Bilaga 4

RO-RO PASSENGER FERRIES HULL SHAPE – IMPACT ON PERFORMANCE AND STRUCTURAL LOADS IN HEAVY SEAS

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1. HULL SHAPE

In the late seventies the ferry owners started to increase the size of their newbuilding projects, the so-called jumbo ferries were developed. The requirement was to increase the passenger and the ro-ro capacity, and the transport role was moved towards cruising, conferences, tax-free, i.e. new type of public spaces were introduced and the ferries lost their liner type outlook and became more box shaped.

At the same time the shipping companies in the traffic between Finland and Sweden wanted to introduce scheduled traffic even in waterline in heavy ice conditions meaning high installed propulsion power. There were hardly any references available and many of the vessel characteristics were extrapolated from some previous smaller references.

Extreme hull forms were introduced; twin skeg hull form for the aft ship causing a lot of vibration problems. And extreme bow shapes were designed with very small flare angles against waterline. This was simply due to the requirement of high amount of lanemeters in limited main dimensions and wide ramps for quick harbour operations. The most extreme bow lines were developed with convex frame shape and a knuckle line just below the main ro-ro deck.

Figure 1.1 presents the hull form of M/S 'Estonia', ex. 'Viking Sally'. Extreme bow flare is applied, minimum angle against waterline being on station 19, only 17 degrees. The ship suffered already in moderate bow quartering seas of heavy wave induced impact loads, noise, whipping vibrations and speed loss. We carried out several measurements for the vessel's original owner Sally Line on the route from Åland Islands to Sweden, and recommended to use a longer route over the Åland sea in heavy south-western seas for better passenger comfort and fuel economy as well as to reduce wave impact loads. It was beneficial to sail in beam seas more north close to the Swedish coast and then in head seas close the coast into the entrance of Stockholm passage.

Figure 1.3 presents the full form of 'Viking Saga' built at the same time as 'Viking Sally' for the same owner by Wärtsilä. The convex type frame shape is not used, but the so-called soft nose type bow flare. Flare angles are clearly higher, ranging from 30 degrees up to 39 degrees.

Figures 1.4 to 1.6 present bow shapes for typical ferries built in the late eighties and figures 1.7 to 1.9 in the nineties. Extreme bow flare shapes are not used anymore.

2. BOW FLARE ESTIMATOR

A simple guidance tool has been developed on basis of seakeeping model test results, the Bow Flare Estimator.
The Bow Flare Estimator is $X / L_{PP} / \tan \alpha$ calculated for the bow stations, typically from station 16 to station 20. X is the distance of the station from midships, L_{PP} is the perpendicular length and α is the smallest angle of the flare at the station against waterplane (MARIN, R. Dallinga).

Ferries with bow flare estimator below 0,50 have shown good performance track record in full scale and the maximum measured bow flare impacts have been below 220 kN/m^2 in typical wave conditions and below 300 kN/m^2 in extreme wave conditions. In full scale this means that the bow flare impacts are not causing noise, vibrations and thus voluntary speed drop.
Figure 2 shows the bow flare estimator for a family of passenger ro-ro ferries. The highest values are for ferries built in the early eighties and the modern ferries are mainly between 0,2 and 0,5.

Figure 3 shows a representative example of the importance of bow flare design. The ex MS 'Skandinavia', today MS 'Viking Serenade' suffered from heavy bow flare impacts in its service on the US West Coast already at a significant wave height of 1,5m, and was not able to maintain her schedule. A conversion of the bow flare was carried out and the problem of bow flare impacts was checked with seakeeping calculations. A reasonable modification of the flare showed clear improvements in the behaviour and a decision was made by the owner to include the modification of bow flare within the conversion. Figure 3 shows the original and modified body plans. *Figure 4* shows the bow flare estimator for the original vessel, marked as 'Skandinavia' and for the modified vessel, marked as 'Viking Serenade'. Service experience has proven the validity of the calculations; the ship is performing well on the route without any problems caused by bow flare impacts.

In the original 'Skandinavia' the bow flare estimator was between 0,5 and 0,7, as in the 'Viking Serenade' it was reduced down to 0,37-0,55, only at station 20 above 0,5.

3. BOW FLARE LOADS

Bow flare dimensioning criteria have not been able to follow the development of modern ferries, their speed and hull form. Several ferries have suffered severe bow flare damages in heavy seas.

Figures 5.1-5.3 show dimensioning loads for bow door for three different ferries calculated in accordance with the old IACS (International Association of Classification Societies), DNV (Det

Norske Veritas) and the new IACS requirements. Figure 5.1 presents 'Estonia'. Astonishingly big differences can be found. The old IACS recommendation was used up till 1995! And even today DNV rules are the only ones taking into account the actual bow flare shape when calculating the dimensioning loads and forces. Design loads at the maximum flare area show even bigger variation, the old IACS (applied design criteria for this specific vessel) are giving only 27,6% of the design load of DNV!

Figure 6 presents calculated design loads for 'Estonia' at the maximum in the area where the flare angle is at minimum against waterplane. The old IACS gives the same design load as for the bow door area, figure 5.1. The actual flare shape is not taken into account at all. The difference between the new IACS and DNV requirements is still astonishingly high, close to 20%. Between the applied old IACS and DNV the difference is 362%!!

MS 'Finlandia' delivered in 1981 had a very similar bow flare as presented in *figure 6*. The vessel suffered from heavy wave induced impacts when sailing between Helsinki and Stockholm already at moderate seas. Strain gauges and pressure pick-ups were installed to measure these impacts. Loads exceeding 400 kN/m^2 were measured below the knuckle line in the area with smallest flare angle in bow quartering seas with significant wave height of about 2,5-3m.

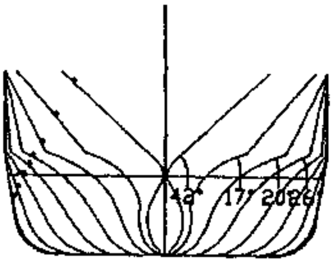
Model test results together with the different dimensioning loads are presented in *figure 7* for two ferries. *Figure 7.1* presents a ferry designed and built according to the old IACS. Model test results were taken seriously by the owner, not by the classification society or by the yard. The owner had already some bad experience of existing ferries in heavy winter weather; bow visors had been welded into the deck to keep their integrity and tightness. The first change was to go for bow doors instead of visor and additional steel of about 200 tons was placed in the bow flare at the owner's account. The vessel has been sailing in extremely bad weathers without damages.

Model test and full-scale measurements are not directly comparable with the dimensioning loads. Measurements are giving values for limited area whereas dimensioning loads are given for much larger area. In this respect the old IACS gives, however, no difference, and the new IACS seems to give also lower loads than DNV. Only the DNV rules take into account the actual hull shape.

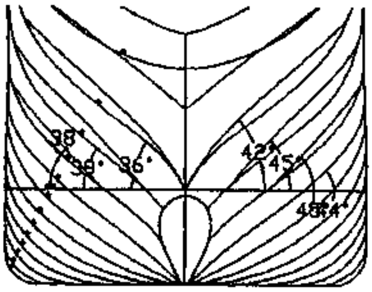
4. CONCLUSIONS

- 'Estonia' had a very extreme hull form in the bow, very low bow flare angles against waterline.
- The extreme bow flare with convex type frame shape causes high wave induced impact loads already at moderate bow quartering seas.

- The ship had suffered already on the original route Turku – Stockholm from wave induced noise and vibration as well as from high additional wave resistance in bow quartering seas.
- The applied design loads in the bow area were not in accordance with the size of the vessel, the hull shape and the actual foreseen loads.
- Only DNV rules take into account hull shape in defining dimensioning loads.
- DNV rules seem to correlate reasonably well with the available measured bow flare loads on model and full scale.



1.1



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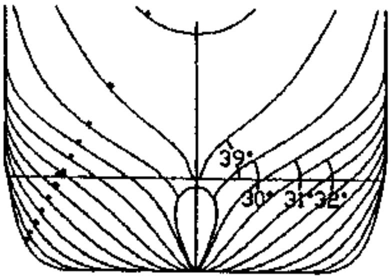

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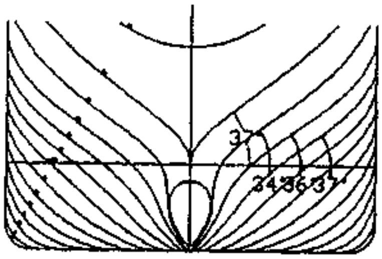

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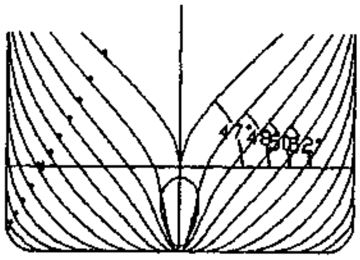

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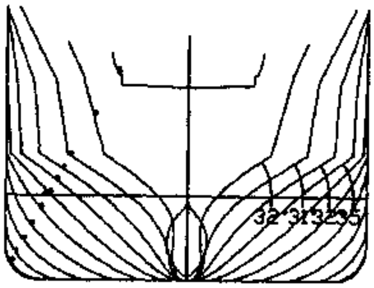

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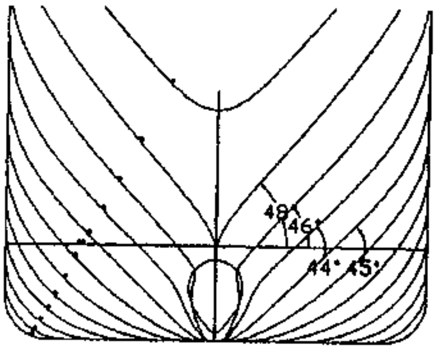

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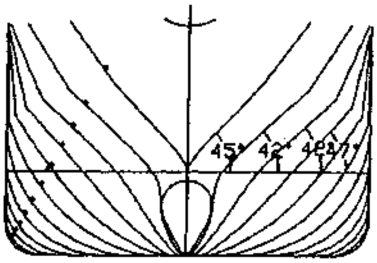

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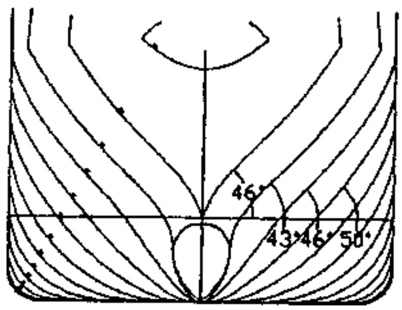

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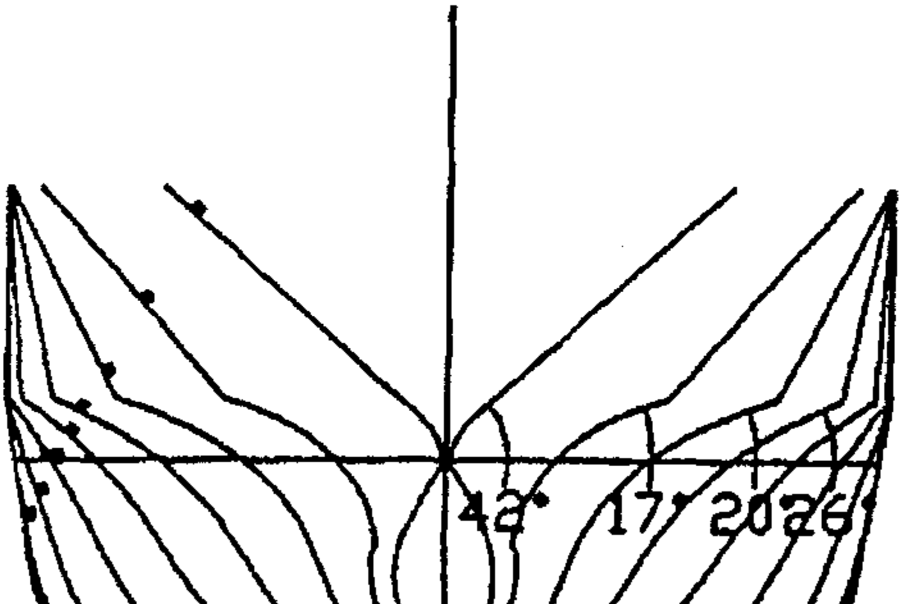

1.1

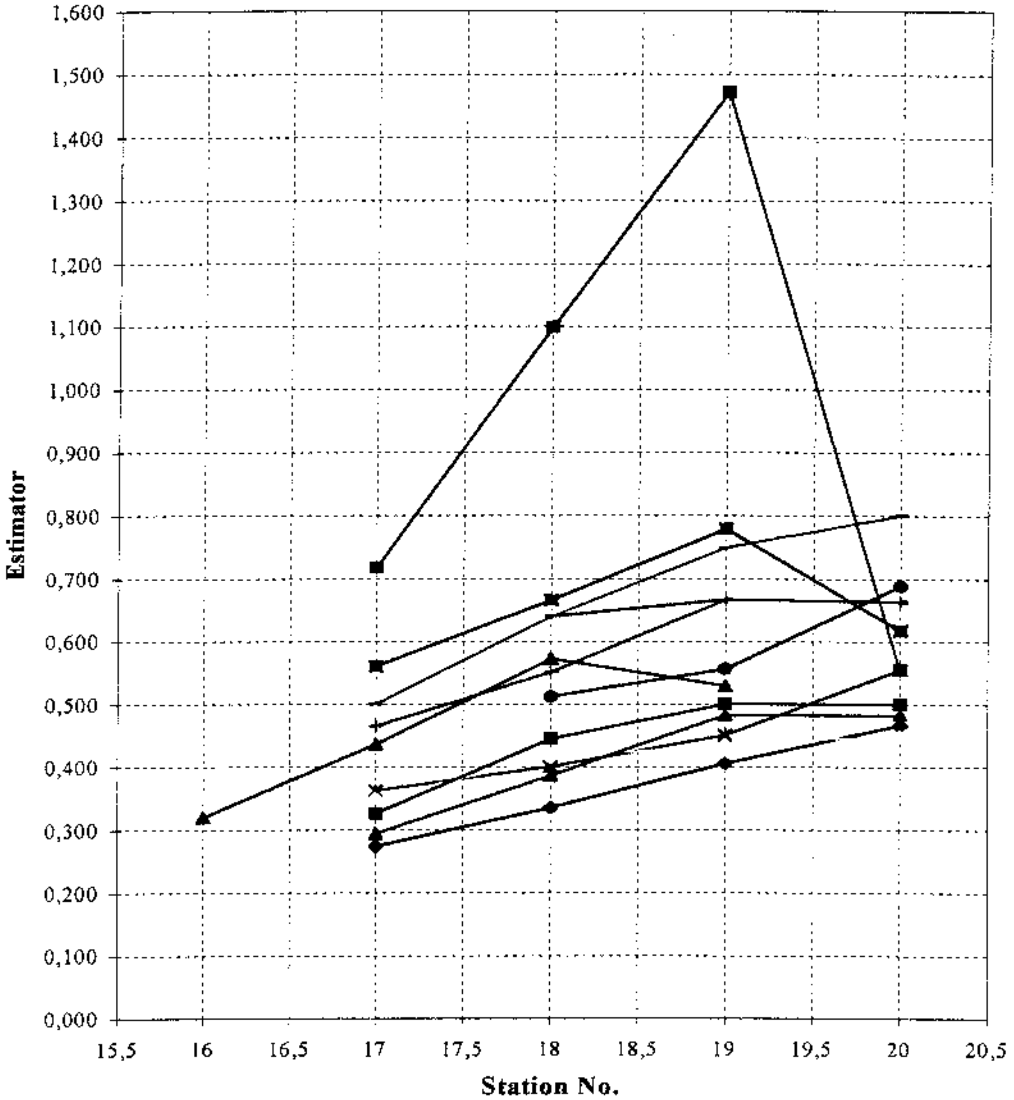

Figure 2. Bow flare estimator for ferries. Non-dimensional distance from midship divided by the tangent of flare angle.

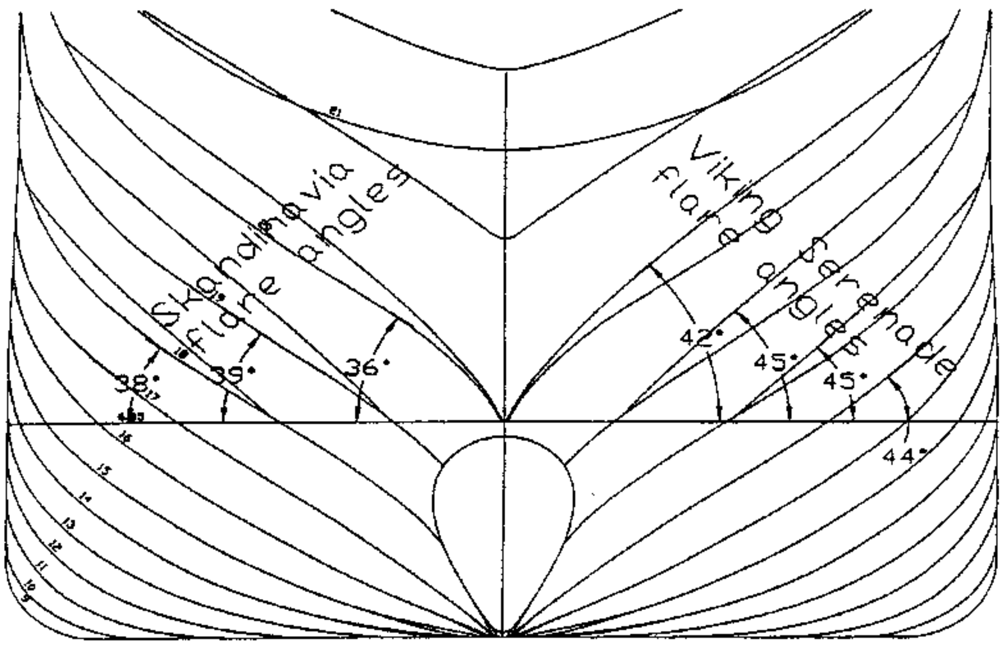

Figure 3.

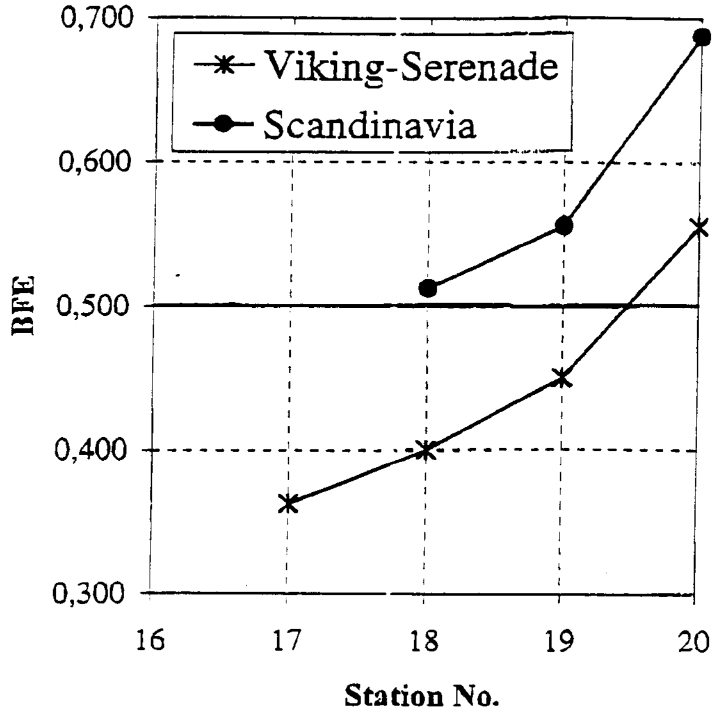

Figure 4. Bow Flare Estimator values for the original (Skandinavia) and modified (Viking Serenade) bow forms.

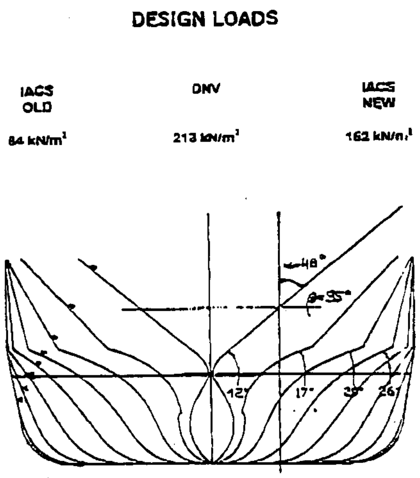

Figure 5.1

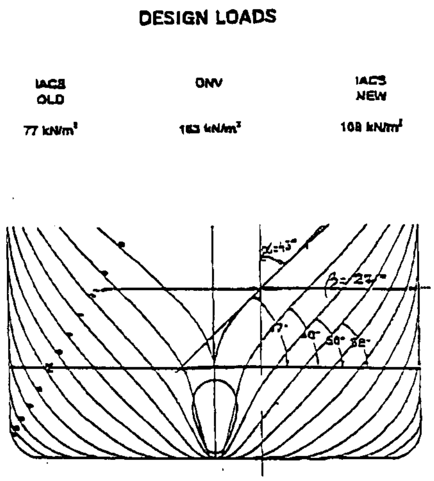

Figure 5.2

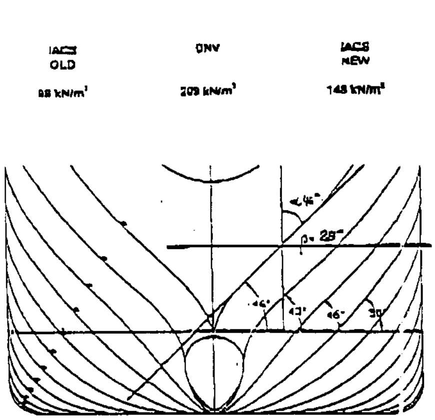

Figure 5.3

DESIGN LOADS, MAXIMUM FLARE AREA

IACS OLD	DNV (37.5% of max. value)	IACS NEW
84 kN/m²	304 kN/m²	256 kN/m²

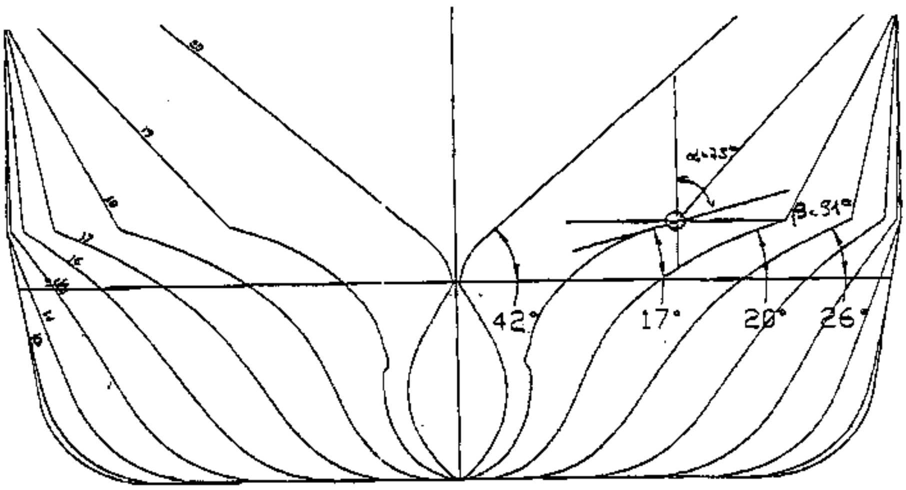

Figure 6.

DESIGN LOAD
ACCORDING TO RULES
SPEED 19.5 KNOTS

IACS OLD	DNV (*	IACS NEW	
77	281	77	kN/m2

(* peak value

MODEL TEST VALUES

	Wave direction		
Speed(kn)	Bow quartering	Head seas	
15	210	145	Sign. wave height 4 m
10	200	132	8 m
	Max. load(kN/m2)		

Panel location: x 127m, z 6.8m

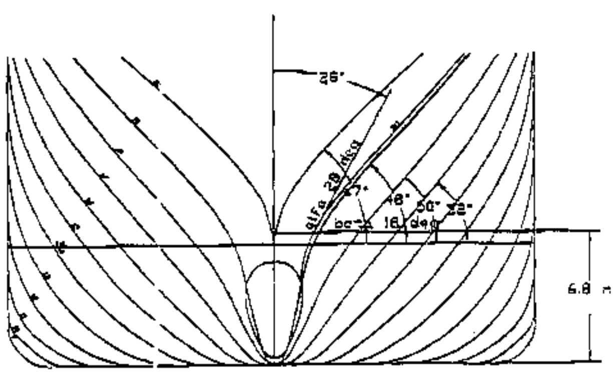

Figure 7.1

DESIGN LOAD
ACCORDING TO RULES
SPEED 21 KNOTS

IACS OLD	DNV (*	IACS NEW	
88	414	112	kN/m2

(* peak value

MODEL TEST VALUES

	Wave direction		
Speed(kn)	Bow quartering	Head seas	
10	[illegible]	[illegible]	Sign. wave height 3.75 m
21	[illegible]	[illegible]	[illegible] m
	Max. impact load(kN/m2)		

Panel location: st 18, z=7.9m

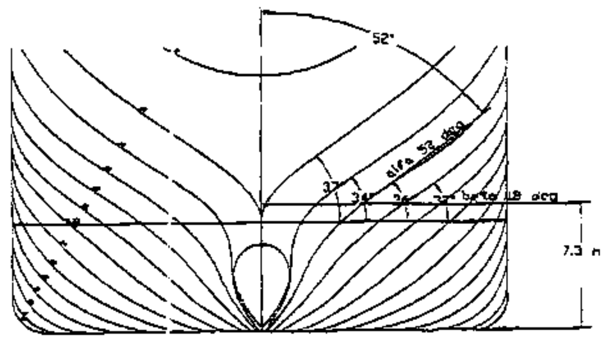

Figure 7.2