New Zealand Naval Architect

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The Improvement of Guidelines for Optimum Spinnaker Trim

by

Damon Jolliffe and Kain Glensor

INSIDE

The aim of the project was to find the manner in which yachts should be trimmed when sailing under spinnaker to yield the fastest boat speed. These optimum trim conditions were compared with the commonly used 'rules of thumb' to examine whether the 'rules of thumb' represent the best trim condition for maximum speed. The 'rules of thumb' were taken to be as follows:

- Spinnaker pole height. The spinnaker pole should be at a height that the luff of the spinnaker curls along the entire luff at the same point of sheet ease.
- Spinnaker pole angle. The spinnaker pole should be placed perpendicular to the apparent wind.
- Spinnaker sheet ease. The spinnaker sheet should be eased until the luff curls, then sheeted in a little. This generates the minimum angle of attack, while remaining stable and full.

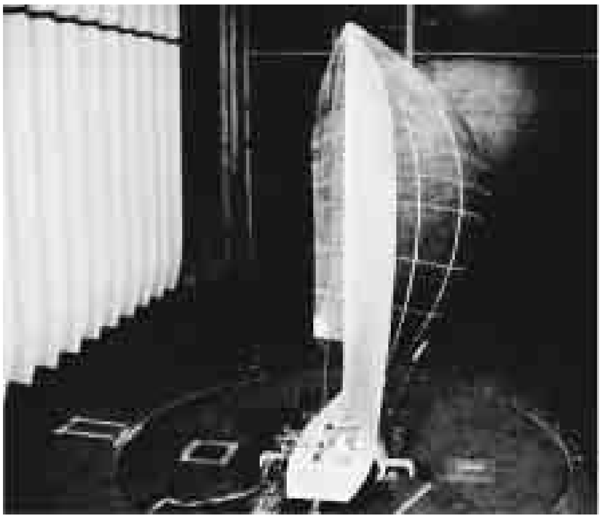

Figure : Model in wind tunnel test section.

The optimum trim was determined by testing various spinnaker sailing trim settings in the University of Auckland's Twisted Flow Wind Tunnel. Twisted flow is a method of replicating the real world phenomena of the change in wind speed and

A Word from the President

I would like to take this opportunity to wish you all a very Merry Christmas and an enjoyable and prosperous New Year. Although the weather still leaves a little to be desired I am sure that like me, you are looking forward to the end of another hectic year and getting time to relax with family and friends over the Christmas break.

After a quiet period in the middle of the year our technical evenings are now back in full swing and the last two events visits to the Devonport Dry-dock and to Auckland University's Centre of Advanced Composite Material have been very interesting. In particular the opportunity to crawl over one of Sealord's trawlers and see the process machinery in the on-board fish factory was an event that will not easily be forgotten (nor will be the sight of the smooth talking Brendan upon discovering an attractive woman on the bridge of the vessel who was willing to provide a guided tour).

The New Zealand Marine Export Group has secured some outstanding speakers for the upcoming Yacht Vision 05 design symposium which will be held in Auckland from 9-12 March 2005. Speakers include Michael Peters, Ed Dubois and Round-the-World sailor Skip Novak. RINA will be putting together a special edition

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of the New Zealand Naval Architect to coincide with this event and I trust that you will take this opportunity to promote your skills and capabilities through this publication to the visiting international guests (see Editor's plea on page 7).

In a slightly longer timeframe Michael Eaglen has assembled an organising committee for the next High Performance Yacht Design conference which will be held at Auckland University in February 2006. Initial planning is already well advanced and a call for papers scheduled to appear in Seahorse and The Naval Architect in the new year. We will also be also shoulder tapping many of the overseas visitors to Yacht Vision and would very much welcome a strong contribution from our members to highlight the strength of technical and design skills resident in New Zealand.

I would like to thank members for their continued support and trust that you enjoy the range of activities that the Council organises on your behalf. We have the upcoming Christmas dinner which is promising to be a very intimate occasion and exciting visits to Navman and Henley Propellers organised for next year, not to mention the AGM in March. My thanks go to fellow Council members through whose efforts the organisation continues in a strong position both financially and technically.

Have a great Christmas and an exciting New Year.

Graeme Finch
President

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direction that the yacht experiences at different heights up the mast, not replicated by a normal wind tunnel.

Forces and force coefficients

Optimum trim was determined as that which resulted in the maximum thrust, which depends on the ability to maximise the size of the total force produced by the sail (FA), and aligning that force as well as possible with the thrust direction (Ft). At 90° apparent wind angle, the sail should be producing only lift to gain maximum efficiency. At 180° apparent wind angle, the sail should be producing only drag. At angles in between, a combination of lift and drag should be produced. The aim is for the sail to produce its total force in, or as close as possible to, the direction of the yacht's travel (Figure 2).

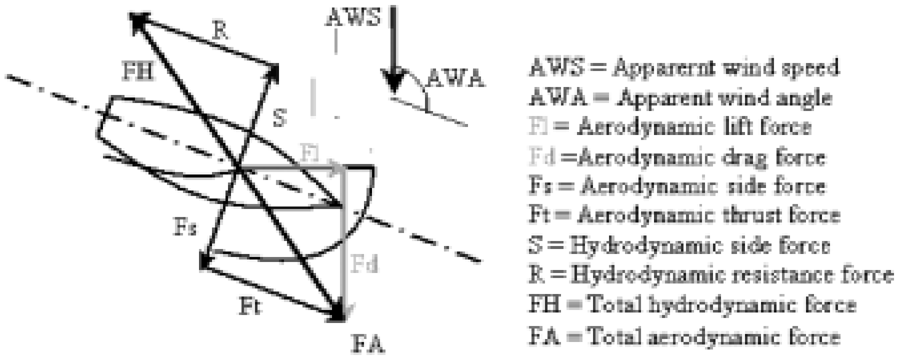
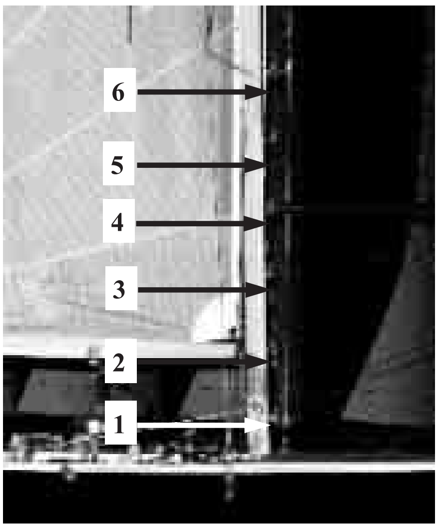


Figure 2: Balance of forces acting on a yacht

Experimental procedure

The following parameters were used in the testing:

- Testing utilised two different shaped spinnakers (black and white) ensuring that any differences weren't solely a factor of the shape of the sail.
- The testing carried out was at 90°, 110°, 130°, 150°, and 170° apparent wind angle, chosen to represent the range that real spinnakers are flown in.
- The spinnaker pole was tested at six discrete heights up the mast. See Figure 3.



- The range of spinnaker pole angles was: -10°, -5°, 0°, 5°, 10°, 15°, 20°, and 25°.
- Positive angles indicate the pole moving toward the windward side stay, using the apparent wind angle at the reference height as 0°.

Figure 3: Pole height settings on model

Flow visualisation

After the completion of the force testing, the focus moved to the understanding of the aerodynamics that were affecting the forces we had attained, using smoke flow visualisation. This was done at apparent wind angles of 90°, 130°, and 170° to show the spinnaker in all three modes of force production.

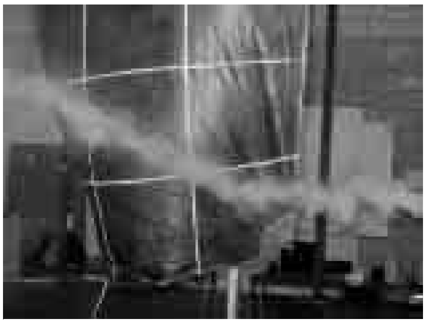


Figure 4: Upward flow around outside of spinnaker set at optimum pole angle and height.

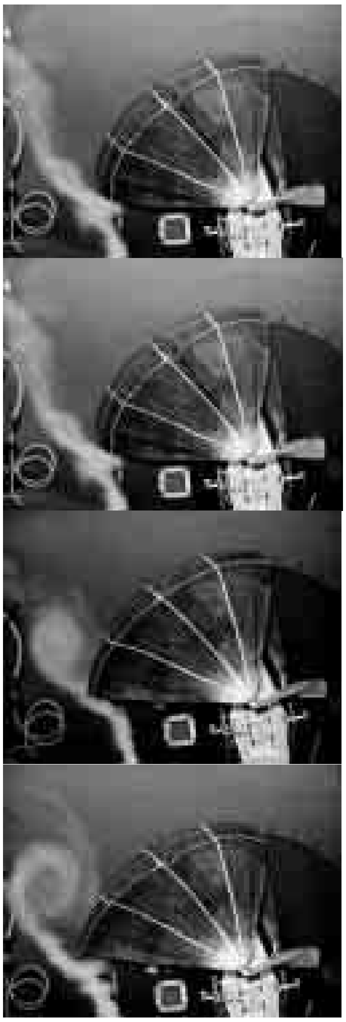


Figure 5: Development of a vortex off the luff of a spinnaker.

The combination of the upward and downward flow, or crossflow, causes the induced drag at the bottom of the sail, due to the affected area of the sail producing lift.

Overall results

Pole angle

The results for pole angle setting are summarised in Table 1 and show that as the apparent wind angle increases, the spinnaker pole should be brought forward. Sailing at 90°, the aim is to maximise the lift produced, having the pole aft of perpendicular minimises the angle of attack, and maximises the amount of lift the sail produces. When sailing more downwind, the target is for the sail to produce less and less lift, while producing more and more drag as the apparent wind angle increases. To this effect the pole should be brought forward to increase the angle of attack of the sail, and thus the amount of drag.

	Spinnaker	
Apparent wind angle	White	Black
90°	Aft as possible	Aft as possible
110°	Aft as possible	15°
130°	Aft as possible	10°
150°	10°	10°
170°	5°	5°

Table 1: Optimum pole angle settings.

The results obtained disagree with the commonly used rule of thumb for spinnaker pole angle at low apparent wind angles. They suggest that the ‘perpendicular to the wind’ condition is appropriate at high apparent wind angles, but as the wind angle decreases so does the effectiveness of the trim. The results show the guidelines recommended by Whidden [11] for pole angle are a good basic guide, but for optimum thrust, a more complex guide should be used.

Based on the results for the black spinnaker; assuming the progression of pole angle to apparent wind angle is linear, a generic equation can be used to calculate the recommended pole angle based on the maximum pole angle that the model/ yacht will allow.

$$\text{pole angle} = \frac{\text{maximum pole angle}}{90} \times \left(180 - \text{wind angle}_{App}\right)$$

Pole height

The results for the pole height that will produce the highest thrust are shown in Table 2. Like the results for pole angle, they show a relatively uniform progression for changing apparent wind angle.

	Spinnaker	
Apparent wind angle	White	Black
90°	2	3
110°	4	4
130°	5	5
150°	6	6
170°	6	6

Table 2: Optimum pole height settings.

For both sails the pole height that delivers the optimum thrust increases in height with increasing apparent wind angle.

This is caused by the change in

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the mode which the sail produces maximum thrust at different apparent wind angles. At 90° apparent wind angle lift is required; this is better generated by a sail that has the luff pulled tight, into a narrower shape with less depth, conforming as close to an aerofoil section as possible. At 170° apparent wind angle, the sail should be a much deeper, wider shape; as close to a bluff body as possible to maximise drag.

Both the relative angle of attack of the luff, and the shape of the sail influence the way that it produces force, and as both are affected by the pole height; as the required mode of force production changes with apparent wind angle, so does the pole height that will deliver the optimum thrust.

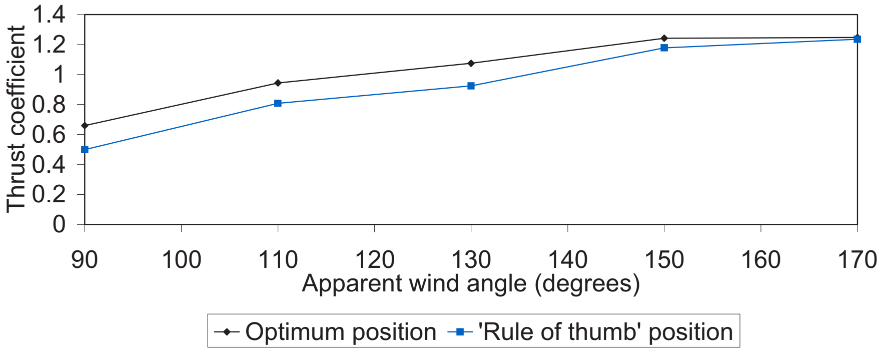

Figure 6: Difference between tested optimum and rule of thumb for white spinnaker

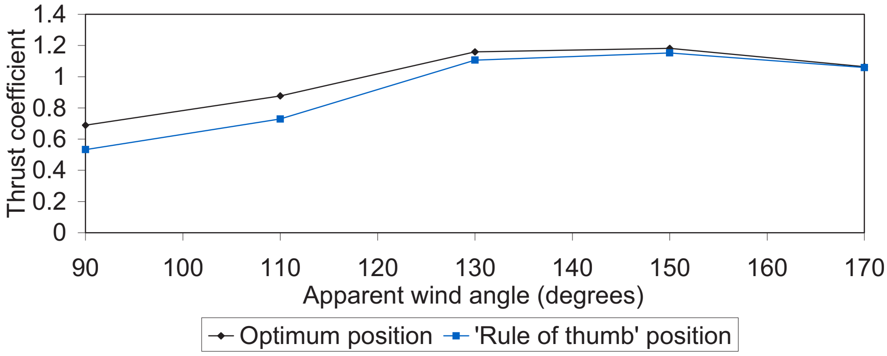

Figure 7: Difference between tested optimum and rule of thumb for black spinnaker

Guideline improvement

Figures 6 and 7 show the comparison between the optimum thrusts obtained from testing and those for the rule of thumb trim. The differences are exactly as expected from theory. At 90° apparent wind angle the 'rule of thumb' does not extract the most thrust from the sail, but as the apparent angle increases the two lines draw closer together indicating the improvement of the 'rule of thumb' in obtaining the optimum thrust. At 180° apparent wind angle the two guidelines produce nearly identical thrusts. The results shown have a relatively uniform decrease in the gap between the optimum and 'rule of thumb', strengthening the validity of the guideline developed for pole angle trim from this project (equation 1).

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Damon and Kain were the recipients of the RINA-Babcock(NZ) Student Naval Architect Award.

On Board Stability Software is a Must—Not an Option

by

John Harrhy FRINA FIPENZ RCNC

Imagine you are the Master of one on New Zealand's major factory fishing trawlers. It has not been a successful trip in the lower latitudes and after 35 days the hold remains largely empty. You are low on fuel and then you are advised on entering Australian waters that you are to discharge the saltwater ballast that you are carrying for environmental reasons. Your first thought as Master will be whether your ship's stability will be adequate.

If your only source of stability information is in the approved Stability Manual you will find that there are no stability conditions that cover such a situation and you will have to determine the adequacy of the stability by hand, an exercise that would take an experienced Naval Architect three hours and which is complex and fraught with the likelihood of numerical error.

Or perhaps you are three days east of the Chatham Islands with little success in finding fish and you wonder how much longer you can remain in the search before returning home in a safe condition.

It's quite probable that in both these situations you would ring up your friendly Naval Architect back in New Zealand, whatever the hour!

The problem is that an approved Stability Manual does not always encompass all situations. In fact the Stability Manual only presents snapshots of a vessel's stability and yet in many types of vessels there is an infinite permutation possible between fuel, fresh water, ballast and product.

In one series of vessels that were considered some time ago by JHCL the conditions presented in the Stability Manual were related like a route map. The first route was the assumption that fish was being caught on entry to the fishing grounds, the second was the assumption of a delay of one

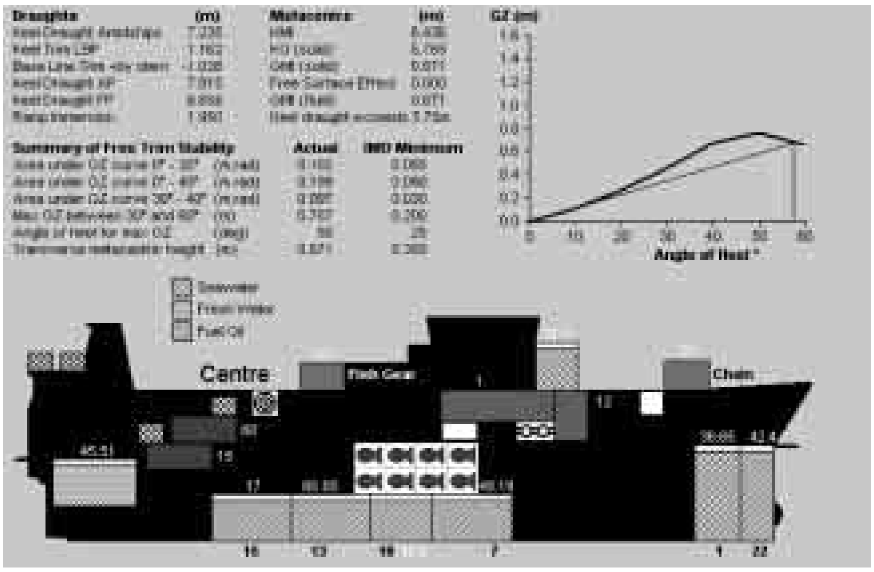

Figure 1: Centreline View showing centreline tanks, centreline pounds and equipment items on the trawl deck and net gantry

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week, the third two weeks and so on. The analysis was also complicated by the requirement not to exceed the scantling draught, that is the deepest approved draught from structural considerations. This meant that if the vessel caught fish too quickly the combination of fuel and product could mean that the vessel would have to leave the fishing grounds early without a full catch.

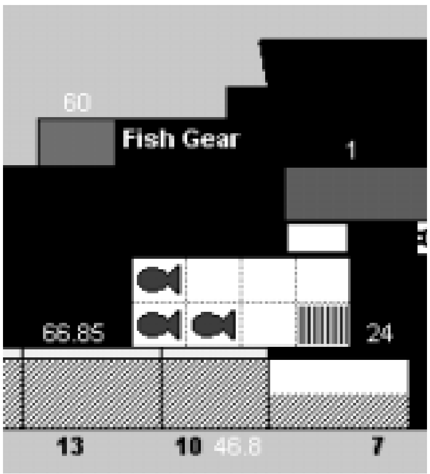

Figure 2: Screen detail showing icons. Quantities in 10000 litres

A Stability Manual has serious limitations. It cannot deal with the unexpected without involving the Master in risky calculation. It is not sophisticated enough to enable the Master to make sound business judgments on how to maximize his catching potential and remain within the law and consequently not prejudice any insurance cover.

StabMaster® was born because of this need to improve the stability information available to the Master, and the need to provide it reliably. It was created in 1992 as New Zealand's major fishing companies saw a need and at that time when larger vessels were starting to carry PCs on board.

The program was designed to be straightforward to operate and capable of reproducing any of the conditions presented in a Stability Manual.

In StabMaster® the loading of holds and changing tank levels can be done graphically on screen. Since most vessels have port, starboard and centre tanks, and holds are similarly divided into pounds, it was decided to present these three profile views to the operator.

Figures 1 and 2 show the centreline profile. The level of the liquid in the tanks can be dragged to adjust the quantity (in 1000s of litres), the items in the hold can be clicked to change their contents from product, to packaging, to void, and other items such as nets and trawl wire can be added or removed

Yellow bars at the top of the full tanks are used to denote when free surface effects are to be ignored. The decision of whether a free surface exists or not is left to the discretion of the Master. A full tank without a yellow bar is assumed to be full but with full free surface effects considered. Tanks may be considered pressed within only about 2% of their full capacity.

Common to each view is an automatically generated statement of draughts and stability information. The current waterline is drawn for a ready appreciation of draughts and trim.

The Master can read whether the base of the trawl ramp is immersed and by how much. In a docking condition he can accurately assess the forward and after draughts to cross the sill to the dock.

If the scantling draught is exceeded the value is highlighted in red.

A table of stability data presents

Yacht Vision 2005

9-13th March 2005

We are looking for articles and advertisers for the next edition of the NZNA. This issue will be handed out to delegates at this symposium.

Please email Helen for more details. hquekett@xtra.co.nz

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each aspect of the stability information required by the regulatory authority and any parameter out of bounds is highlighted in red.

In some cases the menu allows for the consideration of ice on the exposed decks for an assessment of regulatory compliance when operating in the Antarctic zone.

StabMaster® provides a confirmation of input data through the presentation of tables, tank contents, and the breakdown of mass groups making up the displacement

The hull and tank models are as precise as the lines plan. A StabMaster® hull model undergoes a systematic quality check to ensure the model is within acceptable bounds before being used to ensure that a comparison of hydrostatics between StabMaster® and an approved Stability Manual will be within 0.5% on displacement, and 0.3% on KMt, LCB and LCF.

The program features free trim calculations for large angle stability and the centre of gravity and free surface of tanks is calculated to the current tank level.

In most approved Stability Manuals it is assumed that product in the hold is always concentrated at the geometric centre of the hold, however fishing vessels usually have a preferred arrangement of loading the holds, either from the fore end or the after end. The analysis behind StabMaster® breaks down the hold in to a large number of transverse, fore and aft, and vertical geometric segments so that a more accurate and realistic model is achieved.

While the Naval Architectural calculations that form the engine of the program are extensive and complex, the usability of the program must be attributed to its graphical presentation which enables a Master to represent the loading of his vessel with a high degree of certainty and confidence.

A stability program such as StabMaster® can faithfully represent any ship loading imaginable and as such can resolve those unforeseen situations that cannot be included in a Stability Manual.

The development of the use of the PC onboard modern fishing vessels has enabled the stability of a vessel to be easily and quickly monitored by the Master leading to a better assurance of safety than can possibly achieved with a Stability Manual.

On board stability software should not be an option it should be onboard.

John Harrhy is the director of John Harrhy Consulting Ltd.

PhD SCHOLARSHIPS

UNSTEADY LOADS ON HIGH-SPEED VESSELS

A Joint ARC Project of the **University of Tasmania,** the **Australian Maritime College, Revolution Design** and **INCAT Tasmania**

Two three-year Australian Postgraduate Industry Awards (APAI, $23,886pa) are available for postgraduate research for the degree of Doctor of Philosophy. Supplementary industry scholarships of up to $10,000pa may also awarded depending upon qualifications. Structural design of high-speed ships is determined by wave forces and the research will involve analysis of ship data, model testing and computation of extreme structural loads. Applications from honours graduates in Naval Architecture, Mechanical Engineering, Physics or Applied Mathematics are invited. An application package can be downloaded from www.research.utas.edu.au/rhd/schol_forms.htm

An application form and supporting documentation including a CV and referees report forms must be received at the University by 24 January 2005.

For more information contact:

Professor Michael Davis, School of Engineering, University of Tasmania, Private Bag 65, Hobart, Tasmania 7001

Email: M.R.Davis@utas.edu.au Tel: 03 62262074 Fax 0362267247

Technical Meetings

Technical meetings will resume in February after the holidays.

Meetings are generally held at 6pm on the second Tuesday of the month. These meetings are open to all members as well as interested people from the wider community.

If you have any suitable ideas or wish to make a presentation to the members please contact Susan Edinger.

Forthcoming events

More information on the following events will be provided in Update.

FEBRUARY 8th: Offshore Patrol Boats

Speaker: Lt Cdr Robert Ochtman-Corfe, RNZN Hull and Structural Engineering Officer

Preliminary design of an offshore patrol vessel, based on the Project Protector specification for the RNZN. The paper was part of the speakers' final year Naval Architecture degree.

MARCH/APRIL: Site visits

Navman and Henley Winches

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The Royal Institution of Naval Architects (New Zealand Division) would like to acknowledge the continuing support of Clendon Feeney as our Honorary Solicitors.

Don't forget that the NASNZ Standard Terms of Trade and Standard Design Contract are available for free download from the NZ Division website (www.rina.org.uk) as well as www.clendons.co.nz.

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