The Design of a RIB Lifeboat using the "Enlarged Ship Concept"

J.A. Keuning, Jakob Pinkster and J. van der Velde

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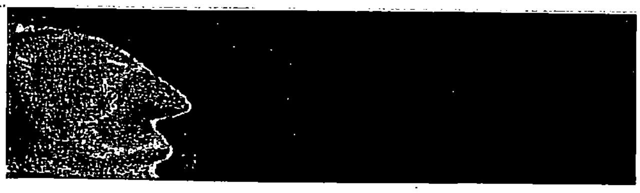

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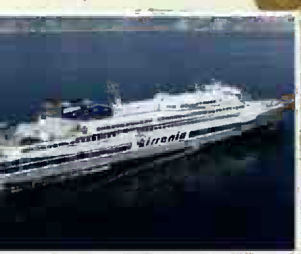
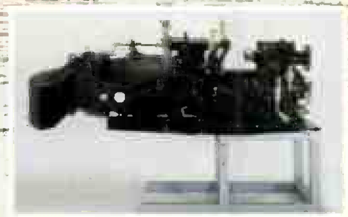

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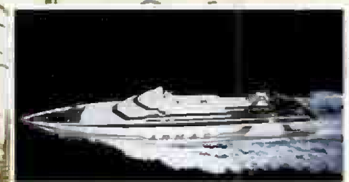

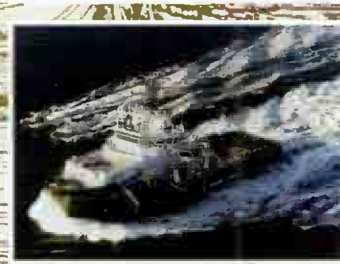
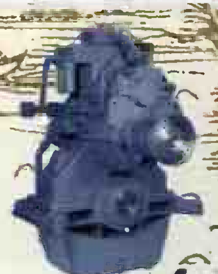

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VENICE, APRIL 16 AND 17, 2002

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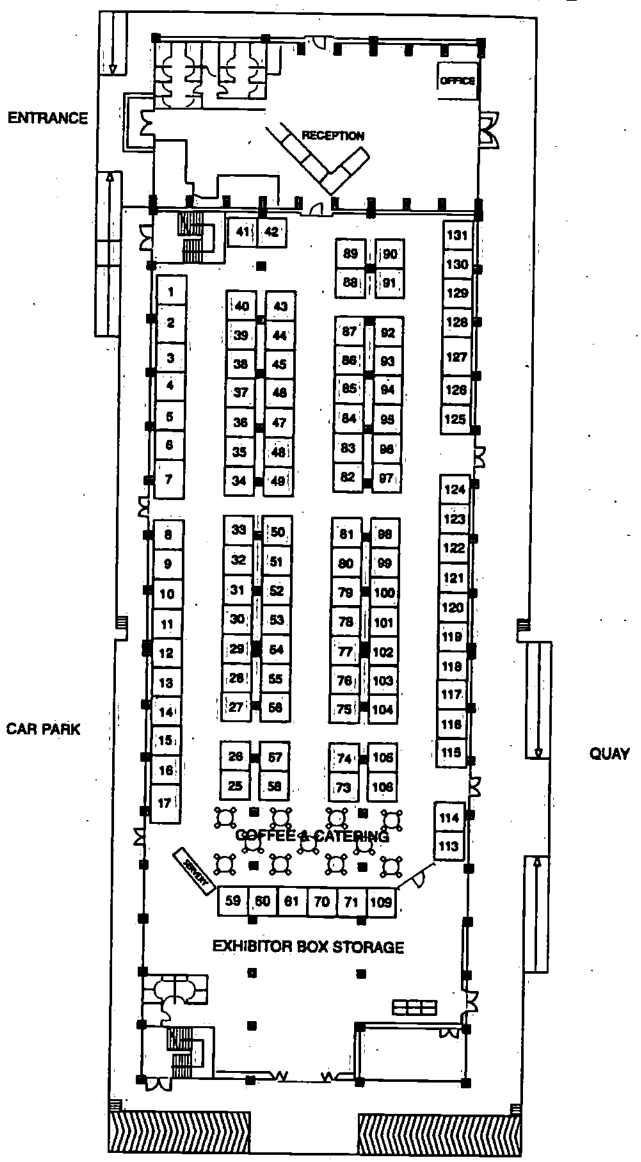

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The Design of a RIB Lifeboat using the "Enlarged Ship Concept".

J.A. Keuning[1], Jacob Pinkster[2] and Jaap van de Velde[3]

ABSTRACT

For a number of years now the Royal Dutch Lifeboat Institution (KNRM) satisfactorily use fast Rigid Inflatable Boats (RIB's) for Search and Rescue (SAR) purpose. These aluminum RIB's,, have a length of around 15m. and a displacement of about 14 tons. Two 500 kW engines combined with a waterjet propulsor give these boats a calm water speed of circa 34 knots. These boats are "All Weather" and have an endurance of 200 nm. in calm water.

The actual speed, which a high speed vessel can maintain in a seaway is strongly dependent on the level of vertical accelerations experienced by the crew on the bridge. In particular the occurrence of high peaks in the vertical accelerations in the wheelhouse will provoke a voluntary speed reduction by the crew. In order to minimize the occurrence of these high peaks in the vertical accelerations, a new design for a SAR RIB for the KNRM was made using the Enlarged Ship Concept (ESC), as introduced by Keuning e.a. in 1995.

First computations were made to assess the expected resistance and ship motions advantage's using the non-linear motion analysis program "Fastship" of the Delft Shiphydromechanics Department. These results were very promising. Based on these results model tests were carried out with the" base boat" of 14.4 m length overall and with the "enlarged" version of 19.2 m both in calm water and in waves. The tests results confirmed that the larger vessel has a lower calm water resistance (up to a speed of 32 knots) than the base boat and, most important, the acceleration levels in the wheelhouse when sailing in a seaway were significantly lower. From a design study it followed that the extra length of the boat resulted in an increase in building costs of only circa 10 % and therefore, in comparison with other international SAR vessels, the price to performance ratio is quite favorable.

From this study it may be concluded that a marked improvement in SAR RIB design is possible and that the ESC is also applicable to such fully planing crafts. The subsequent new SAR RIB design is discussed whereby, from a designers point of view, the application of the ESC to the SAR RIB's also has a number of other advantages such as:

- *a larger deckhouse and larger deck-area, which can be used for a higher rescue capacity of up to 130 persons;*
- *the larger boat may be fitted with more fuel bunkers and thereby the endurance will be increased to 540 nm.;*
- *the draft of the boat is decreased which increases the capabilities in shallow waters.*

Recommendations for further adjustments to the new design are also mentioned whereby the new craft is also suited for yet other purposes.

[1] Associate Professor, Ship Hydromechanics Department, Delft University of Technology
[2] Assistant Professor, Ship Hydromechanics Department Delft University of Technology
[3] Former Graduate Student, Ship Design Department, Delft University of Technology

1 INTRODUCTION

The KNRM (Koninklijke Nederlandse Reddingsmaatschappij, in English: The Royal Netherland Lifeboat Institute) uses rigid inflatable boats (RIB's) for more than 10 years now. These RIB's vary in length from 5 to 15 metres. The operational area of these vessels is the Southern North Sea and the Dutch Coastal waters. Especially dangerous situations can occur for these vessels in the estuaries of the Dutch coast where seas can become very high and steep during Northerly storms.

For safe operation in high seas, it is important that a lifeboat is capable to "ride the waves". For this reason, the maximum attainable speed of the lifeboat must be higher than the maximum wave celerity. For the Dutch conditions this maximum wave speed is taken as being 25 knots. Another essential capability for a lifeboat is fast and safe deployment to the place of action. These two factors determine the KNRM's 33 knot speed requirement.

Not a high forward speed alone is important A lifeboat must be usable in all weather conditions, ranging from 0 to 12 Beaufort. In heavy storm conditions in the Dutch estuaries waves may reach a height of 12 metres and also become very steep. Aside from the fact that the vessel must be constructed strong enough to withstand the subsequent beating from such severe sea conditions, it is also important that the boat has good manoeuvrability characteristics along with high acceleration capabilities. This allows the lifeboat to "flee away" from the breakers and thereby prevent any unnecessary damage from occurring.

However speed and seaworthiness are two separate things, which do not always go well together. For instance a small deadrise leads to a lower resistance and therefore to a higher speed, but increases on the other hand, the level of vertical accelerations onboard the ship.

If a SAR RIB sails in a seaway, then its "sustained speed" will be largely determined by the level of vertical accelerations in the wheelhouse. If extreme slamming occurs the crew will apply a voluntary speed reduction to prevent this from happening again. The level of vertical acceleration in the wheelhouse is also a direct measure for the physical load on the crew.

A coxswain who sails in the estuaries in a seaway, will decrease trottle at the moment he sees a high wave approaching in order to lessen the load due to impact. As soon as he has passed that wave he will increase trottle again. So a better acceleration capability will result in a higher average speed of the lifeboat.

The boats of the Johannes Frederik Class (15 m) are RIB's with a fully enclosed wheelhouse that provides space for four crew and tens of rescued sailors. These large RIB's can be used in the heaviest seas and weather conditions and, in the past, have well proven their seakeeping capabilities.

However good this class of RIB is, the KNRM is ever trying to improve on their equipment. Table 1 shows a list of typical KNRM design demands for their next generation of "All Weather" lifeboats. This paper describes the results of a study carried out to create a craft, which meets these design requirements.

2 THE ENLARGED SHIP CONCEPT

In the Enlarged Ship Concept (ESC) [1], a given vessel, which fits all the required design specifications, is substantially lengthened (between 25 and 50%L) while at the same time the deadweight and the vessel forward speed remain constant. This results in a longer ship with a marked improvement with regard to ship resistance and motions in a seaway.
At the Delft University of Technology, the outset for the ESC lay in the fact that it was considered that most fast vessels are too heavy for their physical size. This was based on the sheer fact that a ship is generally designed in such a way that all objects, i.e. cargo, engines, accommodations and equipment etc., are just about to fit into the boat. This results in poor resistance and seakeeping characteristics. The solution to this problem is sought in the sizable lengthening of the vessel without changing either deadweight or speed. This results in (see also Table 2):

- A relatively lighter ship (ton per meter ship length)
- A slender ship, L/B increases,
- A relative decrease of the longitudinal radius of gyration (% ship length)
- A decrease in the Froude number.

These changes in the design parameters can lead to a reduction in ship motions and resistance.

Keuning and Pinkster applied the Enlarged Ship Concept to the Damen Stan Patrol 2600. In this study this base vessel (1.0L) was lengthened by 35% and 58 %L. The results of this research were rather positive. For a required vessel speed of 25 knots, the required engine power was reduced by 30 % and the vertical acceleration on the bridge in head seas was significantly reduced. When increased in length by 58%L the vessel became only 15% heavier compared to the base boat. The sources for these results are to be found in [1] and [2].

Since then, the ESC has been applied to a series of three Coast Guard Cutters of the Royal Netherlands Navy [3]. This fast 25 knot vessel (see Fig. 1) has become the Damen Stan Patrol 4100 designed and built by the Damen Shipyards BV and is basically the enlarged version from an existing design, i.e. the Stan Patrol 3500 from the same yard. These 41 m. cutters are presently satisfactorily carrying out patrolling duties in the Caribbean.

Table 1. Typical KNRM design demands for a Dutch "All Weather" lifeboat.

	Demand	Lifeboat
1	Speed	>33 kn , by 1 Beaufort
2	Selfrighting	Absolutely
3	Seaworthiness	All weather
4	Manoeuvrability	Very good
5	Waterjets	Yes
6	Safety	High for the crew members
7	Towing capacity	Good
8	Engines/redundancy	> 1
9	Draft	< 1.0 m.
10	Saving capacity	Large as possible for given size
11	Endurance	6 hours at full speed
12	Sound level	< 80 dB in wheelhouse
13	Watertight subdivision	Yes
14	Crew comfort	As high as comfort/weight ratio allows
15	Classification society	ABS

Table 2. Consequences of application of Enlarged Ship Concept
(ESC = deadweight and speed remain constant).

Parameter	Symbol	Dimension	Consequence
Length	L	[m]	Increases
Breadth	B	[m]	Constant
Draft	T	[m]	Decreases
Speed	*v*	*[knots]*	*Constant*
Deadweight	*DWT*	*[ton]*	*Constant*
Relative weight	LSW/L	[ton/m]	Decreases
Slenderness	L/B	[-]	Increases
Relative longitudinal radius of gyration	k_{yy}/L	[-]	Decreases
Froude number	Fn	[-]	Decreases

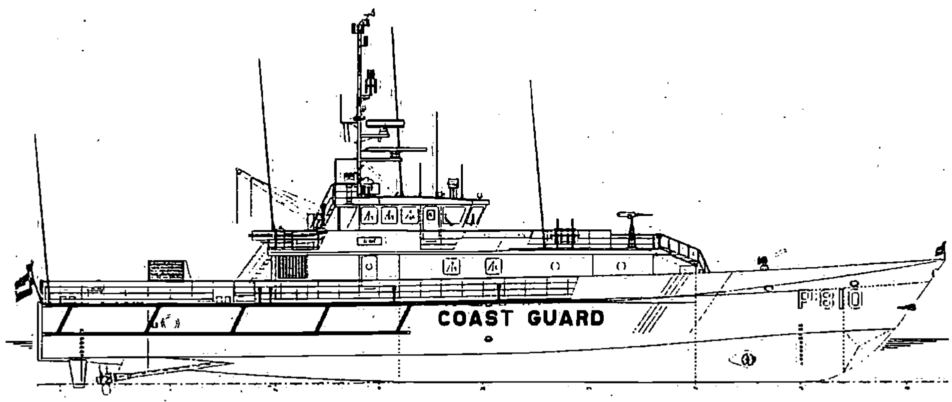


Figure 1. Applied ESC to a Damen Stan Patrol 4100/ 25 knot Coast Guard Cutter [3].
(Built for the Royal Netherlands Navy in 1999).

The ESC studies so far were focused on semi planing and displacement vessels and it appeared that both the actual level of vertical acceleration and the vessel calm water resistance are reduced significantly by lengthening the vessel. If this could also be found to be true for a fully planing SAR RIB then the following double effect would indeed be gained here:

- A lower level of vertical acceleration would lead to a higher average sustained forward speed in a seaway or to a lower loading for the crew and those rescued.
- A lower resistance would lead to an improved acceleration capability and thereby also to a higher average speed.
- A higher average speed renders a faster deployment of the ship. This could save lives etc.

In summary, one may conclude that the advantages of applying ESC to a SAR RIB may result in an improvement in mission fulfillment and sustainability along with a greater seaworthiness. All these aspects are of supreme importance for a SAR craft.

In the aforementioned research projects as reported in [1] and [2], the attention was mainly focused on the effect of enlargement on semi-planing vessels (FnL = 0.4 - 0.8). In the present study the effect on fully planing boats (FnL = 1.36-1.62) is investigated. The main topic of the present study became therefore:

"Do the advantages of application of the ESC, noted from previous research projects, still hold true for the ships operating at considerable higher Froude numbers?"

In addition the design possibilities and consequences of the application of the ESC to the SAR RIB are presented.

3 THE PRELIMINARY DESIGN STUDY

A desk study was carried out with the existing KNRM lifeboat the "Christien", which was consequently used as the "base boat" to find out whether an improved design using ESC was feasible. The lengthened (enlarged) versions of the base boat were named the "ESC1680" and the "ESC1920" respectively. The main dimensions of all three vessels are presented in Table 3. Figure 2 shows corresponding side elevations and Figure 3 shows body plans along with the lines plans (side view only).

The two design variations of the "base boat" were designed in the framework of the present study. For each variation, the lines plan, the hydrostatic curves, the weight and the weight distribution were calculated in order to make a preliminary design evaluation possible.

The principal goal of the desk study was to evaluate the hydrodynamic performance of the three designs with respect to their resistance and operability. This evaluation was carried out by making use of the computer program FASTSHIP, as developed by the Delft Shiphydromechanics Laboratory. This computer code calculates the calm water resistance, the sinkage and the running trim of an arbitrary planing boat at speed and is based on the results of the Delft Systematic Deadrise Series (DSDS). It also calculates the heave and pitch motions as well as the vertical accelerations of these high speed planing craft in both regular and irregular head waves using a non linear mathematical model based on a time domain simulation. This model was presented by Keuning in [5].

First a short description of the three designs used in the evaluation will be presented.

3.1.1 The three design variations.

The base boat was the "Christien" from the "Johannes Frederick" Class of RIB's in service with the KNRM. The principal dimensions of this design are presented in Table 3 and a body and lines plan of the boat is depicted in Figure 3. These RIB type craft are propelled by two Hamilton 362 waterjets and are capable of speeds up to 33 knots. A more detailed description of these craft may be obtained from [6] and [7].

For the enlarged versions of these craft it was important to determine if there were any possible restrictions on the allowable length of the new rescue craft considering their use or other restrictions imposed by the KNRM demands. From numerous discussions with the KNRM and various coxswains of the KNRM lifeboats, it became obvious that they would like to see the maximum overall length restricted to 20 metres. This was based on their experience with handling these RIB's in their typical operating areas. Northwesterly storms in combination with strong tides and shallow waters, will typically produce very short, very high, extremely steep and frequently (spilling) breaking waves. The capability to "flee" these kinds of extreme waves largely determined their formulated length restriction as well as the desirable "full power" operational speed of the crafts. Derived from operational data from the previous years, it was found however, that circa 85% of all KNRM SAR operations occur in weather conditions below Beaufort 6. This generally results in a much more "moderate" wave climate, which would possibly allow larger ship lengths and higher speeds under such prevailing conditions.

To remain within this restricted overall length, as imposed by the KNRM, two new design alternatives were developed (ESC1680 and ESC1920) with an overall length of 16.80 m. and 19.20 m., corresponding to a relative extension, with respect to the base boat, of circa 17 % and 33 %. In the preliminary design evaluation, the increased lengths of these two design variations were obtained by simply extending the original frame spacing of the 14.4 m.

Table 3. Dimensions base boat "Christien" and ESC versions

Parameter	Dimension	BASEBOAT	ESC1680	ESC1920
Loa	[m]	14.40	16.80	19.20
Extra length	[%L]	0	17	33
Lwl	[m]	11.17	13.53	15.93
Boa	[m]	5.4	5.4	5.4
Bhull	[m]	4.2	4.2	4.2
Draft	[m]	0.81	0.75	0.68
LCG	[m]	4.9	5.4	6.3
Mass	[kg]	13.6	14.4	15.0
Speed	[knots]	34	34	34
Engine power	[kW]	2x500	2 x 500	2 x 500
Endurance full speed	[hours]	6	6	6

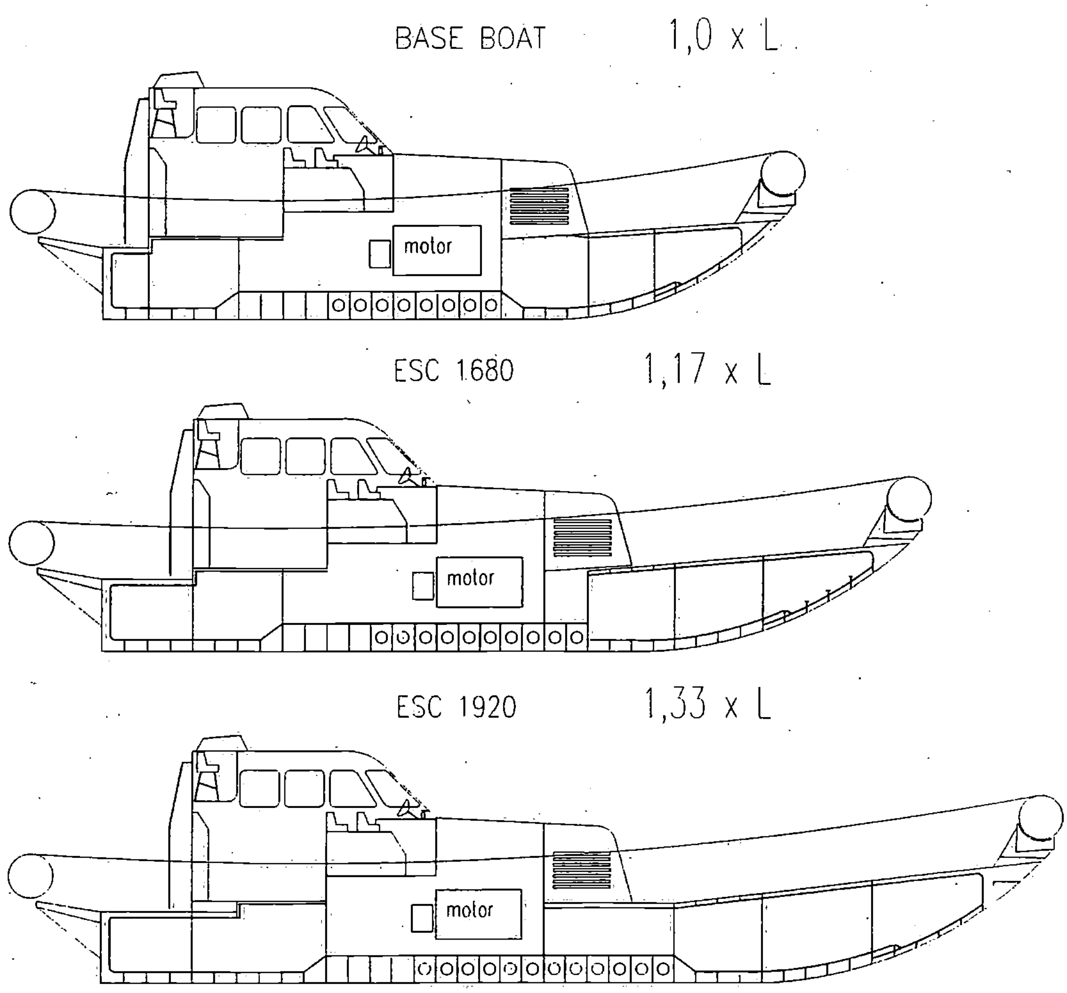
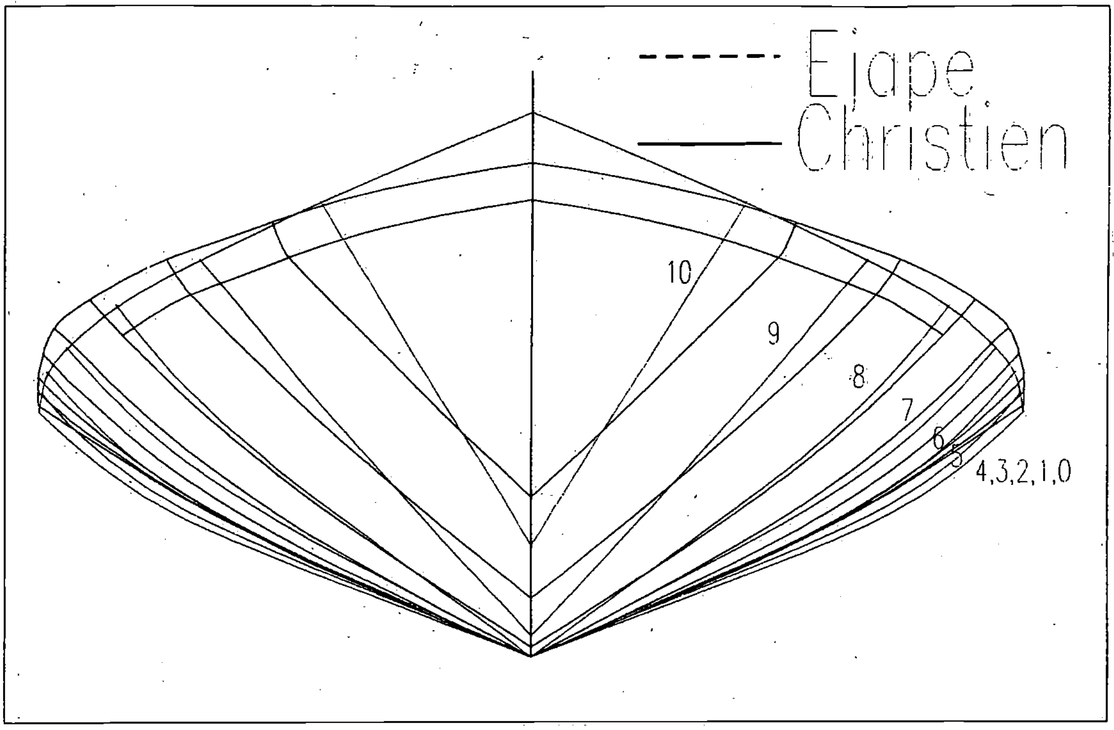
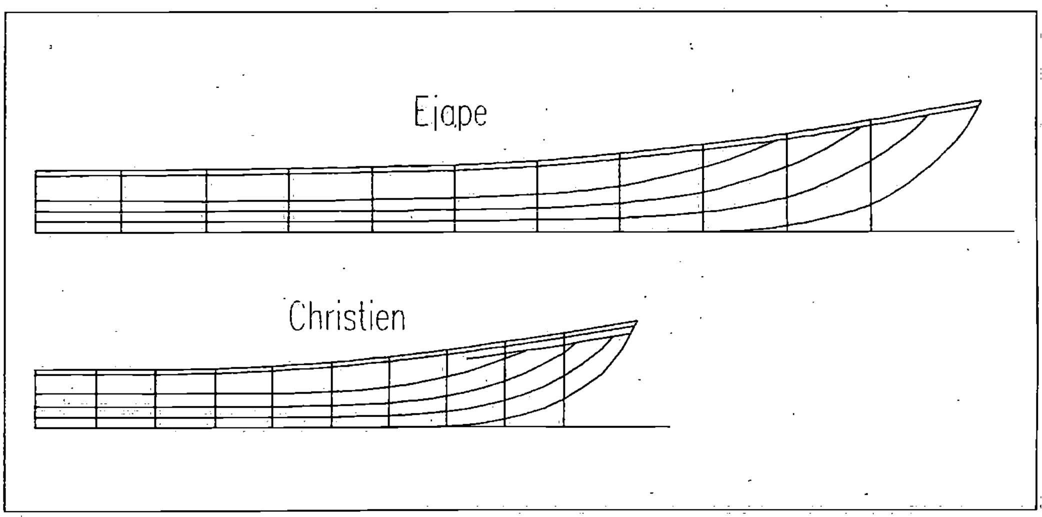


Figure 2. Side elevations of the base boat "Christien" and both ESC1680 and ESC1920.



Body plans



lines plan (side view only)

Figure 3. Body plan and lines plan of "Christien" and Ejape".

overall length base boat to yield the new desired value. For each of the two design variations a weight calculation has been carried out based on the design information available from the original vessel as well as a weight distribution and a corresponding center of gravity and longitudinal mass inertia. Within this exercise the ABS rules were utilised to determine the scantlings.

For the largest design also a bow shape modification has been established, albeit modest to stay within the KNRM requirements. This change in bow shape is based on the fact that the application of the ESC enables a less voluminous bow section due to the additional (void!) space created in this design concept. The bow section has been redesigned with less flare compared to the base boat but with increased sheer. Theory shows this to be favorable for minimizing the vertical exciting forces and so the vertical accelerations. These exciting forces are strongly related to the non linear Froude-Kriloff forces, i.e. the undisturbed wave pressure integrated over the instantaneous submerged volume of the hull whilst performing large relative motions. In addition excessive hydrodynamic lift forces in the bow section are minimized also. The favorable effects of these modifications on the workability of the boats have been shown earlier in by Keuning in Ref [5]. The increased sheer guarantees sufficient reserve buoyancy to prevent the ship from taking on too much green water in head waves or from "bow diving" in following seas.

3.2 Calm water behaviour

The calm water resistance of each of the three designs is presented in Figure 4A over the speed range from 6 to 28 knots. From these results in this figure the beneficial effect of ESC on the resistance of the craft in the speed range from Fn = 1.0 to Fn = 3.0 is clearly demonstrated. The trend is similar to the one found in previous studies carried out on the application of the ESC on fast monohulls. In the present study however, the speed of the boats extends to much higher speeds than investigated in the previous projects. In these higher speed regions the smaller L/B ratio of the base boat will lead to a lower resistance than the ESC variations with their higher L/B ratio's. It should be noted that the longest boat, i.e. the ESC1920, shows the smallest "hump" in the resistance curve at the lower speeds end. This is a particularly favourable effect for craft with a "patrol type" mission profile, which leaves them sailing at cruising speeds well below their design (top) speed during a considerable period of their operational time.

Although not shown here, consistent results are found for the sinkage and trim of the ESC craft at speed: the base boat trims up to 6-7 degrees and the ESC versions only up to 3-4 degrees. The base boat (lower L/B) is lifted considerably further out of the water when sailing at planing speed compared with the enlarged versions, which remain closer to their original trim position.

3.3 Motions in waves analysis

3.3.1 Choice of conditions

The motion analysis of these craft has been carried out with a reduced forward speed of circa 20 knots in a moderate seastate only. The seastate investigated is given by a wave spectrum with a Jonswap energy distribution over the frequency range corresponding to a significant wave height of 1.65 metres and an peak period of $T_p = 7$ seconds. The choice for this moderate sea state was based on the "real live" observations made during full scale test runs on board several fast patrol boats. During these tests it became evident that for the safe operation of these craft in head sea conditions, active use of the engine throttles is a important factor. When asked to leave the throttle "as it is", leading to a more or less "constant" forward speed of the boat (a situation similar to the towing tank tests and simulation runs), the crew found it unsafe to sail at a higher speed than 15 knots in the prevailing conditions. When "playing the throttle" was allowed to evade the severest of the encountered waves, the average speed was increased to circa 22 knots in exactly the same wave and heading conditions. This "throttle control", which is controlled by observations of and anticipation by the coxswain, can not be simulated in the towing tank nor in the computer simulations (yet).

So it was decided to evaluate the mutual merits of the three design variations in a simulation carried out in a "moderate" sea state, which results already in an "extreme" condition with respect to the accelerations levels on board. This turned out to be the aforementioned wave spectrum and a constant (!!) forward speed of 20 knots.

For the sake of shortness, only the results of the calculations of the vertical accelerations at the wheelhouse of both the base boat and the longest of the ESC variations, i.e. the ESC1920, will be presented here.

3.3.2 Limiting Criteria

From an earlier research project on the workability of planing craft in waves, it is known that the real limiting criteria for the "voluntary speed reduction" on board planing craft are related to the occurrence of high peak values in the vertical accelerations in the working area. On the occurrence of one "big peak" during the trials the crew reduced speed to prevent "it from happening again". This reaction turned out to be consistent irrespective of the actual prevailing "significant value" of the vertical accelerations at that time. So the frequency of occurrence of these high peaks in the vertical accelerations should be reduced as much as possible. To analyze the mutual differences between the three designs with regard to their workability, it is therefore of importance to compare their respective frequency distributions of the vertical accelerations in the working area. In the case of the three lifeboats designs in this study this is

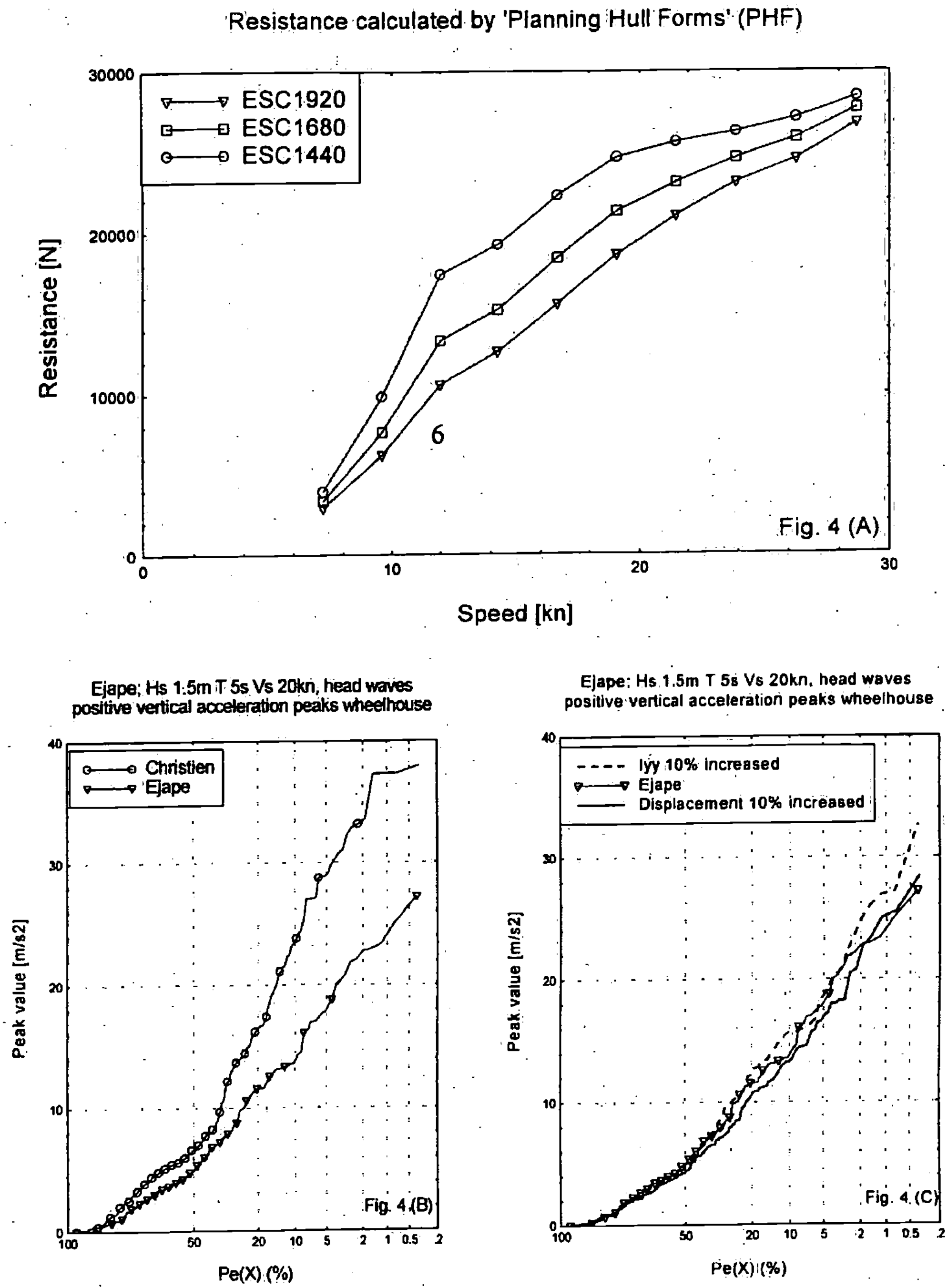


Figure 4. Calculations with FASTSHIP: (A) Resistance. (B) Frequency distribution of positive vertical acceleration amplitudes for "Christien" and "Ejape" and (C) idem also showing effect of change and pitchmoment of inertia for "Ejape" in displacement

taken as the helmsman's position in the wheelhouse.

3.3.3 Results

In Figure 4B the frequency distribution of the positive vertical acceleration amplitudes is presented for the base boat "Christien" and the ESC1920 "Ejape" in the selected wave spectrum and at the selected speed of 20 knots. From these results it is immediately evident that the occurrence of the high peaks in the vertical accelerations at the wheelhouse is considerably smaller for the ESC1920 "Ejape" compared with the original design "Christien".

Because of the fact that the enlarged design can feasibly have a smaller longitudinal radius of gyration Iyy (related to it's overall length), the effect of such a reduction of Iyy on the motions has also been calculated. The results of these calculations with reduced radius of gyration together with the effect of a slightly increased displacement of the boat by 10% are presented in Figure 4C. The effect of the increased displacement is that the highest peaks in the vertical accelerations (with the lowest relative occurrence) are slightly increased. The decrement of the relative longitudinal radius of gyration however is rather beneficial: this results in a 20% reduction in the vertical acceleration level.

Based on the outcome of this analysis it was decided that the ESC1920 with the lowest possible displacement and pitch radius of gyration was the optimal design to strive for within the given constraints.

4 THE MODEL TESTS.

To verify and extend the outcome of the calm water behaviour and motion analysis obtained with the computer code "FASTSHIP", it was decided to carry out a series of model tests in the Delft Shiphydromechanics Laboratory with both the base design "Christien" and the optimised design ESC1920 "Ejape".

These model tests were carried out in calm water to check on the resistance, sinkage and trim of the craft and in irregular head waves to verify the vertical accelerations levels obtained.

In addition, a series of tests were carried out with the model at a higher speed in a more severe following sea state to check on any differences in a possible tendency regarding bow diving behaviour between the two designs, because this was a concern of the KNRM coxwains with respect to the bigger overall length of the enlarged boats.

The measurements were carried out in the large towing tank of the Delft Laboratory. The model was connected to the towing carriage in such a way that it was free to pitch and heave but restrained in all other modes of motion. During the tests the model was towed at a constant forward speed. The irregular waves were generated using a hydraulically activated wave generator of the hinged flap type. For each head wave condition at least 15 different realizations of the same wave spectrum were used to yield a statistically sufficient reliable amount of data. In the following waves, however, this was not feasible within the given time frame of the study due to the very low encounter frequency between ship and the waves. Some of the results of these measurements are presented in the following paragraphs.

4.1 Calm water results

Both the calculated and measured calm water results for the "Christien" and the "Ejape" are presented in Figures 5A, 5B and 5C. Although there is some difference between the calculated and measured values the trends of the earlier calculations are fully confirmed by the measurements.

4.2 Head wave tests

During the head waves tests it appeared not to be possible to use the same spectrum as was used in the calculated simulations. The resulting motions became so large that physical constraints in the measurement set up hampered the motions of the craft. So a moderately reduced seastate had to be used in conjunction with a slightly lower forward speed.

The measured frequency distributions of the vertical accelerations of both designs are presented in Figure 5D. As may be seen from these results, the measurements show identical differences in behaviour between the two designs. The gains to be made by using the ESC concept in this design are rather obvious. Another interesting result was that the added resistance due to the motions in the waves was noticeably less for the ESC1920 design, largely due to its modified bow shape.

4.3 Following waves tests

From the tests in following waves, it became evident (mainly by visual observations) that there was no significant difference between the two designs with respect to their "bow diving" behaviour. Both craft behaved very well in these conditions with respect to green water on deck and relative motions with respect to the waves. The "tube" definitely played an important role in this.

5 THE FINAL DESIGN

In the previous sections, much attention has been paid to the hull form of the enlarged ship and the advantages thereof. In this section the actual design itself will be elaborated upon. Figure 6 shows a general arrangement plan of the final design. Table 4 shows the main dimensions of the "Christien" and the enlarged ship with modified bow ("Ejape"), the ESC1920.

The advantages of this new design are not only due to the application of the ESC. The following paragraphs highlight some parts of the new design in more detail.

5.1 Accommodation and interior

In the preliminary design the accommodation of the enlarged version is taken to be a pure copy of that of the base boat, see Figure 2. This is not the case in the final design and there are several reasons for this:

The large foredeck offers much space for the shipping of green water, this is dangerous for the stability of the craft.

A larger wheelhouse offers more space for crew and those rescued without a large weight penalty.

The present lifeboats are constructed of aluminium and do not have an elastically mounted wheelhouse. Weight and sound reduction are the main reasons for choosing the FRP construction material and elastic mounting.

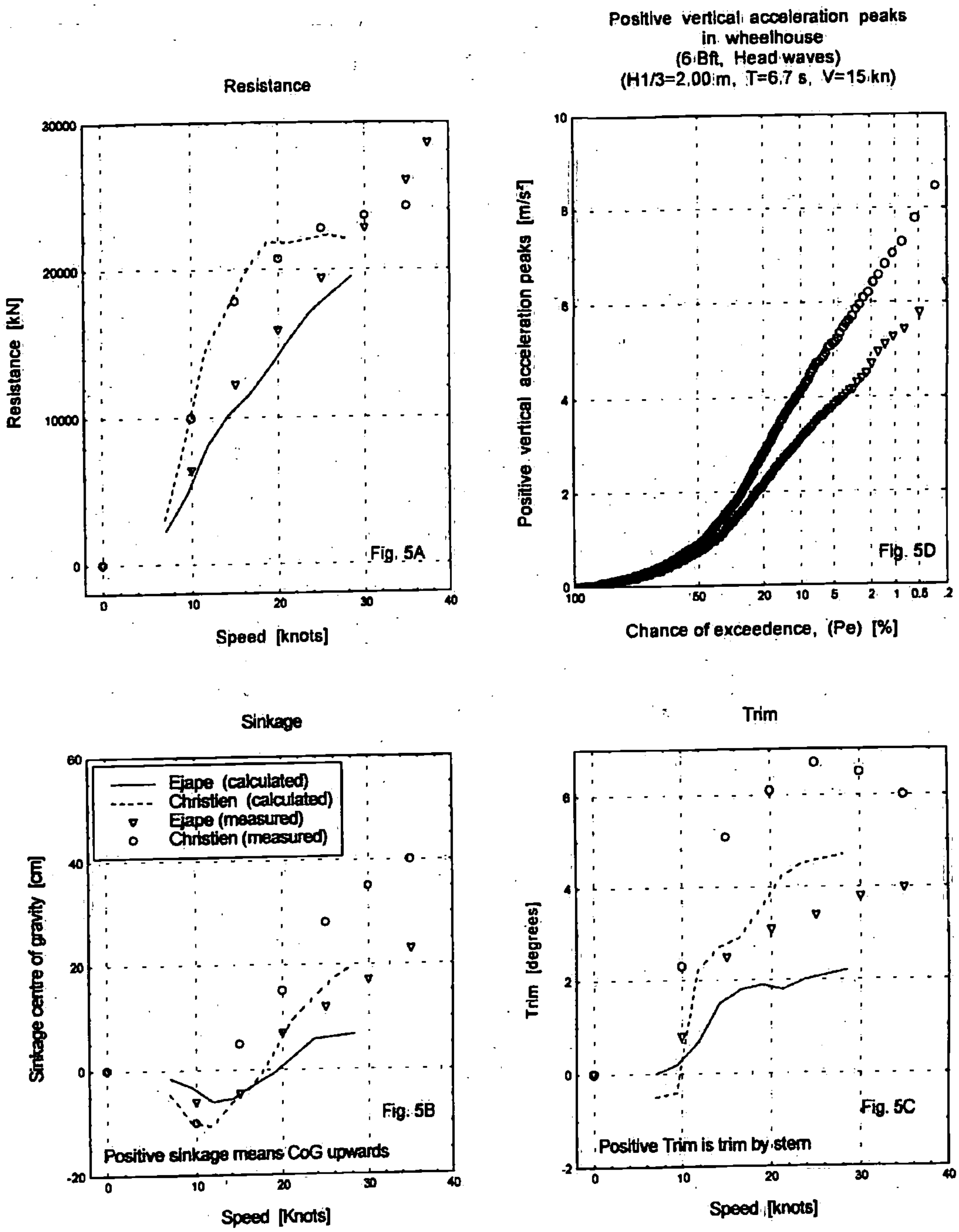


Figure 5. Results (calculated and measured) for "Christien" and "Ejape": (A) Resistance, (B) Sinkage, (C) Trim (all in calm water), (D) Measured frequency positive vertical acceleration peaks in the wheelhouse.

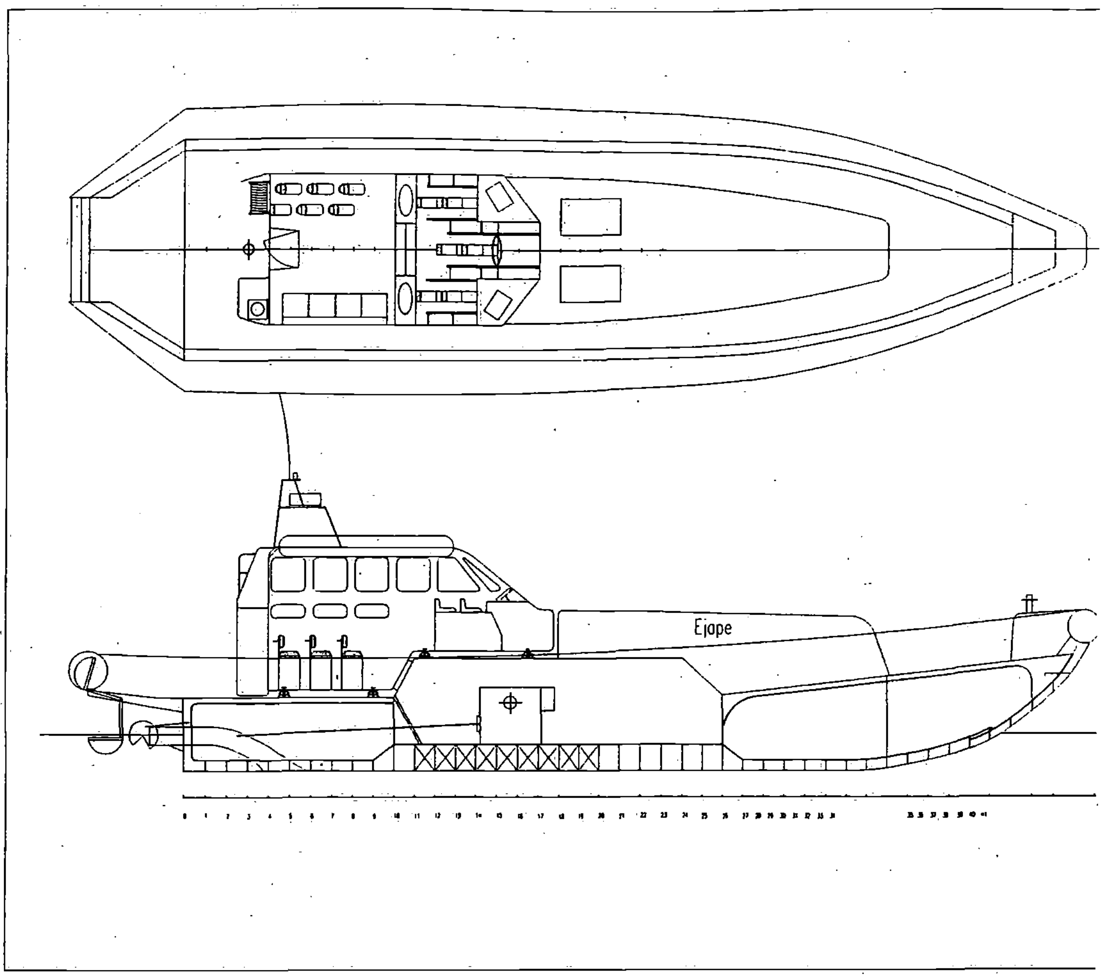


Figure 6. Final design of fast SAR RIB, "Ejape".

Tabel 4. Dimensions base boat and enlarged ship with modified bow

Parameter	Dimension	"Christien"	"Ejape"
Loa	[m]	14.39	19.20
Lhull	[m]	13.65	18.55
Lwl	[m]	11.17	15.85
Boa	[m]	5.39	5.39
Bhull	[m]	4.2	4.18
Bwl	[m]	3.4	3.33
T	[m]	0.81	0.68
Displacement	[m3]	13.57	15.0
LCG	[m]	4.9	6.3
Radius of gyr., iyy	[m]	3.5	3.4
Model scale	[-]	1:9	1:9

Table 5. Survivor capacity of "Christien" and "Ejape"

Parameter	Dimension	"Christien"	"Ejape"
Survivor capacity	[Persons]	90	130

The accommodation consists of two parts, the wheelhouse and the engine cap. The wheelhouse is constructed from sandwich FRP and is flexibly mounted in order to reduce noise and vibration levels. The engine cap is also made from FRP. Besides the limited function of a storage space, the main function of the engine cap is to make sure that not too much green water is shipped on deck.

This extra accommodation space is utilised for:

- Two extra crew saddles, more than the 4 that are now already present,
- Six saddles for the rescued,
- A toilet.

Despite its larger size, the total weight of the accommodation is the same as that of the base boat. This is due to the new construction materials used.

5.2 Hull

The construction material of the hull is aluminium. The plate thickness is 7 mm with a 400 mm frame spacing. The hull is constructed according to the ABS classification rules.

5.3 Displacement and draft

5.3.1 Weight

After the preliminary design was finished a new weight calculation has been made. This resulted in a 5% increase in weight when compared to the calculations made before the model test. The reason for this difference can be mainly attributed to the heavier engines and waterjets. However these engines and waterjets are so powerful that this propulsion system will have no problem to overcome the extra resistance; more about this in section 5.8 of this paper. The weight increase of 5% will have little or no influence on the vertical acceleration levels of the vessel (see Fig. 4C). The final displacement is 15.7 ton, for ESC1920 with the modified bow, modified propulsion installation and extra accommodation space.

5.3.2 Draft

At a displacement of 15.7 tons, the draft is 0.68 m. This draft is 0.13 m. less than that of the base boat. This difference increases the mission capabilities of the vessel in particular in the "strong tidal waters" of the Dutch Coastal Waters.

5.4 Tube

The tube is an essential part of a RIB. Advantages of the application of this tube are brought forward in many publications and is strongly supported by the KNRM. The KNRM has as a design specification that the tube volume must at least be equal to the displacement of the vessel itself. The tube volume is largely determined by its diameter. The larger tube diameter excerpts larger forces of the waves however, when the tube is immersed. In turn, these larger forces again lead to larger vertical accelerations.

The present vessels have a tube diameter of 80 cm. The "Ejape", due to its long length and relatively smaller weight, can accept a smaller tube diameter without departure from the tube volume design specification. The "Ejape" has a tube with a diameter of 75 cm and is gradually tapered to 65 cm. in the bow (total tube volume 17 m3). In this manner, an attempt is made to minimize the by the tube excited forces on the vessel due to large relative motions in a seaway and also the forthwith resulting vertical accelerations.

5.5 The towing bit

The towing bit has to be situated as far as possible forward in order to be able to manoeuvre the vessel well during the towing operations. Due to the longer vessel design it is possible to place the towing bit 1.20 m. ahead of the transom.

5.6 Survivor rescue cradle

A rescue cradle to pick up survivors out of the water is situated behind the transom and the waterjets. The KNRM has positive experiences with this device and therefore requires such a cradle in their design specifications. By applying this a cradle the aft deck is lengthened by 80 cm.

5.7 Self-righting

Obviously an "All weather" lifeboat must be self-righting. Figure 7 shows the calculated stability curves for the "Ejape". From these calculations it appears that the righting arm is positive for the complete heel angle range from 0 up to 180 degrees.

5.8 The propulsion installation

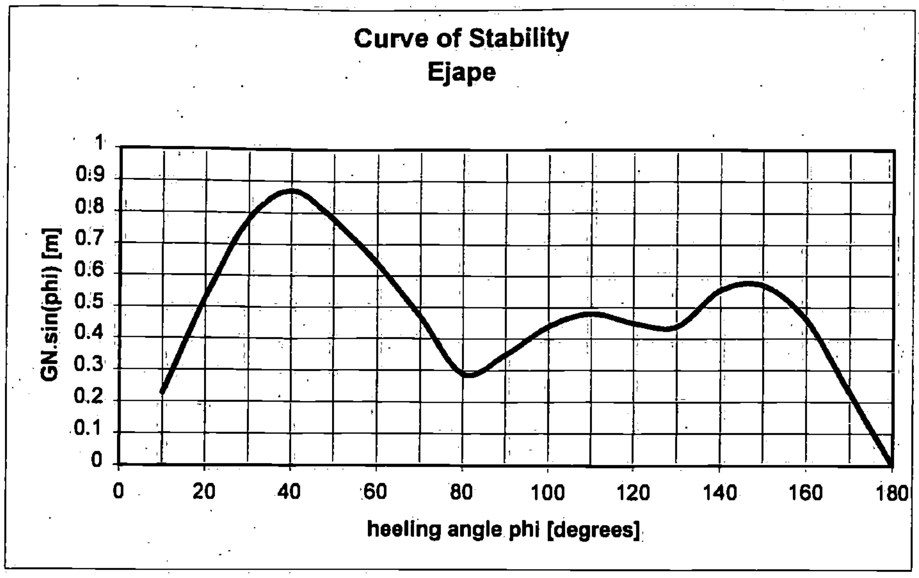
The propulsion installation for the base boat consists of:

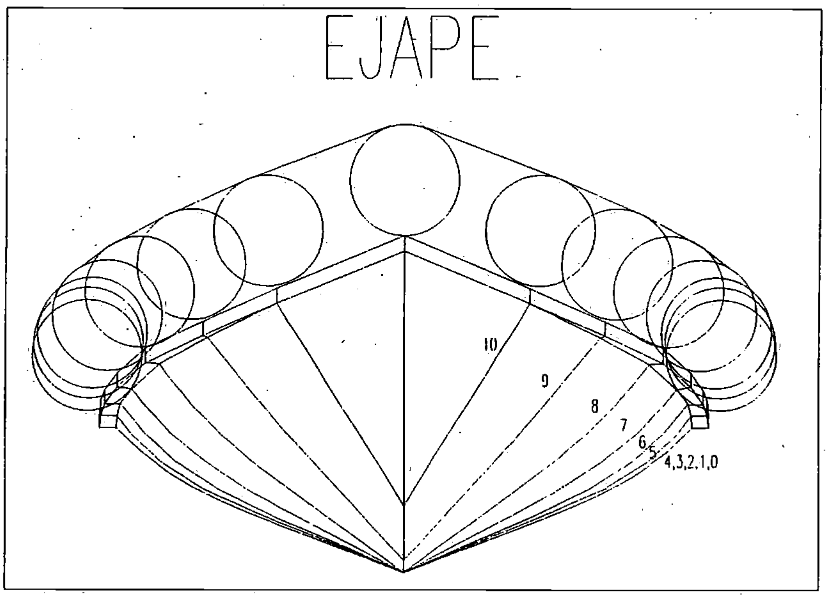
- 2 × Man Rollo D2848 LE401 engines of each 500 kW/2300 rpm,
- 2 × Hamilton 362 waterjets.

A disadvantage of this propulsion installation is that the waterjets are too light as far as performance is concerned. The waterjets are not capable of absorbing full power at low vessel speeds and start to cavitate. This may be noted especially when the vessel is accelerating or towing. The waterjets are able to absorb full engine power at a minimum speed of 22 knots. In order to improve the new design on this point the following different propulsion installation has been chosen:

- 2 × Man Rollo D2848 LE403 engines of each 500 kW/1900 rpm,
- 2 × Hamilton 391 waterjets.

This new propulsion installation has the following advantages and disadvantages with regard to that of the present base boat.





Figuur 7. Calculated stability curves for "Ejape" along with body plan with tube.

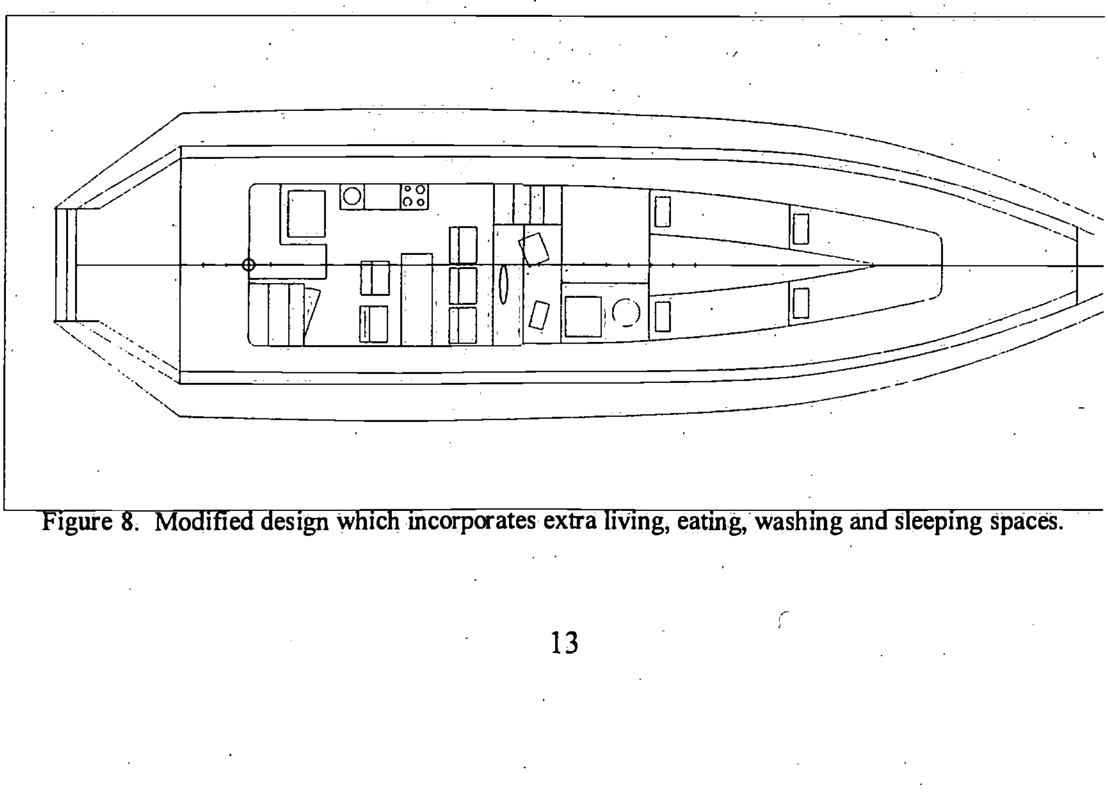


Figure 8. Modified design which incorporates extra living, eating, washing and sleeping spaces.

The advantages are:

- The waterjet can absorb full engine power at a speed of 15 knots without cavitating. This results in a vessel with improved acceleration characteristics.
- The system produces a higher thrust at 10 knots; this improves the towing performance.
- The waterjet has a higher degree of efficiency.
- The engine revolutions are less which leads to a decrease in engine noise level.
- The fuel consumption is lower.
- The propulsion installation has reserve thrust. Should there be an increase in resistance, eg. as a result of a larger displacement, then the boat is still capable of reaching high speeds.

The disadvantages are:

- The complete propulsion installation weight is increased by 530 kg.
- The price of the complete propulsion installation is increased by 20% of the original installation costs .

5.9 The survivor capacity

In order to determine the survivor capacity of a lifeboat, the KNRM looks at scenarios of mass evacuation. In such cases it is imperative that the vessel then carries as many survivors as possible and seating is thereby of less important. The lifeboat must be a stable and safe platform, which provides a temporary transit haven from which the survivors may be transported ashore with the aid of other units. The demand of speed is dropped in such a case, but stability and safety requirements remain. The enlarged vessel has by virtue of both the longer length and larger deck area an increase in survivor capacity. The survivor capacity of "Christien" and "Ejape" are shown in Table 5.

The stability calculations carried out for the boat in mass evacuation conditions show that the vessel remains safe in that condition.

During the model tests, a condition was simulated with 75 survivors on board in following waves while the boat was still sailing at high speed. The vessel sailed well in this condition without any bow diving tendencies observed.

5.10 The endurance

The endurance of the "base boat" the "Cristien" is 6 hours at full speed. The distance traveled (the range) is dependent on the prevailing sea and weather conditions. In calm water the range is circa 200 nautical miles.

During the model tests for the enlarged version, allowance was made for a larger endurance, because the new generation of KNRM lifeboats will have a endurance of 16 hours.

A fuel capacity of 3.800 liter will enable the "Ejape" to sail for 16 hours at full power. The increase in resistance due to the extra displacement can be overcome by the new propulsion installation (this is not the case with "Christien").

If the "Ejape" is fitted out with extra fuel tanks then the subsequent range will be 16 × 34 = 544 nm.

It should be noted that with this increase in vessel weight, little or none of the advantages of the ESC will disappear, (see Fig. 4C).

5.11 Economics

The lengthening of the base boat and some extra building costs go hand in hand. Not only is this due to the extra length but also due to the modification of the propulsion installation. Lengthening the vessel by 33% alone leads to a first costs price increase of roughly 10%. Extra modification of the propulsion installation and accommodation leads to a total price increment of 6%. The "Ejape" costs therefore in total around 16% more than "Christien". In comparison to other international rescue vessels, the price of this vessel is still rather low and it will cost around US$ 900,000.

6 CONCLUSIONS

An improved fast SAR RIB design has been made to meet the latest KNRM specifications whereby it has been shown that application of ESC on such a craft leads to the following hydrodynamic characteristics and advantages:

- A lower resistance up to a speed of 32 knots. This leads to an improved acceleration capability.
- A significantly lower vertical acceleration level in the wheelhouse. This increases the mission operability.
- The smaller draft leads to an increase in mission capabilities in the "strong tidal waters and shallow waters" of the Dutch coast.
- The larger length improves the survivor capacity.

The new propulsion installation has the following advantages:

- Improved acceleration capabilities.
- Improved towing capacity.
- Possibility of range extension.

The new wheelhouse size and construction has the following advantageous:

- Lower noise levels in the wheelhouse.
- Better and larger facilities for crew and survivors.

The total newbuilding price is increased only with 16% when compared to the base boat, 10% for extra vessel length and 6% for modification of the propulsion installation and accommodation.

7 RECOMMENDATIONS

The aforementioned new design is not only suitable as a lifeboat. With yet some more modifications it would be possible to create some extra accommodations under the motor cap, see Figure 6. Obviously, this extra accommodation will include some extra weight penalty which, in turn, may or may not partially diminish some of the ESC advantages. However, when well designed, such possible penalties could be reduced to a minimum. Figure 8 shows such a modified design which incorporates an extra shower/toilet space and 4 sleeping quarters. Finally, enough space is still available in the wheelhouse for cooking and a dinette table which can comfortably seat 5 people.

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REFERENCES

[1] Keuning, J.A., Pinkster, Jakob, "Optimisation of the seakeeping behaviour of a fast monohull". Fast'95 conference, October 1995.

[2] Keuning, J.A., Pinkster, Jakob, "Further design and seakeeping investigations into the "Enlarged Ship Concept". Fast'97 conference, July 1997.

[3] Kok, F., "Kustwachtkotter Jaquar" (Dutch). Schip&Werf de Zee, Febuary 1999.

[4] Velde, J. van der, "Design of a Lifeboat for the KNRM". M.Sc. graduation thesis (Dutch), Delft University of Technology, The Netherlands, September 1998.

[5] Keuning, J.A., "The Non linear behaviour of fast monohulls in head waves". Doctor's thesis TU Delft, 1994.

[6] Stodgon, D, Wiebenga, S, Ruttenberg, M. Dutch R.H.I. "Lifeboats in operation". International Conference of surveillance, pilot & rescue craft for the 21st century-2, 9-10 March 1992.

[7] Zweep, Ch. van der, Stodgon, E.D., "A large RIB for Dutch lifeboat institution". Ship & Boat, June 1987.