EXPERIENCE WITH DOUBLE HULL TANKERS
AN OWNER'S VIEWPOINT

PRESENTED BY:

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ON BEHALF OF

TSCF WORKING GROUP PROJECT # 3

AT

TANKER STRUCTURE CO-OPERATIVE FORUM

2000 SHIPBUILDERS MEETING

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ABSTRACTS:

Experience with DH Tankers - An Owner's Viewpoint

Bergesen had three VLCCs delivered from Japanese yards in 1993 and 1994. All vessels could have been built as single hull vessels, but the Exxon Valdez incident gave the industry sufficient warnings from both IMO and USCG that the single hull SBT type tankers designs were to be modified to reduce the possibilities of cargo outflow in case of collision or grounding.

In cooperation with NKK Corp. different alternatives were studied since no clear preference or requirements had been given at the time where we had to decide what to do. In the end a double hull vessel was selected. A traditional tank arrangement was chosen with five centre tanks and five pairs of cargo wing tanks. Correspondingly five pairs of ballast water tanks were arranged as side tanks. The ballast side tanks were provided with partial stringers in way of the transverse bulkhead and horizontal cross-ties arranged in the cargo wing tanks. Attention was paid to the details of the cut out for longitudinals and of the connections between the side longitudinals and the web frames.

In order to reduce the maintenance cost of important components in the future, strict requirements were made to the choice of materials in cargo and ballast systems.

Attention was paid to the paint quality in general but also to the painting of the ballast tanks. Unfortunately no coating was done in the cargo tanks except for the sumps.

TABLE OF CONTENT

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1. INTRODUCTION

Bergesen contracted three double hull VLCCs in Japan in 1991; two at NKK Corp. and one at Sumitomo Heavy Industries. All three vessels were contracted as single hull vessels with option to convert to double hull, double bottom, double sides or whatever might be required by IMO.

Bergesen was basically not in favour of double hull vessels and would have preferred immediate implementation without further delay of the requirements of MARPOL 73/78 for SBT vessels, because reduced risk of oil spill for the SBT vessels was evident. The requirements for double hull might have been introduced for more political rather than for technical reasons. By the time we had to decide single hull or double hull, no clear indication of what would be mandatory was known. Independent technical consultants and ship building yards made several proposals. The mid-deck tanker from Mitsubishi with full support from Intertanko, the Columbi egg and a couple of other tried to be wise, but neither of them had in our opinion any practical advantage. NKK made several proposals, which we discussed in detail. But both at NKK and SHI there were really only the two options; single or double hull vessels. We ended up with double sides and double bottom. Due to the B/15 temporary requirement, we decided on a double bottom height of about 4 meters, and the width of the double sides was then more or less given. Because of easier maintenance and inspection the end result was 3 meters height in double bottom and 3.740m in the water ballst side tanks. At Sumitomo two double hull vessels had already been contracted and Bergesen accepted their double hull design.

After MARPOL's 1978-decisions to require SBT for tankers, the shipyards became very much in favour of using HT-steel to minimize the steel weight and be more competitive. Most ship yards argued that the reason was to save energy or increase the speed, but in reality it was to build cheaper vessels due to reduced steel weight. Today we all know that the amount of HT-steel was not successful seen from a shipowner's point of view. Too many failures occurred in the structure because parallel by using more HT-steel a continuous refinement of the computer programmes took place. Minimum bending moments according to Class Rules were mostly used and the need of shifting ballast water to reduce bending moments for certain loading conditions was often necessary. Less

than 10 years ago fatigue analysis became for us an important subject for discussion with the Builders. To implement some wording in the technical specification about fatigue became necessary, but the scope of these calculations was in general difficult to agree upon with the Builders. This may have had its reason in different requirements and procedures of all major classification societies.

2.Basic Requirements

If HT-steel were to be used a common census existed between the classification societies: The following conditions should be fulfilled;

1. The details must be made more perfect.
2. The workmanship had to be improved.
3. The tolerances had to be smaller.

When Bergesen made the VLCC contracts with NKK, we had already some experience with this yard. Two years earlier we had contracted four LPG carriers with NKK. Based on our own experience from the building of two ULCCs in Japan ten years earlier, the experience already known through the TSCF, and of course NKK's own experience, we decided to limit the use of HT-36 steel to deck and bottom only. The remaining steel should be of HT-32 steel. The consequence of that was about 1.000 tons additional steel. As these double hull VLCCs were the first vessels for both Bergesen and NKK, a comprehensive detailed FEM analysis was carried out. Double hull vessels will have higher still bending moments both in laden and ballasted condition. For that reason we required that the longitudinal strength should have enough margins and the water ballast tanks should not have reduced filling in any loading condition.

Without doubt, the biggest problem for an operator is when he is facing leakage between water ballast tanks and the cargo oil tanks. We are proud to state that the double hull vessels from NKK and SHI have served the owner and the charterers so far without any technical problems except for the inner bottom plating of the cargo tanks which I will revert to later.

3. Items agreed with Builder.

At this point it may be relevant to make a review of the basis which was behind these designs. When the decision for double hull had been made, both NKK and Bergesen agreed on some critical areas that had to be investigated in more detail. This may be summarised as follows:

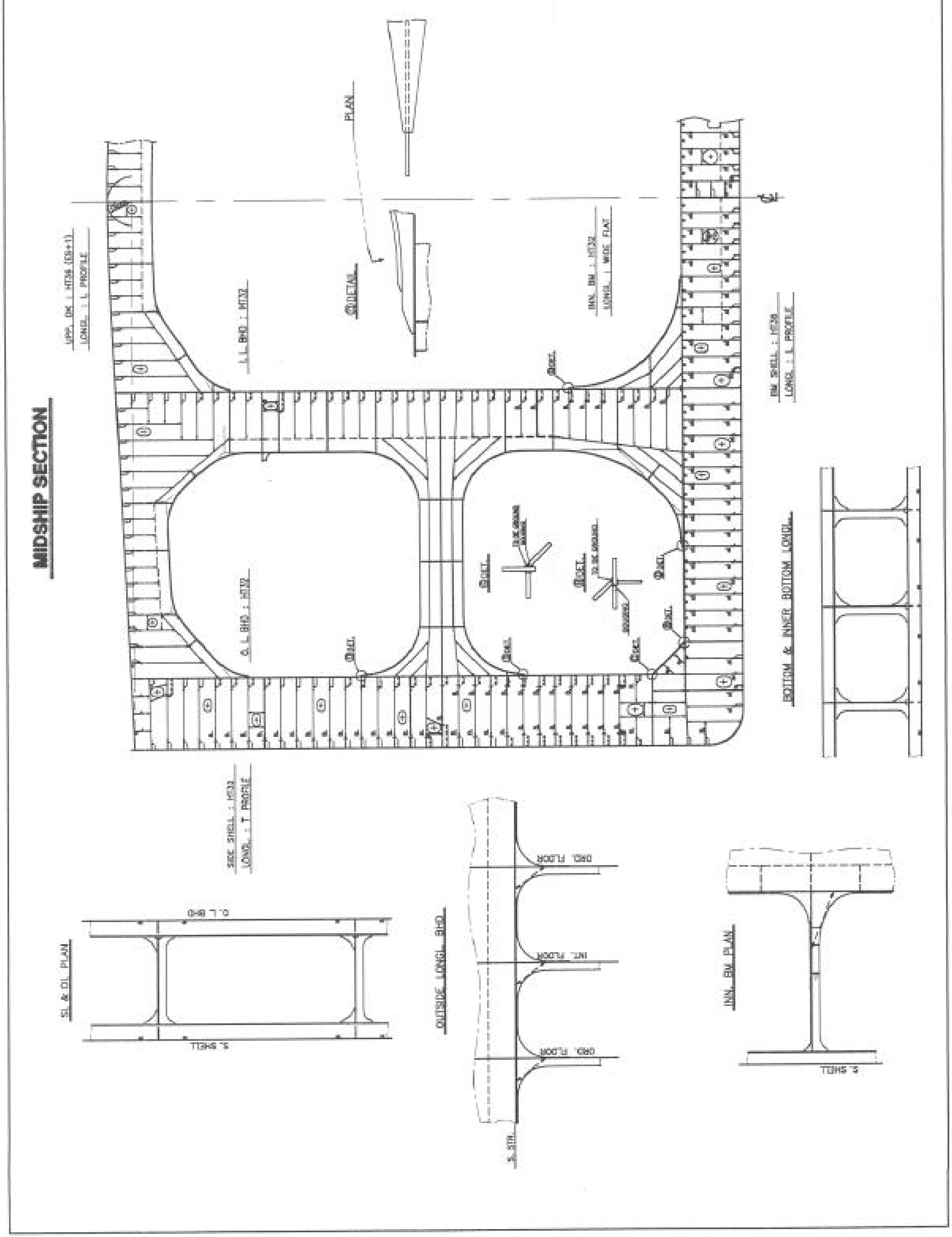
- Loading conditions and longitudinal strength

- HT-36 steel to be used in deck and bottom structures only with one mm added steel in the deck plating – Fig 1.
- T-profiles to be used in the side longitudinals .
- Fatigue calculations to be performed to give an acceptable life time of the side longitudinals for world wide operation – Fig. 2.
- FEM analysis to be carried out on certain structures - Fig 3 & Fig 4.
- Horizontal struts to be arranged in the cargo wing tanks and not in the centre tanks.
- Hopper plate in the cargo wing tanks to be slanted 45 degrees - Fig. 5
- Partial horizontal stringers to be arranged in the water ballast tanks at the transverse bulkheads
- Double brackets to be fitted on the side longitudinal and in the DB structure - Fig 1.
- Grinding of welds where fatigue could be a problem.
- Check the filling ratios of the cargo tanks versus the vessel's natural pitch and roll motions - Fig 6 & Fig 7.
- Implementing operating experiences with tankers previously built.
- Accessibility for maintenance and inspection from three walk ways - Fig. 8.
- Inerting of ballast tank.
- Choice of materials in seawater and crude oil pipes.

4. Items not Agreed with Builder.

- T-profiles on outer shell in double bottom
- Slab type profile in deck longitudinals to prevent solids from the cargo.

Figure 1


MIDSHIP SECTION
BOTTOM & INNER BOTTOM LONGL.
SL & OL PLAN
OUTSIDE LONGL. BHD
INN. BM PLAN
PLAN
S. SHELL
O. L BHD
ORD. FLOOR
INT. FLOOR
S. STR.

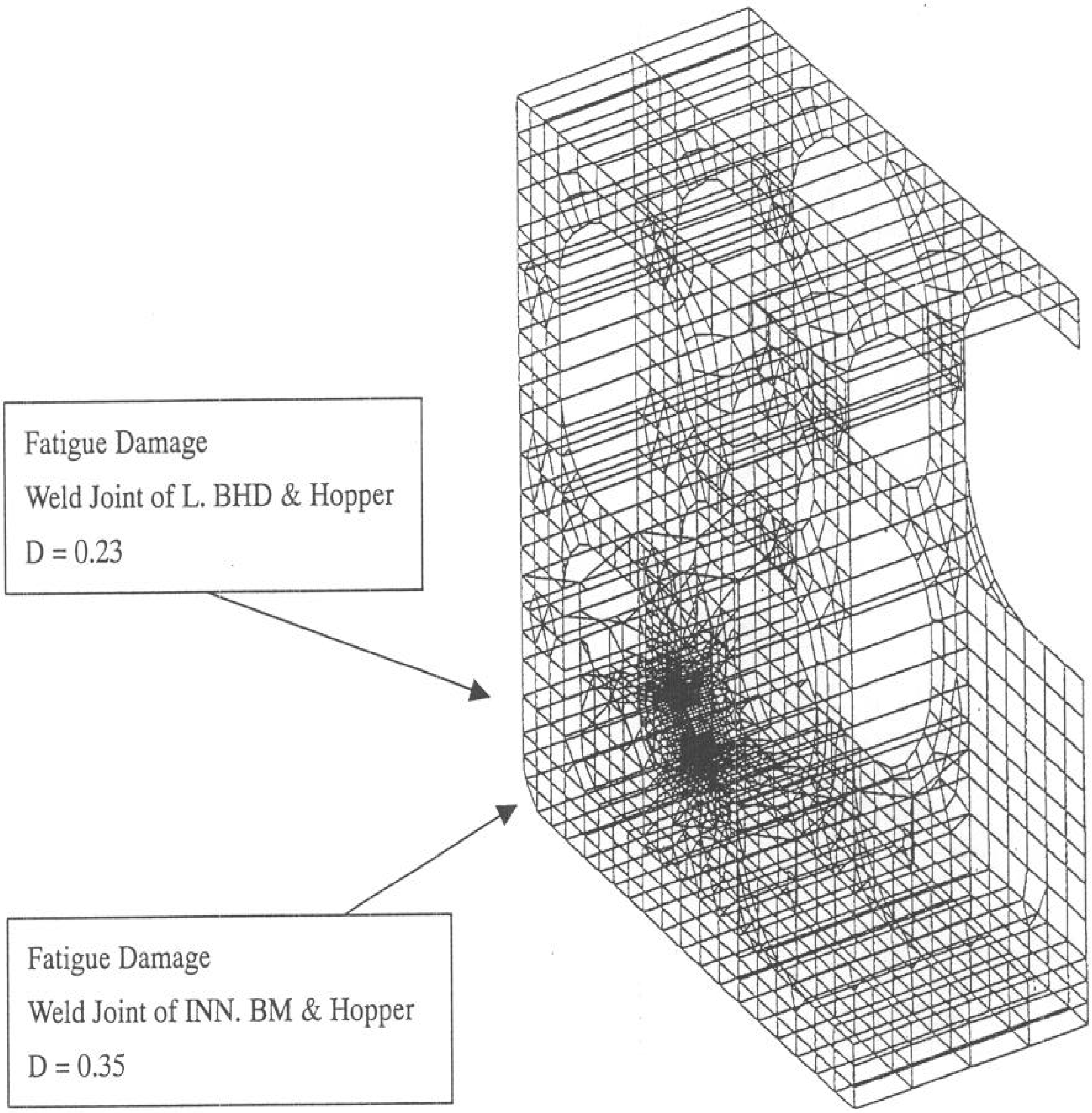


Fig. 2 Fatigue Strength Assessment

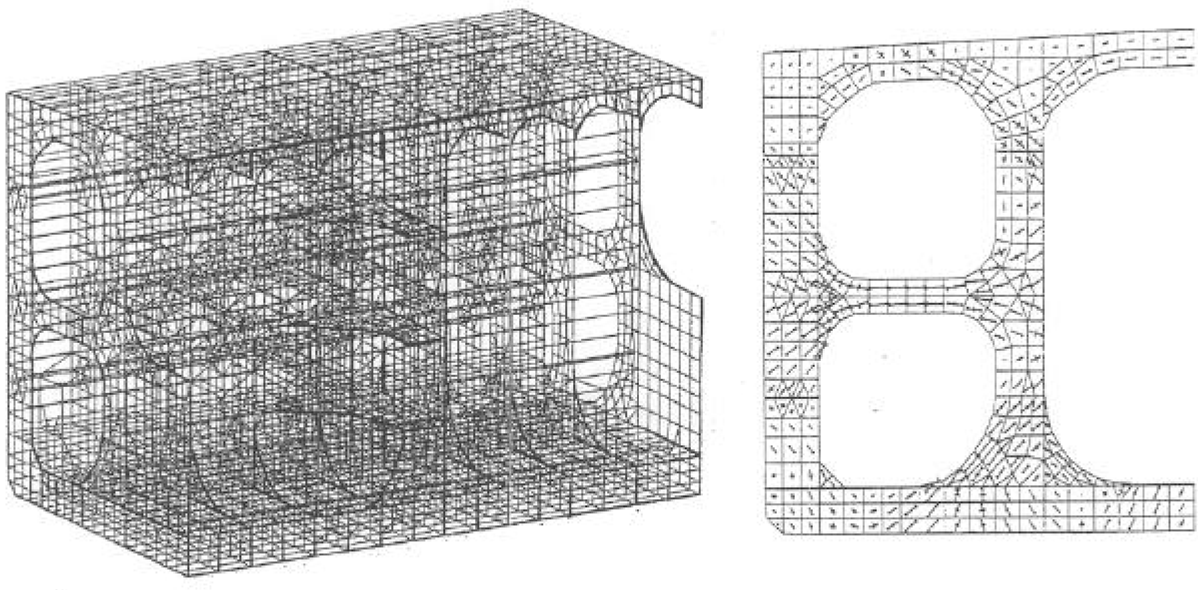


Fig. 3 Cargo Tank FE Model & Result

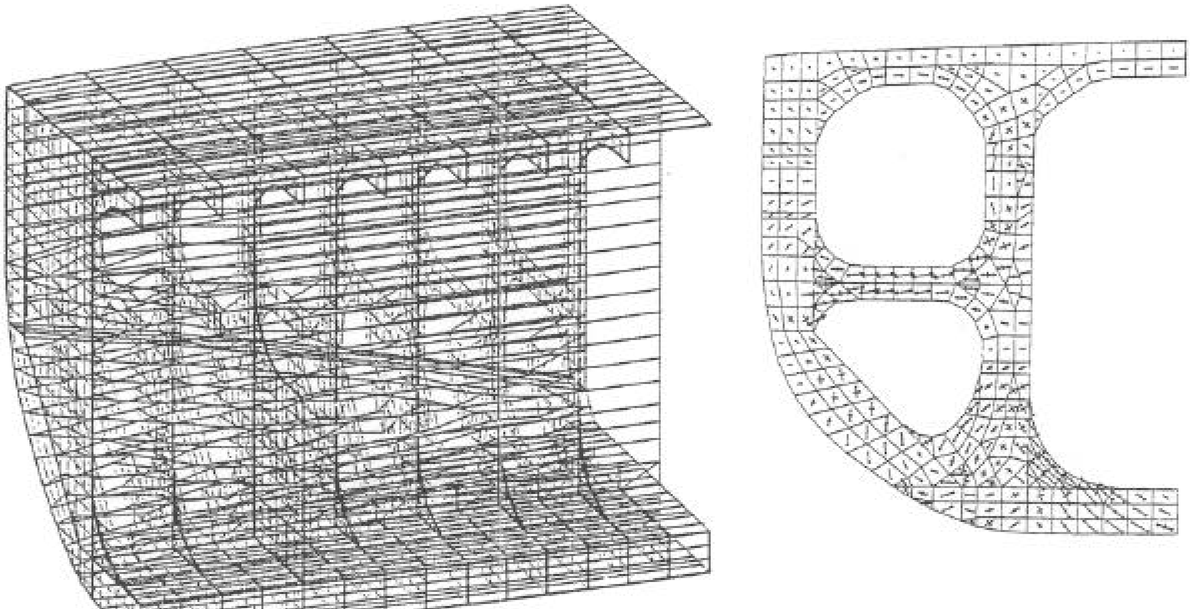


Fig. 4 After Cargo Tank FE Model & Result

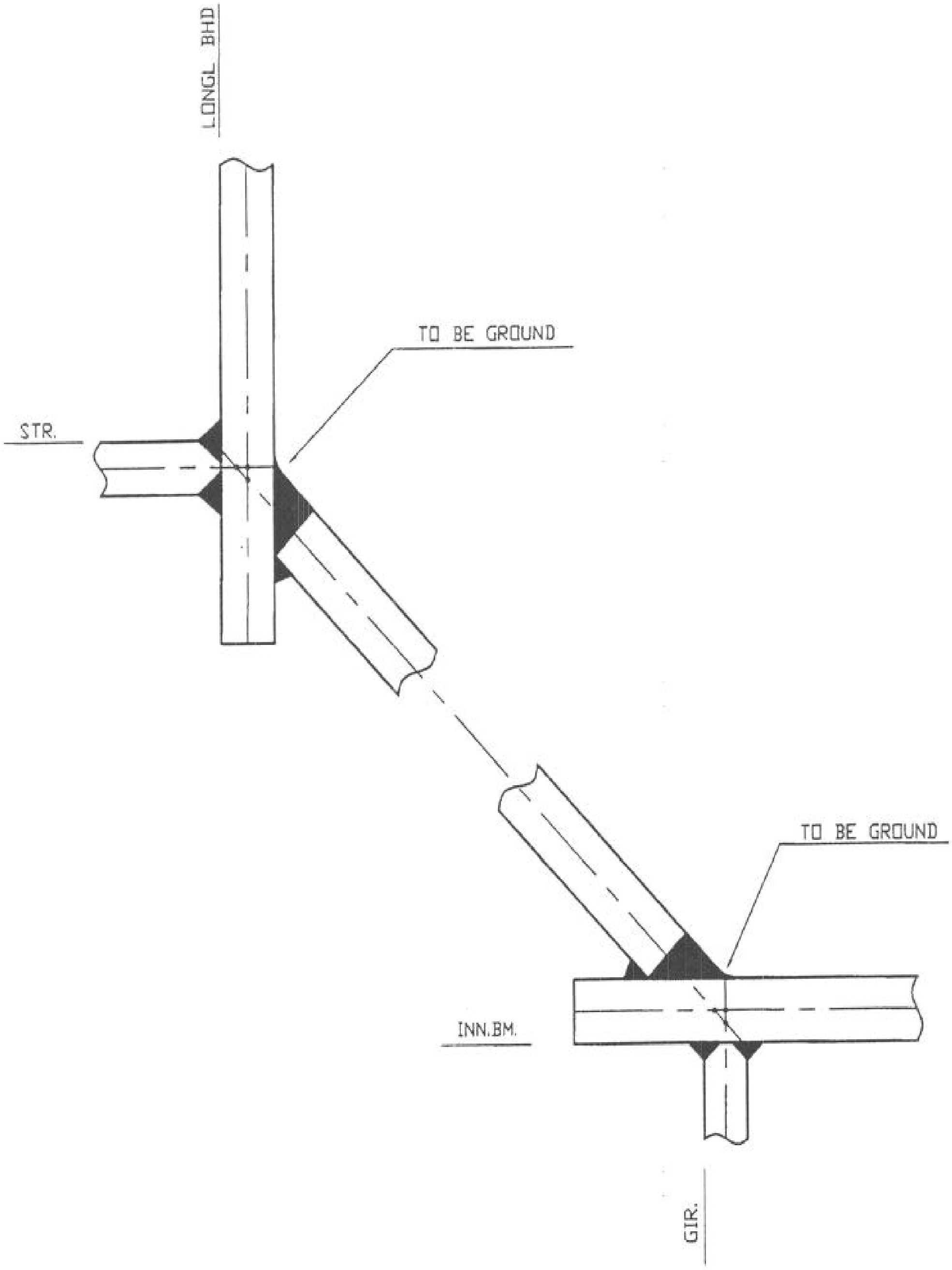


Fig. 5 Weld Detail at Hopper Joints

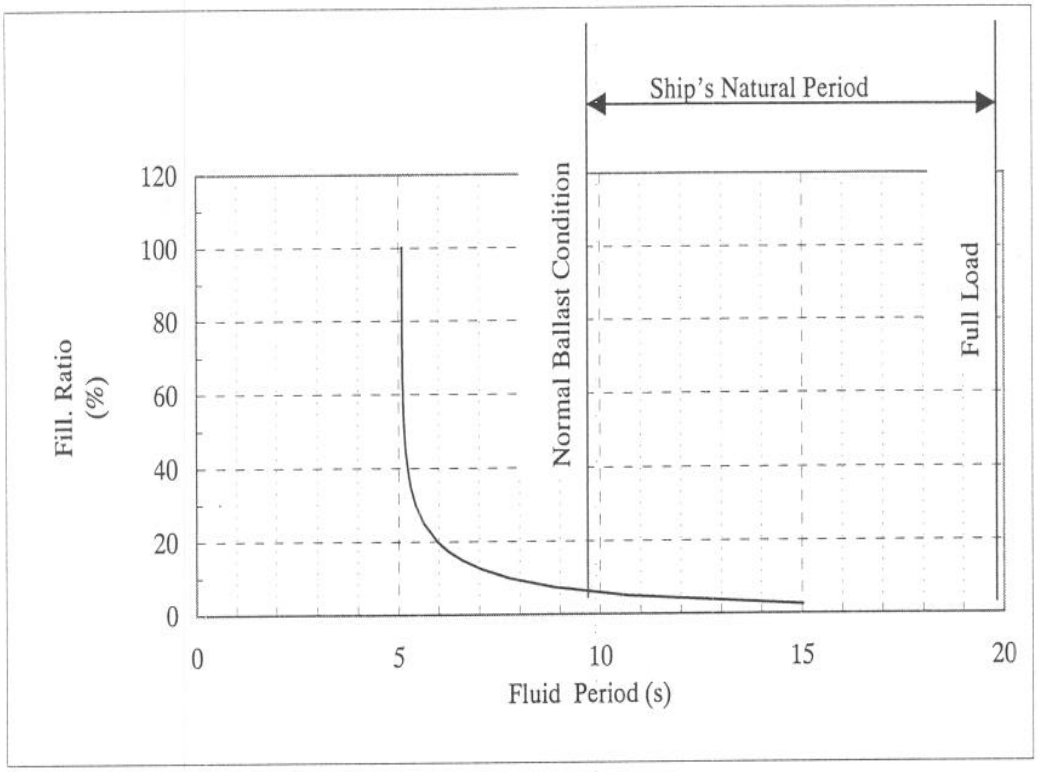


Fig.6 Fill Ratio VS Natural Period (Roll)

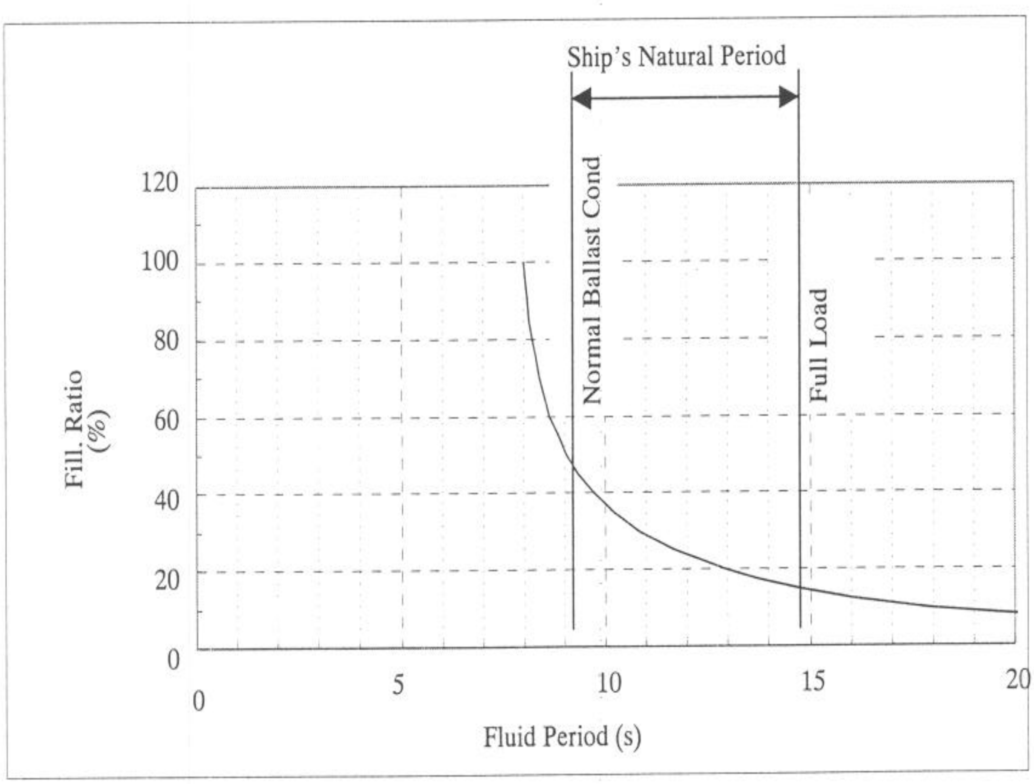


Fig. 7 Fill Ratio VS Natural Period (Pitch)

ACCESS IN CARGO TANK

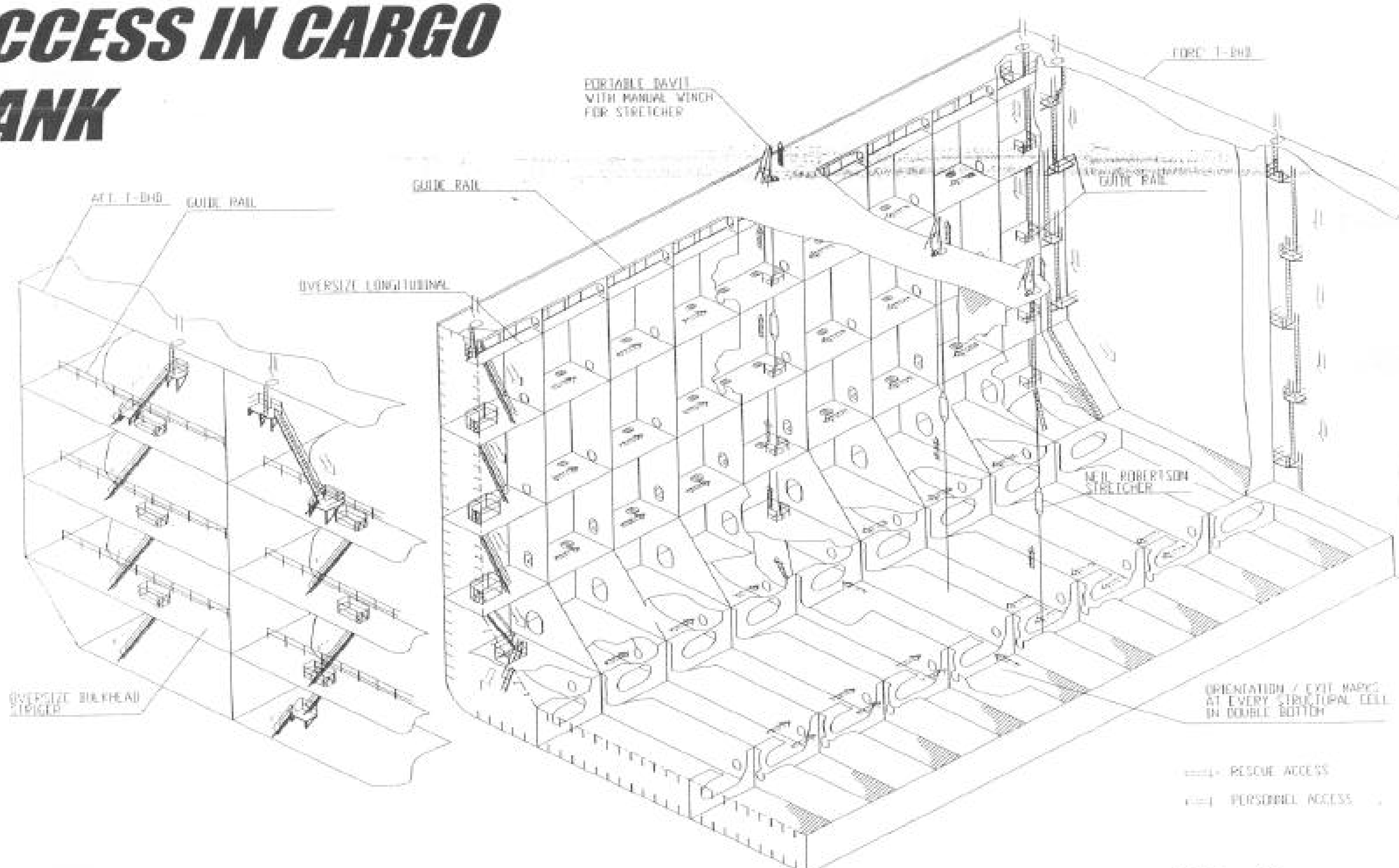


FIG. 8

RETURN

5. Corrosion Protection in Ballast Tanks.

Two different paint manufacturers were used for three vessels but only one manufacturer per vessel. All paint works including surface preparation and application were carried out in accordance with the builders' standard and the paint manufacturer's recommendation. This is always a standard phrase in any Builder's specification and these standards vary from yard to yard. Plates of 4.5 mm in thickness and above were shot-blasted to a minimum standard of Sa 2.5. Soon after shot-blasting a zinc primer was applied on all surfaces to be painted. In general the steel blocks were then shortly afterwards painted with the first coat of coal-tar epoxy paint. Some blocks were completely re-blasted and painted with the coal-tar epoxy paint without the zinc shop-primer. Sharp edges from lighting holes, scallops and other openings in the ballast tanks were ground smooth and received two stripe-coats between the two full coats of 125 microns each. The block joints inside the ballast tanks were mechanically cleaned whilst the outside part was swiped or blasted.

The standard as indicated above has given good results during the first five years and only small amounts of mechanical damages have been repaired. On one vessel, however, we have noted that the coating is more brittle than on the other vessel with a different paint manufacturer but the general conditions are equally good. We are watching this very carefully to see how it develops.

6. Crrosion in Cargo Tanks and Vapour Spaces.

Due to previous good experience with single hull ULCCs built as SBT tankers we did not expect much difference with respect to corrosion in the cargo oil tanks. The ULCCs had been in service for more than ten years with a very moderate and acceptable corrosion rate. Based upon our own experience there was no reason for coating the cargo oil tanks. We discussed the possibilities to coat the cargo tank bottoms or under the deck area, but there was insufficient evidence that the coating was needed. It is also fair to say that the price offered for coating the areas gave us no choice. From vessels being delivered in 1993, there were rumours that something was happening and that the cargo tanks needed to be inspected with shorter intervals than normal. For that reason we decided to apply a shop-primer in the cargo tanks. About 80 % of the area was covered. The vessels were thoroughly surveyed after 3 years in service. The condition of the tanks can be summarised as follows:

6.1 Under deck area

Sheets of scale are detaching on the plates while only minor sheet detachments had occurred on the deck longitudinals. The samples of scales on the web of the longitudinals were collected.

6.2 Transverse bulkheads

These were shop-primed at the newbuilding stage. Traces of flaking were found, mainly on a web of the vertical stiffeners, which were not shop-primed. The transverse plating was shop-primed. Very few flakings were found on the black belts – these came mostly from the slots of the horizontal stringer above. The flakings on the vertical stiffeners were found between the tank top and No. 1 horizontal stringer. Generally, the flat surface was smooth throughout the tanks with a powdery scale, but no hard scale was found on it.

6.3 Longitudinal bulkheads

The surface was smooth without hard scale on it. No burning traces were visible on the heat effected zones from the welding of the stiffeners on to the longitudinal bulkhead, nor from the butt joints. Occasionally blisters were found in the aft bay on the first longitudinal at the bottom of the tank. In way of No. 1 horizontal stringer on the first longitudinal, a thin, grey hard layer was found. It was not easy to scrape away this hard layer. Scrapings came down in a form of powder dust of grey colour.

6.4 Hopper plate

In Nos. 1 and 3 wing tanks, blisters started to form on vertical black belts. On several places, written marks from the newbuilding stage were still intact. Vertical black belts were found almost all over the hopper plate. The blisters were distributed in the same way. There were more dents at the lower part and fewer at the upper part. The maximum height where the blisters were found, was at the first seam above the tank top. In way of the access openings on the hopper plate, more dent blisters were found. In the forward end of the hopper, few blisters were found.

6.5 Tank top

A few pittings and bear patches (footprint shape) were found. Very little scale was found. The pits which were found had an average depth of about 2mm to 3mm. At the point where the potential was measured, a blue grey coloured surface could be seen.

6.6 Transverse web frames

The surfaces were generally smooth with very small flakings. The cross-ties, which are all in the wing tanks, had a black colour. These cross ties had not been shop-primed at the newbuilding stage. At the bottom of the web frames, very small flaking of scale had begun to form at both sides of the plates. The max height where the flakes could be found was at the first seam above the tank top. Samples of the flakes were collected.

7. Observations.

Photos were taken from the inspections above and are shown on photo no. 1 to no. 18. Table 1 gives a summary of the plate thickness diminution for each cargo tank. Table 2 gives the comparison of thickness diminution between 3 years and 5 years after delivery. The results of the measurements have been shown in Fig. 9. It is worth noticing that the shop-primer used in the cargo tanks for one vessel only delayed the corrosion on the inner bottom by two years. On this vessel the deepest pits were 4-5 mm whilst on the vessels without any primer the pits were up to 7-8 mm deep.

8. Corrosion Products.

The analytical results of the corrosion products can be found in Appendix A. As can be seen various methods have been used in the analysis of the products. The high content of sulphur is due to a low pH value. The NaCl is low as compared to the S and Fe-oxides, but no sea water has been filled into the cargo tanks apart from the sea trials. The result is in good agreement with the paper Bjarne Thygesen read in Intertanko in July 1999: "Condensation of water on the steel surface will form during night time, containing S and S02, and is acidic. Water evaporates during daytime/sun heating, leaving a deposit consisting of S, SO2 and traces of CO2. pH values as low as 1 were reported".

Results of Thickness Measurement

Table. 1 Summary of Plate Thickness Diminution

Structure	Diminution (mm at 3 years)			Diminution (mm at 5 years)		
	average	max.	min.	average	max.	min.
Upper Deck Plate	-0.17	-0.7	0.2	-0.29	-1.1	0.5
Deck Longi(web) Upper	-0.31	-0.7	-0.1	---	---	---
Deck Longi(web) Lower	-0.26	-0.4	-0.1	---	---	---
Deck Longi(web) Average	-0.29	-0.6	-0.1	-0.32	-0.7	0.0
Deck Longi(face)	-0.17	-0.5	0.0	-0.18	-0.6	0.2
T.BHD Plate	-0.09	-0.5	0.4	-0.09	-0.6	0.5
Transverse Webframe Plate	-0.11	-0.2	0.1	-0.11	-0.2	0.1
Tank Top Plate	-0.06	-0.6	0.3	-0.23	0.7	0.1
Vertical Stiffner on T.BHD(web)	-0.10	-0.8	0.3	-0.12	-0.4	0.2
Vertical Stiffner on T.BHD(face)	-0.15	-0.5	0.2	-0.23	-0.6	0.2
Swash BHD Plate	0.00	-0.3	0.4	---	---	---
Inner L.BHD Plate	-0.04	-0.4	0.4	-0.09	-0.7	0.2
Outer L.BHD Plate	-0.06	-0.3	0.2	-0.09	-0.7	0.4

Summary of the thickness diminution for each cargo oil tank is shown in Appendix-A.

Gauged locations and the data for the deck plating are shown in Appendix-B.

Gauged locations and the data for the internal structures are shown in Appendix-C.

Comparison of thickness diminution between 3 years and 5 years after delivery.

Table. 2 Comparison of Annual Diminution between 3 years and 5years after delivery.

Structure	Average Annual Diminution (mm/ year)		Ratio
	3 years	5 years	(5 years / 3 years
Upper Deck Plate	-0.07	-0.06	0.9
Deck Longi(web) Upper	-0.12	---	---
Deck Longi(web) Lower	-0.10	---	---
Deck Longi(web) Average	-0.11	-0.07	0.6
Deck Longi(face)	-0.07	-0.04	0.6
T.BHD Plate	-0.04	-0.02	0.6
Transverse Webframe Plate	-0.04	-0.02	0.6
Tank Top Plate	-0.02	-0.05	2.1
Vertical Stiffner on T.BHD(web)	-0.04	-0.03	0.7
Vertical Stiffner on T.BHD(face)	-0.06	-0.05	0.9
Swash BHD Plate	0.00	---	---
Inner L.BHD Plate	-0.02	-0.02	1.3
Outer L.BHD Plate	-0.02	-0.02	0.8

Note:

(1) average annual diminution = average diminution at 3 years / 2.5 and 5 years / 4.5

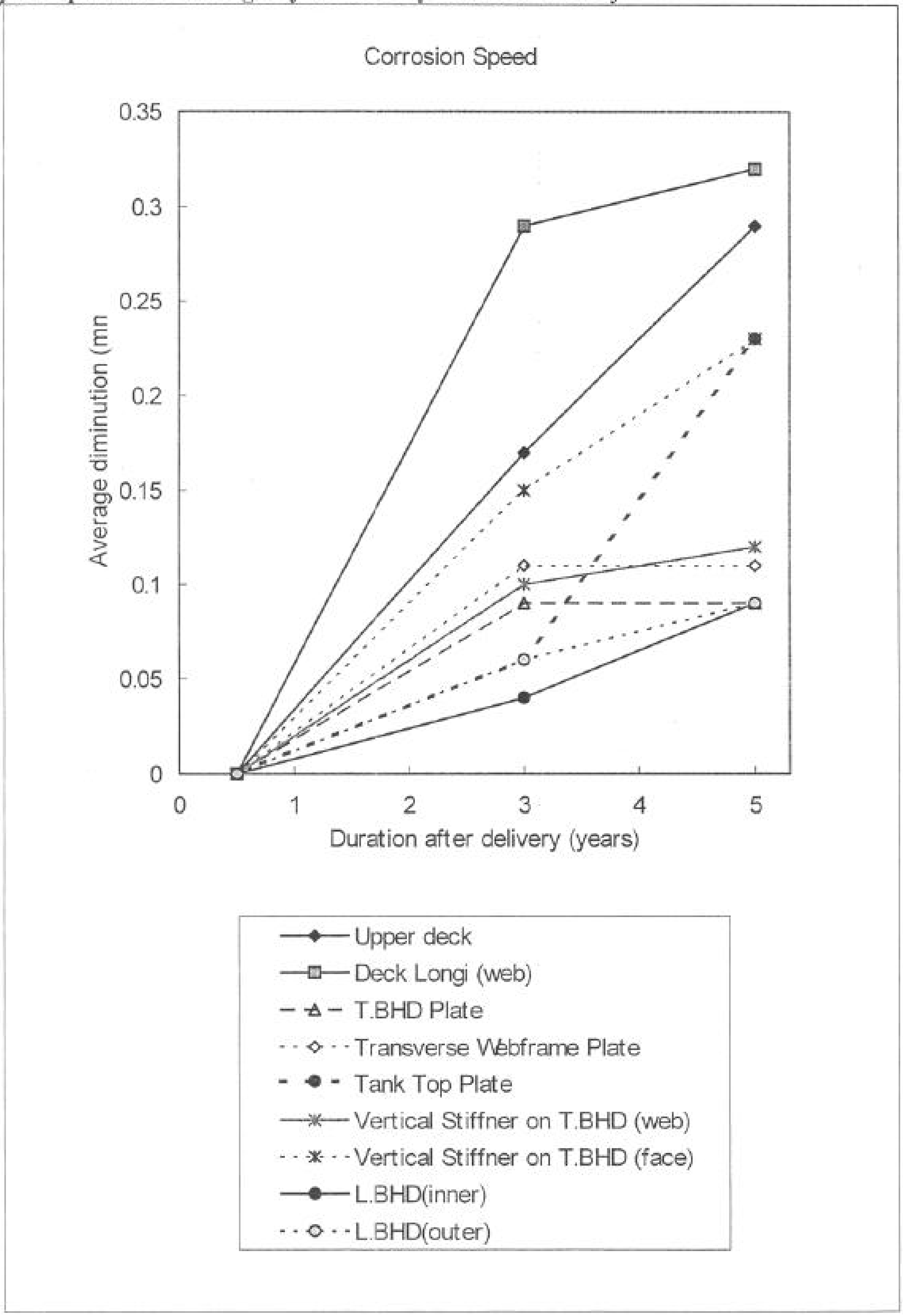
The primer was assumed to have disappeared by half a year after delivery.

Therefore corroded period is to be short half a year.

(3 years in service - 0.5 = 2.5)

(5 years in service - 0.5 = 4.5)

Fig.9.Comparison of wastage 3 years and 5 years after delivery



Analytical Results of Corrosion Product in Cargo Oil Tank (No. 1183 VLCC)

1. Sample

Table 1. Samples of scale

No.	COT. No.	Location of scale	Steel	Morphology
1	1C	Deck Plate	NV-A36	Flaking
2	3S	Hopper Plate	NV-A32	Blister
3	3S	Deck longitudinal Web	NV-A36	Flaking
4	3S	FR 80 Transverse webframe Stiffener	NV-A32	Flaking (very small)
5	3S	FR 79 Transverse webframe Plate	NV-A32	Flaking (very small)
6	3S	Transverse Bulkhead Vertical Stiffener Web	NV-A32	Flaking
7	3S	Transverse Bulkhead Plate (between v. stiffeners)	NV-A32	Flaking & Blister
8	5S	Transverse Bulkhead Vertical stiffener Web	NV-A32	Flaking
9	5S	Transverse Bulkhead Plate (between v. stiffeners)	NV-A32	Flaking & Blister
10	5S	LL 59 (1st Longil above No1 HG) Web	NV-A32	Hard layer

C : Center Tank
S : Wing Tank (Starboard)

A32 : YP32/HT (A grade)
A36 : YP36/HT (A grade)

2. Analysis item

1) X ray diffraction

Identification of rust component
Quantitative analysis (KCl internal standard method)

2) Chemical Analysis

Mn, Si, Mg	: ICP
Na	: Atomic adsorption spectro-photometry
Cl	: Ion chromatography
T-Fe, T-S	: Thermal decomposition-Ion chromatography

3. Results

1) X ray analysis ---------- Table 2.
2) Chemical analysis ---------- Table 3.

Table 2. Results of X ray analysis of scales.

No.	Indentified product	Fraction (%)			
		-FeOOH	-FeOOH	-FeOOH	Fe_3O_4
1	-FeOOH, S	30.88	0	0	0
2	-FeOOH, Fe_3O_4	30.14	0	0	29.04
3	-FeOOH, S	28.93	0	0	0
4	-FeOOH, Fe_3O_4	31.03	0	0	7.06
5	-FeOOH, Fe_3O_4	47.14	0	0	19.69
6	-FeOOH, Fe_3O_4	27.11	0	0	8.17
7	-FeOOH, Fe_3O_4	33.88	0	0	12.75
8	-FeOOH, Fe_3O_4	39.39	0	0	14.25
9	-FeOOH, Fe_3O_4	27.59	0	0	13.01
10	-FeOOH, Fe_3O_4	21.12	0	0	6.48

Table 3. Results of chemical analysis of scales. (Wt%)

No.	T-Fe	T-S	Cl	pH	Mn	Si	Na	Mg
1	33.7	30.8	0.48	2.9	0.2	0.1	0.31	0.1
3	28.3	25.2	0.04	2.8	0.2	0.1	0.06	0.1

9. Coating of Cargo Tanks.

Due to the above results from inspections it was decided that the tank top in all cargo tanks should be painted at the first special periodical survey. All the tanks were cleaned an de-greased wherefore hydroblasting was carried out. Contaminations like grease, salts, oil etc. had to be removed. After successful cleaning the tanks were grit blasted to a minimum standard of Sa. 2.5. The content of chloride was checked. The max. chloride level should be below 60 mg/m2. At least 200 mm of the vertical sides should be blasted. A full coat of paint was applied on all blasted areas with the specified dry film thickness of 600 my (DFT). Following that a stripe coat was made on all scallops, edges and difficult places to achieve overall thickness. Finally we should point out that all work was carried out in accordance with the paint manufacturer coating procedure and their manual.

(NB! A series of photos may be shown from the a.m. treatment if desirable.)

10. Areas Susceptible to Stress Concentrations.

After more than six years in operation it may be interesting to note that the critical areas of the midship structure that were chosen have proven satisfactory according to our basic requirements when using HT-steel. I would therefore like to draw your attention to the Guidance Manual for the Inspection and Maintenance of Double Hull Tanker Structures which Mr. Rynn from ABS also has referred to in his paper.

The so-called “critical areas” are shown by the marked squares in the corners of the vital points on figure 3.6. In the following I would like to compare the different figures in the TSCF

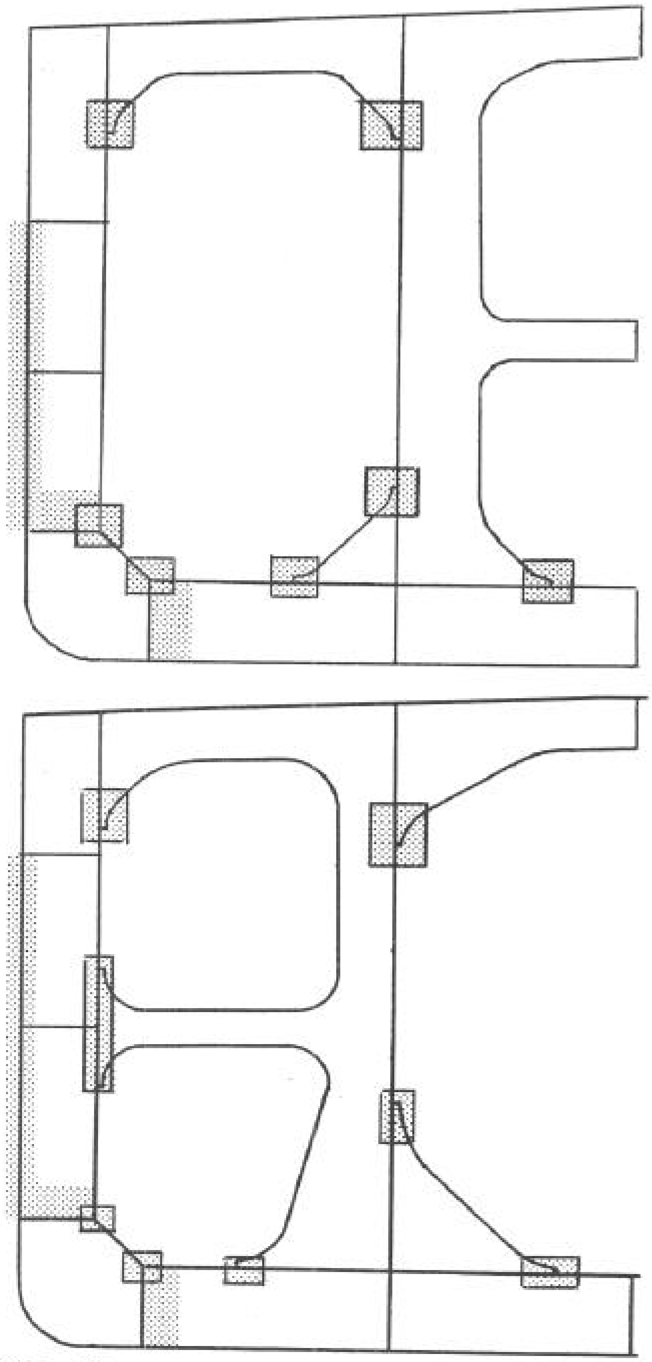
Guidance Manual to the equivalent details on our double hull tankers that were built prior to the publishing of the Manual.

A school example where high stresses will cause cracks is the juncture of hopper plate to the inner bottom plate as shown in Fig. 1. The cracks shown in the bottom plating and in the floor below will not occur if proper attention is paid to those details as shown on the sketches taken from our VLCCs. Both increased plate thicknesses as well as avoiding the scallops are of importance. This is shown in Fig. 4 of the Manual.

Similar defects may be found in the inner hull longitudinal bulkhead where this is connected to the hopper plate. Fig. 9 from the Guidance Manual shows two types in the proposed repair and also a new construction. We have used both types in our newbuildings as previously shown. You may note that the additional bracket which is fitted underneath the inner longitudinal bulkhead can only be done if the hopper plate is not too much inclined. Examples from our two vessels can be shown. It should also be noted that the longitudinals on the inner part of the hopper plate should be fitted with lugs in way of the transverse girder.

Probably the best known examples of cracks have occurred in the side longitudinals in way of the web frames and in the web frame itself. The double bracket solution as shown in the TSCF Guidance Manual Fig. 16 has in our opinion proved to be the best alternative. We adopted the same in our newbuildings as shown before.

An other example which we also would like to recommend is the back brackets in the double bottom as shown in Fig. 20 in the Guidance Manual and on App. E which shows the detail as built.

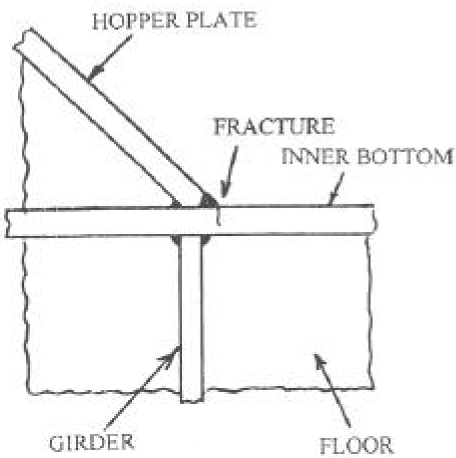


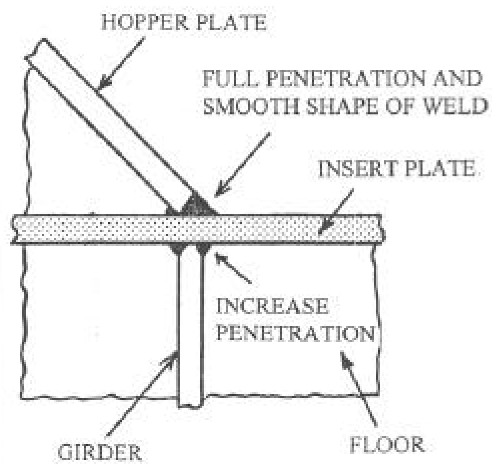
STRESS CONCENTRATION
MISALIGNMENT

FIGURE	TANKER STRUCTURE CO-OPERATIVE FORUM	FIGURE
3.6	SUBJECT: AREAS SUSCEPTIBLE TO STRESS CONCENTRATION AND MISALIGNMENT ON MIDSHIP SECTION OF DOUBLE HULL TANKERS WITH LONGITUDINAL BULKHEADS	3.6

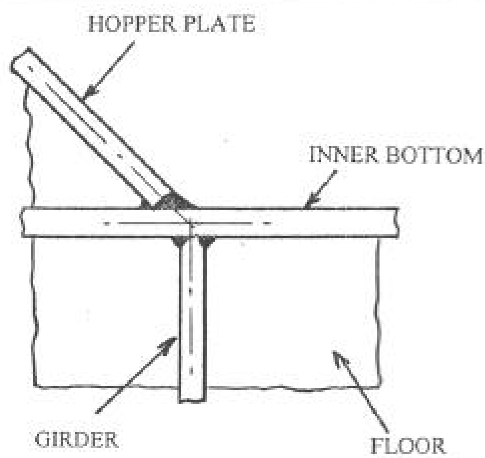
LOCATION : BILGE HOPPER EXAMPLE : CONNECTION OF HOPPER PLATE TO INNER BOTTOM NO 1	GROUP NO 1

TYPICAL DAMAGE	PROPOSED REPAIR





NEW CONSTRUCTION



Notes: Plate midlines intersect.

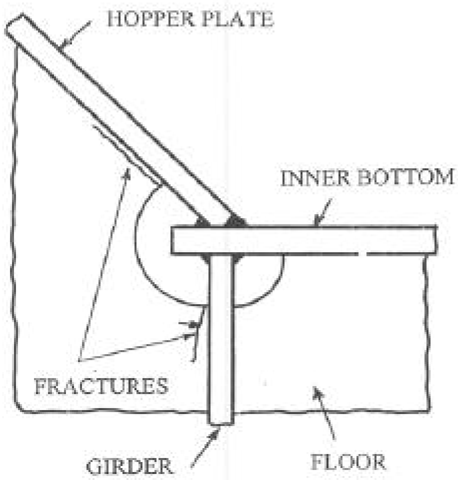
FACTORS CONTRIBUTING TO DAMAGE

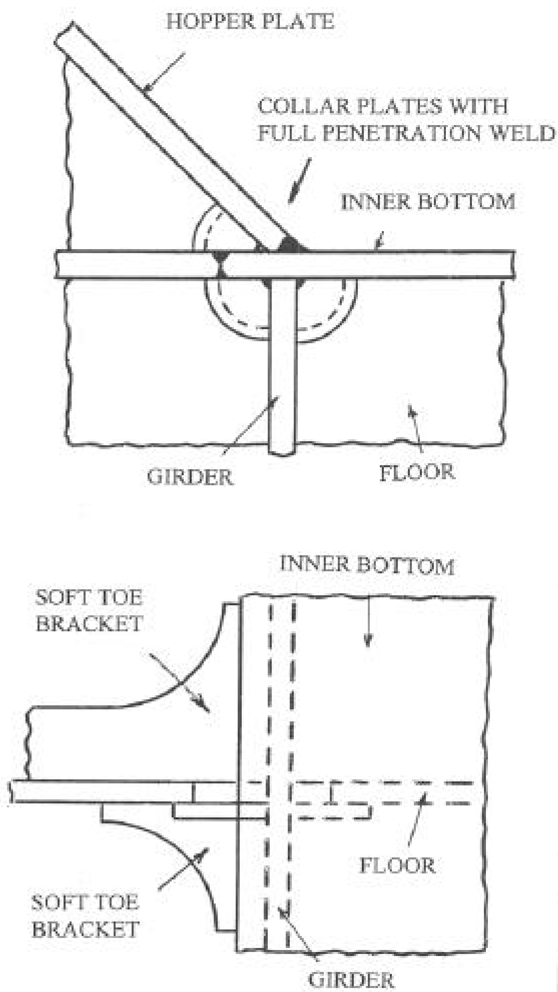
1. Stress concentration at juncture of hopper plate to inner bottom.
2. Insufficient welding connection.
3. Misalignment between hopper plate, inner bottom and girder.

FIGURE 1	TANKER STRUCTURE CO-OPERATIVE FORUM SUBJECT: CATALOGUE OF STRUCTURAL DETAILS	FIGURE 1

LOCATION : EXAMPLE : NO 1	INNER BOTTOM PLATE FRACTURE AT CONNECTION OF BILGE HOPPER PLATE AND INNER BOTTOM	GROUP NO 1

TYPICAL DAMAGE	PROPOSED REPAIR





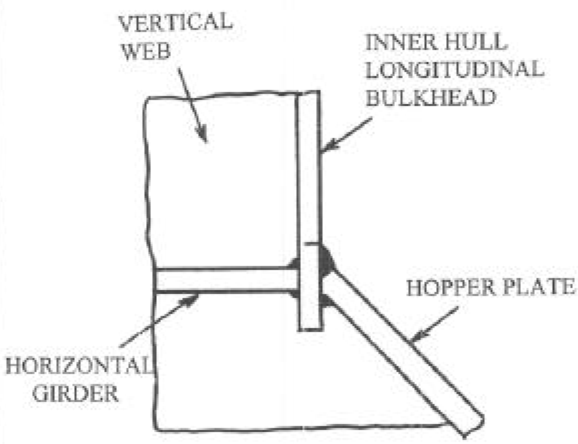
FACTORS CONTRIBUTING TO DAMAGE

1. Stress concentration at the knuckle

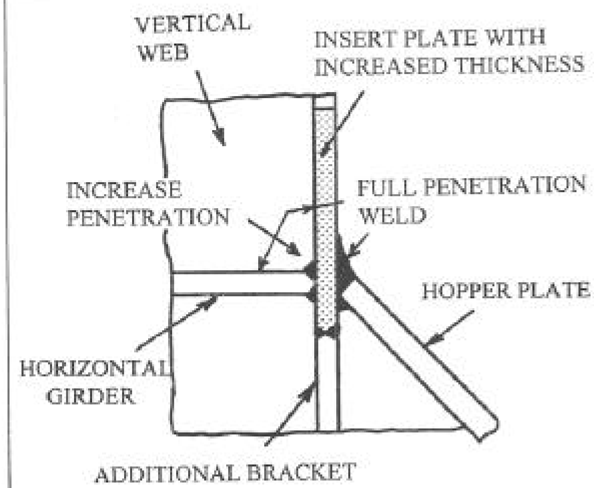
FIGURE 4	TANKER STRUCTURE CO-OPERATIVE FORUM SUBJECT: CATALOGUE OF STRUCTURAL DETAILS	FIGURE 4

LOCATION : EXAMPLE : NO 2	BILGE HOPPER CONNECTION OF HOPPER PLATE TO OUTSIDE LONGITUDINAL BULKHEAD	GROUP NO 1

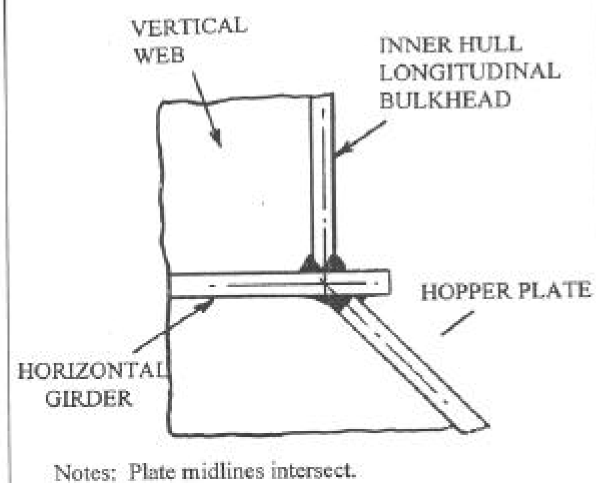
TYPICAL DAMAGE



PROPOSED REPAIR



NEW CONSTRUCTION (ALTERNATIVE)



Notes: Plate midlines intersect.

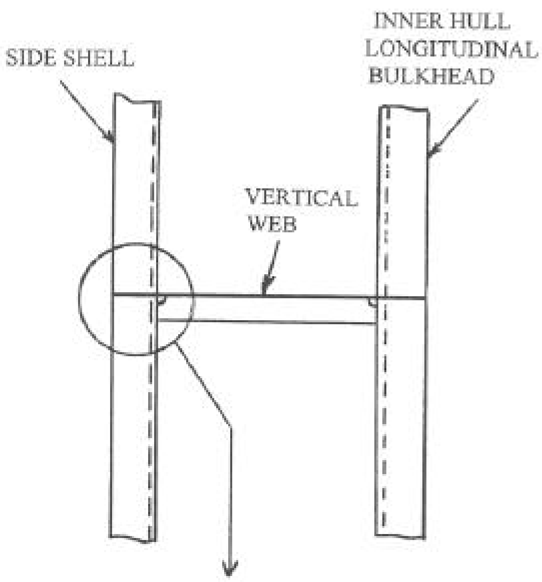
FACTORS CONTRIBUTING TO DAMAGE

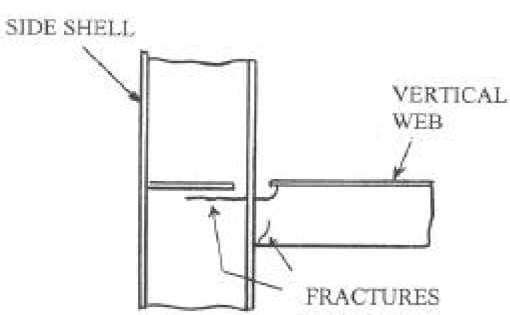
1. Stress concentration at junction of hopper plate to outside longitudinal bulkhead.
2. Insufficient welding connection and/or incorrect shape of the weld toe..
3. Misalignment between hopper plate, outside longitudinal bulkhead and side stringer.

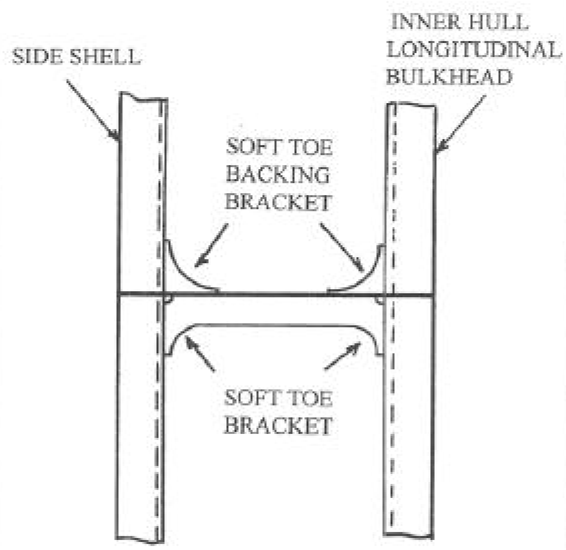
FIGURE 9	TANKER STRUCTURE CO-OPERATIVE FORUM SUBJECT: CATALOGUE OF STRUCTURAL DETAILS	FIGURE 9

LOCATION :	WING BALLAST TANK	GROUP NO 3
EXAMPLE : NO 2	CONNECTION OF LONGITUDINALS TO TRANSVERSE WEBS	

TYPICAL DAMAGE	PROPOSED REPAIR





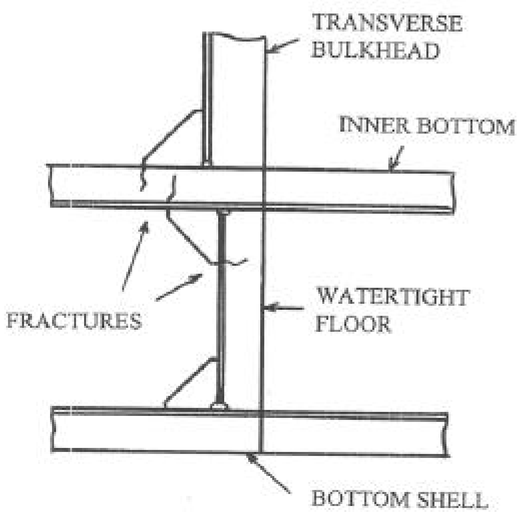
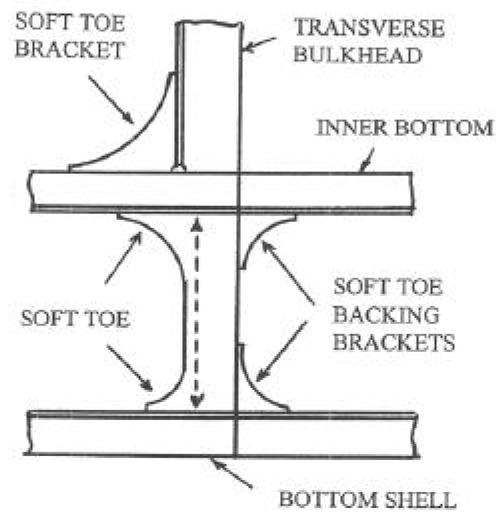


FACTORS CONTRIBUTING TO DAMAGE

1. Asymmetrical connection of flat bar stiffener resulting in high peak stresses at the heel of the stiffener.
2. Insufficient area of connection of longitudinal to web.
3. High bending stresses in the longitudinal.
4. Additional torsional stress due to a symmetry of the longitudinal (angle bar instead of symmetric T bar).
5. Stress concentrations at the square angles at heel and toe of the connections.

FIGURE	TANKER STRUCTURE CO-OPERATIVE FORUM	FIGURE
16	SUBJECT: CATALOGUE OF STRUCTURAL DETAILS	16

LOCATION : EXAMPLE : NO 1	BOTTOM BALLAST TANK CONNECTION OF LONGITUDINALS TO WATERTIGHT FLOORS	GROUP NO 4

TYPICAL DAMAGE	PROPOSED REPAIR
	

FACTORS CONTRIBUTING TO DAMAGE

1. Asymmetrical connection of bracket in association with a backing bracket which is too small.
2. Relative deflection between adjacent floor and transverse bulkhead.
3. Inadequate shape of the brackets.
4. High stresses in the inner bottom longitudinal and the floor stiffener.

FIGURE 20	TANKER STRUCTURE CO-OPERATIVE FORUM SUBJECT: CATALOGUE OF STRUCTURAL DETAILS	FIGURE 20

11. Failure/Damages.

No significant damage or failure has been found on the three vessels in question. We would, however, like to mention that the wave loads imposed on the bow is most likely higher than the classification societies' rules cover. We have noticed local buckling of the stringers and breast hooks. In addition we can clearly see the "starving dog" pattern on the ship side forward. Normally Bergesen has asked for 2 mm increased plate thickness above rules for the bulwark forward. This is a relative cheap insurance to prevent local damage in that area.

On two vessel we noticed elastic buckling on one stringer in the fore peak tank. In fully loaded condition when the vessel was sagging the buckling could be seen whilst in ballast condition or hogging, the panel was straight. Local buckling stiffeners were arranged to prevent this to happen.

The above incidents are the only I can report on these vessels.

12. Conclusion.

What conclusion can we draw from the experience with our three first double hull tankers? We may shortly summarise the most important points as follows:

- Define the critical areas.
- Proper fatigue analysis to be carried out for all the end connections of the longitudinals and at the critical locations of transverse primary members such as hopper connections and toe ends of transverse webs or stringers.
- Current practice is to use 32 HTS in deck and double bottom longitudinal members and partly on transverse primary members to achieve suitable stiffness and fatigue life.

- For side and bottom plating T-profiles should be adopted instead of L-profiles since the T-profiles give much longer fatigue life.
- To enhance the fatigue strength at the critical locations smooth grinding by disc grinder may be applied.
- Flat bars or bulb profiles should be used for deck longitudinals to prevent deposits that settle on the flanges.
- In most cases double brackets should be arranged on the profiles at its end connections to transverse bulkheads, longitudinals in the double bottom and side shell.
- Sloshing analysis and relevant structural reinforcement shall be carried out to avoid any damage which may be induced when tanks are partially filled with cargo or sea water in heavy weather.
- A two coat coating system to be applied in the ballast tanks of min. 300 my and sacrificial zinc anodes to be installed as back-ups.
- Close-up survey to be possible for areas prone to high stresses and fatigue.
- Cargo tanks to be coated at least on the inner bottom and preferably under the deck. This will further increase the fatigue life of the structure.
- Shell plating of the bow and forecastle deck should be above the class rules.

Reference

1) Guidance Manual for the Inspection and Maintenance of Double Hull Tanker Structures
2) Tank Coating Report for Berge Stadt By Sigma Coating March 1999
3) Inspection of Corrosion in Cargo Oil Tanks by Sumitomo Heavy Industries, Ltd. June 1999