A Deep - Vee High Speed Yacht and Development o
Deep Vee Hull Forms

Erbil H. Serter

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by

Erbil H. Serter*

ABSTRACT

A unique 105 fast monohull yacht using the latest variant of the Hydro Research System S.A. deep-Vee hull form is currently being costructed by Yonca Technik of Istanbul, Turkey. This paper will report the features incorporated in this design and the results of the craft's full scale trials. It will describe the seakeeping and powering performance of the deep-Vee hull form used for the craft, and compare it's predicted and actual performance. The special requirements for a medium size, high speed, long range yacht will be described, including provision of adequate disposable payload, structural strength and propulsive power. It will also discuss the historical background behind the design including some data on tank testing executed in some test facilities about similar hull forms for naval or civil applications.

INTRODUCTION

A new type deep vee hull form based on displacement principles has specially been developed for some demanding requirements. These requirements are :

Low resistance characteristics for both high and low speeds.
Extremely good seakeeping and manouverability under adverse sea states.
Spacious interiors for suitable accomodation and large disposable payloads incorporating large fuel tank capacities for range.

Indeed the origin of these requirements was a formulation based on a British Syndicate's design specification. The British Syndicate headed by Mr. Richard Noble OBE, who incidentally reached to an avarage speed of 633 mph on land with his car Thrust-2 in the Nevada desert; wanted to cross the North Atlantic within 50 hours without refueling with sea state 4 conditions prevailing. This of course means an avarage speed in excess of 60 knots under such conditions.

After some comprehensive investigations Hydro Research Systems was selected by the British Syndicate to develop hull form design, and take care of hydrodynamics, tank testing, sea keeping, stability, lcg vcg limits etc.

In order to fulfil these design requirements extensive tank testing was carried out in Hamburg ship model and research facilities (HSVA-Germany) using suitable purpose built models.

The basic design for the British specificaton had about 48 m LWL with a full load displacement around 400 longtons.

The British team in charge of propulsion system selected a RB 211 gas turbine (around 30.000 HP) combined with a triple surface piercing fixed pitch propeller drives. Of course one of the most difficult problems facing this type of hull design is a satisfactory application with selected surface piercing fixed pitch propellers within the availability of a given power and torqe curves.

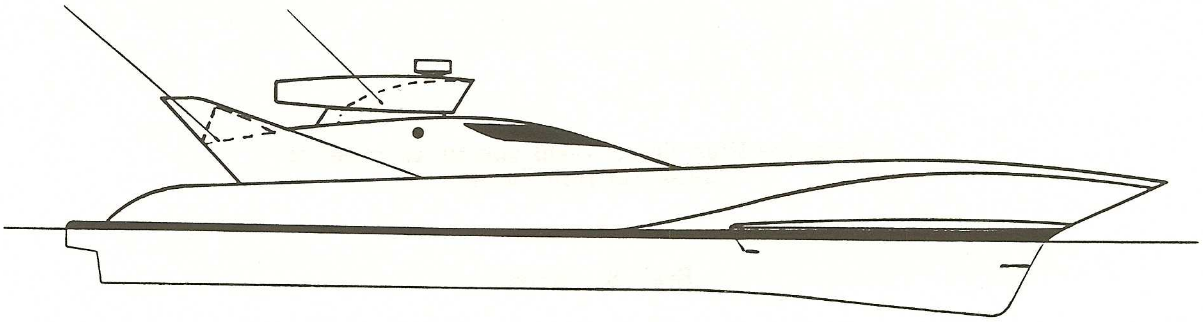
The enormous differences between full loads due to very large quantities of fuel, and light conditions where the former is almost three times of the latter, is the main cause of hull form power-torque interface problem with fixed pitch (surface piercing) propellers.

Under such circumstances required speeds cannot easily be achieved with known planing or displacement type hull forms forcing many designers to adapt hydrojet or variable pitch propulsion systems. Further sea keeping and stability characteristics under such extreme load conditions are very different.

So satisfactory performances achieved by the Hydro Research System design solution can simply be attributes to the proper use of deep vee design concept parameters.

Some data concerning this Atlantic design initially called Atlantic Sprinter will probably be available after completion of the project, subject to owner's approval.

*
Yüksek mühendis; D.I.C.,(Imperial College, London)
Fellow; Royal Institution of Naval Architects
Member; Royal Aeronautical Society
Member; American Society of Naval Engineers; U.S. Naval Institute



One of the design studies of Atlantic Sprinter

However in 1990, during tank testing in HSVA research facilities other design configurations ranging from 50 long tons to 1400 long tons were fully investigated using various models with different displacements and LCG conditions; with different length beam ratios.

In addition some comparative data was also produced between two different hull forms representing a German designed round bridge FPB and HRS designed deep vee FPB, both formulated around same mission profile requirements. The main characteristics of these FPB s are described as following:

	FPB-round bilge concept	FPB deep vee concept
LWL	58.60 m	56.40 m
Beam	7.54 m	8.47 m
Draft	2.84 m	2.31 m
Displacement (trials)	500 LT	500 LT
GM	1.50 m	1.40 m

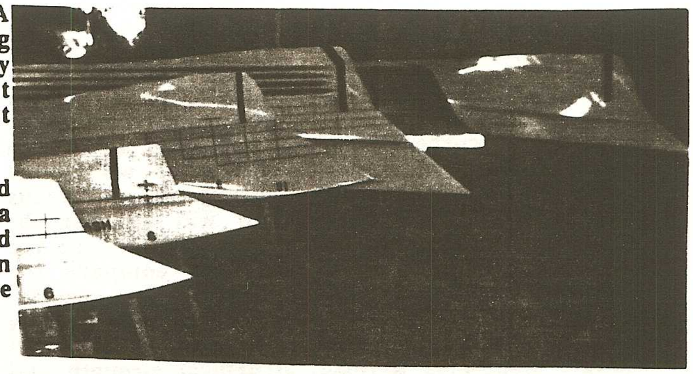


FIG. 1. Various test models at HSVA-HAMBURG

Deep-Vee Hull form

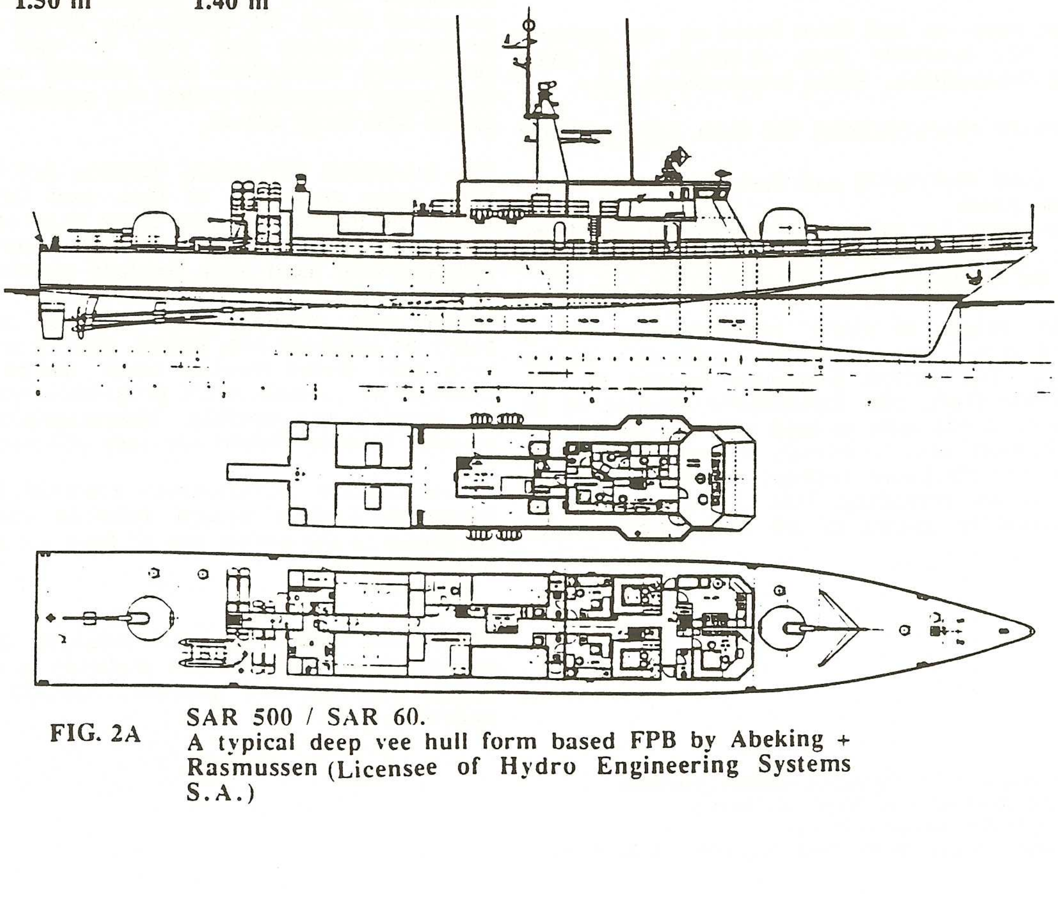


FIG. 2A SAR 500 / SAR 60.
A typical deep vee hull form based FPB by Abeking + Rasmussen (Licensee of Hydro Engineering Systems S.A.)

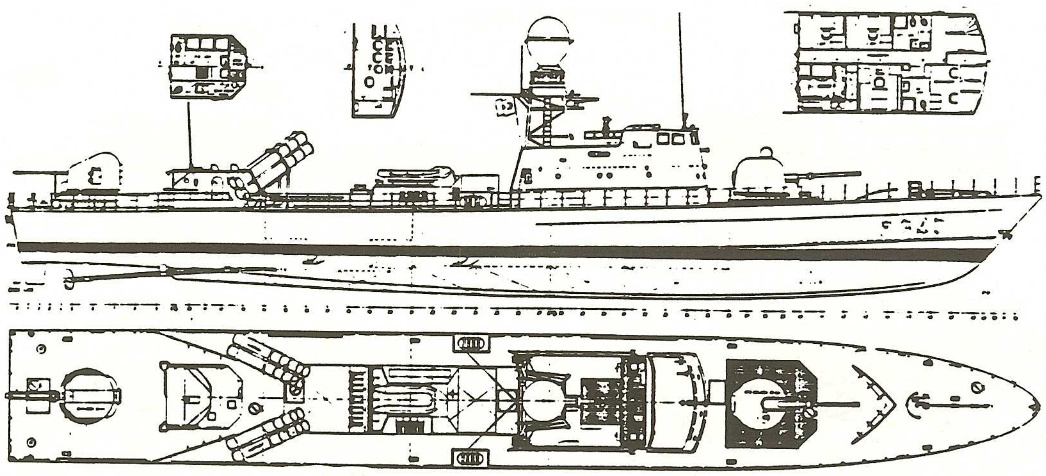


FIG. 2B A typical round bilge hull form based FPB

As far as seakeeping is concerned these FPB'swere evaluated under following conditions.

Sea State no:(JONSWAP SPECTRUM)	5	4
Sign Wave Height	3 m	2 m
Peak Wave Period	9 sec	7 sec
Mean Wave Period	7.5 sec	5.8 sec

(RB)

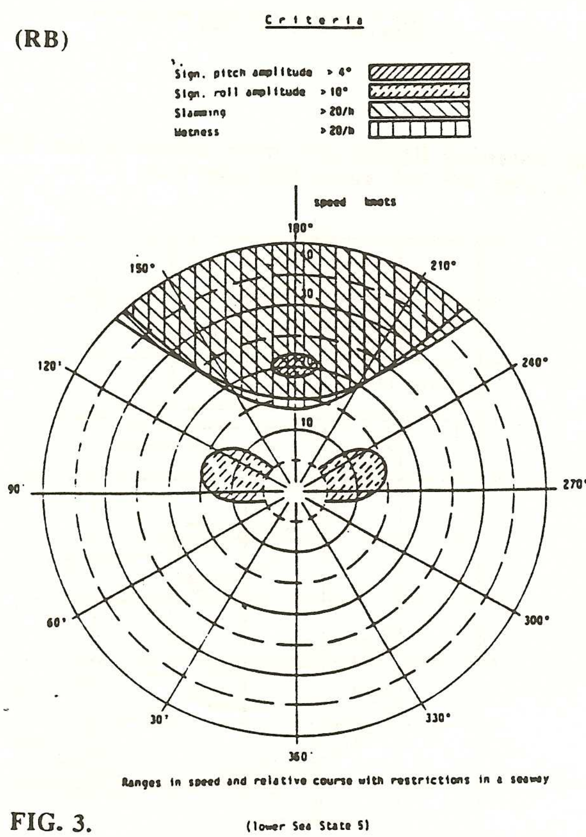


FIG. 3.

(Deep-Vee)

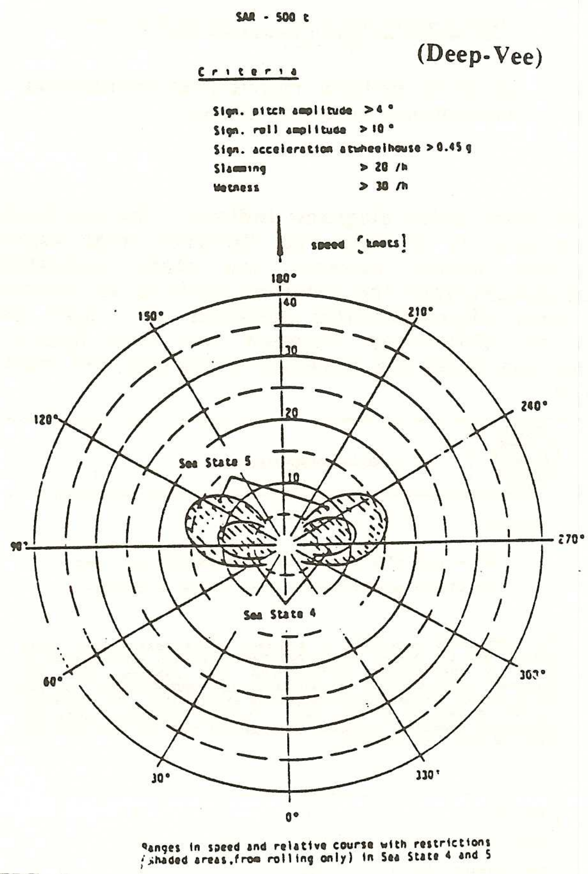


FIG. 4.

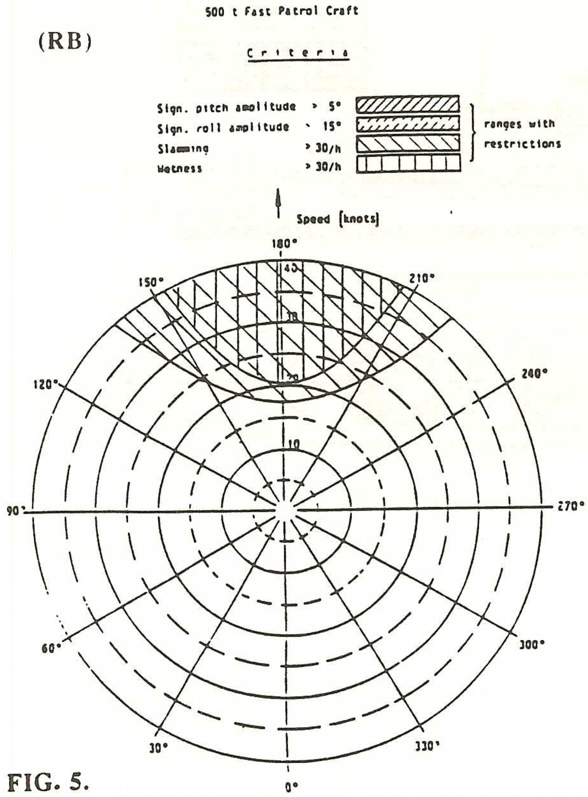


FIG. 5.

Ranges in speed and relative course with restrictions in a seaway with significant wave height 2.0 m and a peak period of 7.0 s (Sea State 4)

Based on given criteria restrictions operational limits can be determined as shown above.

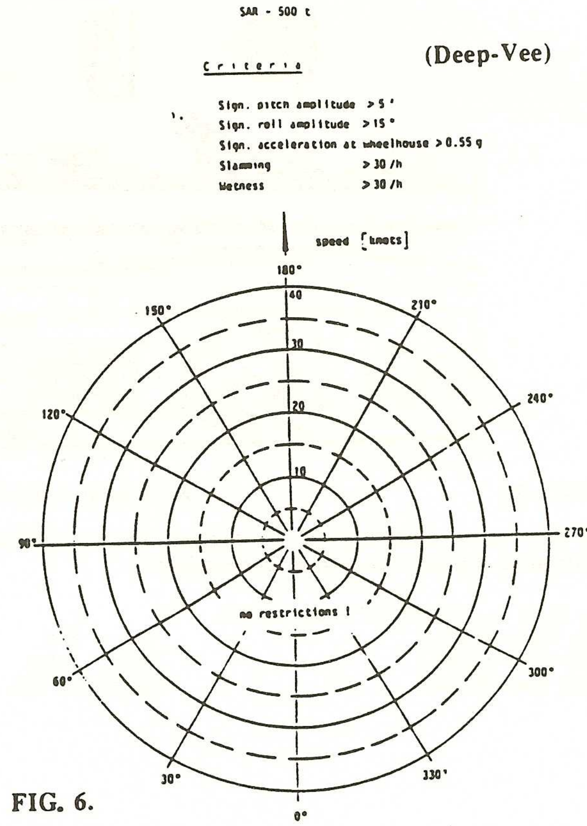


FIG. 6.

Ranges in speed and relative course with restrictions (shaded areas) in Sea State 4 and 5

As all these polar diagrams indicate , the sea keeping characteristics of deep vee illustrate some superior qualities under adverse sea state operational conditions.Further the following table is an indication of slam characteristics between two hull form concepts. Differences between two slam figures at higher sea states are extremely important and must be noted.

Slamming Comparison

Table 1

Comparison of a Round Bilge Fast Patrol Craft and the DEEP-V Design SAR 500 with Regard to Slamming

The seakeeping behaviour of a Round bilge Fast Patrol Craft (RBFPC) and the Deep-V Design SAR 500 have been investigated by means of theoretical calculations. The results valid for different displacements are given in the HSVA-Reports S 277/90 and S 287/91. For comparison purposes the results were converted for 500 t designs in both cases. In the following table the calculated number of slamming impacts per hour in head seas are compiled for both designs:

Sea State	4			5		
sign.wave h. [m]	2.0			3.0		
peak period [s]	7.0			9.0		
speed [knots]	10	20	30	10	20	30
N slam [1/h]						
SAR 500	-	0.3	1.3	-	0.6	7
RBFPC	1	40	89	1	41	135

The following figures give more details on sea keeping of a deep vee hull about 500 long tons.

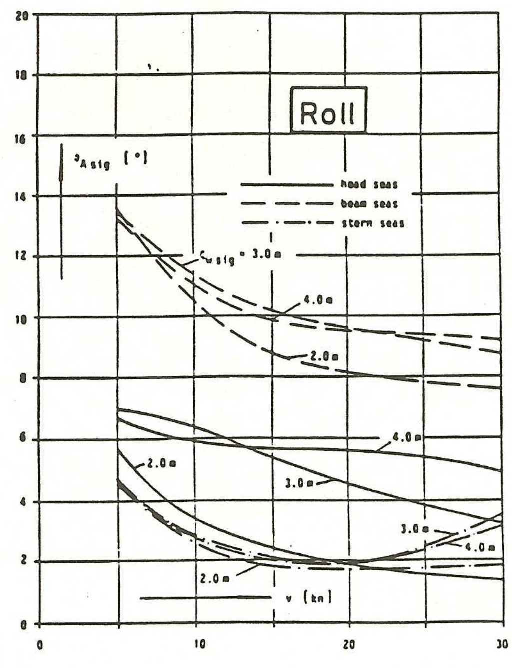


FIG. 7.

Significant single amplitudes of the roll angle ϑ as function of speed

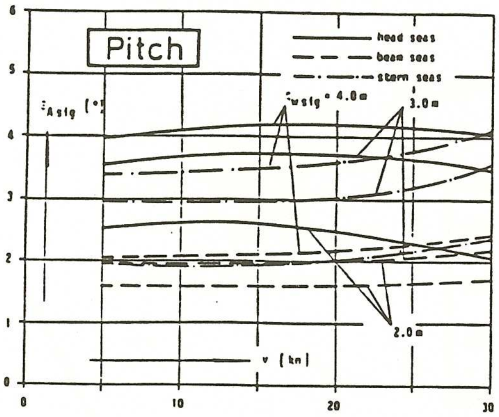


FIG. 8. Significant single amplitudes of pitch angle as function of speed

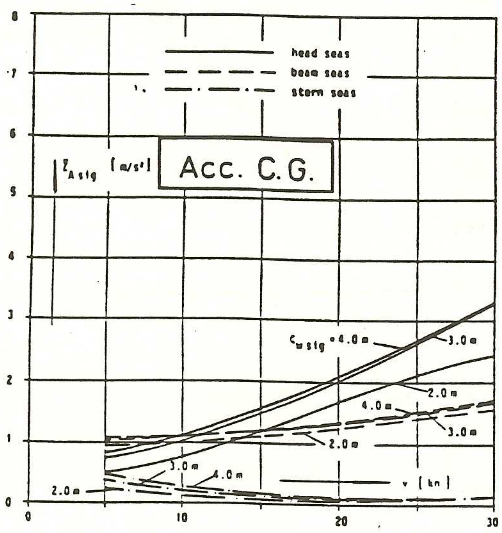


FIG. 9. Significant single amplidudes of the vertical acceleration at the center of gravity

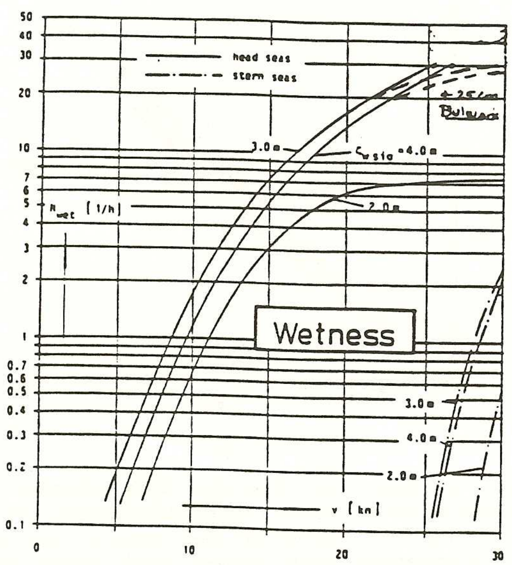


FIG. 10. Wetness rate in head and stern seas as function of speed

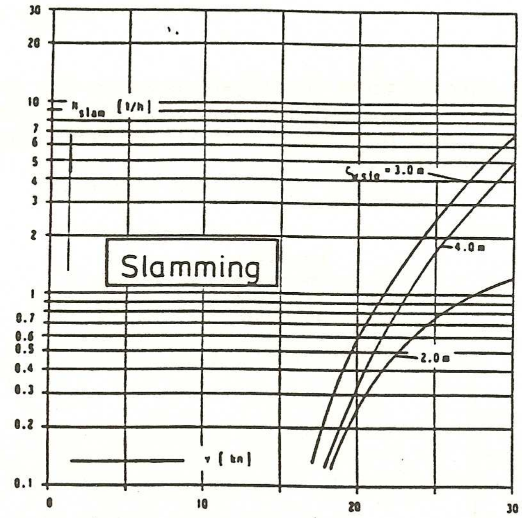


FIG 11. Slamming rate in head seas as function of speed

POWER REQUIREMENTS

The ehp power curve requirements also became a subject of an investigation where under equal conditions ehp curves for both vessels showed almost equal power requirements.

This is very significant due to following two findings :

First trials executed at HSVA (Hamburg) and at BHC (British test facilities - Isle of WIGHT) propulsive efficiences were about 10 to 8 percent better for some propellers operating under a deep vee hull configuration. This was further proven by a series of tests executed by FINCANTIERI (ITALY) test team.

Second, the added resistance due to waves and slam, were so much better for the deep vee configuration operating under adverse sea states that considerable power reductions for same speeds were thus recorded.

Table 2 INCREASE IN POWER DUE TO SEA STATES[x]

		Deepvee			Round bilge		
	H 1/3	2,4 m	3,5 m	5 m	2,4 m	3,5 m	5 m
Percentage	20 KTS	22	49	108	34	90	139
increase	25 KTS	15	48	104	26	66	136
over calm	30 KTS	4	28	/	21	48	/
water ehp	32 KTS	4	24	/	18	44	/

[x] model tests for head seas (H 1/3 : irregular significant wave heights)

As a part of these investigations some ehp curves at various displacements are also presented herewith for different hull form configurations covering some deep vee design concepts.

curves at half load conditions

FIG. 12.

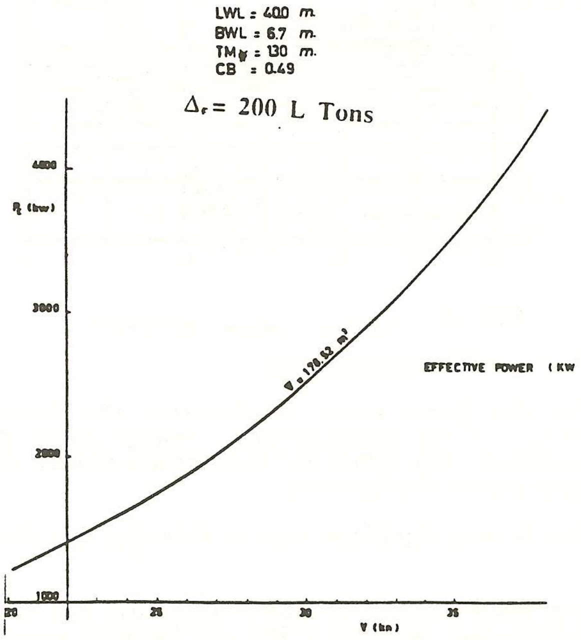


FIG. 13.

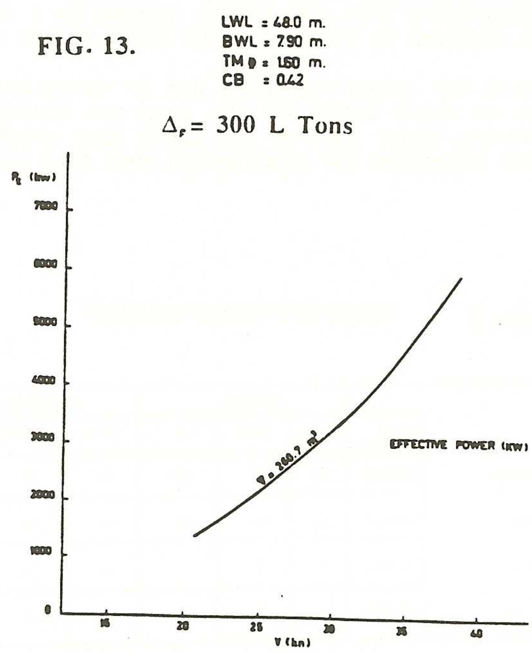


FIG. 14.

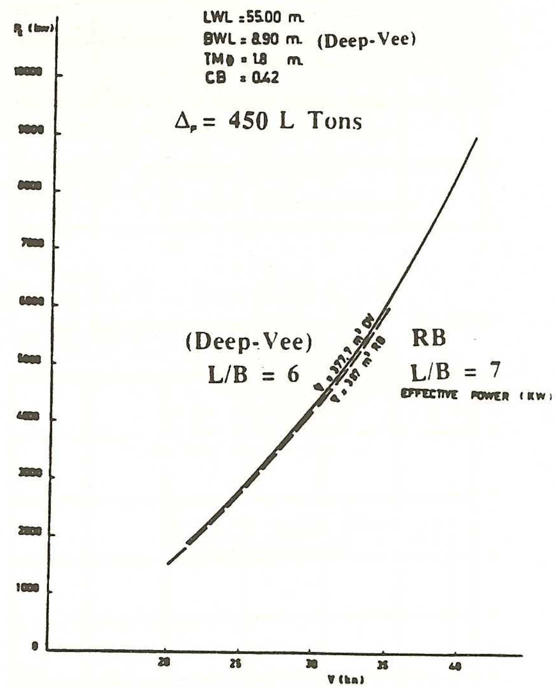
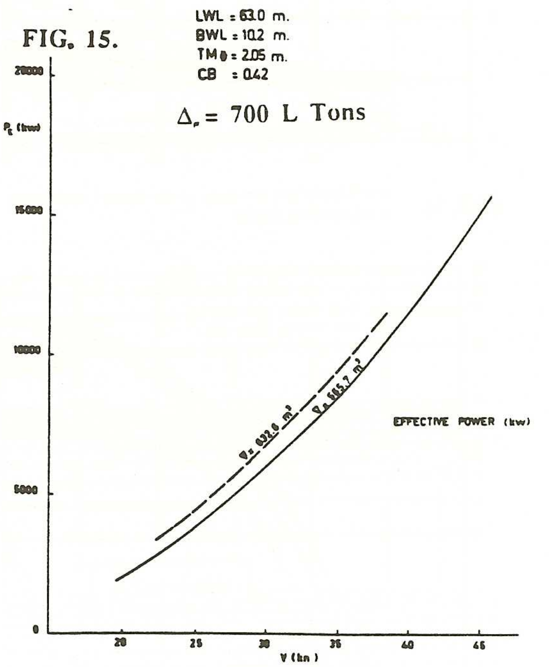


FIG. 15.



It must be well noted that this data contains windage, roughness coefficients (0.0002-0.00025) and some trial predictions based on test tank's experiences.So when comparing such results with other tank test results executed at different places much care must be taken to ensure that all comparative conditions and items are equal.Further presented ehp curves belong not to a point design but to a standard series of hull shapes to be used for the basis of a new design according to owner's mission profile requirements.

FIG. 16.

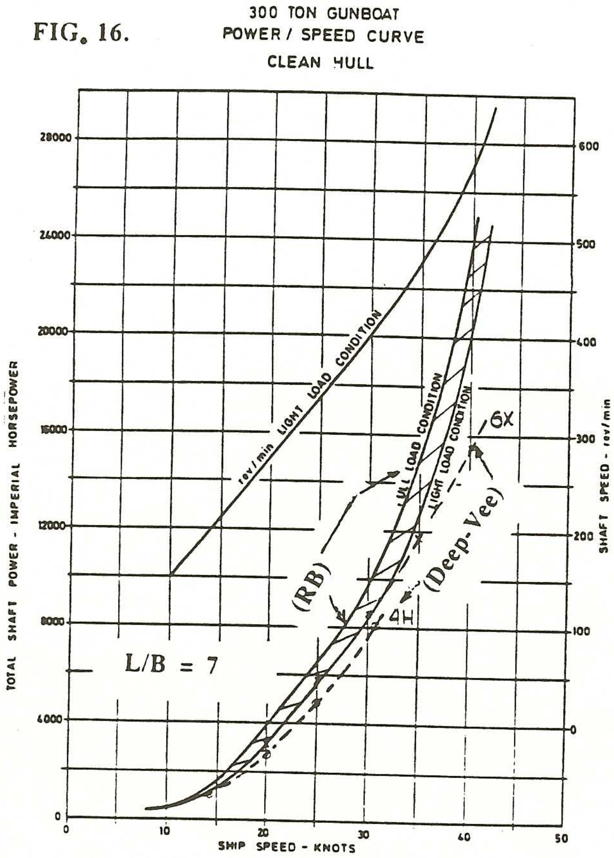
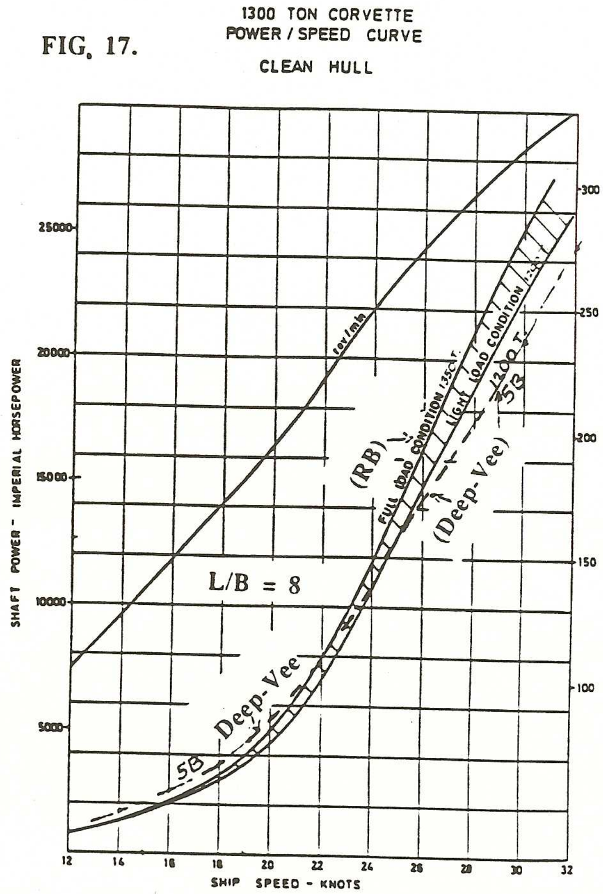


FIG. 17.



The manoeuvrability characteristic between two hulls at 500 LT are shown in the following figure

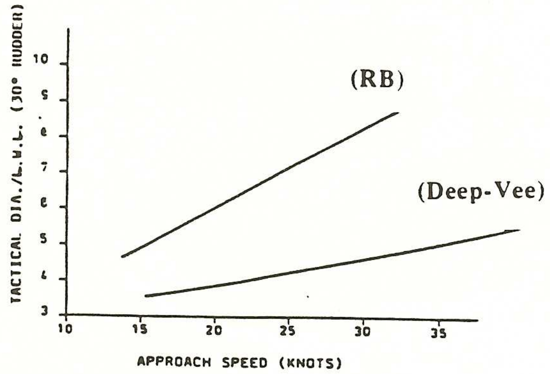


FIG. 18.

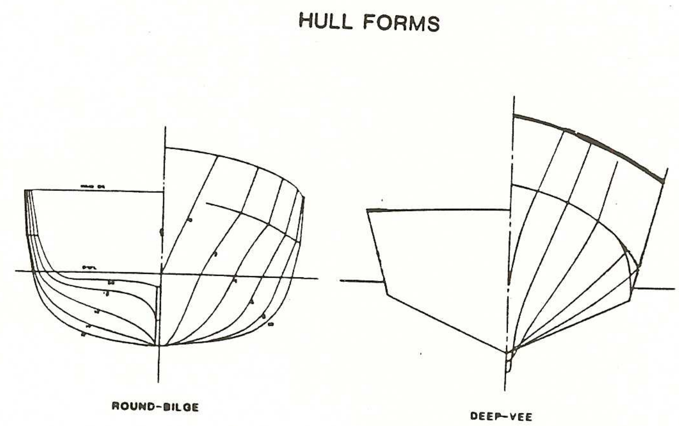


FIG. 19.

Model trials of a 4H series deep vee hull, 250 tons.

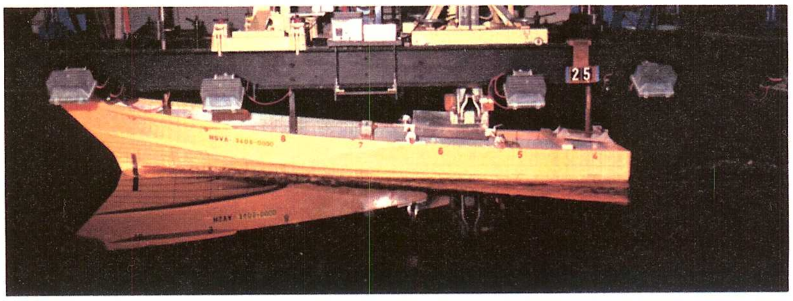


FIG. 20. V = 25. kn

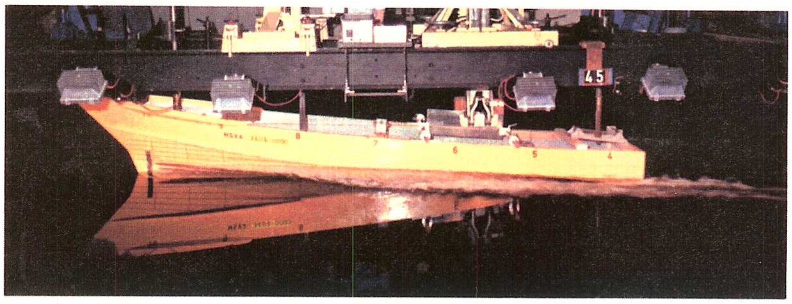
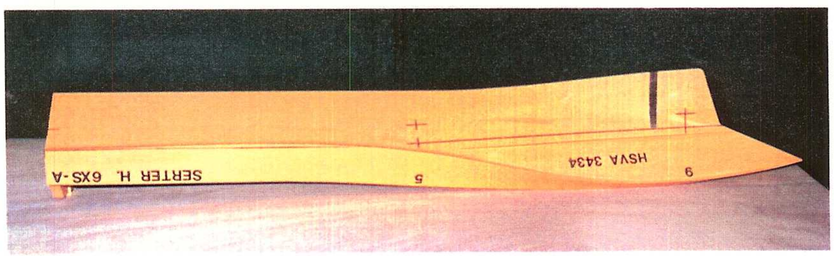


FIG. 21. V = 45 kn

FIG. 22. Hull form (Deep-Vee)



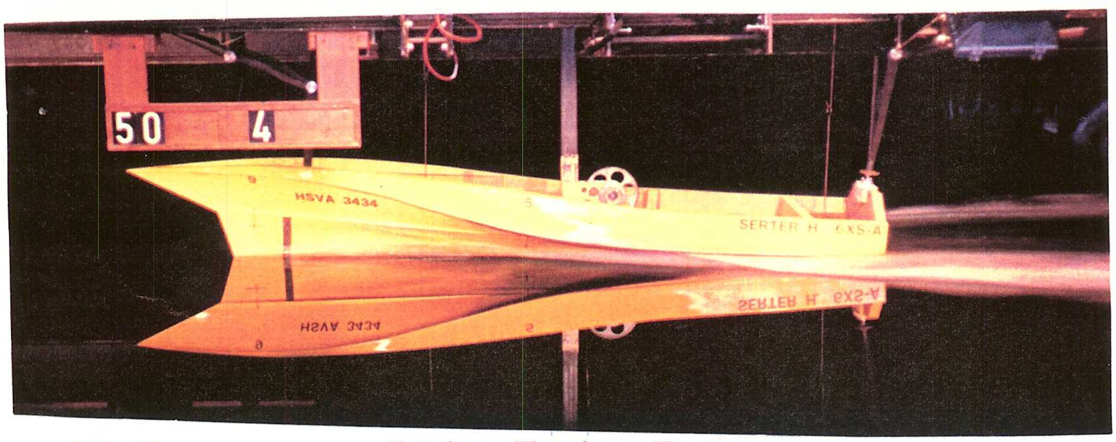


FIG. 23. Hull form 6X series at Hamburg
Test Tank Facilitiest
Speed : 50 knots

YONCA 105

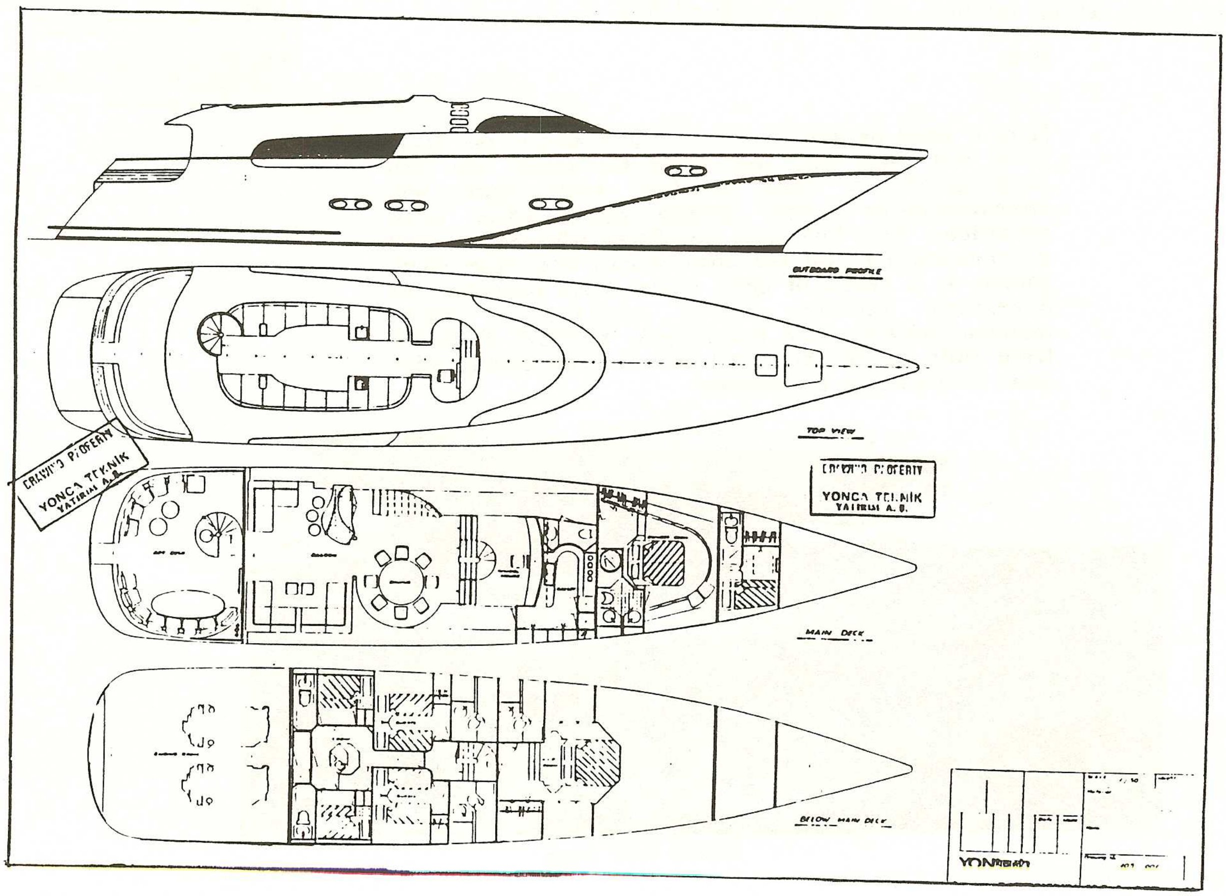
When Yonca Teknik who was already informed about above mentioned research; started to negotiate for a very advanced yacht of special chracteristic Hydro Research Systems 6XS series hull form was the natural choice.

This hull form was one of the end products of more than 1000 tank tests executed during previous investigations. The principle characteristics of 6XS series YONCA yacht are as following

L.O.A about	31.50 m	(105 FT)
LWL about	24.00 m	
Beam at WL about	5.40 m	
Beam (deck)about	6.30 m	
Draft about	1.30 m	
Displacement full (approx)	56 L TONS	
Displacement (trials) "	50 L TONS	
Displacement (light) "	43 L TONS	
Power	2X1100 KW	
Fuel capacity	9000 LIT plus 10% resv.potential	
Water capacity	2000 LIT	
Generating power	2X50 KW	

Water maker, air condition equipment,
Material:composite

FIG. 24.



HULL FORM

The hull as discussed is a deep vee form concept designated as 6XS-A. One of the most important features of this hull form is the "No hump at critical speeds" incorporating anti-slam bow form for adverse sea state operations. It is well known that hump and slam are the most undesirable features for any marine design.Unfortunately some high speed marine vehicles may be a subjectç to such features.

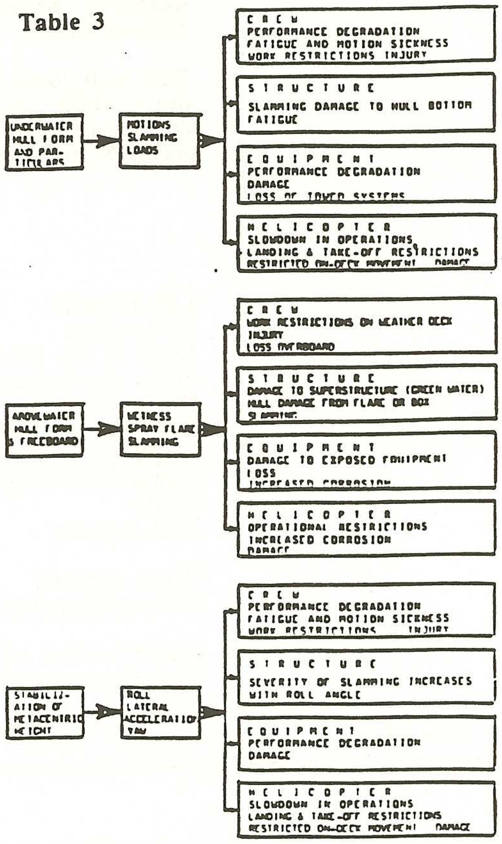
The deep vee 6XS-A has a dehedral angle from midships to transom that varies between more than 25 degrees to less than 30 degrees again with varying convex depths. The relatively high dihedral angled transverse sectional form designs are selected to minimize vertical accelerations, improve roll and yaw damping coefficients, and lateral stability; providing more displacements characteristic than dynamic lift type supported designs. Better resistances are thus obtained when such lines are combined with slightly droop-nose antipitch+antislam bow lines.Furter there is ofcourse a dynamic lift element; but this element is kept at minimum, becoming gradually effective after reaching Froude numbers in excess of 1.5-2

As the beam is increased near the load water line, volumes under water are found to be, suitable for auxillary systems,engine installations,fuel and and water tanks, piping and cabling.

The 6XS hull form incorporate around 30 different design parameters in order to make the YONCA 105 an efficient and satisfactory desin in full compliance with YONCA specification These design parameters may be subject to another paper as it will not be appropriate to go into details within the time and space scope of this paper.

The following table is an extract from a NATO STANAG (STANAG 4154-ED.2) where importance of SLAM and sea keeping is well explained.

Table 3



IMPACT OF MAJOR DESIGN PARAMETERS ON SEAKEEPING

E-8

Here it must be pointed out that a 8. meters sea going (E-8) test boat with hull form 6X series was also constructed in 1989 to test some tank test characteristics under actual open water trial conditions. This boat was not fitted with any special instrumentation. But the observations and experiences gained as a result of open water trials provided the necessary feelings about seakeeping, slam, manoeuvrability, and handling.A YONCA TEKNİK team fully tested this craft before commencing with their construction programme

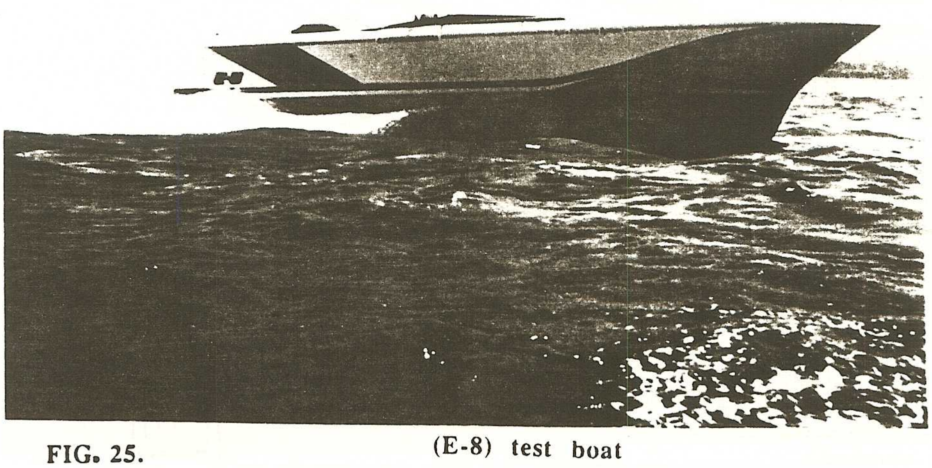


FIG. 25. (E-8) test boat

PERFORMANCE PREDICTION:

The performance of Yonca 105 are expected to be as following

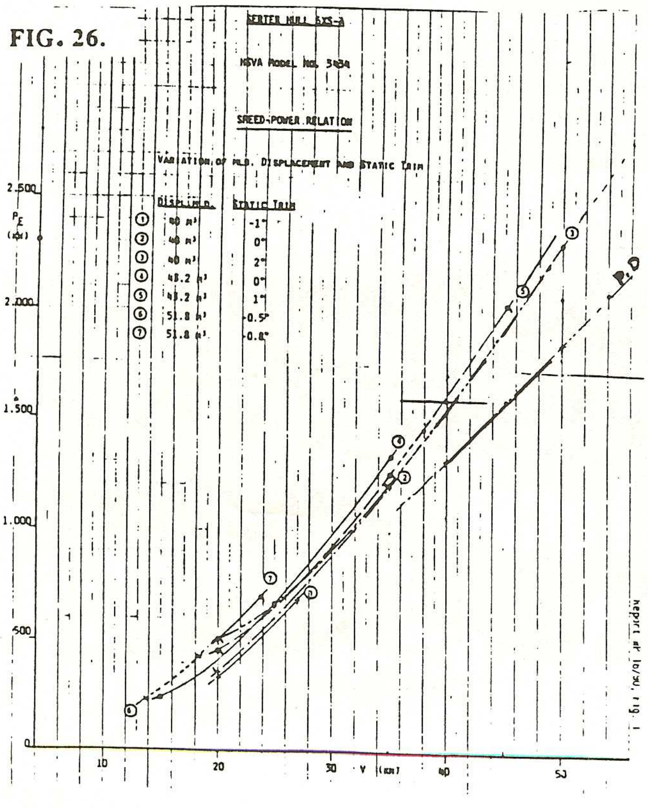
At half load displacements of 50 L TONS
-Max contineous speed about 35 Knots with a P.C. of 0.60
-Continuous speed about 30 Knots
-Range at 20 Knots with a P.C. of 0.50:720 nautical miles.
-A range of 900 nautical miles can be reached with the use of extra fuel tankage capacities.
EHP curve of standard 6X-A series hull form is shown in the Fig.
Sea Keeping Predictions at Sea State 3 and 4 estimated to be within the following limits, up to cruising speeds of 25 Knots(Data is single amplitude significant)

Pitch	3-3.5	degrees at head and following seas
Roll	8-10	degrees at beam seas
Vertical acceleration at CG	0.40-0.50 g	
Slam per hour	20	at head seas
Wetness (depending on bulwark height)	30-40	at head seas

YONCA specifications stipulate roll angles not to exceed 2-3 degrees at single amplitude significant conditions. In order to ensure that this requirement is fulfilled especialy at low speeds around 10-15 Knots at sea state 3/4; VOSPER 0.55 m2 stabilizer are fitted.

The influence of special rail and bow form are expected to reduce slam motions and wetness further, though final sea trials will show the exact nature of their behaviour.

FIG. 26.



Following tables are the seakeeping study for the YONCA 105 (values significant single amplitude)

Sea State No: (Jonswap Spectrum)	3 (LOW)	4 (LOW)
Sign wave height	0.7 m	1.3 m
Peak wave period	4.5 sec	5.6 sec
Average wave period	3.6 sec	4.5 sec

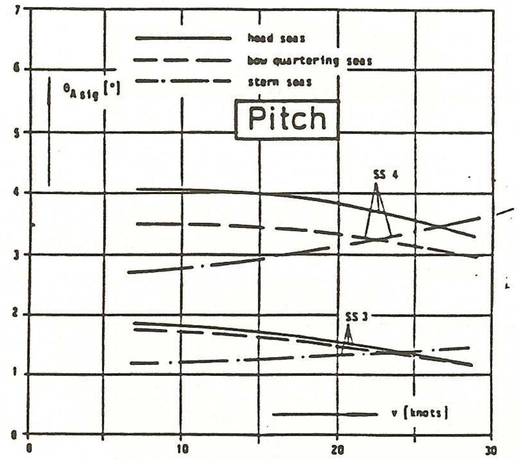


FIG. 27.

Significant single amplitudes of pitch angle as function of speed

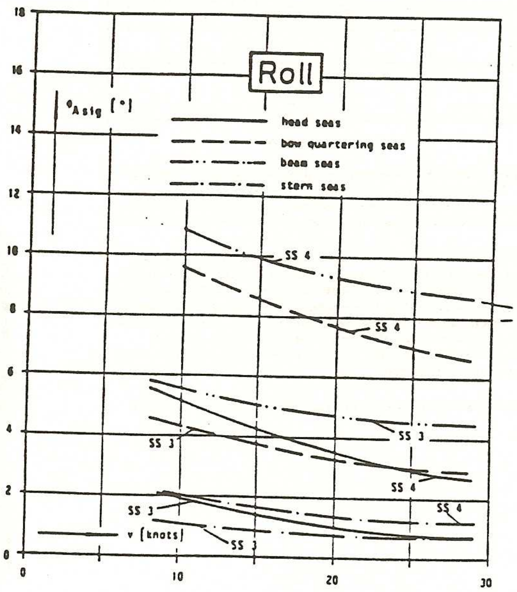


FIG. 28.

Significant single amplitudes of the roll angle as function of speed

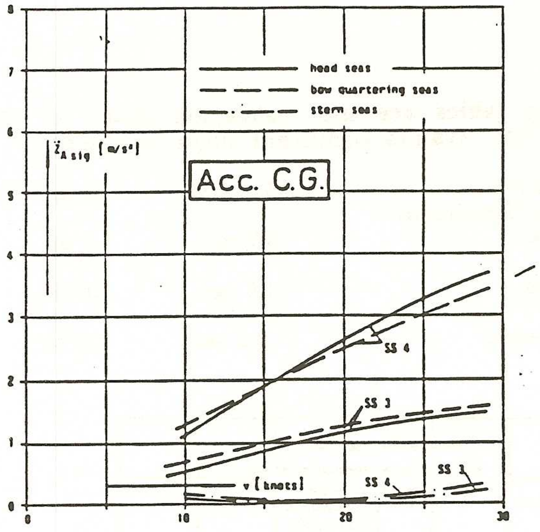
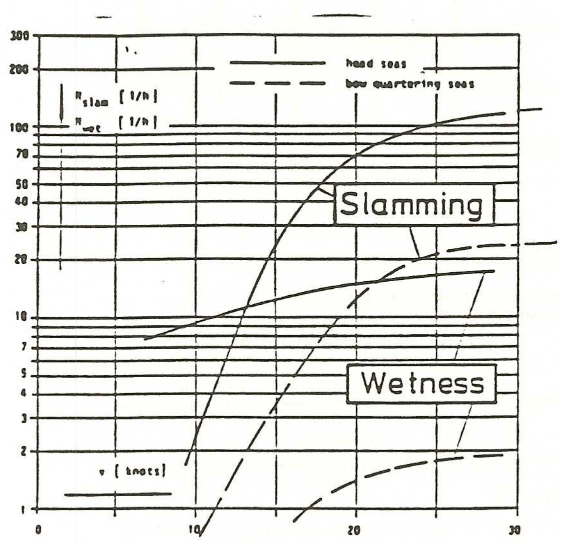


FIG. 29.

Significant single amplitudes of the vertical acceleration at the center of gravity



The calculations showed that no wetness and slamming impacts will occur in Sea State 3. The rates calculated for Sea State 4 are shown in Figure as function of speed. For both phenomenons the most severe course is the head sea condition. The rates are already remarkable lower for bow quartering seas.

With regard to slamming it has to be stated again that the occurrence was calculated according to the Ochi-Criteria, which uses a certain critical relative velocity for immersion of the section. For the fine bow section of Deep-V design it does not mean necessarily that there will be always a strong impact, usually these fine bow sections enter the water again with a relative moderate increase of forces. From the experience with other similar Deep-V hulls, gained in seakeeping tests it is known that this type shows a very good behaviour in this respect which is above the average.

Slamming and wetness rate in head seas as function of speed

FIG. 30.

POWERING AND STEERING:

The YONCA 105 is powered by two MTU 331 V12 diesel engines each developing 1100 KW maximum(1070 KW for YONCA applications) where the propulsion and steering are combined by means of a fixed pitch steerable , surface piercing propellers,An Arneson ASD 14 type adjustible unit had been used for this purpose.
The combined powering-steering offered by ASD 14 drive system is considered to be extremely effective for manouvering steering and powering at low and high speeds with changing immersed blade areas. As far as YONCA 105 is considered extensive trials with E-8 test boat fitted with a similar drive type ASD 6 had shown that under various loads and sea conditions this propulsion system is ideally suited to 6X series hull form.

PAYLOADS:

The following data is an indication of YONCA 105 payloads.

Fully equipped light load	43 L TONS	plus 10%
Fully loaded	56 L TONS	

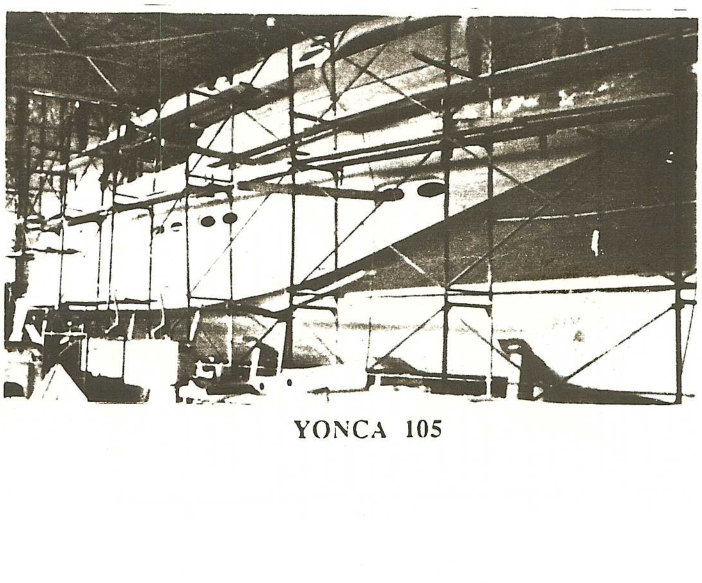
where 9000 LIT is the fuel
2000 LIT is the water
1 TON is the crew and belongings
1 TON is the provision
1 TON is the loose items

The payload ratio is around 30 percent compared with light weight conditions. The hull design however has a capacity up to 60 TONS for the full displacements. As far as the British Atlantic project is concerned payload is over 200 percent. Therefore much depends on what are the requirements for which the marine vehicle is designated for including accomodation,layouts and mission profiles etc.

CONSTRUCTION:

The YONCA hull and superstructures are made from composite material Airex type PVC foam and Kevlar as the main material. Many parts such as engine room girders and some frames are reinforced with carbon fiber laminates.

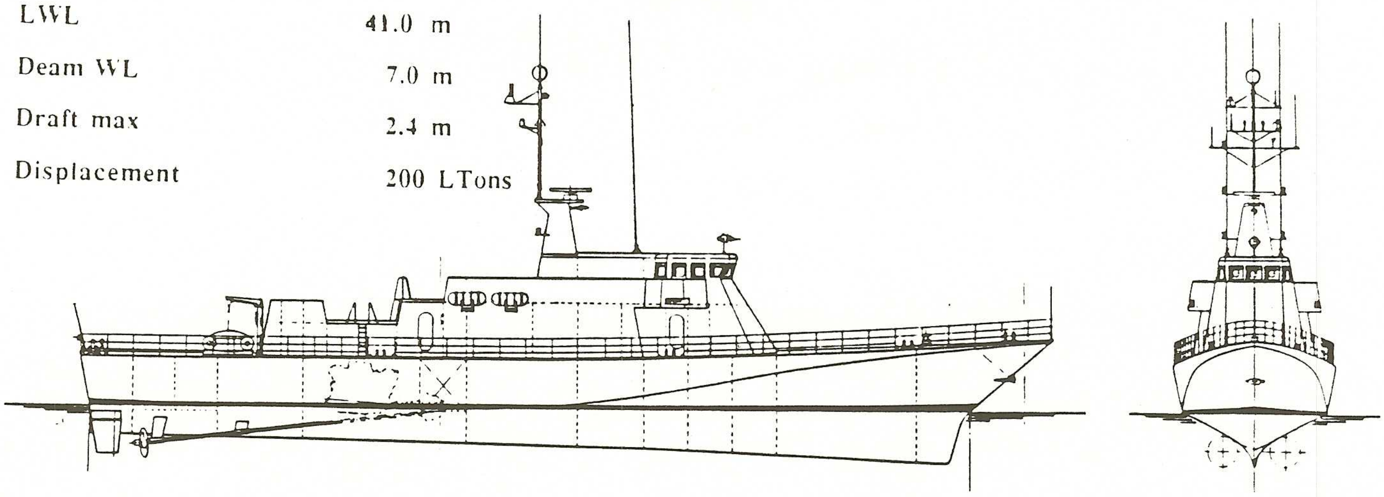
FIG. 31



YONCA 105

FIG. 32 The drawing here under show a different design configuration for Coast Guard duties based on hull form 6X series.

LWL	41.0 m
Beam WL	7.0 m
Draft max	2.4 m
Displacement	200 LTons



CONCLUSIONS

All these tests, investigations, trial and experiments indicate and prove that a properly designed deep-vee hull forms as described hereabove with a historical background lasting just over ten years are ideally suited for various applications.

For same displacement length ratios and for the same length beam ratios deep-vee hull forms have almost the same ehp requirements as round bilge hull forms with a historical background lasting centuries.

On the other hand based on the practical applicabilities, their sea and ocean going shp requirements are less.

Under no circumstances these type of deep vee hull forms must not be confused or compared with planing type deep-vee hull forms seen all around, most of which with bad slam and hump and excessive power requirement characteristics.

The sea keeping capabilities when compared with equal sized round bilge hulls are considerably superior so that much more operational flexibilities with no pay load penalties became feasible.

The development of this new type deep-vee hull form concept had just been started and it is believed that with their simplicity and consequent cost effectiveness in construction and operations will make this type of hull form the basis of a new generation of monohulls with possible applicabilities for catamarans as well. The concept is open to further considerable development and improvements.

It must be noted that up to now designers have confined their vision around some well known round bottom hull shapes based on lowest resistance characteristics. Tests have shown that for a given displacement it is the correct spread combinations and correct formulations of ratios between immersed sectional areas at each station from stem to stern that plays one of the most important factors for obtaining lowest resistance characteristics irrespective of hull shapes, round bilged or deep vee.

Ofcourse ideally for each Froude number these combination of immersed area ratios and their formulation from stem to stern must be different. It is therefore upto designers of hull forms to formulate the best combinations considering sea keeping, stability, manoeuvrability, payloads etc.

This approach is valid for America Cup sail boat challangers to Atlantic blue riband challangers.

REFERENCES

All diagrams, tables, curves and dravings are based on the following data:

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