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Hull Strapping of Ships

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ABSTRACT

The paper presents the results of a study, sponsored by the Ship Structure Committee and administered by the U.S. Coast Guard Research and Development Center, which involved a thorough survey of past strapping designs on fourteen different classes of ships. Data on details of past strapping designs were obtained from various sources including shipowners, shipyards, classification societies, and the U.S. Navy. The variations in the approach to strapping design details were noted and a methodology was developed for use in preparing strapping designs for new applications.

INTRODUCTION

During the service lifetime of a ship, it may be necessary to increase the strength and stiffness of its hull girder structure for a number of reasons. One of the most common methods of accomplishing this purpose is "strapping".

Strapping of ships' hulls involves the attachment to the main hull plating of long and continuous widths of plates that essentially "strap" the existing structure and provide additional material to increase the hull girder section modulus. The reasons for and the objectives of strapping a ship's hull may fall into one or more of the following categories:

(a) To improve the continuity of the structure and to prevent the recurrence of persistent failures such as cracks, severe buckling and extensive distortion of plates, stiffeners, etc.

(b) To enable the ship to withstand more severe service requirements than that for which it was originally designed and built.

(c) To increase the cargo and/or passenger carrying capacity of the ship by jumboizing, i.e. increasing the vessel's size by lengthening, widening, deepening or by any combination thereof.

The use of strapping for category (a) purposes is very rare in present day applications; it was resorted to during and after World War II on early all-welded steel ships. Riveted crack arresters (straps) were installed on many T-2 tankers and Liberty ships to prevent brittle fracture.

Many ships have been strapped in the past for category (b) purposes. Typical applications have included changing the vessel's service from limited inland waterways or lake operation to ocean-going service; converting a vessel from a dry cargo carrier to a container carrier or oil/bulk/ore carrier; and vice versa.

Category (c) is the most common justification for strapping and is generally used in conjunction with jumboizing the vessel by inserting a new midbody. Often in such cases, the new midbody is constructed to the original scantlings and inserted between the fore and aft bodies of the existing ship. In order to meet the hull girder section modulus requirements for the now increased vessel size, continuous doubler plates are added to extend over both the new midbody and the existing fore and aft bodies.

This paper discusses the findings from a Ship Structure Committee project, Reference #1. The objectives of the study were to survey past strapping designs with regard to the method of attachment, longitudinal extent, location, width and thickness tapering, and other details of the doublers, and to develop a practical and cost effective design approach for future strapping applications.

To achieve these objectives, survey questionnaires were sent to the following:

- U.S. based shipowners and operators
- Foreign shipowners and operators
- U.S. shipyards
- U.S. Coast Guard
- U.S. Navy

- o Military Sealift Command
- o American Bureau of Shipping
- o U.S. and major foreign classification societies

The data collected from these sources are summarized and a methodology for future strapping designs is presented as well as the American Bureau of Shipping, Reference #2, and Bureau Veritas, Reference #3, guidelines for strapping details.

RESULTS OF SURVEY

After requesting and receiving from the six major classification societies the lists of vessels jumboized under their inspection, it was found that a total of 1551 ships had been lengthened, widened,or deepened as shown in Table I. The lists were subjected to an initial screening to reduce the otherwise impractical task of searching for information for all of these 1551 ships. This effort reduced the total number of ships to 110 by limiting the ship types and sizes to those of immediate interest.

Survey questionnaires were sent to the 87 owners and operators of these 110 ships and responses were received from 28. Only 11 of the responders provided strapping information and details for their ship(s). Filled out survey questionnaires and drawings or sketches of strapping details were also received form two shipyards.

In the end, sufficient information was obtained for a total of 14 different ship classes to include in the study. Table II lists these ships by type, classification society, flag of registry, year strapped, and the country where strapping was accomplished. The tables in Appendix A summarize the strapping details compiled for each of these fourteen ship classes. The data were sorted in accordance with the following breakdown:

- o Locations of strapping on the ship's hull.
- o Scantlings and longitudinal extent of doubler plates.
- o Materials used in strapping.
- o Method of joining parallel doublers.
- o Tapering of doubler plate scantlings.
- o Edge preparation.
- o Faying surface treatment.

By reviewing the data and comparing the details for various ships in each of the above categories, the summaries given below were made:

Strap Locations

On most of the ships, doubler plates were installed on the deck, and/or the bottom and/or side shell plating. Figures 1 and 2 show the most widely used strap locations for typical tanker and container ship hulls, respectively.

In one ship class, doublers were placed on the innerbottom plating and in another longitudinal girders were added on the bottom instead of doubler plates. Deck and bottom doublers were placed in such a manner that they were "backed-up" by longitudinal bulkheads or girders.

Scantlings and Longitudinal Extent

Doubler plate thicknesses ranging from 3/4" to 2-3/4" were used on different ships and the widths of doublers varied from a minimum of 9" to a maximum of 103". For most ships, the longitudinal extent of doublers was found to be the midship 40% length but there were some ships where the doublers were extended to the midship 6/10 or even to the midship 2/3 length.

Strapping Materials

For most applications, the materials used for doubler plates were found to be of the same strength as the underlying hull plating to which they were attached. The grade of material for doublers were changed for some applications (e.g. ships C, E, K, N, and P) as required by the classification society rules for varying plate thicknesses.

Method of Attachment

Doubler plates of varying widths were, in many cases, attached to the main hull plating by welding only the two sides and the ends. Figure 3 shows the typical arrangements and welding details for this method of attachment and lists the ships where it was used. As seen, the doubler thicknesses ranged from 3/4" to 2.6" and widths from 14" to 55". Fillet welds were used on all but one ship which had bevelled weld connections.

On several ships, e.g. Ships B, D, and G, slot welding was employed for doubler plate widths ranging from 31" to 103". In this case, in addition to the fillet welds at sides and ends of the doubler plate, pre-cut holes in the doubler were slot welded to ensure tight fitting. Figure 4 shows the details of slot welds used on these three ships. The slots were originally filled with an epoxy compound on Ship B to prevent collection of water in the holes. It was found later however that the epoxy had pulled away from the sides of the slot thus allowing water to seep in and cause corrosion of the faying surfaces. The epoxy filling was removed to remedy the situation, holes were blasted and recoated.

CLASSIFICATION SOCIETY	TOTAL NUMBER OF JUMBOIZED SHIPS	NUMBER OF SHIPS AFTER INITIAL SCREENING
American Bureau of Shipping	197	34
Bureau Veritas (BV)	573	27
Det norske Veritas (DnV)	397	6
Germanischer Lloyd (GL)	99	7
Lloyds Register of Shipping (LR)	171	16
Nippon Kaiji Kyokai (NK)	114	20
TOTAL	1551	110

TABLE I: SHIPS JUMBOIZED BY CLASSIFICATION SOCIETIES

SHIP	TYPE	CLASSED BY	FLAG OF REGISTRY	YEAR STRAPPED	WHERE STRAPPED
A	Bulk Carrier	ABS	US	75	US
B	Tanker	ABS	US	84	US
C	Containership	ABS	US	85	Japan
D	Containership	ABS	US	72	US
E	Containership	LR	US	81	Japan
F	Containership	ABS	US	88	W.Germany
G	Ro/Ro	ABS	US	82	US
H	Bulk Carrier	ABS	US	73	US
J	Containership	ABS	US	72	US
K	Containership	GL	US	84	W.Germany
L	Navy Escort	-	US	83	US
M	Multi-purpose	ABS	US	84	US
N	Containership	LR	NOR	84	S.Korea
P	Containership	LR	DAN	84	S.Korea

TABLE II: SHIPS FOR WHICH STRAPPING DETAILS WERE RECEIVED

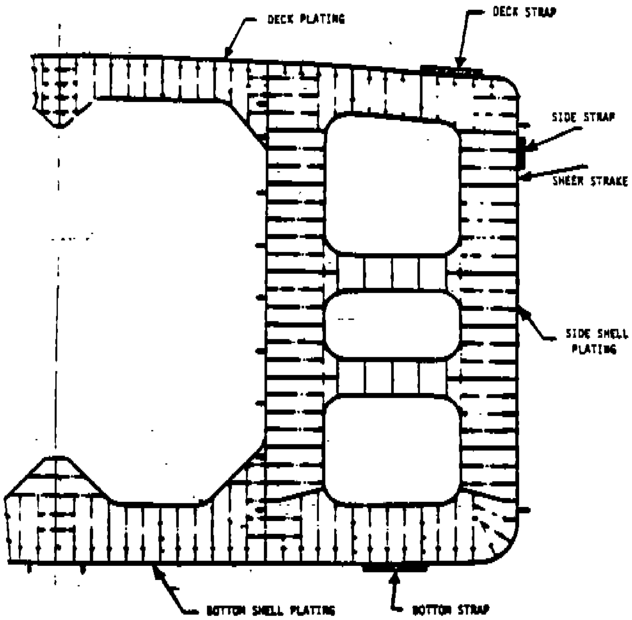


FIGURE 1: STRAP LOCATIONS FOR A TYPICAL TANKER

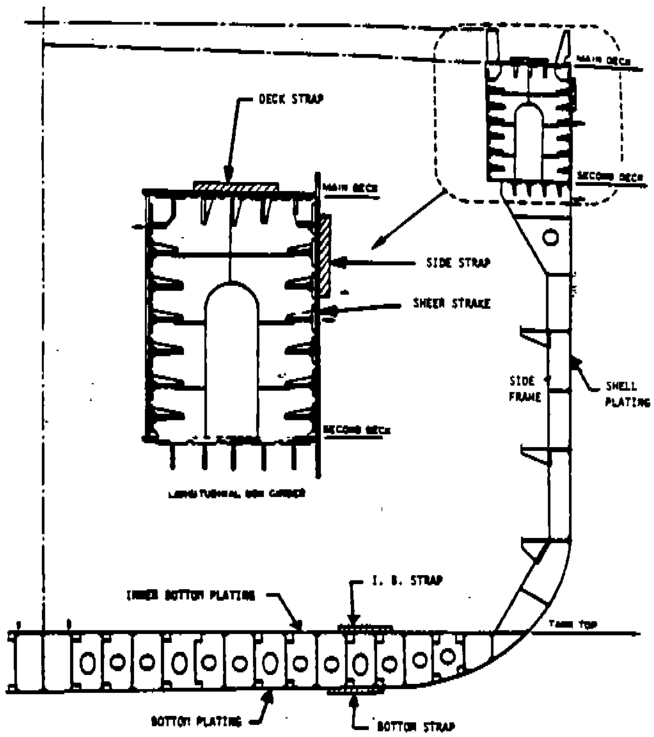


FIGURE 2: STRAP LOCATIONS FOR A TYPICAL CONTAINERSHIP

On two ships (ships J and L), two or more strips of narrow doublers were installed adjacent to each other in order to avoid slot welds and these were joined together by full depth groove welds as shown in Figure 5. The individual strips were 15" and 9" wide, respectively.

Three other ships (A, H, and M) had wider strips of doublers, about 24", joined together by partially welded groove type connections as shown in Figure 6.

The size of fillet welds on the forward and aft ends of long doubler plates on ships C and K were increased to provide reinforcement as shown in Figure 7. Also illustrated in this figure are the extents, i.e. the lengths, of weld reinforcement at ends for both ships.

Individual lengths of plates that combine to form a long and continuous doubler were joined together by butt welding. Different butt welding details were used depending on the configuration of the structure and the plating thickness. When the underlying hull plating was of uniform thickness, the detail shown in Figure 8 was used. The steel backing bar shown in this figure was used only on two of the ships (A and H). The butt welds on the existing hull plating in way of the doublers were ground flush prior to installation of straps.

Where the thickness of underlying hull plating in way of the doublers was stepped on two of the ships (C and L), the butt welding detail shown in Figure 9 was used.

The detail shown in Figure 10, as applied on Ship D, was used in the butt welding of a 3/4" thick doubler plate to a 1-3/8" thick insert plate on the new midbody. The bottom shell plating was first butt welded to the insert plate and then back gouged and chipped to sound metal prior to butting the doubler to the insert.

A different butt weld detail was found on Ship J where the doubler had to pass through a heavy insert plate in way of an opening on the side shell. The insert plate, which was installed to reinforce the opening, was both thicker and wider than the doubler plate as shown in Figure 11. The doubler width was gradually increased to match the width of the insert by means of a transition piece which was then plug welded to ensure tightness.

Tapering of Scantlings

Throughout the midship 4/10 to 2/3 length, the thicknesses and widths of doublers were kept constant on all strapping designs. Where the longitudinal extent of doublers went beyond these midship lengths (as required for structural continuity) however, tapering of doubler scantlings was employed. Shown in Figure 12 are two different details of thickness tapering, "A" and "B." On ships A and H, the doubler plate thickness was tapered in steps as in "A" while on ship C it was accomplished in one step as in "B." The detail in "A" was used where the difference in doubler plate thickness was too great to allow an untapered end. In this case, the end of the thicker plate was ground to form a smooth slope down to the thickness of the thinner plate and then butt welded to it. The detail in sketch B was used in cases where the thickness difference was minor.

The widths of doubler plates were tapered beyond the specified midship length even when the thickness was not tapered. Figure 13 shows the details for two most common types of width tapering, i.e., single sided and two sided.

Edge Preparation

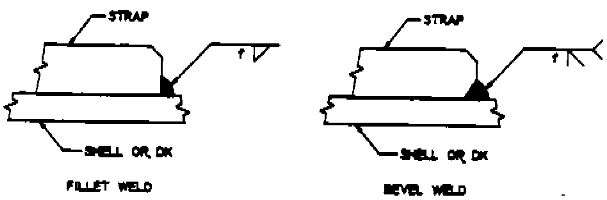
The detailed strapping drawings for most of the ship classes studied contained general notes with instructions for edge preparation. Some of the notes common to most ships were the following:

- Any rough cutting or minor notches on the plating to be ground smooth and plating to be faired prior to installation.
- Deeper notches to be veed-out, welded, and ground smooth.
- Edges of plating to be kept clean, free from moisture, grease, loose mill scale, excessive rust or paint in order to obtain sound welding.
- Corners of all free edges to be dressed smooth and chamfered from about 1/16" X 1/16" to about 1/8" X 1/8" by grinding in order to minimize notch effects.
- Larger chamfers to be provided on deck strapping for stress streamlining and to reduce traffic/tripping hazards, and on bottom strapping to reduce resistance to flow.

Shown in Figures 14 and 15 are the details of "end" and "edge" chamfering applications for some of the ship classes.

Faying Surface Treatment

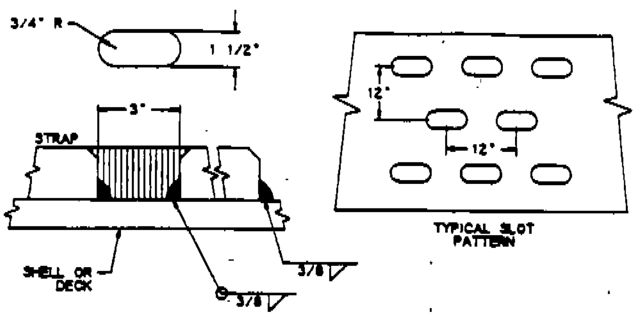
None of the strapping detail drawings for the fourteen ship classes studied in this project specified any faying surface treatments other than requiring the surfaces to be free of moisture, grease, loose mill scale, excessive rust, or paint, etc. Some drawings called for the underlying hull plating in way of doublers to be made even and free of any buckling distortions. It was required that any deformations in hull plating be corrected and faired prior to



SAMPLE APPLICATIONS

SHIP	LOCATION	STRAP WIDTH	STRAP THICK	f	WELD TYPE
C	DECK	24"	2.6"	3/4"	FILLET
	BOT SHELL	18"	1.3"	7/16"	FILLET
E	BOX GIRD	14"	1.57"	1/2"	BEVEL
	BOT SHELL	21"	1.5"	1/2"	BEVEL
F	BOX GIRD	18"	2.75"	5/8"	FILLET
H	BOT SHELL	18"	1.5"	7/16"	FILLET
K	BOT SHELL	55"	0.75"	1/4"	FILLET
	COAMING	35"	1.26"	1/4"	FILLET
N	COAMING	30"	1.77"	N/A	FILLET
	DECK	30"	1.77"		FILLET
	BOT SHELL	22"	1.26"		FILLET
P	DECK	26"	1.77"	N/A	FILLET
	BOT SHELL	25"	1.0"		FILLET

FIGURE 3: STRAP WELDED AT SIDE ONLY



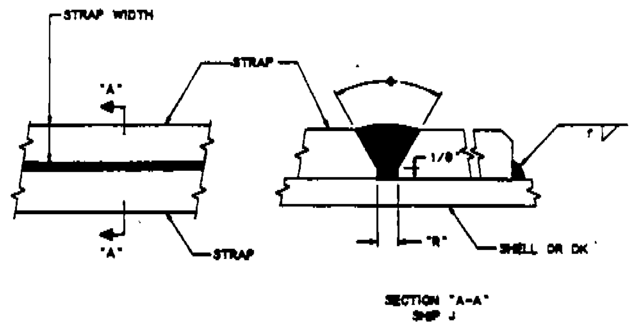
DETAILS

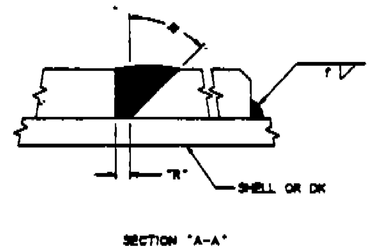
- SLOTS CUT LENGTHWISE
- STRAP EDGES 3/8" FILLET WELDED
- 3/8" FILLET WELD AROUND SLOT HOLE
- SLOT SPACING APPROX. 12 IN.

SAMPLE APPLICATIONS

SHIP	LOCATION	STRAP WIDTH	STRAP THICK	NO. SLOT ROWS
B	DECK	7'-0"	3/4"	6
		8'-7"	3/4"	6
G	INNER BOT	5'-6"	1 1/4"	4
		2'-7"	1 1/4"	2
	BOT SHELL	3'-6 1/2"	1"	3
D	BOT SHELL	7'-0"	3/4"	N/A

FIGURE 4: SLOT WELDING

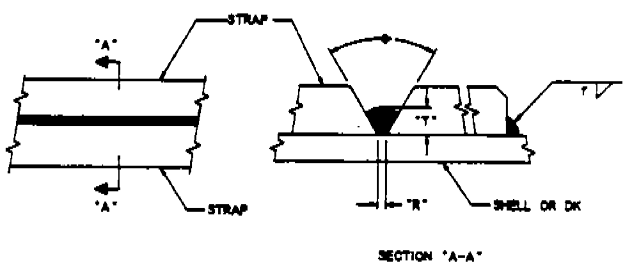




SAMPLE APPLICATIONS

SHIP	LOCATION	STRAP WIDTH	STRAP THICK	◆	R	f
J	DECK	15"	1.38"	30°	3/8"	7/8"
	SHEER STRAKE	15"	1.0"	30°	3/8"	5/8"
L	SHEER STRAKE	8"	3/4"	45°	1/4"	5/8"
	BOT SHELL	8"	3/4"	45°	1/4"	5/8"

FIGURE 5: JOINING STRIPS OF DOUBLERS WITH FULL DEPTH GROOVE WELDING

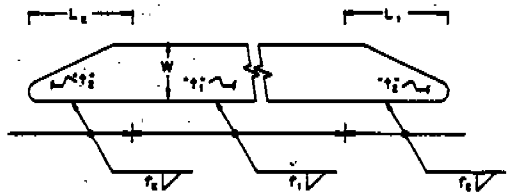


SAMPLE APPLICATIONS

SHIP	STRAP WIDTH	STRAP THICK	◆	R	T	f
A	23.5"	2"	25°	1/2"	1/2"	1/2"
H	25"	1 3/4"	25°	1/2"	1/2"	1/2"
M	24"	1"	30°	3/8"	1/2"	7/16"

(NOTE: ALL STRAPS WERE LOCATED ON DECK)

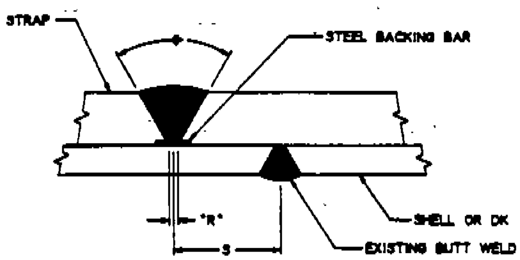
FIGURE 6: STRIPS OF DOUBLERS JOINED WITH PARTIAL GROOVE WELDING



SAMPLE APPLICATIONS

SHIP	LOCATION	f_1	f_2	W	t_1	t_2	L_1	L_2
C	DECK	3/4"	1"	24"	2.60"	1.50"	9.8"	9.8"
	BOT. SHELL	7/16"	5/8"	16"	1.30"	.70"	9.8"	9.8"
K	BOT. SHELL	1/4"	13/32"	55.1"	.79"	.79"	17.1"	17.7"

FIGURE 7: WELD REINFORCEMENT AT ENDS



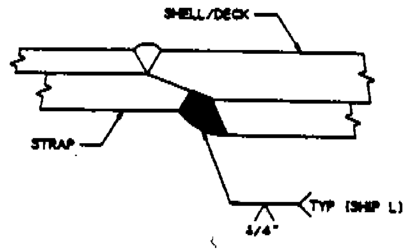
DETAILS

- EXISTING HULL PLATING BUTT WELD GROUND FLUSH IN WAY OF STRAP
- IN SOME CASES A STEEL BACKING BAR WAS INSTALLED BETWEEN STRAP AND DECK

SAMPLE APPLICATIONS

SHIP	LOCATION	STRAP THICK	Φ	R	S(MIN)	BACKING BAR
A	DECK	2"	25°	3/8"	—	YES
B	DECK	3/4"	25°	0"	16"	NO
C	DECK	2.6"	40°	1/4"	12"	NO
	BOT SHELL	1.3"	40°	1/4"	12"	NO
H	DECK	1 3/4"	25°	3/8"	—	YES
	BOT SHELL	1 1/2"	25°	3/8"		YES
J	DECK	1.38"	30°	3/8"	—	NO
	SHEER STRAKE	1.00"	30°	3/8"	—	NO
L	SHEER STRAKE	3/4"	45°	1/4"	6"	NO
	BOT SHELL	3/4"	45°	1/4"	6"	NO
M	DECK	1"	30°	3/8"	12"	NO

FIGURE 8: TYPICAL BUTT JOINT FOR STRAPS



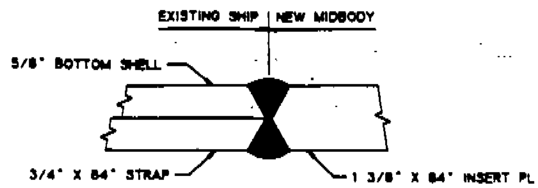
DETAILS

- GRIND STRAP TO SUIT THE CONTOUR OF EXISTING SHELL PLATE TAPER
- GRIND EXISTING BUTT WELD SMOOTH IN WAY OF STRAP

APPLICATION

SHIP	LOCATION
C	DECK
L	SIDE SHELL

FIGURE 9: BUTT JOINT IN WAY OF VARYING HULL PLATING THICKNESS



SAMPLE APPLICATION: SHIP D

- STRAP WIDTH MATCHES THE WIDTH OF HEAVY INSERT PLATE
- SHELL - INSERT BUTT JOINT WELDED FIRST
- SHELL BUTT WELD BACK GOUGED AND CHIPPED TO SOUND METAL

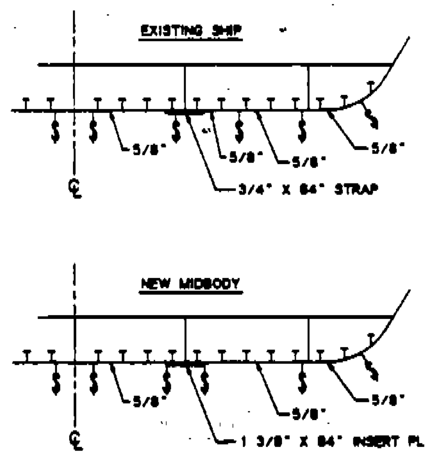
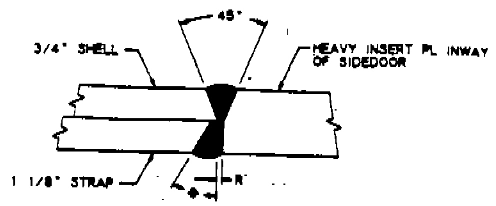


FIGURE 10: BUTT WELDING TO HEAVY INSERT PLATE ON NEW MIDBODY



NOTE: EXISTING SHELL-INSERT WELD BACK-GOUGED AND CHIPPED TO SOUND METAL PRIOR TO WELDING DOUBLER

SAMPLE APPLICATIONS

SHIP	LOCATION	◆	R	STRAP THICK	INSERT PL THICK
J	SHEER STRAKE	30°	3/8"	3/4"	2"

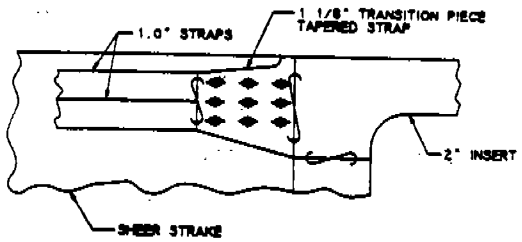
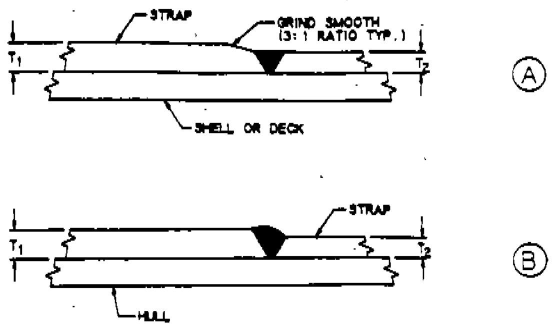


FIGURE 11: BUTT WELDING TO HEAVY INSERT ON EXISTING STRUCTURE



$T_1 - T_2 \leq 1/8"$

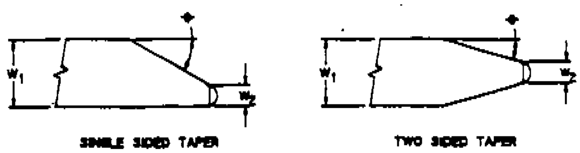
SAMPLE APPLICATIONS

SHIP	LOCATION	T_1	T_2	EXTENT
A	DECK	2"	1 1/2"/1 1/8"•	FWD OF 2/3 L
C	DECK	2.6"	2"	BOTH ENDS BEYOND 0.4L
H	DECK	1 3/4"	1 3/8"/1"•	BOTH ENDS BEYOND 2/3L
	BOT SHELL	1 1/2"	1 1/8"	BOTH ENDS BEYOND 2/3L

• THICKNESS TAPERING ACCOMPLISHED IN 2 STEPS

FIGURE 12: THICKNESS TAPERING

TRANSVERSE SECTION



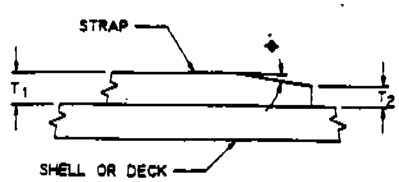
DETAILS

- CORNERS TO BE GROUND OFF AT BEGINNING OF TAPER
- ENDS MAY BE TERMINATED WITH A FULL RADIUS TIP OR SQUARE CUT WITH RADIUS CORNERS

SAMPLE APPLICATIONS

SHIP	LOCATION	◆	W_1	W_2	W_2/W_1	TIP FINISH	TYPE
A	DECK	21°	23.5"	6"	0.26	FULL RADIUS	1-SIDE
B	DECK	15°	84"	24"	0.28	RAD CORNERS	1-SIDE
C	DECK	10°	24"	12"	0.50	RAD CORNERS	1-SIDE
	BOT SHELL	10°	18"	8"	0.44	RAD CORNERS	1-SIDE
F	BOX GIRDER	15°	17.7"	2"	0.11	FULL RADIUS	2-SIDE
H	DECK	27°	25"	6"	0.24	FULL RADIUS	1-SIDE
	BOT SHELL	18°	18"	4 1/2"	0.25	FULL RADIUS	1-SIDE
J	SHEER STRAKE	6°	30"	9"	0.30	RAD CORNERS	1-SIDE
K	BOT SHELL	12°	55"	24"	0.43	RAD CORNERS	2-SIDE
L	SHEER STRAKE	14°	18"	6"	0.33	RAD CORNERS	2-SIDE
	BOT STRAP	14°	18"	6"	0.33	RAD CORNERS	2-SIDE

FIGURE 13: WIDTH TAPERING



LONGITUDINAL SECTION

SAMPLE APPLICATIONS

SHIP	LOCATION	◆	T_1	T_2
A	DECK	30°	2"	5/8"
C	DECK	18°	2.6"	1"
	BOT SHELL	18°	1.3"	5/8"
F	BOX GIRD	15°	2.75"	5/8"
H	DECK	30°	1.75"	5/8"
	BOT SHELL	30°	1.75"	5/8"
J	DECK	14°	1.38"	1"

FIGURE 14: END CHAMFER

SAMPLE APPLICATIONS

SHIP	LOCATION	T	◆	t
B	DECK	3/4"	18°	1/2"
C	DECK	2.6"	45°	2.84"
	BOT SHELL	1.3"	45°	1.24"
E	BOX GIRD	1.57"	25°	1"
	BOT SHELL	1.5"	25°	1"
H	DECK	1.75"	NOTE 1	
	BOT SHELL	1.5"	NOTE 1	
J	DECK	1.38"	14°	1"
L	SHEER STRAKE	3/4"	45°	5/8"
	BOT SHELL	3/4"	45°	5/8"

FIGURE 15: EDGE CHAMFER

installation of strapping. Epoxy filling of the slot welded holes was specified only on one ship, as mentioned earlier, and accomplished but this proved to be undesirable and the epoxy filling was later removed.

In-Service Performance

Efforts to obtain in-service performance data for past strappings from the various sources were not fruitful. In most cases, such data were not available. Upon recommendation from the Ship Structure Committee, the U.S. Coast Guard was requested to provide such data for U.S. flag ships from their Inspection Reports Database. Several inspection reports were received from the local U.S. Coast Guard "Marine Inspection" and "Marine Safety" offices throughout the United States. Upon review of these reports, it was found that data were available on the inspection of doublers on one class of ship only. For this class of ship, cracks were found in the butt welds of both the bottom and the deck doublers when inspected after the vessels had been returned to service following lengthening. An extensive inspection program was undertaken subsequently in order to identify any other defects in the butt welds of all doublers on this vessel. Many were found and repaired using procedures approved by the cognizant classification society.

The inspection reports did not identify the cause of these cracks. It was also not clear whether they were due to initial weld imperfections or if they had developed in service.

Methodology for New Strapping Designs

The strapping of a ship's hull is part of a greater undertaking involving the conversion design for jumboizing of the vessel. In general, the structural aspects of an overall conversion design involve the following investigations:

- o Review of existing vessel's structural background,
- o Determination of classification society rules and USCG regulations applicable to the conversion,
- o Determination of the converted (i.e., lengthened, widened, deepened) ship's required hull girder strength,
- o Computation of the section modulus to meet the required hull girder strength on the basis of longitudinal, and if necessary torsional, strength analyses,
- o Computation of the cross-sectional area to be provided by the strapping based on the choice of material to be used in doublers.

The methodology of the complete conversion design was beyond the scope of the SSC project on which this paper is based. Therefore, the design methodology outlined here concerns itself solely with the design of hull strapping details covering the following areas:

- o Selection of proper location(s) for doublers,
- o Scantlings and longitudinal extent of strapping,
- o Attachment and welding details,
- o Fabrication and inspection,
- o Cost effectiveness of design.

Selection of Strap Locations

Once the required cross-sectional area to be provided by the strapping is determined, the designer should decide on the optimum distribution of the added steel. Depending on the amount of additional steel needed, one or more doublers may have to be installed. The number and location of doubler(s) to be added will be governed by the type and arrangement of the ship to be strapped. The most widely used strap locations for tankers and containership were shown in Figures 1 and 2. The possible locations shown in these two figures are also applicable, respectively, to bulk carrier type vessels and to RO/RO carriers and other ships of similar design. If the structural arrangement of the vessel to be strapped is such that the required number of straps can be installed on the deck and/or bottom shell plating, this may be the most cost-effective approach. If, however, the available clear deck area is limited due to existing structure, fittings, or other obstructions on the deck, then locating the doublers on the side shell plating may be the better choice. Side shell doublers may also be employed if the additional cross-sectional area provided by the deck and/or bottom shell doublers is not sufficient to meet the required section modulus of the jumboized vessel.

For ships with continuous and effective deep hatch coamings and/or hatch side box girders of substantial scantlings, it may be preferable to install the doublers on the coamings or box girders.

Practical considerations such as the availability of drydocking facilities may also play a role in selecting strap locations. In order to eliminate the need for drydocking, installing the doubler(s) on the deck only may result in a less expensive strapping design.

It becomes evident that a standard location for doublers applicable to all ships cannot be recommended. Consideration must be given to all of the factors discussed above and the optimum number of straps and their locations should be decided accordingly. Consideration should also be given to locating and arranging especially the deck doublers in such a manner that they will not only meet the cross-sectional area requirements, but also provide extra reinforcement for heavy deck loadings, ramps, openings, etc.

In installing the doublers, care must be taken to maintain sufficient distances between existing hull butt welds and the butt welds of the strapping, and welding of any structural members to the doublers should not be allowed, nor should any openings be cut in the doublers.

Scantlings and Longitudinal Extent

The longitudinal extent of strapping should cover at least the midship 40% length as dictated by the classification society rules. The actual length of doublers for any specific ship, however, will depend on its type and configuration in addition to the strength requirements. If, for example, the ship to be strapped is a bulk carrier, a container ship, or a similar vessel with hatches along most of its length, any deck doublers will have to extend beyond the hatch ends in order to provide structural continuity and/or to reduce torsional and horizontal bending stresses even if this is not a longitudinal strength requirement. In "open-type" ships especially (e.g. containerships), strapping may have to extend well forward and aft to account for torsional stresses. The American Bureau of Shipping, in Reference #2, recommends that strap ends should terminate at least two frame spaces beyond any structural changes in sections such as hatch ends, superstructures and bulkheads. It is also recommended that deck doublers be situated over underdeck longitudinal girders or bulkheads wherever possible.

The total required cross-sectional area of the strapping may be provided by one or more doublers of appropriate width and thickness. The doubler thicknesses, as a general guideline, should not be less than the thickness of the underlying hull plating to which they will be attached. According to the ABS, the doublers can be up to 50% thicker than the base plating. Bureau Veritas, in Reference #3, allows doubler thicknesses of twice the base plating up to a maximum of 40 mm (1.57") but states that other thicknesses may be used subject to the society's approval.

Thickness selection is also affected by the number of doublers to be installed and the width of each doubler. If ample deck or bottom shell space is available, two or more doublers of narrow width and small thickness may be used to achieve the same cross-sectional area as a single wider and thicker doubler. This will eliminate the need for plug welding the wide doubler.

Obviously, the designer will have to take into consideration all of the above factors in determining the numbers, scantlings, and the longitudinal extent of doublers to be installed in strapping of a specific ship's hull.

Attachment and Welding

The doublers should be attached to the underlying hull plating by continuous fillet welds. Individual lengths of doublers should also be butt welded to each other. In order to provide proper tightness to prevent corrosion of the faying surfaces and to ensure effective shear transfer, the side and end welding details should be carefully determined.

For sizing the throat thicknesses of fillet welds, classification societies provide some guidance; e.g. ABS recommends that the throat thickness should equal one third of the doubler plate's thickness and BV recommends that it could be up to one half the doubler thickness but not more than 60% of the underlying hull plating thickness (see Figure 16).

If the sectional area requirements are to be met with one or more strips of adjacent doublers to avoid plug welding, then the approach shown in Figure 17 could be employed in welding the strips together. The total area of the doublers can be utilized by cutting bevels in the plate as shown in the upper sketch and inverting them as in the lower sketch. The gap between two strips should not be less than the doubler thickness as recommended by BV. The strips may be joined together by a full depth groove weld as shown in Figure 5 or if the doubler plate is too thick, by a partially welded groove as in Figure 6.

The butt welds used in joining separate lengths of doubler plates can be made as shown in Figure 18. The installation of a thin backing bar and a continuous full penetration weld is recommended by BV. Figure 19 shows the doubler butt weld to be utilized in cases where the existing shell plating thickness is reduced near the ends of the doubler length.

When it becomes necessary to join doubler plates to a wider insert plate, the arrangement shown in Figure 11 may be employed. A slot welded transition piece is fitted between the insert and the doublers. The combined width of the doubler plate and the existing hull plating should match the width of the insert plate. Dimensional details of doubler butt welds may be selected from those given in Figures 8, 9 and 11, as appropriate.

As stated earlier, slot welding should be avoided whenever possible by utilizing

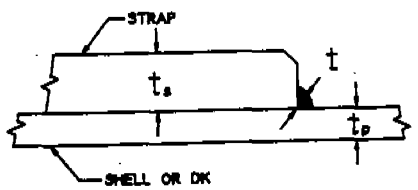


FIGURE 16

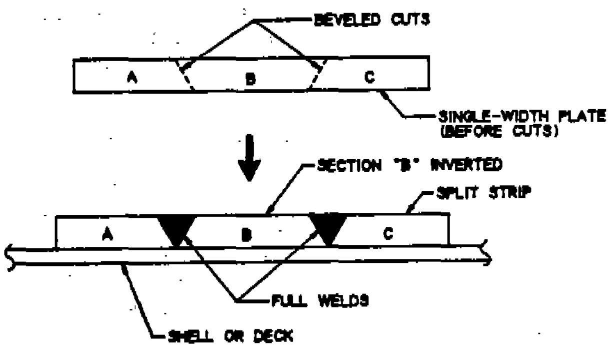


FIGURE 17

several narrow doublers instead of a single wide doubler. However, if for unavoidable reasons a wide doubler has to be installed whose width exceeds 30 times its thickness, it should be plug welded to the underlying hull plating. This can be accomplished by means of cutting holes of the size and spacing shown in Figure 4 and welding the circumference of the slots.

In all cases, classification society review and approval of the design is required prior to installation of strapping.

The extreme forward and aft ends of doublers may be subjected to repeated high stress fluctuations and therefore to resulting fatigue failures. Since the allowable stress ranges for the ends of long and narrow plates are only about one half of those at the sides, it is recommended that some end reinforcing be provided. This can be accomplished by increasing the throat thickness at the ends for a length equal to two or three times the doubler width. The amount of throat thickness increase recommended by ABS is from 3/10 of doubler thickness to 1/2 and by BV from 1/2 to 7/10.

In order to improve the structural continuity and to reduce the risk of tripping by personnel, the corners of all free edges of doubler plates should be dressed smooth and chamfered by grinding to 1/16' x 1/16" or 1/8" x 1/8". Chamfering also serves to minimize the notch effect. The approach shown in Figure 14 may be utilized in chamfering.

The forward and aft portions of doublers extending beyond the midship 40% length can be tapered in width and thickness. If such extensions are small compared to the overall strapping length, only width tapering may be used as shown in Figure 13. If however, the doublers have to continue extensively beyond the midship length in a specific application, thickness tapering may be combined with width tapering. Details for thickness tapering may be as shown in Figure 11.

Fabrication and Inspection

Following preparations should be made and precautions taken prior to installation of strapping on the ship's hull:

- The existing hull and the new midbody plating to be strapped should be flat, fair, and well supported by existing longitudinal structural members.
- If the plating is buckled or otherwise unfair, any fairing or repairs to the existing plating should be accomplished prior to installation of doublers.
- Existing hull or new midbody erection butts must be ground flush; undercuts, if any exist, should be repaired; weld spatters and burrs at ends should be removed.
- Faying surfaces should be clean, free of moisture and any foreign materials such as grease, mill-scale, paint or rust. An ordinary thickness of primer coating or a thin linseed oil coating may be allowed, upon approval by the classification society, provided it is demonstrated that their use will have no adverse effect on the production of satisfactory welds.
- A welding specification should be prepared detailing the welding procedure on the basis of cognizant classification society's rules.
- Preheating and temperature maintenance requirements for welding high strength steels in accordance with the rules must be observed.
- A proper welding sequence for installing doublers should be established in accordance with the rules of the cognizant classification society.

- In installing doublers in way of hull erection joints, a short section of the doubler (about 3 ft. in length) may be left unwelded until after completing, testing, and flush grinding the hull joint.

All doubler plates should be thoroughly inspected before, during and after the welding operations in the course of the strapping. Visual inspections should be supplemented by ultrasonic, dye-penetrant and magnaflux testing, and by radiography as required by the cognizant classification society rules and called for by their surveyors.

Cost Effectiveness of Design

With the objective of developing the most cost effective design for the strapping of a ship's hull, the designer should consider the following recommendations:

- Determine the optimum locations of doublers on the basis of ease of construction (i.e. minimum amount of removal/re-installation, ample support from existing structure, etc.)

- If the vessel is not to be drydocked for other reasons, investigate the possibility of using only deck, sheer strake, or inner bottom doublers to avoid drydocking the vessel for strapping purposes. Doublers at these locations may be installed while the vessel is afloat provided adequate provisions are made to avoid undue hogging or sagging stresses.

- Utilize the additional material provided by deck doublers in reinforcing heavy deck loadings, ramp/hatch openings, etc. if such exist on the ship.

- Extend the doublers sufficiently beyond the rule required midship length to obtain good structural continuity and to avoid costly additions/reinforcements in later stages of the strapping installation.

- Select the optimum and most economical numbers and widths of doublers to be installed keeping in mind the fact that the more the number of doublers the greater the cost of welding operations. If the required reinforcement can be provided by installing only one doubler plate of reasonable width and thickness, select this option and determine the best location for it.

- Assure compatibility of the strapping material with existing hull plating, i.e. if the base plating is Grade B steel, then the doublers should also be at least Grade B and may be of higher grade to meet Classification Society rules and/or to provide increased notch toughness.

- Avoid designing very thick doublers, if possible, since they require multiple pass welding which is labor intensive and therefore costly.

- If the required reinforcement can only be obtained by installing a thick doubler of maximum allowable width, conduct a trade-off study and try installing two parallel doublers of smaller thickness and narrower width. Include in this analysis the consideration of the extra length of welding required for the two straps versus the extra amount of welding passes needed for the single thick doubler.

- Avoid plug welding (which is a costly operation) by using narrower doublers unless absolutely dictated by the particular configuration of the ship and the complexity of obstructions on the deck.

CONCLUDING REMARKS

The hulls of very many ships have been strapped for various reasons since the days of riveted and early all-welded steel ships. Most of these strappings have performed successfully throughout the years while others reportedly have had problems in service, sometimes leading to serious failure.

Strapping usually involves increasing a ship's size by the addition of a new midbody or a new fore or aft body. It essentially changes the ship into something other than that for which it was originally designed and built.

Frequently however, for reasons of economics and available scheduling time, strapping proves to be the most feasible approach to make further use of an otherwise idle or inefficient existing vessel in a new service or trade. This is why a review of the six major classification societies' records revealed that a total of 1551 ships had been jumboized, many involving strapping.

It was found during this search that an interesting and novel approach was used in the lengthening of one specific ship. The original design of this ship had allowed for the installation of a future midbody of a specified length. The future midbody would have a deck box girder which would be installed at the time of lengthening. It is apparent that in a case like this, strapping would not be necessary. But if the original design of the existing vessel did not allow for the insertion of a new midbody, as happens in most cases, then strapping would again probably be proven to be the most economical approach. Otherwise the deck box girder of the new midbody would have to be extended forward and aft, over 40% of the new midship length, on the existing hull as well. This would have been a labor-intensive and therefore costly approach.

Other alternative approaches to provide the additional section modulus needed are also possible. Examples are installing longitudinal girders on the deck, innerbottom or the bottom of the ship. But these would probably require extensive ripouts/removals on most ships and would likewise prove to be labor intensive and uneconomical compared to strapping of the hull.

The survey of past strapping designs undertaken for this study represents a small portion of all the ships on which hull strappings were installed. For various reasons as stated by the responding organizations (such as the records having been lost/misplaced, ships having gone out of service, shipyards having gone out of business, no inspection records having been kept, etc.), it was possible to extract sufficiently detailed data for only fourteen classes of ships after extensive correspondence with the sources. Relevant data for other strapping applications were just not available from the owners, operators or shipyards involved. It would have been desirable to have a much broader database and to conduct a more reliable evaluation of past strappings which could result in a clear determination of successful and unsuccessful designs employed in each case.

Based on the review of data obtained for the aforementioned fourteen ship classes, it was not possible to judge if any of these past strapping designs were unsuccessful. Respondents all stated that their designs were successful and that no specific structural problems had been experienced with strapping during the in-service performance of their ships.

It was nevertheless possible to note the variations in the design details encountered in some applications and to adopt one design detail in preference to another less desirable application for inclusion into the recommended strapping design methodology.

The authors remain convinced that hull strapping will still be a feasible approach in the coming years whenever an existing ship (not originally designed for future midbody insertion) has to be lengthened to serve in a new capacity or trade. It is hoped that the guidelines provided in this paper will prove useful in developing a customized strapping design for application to any specific ship.

It is highly desirable that the experience from past strapping designs be collected and fed back to the designers. One possible way of accomplishing this is to have one central authority collect all original designs and inspection results for ships with hull strappings in a separate and dedicated database.

The USCG inspection database currently contains some data for U.S. flag merchant ships. It is recommended that specific instructions be added for the USCG inspectors to at least visually examine hull strapping, if present, on every occasion even if it does not seem necessary. If the visual examination reveals any defects, then appropriate additional inspections such as ultrasonic, magnaflux, or dye-penetrant testing should be requested. The results of doubler inspections should be recorded in a separate data file for easy retrieval. This will make it possible to maintain a running record for the in-service performance of doublers so that the more successful applications may be identified and utilized in future hull strapping of ships.

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ANALYSIS OF DATA FROM PAST STRAPPING DESIGNS

SHIP	A	B	C
Year Built:	1952	1984	1980
Type, Original:	Bulk Carrier	Tanker	Containership
Type, Converted:	Self-Unloader	Tanker	Containership
Year/Country:	75/U.S.A.	84/U.S.A.	85/Japan
Classification:	ABS	ABS	ABS
New Midbody:	120 FT	144 FT	100 FT
L/D Original:	9.0	10.2	12.9
L/D Converted:	10.7	12.6	14.8
General Description of Strapping:	Strapping on Deck; Add'l girder at bottom in lieu of of strapping	Strapping on Dk only Design changed to jumbo before construction started	Strapping on Deck, Sheer Strake & Bottom Shell
Strapping Details:	Deck Straps	Deck Straps	Deck Straps, each side
Extent	2/3 L + 75'	0.6 L	0.55L (From E.R. Bhd to Fwd End of Wide Hatches)
Size each side	1 X 70.5" X 2" (Split to 3 X 23.5" Strips)	2 X 84" X 0.75" 1 X 103" X 0.75"	3 X 24" X 2.6"
Material	Gr C Normalized	AH 32	Grade E
Base	1.35" Dk	0.63/0.59 AH32 Dk	1.7" Grade E Dk
Middle Attachment	1/2" X 3/8" Root Groove W.	1-1/2" X 3" Slot W	None
Side Weld	1/2" Fillet	3/8" Fillet	3/4" Fillet
End Weld	1/2" Fillet	3/8" Fillet	1" Fillet
Butt Weld	25 X 3/8 Root Gap With Shim	45 X 0 Root Gap Without shim	40° X 1/4" Root Gap Without Shim
Thickness Tapering	To 1.5"/1.125" Fwd. 2/3 L	None	To 1.5" at ends in steps outside 0.4L
Width Tapering	From 23.5" to 6" R	From full width to 24" in 18 FT	From 24" to 6" R
Side Chamfer	None	3:1 to 1/2"	1/16"
End Chamfer	30 to 5/8"	3:1 to 1/2"	3:1 to 1" at ends and sides
Remarks	No Structural Problems In Service		

ANALYSIS OF DATA FROM PAST STRAPPING DESIGNS

SHIP	C (contd)	C (contd)	D
Year Built:			1967
Type, Original:			General Cargo
Type, Converted:			Containership
Year/Country:			72/U.S.A.
Classification:			ABS
New Midbody:			90'
L/D Original:			12.0
L/D Converted:			14.0
General Description of Strapping			Long '1 BHD installed to form Box Girder at Top. Existing bottom connected to heavy insert in new midbody by strapping
Strapping Details:	Bottom Straps	Sheer Strake Straps	Bottom Straps
Extent	(Each Side) 0.5L	(Each Side) 0.55L	0.4 L
Size each side	10 X 18" X 1.3"	1 X 19" X 2.6"	1 X 84" X 0.75"
Material	Grade D	Grade E	ASTM A441
Base	7/8" Gr. B Shell	1.7" Grade E (Sheer Strake)	ASTM A441 5/8" shell
Middle Attachment	None	None	(Slot Weld)
Side Weld	7/16" Fillet	3/4" Fillet	( ) Fillet
End Weld	5/8" Fillet	1" Fillet	( ) Fillet
Butt Weld	40° X 1/4" Root Gap w/o Shim	40° X 1/4" Root Gap w/o Shim	N/A
Thickness Tapering	To 3/4" at about 5' from ends	To 1.5" at ends in steps outside 0.4L	None
Width Tapering	From 18" to 4" R	From 19" to 5" R	N/A
Side Chamfer	1/16"	1/16"	N/A
End Chamfer	3:1 to 7/8" at edges of 1.3" doubler, no chamfers in 3/4" end doubler.	3:1 to 1" at ends and sides	
Remarks			Fillet and Slot Welding details not available

ANALYSIS OF DATA FROM PAST STRAPPING DESIGNS

SHIP	E	E (contd)	F
Year Built:	1981		1987
Type Original:	Containership		Containership
Type, Converted:	Containership		Same (Design Proposal)
Year/Country:	1981/Japan		1988/W. Germany
Classification:	LR		ABS
New Midbody:	96 FT		87 FT
L/D Original:	11.4		11.0
L/D Converted:	12.9		12.3
General Description of Strapping	Hatchside Box Girder w/straps and strapping on bottom shell installed		Hatchside Box Girder installed w/straps
Strapping Details:	Straps on Box	Bottom Straps	Straps on Box
Extent	N/A	N/A	1/3L in way of new midbody
Size, each side	2 X 14" X 1.57" 1 X 17.7" X 1.57"	2 X 21" X 1.5"	2 X 17.7" X 2.76"
Material	DH	Gr. D	EH
Base	1.57" DH	3/4" Shell, Gr. B	2.2" EH Box Side Pl.
Middle Attachment	None	None	None
Side Weld	1/2" Fillet (Bevel)	1/2" Fillet (Bevel)	5/8" Fillet
End Weld	Same	Same	5/8" Fillet
Butt Weld	N/A	N/A	N/A
Thickness Tapering	N/A	N/A	None
Width Tapering	N/A	N/A	15 both side to 1" R tip end
Side Chamfer	25 to 1"	25 to 1"	None
End Chamfer	N/A	N/A	15 to 5/8"
Remarks	Welding details not available.	Welding details not available	

ANALYSIS OF DATA FROM PAST STRAPPING DESIGNS

SHIP	G	H	H
Year Built:	1973	1958	
Type Original:	Ro/Ro	Great Lakes Bulk	
Type, Converted:	Ro/Ro Containership	Same	
Year/Country:	82/U.S.A.	73/U.S.A.	
Classification:	ABS	ABS	
New Midbody:	126.5 FT	96 FT	
L/D Original:	10.7	N/A	
L/D Converted:	12.8	N/A	
General Description of Strapping	New Box Girder for new container Holds. Strapping on Inner Bottom	Strapping on Deck and Bottom Shell	
<u>Strapping Detail:</u>	<u>I.B. Straps</u>	<u>DK Straps</u>	<u>Bottom Shell Straps</u>
Extent	0.4 L	2/3 L	2/3 L
Size, each side	1 X 66" X 1.25" 1 X 31" X 1.25"	1 X 75" X 1.75" (Split to 3 X 25" Strips)	3 X 18" X 1.5"
Material	Gr. B	Gr. D	Gr. D
Base	N/A	N/A	N/A
Middle Attachment	1-1/2" X 3" Slot Weld	1/2" X 1/2" Root Groove W.	None
Side Weld	( ) Fillet	1/2" Fillet	7/16" Fillet
End Weld	( ) Fillet	1/2" Fillet	7/16" Fillet
Butt Weld	N/A	25 X 3/8" Root Gap w/shim	25 X 3/8" Root Gap w/shim
Thickness Tapering	None	Yes, beyond 2/3 L	Yes, beyond 2/3 L
Width Tapering	Yes	To 6" R Tip in 3 Ft	To 4-1/2" R Tip in 3 FT
Side Chamfer	N/A	Ground Smooth	Ground Smooth
End Chamfer	N/A	30 to 5/8"	30 to 5/8"
<u>Remarks</u>	Welding sizes not available		

ANALYSIS OF DATA FROM PAST STRAPPING DESIGNS

SHIP	J		K	
Year Built:				
Type Original:	General Cargo		Containership	
Type, Converted:	Container/Gen. Cargo		Containership	
Year/Country:	72/U.S.A.		84/W. Germany	
Classification:	ABS		GL	
New Midbody:	97.5 FT		99 FT	
L/D Original:	11.3		10.6	
L/D Converted:	13.7		12.7	
General Description of Strapping:	Add Longl BHD installed to form Box Girder in way of new container holds; strapping installed on Deck and sheer strake		Strapping installed on Hatch Side Coaming and bottom shell	
Strapping Detail	Deck Strap	Side Strap	Hatch Side Straps	Bottom Strap
Extent	0.5L	0.4L	N/A	0.4L
Size, each side	1X30"X1.2"/1.38"* (Split to 2X15" Strips)	1X30"X1" (Split to 2X15" Strips)	1X35.4"X1.26"	3X55"X0.75"
Material	Gr. B	Gr. B	Gr. D	Gr. B
Base	1/1/8" Gr. B	3/4" Gr. B	1/2" Gr. B	Gr. B
Middle Attachment	Full Groove W.	Full Groove W	None	None
Side Weld	5/8"/7/8" Fillet	5/8" Fillet	1/4" Fillet	1/4" Fillet
End Weld	Same	Same	3/8" Fillet	3/8" Fillet
Butt Weld	30 X3/8" Root Gap w/o Shim	30 X 3/8" Root Gap w/o Shim	N/A	N/A
Thickness Tapering	None	None	None	None
Width Tapering	N/A	To 9" end width in last 10 FT	N/A	To 24" in last 2 frame space
Side Chamfer	1.5" to 3/4"/1"	None	None	None
End Chamfer	N/A	None	N/A	None
Remarks	*Deck straps moved outboard in way of deckhouse and thickness increased from 1.2" to 1.38" for compensation.			

ANALYSIS OF DATA FROM PAST STRAPPING DESIGNS

SHIP	L	L (contd)	M
Year Built:	1977		
Type Original:	Navy Escort		Multi-Purpose
Type, Converted:	Navy Escort		Multi-Purpose
Year/Country:	83/U.S.A.		84/U.S.A.
Classification:	-		ABS
New Midbody:	0		126 FT
L/D Original:	13.6		9.4
L/D Converted:	-		11.3
General Description of Strapping	Strapping installed on Bottom and Sheer Strake to increase payload/draft		Strapping Installed on Deck to suit new length and loading condition
<u>Strapping Details</u>:	<u>Side Strap</u>	<u>Bottom Strap</u>	<u>Deck Straps</u>
Extent	N/A	N/A	Varies
Size each side	1 X 18" X 3/4" (split to 2 X 9")	1 X 18" X 3/4" (Split to 2 X 9")	P/S 2 X (3 X 24") X 1" S 1 X (7 X 24") X 1" P 1 X (4 X 24") X 1" (all split to 24" strips)
Material	HY 80	M.S.	
Base	HY 80	M.S.	
Middle Attachment	Full Groove W.	Full Groove W.	1/2" X 3/8" Root Groove W.
Side Weld	5/8" Fillet	5/8" Fillet	7/16" Fillet
End Weld	5/8" Fillet	5/8" Fillet	7/16" Fillet
Butt Weld	Single 45 Bevel w/ 1/4" Root Gap w/o shim	Single 45 Bevel w/ 1/4" Root Gap w/o shim	30 X 3/8" Root Gap w/o shim
Thickness Tapering	None	None	None
Width Tapering	To 6" width in last 24"	To 6" width in last 24"	Yes
Side Chamfer	1/8" X 1/8"	1/8" X 1/8"	None
End Chamfer	Same	Same	None
<u>Remarks</u>			

ANALYSIS OF DATA FROM PAST STRAPPING DESIGNS

SHIP	N	N (contd)	N (contd)
Year Built: Type Original: Type, Converted: Year/Country: Classification: New Midbody: L/D Original: L/D Converted:	1972 Containership Containership 1984/S. Korea LR 52.4 FT 10.8 11.5		
General Description of Strapping	Strapping on Coaming, Deck and Bottom		
Strapping Details:	Coaming Straps	Deck Straps	Bottom Straps
Extent Size each side	0.41L 1 @ 29.52"X1.77"	0.48L 2 @ 29.52"X1.77"	0.43L 2 @21.65"X1.26"
Material Base	GR E MS Coaming	Gr E MS Dk	GR D MS Bott
Middle Attachment	None	None	None
Side Weld End Weld Butt Weld	( ) Fillet ( ) Fillet N/A	( ) Fillet ( ) Fillet N/A	( ) Fillet ( ) Fillet N/A
Thickness Tapering	N/A	N/A	N/A
Width Tapering	Ratio abt. 3:1 Abt 50% of Width @ Ends	Ratio abt. 3:1 Abt. 50% of Width @ Ends	Ratio abt. 3:1 Abt. 50% of width @ Ends
Side Chamfer	N/A	N/A	N/A
End Chamfer	N/A	N/A	N/A
Remarks	No structural problems while in service. Welding sizes not available.	Welding sizes not available.	Welding sizes not available.

ANALYSIS OF DATA FROM PAST STRAPPING DESIGNS

SHIP	P	P (contd)	
Year Built: Type Original: Type, Converted: Year/Country: Classification: New Midbody: L/D Original: L/D Converted:	1972 Containership Containership 1984/S. Korea LR 49.4 FT 10.8 11.4		
General Description of Strapping	Strapping on Deck and Bottom Shell		
Strapping Details	Deck Straps	Bottom Shell Straps	
Extent Size, each side	Midship to 0.24L Fwd 3 @ 26.38"X1.77" P/S	0.49L 4 @ 24.61" X 1.00"	
Material Base	GR E/EH36 MS EH36	GR D MS	
Middle Attachment	None	None	
Side Weld End Weld Butt Weld	( ) Fillet ( ) Fillet N/A	( ) Fillet ( ) Fillet N/A	
Thickness Tapering	Ratio Abt. 3:1	Ratio Abt. 3:1	
Width Tapering	Ratio Abt. 2:1 Abt 10% of Width @ Ends	Ratio Abt. 2:1 10% of Width @ Ends	
Side Chamfer	N/A	N/A	
End Chamfer	N/A	N/A	
Remarks	No structural problems reported in service. Welding sizes not available.		

Robert A. Sielski

I'd like to comment in one part from a Navy perspective. One of the ships you listed is our FFG-7 class which got straps for a different reason than most of them. Rather than lengthening, the fact that the ship was originally designed to a 3,800 ton displacement but soon grew to 4,500 tons and so the longitudinal strength had to be increased. That started about ten years ago and since then we have not had any reports of any failures or any other problems associated with the strapping. So far, so good, but we'll try to keep our eyes on it as it develops.