserve buoyancy to support themselves together with keel, stores, crew and a reserve of at least of 250 lbs.

In 1999 the new BT Global Challenge yachts are being fitted with five watertight bulkheads. This limits potential flooding between compartments. Protection for the crew from the weather and waves is deemed important and the new yachts also have a higher coachroof. The freeboard is increased as is the height of the bow. The coachroof, which is a bolt-on glass fibre moulding and not part of the steel structure, will divert waves and give more shelter to the crew. At the same time, a separate companionway hatch reduces the chance of a solid wave entering the yacht.

Forward watertight bulkhead fitted to the new BT Global Challenge yachts

Non critical failure or performance failure

We believe the engineering principle of "Non Critical Failure" or "Performance Failure could be considered for ocean racing yachts.

The principle espoused is: "If an item on an ocean racing yacht is to fail, which item would one prefer to fail first, without endangering yacht and crew?"

We consider that a jib halyard should be the sacrificial item to slowing the boat down. Either the halyard itself breaks or the Spinlock jammers have an in–built loading mechanism which release at a pre-determined loading. The application of this principle can also act as a safety precaution for crews to shorten sail and not overload the structure.

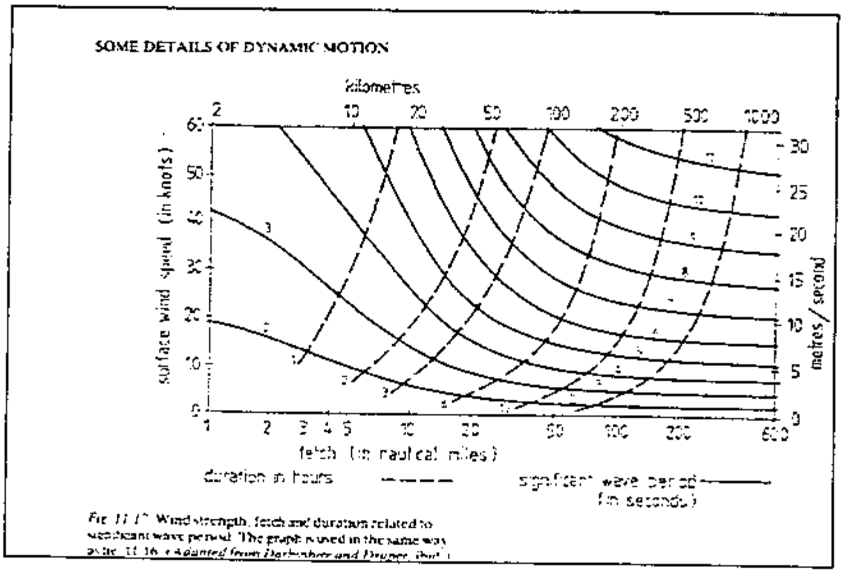
METEOROLOGY

Weather, waves knowledge and forecasting

It only takes a 3 metre wave to roll a 10 metre yacht at sea. The dynamic stability of yachts in large waves, especially in following, breaking seas; and the physics of wave speeds, swell length and fetch appears to be not well understood, as evidenced by the participants response to the survey of the 1998 Sydney Hobart Race Review Committee of the CYCA. (Ref: Offshore April-May 1999, pages 4-7).

Swell is a sea state forecaster as the build up in height and length of waves requires time and sea space. If a long, low swell of regular length builds up fast, the edge of the storm is approaching fast. Also as the storm approaches the crests of the swell waves get shorter in lateral length. If there is little or no increase in swell wave height then the storm may pass by. A circular moving storm of full gale force with a 20 mile radius might build up its full sea in as little as 5 hours. It appears that the 1998 event experienced a tight radius circular moving storm of 'storm- force' strength. One with a 200 mile radius might take 24 hours: but the seas will be bigger (ref. "Further Offshore", J. Illingworth, Adlard Coles, 1969).

Clearly more education on the physics of waves, wind and weather is required.



SOME DETAILS OF DYNAMIC MOTION

Fig. 11.17 Wind strength, fetch and duration related to significant wave period. The graph is used in the same way as fig. 11.16. (Adapted from Darbyshire and Draper, ibid.)

Relationship between wind strength, fetch and duration to significant wave period.

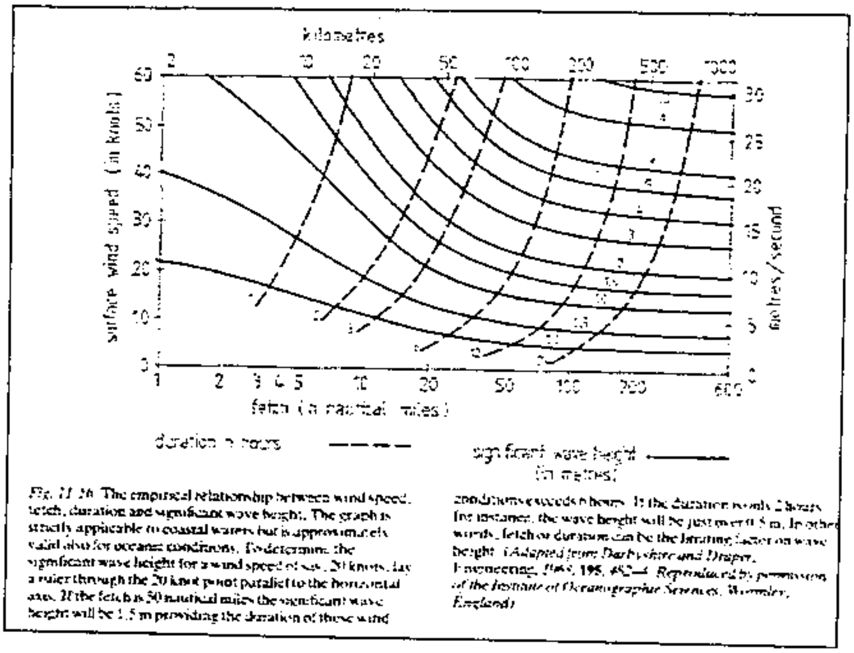
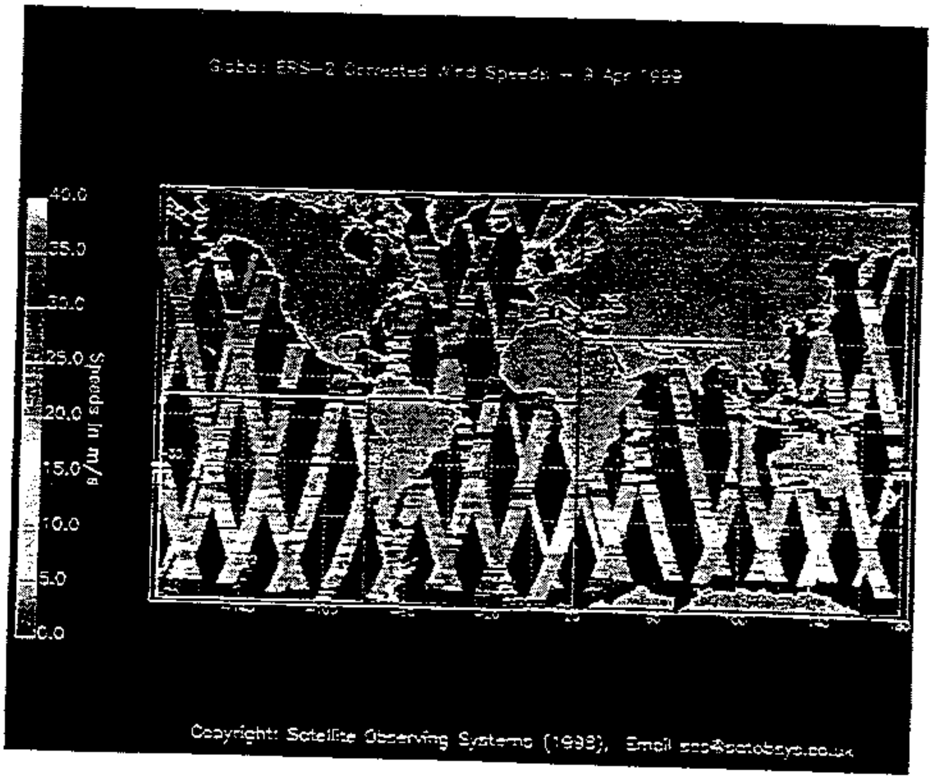


Fig. 11.26 The empirical relationship between wind speed, fetch, duration and significant wave height. The graph is strictly applicable to coastal waters but is approximately valid also for oceanic conditions. To determine the significant wave height for a wind speed of say, 20 knots, lay a ruler through the 20 knot point parallel to the horizontal axis. If the fetch is 50 nautical miles the significant wave height will be 1.5 m providing the duration of these wind conditions exceeds 6 hours. If the duration is only 2 hours, for instance, the wave height will be just over 0.5 m. In other words, fetch or duration can be the limiting factor on wave height. (*Adapted from Darbyshire and Draper, Engineering, 1963, 195, 482–4. Reproduced by permission of the Institute of Oceanographic Sciences, Wormley, England*)

Relationship between wind speed, fetch, duration and significant wave height.

Ref. Garrett, Ross, "The Symmetry of Sailing- The Physics of Sailing for Yachtsmen", Adlard Coles, 1987)

Global satellite technology enables a complete weather analysis even to the extent of wind speeds, swell and wave heights. Satellite Observing Systems (SOS) use the ERS-2 satellite to gather wind and wave data over the entire globe and process data to provide accurate and timely information to mariners.



A sample of the latest "real time" technology from SOS UK is presented above.

SOS provide:

A daily summary of 48 hour old wind and waves measured globally (including the hurricane and tropical storm archive).

A daily service: summary of wind & waves measured yesterday. These products are available for each of seven ocean areas.

A fast delivery service: based on ERS data as we receive them (3-4 hours after acquisition).

A sea state alarm: a warning service which continually monitors wave conditions and e-mails the subscriber if a threshold sea state is exceeded. (ref. SOS website)

COMMUNICATIONS

Automatic positioning beacons transmitting in "normal" mode can determine whether trouble has been struck.eg. The ARGOS tracking for Bullimore and Dubois in the Southern Ocean in 1996 alerted the Race HQ to a probable emergency. Philippe Jeantot surmised (correctly) they had capsized.

Continuous real time tracking of whales' position, speed, direction, body temperature, water temperature and swell wave heights information is fed via Inmarsat. (even down to 500 metres, with delayed feedback when they surface again)The transmitter is no larger than a Walkman and can transmit continuously for months.

The technology already exists and it should become mandatory for the Class One Ocean Racing category.

RACE ORGANISATION

Yacht races are organised under IYRU, AYF and local Club rules. Whilst there has been significant change following the 1979 Fastnet Race, there is still room for improvement in many areas, not the least of which is search and rescue.

On 31st December 1998 the Australian Maritime Safety Authority released details of the civil resources and civil costs associated with the Sydney to Hobart yacht race rescues. Civil aircraft - both fixed wing and helicopters - flew about 500 hours in the rescues. About 45 civil and defence aircraft and three surface vessels were engaged by AMSA in the rescue efforts, in which 55 sailors were saved. The costs of the civil resources employed were approximately $650,000. The estimate did not include the cost of assistance provided by Defence aircraft (RAAF and RAN) and the Navy frigate HMAS Newcastle. (ref SMH article 31/12/98)

It is encouraging to see that one of the primary objectives of the Ocean Racing Club of Victoria is to pursue policies that ensure Ocean Racing is an exciting but intrinsically safe and carefully regulated sport, which does not impose a cost burden on the general community. This objective clearly sheets home safety issues and cost burdens to the Club, and not to owners/skippers individually, nor the public.

The organisers of the Sydney – Hobart Race need to act to ensure the safety of participants and of those engaged in search and rescue. Rule 32 of the IYRU Rules ("Shortening or Abandoning a Race after the Start) can be enacted.

Rule 32 was inserted into the Rules for a purpose. It is not acceptable to debate "as to when one stops a race".

SAFETY

Safety equipment

The 1999 BT Global Challenge safety requirements for example, go beyond the standards specified by the UK Department of Transport and Bureau Veritas, and are detailed below.

Lifejackets - Brightly coloured lifejackets automatically inflate on immersion in sea water, are designed to keep the head above the water and are equipped with a whistle and light. Special modifications are made to prevent accidental inflation. Lifejackets are worn at all times on deck.

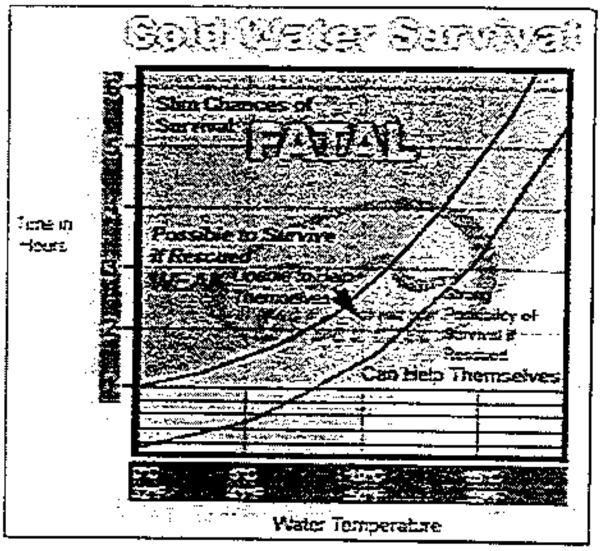
Liferafts - 4 x 6 man Autoflug liferafts are located at the transom of the yacht below the Satcom Dome and are easily launched off the stern of the yacht in an emergency.

Flares/Location Devices - Emergency Position Indicating Radio Beacons (EPIRB) are used throughout the fleet. Any yacht that is disabled or endangered automatically releases an EPIRB which floats to the surface and transmits a distress signal on the 406 MHz frequency. Aircraft and a network of COSPAS SARSAT satellites can relay the signals to land-based emergency services which identify the distressed yacht and direct search and rescue craft to the location. Flares are also used in an emergency. Breaking the cap and seal sets off an intense pyrotechnic light which can clearly be seen by passing aircraft and vessels. There is a combination of red and white rocket flares, red and white pin point flares, lifesmoke and dyemarker flares. In addition, Inmarsat 'C' is fitted with a distress feature, which will automatically provide global positioning of the yacht.

Fire Extinguishers/Blankets - All yachts carry 7 fire extinguishers, distributed throughout the yacht, together with 2 fire blankets.

Man Overboard Equipment - In the freezing waters of the Southern Ocean, there must be no delay in the recovery of a man overboard. In such conditions the person must be removed horizontally from the water. Vertical removal can result in shock as blood suddenly drains away to the legs. All yachts carry the Tri-Buckle - a simple triangular shaped piece of PVC-coated polyester which is easy to use, weighs only 2kg and is very compact to stow. Remaining attached to the yacht, the Tri-Buckle is lowered into the water. The victim swims inside the triangle and then is winched back onboard. Horseshoe shaped lifebuoys can also be thrown to a man in the water.

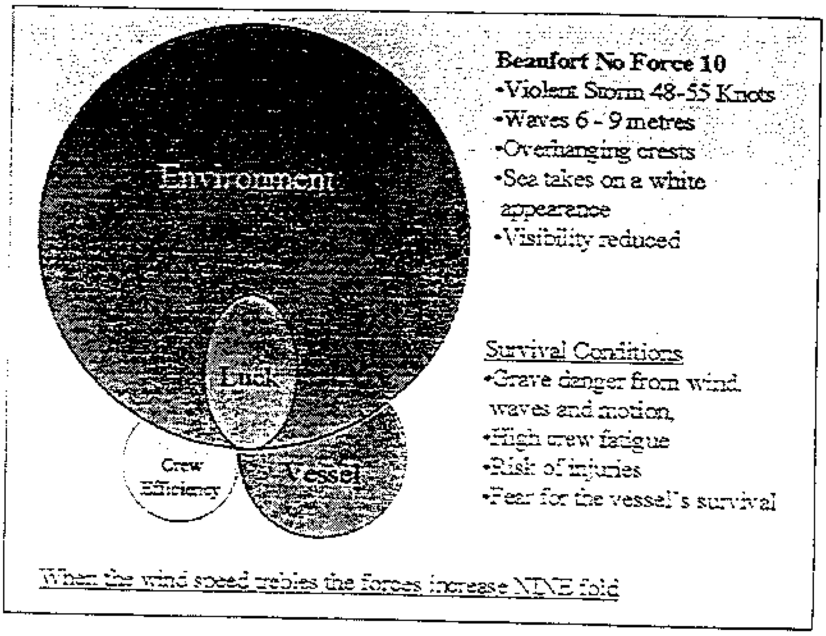
Safety Clothing - Musto HPX Ocean Drysuit type clothing meets the criteria for working in tough conditions, and providing 2-3 hours survival time in 5 degrees C water.



Seamanship and survival

Reference is made to an excellent series of policies and procedures in "Preparing for heavy weather" - Robin Hewitt – 1996, derived from some of the articles written about the storm known as the Tonga Bomb of 1994 experienced in the Auckland – Suva Race. The article covers heavy weather set-up, seamanship for heavy weather, rescue situations, and roll-overs. (ORCV, April 1999, Internet Web Site).

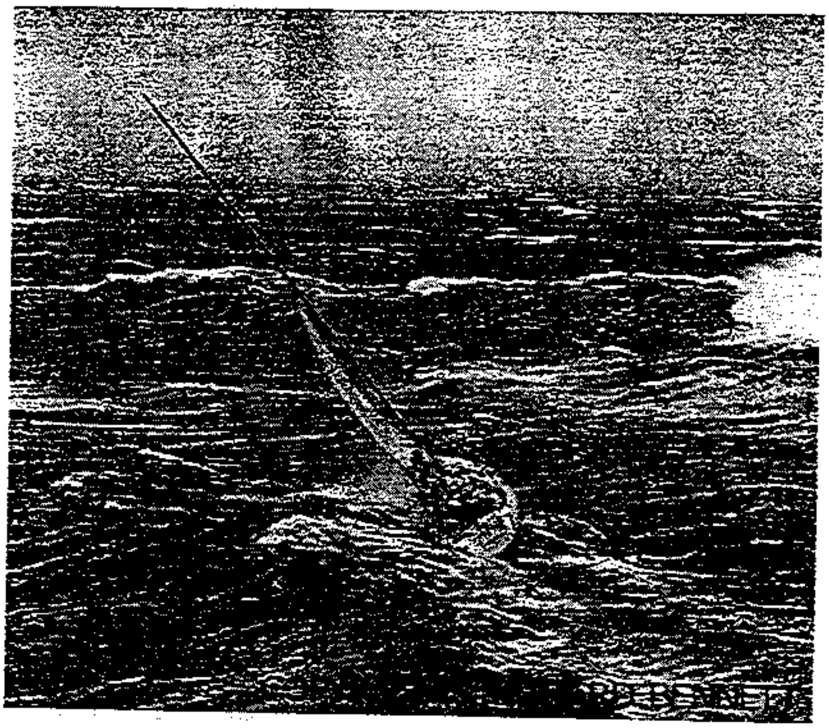
In the following diagram taken from John Quinn's presentation slide, 'Factors of Safety at Sea', (Ref: "Seaworthiness – The Forgotten Factor" C.A Marchaj, p.15), we offer an expanded view of the Environment in survival conditions; and its effect on Crew Efficiency and the Vessel.



Beaufort No Force 10
- Violent Storm 48-55 Knots
- Waves 6 - 9 metres
- Overhanging crests
- Sea takes on a white appearance
- Visibility reduced

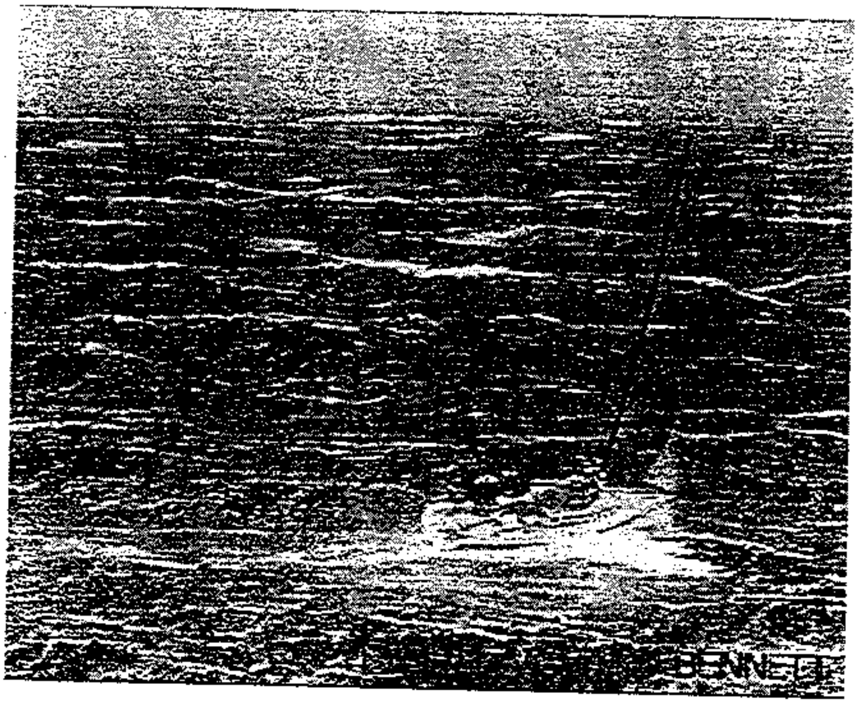
Survival Conditions
- Grave danger from wind, waves and motion,
- High crew fatigue
- Risk of injuries
- Fear for the vessel's survival

When the wind speed trebles the forces increase NINE fold



Aspect Computing 14m.

For "Aspect Computing" every 1 in 1000 waves is twice the height of the average wave height.



Secret Mens Business 14m

For half the crew of "Secret Mens Business" sitting out and facing into 70 knots of wind and extreme sea conditions is very dangerous. Refer John Quinn's experience in 1993.

RECOMMENDATIONS

THE DESIGN PROBLEM

Rules for Design

We recommend that:

- A new set of Rules for Design both at plan approval and construction stages be enacted.

  The high inherent strength in materials for sails and running rigging with the interaction of the remainder of the platforms which support the vessel's "power", will be of considerable importance in future ocean racing yacht design.

Hull and rig

- Construction of yachts be designed and built to ABS Regulations, and inspected by independent qualified surveyors, with appropriate updates.
- Strength of masts and strength of rigging needs improving by increasing the size and strength of mast sections.
- The construction of steering gear mechanisms be strengthened, in particular the rudder shafts and bearings of dagger profile rudders.
- The safety of vessels be improved by the inclusion of bow and stern watertight/collision bulkheads which are able to provide sufficient buoyancy to keep the vessel afloat in damaged condition.
- Engines and ancillary equipment must be able to withstand roll overs and be able to be started.

Vessels static stability and dynamic stability

- Strict adherence to minimum "angles of vanishing stability" of vessels in <u>fully loaded race condition is applied</u>.

Surveys and inspections

- There is licensing and certification of Pleasure vessels venturing offshore to USL codes or equivalent. eg. USL codes 2A, 2B and 2C.
- Yacht owners should avoid self regulation of safety and construction issues by leaving this to Classification Societies or Government Regulators.

COMMUNICATIONS

- We recommend that a "Black Box" which transmits information regarding positional and environmental conditions from the yacht's own GPS and navigational units via satellite every 10 minutes to shore, be mandatory equipment on each race vessel.

In this way race communications centres can build a complete picture of the fleet and the environment which the fleet is experiencing. The black box also acts as an emergency beacon if transmission ceases or progress is tracked to be very slow.

METEOROLOGY

Weather and sea state conditions reporting

- Real time weather data from oil rigs and other sources in the vicinity, and relevant race information be transmitted automatically to a receiving unit on board competing yachts.

  Akin to a bedside alarm clock radio, the signal is triggered via radio or satellite and broadcasts the latest weather conditions, forecasts and other race information. This may include shortening a course or abandonment of race under Rule 32 of the AYF Sailing Rules.

- There be accredited courses to improve the education and understanding by race crews of the physics of weather and waves.
- There be a vastly improved frequency and regularity of communication of weather information, forecasts of wind, waves and sea states.

SAFETY

Crew training and education aspects

- There be accredited courses to improve the skills and safety and survival training of crews.
- Emphasis is placed on the importance of race fitness, education and training.
- Improvements be made to the design and performance of safety gear so that it is viable and sustainable in all situations.eg. harnesses, life rafts and safety equipment carried.
- It is far better to have more crew than less.
- In heavy weather an absolute minimum number of crew should be on deck, with the other watch members down below (ready for action).

  Off watch members are resting or consuming food and adding to stability in windward berths when on the wind. In smaller yachts the ability to get to windward in heavy weather is of paramount importance, but crew safety cannot be compromised in the design by having crew sitting out over the rail in heavy conditions.

Owners/skippers qualifications and endorsements

- Licensing and certification of Skippers, owners, navigators be to Master Class 5 level.

ORGANISATIONAL ASPECTS

IYRU yacht racing rules

- Rule 32 can be invoked as necessary by prudent organisers.

Race organisation

- Lower risks be placed on veteran vessels and vessels with modifications, via stricter entry requirements.

- Entrants and organisers take prime responsibility for self reliance in search and rescue operations rather than at the taxpayers expense (or pay a premiums and/or costs).

- The threat of law suits is avoided in the future by implementing the most careful organisation and conduct of events.

- If deemed necessary under Rule 32 the race could be sailed in 2 stages for a combined elapsed time.

  Such an occurrence could be if the conditions on the race course over a period of 5 – 6 hours result in wind speed of 40 - 45 knots and wave heights of 4 - 6 metres at Gabo Island and/or the Gippsland Oil fields in Bass Strait or at Flinders Island in the event of SE gales.

Conclusion

We are keen to see renewed growth of the Sydney to Hobart Yacht Race with a concerted drive towards "World's Best Practice". The tax payer is tiring of the cost and risk for search and rescue operations of yachting's elite contestants. The rampant commercialism and competition at all costs demonstrated especially by Round the World Alone entrants is not healthy in developing the sport's image with the public and the media.

Ultimately we believe there should be a partnership between the yachting authorities, insurance companies, government and other stakeholders in developing a system of Accreditation which will ensure the safety of participants and equipment, reduction in insurance claims and savings in government expense in search and rescue.

We believe attention to and discussion of the issues raised in this paper will contribute to improved design and construction of ocean racing yachts and to the education and safety of sailors who participate in the sport of ocean racing.

The authors wish to thank Richard Bennett of Richard Bennett Photography, Hobart for his kind permission to use his dramatic shots taken above Bass Strait on 27th December 1998.