THE USE OF MODEL TESTS IN THE DEVELOPMENT OF THE NEXT GENERATION OF RNLI SLIPWAY LAUNCHED LIFEBOATS

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SUMMARY

This paper describes the range of model tests undertaken during the twelve month development period of the lines of a new lifeboat. The tests included investigations of resistance, wake survey, self propulsion, seakeeping, rolling, and manoeuvring in calm water and waves. Rather than the progressive development of the design, which is the concern of the RNLI's naval architects, the paper concentrates on the value of the tests in guiding the development, and the test methods employed, which in some cases were innovative.

AUTHORS' BIOGRAPHIES

Mr Barry Deakin has been employed at the Wolfson Unit since 1978, specialising in stability assessment and model tests on a wide range of vessel types.

Mr Ian Campbell has been at the Wolfson Unit since 1973, during which time he has been involved with many small high speed craft, and a number of research projects involving their motions, handling and stability under way. He has also worked extensively on lifeboat trials in calm and rough water, gathering and analysing data for the RNLI.

1. INTRODUCTION

A new generation of fast, self righting lifeboats is being designed by naval architects at the Royal National Lifeboat Institution. Already in service are the Severn and Trent classes, which operate from moorings in sheltered harbours and were known during their development as Fast Afloat Boats. The Fast Slipway Boats will be required to operate at speeds of up to 25 knots from the many lifeboat stations with slipway launching facilities, where permanent mooring in a sheltered harbour is not possible. The boats have to meet an extremely high specification, being operated by volunteer crews in severe sea conditions, and the RNLI required reliable evidence that their design was not lacking in terms of its operational characteristics.

Following an overall review of the operational requirements, the RNLI commissioned an extensive programme of model tests to aid the development of the hull form for the boats and, to maximise the level of expertise involved in their interpretation, requested that staff of both the Wolfson Unit and British Maritime Technology (BMT) be involved in the testing and analysis. Both organisations had previously worked with the RNLI, BMT having conducted model tests on the Fast Afloat Boat and the Wolfson Unit having conducted full scale seakeeping trials (Ref.1). BMT's involvement was also through their collaborative partnership with DERA in the Haslar Hydrodynamic Test Centre (HHTC) and use was made of the facilities at DERA Haslar. The self propulsion tests were instrumented and conducted by staff from HHTC, and the other tests were instrumented and conducted by the Wolfson Unit. Where possible, staff from the partner organisation were present to witness, and assist with, the tests. Overall project management was by the Wolfson Unit, and the results were reviewed by all parties as the work progressed. Following these reviews RNLI staff prepared the drawings for the later designs.

2. HULL DESIGNS

A decision was made early in the programme to start with proven designs, only to test designs that were representative of actual boats, and not to test hull forms where only one parameter was changed without realistic variations in the others. Thus the programme was aimed at development, rather than research into the effects of separate parameters from which a design could be developed.

Initially six hull designs were produced by the RNLI, with suitable length and beam to meet the slipway and boathouse requirements but only four of these were tested. The possibility of either water jet or propeller propulsion was under consideration. Hull H1 served as a reference design, being based on an existing Fast Afloat Boat (Ref. 2) with deep, square propeller tunnels. A lines plan of this hull is reproduced at the end of this paper.

Hulls H3 and H4 were variants of hull H1 and were not tested. Hull H6 was a rigid inflatable form suitable for water jet propulsion. The other two were H5, with a constant deadrise, and H2, a warped bottom form, both without propeller tunnels.

The constant deadrise hull was modified, and extended in length by 10%, to produce a fifth design, hull H5-2, and then hull H7 was produced following initial testing on the first models. It was tested in two configurations, one suitable for water jets and the other for propellers in simple, semi-cylindrical tunnels.

A further design, H8, was developed as a hybrid incorporating some successful features of the others, and again was tested in jet and propeller versions.

The latest design, H9, was based on H8, extended in length, and tested with four subtly different propeller tunnel variations. The tunnels were shallower, and with a wider entry, than those of H7 and H8.

To ensure complete protection of the propellers and rudders during launch, recovery or on grounding, the tunnel hulls incorporated a deep centreline keel and bilge keels.

TABLE 1 Principal Dimensions of the Hull Designs

(All linear dimensions are in metres full scale)

Hull design number	H1	H2	H5	H5-2	H6	H7	H8	H9
Displacement, tonnes	28	28	28	28	28	28	28	28
Length overall	15.00	15.00	15.00	16.11	15.76	15.00	15.00	16.00
Length WL	13.72	13.70	13.73	15.08	13.26	13.60	13.57	14.56
Beam overall	5.20	5.09	4.90	4.90	5.49	5.20	5.20	5.20
Deadrise @ Stn 5, degrees	21.4	21.8	21.5	21.5	22.7	18.2	20.0	19.04
Deadrise @ transom, degrees	20.5	4.5	17.9	18.0	22.6	3.1	13.3	12.00
Draught to USK	1.33	1.29	1.12	1.04	1.16	1.17	1.19	1.17
LCG, %LWL aft of Stn 5	5.1	5.8	8.8	8.1	7.4	9.0	11.7	9.05

3. MODELS

Models of all designs were constructed at a scale of 1:10, at which scale they were suitable for the resistance, seakeeping, rolling, and manoeuvring tests. The final version, H9, was also constructed at a scale of 1:6 to facilitate wake survey and self propulsion tests.

The final 1:6 scale model, and two of the initial designs, were to be used only for captive tests in the towing tank, and these were constructed using machine cut rigid foam blocks. The other 1:10 scale models were required to be suitable for outfitting with motors, propellers and control gear for radio controlled manoeuvring trials. These were of a more durable strip plank on frame construction, sheathed with GRP.

All models were fitted with adjustable trim tabs on the outboard parts of the transom. Standard turbulence inducing studs were fitted around the girth at station 5.

4. TEST FACILITIES

The majority of the captive tests were conducted in the towing tank at HHTC, which is 258 metres long by 12.2 metres wide by 5.5 metres deep. While this tank was much larger than necessary for resistance tests on the 1:10 scale models, its wave making facilities satisfied the requirements for testing in seastates up to 3 metres significant height.

Supplementary resistance tests were conducted in towing tanks at Southampton Institute, with dimensions 60 metres long by 3.6 metres wide by 1.8 metres deep, and at Westland Aerostructures, with dimensions 200 metres long by 4.6 metres wide by 1.7 metres deep. These facilities were more readily available, and were used for tests required to extend the resistance database on a model, when further seakeeping tests were not required.

The Southampton Institute towing tank was used for the roll tests in beam seas.

Calm water manoeuvring tests took place on an outdoor lake. Manoeuvring tests were also conducted in following seas in the towing tank, and in the complex sea basin at HHTC, which is 60 metres wide by 120 metres long.

5. TOWING ARRANGEMENT

The 1:10 scale models were towed using the Wolfson Unit's portable towing and measurement system. This comprises a single free to heave tow post, and a fitting in the model which enables freedom in pitch, adjustment of yaw and roll angles, and measurement of resistance, sideforce, yaw moment, roll moment, pitch and heave. With the addition of two accelerometers, this comprehensive system incorporated all of the transducers necessary to enable all of the captive tests to be conducted using a common set up.

The models were towed from the centre of gravity, and a trimming moment was applied, by moving internal ballast, to correct for the separation of the tow point and the anticipated thrust line. They were ballasted to a standard vertical centre of gravity and pitch inertia, the latter being based on data for existing lifeboats.

The decked models were fitted with a central turret through which the tow post was fitted. With a thin polythene boot to seal between the post and the turret, this arrangement minimised water ingress during the severe seakeeping runs.

6. RESISTANCE TESTS

Each model was tested over a matrix of speed and trim tab settings, including speeds of 15, 20, 25 and 27.5 knots, and tab angles of 0, 5 and 10 degrees. Additional tests were conducted in some cases to extend, or provide more detailed information within the matrix, or to quantify the effects of LCG variation.

Using standard Wolfson Unit procedures, the model resistance data were corrected to allow for the resistance of the studs and the region of laminar flow ahead of them. The corrected data were extrapolated to full scale using the measured running wetted area with the ITTC Model-Ship Correlation Line.

Figure 1 presents a comparison of the resistance curves for the models. In each case a tab angle was selected which gave good performance over the speed range, taking account of the resistance and trim characteristics. In some cases the LCG was moved from the initial design point, to achieve a substantial reduction in the resistance, and this project served as a good illustration of the value of testing over a comprehensive matrix of LCG values, tab angles and speeds.

Differences in resistance between the first models, hulls H1, H2, H5 and H6, were in excess of 10%, and it was clear that a worthwhile improvement could be made over the base design, H1. Hull models H2, H5 and H6 did not, however, allow for the protection of propellers and as jet propulsion became the less favoured option, propeller tunnels were introduced into the subsequent designs. Data for hulls H7 and H8 are presented for the tunnel hull versions only, and suggest that no improvement in resistance had been made with these designs. In fact the tunnels in these models were of simple semi-cylindrical form, which introduced resistance penalties of 10% or more compared with the versions configured for water jet propulsion. The hulls as configured for jet propulsion had similar low resistance characteristics to those of hull H5. Refinement of the tunnels used on hull H9 enabled some reduction of their resistance penalty.

The hulls were heavily loaded, with a displacement of 28 tonnes on a waterline length of less than 14 metres, and hull H5-2 demonstrated the desirability of an increase in length without an attendant increase in displacement. As a result of these data the designers decided to extend the length of the boat to the maximum possible within the constraints of the boathouse envelope.

7. PROPULSION TESTS

The 1:10 scale models were too small to fit stock propellers and associated dynamometry for propulsion experiments, so a 1:6 scale model of hull H9 was built for this purpose. Resistance tests were conducted by towing the model with a similar system to that used for the 1:10 scale tests and the scaled resistance, heave and trim values were within 2% of those obtained from the 1:10 scale tests. A different trailing link arrangement was used for the propulsion tests and the results from this test correlated well with those from a similar test previously conducted with a model of the Fast Afloat Boat, on which hull H1 was based. This confirmed that the developed hull form would require substantially less installed power than the base boat to achieve the required speed.

8. FLOW VISUALISATION

Following disappointing resistance results on hull H8, a paint flow visualisation test was conducted to investigate the tunnels. This revealed poor flow in the tunnel top in the vicinity of the propeller, and strong curvature of the flow at the elliptic tunnel entry.

As a direct result of this simple test, the tunnel entry was altered, and the depth of the tunnels reduced.

Further flow visualisation tests were conducted on the four tunnel variants used on the 1:6 scale model of hull H9, and these assisted in the selection of the final tunnel configuration. An example of the flow visualisation is illustrated in Figure 2, which shows the view looking forward into the port side propeller tunnel. The streaks in the paint indicate the flow strength and direction and in the tunnel roof these can be seen to be short compared with those on the bottom of the hull, indicating the weak flow.

9. OBLIQUE TOW TESTS

Oblique tow tests were conducted at the time of the resistance tests, to obtain the static margin between the longitudinal centre of gravity, LCG, and the centre of lateral resistance, CLR. The CLR must be aft of the LCG for weathercock stability, in the directional sense, but previous work on RNLI lifeboats, by BMT (Ref. 3), had shown that boats had directional stability with the CLR ahead of the LCG by some margin and without weathercock stability. The static margin was therefore used as one of several criteria to assess the potential directional stability of the different hull forms.

The oblique tow tests consisted of towing each model from its LCG at different fixed yaw angles and measuring the sideforce and yaw moment. The static margin, by which the CLR was forward of the LCG, was obtained from the slope of the linear fit through a plot of these two measurements and results are given in Table 2.

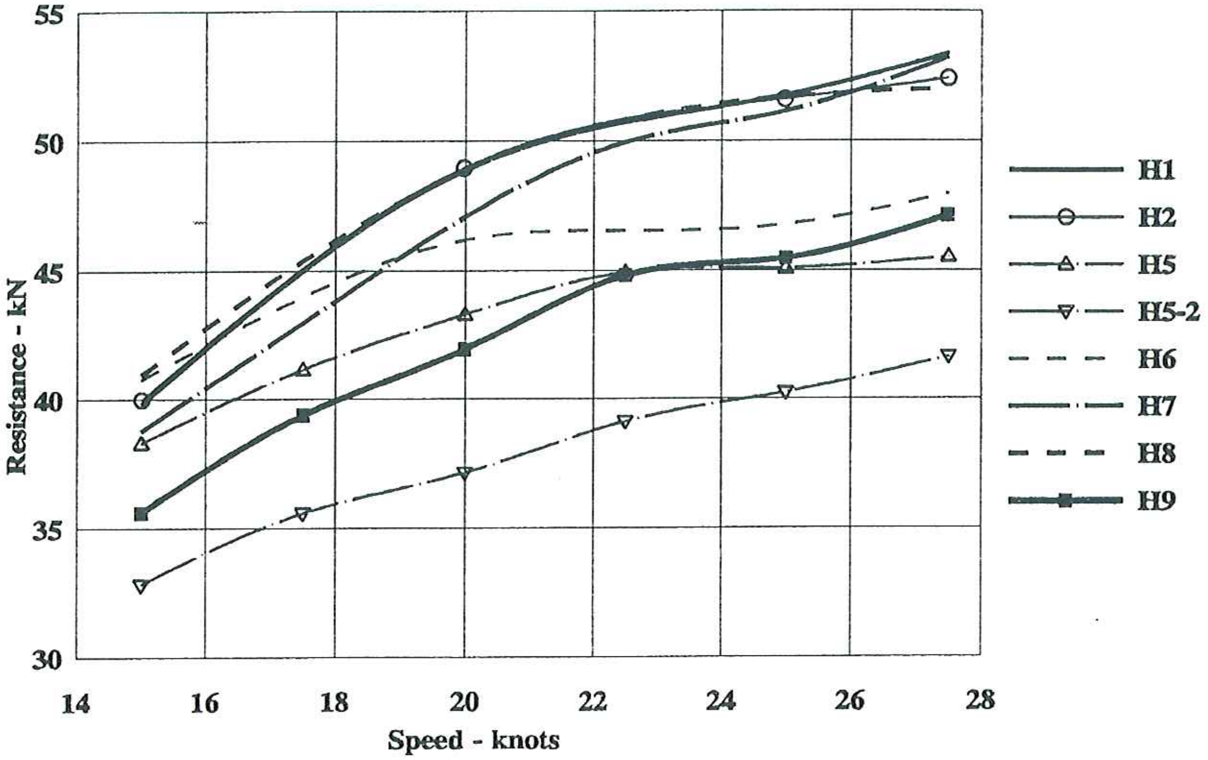

Fig. 1 Variation of Resistance with Speed for Eight Models

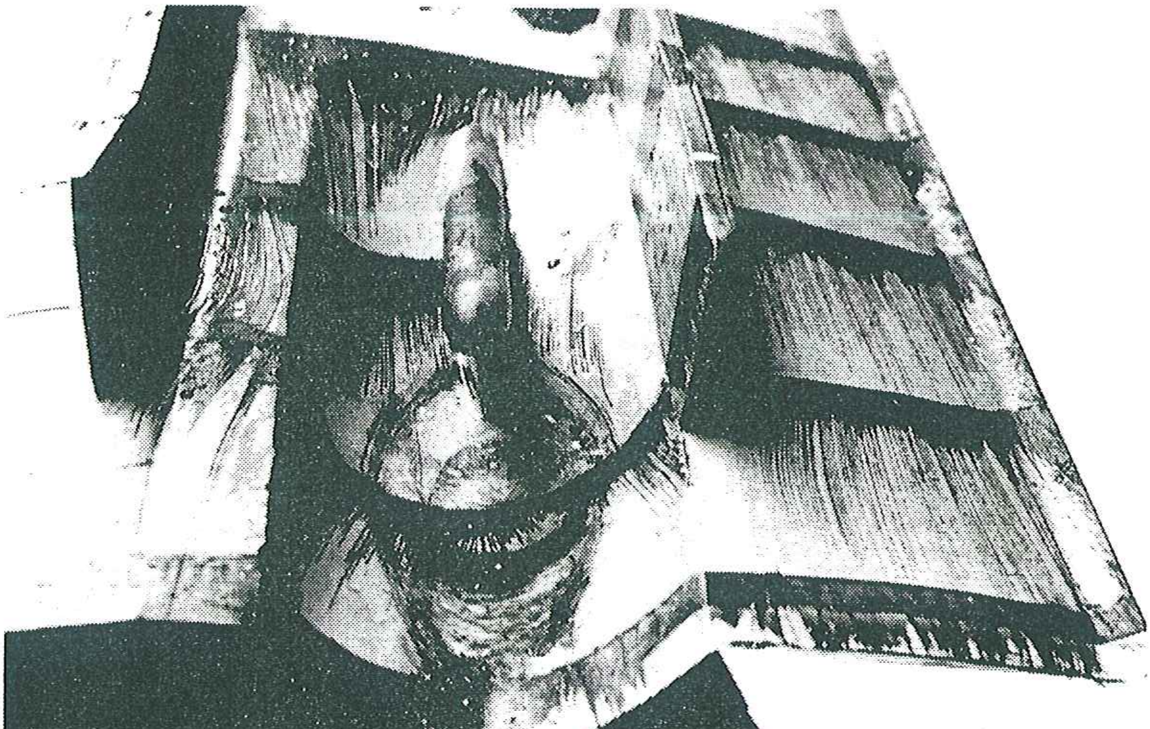

Fig. 2 Example of Paint Flow Visualisation
(The view is forward along the propeller shaft, on the upturned model)

TABLE 2 Static margin as % of length between perpendiculars

Hull design number	H1	H2	H5	H5-2	H6	H7	H9
Static margin with tabs at 0°	-4.0	6.2	3.0	-1.9	4.7	10.6	5.1
Static margin with tabs at 10°	0.9	11.4	10.6	7.7	10.7	16.1	9.7

It can be seen that only hull H1 had weathercock stability, i.e. its CLR was aft of its LCG, although this was partly due to the relative forward location of its LCG compared with the other models. Hull H7 had the worst static margin and, as described in section 13, was found to be directionally unstable. It can also be seen that the value of the static margin increased with the application of trim tabs. This was consistent with the effect of the trim change on the centre of immersed lateral area and confirmed the desirability of reducing the trim tab angle when running before following seas.

10. SEAKEEPING

10.1 SCOPE OF THE TESTS

Each model was tested over a matrix of JONSWAP spectra, predominantly at a scaled speed of 25 knots with a limited number of tests at 15 knots and 20 knots. The trim tab settings were kept constant throughout the tests, at a suitable value as determined from calm water resistance tests. The wave spectra had significant heights from 1 metre to 2.5 metres and modal periods from 4 seconds to 9.6 seconds. For some of the speed and spectra combinations, it was necessary to do more than a single run in order to achieve statistically reliable data, based on approximately 100 wave encounters.

In addition to the motion and acceleration measurements, the high quality 'Hi8' video format was used to record the model's motion. This was used to indicate the wetness associated with the motions, and the emergence of the keel from the water.

Three types of analyses were used in order to compare the sea-keeping performance of the hulls. These were root mean square values, RMS; peak exceedances; and human factors based on weighted RMS values.

10.2 RMS MOTION

The RMS values indicate the average magnitude of the motions. The raw data from the two accelerometers, pitch angle transducer and wave probe were analysed to yield RMS values. In addition, the wave probe data were analysed to yield the encounter period and, subsequently, the original period of the waves which would be observed if the probe were stationary. Sample RMS data are presented in Figure 3. This conventional presentation incorporates wide scatter which hinders useful comparisons between boats.

Attempts were made to find a non-dimensional representation for the data which would reduce the scatter. In the best representation the data were reduced to a dimensional ratio using a factor formed from the encounter wave period and wave height. The acceleration factor used for the analysis was: Tze*g/Hs, where Tze is the encounter wave period, g is the acceleration due to gravity and Hs is the significant height of the spectrum. The values of this acceleration ratio were found to be largely independent of speed, wave height and period.

The pitch data were factored in a similar way to the acceleration data, but the original wave period was used instead of the encounter wave period. The factor used for the analysis was: Tz*g/57.3/2/Pi/Hs, where Tz is the original wave period, and 57.3 is used to convert degrees to radians.

Following earlier work by the Wolfson Unit (Ref. 1), the forward acceleration data were also factored by the midship acceleration data, which also produced values that were largely independent of speed, wave height and period.

A linear regression line was fitted to all of the data presented, for ease of comparison between hulls, see Figure 4. To further aid comparison of the hulls, mean values from all the runs were calculated for all of the factors, and these were presented as a ratio of the equivalent values obtained for the base hull H1.

The forward to midship vertical acceleration ratios were similar for all hulls, with hull H9 being the least at all wave heights.

A summary of the pitch data is presented in Figure 5. The lower pitch angle for hull H9 may be a consequence of the increased length, and is consistent with lower values obtained for the ratio of forward to midships accelerations.

10.3 EXCEEDANCES

RMS values are affected by the peak values but do not provide information about their magnitude. The raw data from the forward accelerometer were therefore analysed to yield the occurrence of exceedances of peak values with respect to the RMS value. This analysis was conducted for each test run and the occurrence of high peak accelerations with respect to the average acceleration indicates the propensity to slam. The occurrence of exceedance was normalised with respect to the number of peaks found, and thus its values fall within the range of 0 to 1. The highest accelerations were associated with the deceleration of the boat as it slammed but in general peaks had both positive and negative values.

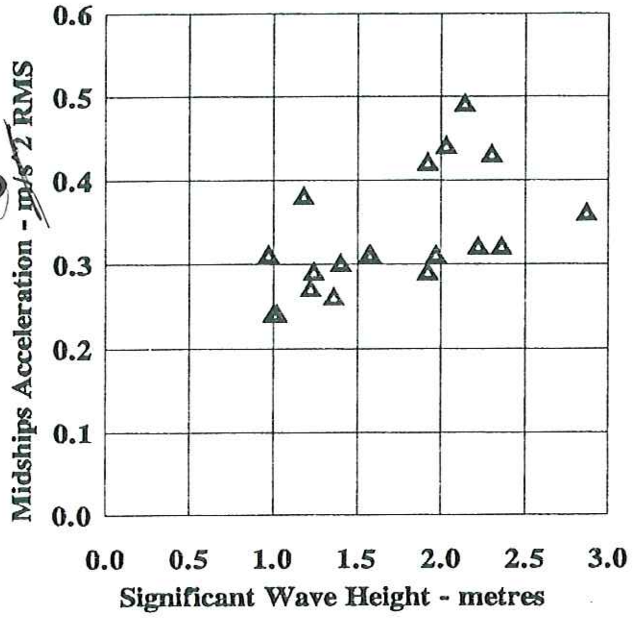

Fig. 3 Variation of RMS Acceleration with Wave Height for Hull H1

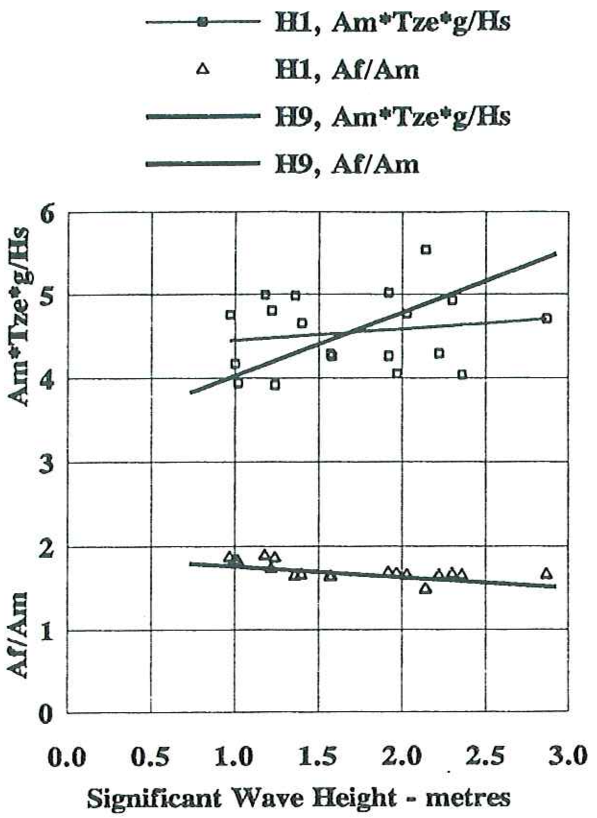

Fig. 4 Acceleration Ratios

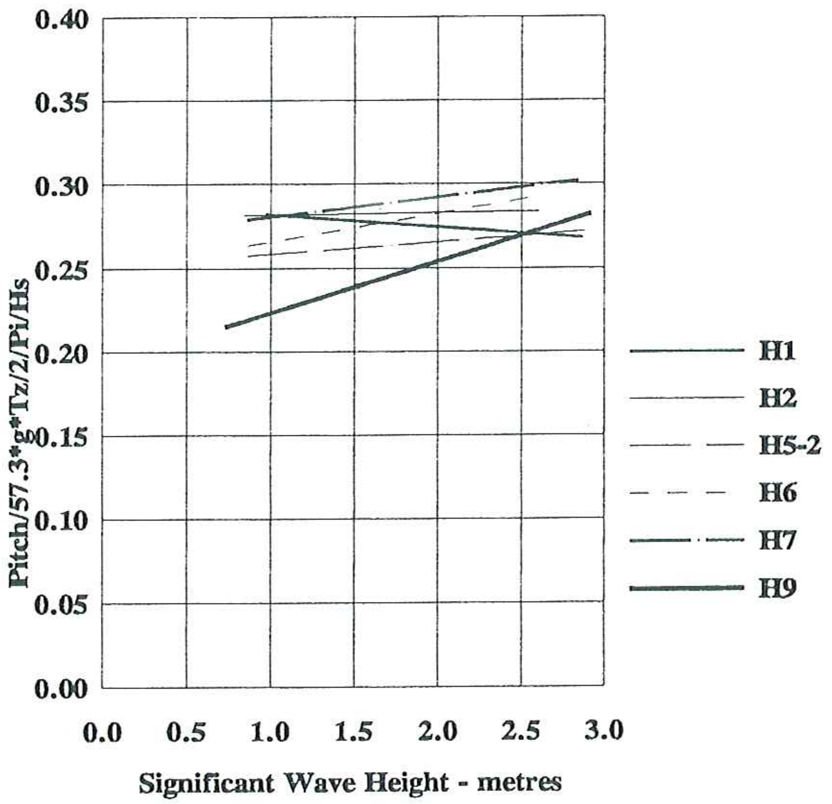

Fig. 5 Variation of Pitch Ratio with Wave Height

The data were also averaged at each peak/RMS ratio for all the runs in different spectra to give a mean exceedance value. These data for each hull were fitted with a 6 parameter polynomial, for ease of comparison, see Figure 6. The spread of these mean data for different hulls are about half the spread for any given hull, so care needed to be exercised when drawing conclusions.

10.4 HUMAN FACTORS

The raw data from the two accelerometers and pitch angle transducer were analysed to yield the incidence of seasickness, the weighted discomfort levels and weighted hand control levels. These data were analysed as laid out in BS 6841:1987 (Ref. 4).

The seasickness levels are for a voyage duration of 2 hours and are predictions for unadapted personnel, that is people unused to travelling at sea. This is not necessarily the case for either lifeboat crews or the people they rescue, and therefore may indicate a pessimistic result. Figure 7 presents a summary of these data, and shows negligible difference between the hulls, but does illustrate the strong relationship between seasickness incidence and wave height. These data were found to be virtually independent of speed.

The discomfort levels as indicated in the British Standard are a weighted combination of the six degrees of freedom accelerations. Only two degrees of freedom were measured, since the model was restrained in the other degrees. For the wheelhouse calculations only, surge acceleration was calculated using the appropriate lever arm and the pitch acceleration. The hand control levels were similarly adjusted, since they are a weighted combination of the three degrees of freedom linear accelerations, and only one degree of freedom was measured.

10.5 DECK WETNESS

It was surprising, in view of the small differences between the measured motions and accelerations of the models, that substantial differences were observed in deck wetness. The watertight integrity of the turret around the towing post on model hull H5 was tested frequently, being inundated with solid water during tests in the steeper waves, and water ingress occurred on several occasions.

During tests on the first four models it became apparent that two of the hulls were particularly prone to deck wetting, while hull H1 performed relatively well. In developing subsequent hull forms, the bow lines, particularly above the waterline, were given careful consideration, and slow motion viewing of the video recording was a guide to the progressive adjustments to the chine and upper spray rail.

Hull H9 was notably drier than the other models, with little or no solid water taken on deck, and this was regarded as a great success in the development process.

11. ROLL TESTS IN BEAM SEAS

Each model was ballasted to the same displacement, centre of gravity and roll inertia, and was positioned near the wavemaker at 90° to the tank centre line. It was restrained from yawing by experimenter, using light strings attached bow and stern, just above the waterline. Measurements of the roll angle were made using a roll gyro. Regular waves of an appropriate height with respect to their length were generated for a period of 30 seconds, during which time measurements of wave height and roll angle were made.

At low frequencies, where the roll natural period was of the order of twice the wave period, the model was excited at its natural roll frequency and not the wave frequency. This frequency was used as the lower limit of usable data.

Because the various hull forms were tested with the same vertical centre of gravity above the underside of the skeg, the metacentric height, GM, was not constant. This was evident in the resulting variation of the resonant roll frequency, between 0.25 and 0.29 Hz.

The roll angle data were non-dimensionalised by maximum wave slope to give the roll RAO curves. Comparisons were made between the peaks of the RAO curves, the RAO values at 0.2 and 0.4 hz and the area under the RAO curve between these values.

The RAO data were used to predict the roll motion for a range of JONSWAP spectra for the purpose of assessing the likely ease or difficulty with which the boat might be recovered onto a slipway, without damage due to beam seas. For a given spectrum, small differences noted in the resonant periods were probably due to the differences in GM. Quite large differences were noted in the height of the resonant peaks, and hull H9 had a peak 13% less than H1.

12. MANOEUVRING IN CALM WATER

12.1 CHOICE OF TESTS

It is important to have good directional control in any fast boat, but it is particularly important for lifeboats, which have to operate in sea conditions from which most fast pleasure craft will have sought shelter. It is, however, rather difficult to predict whether a new design will have good control characteristics. Designers base their knowledge on the experience of the behaviour of past designs, and anecdotal evidence of boats that have reputedly had poor control characteristics. Whilst this approach may work for the development of an existing hull shape it is not a satisfactory way to proceed where a completely new hull form is being developed.

Various numerical and experimental approaches have been applied by other investigators into the problem of measuring the control characteristics of a model, but the most complete simulation was considered to be the free running of a model under radio control. Manoeuvring tests, involving course keeping, spirals, turns and zig-zag

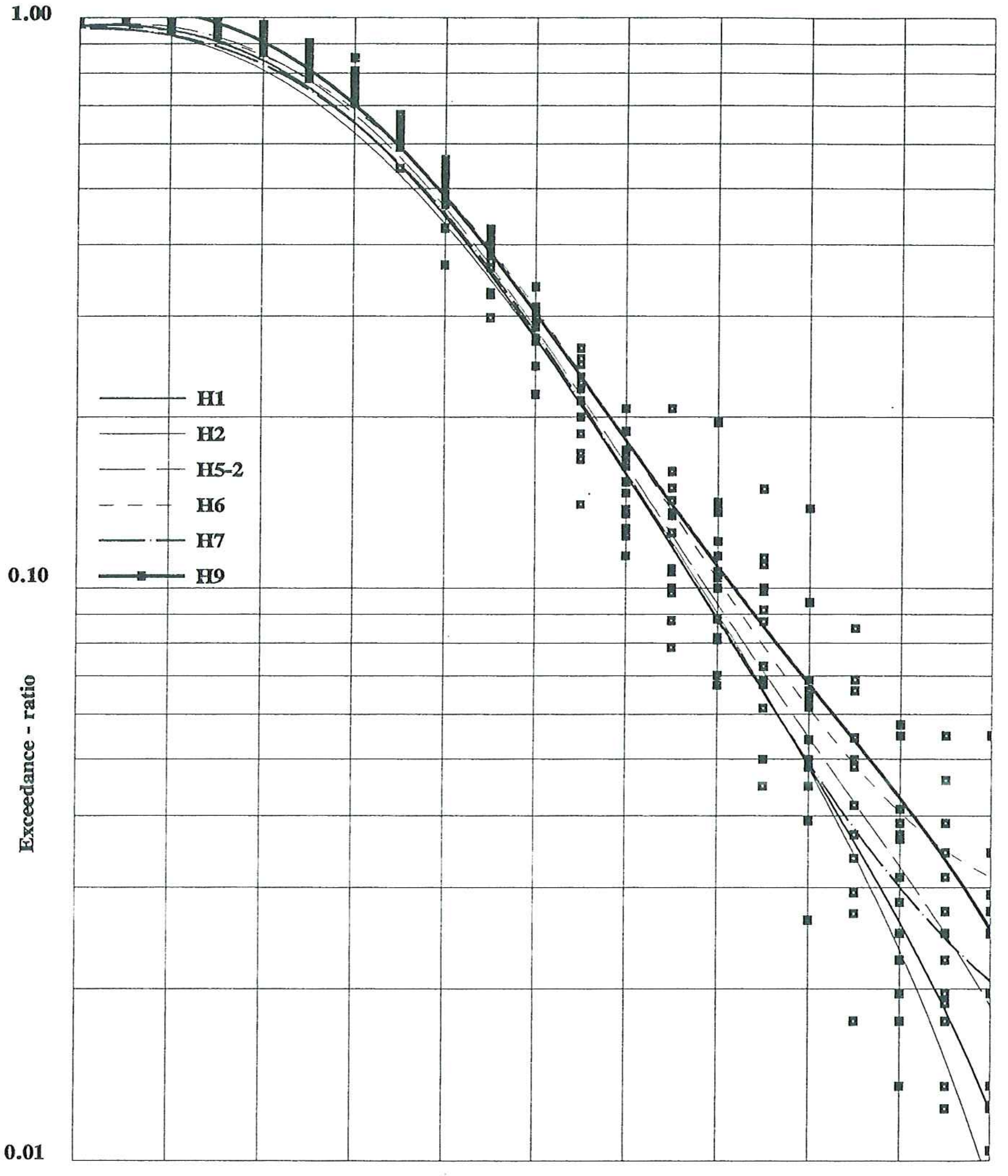

Fig. 6 Variation of Mean Exceedance with Peak/RMS Ratio

manoeuvres were conducted using the 1:10 scale models, running mainly in calm water, except for the final version which was also run in waves. The tests revealed some significant differences in the control characteristics of the various designs and, once the model propulsion arrangements had been sorted out, the tests proved straightforward to conduct and involved only a few hours running, on two or three occasions on a local lake.

The small size of the models and the available budget precluded the use of on-board instrumentation, and all of the tests were conducted without instrumentation other than a stop watch and video camera. The model speed control was calibrated by timing the model over a measured distance, and the manoeuvring data were measured from the video record.

The model was tracked in the video recording during the execution of medium and large diameter turns by the use of camera zoom and pan facilities. This enabled turn times and heel angles to be obtained from the recordings and showed details of the water flow around the models. The rates of turn were obtained to a high level of accuracy by timing the model over turns of 180 or 360 degrees, with masts located to port and starboard amidships to indicate the model heading. The video camera settings were fixed for tight turns to provide a recording of the complete turn and enable the turn diameters to be obtained. The rudder settings were spoken into the camera microphone by the operators of the camera and the radio control.

12.2 MODEL ARRANGEMENTS

The first model, hull H6, was outfitted with a glow plug internal combustion engine, driving toothed belts to twin model water jets, obtained from Austria. The engine proved difficult to cold start on the winter days when the project began and its vibration caused many problems with the fittings. These problems vanished when the engine was replaced by twin dc electric motors, although it took a little while to find motors which performed to their specification. The motors had to operate at the higher end of their torque range since scale models for research are considerably heavier than other model boats.

Some of the models tested, including hulls H7, H8, and H9, had tunnels and were fitted with handed propellers, with blades cut from brass plate, and rudders with NACA aerofoil sections. These models were also powered by the electric motors driving through toothed belts, with pulleys arranged to give the required gearing. Five, 6 volt, sealed lead acid batteries were used in series to provide the power and comprised the bulk of the ballast for the model. The batteries were positioned in the model to give the required centre of gravity and radius of gyration. With two sets of batteries, testing could be conducted over a period of three or four hours, provided runs were kept to the minimum duration.

12.3 TEST RESULTS

It was found that spiral manoeuvres could be conducted with the water jet drives although it took at least half a turn for the model to settle into a steady turn of constant diameter. Figure 8 shows the non-dimensional rates of turn plotted against jet deflector angle for hull H6, and the results are consistent with the boat being directionally stable. The boat also heeled slightly inward in the turns, exhibited good manoeuvring characteristics in the zig-zags, and was very manoeuvrable at slow speeds due to the vectored thrust from the water jets.

By contrast, hull H7, with propellers in tunnels protected by a skeg and bilge keels, and with a highly warped bottom, exhibited directional instability and was very difficult to control at 25 knots. The rates of turn at the lower speed of 20 knots, when the boat was directionally stable, are also shown in Figure 8. It can be seen that hull H7 exhibited faster non-dimensional rates of turn than hull H6 due to its directional instability. At the higher speed of 25 knots the model would continue to turn to port with small degrees of starboard rudder applied, then would suddenly veer to starboard. These characteristics were demonstrated to all the parties involved in the hull development programme, who expressed both general surprise that the problem was so manifest, and agreement that the problem existed.

The initial application of rudders tended to heel all the propeller driven models into the turns. Some of the models heeled outwards in a steady turn, so in the initial phase of the turn the model could be observed to first roll inwards and then outwards. This behaviour was part of the instability characteristic of hull H7, with the model rolling as it veered from turning one way to the other.

The minimum turning circle diameters were also measured for comparison with a criterion based on the performance of existing RNLI lifeboats, for a diameter of less than five boat lengths. Both hulls H6 and H7 met this criterion but for different reasons, hull H6 because of the water jet characteristics and hull H7 because of the manoeuvrability associated with its directional instability.

A dynamic inclining test was performed, based on the IMO Draft Guidelines for the Code of Safety for High Speed Craft (Ref.5). This involved heeling the models to an angle of approximately 3 degrees, by moving ballast, then running the model on a straight course and measuring the change in heel angle, which should not increase by more than 5 degrees. Hull H7 met this criterion despite its directional instability.

Following the experience with hull H7, the design was modified and two further models were tested. Hull H8 was run propelled alternatively by water jets and propellers in tunnels, and the final lengthened version hull H9 was propelled by propellers. These hulls were found to be directionally stable and were controllable without any problems.

The tests proved the value of such low cost methods in determining the handling characteristics, highlighting problems, and guiding the design development.

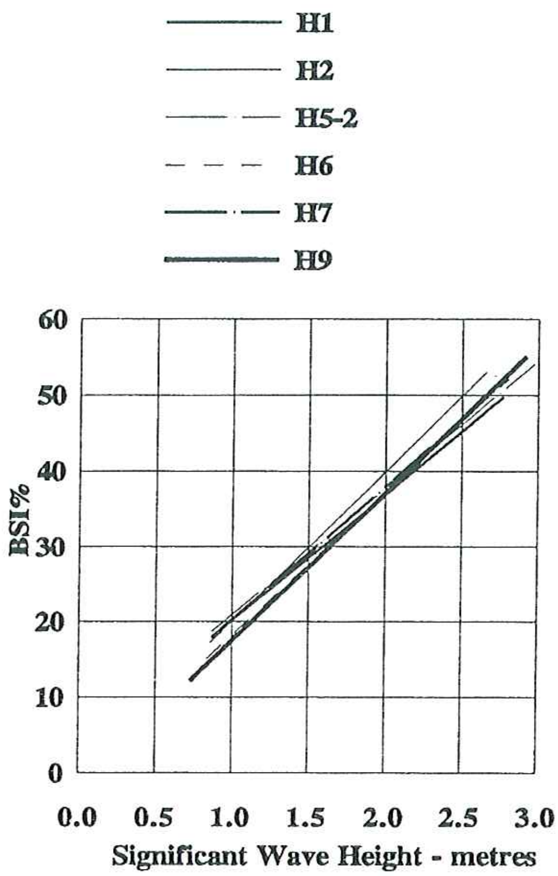

Fig. 7 Variation of Seasickness Incidence in the Wheelhouse

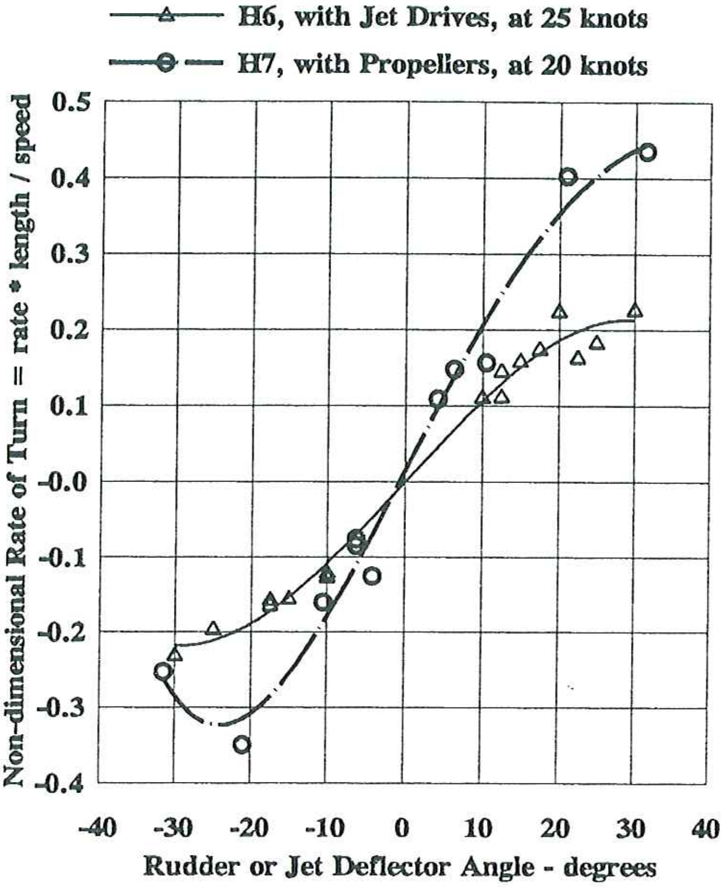

Fig. 8 Manoeuvring Test Results for Two Models

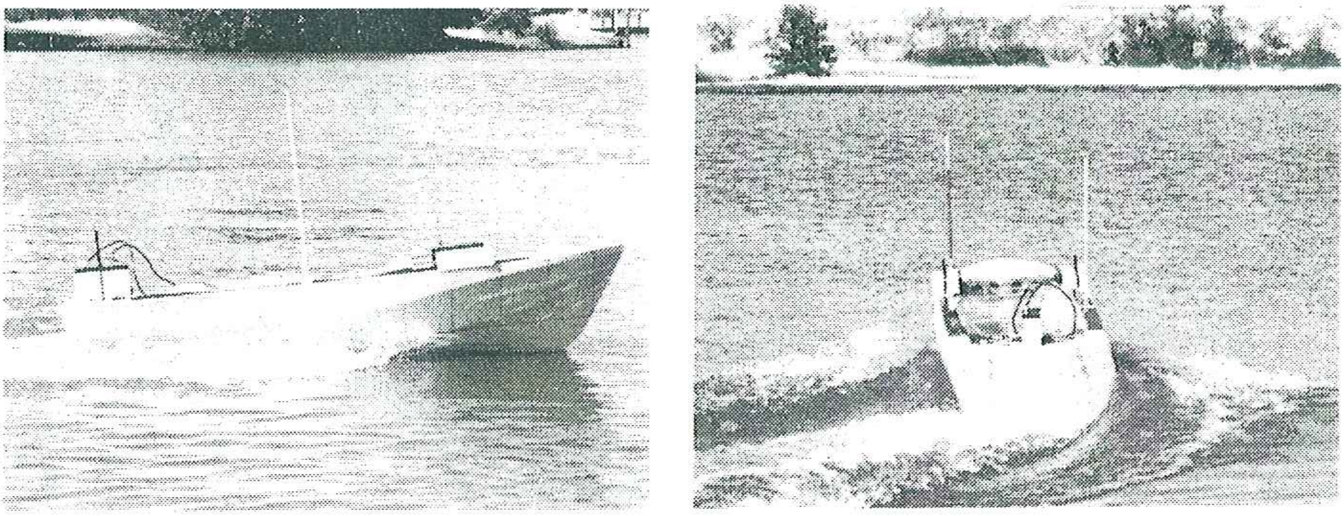

Fig. 9 One of the Radio Controlled Models Executing a Tight Turn

13. MANOEUVRING IN WAVES

Frequently rescue craft are operated at their design speed in severe weather conditions, when any undesirable characteristics in their handling might prove hazardous. Tests were commissioned to observe the behaviour of the developing design in a range of conditions which, it was hoped, would provide the opportunity for the model to demonstrate any tendency for misbehaviour.

13.1 TESTS IN THE TOWING TANK

Following the calm water manoeuvring tests, the radio controlled model of hull H9 was taken to the towing tank and run in a variety of regular and irregular following seas. The experimenters controlling and filming the model were stationed on the towing tank carriage and were able to follow the model along the tank.

Wave heights of 2.5 to 3.5 metres were used, and regular wave periods were set to produce wave celerity speeds equivalent to 20, 25 and 30 knots full scale, so that the model would surge down the forward face of the waves.

Tests were conducted in two different irregular seastates, with significant wave heights of 2 and 2.5 metres. The tests were conducted by generating waves to fill the tank, then running the model for the first half of the run with the aim of maintaining a straight course, and performing zig-zag manoeuvres for the second half of the run. It proved quite feasible to manoeuvre the model within the confines of the tank, the width of which represented 120 metres full scale, and the tests gave great confidence in the ability of the boat to turn on the face of steep following seas.

Whilst no measurements were made, observations from the tests were recorded, and runs were repeated in similar waves to confirm these observations. Due to tracking the model with the carriage, the video record provided a better close up view of the motions of the boat than was possible from tests in the lake or the manoeuvring tank. The observations revealed the adverse influence on control of using excessively large rudder angles, due to the roll motions and bow down trim which they induced.

13.2 TESTS IN THE MANOEUVRING TANK

The model was tested in the manoeuvring tank in similar regular and irregular waves to those generated in the towing tank. The model was run freely, under radio control, at a variety of headings to the waves whilst maintaining a steady course and executing zig-zag manoeuvres and turns.

There was much more sea-room in the manoeuvring tank in which to execute manoeuvres and it was found that at the end of a run in following or quartering seas, the model could be turned back into the waves and then across the waves for a run in beam seas. When running in head or oblique bow seas the model took no green water and very little spray on deck, despite on occasions leaping clear of the water through wave crests, and the model required nothing more than a foredeck with a small breakwater, to prevent water entering the hull.

Representatives of the RNLI were able to take the controls to satisfy themselves as to the adequacy of the performance, and again the tests provided valuable advance knowledge of the manoeuvring capabilities of the boat in steep seas, where the benefits of controlled use of the rudders was demonstrated again.

14. WAKE SURVEY

As the design developed, the proposed propulsion arrangement settled on propellers in deep tunnels, with substantial bilge keels on the outboard edges. A requirement for oil lubricated shafts resulted in large diameter stern tubes, and these were to be supported by bossings within the tunnel. This arrangement gave some cause for concern regarding the probable non-uniformity of the wake, and consequent propeller vibration. Furthermore, the flow visualisation test on the early tunnel design indicated a region of weak flow at the top of the propeller disc, as described in section 8. Wake survey tests were suggested as the preferred way to quantify any potential problems, and four tunnel variants were modelled at 1:6 scale to study the effects of tunnel shape and entry angle.

Conventional tests with a stationary pitot rake, collecting data for, say, five locations in the propeller disc per run, would have involved considerable investment in towing tank time, which was difficult to justify. A prototype system was devised, incorporating five miniature pressure transducers fitted at the open ends of tubes and arranged along the propeller radius in a rotating rake. The frequency response of the transducers, and their location in the plane of the propeller, enabled the rake to be rotated slowly through a complete revolution during the course of a single run in the towing tank, and the complete wake survey could thus be derived from one run. To check the reliability of the system, three runs were made on each model configuration, starting at a different angular position each time, and the data proved to be repeatable within a few percent of the free stream value.

Data from one of the later runs, where the equipment and measurement technique had been refined, is shown in Figure 10. The transducer in way of the propeller tip produced a curve showing a considerable reduction in the dynamic pressure in the roof of the tunnel. The transducer near the hub revealed a generally smaller reduction in pressure except in the wake from the stern tube and its bossing.

These curves can be integrated to derive the wake fraction, and they reveal the variation in the wake which, if excessive, may lead to propeller induced vibration. The effect of fairing the shaft bossing was also assessed by comparing pressure plots.

15. CONCLUSIONS

The aim of this paper has been to illustrate the practical

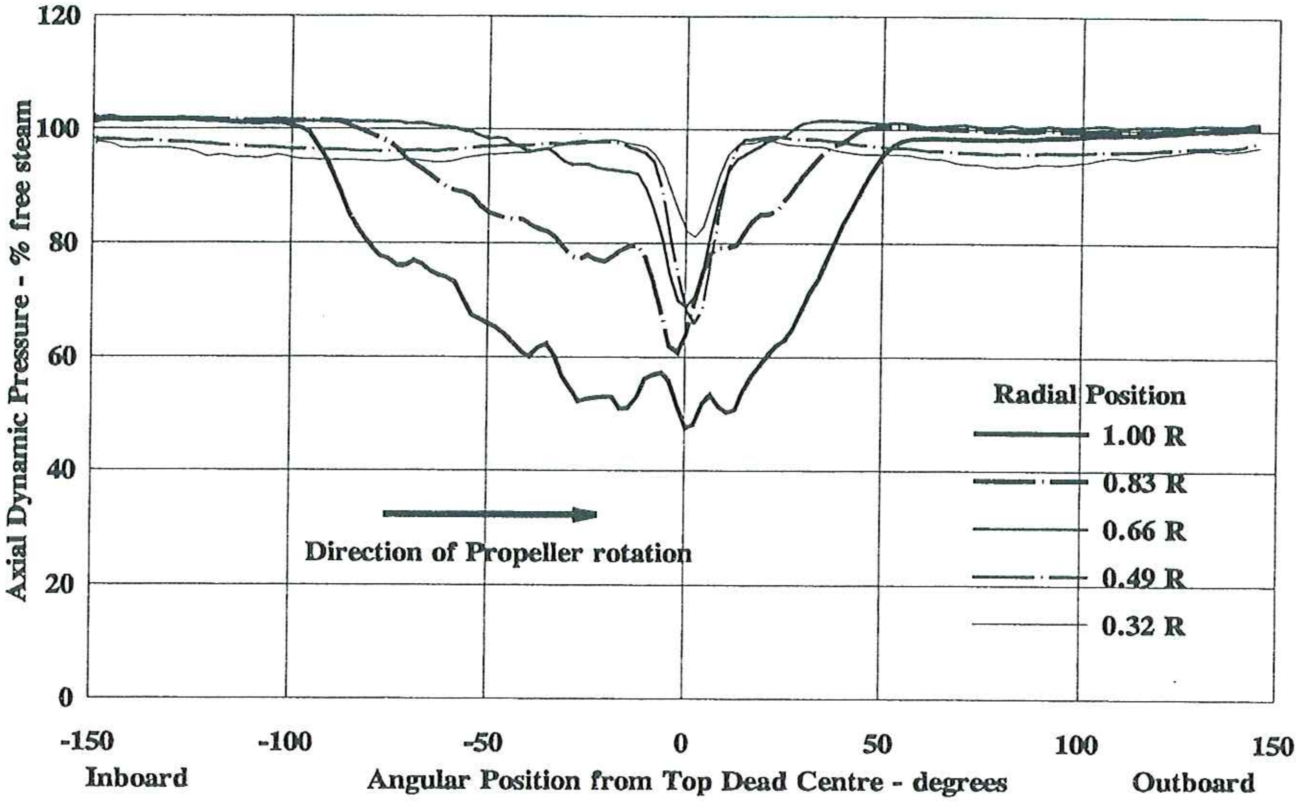

Fig. 10 Wake Survey Data from One Run

use of a wide range of model tests in the development of a new hull form. At the outset of the work it was anticipated that improvements could be made to the seakeeping performance, by way of reducing acceleration levels, but this would probably be to the detriment of the directional control. In fact the most dramatic improvements in seakeeping were the reduction in deck wetness and pitch motion, whilst the accelerations remained stubbornly similar to the base boat. The only practical way to assess deck wetness is from model tests, and it was surprising how sensitive the wetness was to subtle changes in bow shape. As anticipated, one of the hull forms was directionally unstable and this was demonstrated in a dramatic way using a radio controlled model. Again, subtle changes to the hull form made considerable differences to the directional stability, and these could be quantified from the model tests.

Significant differences were found in the resistance of the models and on some models the resistance was sensitive to the centre of gravity location and trim tab settings, so it was important to optimise these. One of the major improvements achieved through the development programme was a reduction in resistance from the base boat. The deep tunnels, which reduce the draft and skeg size required to protect the propellers during launch down the slipway, cause an increase in resistance, over that for a similar hull without tunnels, but the flow visualisation and wake survey tests enabled changes in the tunnel shape to be investigated in order to optimise the flow into the propellers. It would have been difficult to select an overall propulsion coefficient appropriate to the tunnel hull in the absence of ship model correlation data from similar hulls, so the propulsion experiment, conducted once the hull form had been optimised, was an ideal way to avoid this problem and provide a prediction of the required installed power.

Whilst seakeeping in head seas can be accomplished in a towing tank using restrained models, seakeeping at other headings required the use of free models. The beam sea case was also studied in the towing tank, at zero forward speed. This was of particular relevance to work on the boat at the casualty site, and during recovery of the boat on the slipway, since slipways are in partially exposed locations. Control in following and quartering seas is of particular concern and the tests in the manoeuvring basin extended the work on calm water manoeuvring. Previous experience in conducting model tests at sea showed that they can be fraught with practical difficulties, and ideal conditions rarely prevail, so these tests were run within the controlled environment of the basin. The small model size was suited to the basin and it provided the most enjoyable day's testing for the participants, enabling them to gain confidence in the control characteristics of the hull form within an excellent working environment.

16. ACKNOWLEDGEMENTS

It is rare for test establishments to have the opportunity to be involved during the early stages of the development of a new hull form so this was a particularly interesting project. The major part of the development programme has been completed but work is continuing, to study the effects of small refinements to the hull form. The RNLI will integrate the results from this programme into a wider study of the design of the Fast Slipway Boat, so their permission to publish some results at this stage in the design process is gratefully acknowledged.

The contributions of staff from BMT and HHTC to the programme, and their co-operation throughout, is also gratefully acknowledged.

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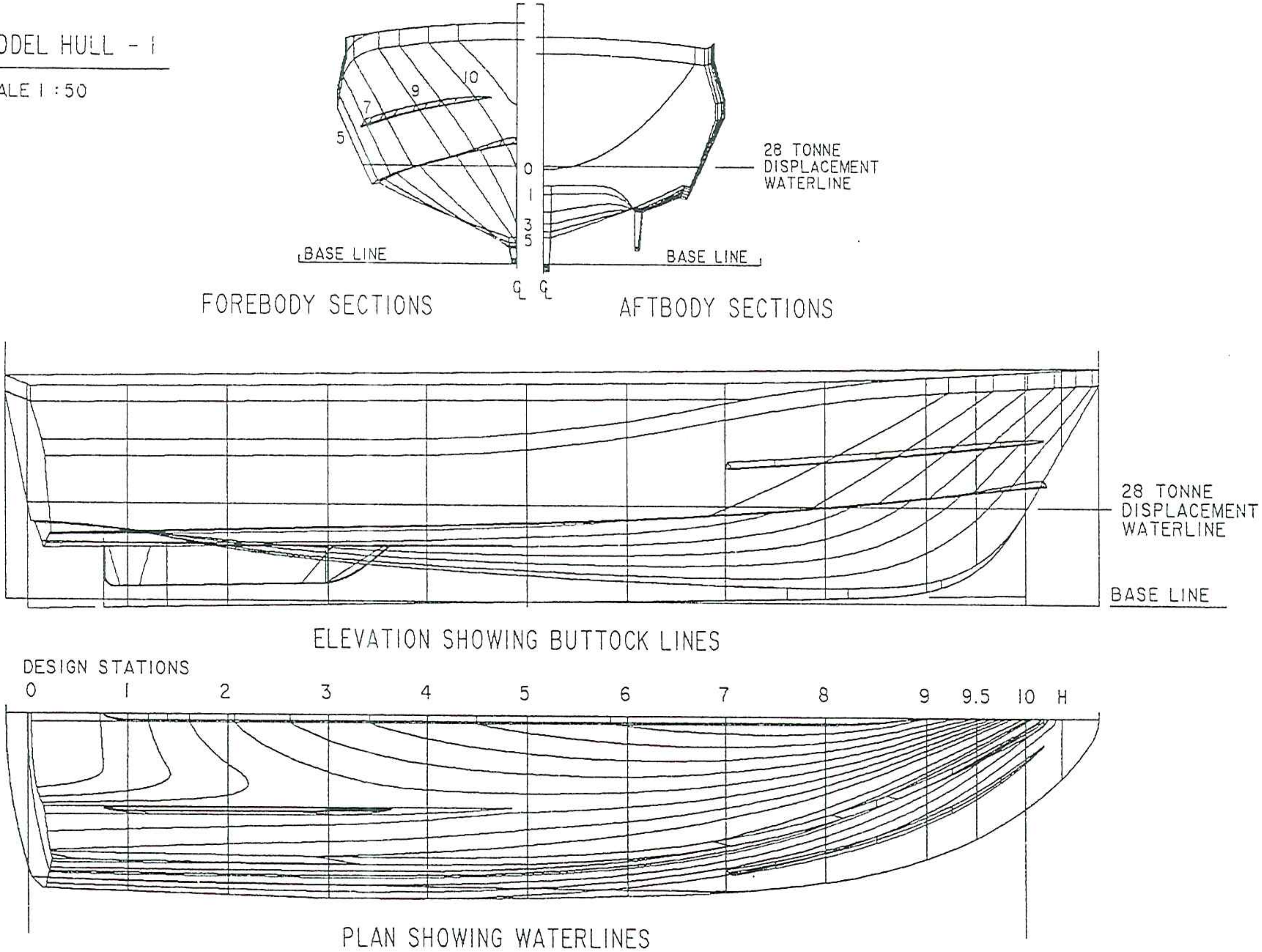
TANK MODEL HULL - I

SCALE 1 : 50



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