



Tanker Structure Co-operative Forum

Outfitting related structural defects

SUMMARY

The paper reviews the outfitting defects based on TSCF member experience and provides analysis on potential causes and repair proposals.

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Reference	Revision N°	Revision Date
IP 001/2011	0	2011/03/31



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1 General

With reference to “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. The outfitting details selected for design must eliminate structural hard spots, and consider the loads to be imposed by the connection at the deck”

Outfitting reinforcements should be considered as part of the ship structure because a failure of this kind of local reinforcement may affect even the primary structure and cause a critical failure.

Generally outfitting reinforcements are designed taking into account static loads on outfitting items. Reinforcements fitted under deck are fit mainly for this purpose. Smooth transition is desirable. Any stress concentrations created by local reinforcement must be considered and addressed in the design. Hard points have to be avoided.

As reinforcement below outfitting are included in the hull structure they will also be subject to hull girder load, pressure load, vibration load, etc. Outfitting reinforcements are usually not checked against these loads and the normal practice is to apply “shipyard standard” and/or “recognized industry standard” so that they conservatively cope with ship loads. This includes proper connection of the reinforcement to the ship structure and/or effective adaptation and/or modification of the ship structure in way of the outfitting item.

Good workmanship is also a critical issue because 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 and education of the outfitting workers in term of steel structure quality is very important.

New-building and repair process are different challenges. Where design can be easily adapted at the design stage to select the most efficient as well as cost-effective configuration, compromises have to be done at repair stage to minimize changes and make repair reliable for working onboard where scaffolding, parts weight, etc are critical issues.

2 TSCF members experience

This information paper is based on TSCF members' experience of fractures related to reinforcement below and in way of outfitting items. In order to describe the defects found on board vessels and find general categories of defects we first define a typical characterization framework that is:

- Category: Design or Construction & Installation.

Design related issues are when ship structures have not been designed to accommodate the load transferred by outfitting items: such failures can be attributed to poor design, poor detail, lack of use of recognized standards for outfitting or poor management of changes, incorrect materials, etc. Construction & Installation related issues are when the source of problem is poor workmanship, misalignment, or incorrect materials compared to the drawings.

- Type of defect: Cracking, Fractures or Deformation, Collapse
- Cause of defect: a defect detailed description.
- Area: the location of the defect primarily if it is located in the 0.4L main deck area or elsewhere.

See Appendix 1 for examples of outfitting defects, their causes and their correction.

See Appendix 2 for recommendations of typical structural reinforcement details.

3 Recommendations

To deal with the above this paper includes recommendations for the design, repair and enhanced inspection awareness.

3.1 Shipyard standard

Plan approval mainly focuses on primary structure and may consider reinforcement below and in way of outfitting “to be as per shipyard standard”.

Typical reinforcements underneath and in way of outfitting are specific for each shipyard. There are few recognized industry standards. Generally shipyard standards are 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.

According to class rules some main equipment reinforcements are subject to specific approval. With reference to CSR for Double Hull Oil Tankers Section 11 / 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”*

Equipment and fittings whose support structures have to be approved are well identified but equipment and fittings under (g) and (h) are unspecified. Owners should discuss and agree the extent of drawings for approval with the shipyard and this should include reinforcements in way of outfit items.

3.2 Design and plan approval

Basic hull structure design typically precedes outfitting design. Hull plans for approval may not include all reinforcements below and in way of outfitting. Moreover late changes (e.g. change of supplier) may not be reflected in hull structural design details (e.g. underdeck stiffeners). While CSR does require a booklet of standard construction details to be provided for review this typically does not include outfitting supports (CSR OT 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. 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” is

usually made to give the owner the opportunity to review all yard changes during production.

3.3 Inspection

As reinforcement below and in way of outfitting structure may not be on the shipowner's plans, the only opportunity to check compliance with the "outfitting booklets" is during inspection. Inspection should not only focus on compliance with approved drawing but should also focus on compliance with the "outfitting booklets".

At the block inspection stage outfitting reinforcement may already be fitted, so the inspector has the opportunity to check compliance of the reinforcement with the "outfitting booklets". 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. Whenever possible, outfitting inspections should be done at the block stage. The deck outfit must match with the underdeck structure. Patrol inspections are also a good way to check compliance.

The shipowner's outfitting inspections should include checks for:

- Material grade and scantling,
- Missing structure,
- Misalignments,
- Missing and undersize weldings,
- Interferences,
- Mis-cuts,
- Proper surface preparation and painting of outfitting.

3.4 Typical design considerations

Even if the "outfitting booklets" are specific to each yard some typical design considerations are provided below and also in Appendix 2. 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 backup to flange.
- 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.

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.

Underdeck Backing:

- Transitions to extend to stiffener/frame break. Partial transitions to be avoided. (See Appendix 1 page 26, Crane example)
- 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.

Appendix 1

Examples of outfitting defects

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1 Main deck cargo line supports in way of manifold area (a)

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



Cracks at the pipe support bracket connection to main deck toe



Corrective action

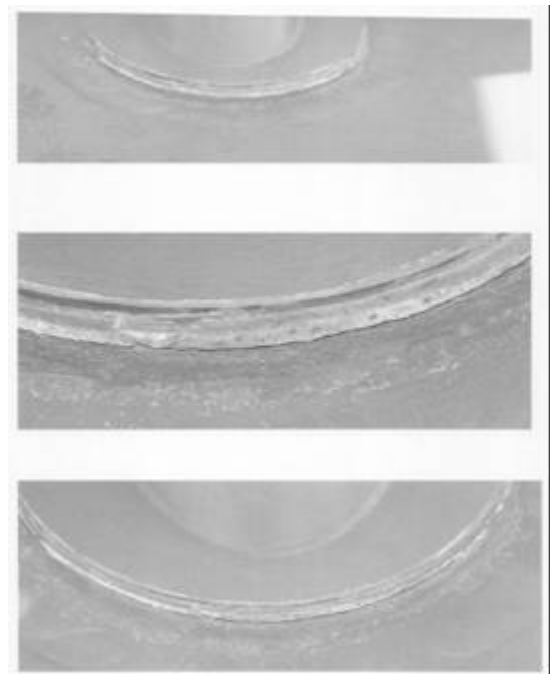
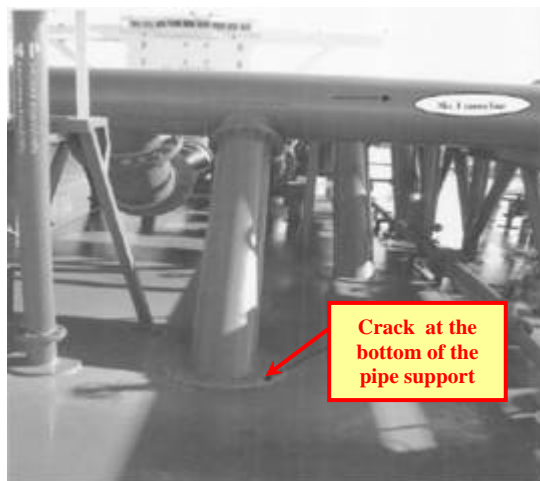
2 Main deck cargo line supports in way of manifold area (b)

Location:	Main deck cargo area (0,4L)
Category:	Design / Construction & Installation
Type of Defect:	Transverse crack developed on upper deck along the fillet welding of a doubling plate for pipe support
Cause:	Fatigue and poor underdeck support
Corrective Action:	Fit doubler with radiused corners
Recommendation:	Align with underdeck structure and fit well rounded brackets with soft toes, with maximum toe height 10-15mm at connection of support to deck. Smooth grinding to the fillet welding to reduce local stress. Modify details to interrupt the length of the support



3 Main deck cargo line supports in way of manifold area (c)

Location:	Main deck cargo area (0,4L)
Category:	Design
Type of Defect:	Transverse crack developed through the 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



4 Midship manifold drip tray supports (a)

Location:	Main deck cargo area (0,4L)
Category:	Design
Type of Defect:	Cracks in upper deck plating in way of drip tray supports
Cause:	The drip tray participates in the longitudinal hull girder bending and this in turn is transferred to the connection of the drip tray support at the connection to the upper deck
Corrective Action:	Flange connection introduced in way of drip tray supports i.e. oversize bolt holes and Teflon type packing (see picture). Other means of ensuring flexibility could also be considered, e.g. flat bar supports
Recommendation:	Drip tray supports to be fitted in way of underdeck stiffening. The supports to be flexible and / or soft brackets to be fitted where the supports connect to the upper deck



5 Midship manifold drip tray supports (b)

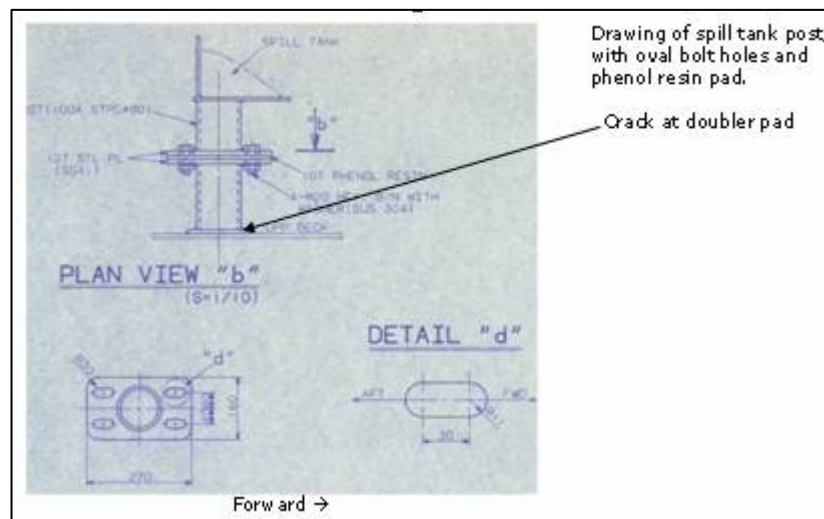
Location:	Main deck cargo area (0,4L)
Category:	Design
Type of Defect:	Cracks in upper deck plating in way of drip tray supports
Cause:	The drip tray participates in the longitudinal hull girder bending and this in turn is transferred to the connection of the drip tray support at the connection to the upper deck
Corrective Action:	The drip tray to be rebuilt in several sections
Recommendation:	The drip tray to be constructed in several sections along the length of the drip tray to make it more flexible



Drip tray being modified from continuous to several separate sections

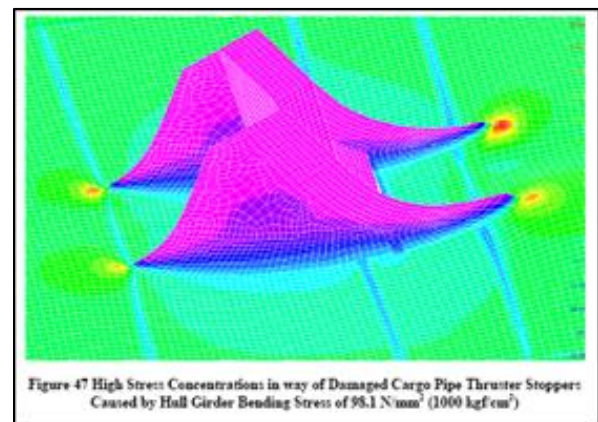
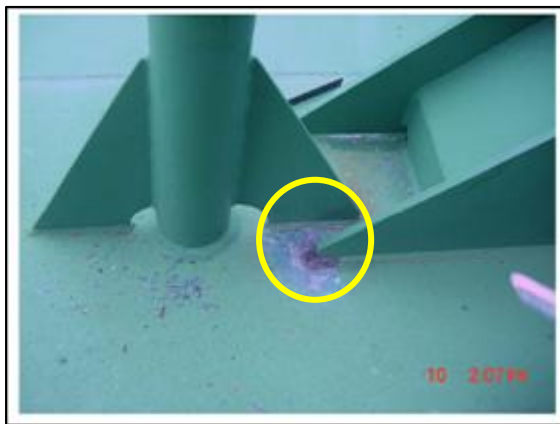
6 Midship manifold drip tray supports (c)

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:	<p>Suggested long term repairs include:</p> <ul style="list-style-type: none"> • Cutting the spill tank into two pieces, thereby reducing its length and the effect of hull bending. Drainage arrangements (i.e. piping) between the two spill pans should allow complete draining without pockets that may freeze. Regulatory impact should be checked. The location of the joint should not be below a discharge flange. • Modifying the support structure to allow greater flexibility. Currently the supports are 100 mm schedule 80 pipe. One such support could be kept for fixity, and the others replaced with an arrangement to allow more flexibility while still adequate to resist the weight, wave impact, and buoyancy forces. • The design drawings show a 12 mm thick phenol resin pad between the flanges on the pipe supports, and the holes in the flanges are slotted to allow movement.



7 Thrust Stopper

Location:	Pipe Thrust Stopper
Category:	Design
Type of Defect:	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. Fracture due to stress concentration. As stoppers were not aligned directly with longitudinals, the brackets terminated on soft plate, leading to a stress concentration. Analysis carried out 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 in this area. For the follow ships in this series, 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 to be made to align with brackets



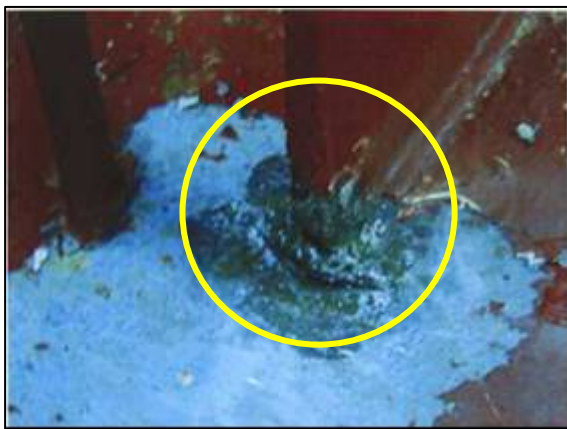
Crack at the pipe stopper connection to main deck toe



Corrective action

8 Main deck cargo line stanchion (a)

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



Corrective action

9 Main deck cargo line stanchion (b)

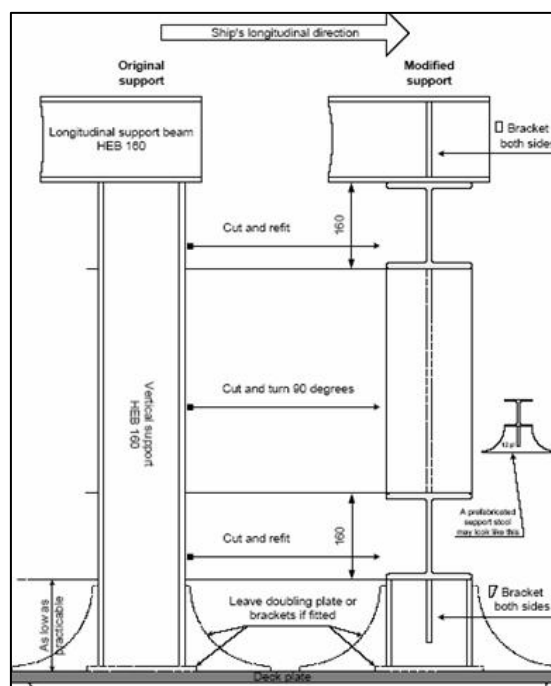
Location:	Main deck cargo area (0,4L)
Category:	Design
Type of Defect:	Cracking of the upper deck plating at the support connection to the deck plating
Corrective Action:	Soft brackets to be fitted on either side of the supports and these to be in alignment with the underdeck structure i.e. the brackets 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



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



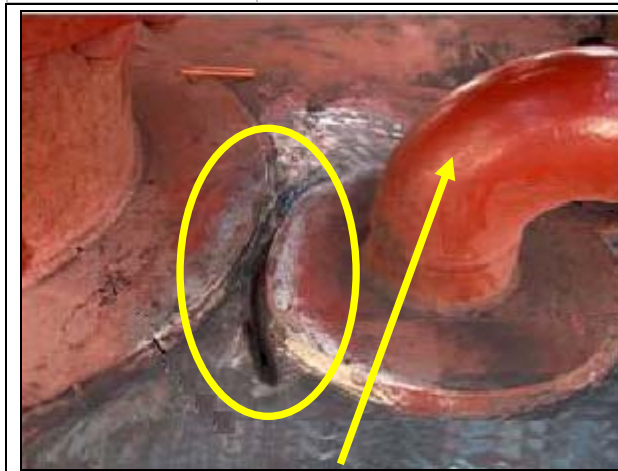
Many typical outfit item connections to upper deck – one of which is modified pipe support.



Drawing showing pipe support modification

10 MARPOL line deck crack

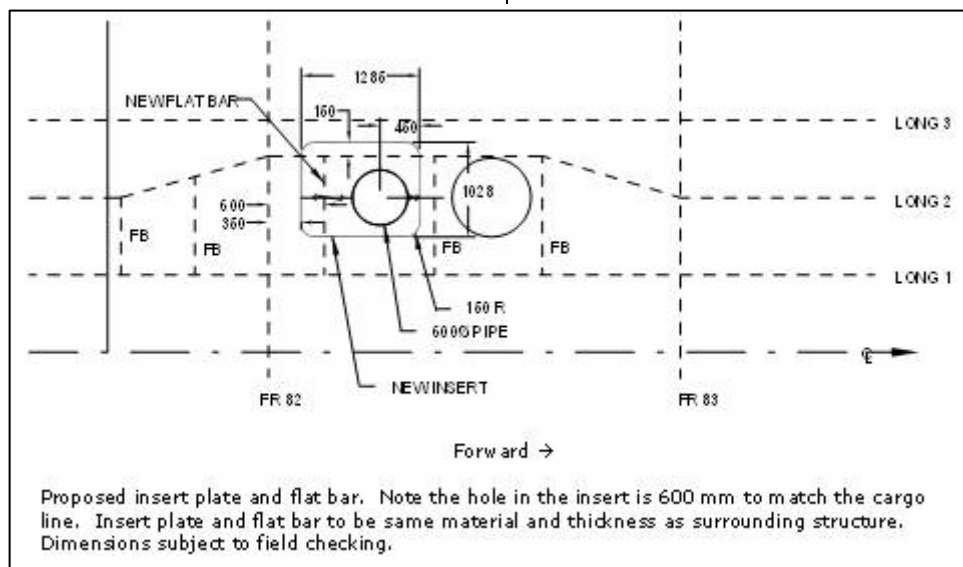
Location:	Main deck cargo area (0,4L)
Category:	Design
Type of Defect:	Cracking on MARPOL line deck penetration
Cause:	Most likely the result of deck penetrations placed closely, together with pipe movement. There are two large (855 mm diameter for 600 mm pipe) penetrations in line with each other, with a small (315 mm diameter for 150 mm pipe) penetration in close proximity
Corrective Action:	<p>Considered long term repair possibilities include:</p> <ul style="list-style-type: none"> 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



Marpol line, 150mm

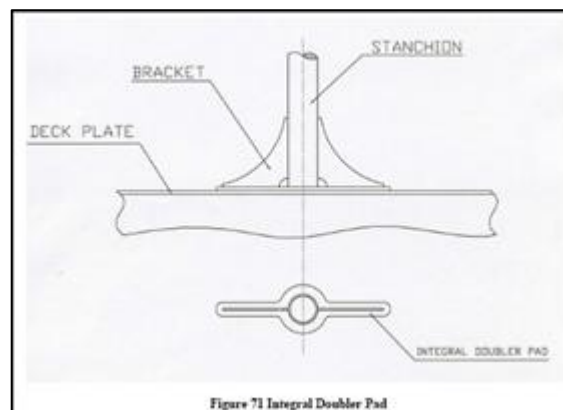
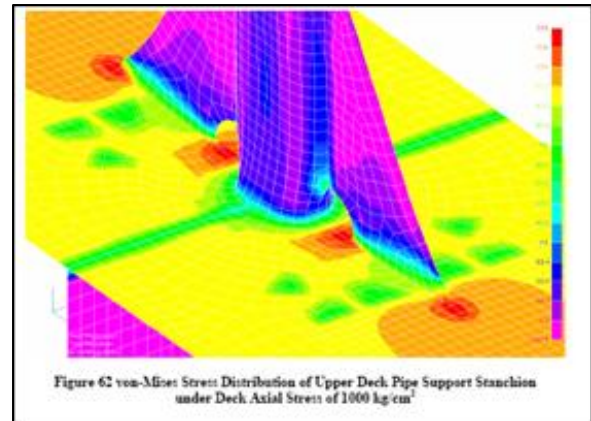


Cargo line 600mm



11 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 design of the pipe supports was fairly well developed. The cargo pipes were fitted with expansion joints spaced approximately 20 meters. Furthermore, the support stanchions were fitted with brackets in the longitudinal direction and both the stanchions and brackets were aligned with underdeck longitudinals. The cargo pipes were attached using U-bolts, intended to permit deflection of the pipes relative to the hull. The depth of bracket toes on this vessel ranged from 35-80 mm. It is unclear whether all U-bolts were installed with sufficient clearance to permit longitudinal deflection. 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

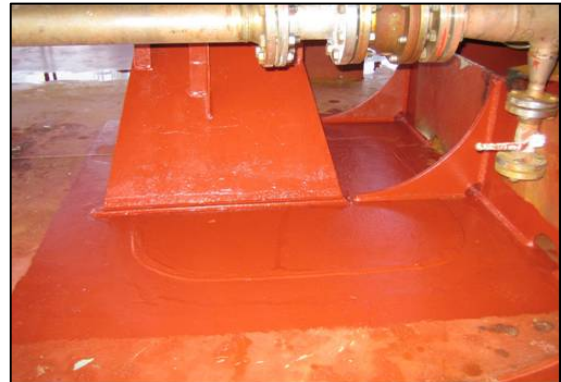


12 Bracket toe heights

Location:	Main deck cargo area (0,4L)
Category:	Design / Construction & Installation
Type of Defect:	Upper deck plating cracks at the toes of miscellaneous brackets on the upper deck
Cause:	Excessive toe height. Bracket toes need only be a sufficient height to facilitate the bracket return welding
Corrective Action:	The upper deck to be inspected and if paint disturbance is noted in way of bracket toes etc any attached scale to be removed and the deck plating NDT tested. If deck plate cracks are found this will require local inserts. The shape of brackets with excessive toe “nose” heights should be altered to reduce the height of the bracket “nose”
Recommendation:	Bracket toe height to be as small as possible (10 – 15 mm). Connecting the bracket and the pump foundation by a common stiffener type bracket should be considered when as closely fitted as in this case. Bracket on the pump foundation should also be considered



Deck machinery coaming bracket erroneously trimmed hence creating excessive toe height. Crack in deck plate resulted



Deck plate inserted. Pump foundation seat moved aft and coaming bracket renewed with minimum toe “nose” height.

13 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

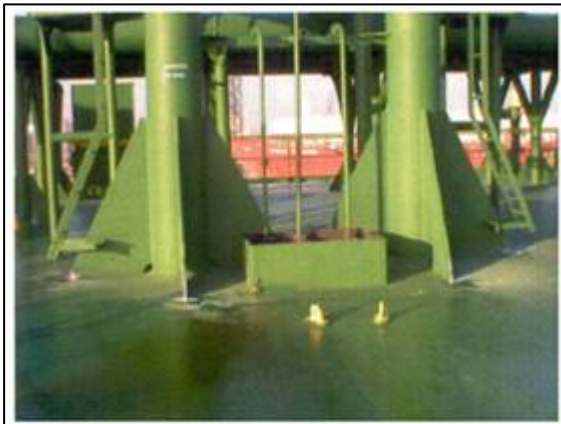


Figure 34 Deck Cracks IWO Bracket Toes of Vent Riser Pipe Support



Figure 35 Misalignment Brackets of Vent Riser Pipe Support



Corrective action

14 Miscellaneous penetrations 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 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



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.

15 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 300mm above the upper deck is the most preferred option. 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. If ship side gutter bars are fitted these should be free of any connections and the upper edge and treated the same as the upper edge of the sheer strake, including 3mm radius corners



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.

16 Manifold hose resting support (a)

Location:	Main deck cargo area (0,4L), manifold
Category:	Design
Type of Defect:	Fracture
Cause:	Flexible hose resting outfitting support consists of a structure with a plate welded directly on the sheer strake/gutter bar. Outfitting support plate end is tapered with a bracket. Fatigue crack developed at the end of the bracket through the sheer strake. The straight edge bracket with edge face flat has resulted in increased stress concentration at the connection to the ship side gutter bar. Also excessive toe height
Corrective Action:	Repair solution applied was to increase bracket size. Further improvement could be to soften the bracket design, making it well rounded. The toe/bracket should be full pen welded over 200-500 mm and the toe ground flush with the sheer strake/gutter bar. Also the flange should be reduced, one sided and well tapered
Recommendation:	Generally this kind of design must be avoided. At the design stage prefer piping type resting support not connected to sheer strake. If the bracket is required due to the arrangement the bracket is to be elliptical in shape, and utilize higher strength steel, full penetration welding of bracket to the gutter bar and minimum toe height. The size and thickness of the bracket to be such that no edge stiffener is required



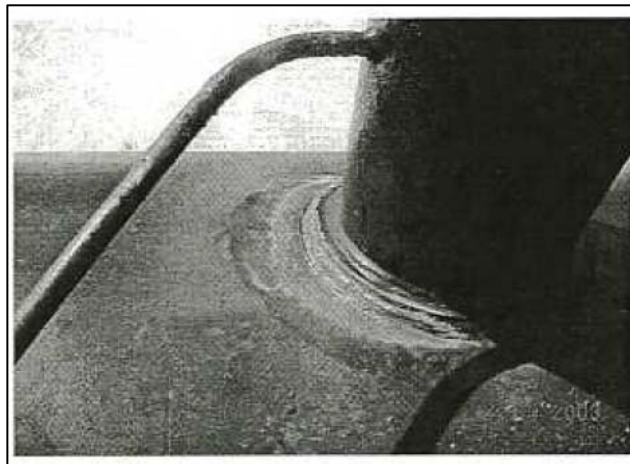
Crack developed through the sheerstrake at the manifold resting support.



Corrective action

17 Manifold hose resting support (b)

Location:	Main deck cargo area (0,4L), manifold
Category:	Design
Type of Defect:	A crack developed on upper deck (gunwale plate) around the fillet welding of doubling plate for the connection to stanchion
Cause:	Slight undercut was found at the cracked area and this area has high stress by longitudinal moment
Recommendation:	The fillet welding should be grinded smoothly to eliminate the possible undercuts and reduce stress concentration. Additional soft bracket fitted in line with under deck structure should also be considered. Such bracket should be fitted without doubler. Alternatively the hose rail should be considered cut in several lengths, this will make it more flexible and hence reduce the likelihood of deck cracks where the hose rail supports connect to the upper deck



18 Local underdeck structure in way of deck crane pedestal (a)

Location:	Main deck cargo area (0,4L)
Category:	Design / Construction & Installation
Type of Defect:	Fracture
Cause:	The local underdeck structure fitted in way of hose handling deck crane pedestal(s) is usually but not always local longitudinal girders fitted between two underdeck transverse web frames. A bracket arrangement is normally provided at the ends of these partial girders. If the bracket shape is not correct or the bracket toe heights are excessive cracks in the underdeck longitudinals are likely and such cracks may propagate into the upper deck plating
Corrective Action:	This underdeck structure should be specifically inspected during routine tank inspections and any defects found to be dealt with as necessary, with a view to integrating the increased local structure more gradually into the normal underdeck structure, hence reducing the stress concentration at the ends of the partial girders. This could take the form of fitting new brackets or modifying the toe design of existing brackets
Recommendation:	Locate the deck cranes in way of longitudinal / transverse bulkhead intersections, pass the deck crane pedestal through the deck, and integrate the pedestal into the bulkhead structure



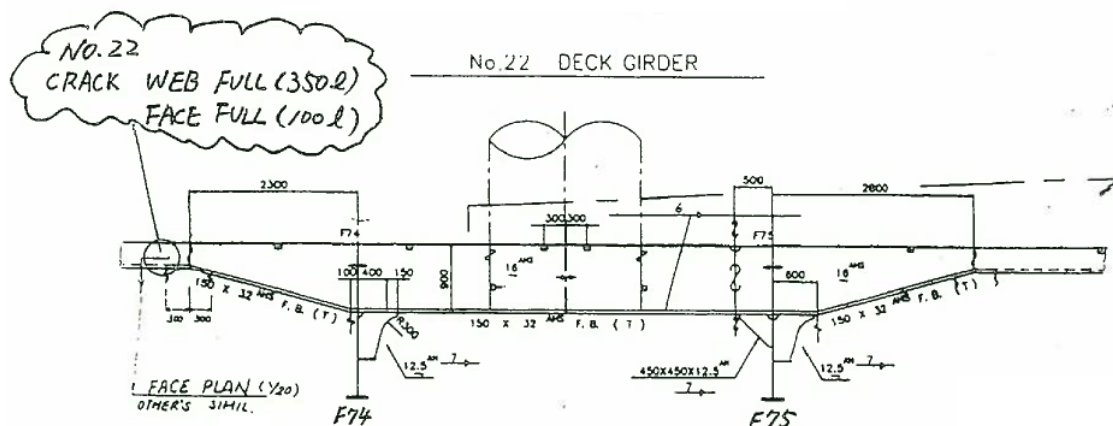
Crack in way of local underdeck girder end bracket toe



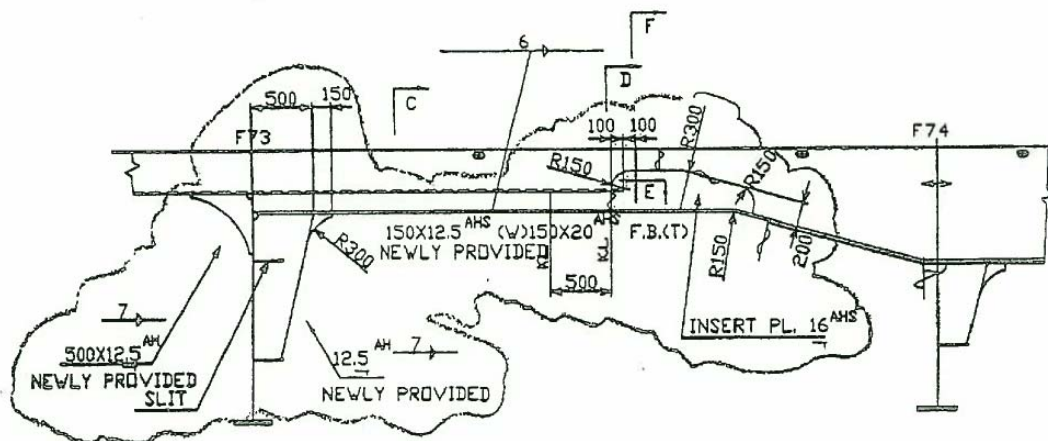
Local repairs / alterations in way of local underdeck girders

19 Local underdeck structure in way of deck crane pedestal (b)

Location:	Main deck cargo area (0,4L)
Category:	Design
Type of Defect:	Fracture of the deck structure under hose handling crane including local reinforcements. Fractures at the end of partial girders propagating into underdeck longitudinals and deck plating
Cause:	Stress concentration. The cracks are caused by longitudinal hull girder bending stresses and stress concentrations due to the change of design
Corrective Action:	The welding connections of both of web plate and face plate between the partial deck girders and ordinary deck longitudinals were arranged in the same line. The welding connections of web plate and face plate were re arranged 300mm apart and the reduction of the scantling between the partial girders and the ordinary deck longitudinals was made smoother than the original design by increasing the scantling of ordinary deck longitudinals adjacent to the partial girders in order to make the transference of stress from the partial girders to the ordinary longitudinals smoother
Recommendation:	Locate the deck cranes in way of longitudinal / transverse bulkhead intersections, pass the deck crane pedestal through the deck, and integrate the pedestal into the bulkhead structure. Ensure smooth transitions with small stress concentrations in the connections between the longitudinals and the girders



AFTER REINFORCEMENT



20 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



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

21 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



22 Staging lug left from newbuilding 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



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

23 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



25 Pipe penetration at transverse 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:	To avoid vibration damages, additional stiffener on BHD plates and additional pipe supports were recommended. Making pipe flexible (couplings)
Recommendation:	Routine management of the pipe supporting “u” bolts and flexible couplings should be carried out i.e. one end fixed and one end flexible. “u” bolts not to be over tightened



26 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.



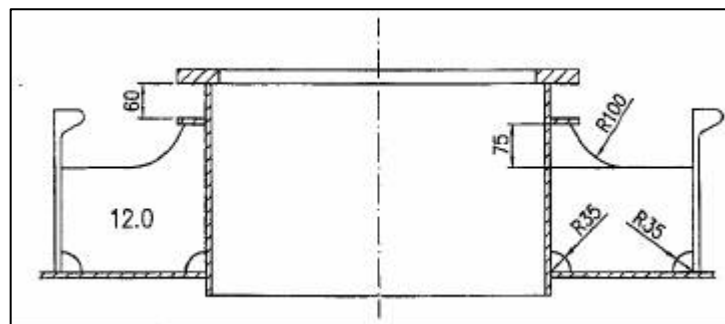
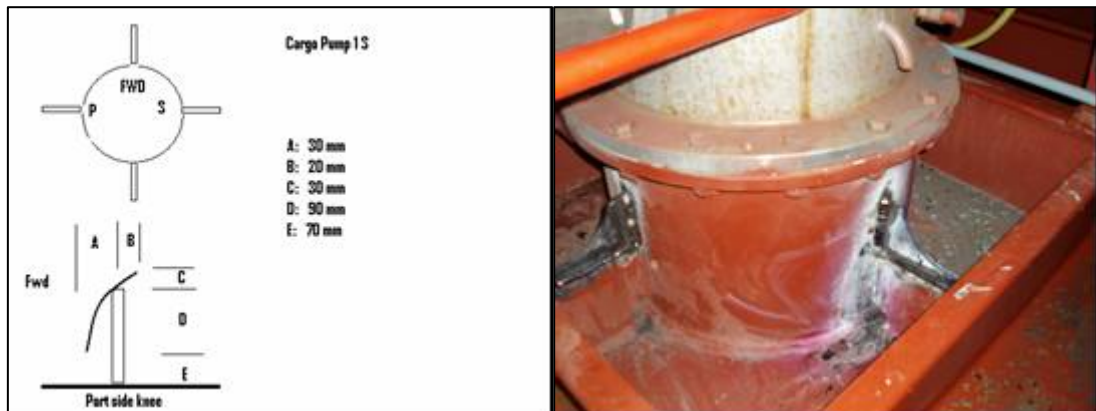
Deckhouse corner at connection to upper deck. Note crack in way of fillet welding and local scale



Deckhouse corner welding repaired and soft bracket fitted

27 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

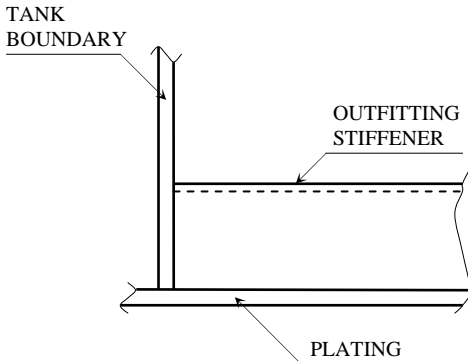
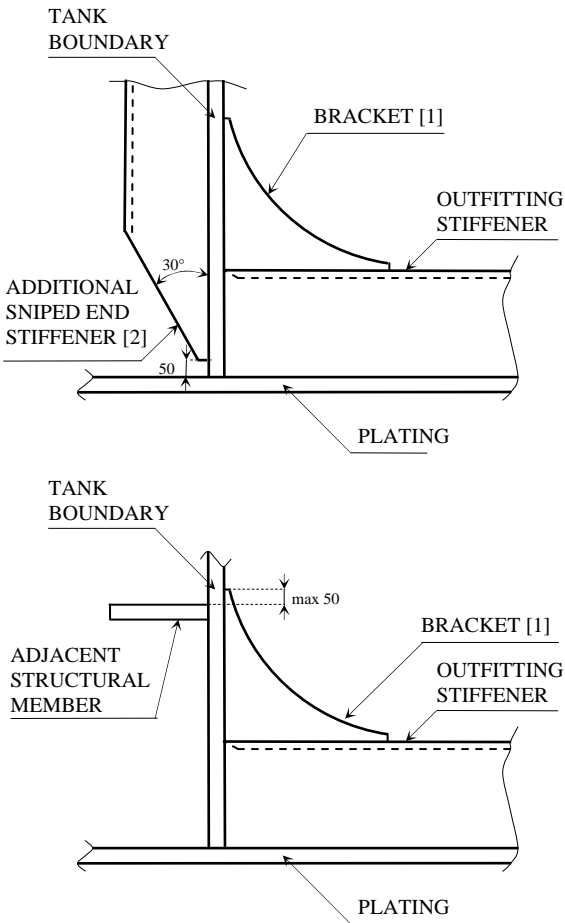



Appendix 2

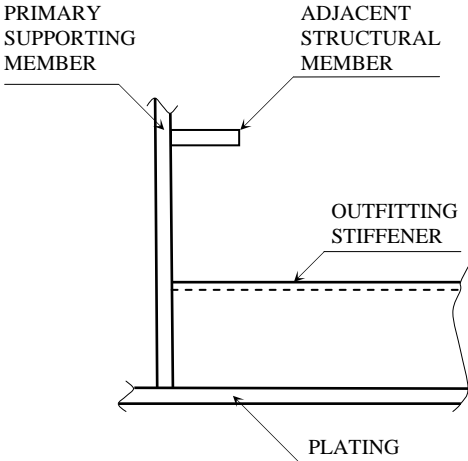
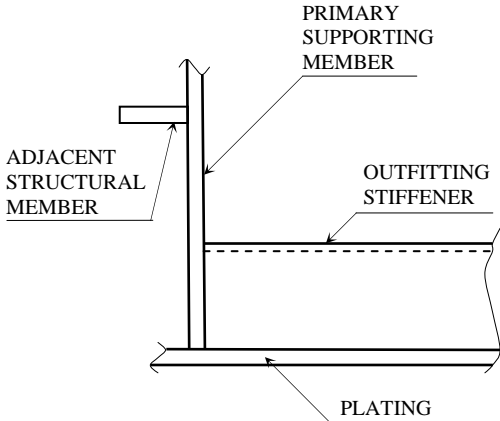
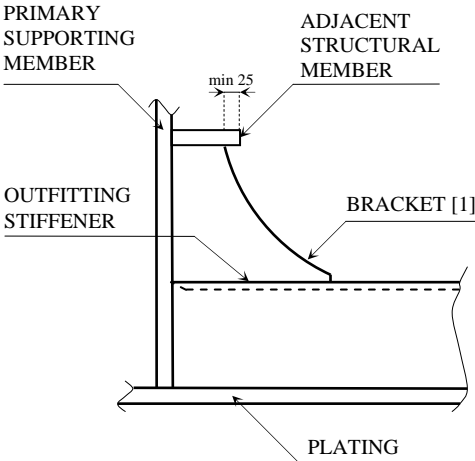
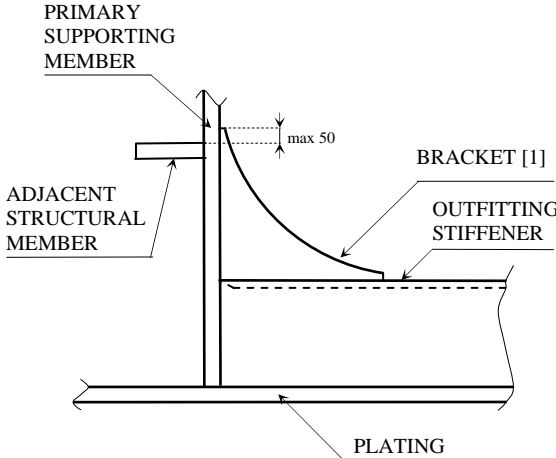

Recommendations for typical structural reinforcements

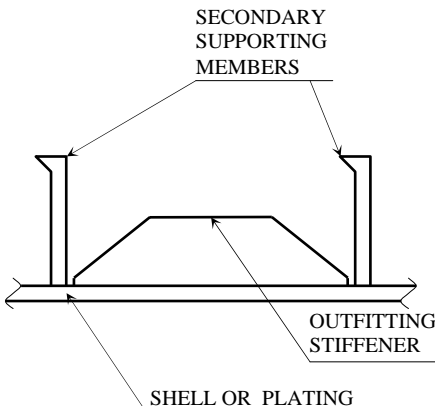
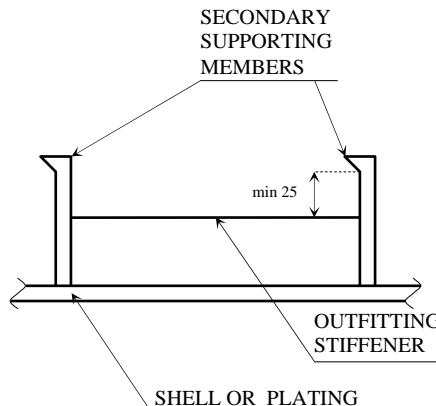

The purpose of this appendix is to summarize the minimum requirements for typical structural reinforcements in way of outfitting.

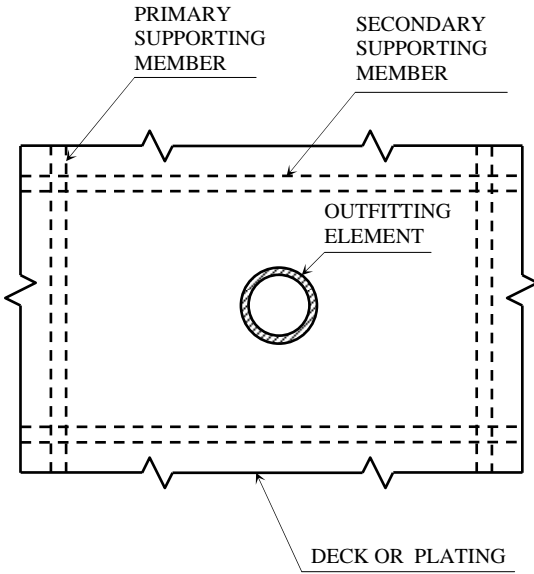
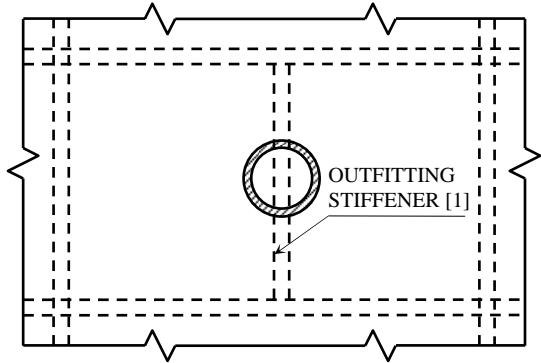
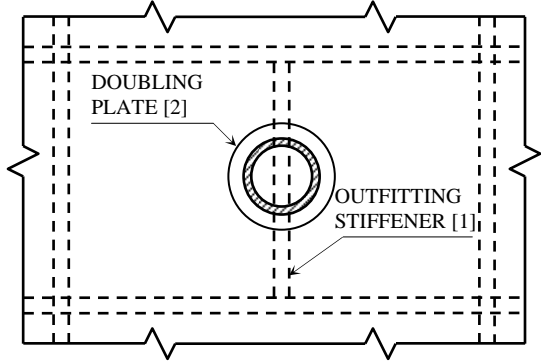

Reinforcement scantling to be according to expected load approved by class.

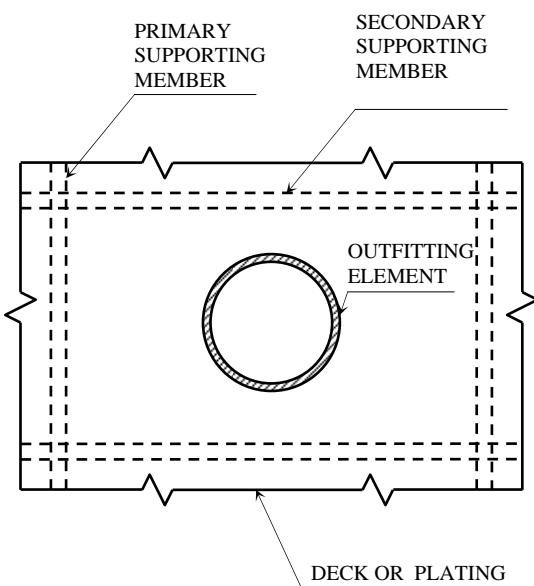
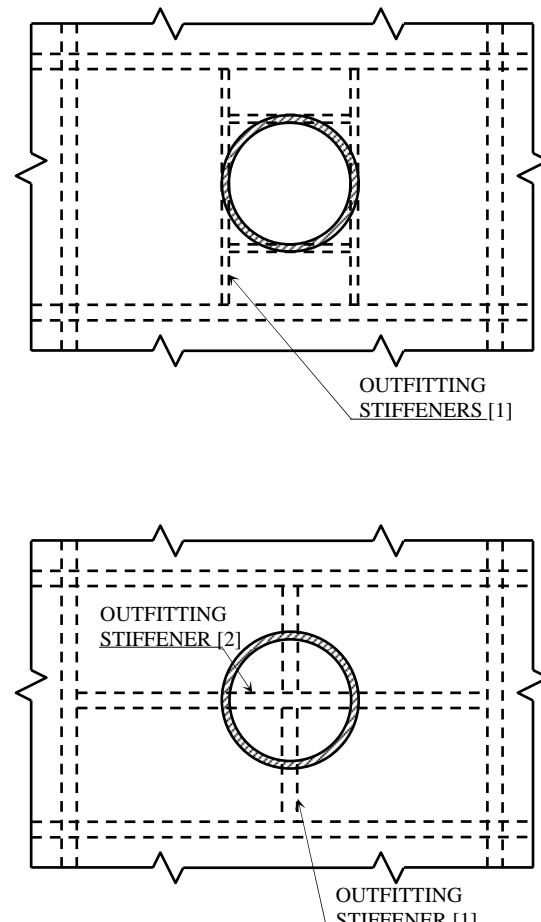

DESCRIPTION: CONNECTION OF OUTFITTING STIFFENER WITH A PLATE CONSTITUTING TANK BOUNDARY		APPENDIX 2
LOCATION: ENGINE ROOM, CARGO HOLD, FORE PART		
TO BE AVOIDED	TYPICAL RECOMMENDATION	
		
REMARKS: [1]: Brackets are to be fitted in compliance with FIGURE 11 [2]: The additional sniped end stiffener is to be aligned with the other stiffener and bracket		
 TANKER STRUCTURE CO-OPERATIVE FORUM	SUBJECT: TYPICAL RECOMMENDATIONS FOR OUTFITTING RELATED STRUCTURAL REINFORCEMENT	FIGURE 1

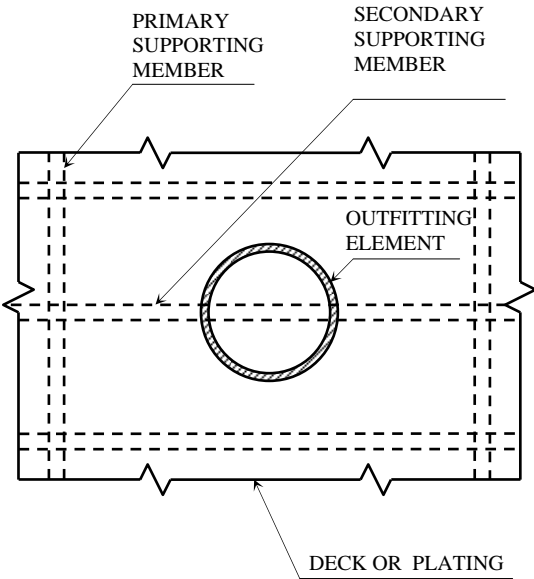
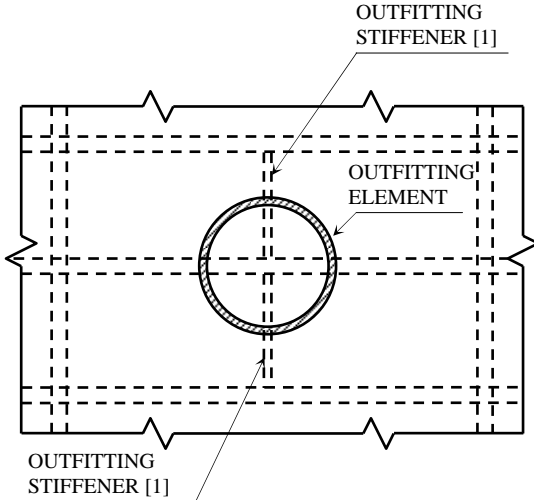

DESCRIPTION: CONNECTION OF OUTFITTING STIFFENER WITH T-SECTION PRIMARY SUPPORTING MEMBER		APPENDIX 2
LOCATION: ENGINE ROOM, CARGO HOLD, FORE PART		
TO BE AVOIDED		TYPICAL RECOMMENDATION
<div>PRIMARY SUPPORTING MEMBER</div> <div>OUTFITTING STIFFENER</div> <div>PLATING</div>		<div>PRIMARY SUPPORTING MEMBER</div> <div>OUTFITTING STIFFENER</div> <div>BRACKET [1]</div> <div>PLATING</div> <div>min 25</div>
REMARKS: [1]: Brackets and bracket toes are to be fitted in compliance with FIGURE 11		
	TANKER STRUCTURE CO-OPERATIVE FORUM	SUBJECT: TYPICAL RECOMMENDATIONS FOR OUTFITTING RELATED STRUCTURAL REINFORCEMENT
		FIGURE 2

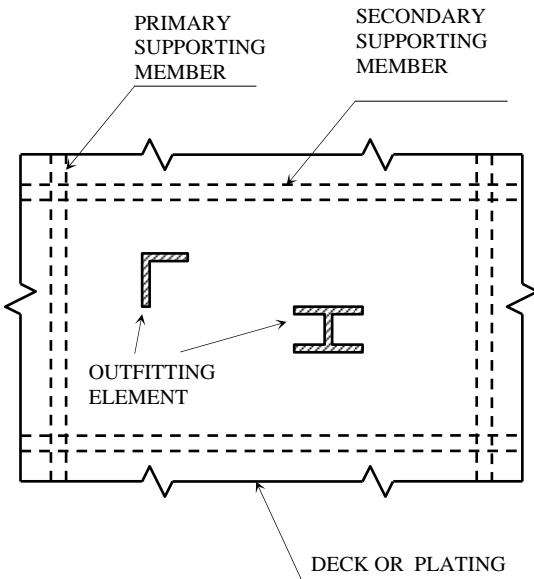
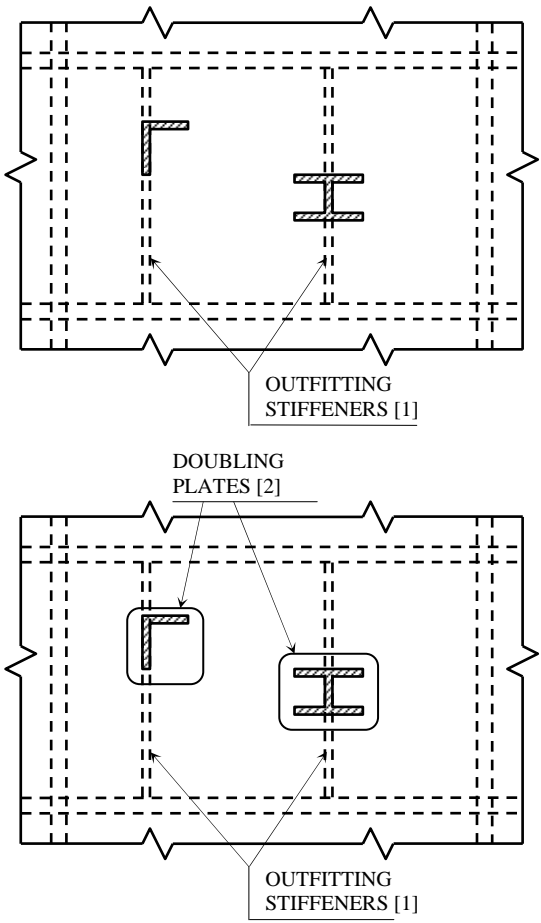

DESCRIPTION: CONNECTION OF OUTFITTING STIFFENER WITH ADJACENT STRUCTURAL ELEMENT PRIMARY SUPPORTING MEMBER [2]		APPENDIX 2
LOCATION: ENGINE ROOM, CARGO HOLD, FORE PART		
TO BE AVOIDED		TYPICAL RECOMMENDATION
<div></div> <div></div>		<div></div> <div></div>
REMARKS: [1]: Brackets and bracket toes are to be fitted in compliance with FIGURE 11 [2]: The details in the present figure are applicable for connection of outfitting stiffener with the flange of L-section primary supporting members		
 TANKER STRUCTURE CO-OPERATIVE FORUM	SUBJECT: TYPICAL RECOMMENDATIONS FOR OUTFITTING RELATED STRUCTURAL REINFORCEMENT	
		FIGURE 3

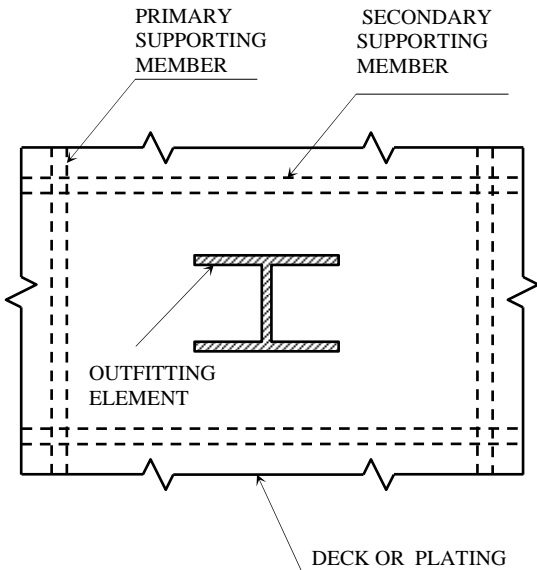
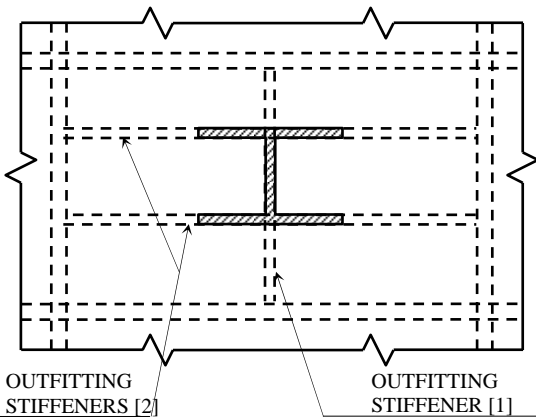

DESCRIPTION: CONNECTION OF OUTFITTING STIFFENER WITH SECONDARY SUPPORTING MEMBERS		APPENDIX 2
LOCATION: ENGINE ROOM, CARGO HOLD, FORE PART		
TO BE AVOIDED		TYPICAL RECOMMENDATION
		
REMARKS: When any outfitting stiffener has a face plate or flange, it is to be sniped and tapered to an angle not greater than 30°		
 TANKER STRUCTURE CO-OPERATIVE FORUM	SUBJECT: TYPICAL RECOMMENDATIONS FOR OUTFITTING RELATED STRUCTURAL REINFORCEMENT	FIGURE 4

DESCRIPTION: REINFORCEMENT UNDER DECK OR BULKHEAD DUE TO OUTFITTING ROUND ELEMENT WITH SMALL SECTION UNDER LOW LOAD		APPENDIX 2
LOCATION: ENGINE ROOM, CARGO HOLD, FORE PART		
TO BE AVOIDED	TYPICAL RECOMMENDATION	
<div><p>PRIMARY SUPPORTING MEMBER</p><p>SECONDARY SUPPORTING MEMBER</p><p>OUTFITTING ELEMENT</p><p>DECK OR PLATING</p></div>	<div><p>OUTFITTING STIFFENER [1]</p></div> <div><p>DOUBLING PLATE [2]</p><p>OUTFITTING STIFFENER [1]</p></div>	
REMARKS: [1]: Outfitting stiffeners are to be connected as in FIGURE 4 [2]: Doubling plates are to be used only when appropriate, when under compression only. Doubling plates are to comply with FIGURE 13		
<div><p>TANKER STRUCTURE CO-OPERATIVE FORUM</p></div>	SUBJECT: TYPICAL RECOMMENDATIONS FOR OUTFITTING RELATED STRUCTURAL REINFORCEMENT	
		FIGURE 5

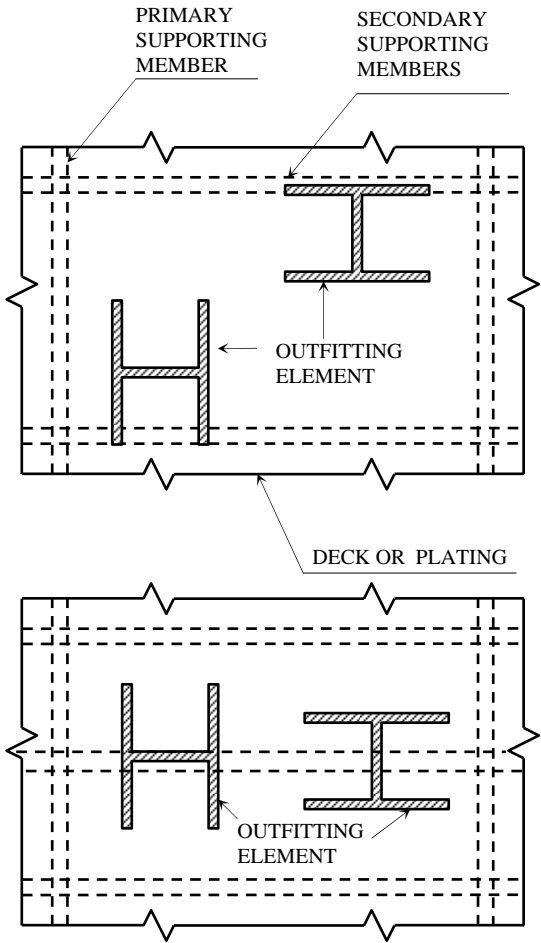
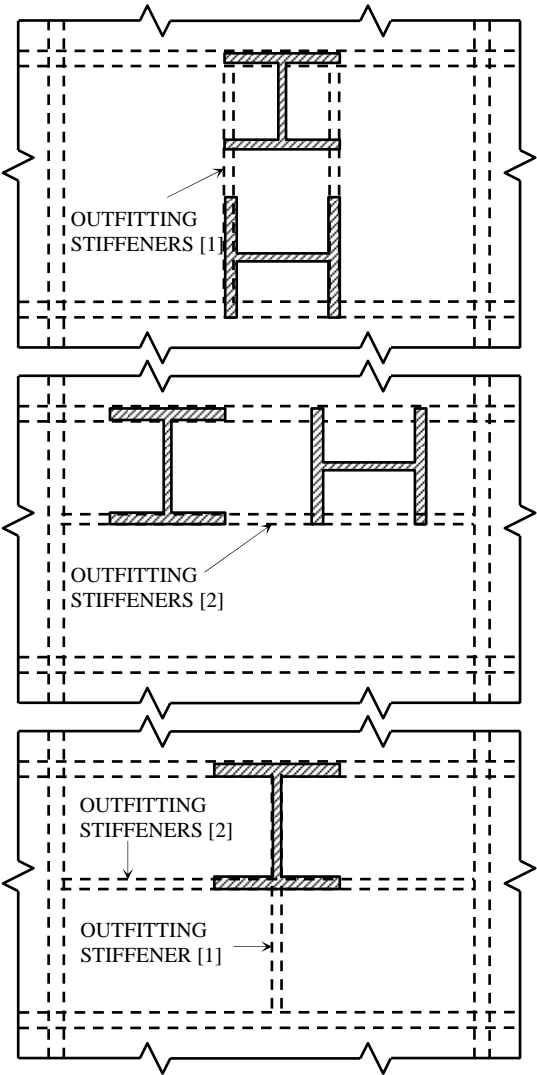

DESCRIPTION: REINFORCEMENT UNDER DECK OR BULKHEAD DUE TO OUTFITTING ROUND ELEMENT WITH LARGE SECTION		APPENDIX 2
LOCATION: ENGINE ROOM, CARGO HOLD, FORE PART		
TO BE AVOIDED		TYPICAL RECOMMENDATION
		
REMARKS: [1]: Outfitting stiffeners are to be connected with secondary supporting members as shown in FIGURE 4 [2]: Outfitting stiffeners are to be connected with primary supporting members as shown in FIGURE 2 or FIGURE 3, as relevant.		
 TANKER STRUCTURE CO-OPERATIVE FORUM	SUBJECT: TYPICAL RECOMMENDATIONS FOR OUTFITTING RELATED STRUCTURAL REINFORCEMENT	FIGURE 6

DESCRIPTION: REINFORCEMENT UNDER DECK OR BULKHEAD DUE TO OUTFITTING ROUND ELEMENT IN WAY OF A STIFFENER LOCATION: ENGINE ROOM, CARGO HOLD, FORE PART	APPENDIX 2	
TO BE AVOIDED		TYPICAL RECOMMENDATION
		
REMARKS: [1]: Outfitting stiffeners are to be connected with secondary supporting members as shown in FIGURE 4		
 TANKER STRUCTURE CO-OPERATIVE FORUM	SUBJECT: TYPICAL RECOMMENDATIONS FOR OUTFITTING RELATED STRUCTURAL REINFORCEMENT	FIGURE 7

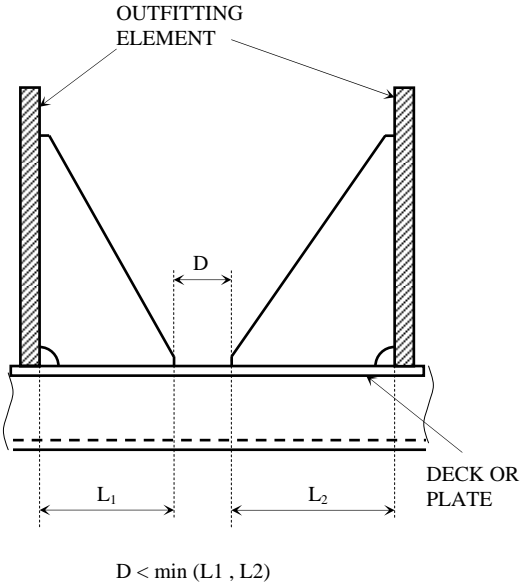
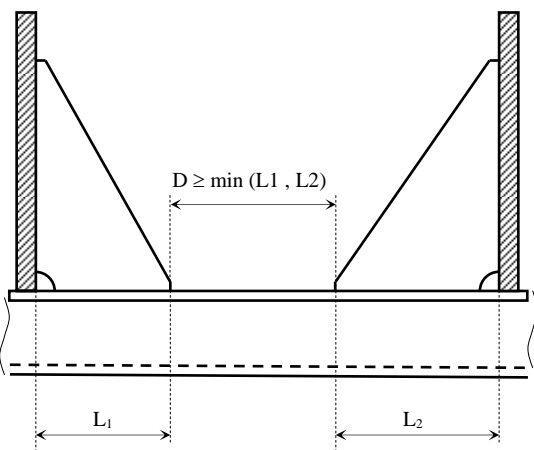
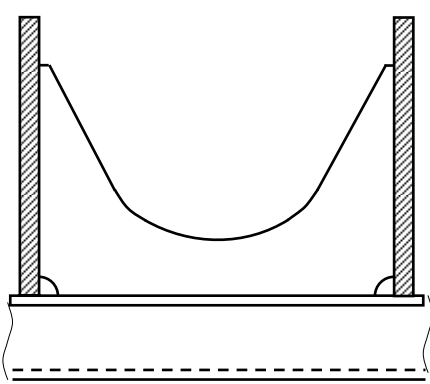

DESCRIPTION: REINFORCEMENT UNDER DECK OR BULKHEAD DUE TO OUTFITTING H or L ELEMENT WITH SMALL SECTION UNDER LOW LOAD		APPENDIX 2
LOCATION: ENGINE ROOM, CARGO HOLD, FORE PART		
TO BE AVOIDED		TYPICAL RECOMMENDATION
		
REMARKS: [1]: Outfitting stiffeners are to be connected with secondary supporting members as shown in FIGURE 4 [2]: Doubling plates are to be used only when appropriate, when under compression only. Doubling plates are to comply with FIGURE 13		
 TANKER STRUCTURE CO-OPERATIVE FORUM	SUBJECT: TYPICAL RECOMMENDATIONS FOR OUTFITTING RELATED STRUCTURAL REINFORCEMENT	FIGURE 8

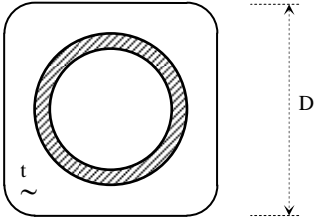
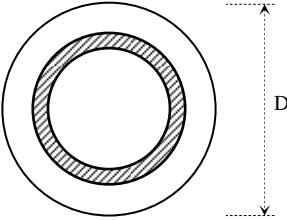
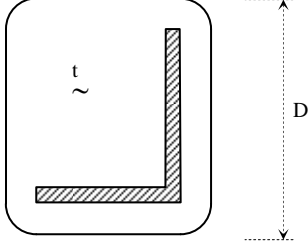
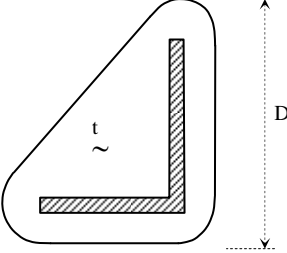
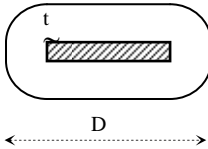
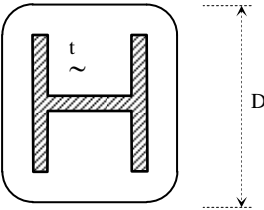

DESCRIPTION: REINFORCEMENT UNDER DECK OR BULKHEAD DUE TO OUTFITTING H ELEMENT WITH LARGE SECTION		APPENDIX 2
LOCATION: ENGINE ROOM, CARGO HOLD, FORE PART		
TO BE AVOIDED		TYPICAL RECOMMENDATION
<div></div>		<div></div>
REMARKS: [1]: Outfitting stiffeners are to be connected with secondary supporting members as shown in FIGURE 4 [2]: Outfitting stiffeners are to be connected with primary supporting members as shown in FIGURE 2 or FIGURE 3, as relevant.		
 <div>TANKER STRUCTURE CO-OPERATIVE FORUM</div>	SUBJECT: TYPICAL RECOMMENDATIONS FOR OUTFITTING RELATED STRUCTURAL REINFORCEMENT	FIGURE 9

SUBJECT: TYPICAL
RECOMMENDATIONS FOR
OUTFITTING RELATED
STRUCTURAL REINFORCEMENT

DESCRIPTION: REINFORCEMENT UNDER DECK OR BULKHEAD DUE TO OUTFITTING H ELEMENT WITH LARGE SECTION IN WAY OF PRIMARY OR SECONDARY MEMBER		APPENDIX 2
LOCATION: ENGINE ROOM, CARGO HOLD, FORE PART		
TO BE AVOIDED	TYPICAL RECOMMENDATION	
		
REMARKS: [1]: Outfitting stiffeners are to be connected with secondary supporting members as shown in FIGURE 4 [2]: Outfitting stiffeners are to be connected with primary supporting members as shown in FIGURE 2 or FIGURE 3, as relevant.		
 TANKER STRUCTURE CO-OPERATIVE FORUM	SUBJECT: TYPICAL RECOMMENDATIONS FOR OUTFITTING RELATED STRUCTURAL REINFORCEMENT	
		FIGURE 10

<p>DESCRIPTION: DETAILS OF BRACKETS</p> <p>LOCATION: ENGINE ROOM, CARGO HOLD, FORE PART</p>	<p>APPENDIX 2</p>
<p>TYPICAL RECOMMENDATION</p>	
<p>ADJACENT STRUCTURAL MEMBER</p> <p>PRIMARY SUPPORTING MEMBER OR BULKHEAD</p> <p>SHELL</p> <p>OUTFITTING STIFFENER</p> <p>max 50</p> <p>t</p> <p>STIFFENER OF PRIMARY MEMBER OR BULKHEAD</p> <p>PRIMARY SUPPORTING MEMBER OR BULKHEAD</p> <p>SHELL</p> <p>OUTFITTING STIFFENER</p> <p>t</p> <p>OUTFITTING ELEMENT</p> <p>UNDERDECK STIFFENER</p> <p>DECK OR PLATING</p> <p>R = 35 + 50</p> <p>t</p> <p>10 + 15</p> <p>R = 35 + 50</p> <p>10 + 15</p> <p>SOFT BRACKET – TO BE USED FOR ALL CONNECTIONS IN LOCATIONS WITH HIGH LEVEL OF VIBRATION</p>	
<p>REMARKS:</p> <ul style="list-style-type: none"> • Bracket toe height is to be kept to a minimum of 10 – 15 mm • All brackets are to be aligned with adjacent stiffeners or underdeck structure, with an acceptable tolerance of $t/2$ • When a flange or faceplate is fitted, it is to be sniped to an angle not above 30° 	
<p>TANKER STRUCTURE CO-OPERATIVE FORUM</p>	<p>SUBJECT: TYPICAL RECOMMENDATIONS FOR OUTFITTING RELATED STRUCTURAL REINFORCEMENT</p> <p>FIGURE 11</p>

DESCRIPTION:	CONNECTIONS WITH BRACKETS OF ADJACENT OUTFITTING ELEMENTS	APPENDIX 2
LOCATION:	ENGINE ROOM, CARGO HOLD, FORE PART	
TO BE AVOIDED		TYPICAL RECOMMENDATION
 <p>OUTFITTING ELEMENT</p> <p>DECK OR PLATE</p> <p>$D < \min (L_1 , L_2)$</p>		 <p>$D \geq \min (L_1 , L_2)$</p> 
REMARKS: Brackets and bracket toes are to be fitted in compliance with FIGURE 11.		
	TANKER STRUCTURE CO-OPERATIVE FORUM	SUBJECT: TYPICAL RECOMMENDATIONS FOR OUTFITTING RELATED STRUCTURAL REINFORCEMENT
FIGURE 12		

DESCRIPTION: DETAILS OF DOUBLING PLATES		APPENDIX 2
TYPICAL RECOMMENDATION		
<div><div></div><div></div><div></div><div><div>FOR $t < 15\text{ mm} \rightarrow D / t < 20$</div><div>FOR $t \geq 15\text{ mm} \rightarrow D / t < 25$</div></div></div>		
REMARKS: <ul style="list-style-type: none">• Doubling plates are to be used only when appropriate, when under compression only.• Doubling plates corners (when relevant) are to be rounded with a radius not less than 25 mm		
	TANKER STRUCTURE CO-OPERATIVE FORUM	SUBJECT: TYPICAL RECOMMENDATIONS FOR OUTFITTING RELATED STRUCTURAL REINFORCEMENT
		FIGURE 13