

Outfitting Related Structural Defects

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Outfitting Related Structural Defects

►“Structure Defects on Double Hull Tankers”, Philip G. Rynn, American Bureau of Shipping, TSCF 2007 Shipbuilders Meeting

*“The service history of existing double hull oil tankers has revealed the fact that outfitting details are not to be neglected. **Since about 5 in 6 defects found in the upper deck plate and stiffeners were cracks due to outfitting,** shipyards and others must consider developing the appropriate design standards to avoid such failures in the future double hull oil tanker.”*

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Outfitting Related Structural Defects

- ▶ Considering the above, TSCF decided to set up a Working Group in order to produce an Information Paper detailing the problems encountered and their consequences, and establishing best practice and recommendations for design of outfitting details, and verification during construction.
- ▶ Final Information Paper is still to be approved by the TSCF Steering Committee, and will be issued by the end of the year
- ▶ The purpose of this presentation is to offer some insights into the final Paper

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Outfitting Related Structural Defects

Introduction

Shipyard Standard

Design and Plan Approval

Inspection

Typical Design Consideration

Examples of Defects

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Introduction

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Introduction

► Outfitting reinforcements should be designed considering that:

- Dynamic loads have to be taken into account
- Any stress concentrations created by local reinforcement must be considered and addressed in the design
- Smooth transition is desirable
- Hard points have to be avoided

► Good workmanship is also a critical issue as:

- Poor alignment or poor welding can lead to structural failure even for a good design
- Outfitting works may not be done by same working force as structure work

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Shipyard standard

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Shipyard standard

Specific analysis for each connection detail would be time consuming, and in most cases not worth the effort.

- ▶ **Outfitting is generally governed by the “Shipyard Standard”, which is:**
 - Specific for each shipyard: only few recognized industry standards
 - Generally not submitted to the Classification society for Approval
- ▶ **The shipowner should request the shipyard standards for review and comment, as part of his building contract.**
- ▶ **Owners should also discuss and agree the extent of drawings for approval with the shipyard and this should include reinforcements in way of outfit items.**

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Shipyard standard

Application of Rules:

According to class rules some main equipment reinforcements are subject to specific approval. With reference to CSR for Double Hull Oil Tankers Section 11 chapter 3 "Support structure and structural appendages":

3.1.1.2 This sub-section includes scantling requirements for the support structure and foundations of the following pieces of equipment and fittings:

- (a) Anchor windlasses*
- (b) Anchoring chain stoppers*
- (c) Mooring winches*
- (d) Deck cranes, derricks and lifting masts*
- (e) Emergency towing arrangements*
- (f) Bollards and bitts, fairleads, stand rollers, chocks and capstans*
- (g) Other deck equipment and fittings which are subject to specific approval*
- (h) Miscellaneous deck fittings which are not subject to specific approval*

The extent of the support structures covered by the sub-section is not obvious!

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Design and plan approval

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Design and plan approval

- ▶ While CSR requires a “Booklet of Standard Construction Details” to be provided for review, this typically does not include outfitting supports (CSR Oil Tankers Sect 4/3).
- ▶ During plan approval the shipowner should request the shipyard to supply booklets of outfitting details (“Outfitting Booklets”) such as piping supports, mooring fittings supports, deck attachments, penetrations, etc.

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Design and plan approval

- ▶ **When is outfitting work performed?**
 - At block stage
 - During erection
 - When modifications are required... Reworking of drawing is more cost effective than modifying already built structure
- ▶ **The building contract should have provisions for management of changes to design and approved plans.**
 - For example, comment such as “any modification of the approved drawing is subject to approval” can be made to give the owner the opportunity to review all yard changes during production.

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Inspection

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Inspection

- ▶ Reinforcement below and in way of outfitting is not always on the shipowner's plans
- ▶ Inspection should focus on compliance with outfitting booklets
- ▶ Whenever possible, outfitting inspections should be done at the block stage.
- ▶ When outfitting items are installed at a later stage, final inspection of the outfitting items and associated reinforcement structure can be done at the outfitting inspection.
- ▶ Don't forget patrol inspections!

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Inspection

- ▶ The inspectors should check that the deck outfit matches with the underdeck structure
- ▶ Shipowner's outfitting inspections include checks for:
 - material grade and scantling,
 - missing structure,
 - misalignments,
 - missing and undersize weldings,
 - interferences,
 - mis-cuts,
 - proper surface preparation and painting of outfitting

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Typical Design Considerations

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Typical design considerations

The necessary improvement of detail design depends on the stress level in the deck structure, i.e. increases when higher tensile steels are used.

► Stanchions or supports:

- Consider reducing or eliminating pipe sections (internal corrosion).
- Use open type rolled / fabricated sections such as T, L, I, X, H, etc.
- Align with underdeck structure (largest member is preferable)
- Provide additional backing structure to supports if necessary
- Use doublers only when appropriate, when under compression only.
- Use collar plates on stiffener cutouts directly beneath supports

► Through Fittings (Pipes, radar stands, etc.):

- Where possible pass fitting through deck with sleeves
- Ensure sleeve pipe is either seamless or if welded pipe the external weld reinforcement is ground flush.
- Use ring support for larger pipe (e.g. 200+ mm diameter)
- Tie ring support into underdeck framing system.

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Typical design considerations

► Deck openings (e.g. coamings):

- Ensure the plate edges of the deck opening are machine cut and smooth i.e. no notches.
- Welding of fittings and coamings to the deck to be well clear of opening edges.
- Manholes, access openings etc are to be avoided in way of concentrated loads and high stress areas.

► Miscellaneous:

- Bracket toe heights to be within 10-15mm. The purpose of the bracket "nose" is only to facilitate the effective wrap weld.
- Use soft toe terminations
- When outfitting dimension is large and its stiffness is high, consider splitting the item.
- Check hull girder loads when working with structures longer than 3 frame spaces.
- For tall structures (e.g. radar mast) consider vibration loads.
- Lack of access (for maintenance purposes) is to be avoided.

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Typical design considerations

► Underdeck Backing:

- Transitions to extend to stiffener/frame break. Partial transitions to be avoided.
- Use conservative load calculations (including global and local stresses) and assume no support from the deck plate.
- Use deck inserts where shear loads are high.

► Gutter bars :

- Continuous gutter bars should be treated like a sheer strake.
- Avoid connections to the upper edge of ship side gutter bars.

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Examples of Defects

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Examples of Defects: Framework

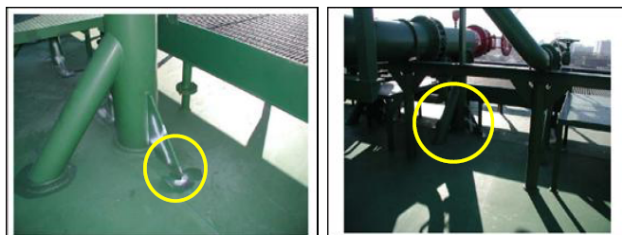
1. Location
2. Category
3. Type of defect
4. Cause
5. Corrective Action
6. Recommendation

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Main deck cargo line supports i.w.o. manifold area



Cracks at the pipe support bracket connection to main deck toe



Corrective action

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Main deck cargo line supports i.w.o. manifold area



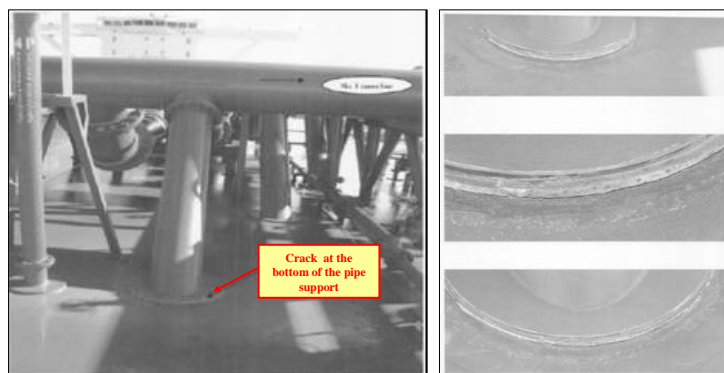
- ▶ **Location:** Main deck cargo area (0,4L)
- ▶ **Category:** Design / Construction & Installation
- ▶ **Type of Defect:** Fracture
- ▶ **Cause:** Bracket toes of 50 mm, possible misalignment
- ▶ **Corrective Action:** Radius brackets, reduce the toe height to no more than 10-15mm, and support toe of bracket if on unsupported panel
- ▶ **Recommendation:** Toe height to be no more than 10-15mm. Support toe of bracket with underdeck stiffening if on unsupported deck plate and check alignment.

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Main deck cargo line supports i.w.o. manifold area



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Main deck cargo line supports i.w.o. manifold area

- ▶ **Location:** Main deck cargo area (0,4L)
- ▶ **Category:** Design
- ▶ **Type of defect:** Transverse crack developed through main deck at the fillet weld toe
- ▶ **Cause:** No backing structure provided for pipe support doubler
- ▶ **Corrective Action:** Backing structure added.
- ▶ **Recommendation:** Proper backing structure is to be provided below deck or improved structure above deck is to be provided to better distribute the load. The support structure should preferably be made with open sections making alignment with under deck structure easier. Align with underdeck structure and fit well rounded brackets with soft toes, aligned with longitudinal below, with maximum toe height 10-15mm at connection of support to deck. If necessary additional under deck supports to be made to align with brackets.

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Midship Manifold Drip Tray Supports



Drip tray being modified from continuous to several separate sections

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Midship Manifold Drip Tray Supports

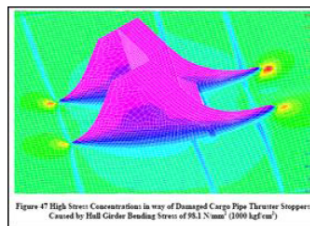
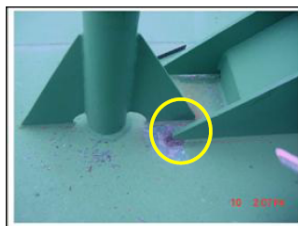
- ▶ **Location:** Main deck cargo area (0,4L)
- ▶ **Category:** Design
- ▶ **Type of defect:** In this vessel, the manifold drip trays are reported to be cracking where their supports are welded to the upper deck. The cracks have been located where the doubler is welded to the upper deck, but have not penetrated into the cargo tank. There are 9 pairs of supports for the drip tray, all landing on web frames or transverse stiffeners. The tray is 1.8 m wide and approx. 19 m long.
- ▶ **Cause:** It is believed that this is the result of the ship's structure bending in waves and while loading. The spill trays are quite stiff therefore large forces are created as the spill tray attempts to prevent the upper deck from moving.
- ▶ **Recommendation:** The drip tray to be constructed in several sections along the length of the drip tray to make it more flexible. The support structure to allow flexibility, while still adequate to resist the weight, wave impact, and buoyancy forces. Arrange thick phenol resin pad between the flanges on the pipe supports, and the holes in the flanges to be slotted to allow movement.

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Thrust Stopper



Crack at the pipe stopper connection to main deck toe



Corrective action

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Thrust Stopper

- ▶ **Location:** Pipe Thrust Stopper
- ▶ **Category:** Design
- ▶ **Description:** Cracks occurred at the toe of the brackets
- ▶ **Cause:** These brackets were originally designed with radii and 10-15 mm toes. The stoppers were not aligned with underdeck longitudinals and were instead supported by transverse stiffeners. As stoppers were not aligned directly with longitudinals, the brackets terminated on soft plate, leading to a stress concentration. Analysis after the incident indicated that the underdeck structure was sufficient for the loads induced by the pipes, however the toes of the brackets did increase the stress in the deck. This stress concentration quickly led to cracks in an already highly stressed deck.
- ▶ **Corrective Action:** The vessel in service was retrofitted with additional underdeck support and doublers were added in way of the toes. The doubler pads reduced the stress concentration in the deck sufficiently to eliminate cracking. For the next ships, it was recommended that the stoppers be aligned with longitudinals or integral doubler plates
- ▶ **Recommendation:** Align with underdeck structure and fit well rounded brackets with soft toes, aligned with longitudinal below, with maximum toe height 10-15mm at connection of support to deck. If necessary additional under deck supports in alignment with brackets.

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Main deck cargo line stanchion



Corrective action

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Main deck cargo line stanchion

- ▶ **Location:** Main deck cargo area (0,4L)
- ▶ **Category:** Design
- ▶ **Type of defect:** Cracks developed on upper deck around bracket toes of pipe line stanchions.
- ▶ **Cause:** This was a fatigue crack.
- ▶ **Corrective action:** A doubling plate was provided to reduce the stress induced by longitudinal moment. Soft toe type is also preferable way to reduce the stress level
- ▶ **Recommendation:** The support structure should align with the underdeck structure and fit well rounded brackets with soft toes, aligned with longitudinal below, with maximum toe height 10-15mm at connection of support to deck. If necessary additional under deck supports to be made to align with brackets.

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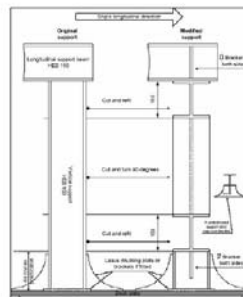


Main deck cargo line stanchion



Crack i.w.o fillet welding i.w.o pipe support connection to upper deck.

Many typical outfit item connections to upper deck – one of which is modified pipe support.



Drawing showing pipe support modification

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Main deck cargo line stanchion

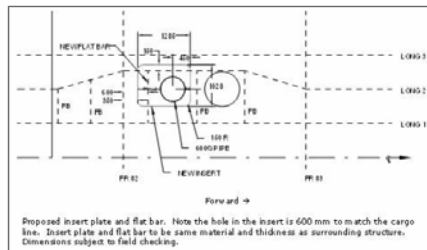
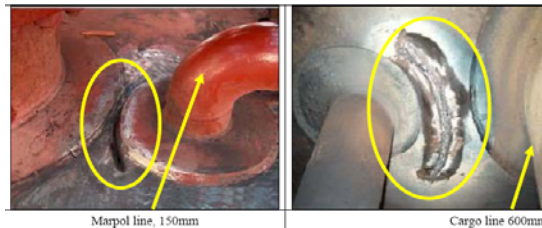
- ▶ **Location:** Main deck cargo area (0,4L)
- ▶ **Category:** Design
- ▶ **Type of defect:** Cracking of the upper deck plating at the support connection to the deck plating.
- ▶ **Corrective action:** Soft brackets to be fitted on either side of the supports and these to be in alignment with the underdeck structure i.e. the brackets to be fitted to reduce the stress concentration where the pipe support on the top side of the deck crosses the longitudinal on the underside of the deck.
- ▶ **Recommendation:** Supports should always be in alignment with underdeck structure and if possible the supports to be of a flexible design. The solution shown is one option and so far has worked. As a general comment: pipe support arrangements should be flexible and this should include the correct securing of pipes to the supports to allow the flexible couplings to work.

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MARPOL line deck crack



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MARPOL line deck crack

- ▶ **Location:** Main deck cargo area (0,4L)
- ▶ **Category:** Design
- ▶ **Type of defect:** Cracking on MARPOL line deck penetration
- ▶ **Cause:** Most likely the result of deck penetrations placed closely, together with pipe movement. There are two large (855 mm diameter for 600 mm pipe) penetrations in line with each other, with a small (315 mm diameter for 150 mm pipe) penetration in close proximity.
- ▶ **Corrective actions:** Considered long term repair possibilities include:
 - Relocate the MARPOL line penetration through the upper deck aft by 1-2 meters.
 - Insert the upper deck with similar thickness and grade of plating.
 - Add a transverse stiffener approx. 600 mm aft of the center of the #3 drop line, spanning the upper deck longitudinals at 840 and 1680 mm off centerline
- ▶ **Recommendation:** Allow sufficient space between penetrations. Doublers should be avoided, especially when the deck is made of Higher Tensile Steel

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Penetration on the upper deck



Radar contents gauge pedestal. Note paint disturbance at pedestal connection to the upper deck.



Close-up showing crack in deck plating.



Butterworth hatch modified to ensure welding is clear of deck opening.

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Penetration on the upper deck

Cargo Tank Radar Contents Gauge Pedestal / Butterworth hatches / Crude Oil Washing Machine penetrations ...

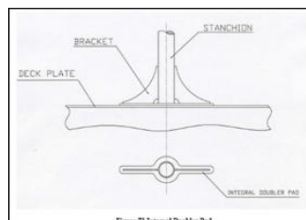
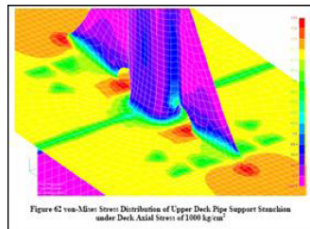
- ▶ **Location:** Main deck cargo area (0,4L)
- ▶ **Category:** Design / Construction & Installation
- ▶ **Type of Defect:** Cracking of the upper deck plating at the edges of the deck openings.
- ▶ **Corrective Action:** Penetration extended through deck plating or ensure welding is well clear of deck opening. Ensure that possible cracks are removed by the grinding; in case of larger cracks, insert to be fitted.
- ▶ **Recommendation:** Wherever possible the fittings should penetrate through the deck plating and the penetration piece be full penetration welded to the deck above and under the deck. If the fitting stops at the deck level, the deck opening plate edges to be well clear of the fitting to facilitate good full penetration welding detail. Such openings to be machine cut and smooth i.e. no notches

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Pipe Support



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Pipe Support

- ▶ **Location:** Main deck cargo area (0,4L)
- ▶ **Category:** Design / Construction & Installation
- ▶ **Type of Defect:** Fracture
- ▶ **Cause:** Excessive stress at the bracket toes. The problem was most severe near the Midship area where the relative displacement between the hull and cargo pipes is most extreme.
- ▶ **Corrective Action:** For the vessels in operation the brackets were modified to provide a gradual radius and a toe of 10-15 mm. The brackets were also fitted with doublers to further reduce the stress concentration in the deck.
- ▶ **Recommendation:** Expansion couplings to be provided where necessary. Care should be taken to ensure the "u" bolts are fitted to allow one end of each pipe length to be flexible. The doubler should only be fitted below the tubular pipe support, not below the new brackets. The support structure should preferably be made with open sections making alignment with under deck structure easier. Align with underdeck structure and fit well rounded brackets with soft toes, aligned with longitudinals below, with maximum toe height 10-15mm at connection of support to deck. If necessary additional under deck supports to be made to align with brackets.

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Vent riser supports



Figure 34 Deck Cracks: TWO Bracket Toes of Vent Riser Pipe Support



Figure 35 Misalignment Brackets of Vent Riser Pipe Support



Corrective action

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Vent riser supports

- ▶ **Location:** Main deck cargo area (0,4L)
- ▶ **Category:** Construction & Installation
- ▶ **Type of Defect:** Fracture
- ▶ **Cause:** Misalignment
- ▶ **Corrective Action:** For this particular vessel the brackets were close enough to additional above deck structure that they were fitted with a bracket above deck that linked to the adjacent riser.
- ▶ **Recommendation:** Align with the underdeck structure

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Ship side gutter bars



Paint disturbance noted in way of gutter bar taper toe



Upper deck plate crack in way of gutter bar taper toe



Upper deck repair / gutter bar taper toe "nose" minimum height



Gutter bar cracked in way of connection to mooring fairlead.

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Ship side gutter bars



- ▶ **Location:** Main deck cargo area (0,4L)
- ▶ **Category:** Design / Construction & Installation
- ▶ **Type of defect:** Cracking of the upper deck plating in way of the ends of expansion gaps in the gutter bar or in way of expansion swedges or knuckles.
- ▶ **Cause:** Toe nose too high
- ▶ **Corrective action:** Crop and renewal of deck plating. If there are expansions arrangements along the length of the gutter (P&S) the deck plating at the toes of the gaps in the gutter bar or in way of swedges / knuckles to be inspected and dealt with as necessary.
- ▶ **Recommendation:** There are numerous expansion arrangements for ship side gutter bars i.e. gaps, knuckles, swedges etc. They should generally be avoided, and extension of sheer strake is the most preferred option.
- ▶ **Nota:** Mooring fairleads and other outfit items connected to the upper edge of ship side gutter bars in general results in gutter bar cracks. Such cracks if left unattended will eventually propagate downwards and into the deck plating.

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Ladder connection to oil tank



Crack in way of ladder lug doubler – connected to unsupported plate of oil tank. Vibration induced crack.

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Ladder connection to oil tank



- ▶ **Location:** Engine room oil tank.
- ▶ **Category:** Design.
- ▶ **Type of Defect:** Crack in engine room oil tank bulkhead.
- ▶ **Cause:** Vibration
- ▶ **Recommendation:** The ladder lug should be located in way of internal stiffening structure. A bolted connection between the lug and ladder would be preferable.

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Ladder Support



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Ladder Support



- ▶ **Location:** Cargo area, tank bottom
- ▶ **Category:** Design / Construction & Installation
- ▶ **Type of Defect:** crack develop at the ladder connection to tank bottom
- ▶ **Cause:** No support
- ▶ **Recommendation:** Ladder should be welded on a doubling plate with backing structure below deck if the preferred bolted structure is not used.

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Staging lug left from new building stage



Non structural staging lug in fresh water tank. Abrupt connection and poor return weld detail resulted in the crack shown – vibration induced crack.

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Staging lug left from new building stage

- ▶ **Location:** Fresh water tank in engine room.
- ▶ **Category:** Design / Construction & Installation
- ▶ **Type of Defect:** Crack in way of the fresh water tank stiffener that propagated into the bulkhead plating resulting in a leak.
- ▶ **Cause:** Vibration induced crack.
- ▶ **Recommendation:** Such lugs should have a "softer" shape and although not structural the welding condition should be improved by a smooth and correct profile. Removing the lug should also be considered, especially at locations where excessive vibration is expected.

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Instrument pipe support in cargo tanks



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Instrument pipe support in cargo tanks

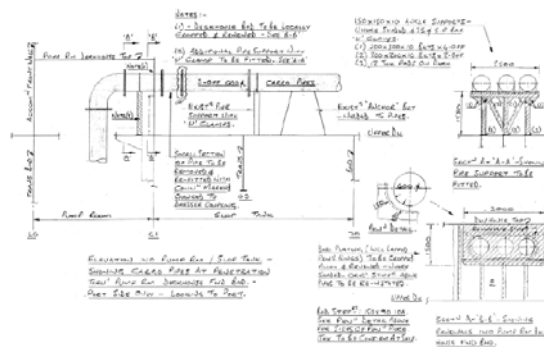
- **Location:** Cargo area (inside tank)
- **Category:** Design
- **Type of Defect:** The transverse BHD had a crack around fillet welding to pipe support.
- **Cause:** Doubling plate had not been provided at the connection. The cause of damage is vibration.
- **Recommendation:** A doubling plate should be provided and number of supports increased. Stiffeners to be considered, especially at locations where excessive vibration is expected.

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Pipe Penetration at Pump Room Bulkhead



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Pipe Penetration at Pump Room Bulkhead

- ▶ **Location:** Cargo area (aft)
- ▶ **Category:** Design
- ▶ **Type of defect:** Crack developed along with fillet welding of pipe penetration at a bulkhead.
- ▶ **Cause:** Vibration
- ▶ **Corrective action:** Making the bulkhead stiffener arrangement "softer" did not work. The pipes were supported inside the pump room deckhouse and the pipe securing arrangement outside the deckhouse made more flexible.
- ▶ **Recommendation:** To avoid vibration damages, additional stiffener on BHD plates and additional pipe supports were recommended. The pipe supporting arrangement should be more flexible (couplings).

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Lower corners of deckhouses on the upper deck



Deckhouse corner at connection to upper deck. Note crack in way of fillet welding and local scale



Deckhouse corner welding repaired and soft bracket fitted.

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Lower corners of deckhouses on the upper deck

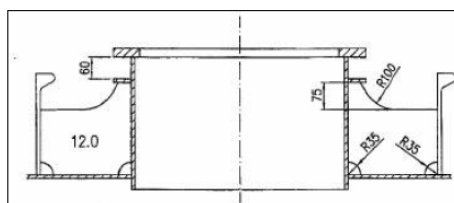
- **Location:** Main deck cargo area (0,4L)
- **Category:** Design
- **Type of Defect:** Cracking in way of the fillet welds at the corners of the deckhouse where the deckhouse connects to the upper deck and such cracks propagating into the upper deck plating.
- **Corrective Action:** The corner fillet weld to be gouged out and the location MPI tested. The fillet weld at the corners to be re-welded or if cracks are found in the upper deck plating the deck to be inserted the deck. Brackets fitted at the corners.
- **Recommendation:** Deck house sides should be aligned with under deck structures and brackets to be fitted at the corners of deckhouses / accommodation blocks etc.

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Submerged pump supports



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Submerged pump supports

- ▶ **Location:** Cargo area
- ▶ **Category:** Design
- ▶ **Type of Defect:** Fracture
- ▶ **Cause:** Stiffener fitted on submerged pump trunk created hard point (high distance between stiffener toe and trunk flange). Cracks developed through the trunk due to vibration of the trunk and the pump.
- ▶ **Recommendation:** Stiffener to be fitted with a soft toe bracket with bracket toe connected to trunk flange.

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And more



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