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REVIEW OF SHIP STRUCTURAL DETAILS

SHIP STRUCTURE COMMITTEE
1977

SHIP STRUCTURE COMMITTEE

AN INTERAGENCY ADVISORY
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SR-216

15 APR 1977

The fabrication of structural design details represents a significant part of shipbuilding costs. These details also represent potential sources of premature failure, fatigue cracking, and brittle fracture. At present, a unifying rationale for design details that includes consideration of reliability and maintainability is not available.

The Ship Structure Committee initiated a program with the initial objective to conduct a state-of-the-art study in the area of shipbuilding structural design details. This study was to evaluate and determine design and construction methods currently in use, and to recommend improved and optimal methods.

This is a final report of that task and is being published to assist in developing cost effective and safe design details. The Ship Structure Committee expects to consider projects which will provide the rationale for evaluating the reliability and maintainability of details. This effort is limited at present to an evaluation of the performance of details on ships in actual service. The results of that study will be published when they are available.

W. M. BENKERT
Rear Admiral, U.S. Coast Guard
Chairman, Ship Structure Committee

FINAL TECHNICAL REPORT

on

Project SR-216

"Structural Details Design Review"

REVIEW OF SHIP STRUCTURAL DETAILS

by

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GENERAL DYNAMICS

Quincy Shipbuilding Division

under

Department of the Navy
Naval Sea Systems Command
Contract No. N00024-74-C-5230

U. S. Coast Guard Headquarters
Washington, D.C.
1977

ABSTRACT

The review of structural detail design is intended to serve as a summary of the state of the art and a guide to development of tools for design and analysis of these details.

The report includes a count of common structural details aboard two modern commercial vessels, and labor estimates for representative sizes of those details intended to provide a total cost per type of detail ranking for those ships

Current shipyard practice is reported with sketches and application description of about 160 ship structural details. Design improvements related to shipyard producibility are suggested.

The most relevant rules promulgated by technical and classification societies are excerpted, and comparison of rules is illustrated by application to specific examples.

Damage induced by poor design or fabrication of details is reviewed and illustrated.

The relatively sparse technical literature related to analysis and design of structural details is reviewed and summarized.

A framework for fatigue criteria is developed as a suggestion for possible detail strength criteria, and recommendations for future work in the area of detail design are presented.

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NOMENCLATURE

The following definitions of symbols and terms are to be understood, in the absence of other specifications, where they appear in the text.

B = Breadth, the greatest molded breadth in meters or feet.

D = The molded depth at side in meters or feet, measured at the middle of L, from the molded base line to the top of the freeboard-deck beams. In cases where watertight bulkheads extend to a deck above the freeboard deck and are considered effective to that deck, D is then measured to the bulkhead deck.

d = The molded draft in meters or feet from the molded base line to the summer load line.

L = The distance in meters or feet on the estimated summer load line, from the fore side of the stem to the after side of the rudder post or stern post; where there is no rudder post or stern post, L is to be measured to the rudder stock. L is not to be less than 96% and need not be greater than 97% of the length on the summer load line.

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The SHIP STRUCTURE COMMITTEE is constituted to prosecute a research program to improve the hull structures of ships by an extension of knowledge pertaining to design, materials and methods of fabrication.

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Section 1

INTRODUCTION

The principal aim of this report is to review current practices related to the design of ship structural details. The importance of structural details is clear:

- Their layout and fabrication represent a sizable fraction of hull construction costs.

- Details are often the source of cracks and other failures which, under certain circumstances, could lead to serious damage to the ship hull girder.

- The trend toward decreasing ship hull scantlings (i.e. increasing average hull stresses) has the potential of increasing the damage at details discussed above.

- Researchers have largely neglected the analysis of structural details; at least in part because the configuration and purpose of these details vary greatly and are not commonly described or discussed in the literature.

Due to the lack of analytical and experimental effort devoted to structural details, their determination has been left up to draftsmen and designers, with only small engineering input.

In Sections 3 and 4 is presented a fairly comprehensive catalogue of common structural details and of published rules most applicable to their design. Review of those sections indicates that rule applicability is most tenuous: only for brackets is there some guidance on scantlings. Therefore the two sections are essentially independent of one another, with Section 4 serving more to illustrate the lack of applicable guidance than to provide technical direction. This sufficiently defines the scope of the problem facing the designer, and should help to guide the needed efforts of interested researchers.

Welding details are not discussed in this review for two equally compelling reasons:

- They are too varied in cónfiguration, purpose and relevant material and fabrication parameters to be properly considered as only part of a modest study effort, and

- The Rules of the American Bureau of Shipping were in the process of drastic revision on this subject during the course of the Project.

The report makes evident both the need and possibility of standardization of structural details, but that can best be accomplished based on analytical or experimental work that will provide a sound basis for such selection.

No analytical work related to detail design is included in this Report because exhaustive literature search provided a most inadequate background on which to build further development within the limited scope of this Project.

Section 2

COUNT AND RANKING OF STRUCTURAL DETAILS

The specific and limited objective of this section was to establish a ranking, by total manhours, of broad categories of structural details. The importance of structural details is based more on their effect on ship strength than on ship cost, but the ranking provided herein can give insight into the need for analytical and design effort geared to reduction in ship production costs.

The overall categories of details counted for which manhour estimates were prepared are shown in Table 2-1. The count was made based on study of about fifty structural plans for each of two ships: a barge carrying ship and an LNG tanker. These two vessel types were selected solely because they represent our most recent commercial shipbuilding experience.

Manhours were estimated using conventional cost engineering data for the following individual activities involved in detail fabrication:

> Layout and lofting.
>
> Cutting and burning.
>
> Subassembly (where applicable).
>
> Installation, fitup, welding, inspection.
>
> Handling.

Estimates are not based on actual returned labor data because those are not available at such a fine work package breakdown level. Therefore the data presented should not be construed as capable of accurately discerning between alternative designs.

Estimated manhours and corresponding typical scantlings are reported, where applicable, under the appropriate detail sketches in Section 3. This was done for convenience only, to avoid repetition of the necessary sketches in this section.

Approximate total hull steel weight (as an indication of ship size) for the two ships used is:

> Barge Carrier: 14, 000 long tons
>
> LNG Tanker: 22, 600 long tons

A rough estimate of the percentage of manhours required for all phases of structural detail fabrication and installation as compared to total manhours required for all hull steel fabrication and erection is in the range of 10 to 20 percent.

This proportion, which is high in terms of tonnages involved, is clearly explained in terms of the relative complexity of structural details and other components such as framing members and shell, deck and bulkhead plating.

Standardization and simplification of structural details can therefore be expected to play a noticeable role in reducing shipbuilding costs.

TABLE 2-1
COUNT AND RANKING OF SHIP STRUCTURAL DETAILS

LNG CARRIER

RANK	TYPE - DESCRIPTION	TOTAL COUNT	TOTAL MANHOURS
1	Panel Stiffeners	11090	51835
2	Brackets	1330	14760
3	Scallops	20020	10605
4	Openings in Girders	12700	10510
5	Structural Intersections	4950	8640
6	Chocks	1180	5080
7	Tripping Brackets	740	2530
8	Stanchion Support	190	2000
9	Stiffener Endings	1360	1180
10	Snipes	770	230
11	Miscellaneous Cutouts	150	70

Total 107,440

BARGE CARRIER

1	Structural Intersection	22880	62910
2	Stiffener Endings - Chocks	11590	27125
3	Panel Stiffeners	7050	26455
4	Brackets	1200	4550
5	Tripping Brackets	250	3333
6	Openings in Girders	7370	3270
7	Stanchion Support	390	2700
8	Snipes	500	140
9	Scallops	200	90

Total 130,573

NOTES

3.0 SHIP STRUCTURAL DETAILS

This section presents a summary of current ship structural detail design practice. Details shown were taken from booklets of standard details used by six U. S. shipyards for at least ten classes of ships.

Ship and shipyard designations used are tabulated below.

SHIPYARD	SHIPYARD DESIGNATION	SHIP TYPE	SHIP DESIGNATION
G. D., Quincy	U	LNG Carrier (Comm'l)	A
G. D., Quincy	U	Barge Carrier (Comm'l)	B
G. D., Quincy	U	Oiler-replenishment (Navy)	C
G. D., Quincy	U	Ammunition (Navy)	D
G. D., Quincy	U	Tracking (Navy)	E
Anonymous	V	Frigate (Navy)	F
Anonymous	W	Container (Comm'l)	G
Anonymous	X	Drilling (Comm'l)	H
Anonymous	Y	Tanker (Comm'l)	J
Anonymous	Z	Catamaran (Navy)	K

Details are presented in the following categories:

DETAIL TYPE	DESIGNATION	PAGE
1. Clearance Cuts	CC-1 to CC-15	3-2 to 3-16
2. Snipes	S-1 to S-3	3-17 to 3-19
3. Tight Collars	TC-1 to TC-11	3-20 to 3-31
4. Reeving Slots	RS-1 to RS-6	3-32 to 3-37
5. Structural Intersections	NC-1 to NC-17	3-38 to 3-54
6. Miscellaneous Cutouts	MH-1 to MH-8	3-55 to 3-62
7. Patches	TP-1 to TP-5	3-63 to 3-67
8. Stanchion End Connections	SS-1 to SS-13	3-68 to 3-81
9. Tripping Brackets	TB-1 to TB-8	3-82 to 3-89
10. Face Plates	FP-1 to FP-3	3-90 to 3-92
11. Stiffener Ends	SE-1 to SE-16	3-93 to 3-108
12. Clip Connection	C-1 to C-3	3-109 to 3-111
13. Chock	CH-1 to CH-11	3-112 to 3-122
14. Panel Stiffener	PS-1 to PS-16	3-123 to 3-136
15. Beam Bracket	B-1 to B-22	3-137 to 3-158

Note: Fillet size "S" on any detail that follows implies the weld size is based on the thickness of the thinner member being welded.
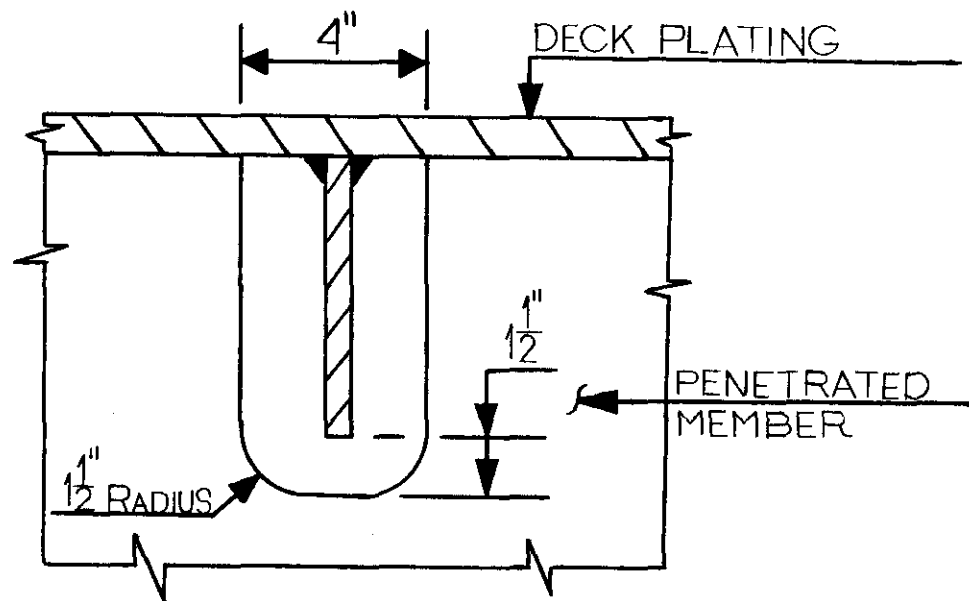
CC-1

Detail Type: CLEARANCE CUTS FOR LONGITUDINAL BEAMS

Comments: This detail is used by Shipyard "Y" on ship type "J" to provide openings in non-tight structure for the passage of flat bar longitudinals. These details can be found in areas where deck longitudinals pass through transverse girders and non-tight bulkheads. Use is limited to members requiring no support assistance from the penetrated members, such as in a tensile domain.

¢ FLAT BAR

DECK PLATING

3"

SNIPE 2"× 2"
SEE S-1

S

X

1½" RADIUS

PENETRATED MEMBER
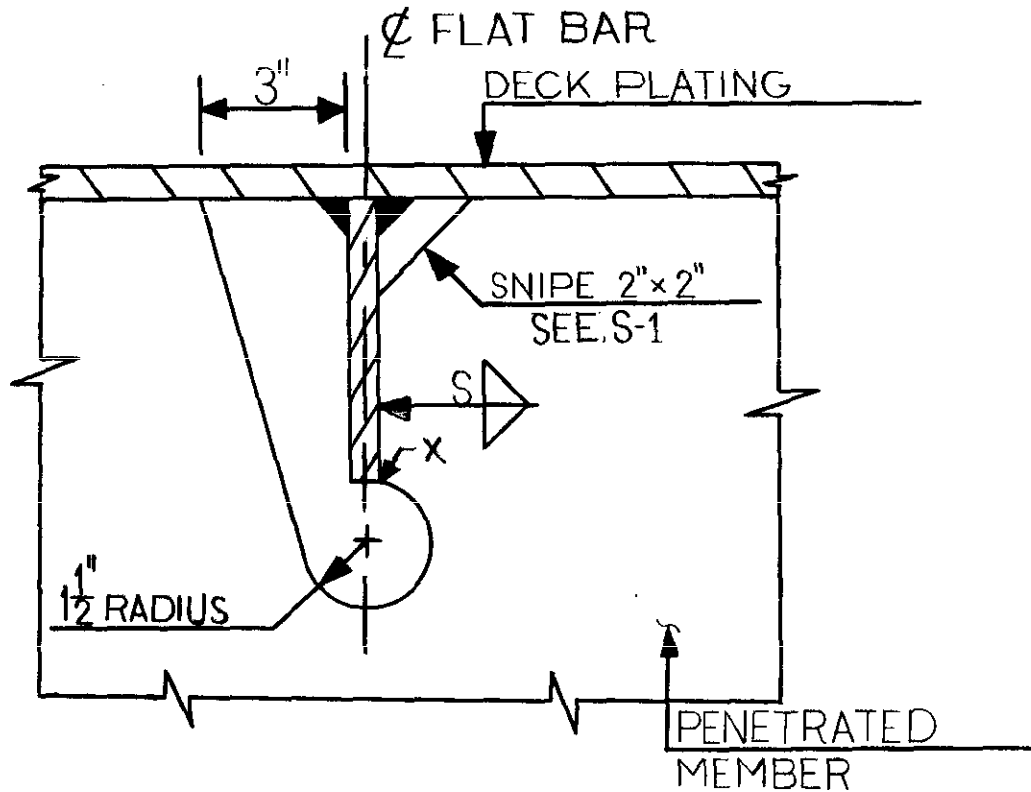
CC-2

Detail Type: CLEARANCE CUTS FOR LONGITUDINAL BEAMS

Comments: This detail is used by Shipyard "W" on ship type "G" to provide an opening in non-tight structure for the passage of flat bar longitudinals. These details can be found in areas where deck longitudinals pass through transverse girders and non-tight bulkheads. Use of this detail provides stiffener support due to the welding to the penetrated member.

Producibility and Maintainability Problem Areas: The problem of maintaining alignment occassionally necessitates the installation of liners along the welded face of the member. This is a problem inherent in production and there is no practical modification that can be made to the detail to correct this problem.

It should be noted that point X has a high crack potential since this creates a notch effect, it is our recommendation that the center of the radius be moved to the bottom edge of the longitudinal.

DECK PLATING

4"

1½" RADIUS

SEE S-2

S

1"RADIUS

1"RADIUS

1"

PENETRATED
MEMBER

CC - 3

Detail Type: CLEARANCE CUTS FOR LONGITUDINAL BEAMS

Comments: This detail is used by Shipyard "Y" on ship type "J" to provide an opening in non-tight structure for the passage of flat bar longitudinals. These details can be found in areas where deck longitudinals pass through transverse girders and non-tight bulkheads. Use of this detail provides some degree of support assistance due to the welding to the penetrated member.

Producibility and Maintainability Problem Areas: The problem of maintaining alignment occassionally necessitates the installation of liners along the welded face of the member. This problem is inherent in production and can be improved by using NC-1.

DECK OR SHELL
PLATING

0° TO 30°

SNIPE: $\frac{3}{4}"$ × $\frac{3}{4}"$ TO
2"×2": SEE S-1

S

$\frac{3}{4}"$ TO 1"

$\frac{3}{4}$ TO 1" RADIUS

1" TO 1$\frac{1}{2}"$

PENETRATED MEMBER

CC-4

Detail Type: CLEARANCE CUTS FOR LONGITUDINALS

Comments: This detail used by Shipyards "U" and "W" for Ship Types "B" and "G". This detail is used when the depth of the penetrating member is one-half the depth of the penetrated member or less. It is used for rolled angles penetrating non-tight structure and can be found in areas where deck and shell longitudinals penetrate transverse girders. Detail provides some end reaction capability.

Detail Count Ship "B": 770

Manhours Required to Complete Typical Detail: 0.6

Typical Scantlings: 7" x 4" x 1/2" ∠ penetrating 1/2" plate.

Producibility and Maintainability Problem Areas: A cut at the heel of the angle, similar to CC-7, is recommended since this will lessen the notch effect. See Detail CC-2 for additional comments.
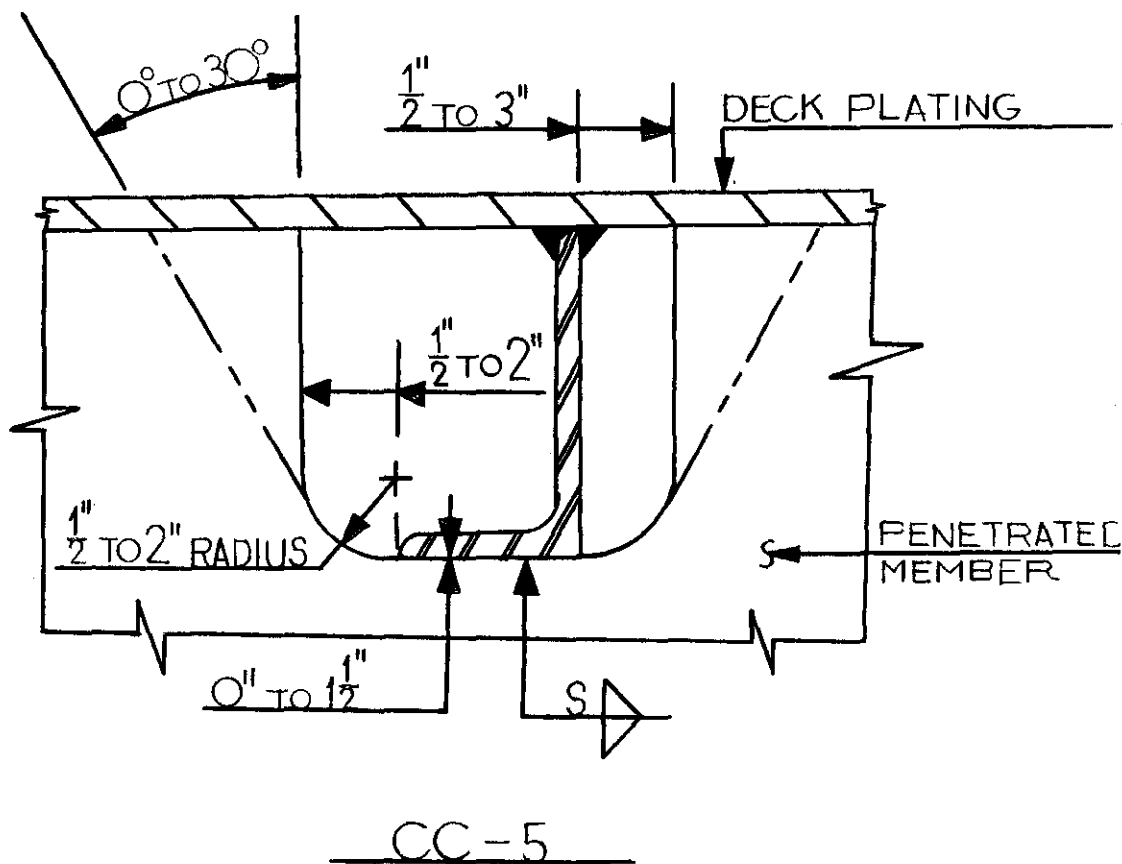
0° TO 30°

$\frac{1}{2}$ TO 3"

DECK PLATING

$1\frac{1}{2}$ TO 2"

$\frac{1}{2}$ TO 2" RADIUS

0" TO $1\frac{1}{2}$"

S

PENETRATED MEMBER

CC - 5

Detail Type: CLEARANCE CUTS FOR LONGITUDINALS

Comments: This detail is used by Shipyards "W", "X" and "Y" on ship types "G", "H", and "J" to provide an opening for the passage of rolled angle longitudinals through non-tight structure. This detail is restricted to longitudinals carrying a low lateral load because there is questionable reaction capability at the web-stiffener intersection. This capability may be improved by using NC-5. These details can be found in areas where deck and shell longitudinals intersect transverse girders and non-tight bulkheads.

Producibility and Maintainability Problem Areas: When the gap between the flange of the penetrating member and the penetrated structure is zero, the problem of alignment, similar to CC-2 occurs here. A minimum clearance of 1/16" should be provided between the stiffener flange and cutout to facilitate fit-up.

This detail is used when it is necessary to limit depth of cutout in penetrated member.

DECK OR SHELL PLATING

$1\frac{1}{2}$" RADIUS
SEE S-2

$\frac{1}{2}$"

$\frac{1}{8}$"

$\frac{1}{2}$RAD.

S

$\frac{1}{2}$" RADIUS

PENETRATED MEMBER

CC - 6

Detail Type: CLEARANCE CUTS FOR LONGITUDINALS

Comments: This detail is used by Shipyard "Y" on ship type "J" to provide an opening for the passage of rolled angle longitudinals through non-tight structure. These details can be found in areas where deck, shell and inner bottom longitudinals intersect transverse girders and non-tight bulkheads. This detail provides a certain degree of end reaction capability at the web stiffener intersection.

Producibility and Maintainability Problem Areas: A minimum clearance of 1/16" should be provided between the stiffener flange and web and the cutout to facilitate fit-up. This cut is used when it is necessary to limit the depth of cutout to one third the depth of the penetrated member. Radius at the heel is not adequate when seal welds are required.

See CC-2 for additional comments.
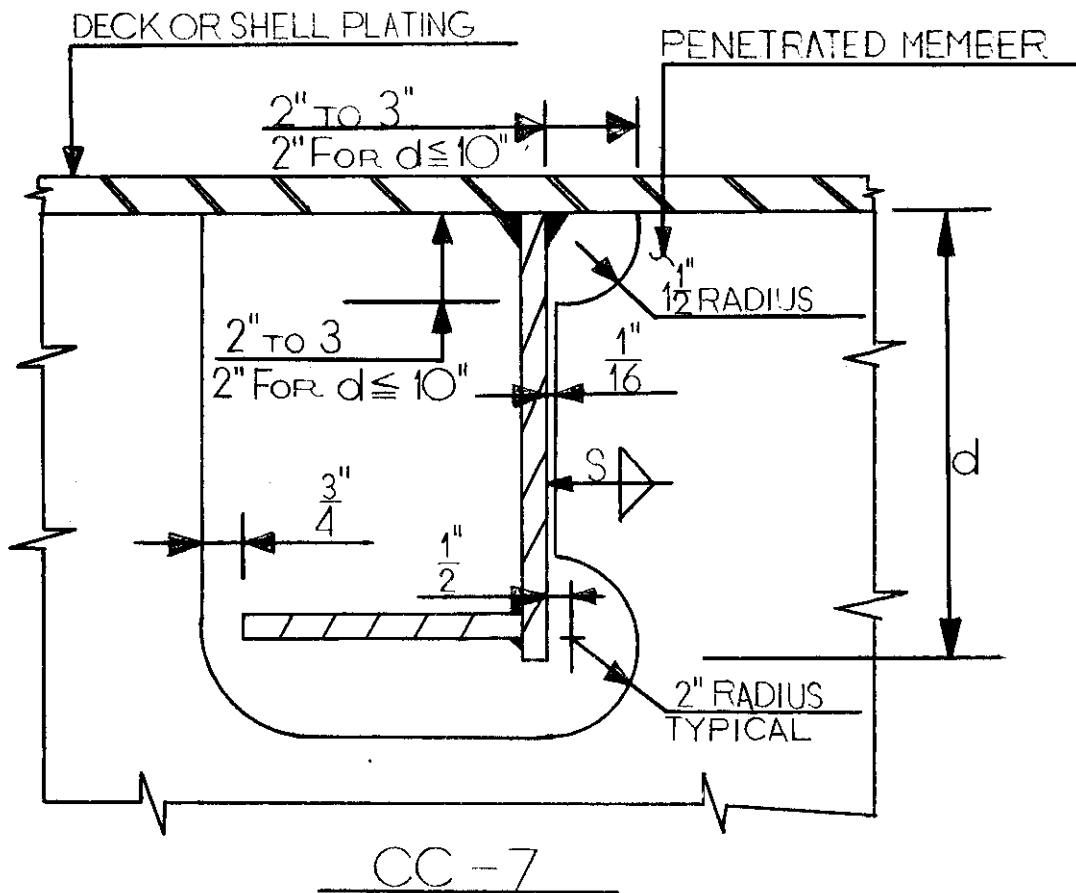
DECK OR SHELL PLATING

PENETRATED MEMBER

2" TO 3"
2" FOR d ≤ 10"

$1\frac{1}{2}$" RADIUS

2" TO 3
2" FOR d ≤ 10"

$\frac{1}{16}$"

d

$\frac{3}{4}$"

S

$\frac{1}{2}$"

2" RADIUS
TYPICAL

CC - 7

Detail Type: CLEARANCE CUTS FOR LONGITUDINALS

Comments: This detail is used by Shipyard "U" on ship type "A" to provide an opening for the passage of fabricated angle longitudinals through non-tight structure. This detail may only be used when the depth of cutout is equal to or less than one-third the depth of the penetrated members. These details can be found in areas where inner bottom and bottom shell longitudinals are penetrating non-tight floors. This detail provides some end reaction capability. Shear capacity of web attachment should be examined. The use of the radius cut at the heel of the angle minimizes welding and facilitates installation of flat bar chocks, see chock CH-5, since the inclined snipe is now accessible from both sides. Also, this configuration reduces the notch effect found in details CC-4, CC-9.

Detail Count Ship Type "A": 10,600

Manhours Required to Complete Typical Detail: 0.9

Typical Scantlings: 14-5/8" x 1/2" x 6-3/16" x 1/2" ∠ penetrating 1/2" Plate.

Producibility and Maintainability Problem Areas: See CC-2 for details.

3-8

DECK PLATING

2" RADIUS
SEE S-2
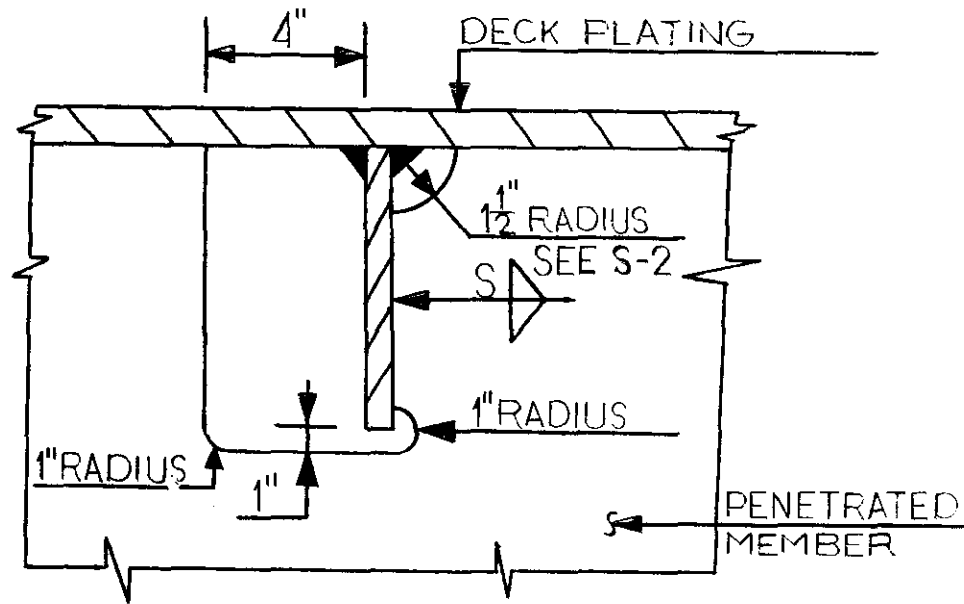
S

$\frac{1"}{16}$

PENETRATED
MEMBER

$2\frac{1}{2}"$ RADIUS
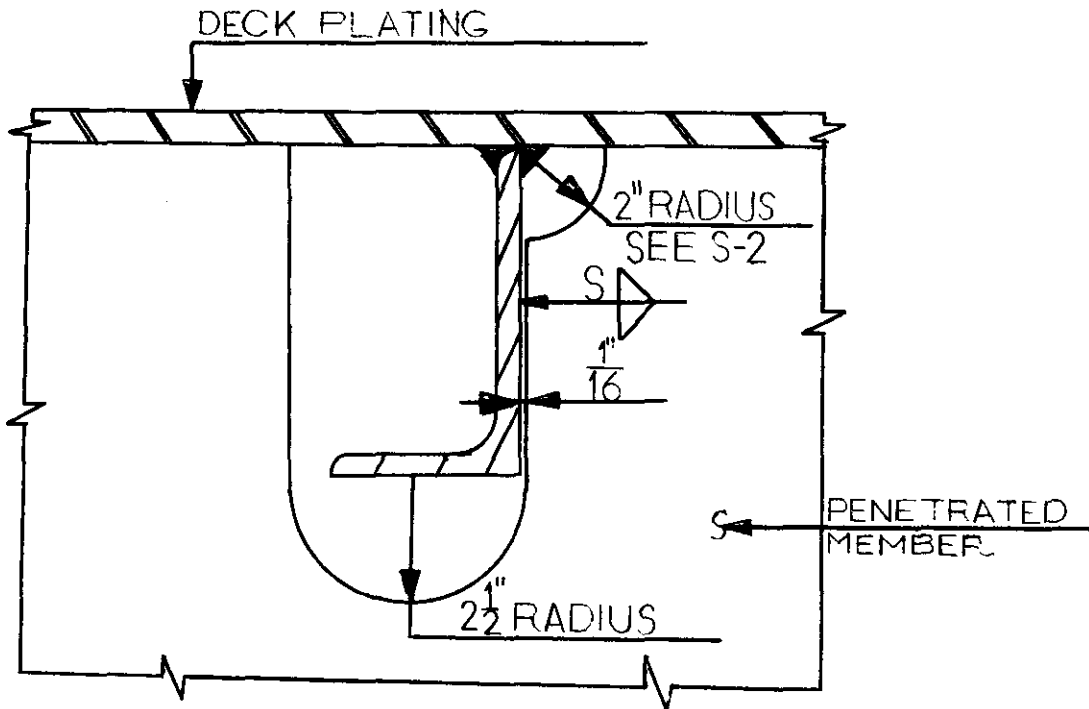
CC-8

Detail Type: CLEARANCE CUTS FOR LONGITUDINALS

Comments: This detail is used by Shipyard "U" on ship type "A", to provide an opening for the passage of rolled angle longitudinals through non-tight structure. This detail is used when the depth of the cutout is not critical to the penetrated member. These details can be found in areas where deck and side shell longitudinals penetrate transverse girders and/or non-tight bulkheads. This detail provides some end reaction capability.

Detail Count Ship Type "A": 700

Manhours to Complete Typical Detail: 0.6

Typical Scantlings: 7" x 4" x 1/2"∠ penetrating 1/2" Plate.

Producibility and Maintainability Problem Areas: When the depth of the cutout becomes critical a collar plate may be fitted or CC-9 may be used. See CC-2 for additional comments.
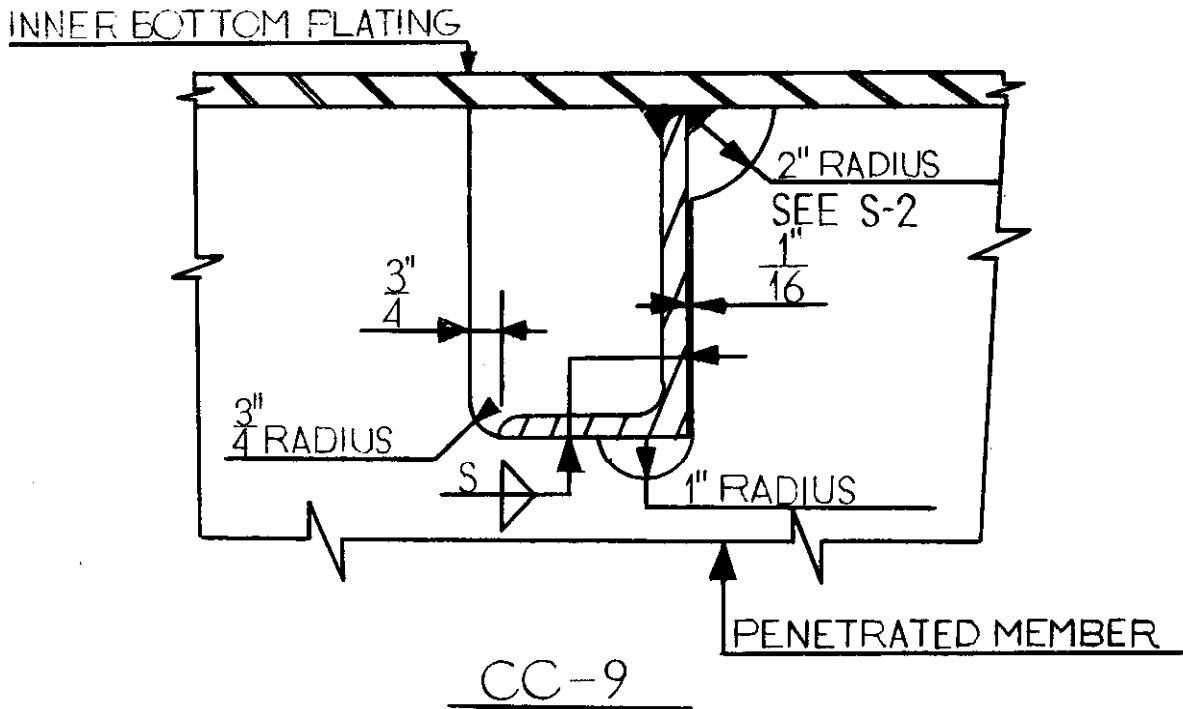
INNER BOTTOM PLATING

2" RADIUS
SEE S-2
$\frac{3}{4}$"
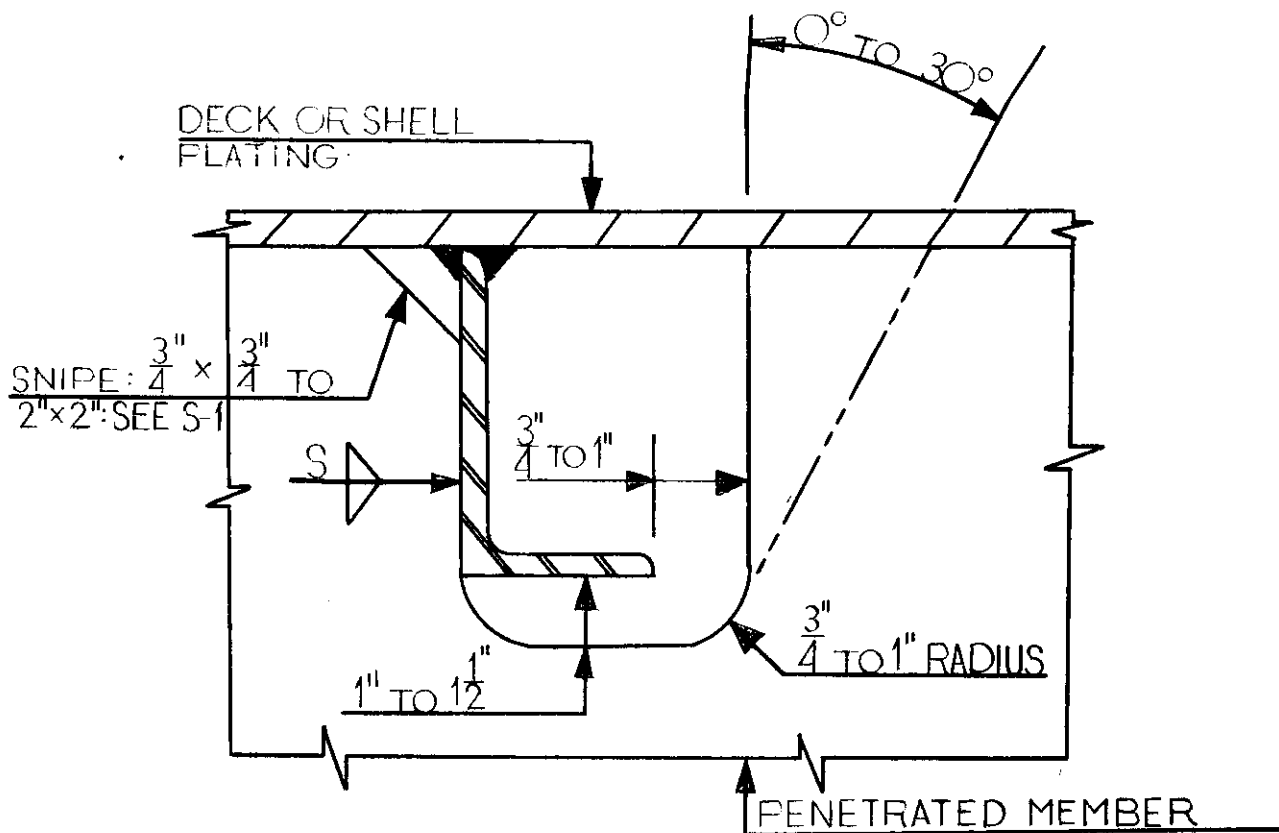$\frac{1}{16}$"
$\frac{3}{4}$" RADIUS
S
1" RADIUS

PENETRATED MEMBER

CC-9

Detail Type: CLEARANCE CUTS FOR LONGITUDINALS

Comments: This detail is used by Shipyard "U" on ship type "A" to provide an opening for the passage of rolled or fabricated angle longitudinals through non-tight structure. It is to be used when the depth of penetrating member is greater than one-third the depth of the penetrated member. These details can be found in areas where inner bottom and bottom shell longitudinals penetrate shallow transverse girders. This detail provides some end reaction capability.

Detail Count Ship Type "A":   1400

Manhours Required to Complete Typical Detail: 0.6 to 1.0

Typical Scantlings: 7" x 4" x 1/2" $\angle$ to 10" x 1/2"-6-3/16" x 1/2" $\angle$ penetrating 1/2" Plate.

Producibility and Maintainability Problem Areas: Detail CC-6, with a 1" heel radius is preferred over this detail since crack potential at the heel of the angle is removed. See CC-2 for additional comments.

3-10

DECK PLATING

$\frac{1"}{2}$ TO $1\frac{1"}{2}$

$\frac{1"}{2}$ TO $1\frac{1"}{2}$ RADIUS

$0"$ TO $1\frac{1"}{2}$
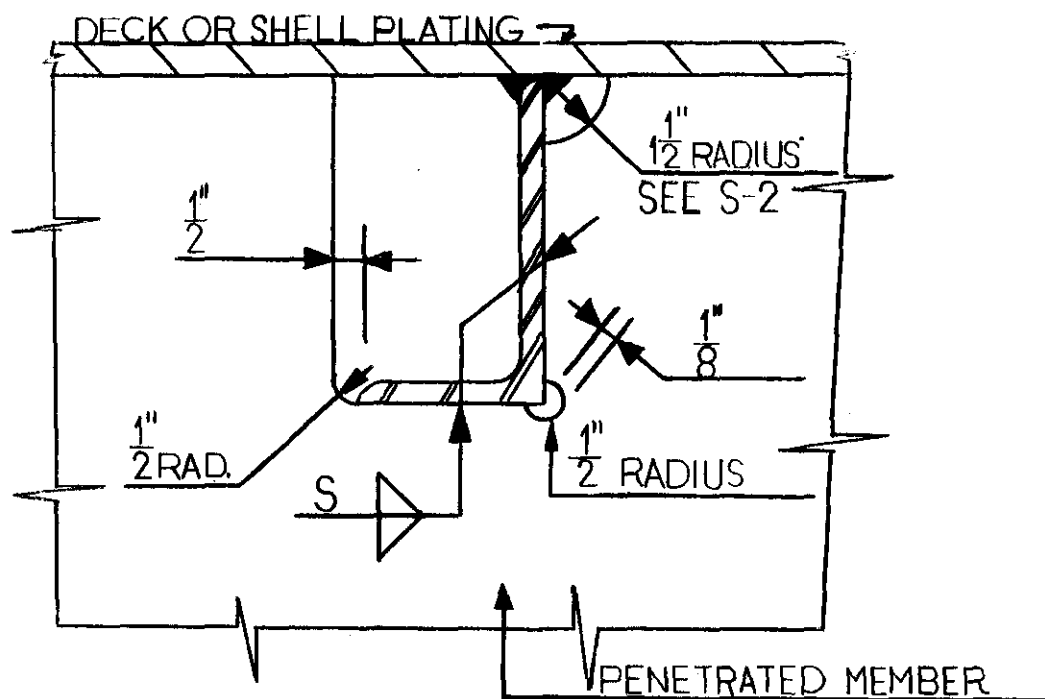DIM."A"

PENETRATED MEMBER

CC - 10
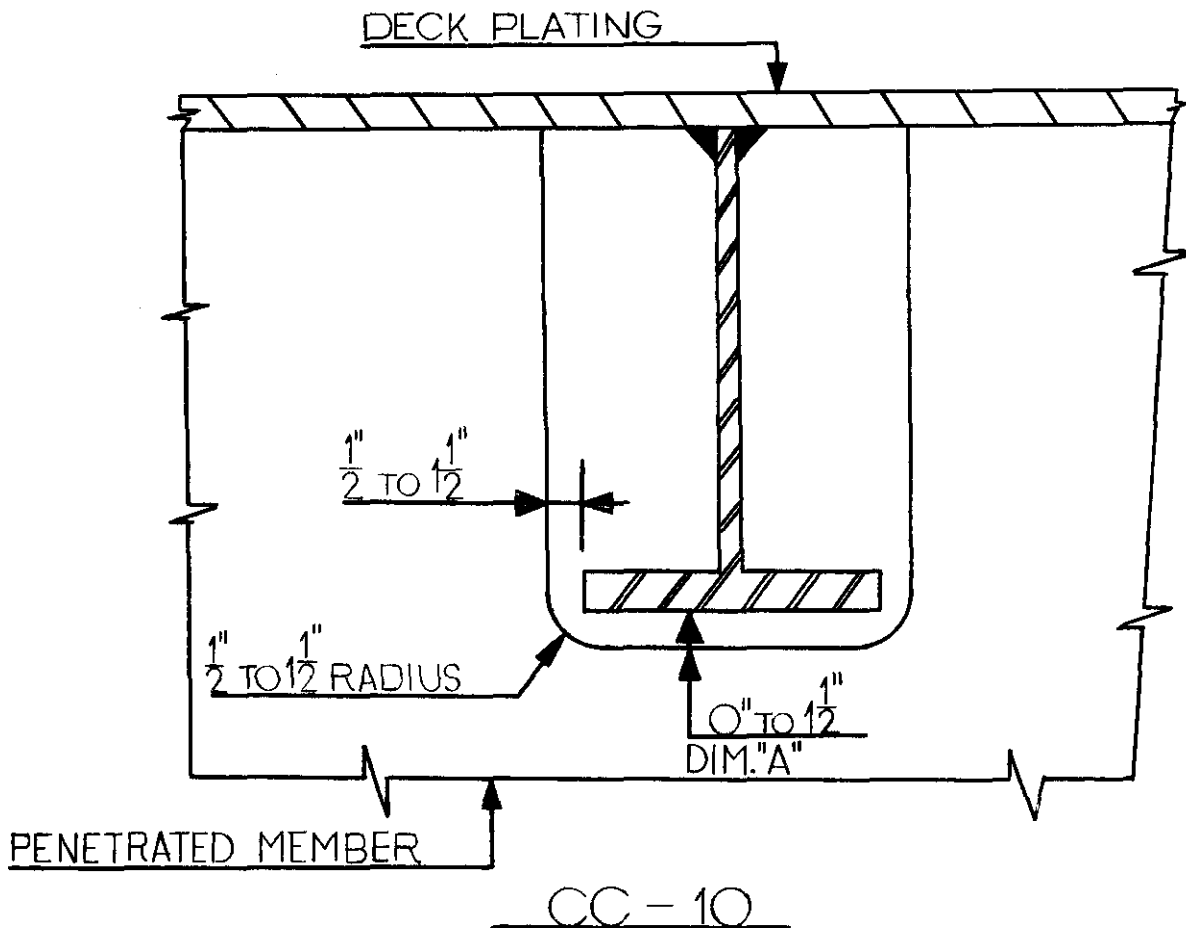
Detail Type: CLEARANCE CUT FOR LONGITUDINAL GIRDER

Comments: This detail is used by Shipyards "U", "X" and "Y" on ships "A", "H" and "J" to provide an opening for the passage of rolled or fabricated Tee beams through non-tight transverse structure. These details can be found in areas where longitudinal deck girders penetrate transverse non-tight bulkheads. This detail is restricted to longitudinals with a low lateral load or having a separate support system because there is small or no reaction capability at the joint. Where the flange is welded to the penetrated member, a 1/16" clearance is recommended to facilitate fit-up.

Detail Count Ship Type "A": 20

Manhours Required to Complete Typical Detail: 1.0

Typical Scantlings: 18-13/16" x 1/2"-12-1/2" x 3/4" T penetrating 5/8" Plate and Dimension "A" = 0.

NONTIGHT STRUCTURE

IF APPLICABLE

1" TO 3" RADIUS

A   A

DECK, SHELL OR BULKHEAD

SHIP ERECTION BUTT
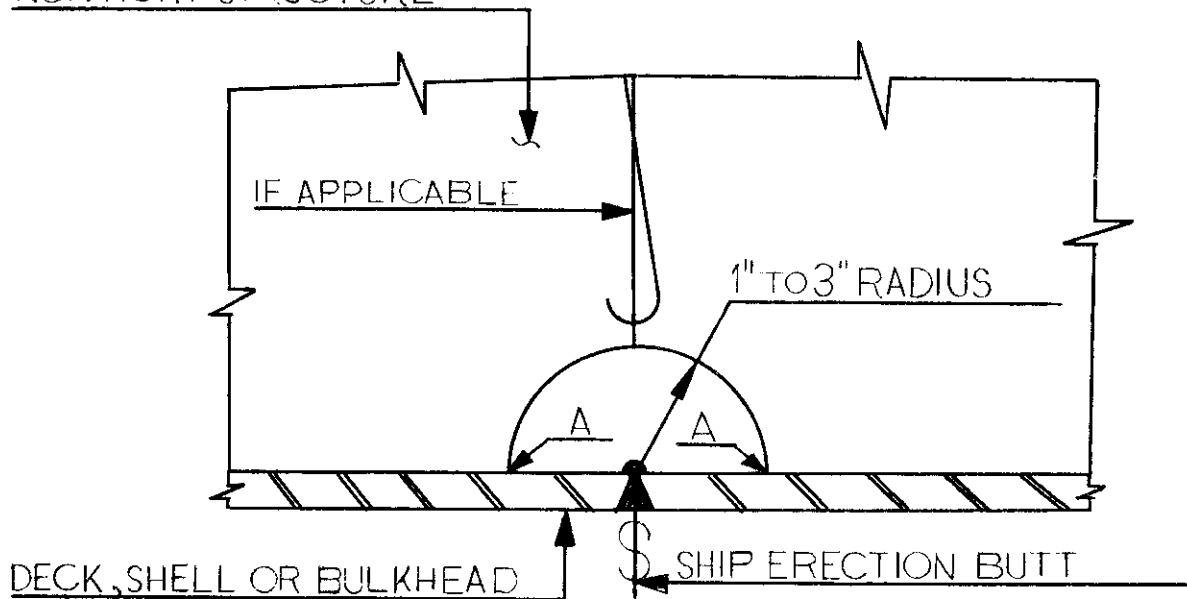
CC-11

Detail Type: CLEARANCE CUTS FOR WELDING (RATHOLES)

Comments: This detail is used by Shipyards "U", "W", "X" and "Z" on ships "A", "B", "C", "D", "E", "G", "H" and "K", to facilitate welding of erection and sub-assembly butts in non-tight structure. If there is no weld at point "A" the detail is only applicable to butts in non-tight structure clear of tanks. Wrapping the weld at point "A" creates a water or oil stop and this permits the use of this detail in non-tight structure in tanks. The radius of the cut depends on the depth of member being cut, a relationship of Radius = 1/4 Depth of Member can be established with a maximum value of R = 3 inches.

Detail Count: Ship Type "A" = 1170; Ship Type "B" = 3040

Manhours Required to Complete Typical Detail: 0.3

Typical Scantlings: 3" Radius penetrating 5/8" Plate.

Producibility and Maintainability Problem Areas: If the cut is made by hand, it is difficult to obtain a smooth cut. If ragged edges exist, stress concentrations at these locations may lead to fracture failure. To correct this situation the radius should be cut with a template or an automatic burning machine. Where this solution is not practical, a patch may be installed (see TP-1 for details). With this detail the shipyard also eliminates the possibility of cracks occurring due to faulty chipping of the butt weld reinforcement.

3-12

TRANSVERSE FLOOR

NONTIGHT MEMBER

3"× 3" SNIPE
SEE S-2

$1\frac{1}{2}$" RADIUS

SHELL OR DECK

4" MAX.
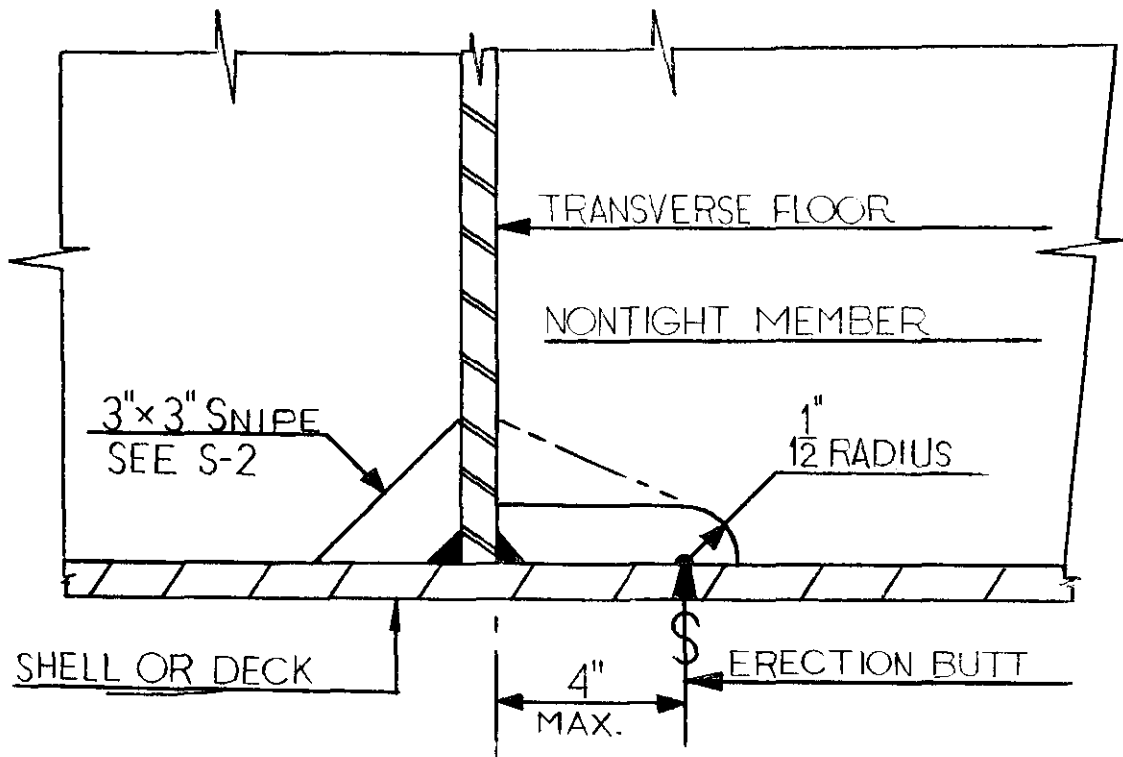
ERECTION BUTT

CC – 12

Detail Type: CLEARANCE CUTS FOR ERECTION BUTTS

Comments: This detail is used by Shipyards "U", "V", "W" and "Y" on ships "D", "E", "F", "G" and "J" to provide welding access for erection butts close to floors or bulkheads. The welding rationale used for CC-11 is applicable to this detail. This detail also provides clearance for the weld of the transverse floor to the shell or deck.

Producibility and Maintainability Problem Areas: The problem of insuring a smooth cut as mentioned in CC-11 also occurs here. If weld wrapping is desired, CC-13 is preferable.

TRANSVERSE FLOOR

NONTIGHT MEMBER

2" RADIUS

2" RADIUS
SEE S-2

6" MAX.
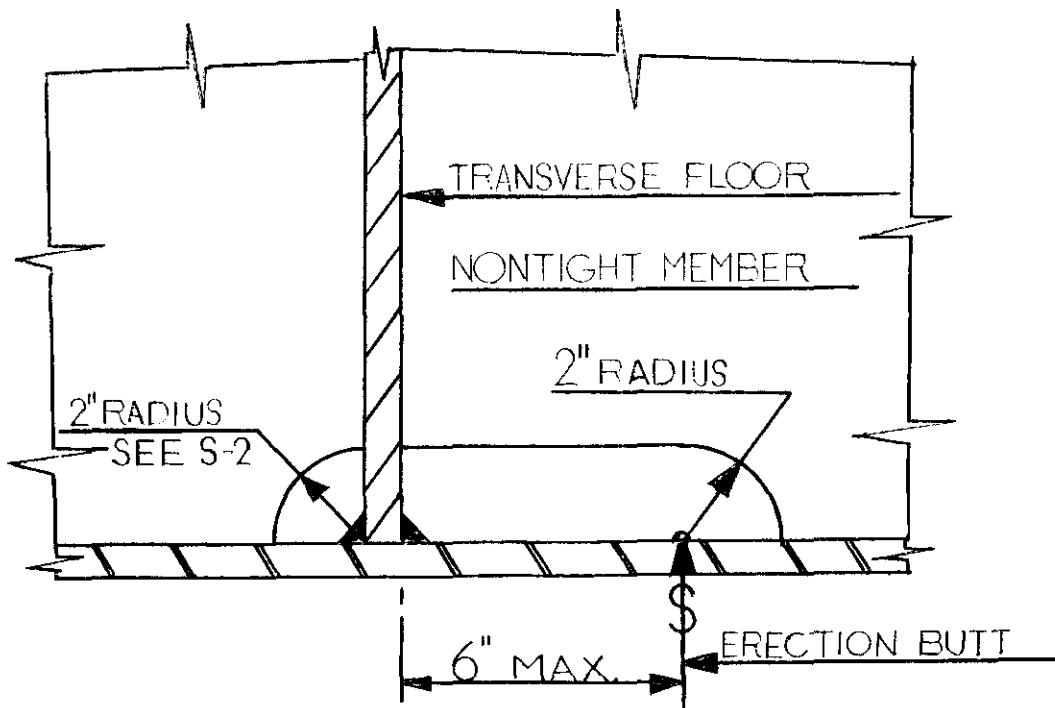
ERECTION BUTT

CC - 13

Detail Type: CLEARANCE CUTS FOR ERECTION BUTTS

Comments: This detail is used by Shipyards "U" and "X" on ships "A", "B", "C" and "H" to provide welding access for erection butts close to floors or bulkheads. For additional comments see CC-11 and CC-12.

Detail Count: Ship Type "A" = 150; Ship Type "B" = 200

Manhours Required to Complete Typical Detail: 0.5

Producibility and Maintainability Problem Areas: For details see CC-11.

3-14

6"

$1\frac{1}{2}$" RADIUS

3"
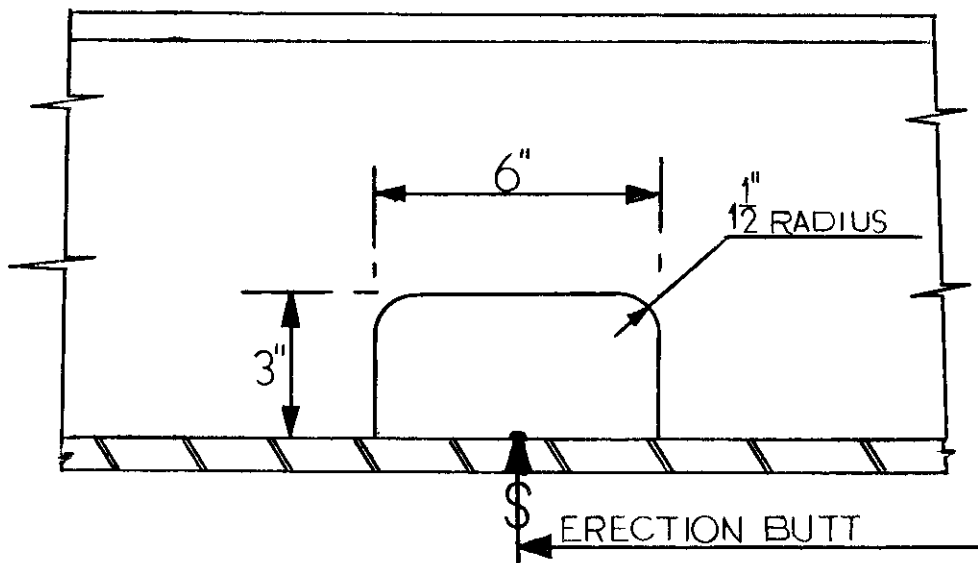
℄ ERECTION BUTT

CC-14

Detail Type: CLEARANCE CUTS AT ERECTION BUTTS

Comments: This detail is used by Shipyard "U" on ship type "A" to provide welding access for the AVA welding machine in way of erection butts.   When this cut is made in shallow members a patch may be required, see TP-5.   This detail is often used in lieu of CC-11.

Detail Count Ship Type "A":   19400

Manhours Required to Complete Typical Detail: 0. 5

Producibility and Maintainability Problem Areas: For details see
          CC-11.

NONTIGHT MEMBER

2"RADIUS

$\frac{1"}{2}$
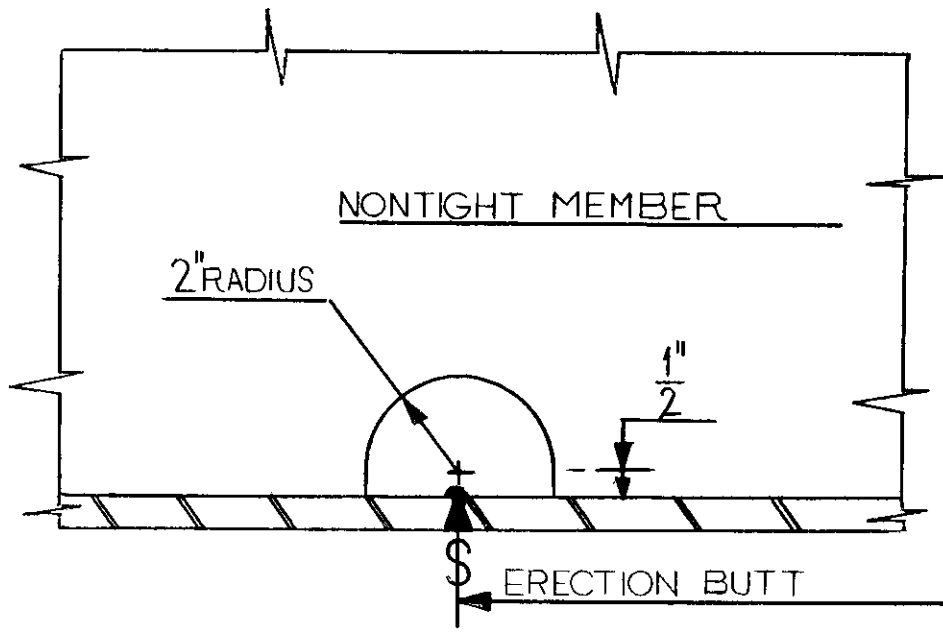
ERECTION BUTT

CC - 15

Detail Type: CLEARANCE CUTS FOR ERECTION BUTTS

Comments: This detail is used by Shipyard "Y" on ship type "J"
                to provide clearance for welding of erection butts and
                sub-assembly butts.   For other comments see CC-11.

3-16

NON TIGHT
STRUCTURE

$\frac{3}{4}" \times \frac{3}{4}"$ TO 5"×5"
SNIPES
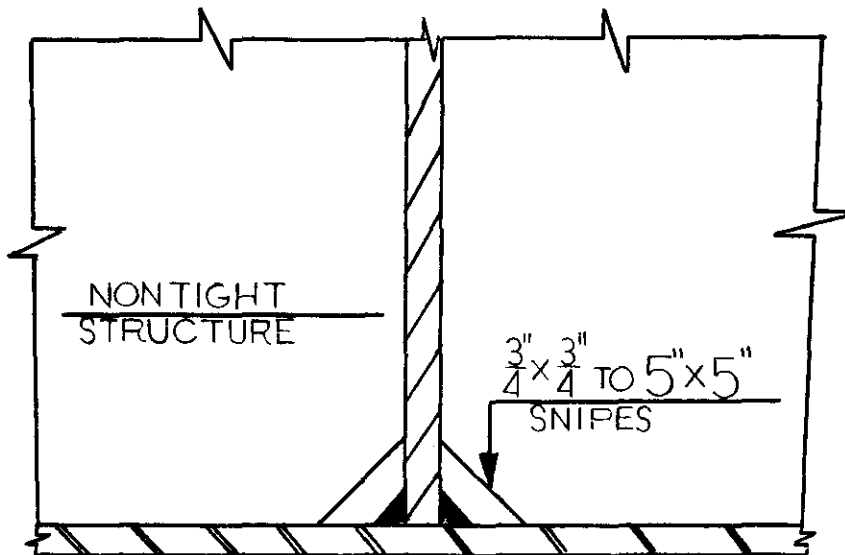
S - 1

Detail Type: SNIPE

Comments: This detail is used by Shipyards "U", "V", "W" and "Z" on ships "B", "C", "E", "F" and "K" to facilitate fitup of intercostal non-tight structure, including deck beams, brackets, chocks, etc. ; at the junction with continuous structure. The length of the snipe leg is about one fourth of the depth of the member. For member depths above 9 to 12 inches snipe leg remains constant at 3 to 5 inches, depending on specific shipyard. Snipes are not allowed in stanchion end connections. Snipes larger than 3"x3" may produce cracking.

Producibility and Maintainability Problem Areas: At the toes of the snipe it is difficult to wrap the weld, when desired to insure a good coating. To correct this problem use detail S-2.

NONTIGHT
MEMBER

$1\frac{1}{2}"$ TO $3"$
RADIUS
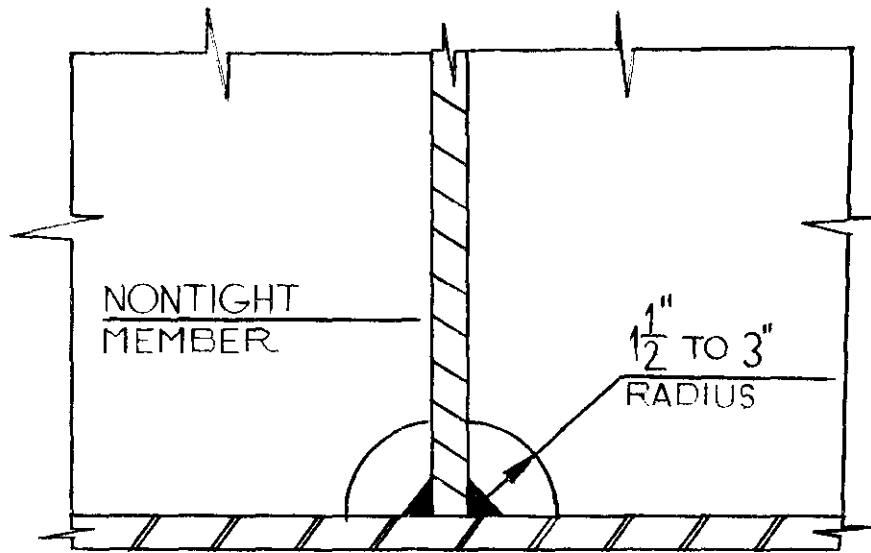
S - 2

Detail Type: SNIPE

Comments: This detail is used by Shipyards "U", "W" and "X" on
ships "A", "B", "C", "D", "E", "G" and "H", to
facilitate fitup of intercostal non-tight structure at
the intersection with continuous structure. Snipe
radius is a function of member depth: R = 1/4 depth.
When depth is greater than 12 inches, R remains
constant at 3 inches.

Detail Count: Ship Type "A" = 770; Ship Type "B" = 500

Manhours Required to Complete Typical Detail: 0.3

Typical Scantlings: 3" Radius penetrating 5/8" Plate.

TIGHT STRUCTURE
$\frac{1}{2}'' \times \frac{1}{2}''$
FILL WITH WELD

TIGHT STRUCTURE
$\frac{3}{4}''$ RADIUS
FILL WITH WELD
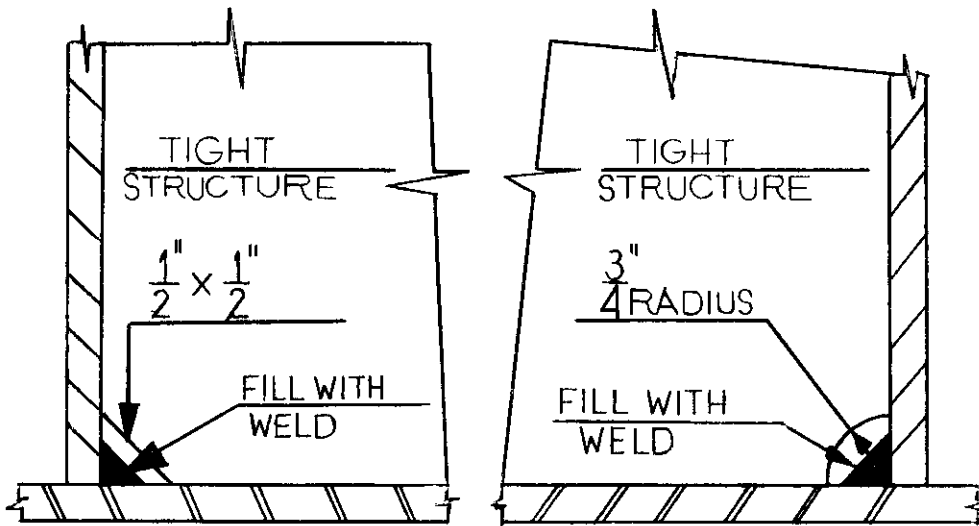
S - 3

Detail Type: SNIPE

Comments: This detail is used by all six shipyards surveyed. It is used in way of tank boundaries, stanchion end connections, and other tight structure. The straight edged snipe is favored since this detail requires less weld metal to close the gap. When the size of the fillet weld necessitates using detail S-1 or S-2, detail TP-4 provides an alternative.

2"

$\frac{1"}{16}$ CLEAR ALL AROUND

COLLAR PLATE

S

$1\frac{1"}{2}$ RADIUS

S

2" LAP

3" LAP   TIGHT MEMBER

FOR CUT DETAILS SEE CC-1

TC-1
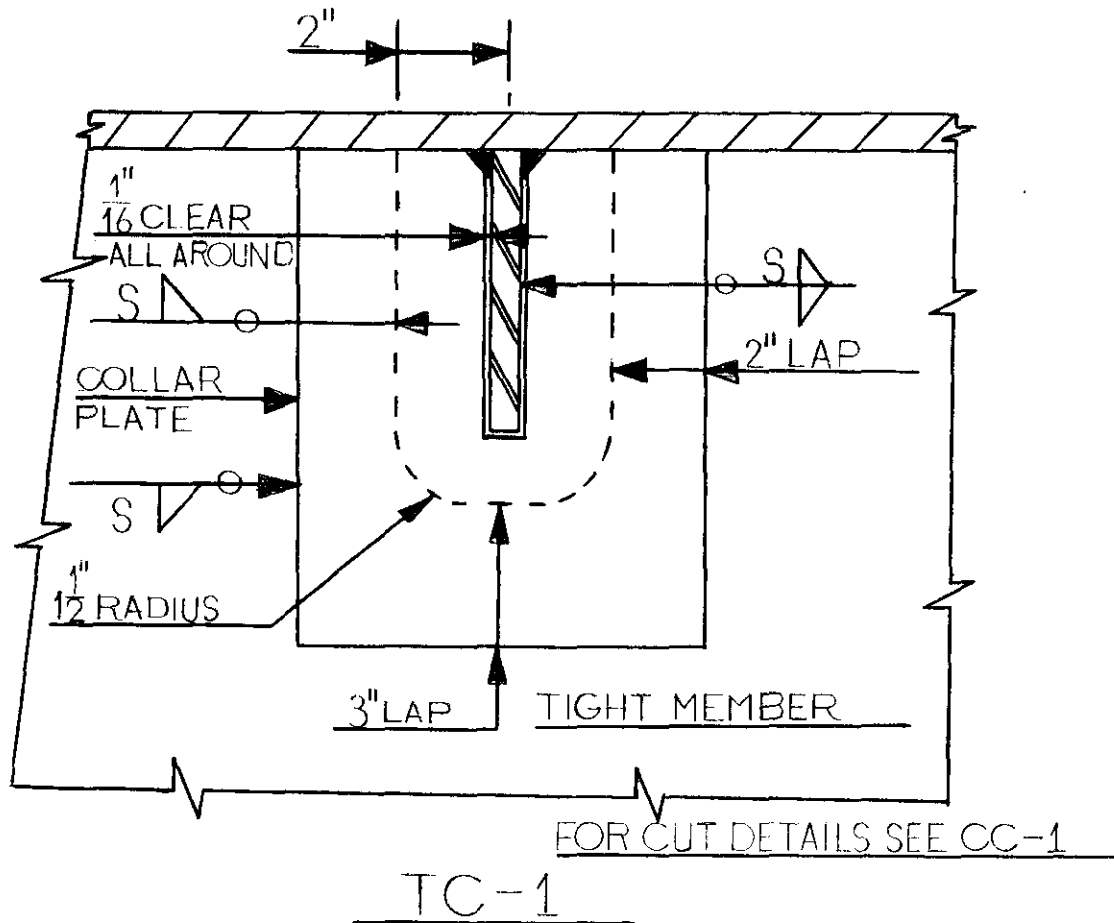
Detail Type: LAPPED TIGHT COLLARS

Comments: This detail is used by Shipyard "Y" on ship type "J", for collaring longitudinal flat bar deck beams penetrating tight bulkheads and in areas of high stress. Generally, the thickness of the collar plate is to be the same as the web of the penetrated member.

Producibility and Maintainability Problem Areas: Welding collar plate to penetrated member is a problem at the square corners because this requires striking a new arc along each side, this welding may also lead to a potential crack problem at the intersection. Fitup along the top will be difficult because the collar plate will interfere with the weld of the web to the deck.

Proposed Modifications: Radius the lower corners of the collar plate and snipe the upper corners. See figure MTC-1, pg 3-21, for recommended improvements.

$\frac{3"}{8}$ RADIUS　　　　　　　　FILL WITH WELD

45°
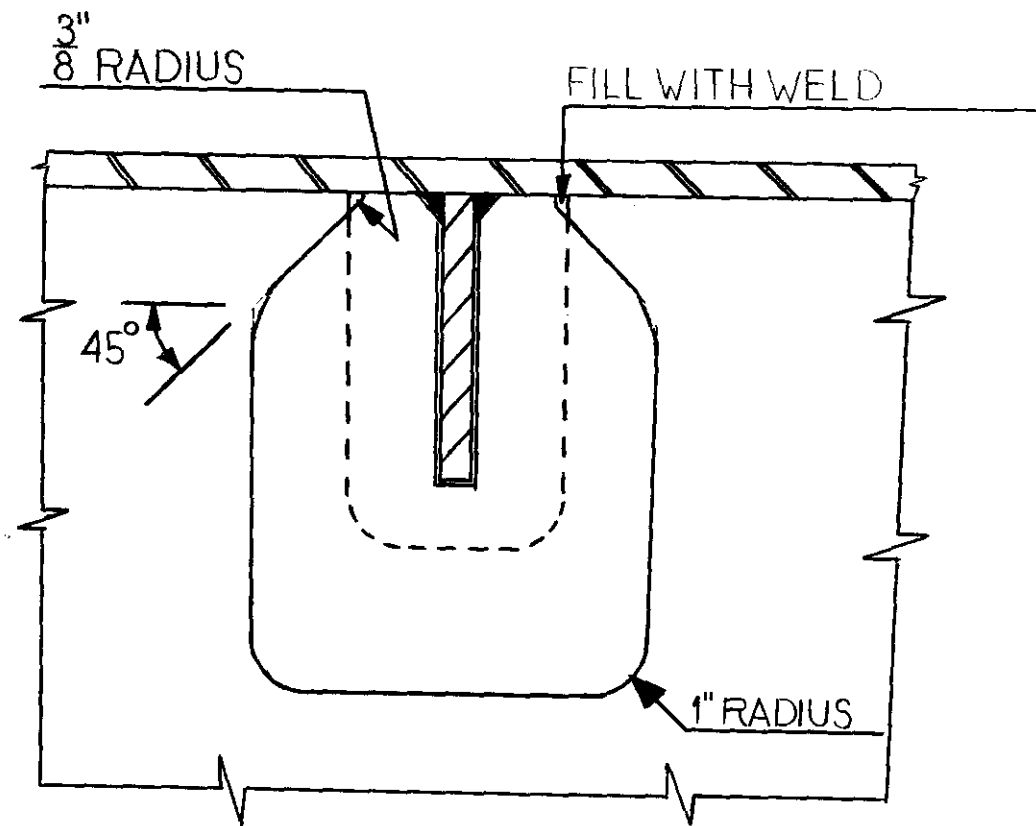
1" RADIUS

FOR DETAILS SEE TC-1

MTC-1

Detail Type:　RECOMMENDED LAPPED TIGHT COLLAR

Comments:　Although this detail is drawn for a flat bar, the improvements
shown here are applicable to all lapped collars. The
radiusing of the corners provides for a smooth weld path
and eliminates the possibility of cracks occurring at these
corners. Sniping the upper portion of the collar eases fit-
up and provides better weld accessibility.

FILL WITH WELD

$\frac{3}{4}$" x $\frac{3}{4}$"

S

$\frac{3}{8}$" PLT-A

OPTIONAL

FILL WITH WELD

$\frac{1}{4}$

3" x 8" x $\frac{3}{8}$" PLT-B

FOR CUT DETAILS SEE CC-4

TC-2
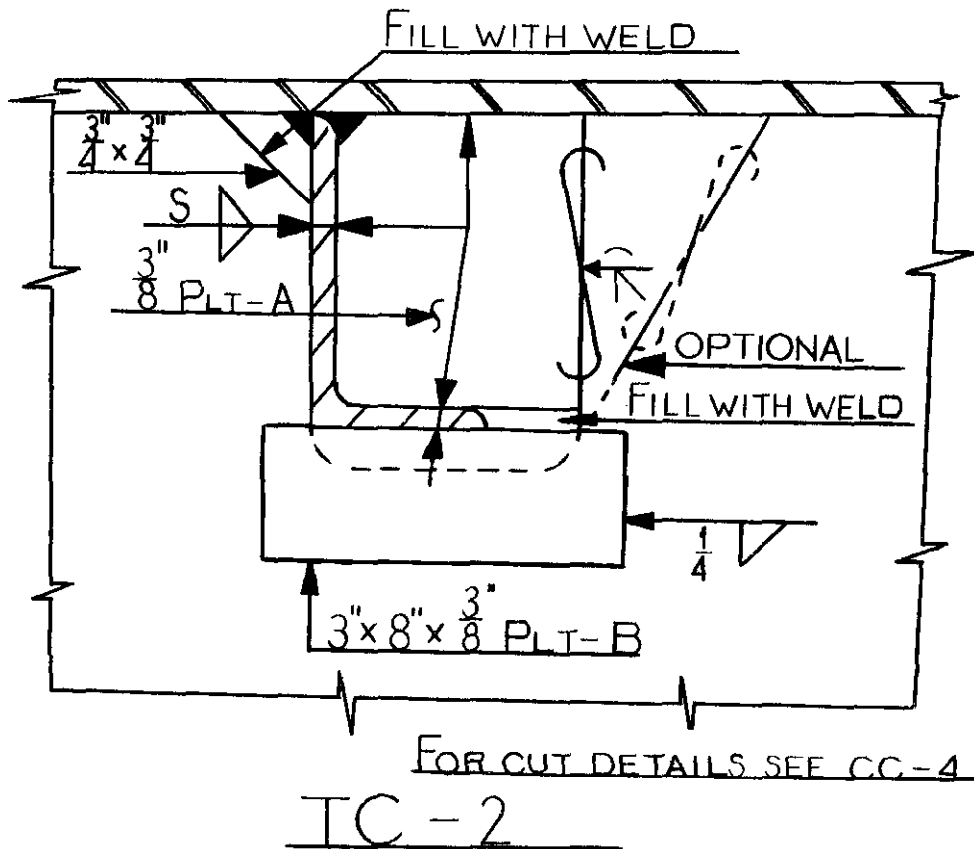
Detail Type: STRUCTURAL INTERSECTION (TIGHT COLLAR)

Comments: This detail is used by Shipyard "U" on ship type "B", for collaring rolled angles used as deck, shell, inner bottom and bulkhead longitudinals penetrating tight structures or in areas of high stress. Purpose of this detail is to ease fit-up of angle to penetrated member.

Detail Count Ship Type "B":   570

Manhours Required to Complete Typical Detail: 2.9

Typical Scantlings: 8" x 4" x 1/2" ∠ penetrating 1/2" Plate.

Producibility and Maintainability Problem Areas: Welding the periphery of the lapped portion of the collar plate to penetrated member causes problem mentioned for Detail TC-1. Filling of voids with weld requires procedures that minimize residual stress.

Proposed Modification: Introducing a 1" radius at all the corners will facilitate welding. Plate A should be cut 1/16" undersized all the way around to facilitate fit-up and welding.

3-22

FILL WITH WELD

S

FILL WITH WELD

$\frac{3"}{4} \times \frac{3"}{4}$
SEE S-1

$\frac{1"}{2}$

30°

$\frac{3"}{8}$ PLATE-A

LAP ABOUT 2"

S

S

FILL WITH WELD

$3" \times 8" \times \frac{3"}{8}$ PLATE-B

S

S

FOR CUT DETAILS SEE CC-4

TC-3

Detail Type: STRUCTURAL INTERSECTION (LAPPED TIGHT COLLAR)

Comments: This detail is used by Shipyard "U" on ship type "B" for collaring
rolled angles used as deck, shell, inner bottom, and bulkhead
longitudinals penetrating tight structure and in areas of high stress.
This detail requires less fit-up and should be used in lieu of
detail TC-2 when shear or compressive stresses are less severe.
(See TC-7)

Detail Count Ship Type "B":   2740

Manhours Required to Complete Typical Detail: 2.6

Typical Scantlings: 8" x 4" x 1/2" ∠ penetrating 1/2" Plate.

Producibility and Maintainability Problem Areas: Welding of the square corners
may be improved by radiusing, and weld accessibility may be
improved by increasing the snipe angle to 45°.   See figure MTC-1
for details.   Collar plate A should be cut 1/16" undersize to
facilitate fitting and welding.

3-23

$\frac{3}{8}$ PLATE USED BY SHIPYARD Y ONLY

$\frac{9}{16}$ RADIUS

S

S

$\frac{3}{8}$ RADIUS, FILL WITH WELD

$\frac{1}{2}$"

2" TO 3" LAP

$\frac{3}{8}$ PLATE

$\frac{1}{16}$"

USED BY SHIPYARD U

2" TYP.

S

S

S

FILL WITH WELD

1" TO 3" LAP

FOR CUT DETAILS SEE CC - 6
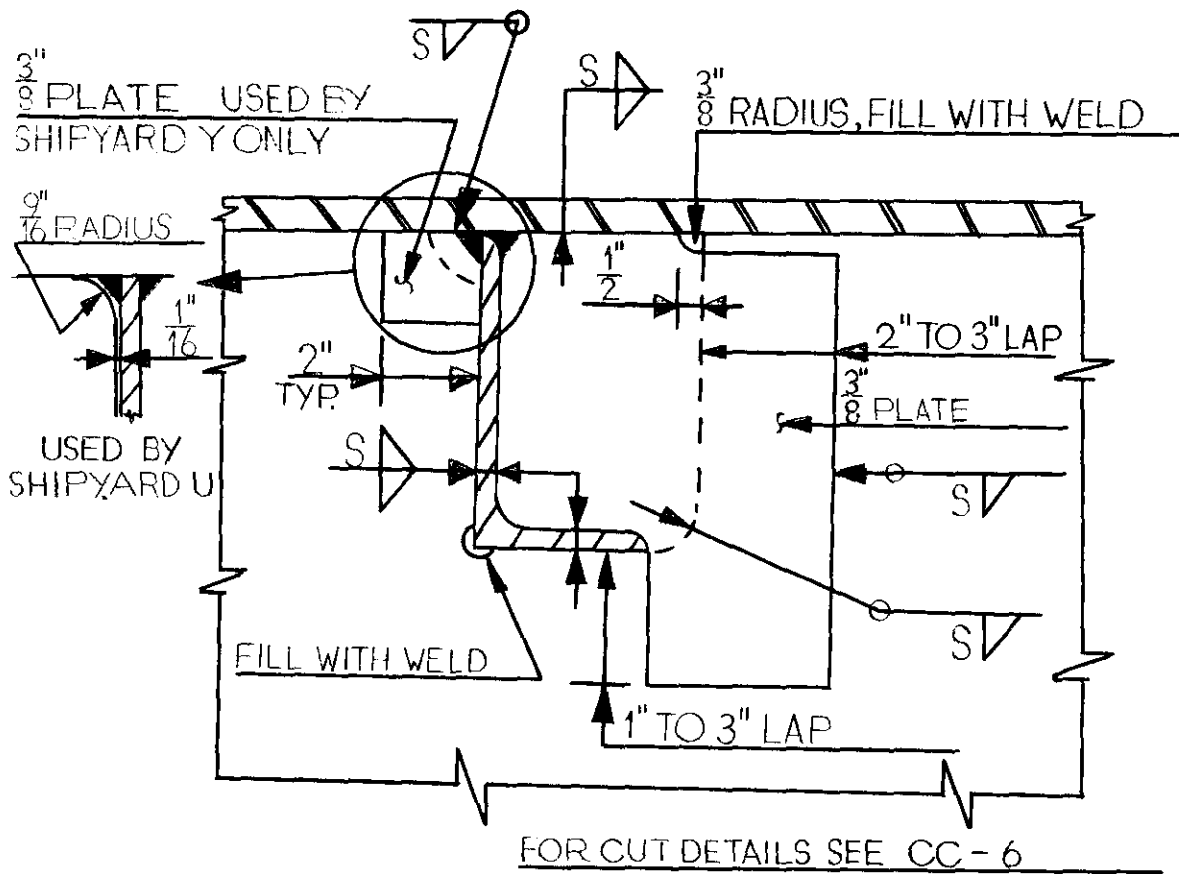
TC - 4

Detail Type: STRUCTURAL INTERSECTION (LAPPED TIGHT COLLAR)

Comments: This detail is used by Shipyards "U" and "Y" on ships "A" and "J" for collaring rolled or fabricated angles used as deck, shell, inner bottom, and bulkhead longitudinals penetrating tight structure and in way of high stresses.

Detail Count Ship Type "A":   2270

Manhours Required to Complete Typical Detail: 1.9

Typical Scantlings: 7" x 4" x 1/2" ∠ penetrating 1/2" Plate.

Producibility and Maintainability Problem Areas: The difficulties mentioned for detail TC-1 apply here also, thus the same improvements are recommended. The 3/8" Plate used by Shipyard "Y" necessitates added handling and welding for this detail. The 9/16", radius used by Shipyard "U" (see insert) eliminates this problem. This detail does not allow for variations in rolling or fabrication tolerances of the longitudinal as does TC-3. A minimum clearance of 1/16" is recommended for the collar plate to facilitate fit-up.

3-24

DECK PLATING

2" TO 3" LAP

$\frac{3"}{8}$ PLATE-A

$\frac{3"}{8}$ PLATE-B

2" TO 3" LAP
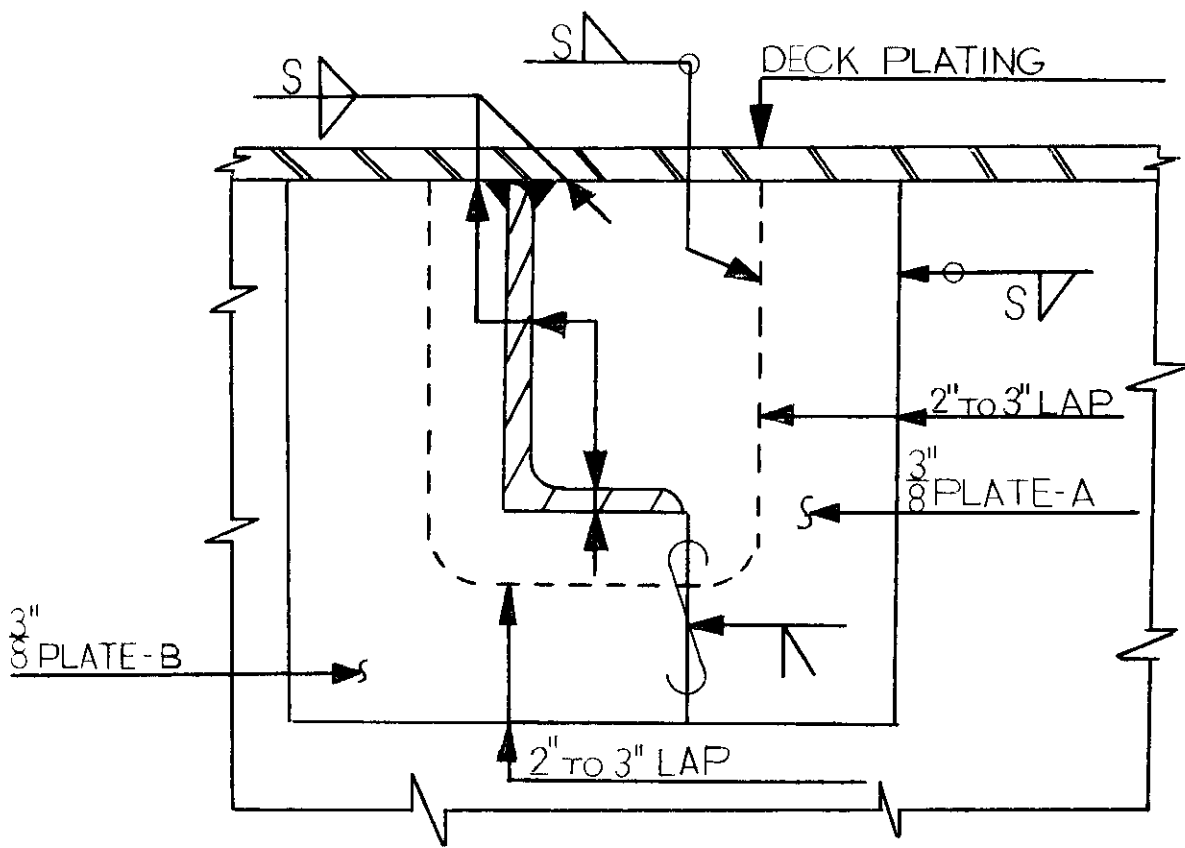
FOR CUT DETAILS SEE CC-5

TC-5

Detail Type: STRUCTURAL INTERSECTION (LAPPED TIGHT COLLAR)

Comments: This detail is used by Shipyards "X" and "Y" on ship types "H" and "J" for collaring rolled angles used as deck longitudinals penetrating tight bulkheads.   Other details and comments for this collar are similar to those recorded in TC-1.   To facilitate fit-up, collar plate A should be cut 1/16" undersize.

S ▷ DECK PLATING

S ◁ S ▽

1½" TO 3" LAP

$\frac{3}{8}$" PLATE-B

$\frac{3}{8}$" PLATE-A

1½" TO 3" LAP
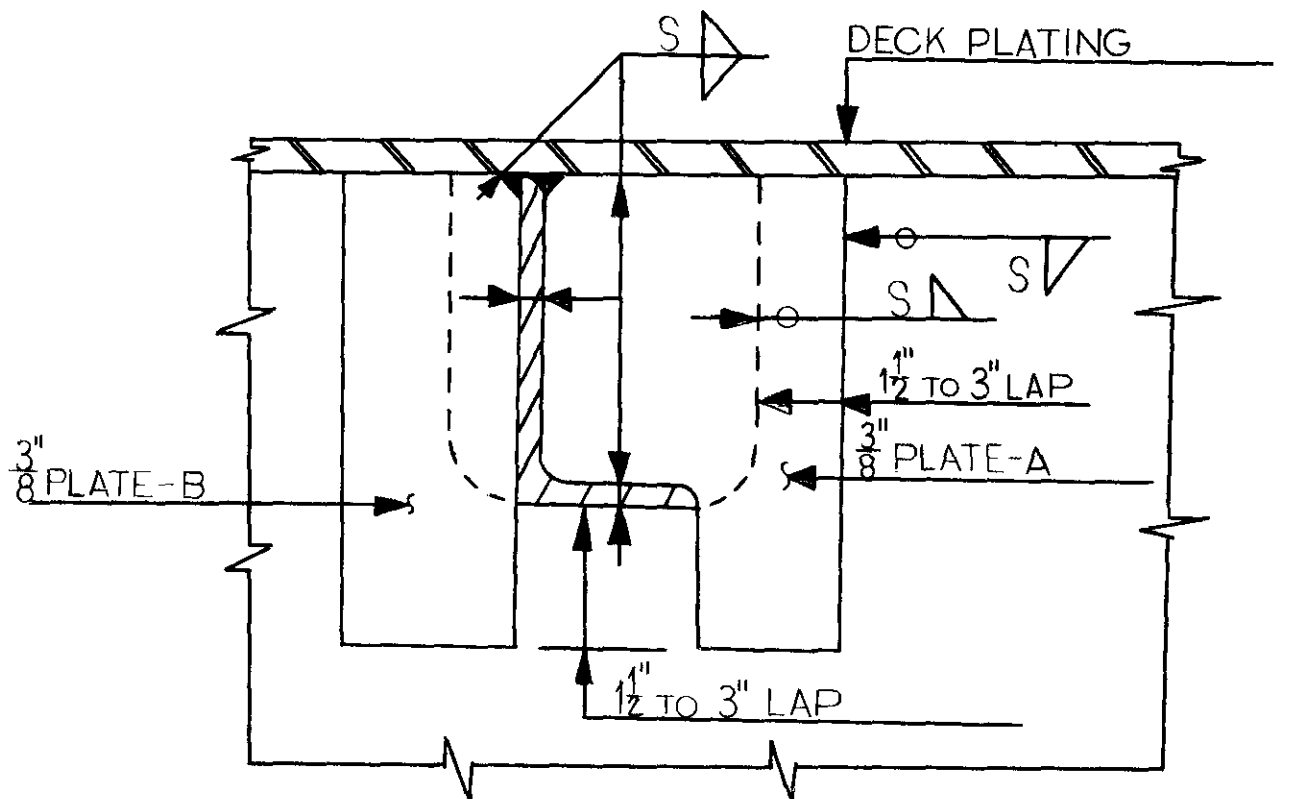
FOR CUT DETAILS SEE CC-5

TC-6

Detail Type: STRUCTURAL INTERSECTION (LAPPED TIGHT COLLAR)

Comments: This detail is used by Shipyards "W", "X" and "Y" on ship types "G", "H" and "J" for collaring rolled angles used as deck longitudinals penetrating tanks and other tight structure. Other details and problems for this collar are similar to those recorded in TC-1. Plate A should be cut 1/16" undersize to facilitate fit-up.
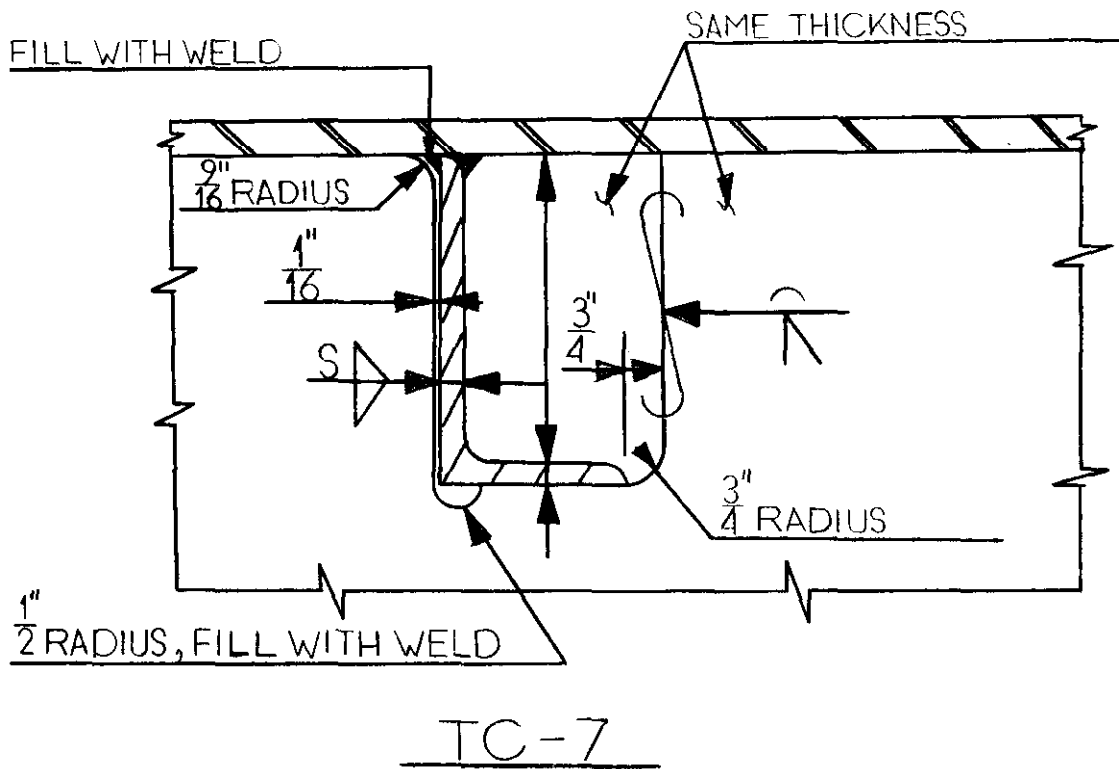
3-26

FILL WITH WELD

SAME THICKNESS

$\frac{9"}{16}$ RADIUS

$\frac{1"}{16}$

$\frac{3"}{4}$

S

$\frac{3"}{4}$ RADIUS

$\frac{1"}{2}$ RADIUS, FILL WITH WELD

TC-7

Detail Type: STRUCTURAL INTERSECTION (FLUSH TIGHT COLLAR)

Comments: This detail is used by Shipyard "U" on ship types "A" and "E" for
collaring rolled or fabricated angles used as deck longitudinals.
Flushtight collars are to be fitted when shear and compressive
stresses are critical such as below heavy equipment foundations
and in way of stanchions. Manhours to complete this detail could
be reduced slightly by modifying the detail in the following
manner: to facilitate fit-up, the collar plate should be cut 1/16"
undersize, and the detail at the toe of the angle should be similar
to TC-9. A radius at the heel of the angle similar to that shown
in TC-4 is recommended to reduce crack potential.

Detail Count Ship Type "A":   100

Manhours Required to Complete Typical Detail: 2. 2

SAME THICKNESS

OPTIONAL
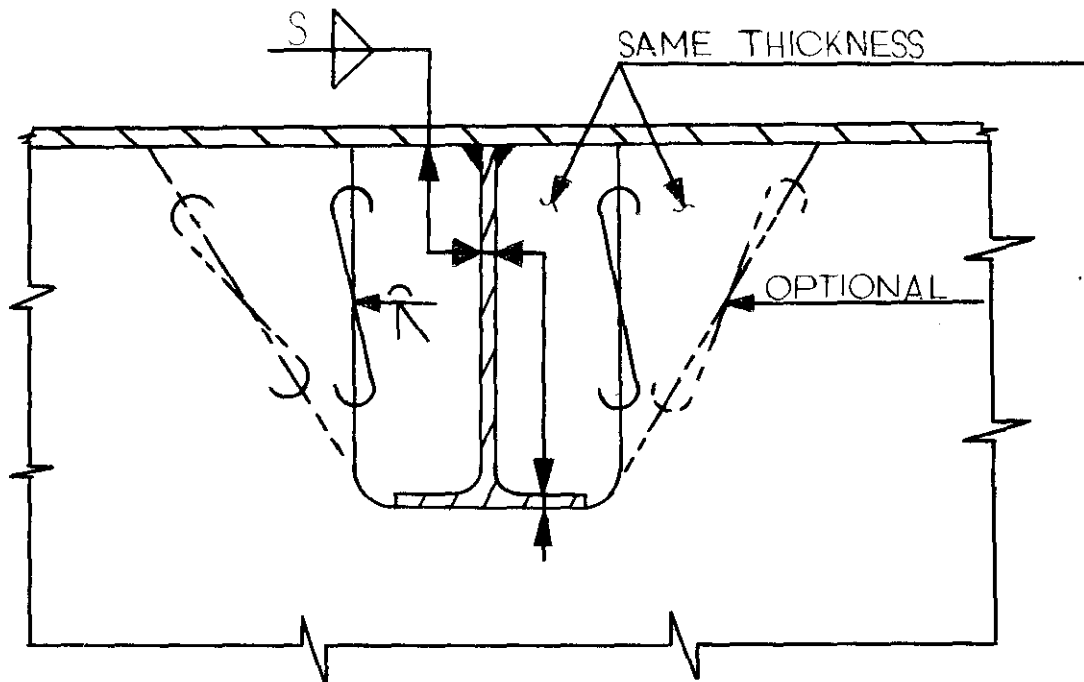
FOR CUT DETAILS SEE CC-10

TC-8

Detail Type: STRUCTURAL INTERSECTION (FLUSH TIGHT COLLAR)

Comments: This detail is used by Shipyard "U", "V" and "Z" on ship types
                "A", "C", "D", "F" and "K" for rolled or built-up Tee beams.
                Flushtight collars are to be fitted only when continuity of highly
                stressed structural members is required.

Detail Count Ship Type "A":   20

Manhours Required to Complete Typical Detail: 9.5

Typical Scantlings: 18-13/16" x 1/2" x 12-1/2" x 3/4" Tee penetrating 5/8"
                      Plate.

Producibility and Maintainability Problem Areas: Fitup time required for this
                detail could be reduced by substituting TC-9.
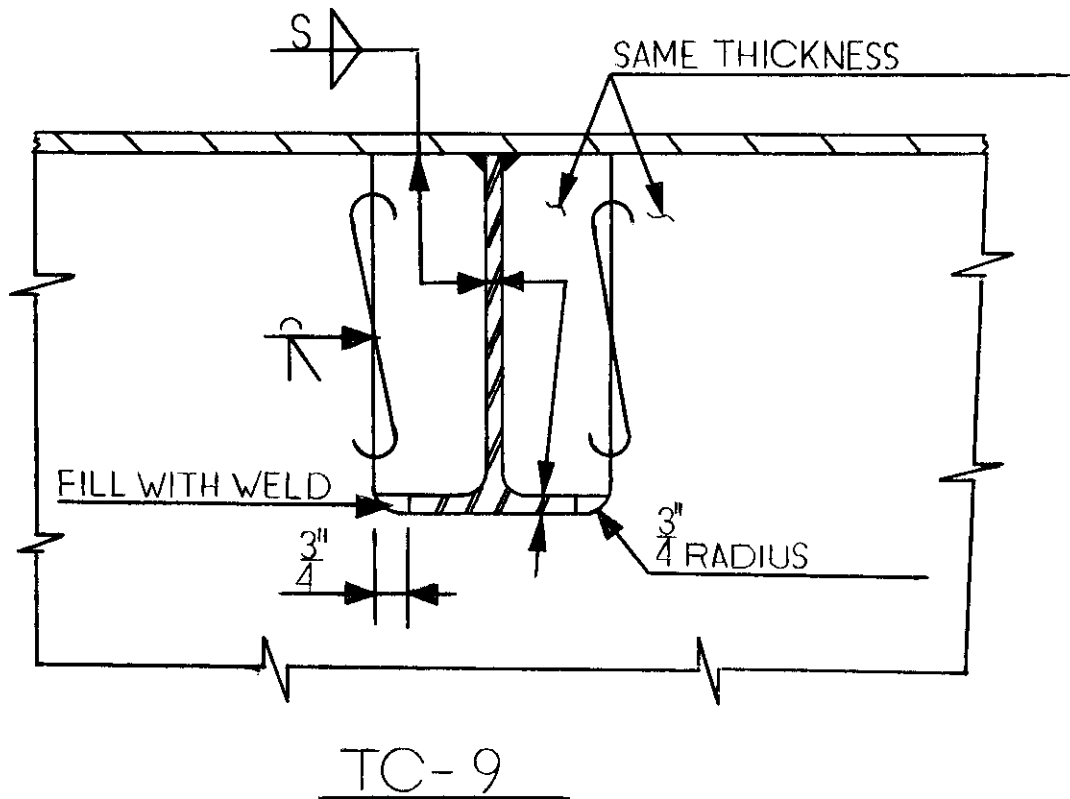
TC-9

Detail Type: STRUCTURAL INTERSECTION (FLUSH TIGHT COLLAR)

Comments: This detail is used by Shipyard "U" on ship type "B" for collaring rolled or built-up Tee sections used as transverse or longitudinal girders penetrating tight structure. Flush tight collars are to be fitted only when continuity of highly stressed structural members is required.
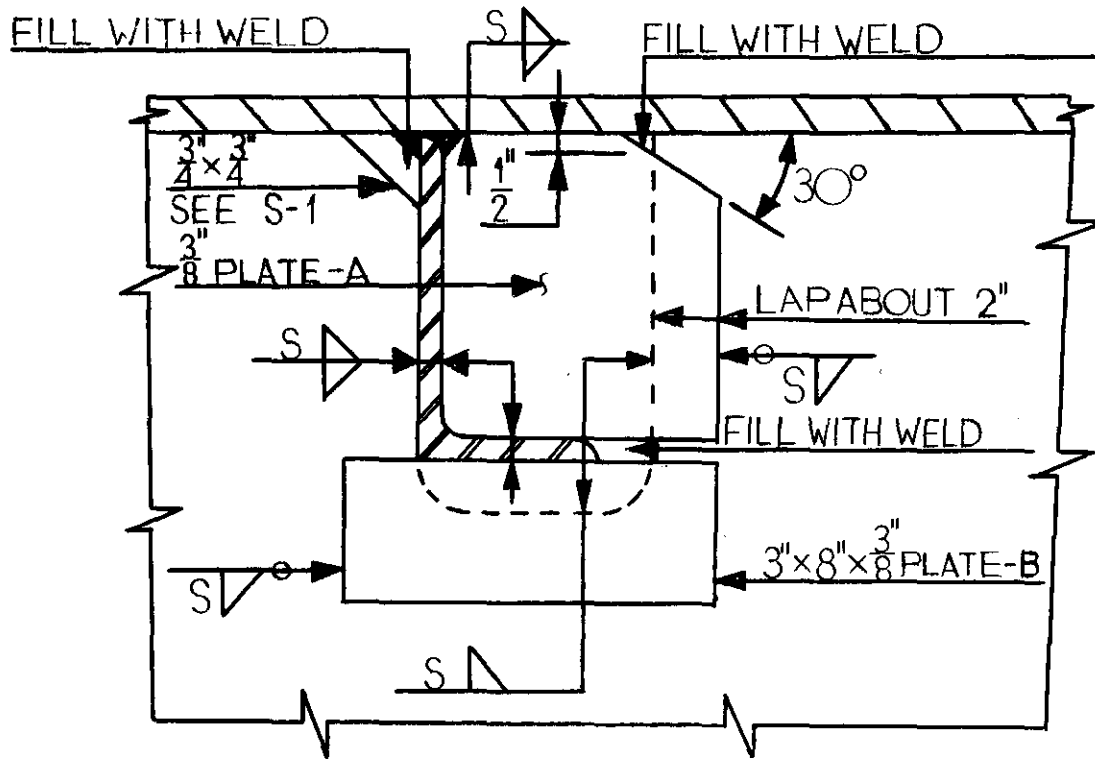
Detail Count Ship Type "B": 4270

Manhours Required to Complete Typical Detail: 9.0

Typical Scantlings: 16" x 5" x 50# I cut to T penetrating 1/2" Plate.

SAME THICKNESS

LAP: 5 Tw

OPTIONAL

THICKNESS: Tw
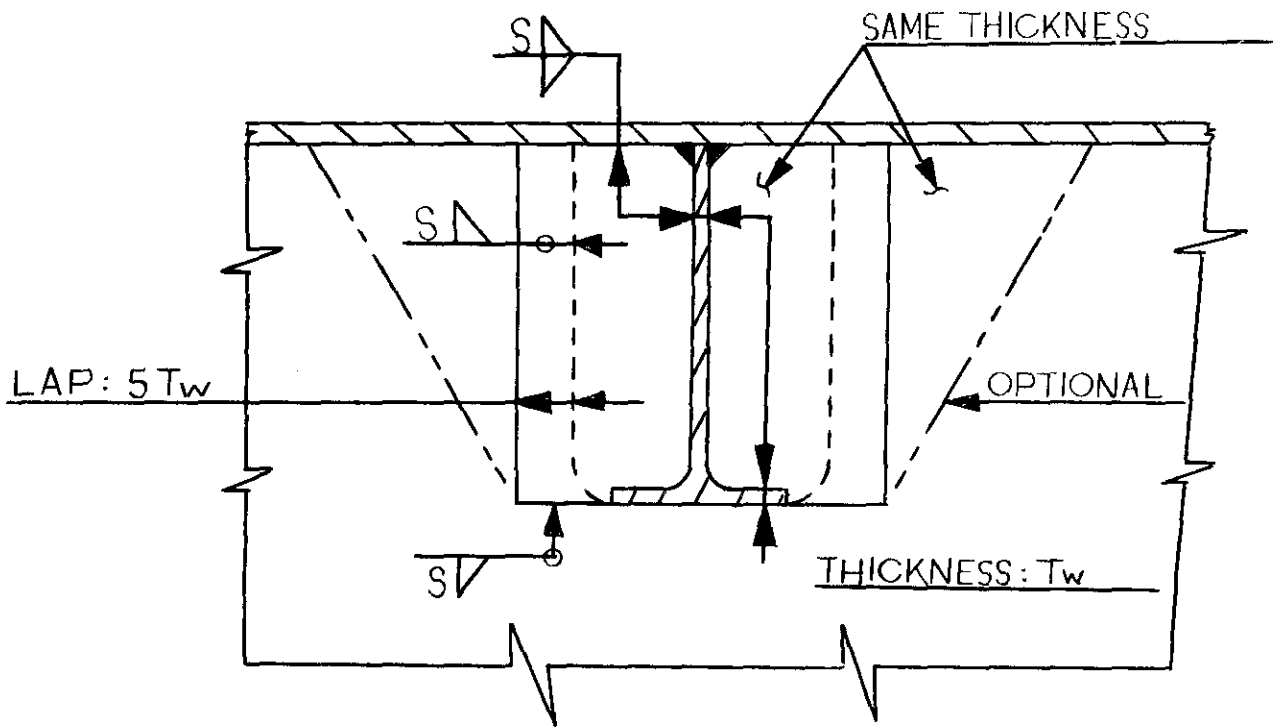
FOR CUT DETAILS SEE CC-10

TC-10

Detail Type: STRUCTURAL INTERSECTION (LAPPED TIGHT COLLAR)

Comments: This detail is used by Shipyards "U", "V" and "Z" on ship types "C", "D", "E", "F", and "K" for collaring rolled or fabricated Tee beams used as longitudinal or transverse girders. This detail is used extensively on Navy ships.

Producibility and Maintainability Problem Areas: For details of problem areas and proposed modifications see detail TC-1. Fit-up could be simplified by cutting the collar plate 1/16" undersized, and the plate itself straight across at the flange with the gap filled with weld similar to detail TC-3.

3-30

S

S

S

2" TO 3" LAP

$\frac{3"}{8}$ PLATE

1" TO 3" LAP

FOR CUT DETAILS SEE CC − 10

TC − 11

Detail Type: STRUCTURAL INTERSECTION (LAPPED TIGHT COLLAR)

Comments: This detail is used by Shipyards "U", "W", "Y" and "Z" on ship types "A", "D", "G", "J" and "K" for collaring Tee sections used as longitudinal or transverse girders which penetrate tight structure.

Detail Count Ship Type "A":   50

Manhours Required to Complete Typical Detail: 6.5

Typical Scantlings: 18-13/16" x 1/2"-12-1/2" x 3/4" Tee penetrating 5/8" Plate.

Producibility and Maintainability Problem Areas: For details of problem areas and proposed modifications see detail TC-1 and TC-10.
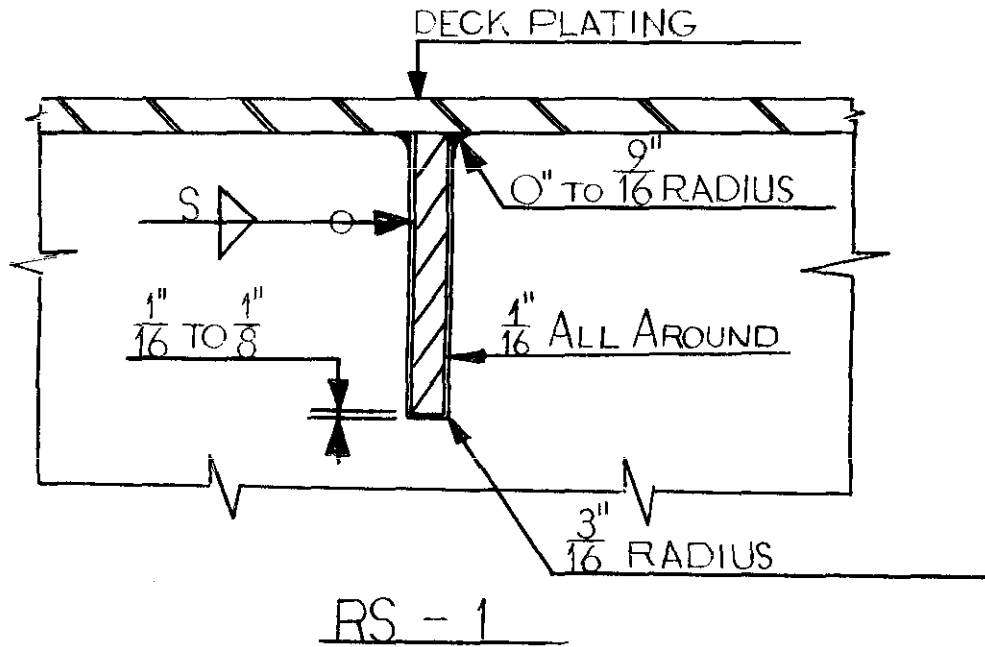
DECK PLATING

O'' TO $\frac{9''}{16}$ RADIUS

S

$\frac{1''}{16}$ TO $\frac{1''}{8}$

$\frac{1''}{16}$ ALL AROUND

$\frac{3''}{16}$ RADIUS

RS - 1

Detail Type: REEVING SLOT

Comments: This detail is used by Shipyards "U" and "Y" on ship types
"A" and "J" for flat bar longitudinal deck beams penetrating
tight structure or members that are only slightly deeper
than the penetrating member. This detail eliminates the
handling time involved with a collar plate. Close tolerances
must be maintained throughout the manufacturing process
to insure proper alignment between the members.
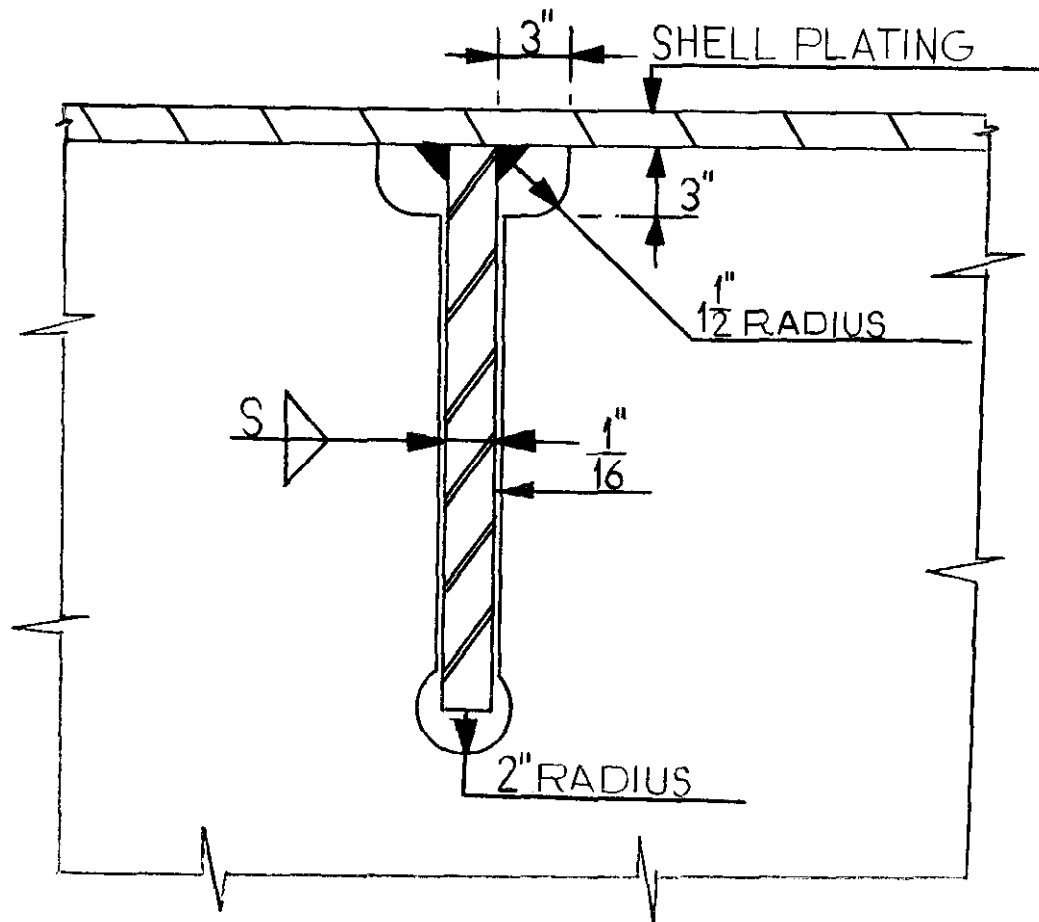
$$\text{RS} - 2$$

Detail Type: REEVING SLOT

Comments: This detail is used by Shipyard "U" on ship type "A". This detail was developed for use in way of deep (24"x2" to 32"x 2") slabs penetrating non-tight webs in the upper wing wall of the ship. The radius cut at the free edge of the slabs eliminates the possibility of notching the slab by welding, thereby reducing its efficiency. See RS-1 for additional comments.

DECK PLATING

$0''$ TO $\frac{3''}{4}$ SNIPE

$\frac{1''}{16}$ TO $\frac{1''}{8}$

$\frac{1''}{2}$ RADIUS

S

$0''$ TO $\frac{3''}{16}$ RADIUS
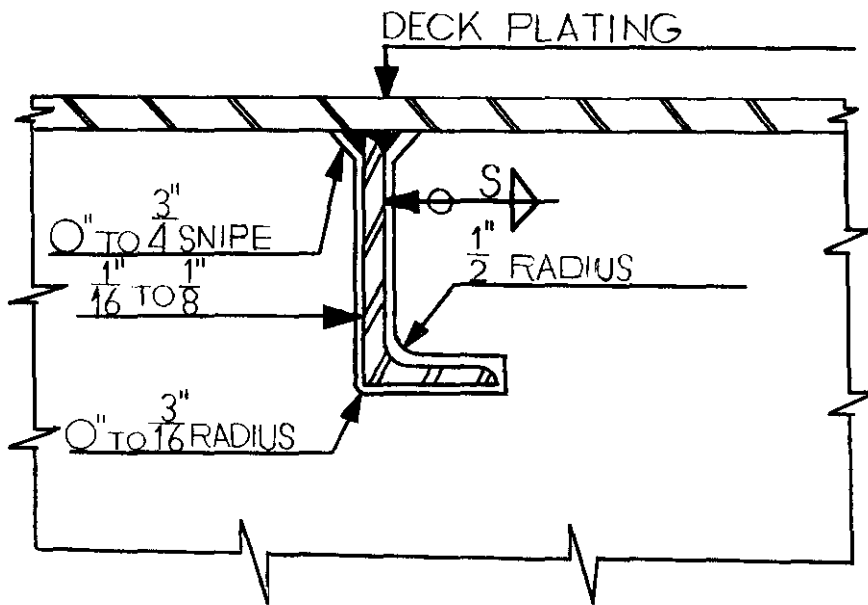
RS - 3

Detail Type: REEVING SLOT

Comments: This detail is used by Shipyards "U" and "Y" on ship types "A", "B", "E" and "J" for rolled angles used as deck and bulkhead longitudinals penetrating tight structure, or for bulkhead stiffeners penetrating shallow webs.

Comments for RS-1 apply, except that tolerances for this detail must be tighter since assembly is possible only be reeving.

3-34
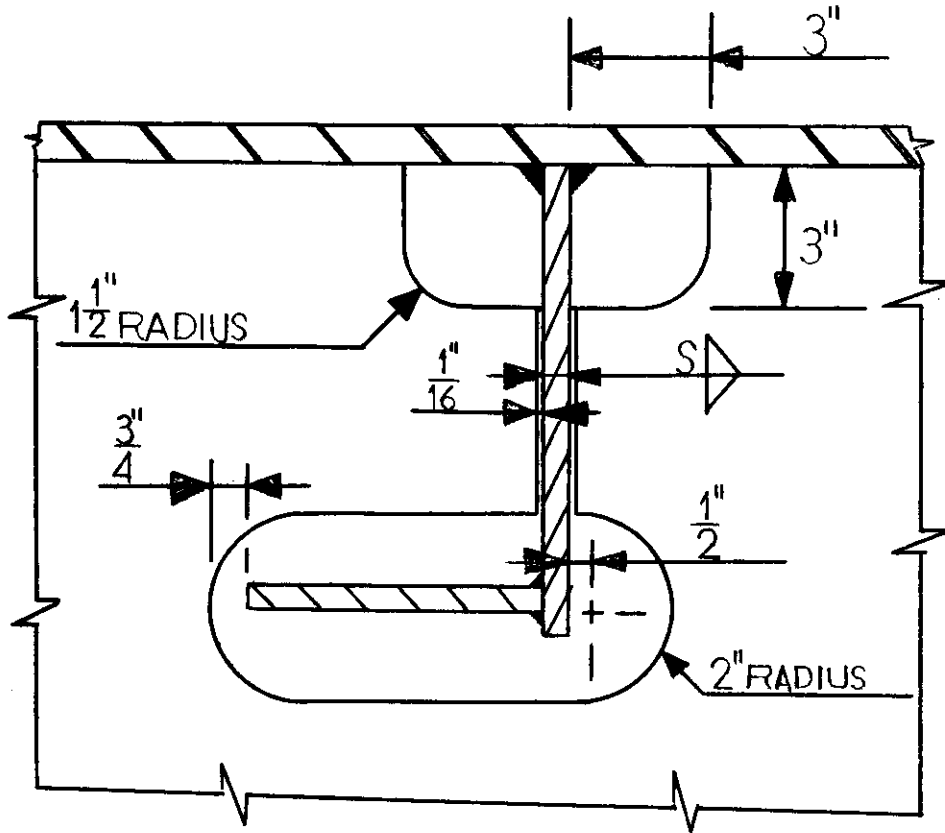
$$RS - 4$$

Detail Type: REEVING SLOT

Comments: This detail is used by Shipyard "U" on ship type "A". This detail is for fabricated angles penetrating non-tight structure. Areas of occurrence are shell and inner bottom longitudinals penetrating non-tight floors. Shear capability of web attachment should be examined for shallow members (less than 12") and depth of clearance cut adjusted accordingly. See RS-1 for additional comments.
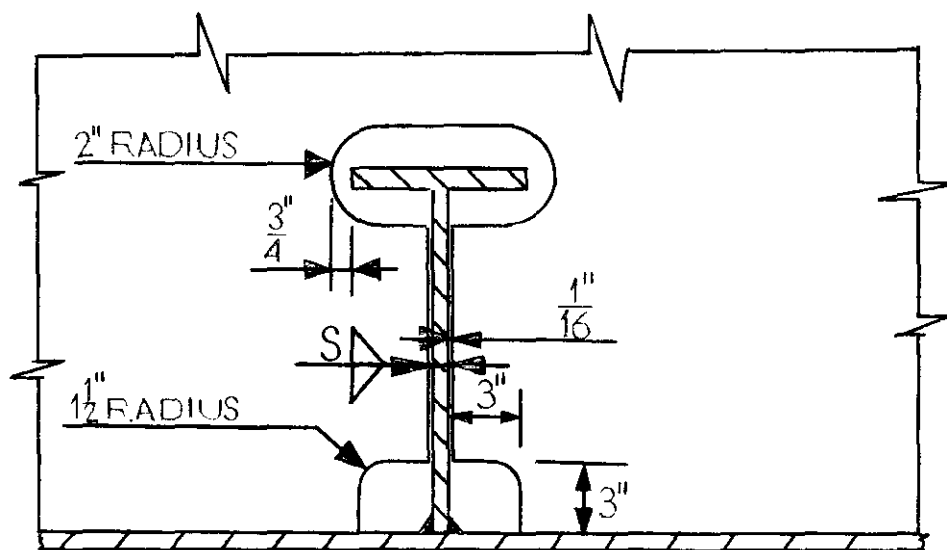
RS-5

Detail Type: REEVING SLOT

Comments: This detail is used by Shipyard "U" on ship type "A". This is a non-tight reeving slot for rolled or fabricated Tee sections penetrating areas such as non-tight floors or deep transverse webs. See RS-1 for additional comments.

3-36

$0"$ TO $\frac{9"}{16}$ RADIUS

$\frac{1"}{16}$ TO $\frac{1"}{8}$

S

RADIUS TO SUIT
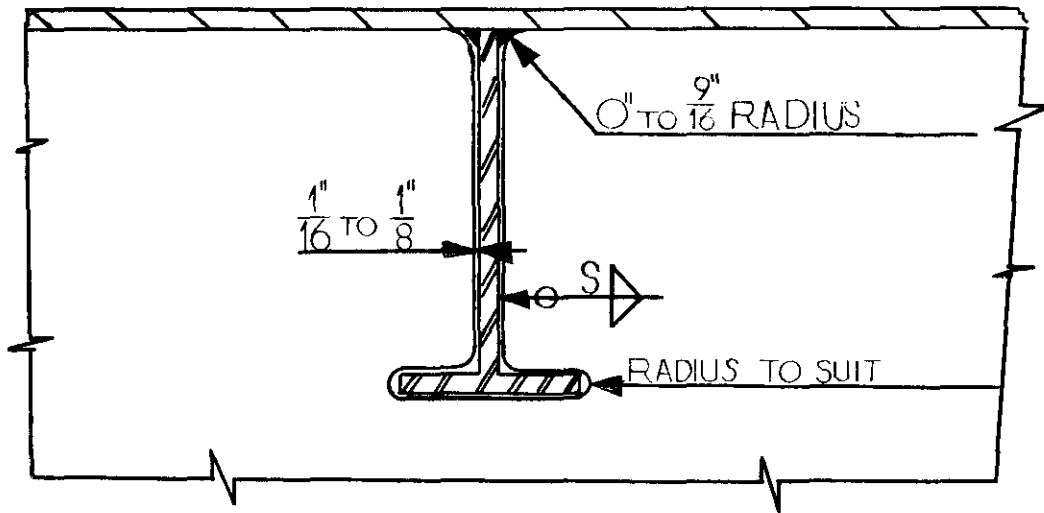
RS-6

Detail Type: REEVING SLOT

Comments: This detail is used by Shipyards "U" and "Y" on ship types "A",
"B", "E" and "J" for rolled or fabricated Tee sections penetrating
tight structure or areas of high stress.   See RS-1 for additional
comments.

DECK PLATING

$\frac{3}{8}$" PLATE

1" TO 2"

S

S

S

S

2"

$\frac{1}{2}$"

FOR CUT DETAILS SEE CC-1
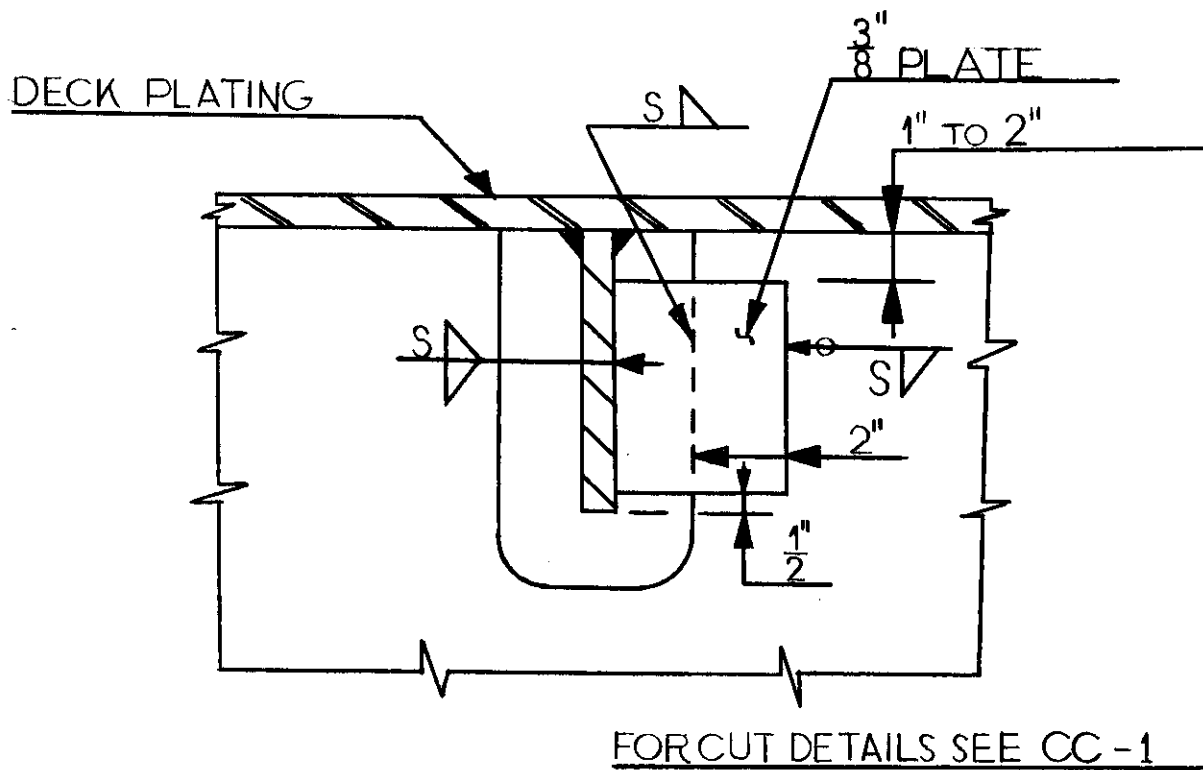
NC-1

Detail Type: STRUCTURAL INTERSECTION (CLIP CONNECTION)

Comments: This detail is used by Shipyard "Y" on ship type "J" where flat
bar deck longitudinals penetrate non-tight structure. A 1" radius
at the corners of the clip where it is welded to the penetrated
member will facilitate welding. The clip provides support at
the member ends and eases fit-up, since the lap dimension can
be allowed to vary.
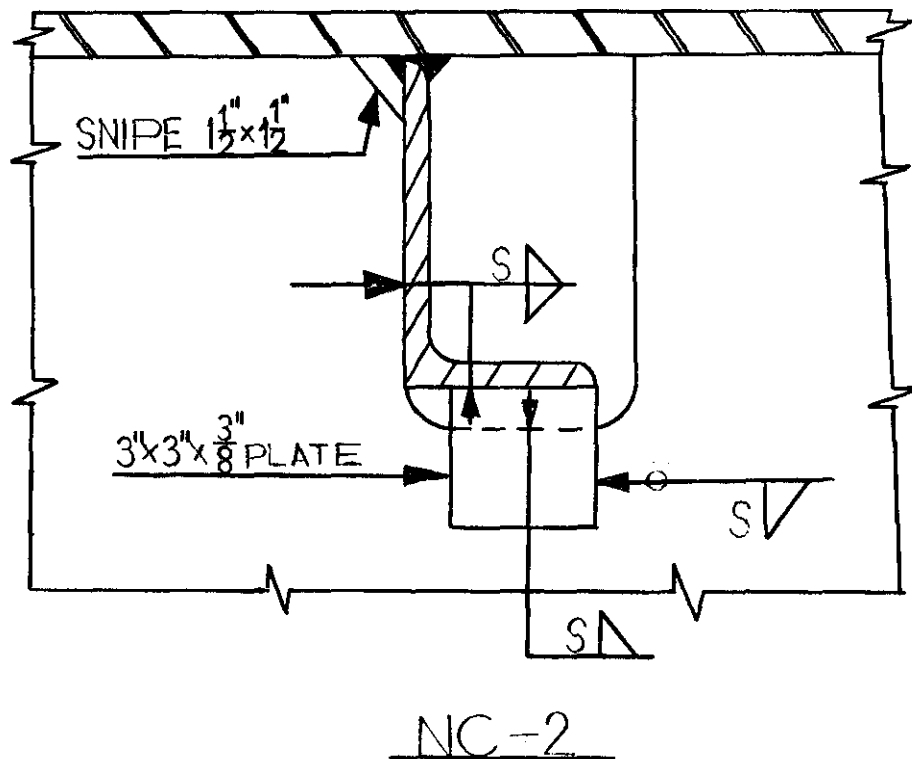
SNIPE 1½"×1½"

3"×3"×⅜" PLATE

NC-2

Detail Type: STRUCTURAL INTERSECTION (CLIP CONNECTION)

Comments: This detail is used by Shipyard "U" on ship type "B" where rolled angle deck longitudinals penetrate non-tight structure. Used where flange support is desirable. A 1" radius at the corners of the clip where it is welded to the penetrated member will facilitate welding. A cut similar to CC-7 would facilitate fit-up and reduce the crack potential at the heel of the angle.

Detail Count Ship Type "B":   3200

Manhours Required to Complete Typical Detail: 0.7

Typical Scantlings: 7" x 4" x 1/2" ∠ penetrating 1/2" plate.
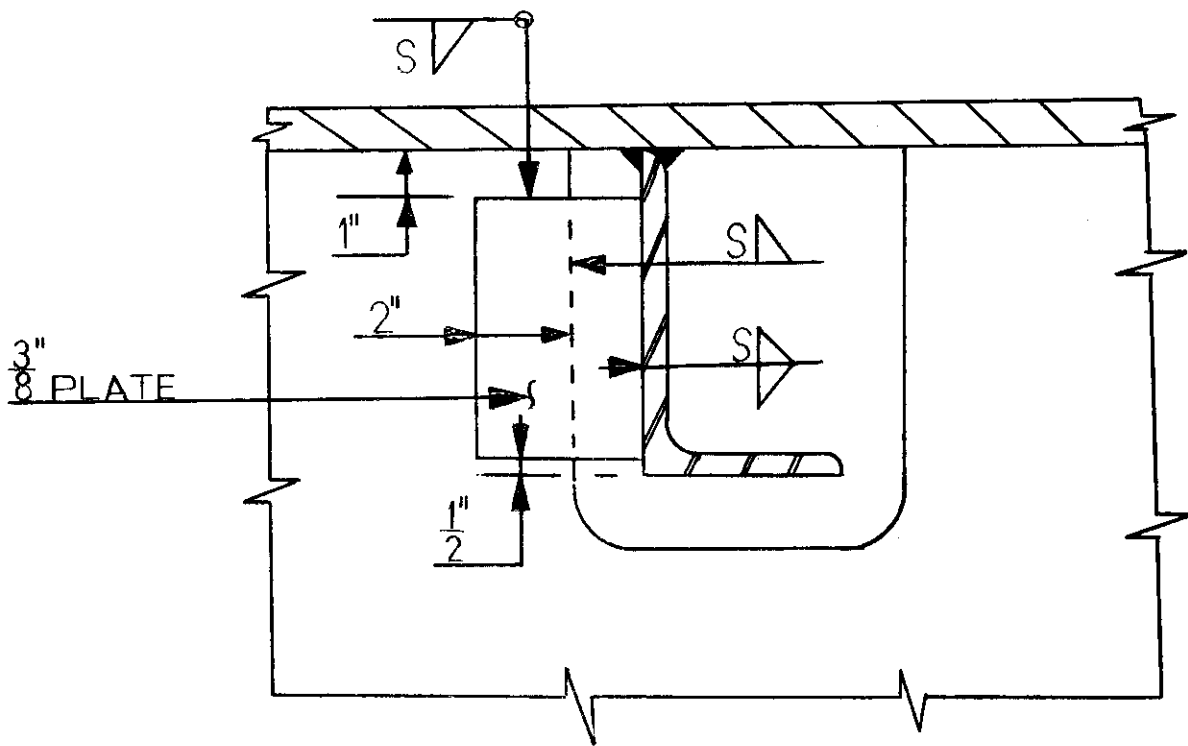
For cut details see CC-5

NC-3

Detail Type: STRUCTURAL INTERSECTION (CLIP CONNECTION)

Comments: This detail is used by Shipyard "Y" on ship type "J" where rolled angles used as deck longitudinals penetrate non-tight structure. For other comments see NC-1.
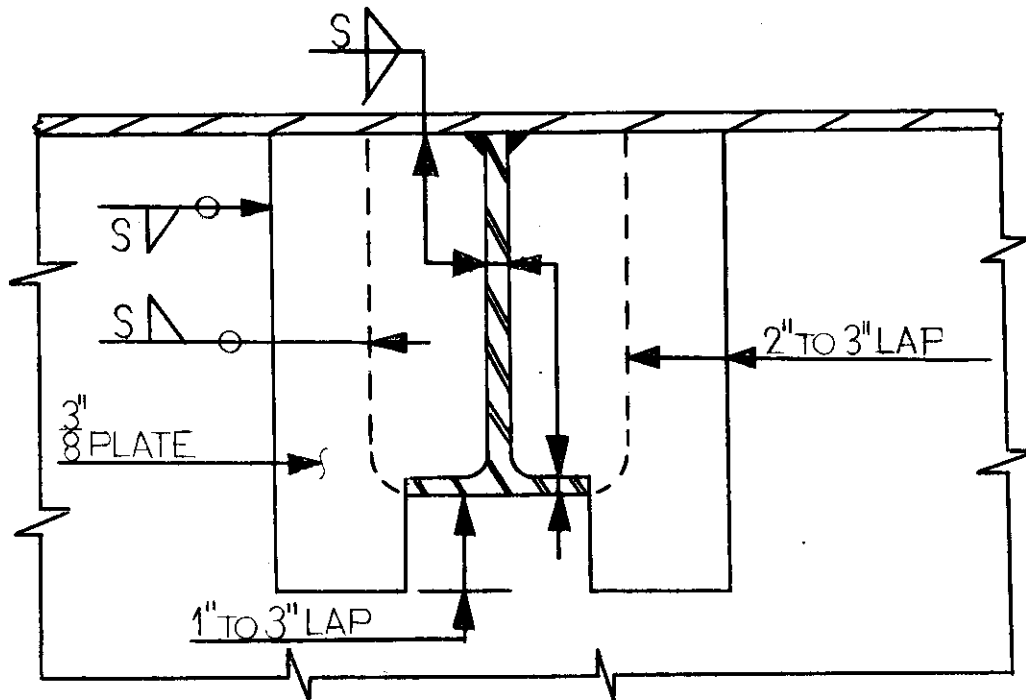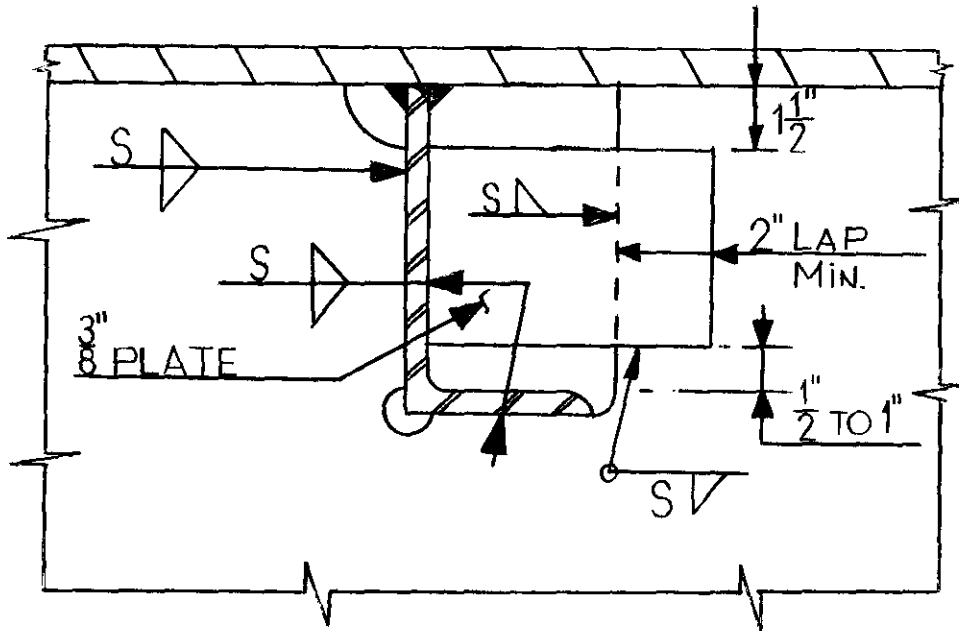
FOR CUT DETAILS SEE CC-4 TO CC-9

NC - 4

Detail Type: STRUCTURAL INTERSECTION (NON-TIGHT LAPPED
               COLLAR)

Comments: This detail is used by Shipyards "U" and "Y" on ship types
               "A" and "J" for rolled or fabricated angles used as deck
               longitudinals. The collar plate is added to replace area
               removed by the cut. To facilitate welding the corners of
               the collar plate should be cut with a 1" radius.

Detail Count Ship Type "A":   800

Manhours Required to Complete Typical Detail: 0.8 To 1.2.

Typical Scantlings: 7" x 4" x 1/2" ∠ to 14-5/8" x 1/2"-6-3/16" x 1/2" ∠
               penetrating 1/2" Plate.

FOR CUT DETAILS SEE CC-5

NC - 5

Detail Type: STRUCTURAL INTERSECTION (NON-TIGHT LAPPED COLLAR)

Comments: This detail is used by Shipyard "X" on ship type "H". This collar is used on fabricated angles or channels cut to angles over 9" in depth. Areas of occurrence are shell stringers penetrating deep web frames and longitudinal girders penetrating deep transverses. This is not a common detail. If double clips are required consideration should be given to use of a balanced section. Radiusing the corners of the collar plates improves welding.

In the absence of radii at the upper corners the snipe shown should begin beyond the cutout to facilitate welding.

3-42

FOR CUT DETAILS SEE CC-4

NC - 6

Detail Type: STRUCTURAL INTERSECTION (NON-TIGHT LAPPED COLLAR)

Comments: This detail is used by Shipyard "U" on ship type "B", for rolled or fabricated angles used as deck or shell longitudinals. The collar plate is installed to replace area removed by the cut, to provide flange stability, and to provide improved end support. To facilitate welding, the lapped corners of the collar plate should be cut with a 1" radius.

Detail Count Ship Type "B":   10100

Manhours Required to Complete Typical Detail: 1.0

Typical Scantlings: 8" x 4" x 1/2" ∠ penetrating 1/2" Plate.

SNIPE 1½" × 1½"

S

4"
MAX.

1½" RADIUS

⅜" PLATE

S

1"

S

1" RADIUS

1" RADIUS

½"

NC-7
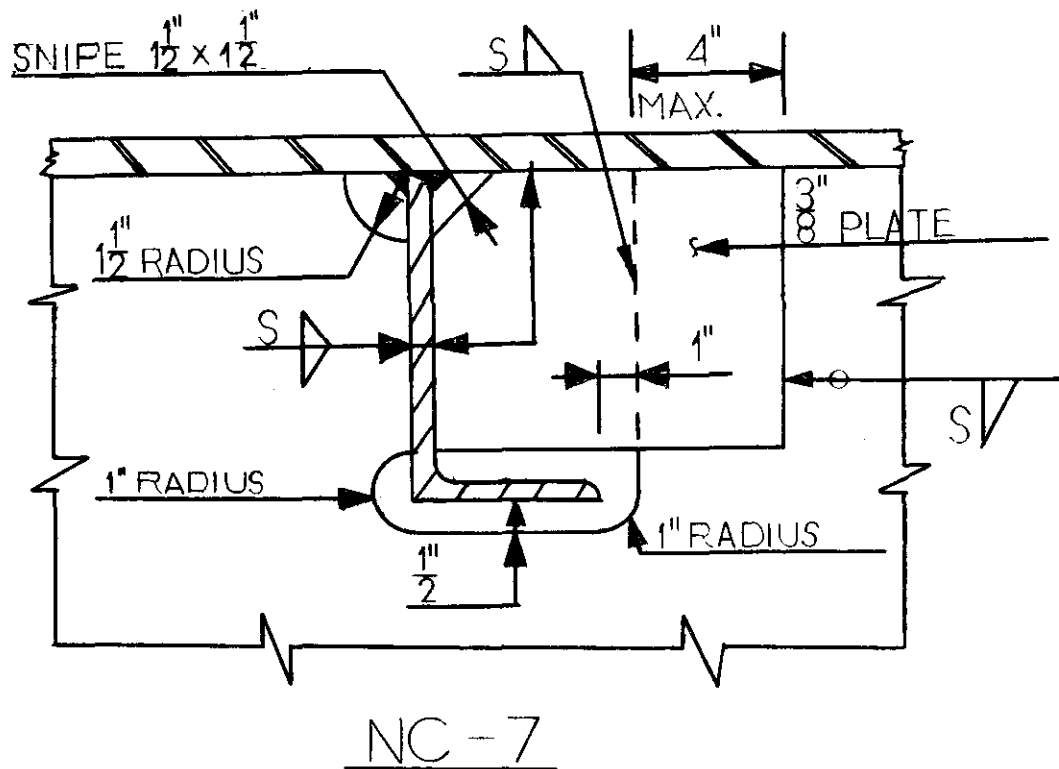
Detail Type: STRUCTURAL INTERSECTION (NON-TIGHT LAPPED COLLAR)

Comments: This detail is used by Shipyards "U" and "Y" on ship types "E" and
"J". It is used to collar rolled angles, used as deck and side shell
longitudinals penetrating non-tight structure. This detail modified
as detail below is preferred over detail NC-4 because it has a
lower stress at the clip edge, i.e. reduced stress concentration.
It is also more effective in restoring shear strength to the
penetrated member. To facilitate fitup and welding of collar plate,
the lower corner of the plate should be radiused and the upper edge
should be sniped. See MTC-1 for details. This detail does not
provide flange support.

FOR CUT DETAILS SEE CC-4
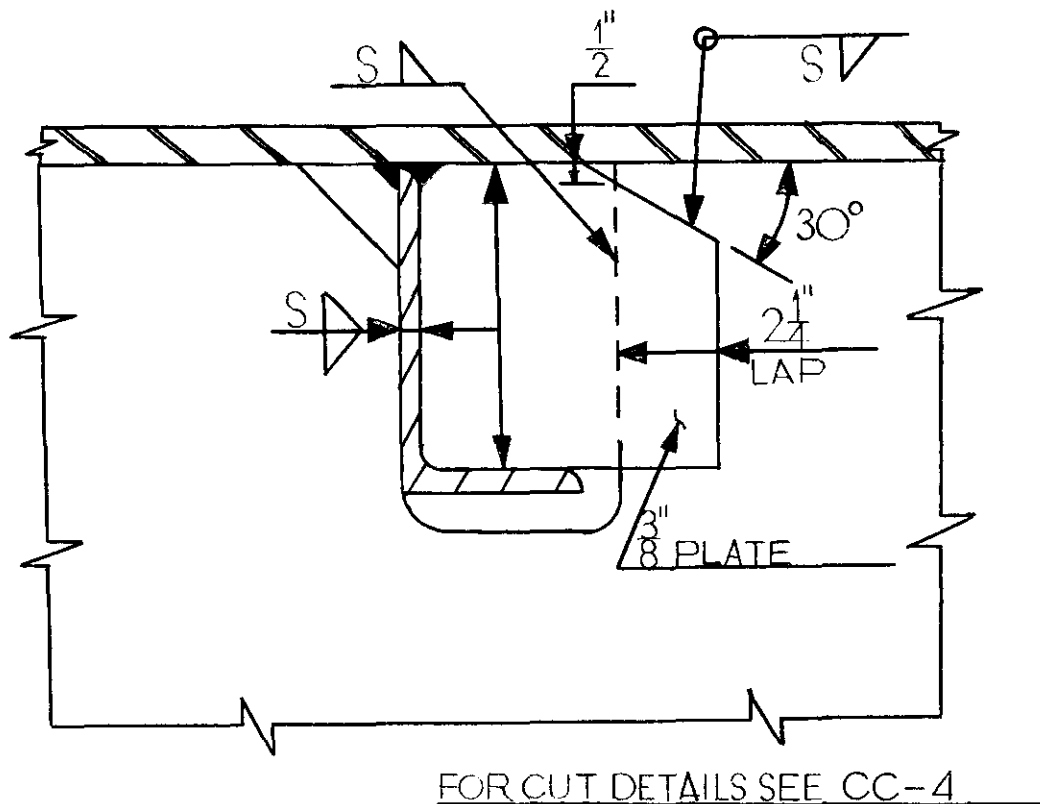
NC-8

Detail Type: STRUCTURAL INTERSECTION (NON-TIGHT LAPPED COLLAR)

Comments: This detail is used by Shipyard "U" on ship type "B" for collaring
rolled angles used as deck or side shell longitudinals penetrating
non-tight structure.   This detail is used in areas of high shear
stress when the member is carrying a large lateral load.
Increasing the snipe angle to 45° and radiusing the lower corner
similar to MTC-1 will improve welding.   Cutting the collar 1/16"
undersize will facilitate fit-up.   The corners of the collar at the
web attachment require trimming.   The clearance cut for NC-7
is preferable.

Detail Count Ship Type "B":   1400

Manhours Required to Complete Typical Detail: 1.9

Typical Scantlings: 8" x 4" x 1/2" ∠ penetrating 1/2" Plate.

3-45

SAME THICKNESS

CUT DETAILS SIMILAR TO CC-4

NC-9
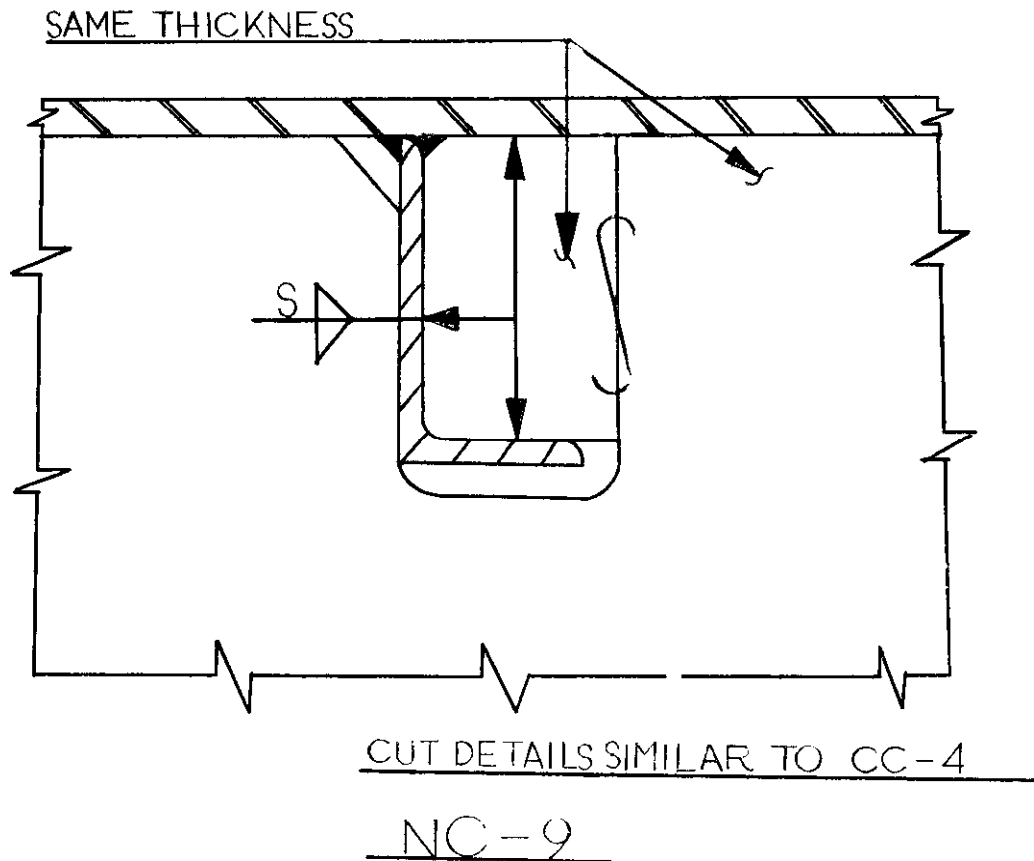
Detail Types: STRUCTURAL INTERSECTION (NON-TIGHT FLUSH COLLAR)

Comments: This detail is used by Shipyard "U" on ship types "B" and "E"
             for collaring rolled angles used as deck longitudinals penetrating
             non-tight bulkheads. This detail is used when high shear is
             present in the bulkhead. Cutting the collar plate 1/16" under-
             size will facilitate fit-up. The corners of the collar at the web
             attachment require trimming. The clearance cut for NC-7 is
             preferable.

Detail Count Ship Type "B":   1100

Manhours Required to Complete Typical Detail: 2. 2

Typical Scantlings: 8" x 4" x 1/2" ∠ penetrating 1/2" Plate.

$\frac{3''}{8}$ PLATE (UNLESS OTHERWISE NOTED)

$3'' \times 8'' \times \frac{3''}{8}$ PLATE

FOR CUT DETAILS SEE CC-4

NC - 10
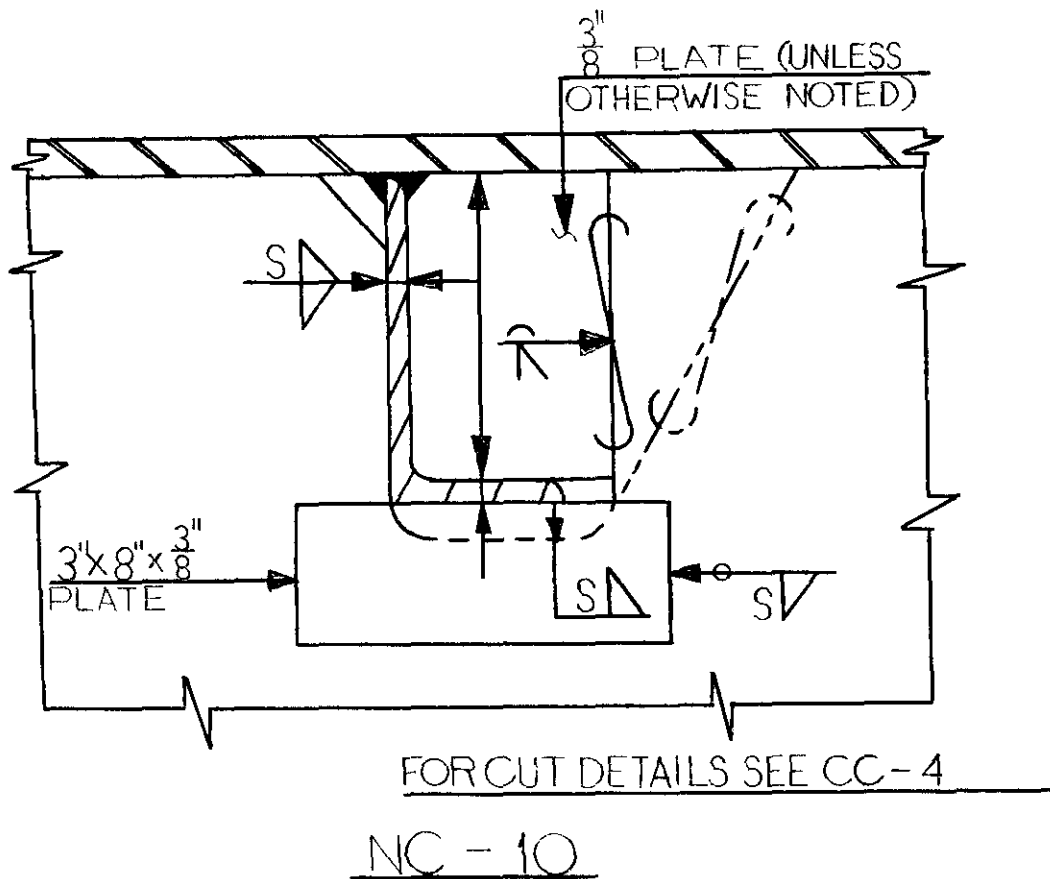
Detail Type: STRUCTURAL INTERSECTION (NON-TIGHT COLLAR)

Comments: This detail is used by Shipyard "U" on ship type "B", for collaring members penetrating non-tight structure, subject to high shear in penetrated and penetrating members. Not frequently used. For other comments see TC-2.
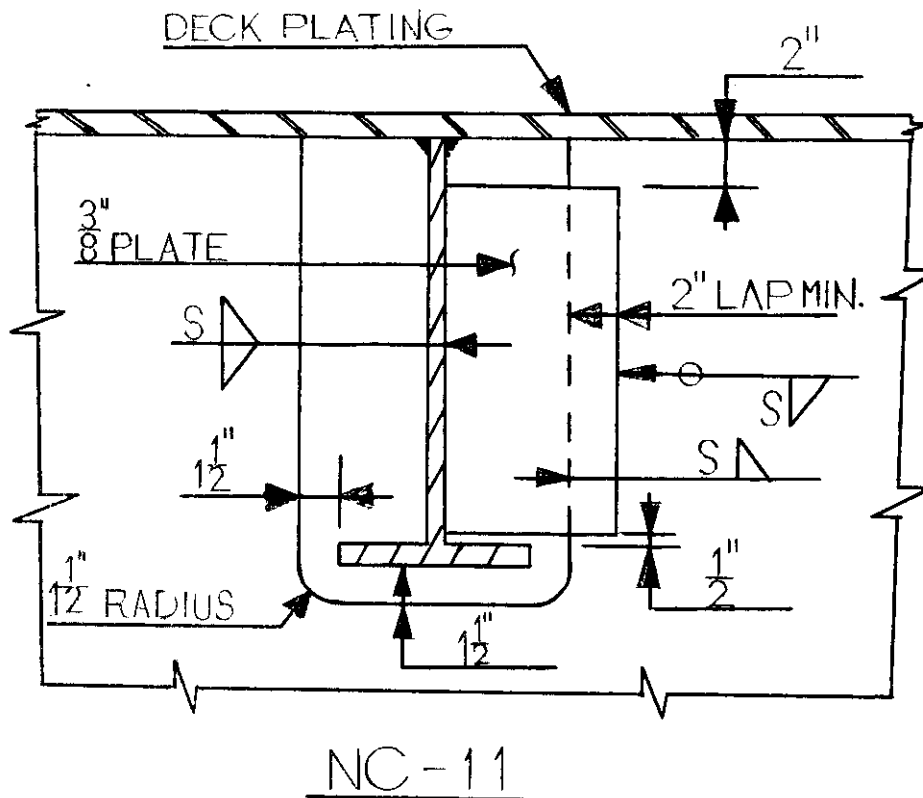
NC-11

Detail Type: STRUCTURAL INTERSECTION (NON-TIGHT LAPPED COLLAR)

Comments: This detail is used by Shipyard "Y" on ship type "J" for collaring rolled or fabricated Tee sections penetrating non-tight structure. This detail provides no flange support or area replacement. To facilitate welding the corners should be radiused.

SAME THICKNESS

1" TO 2"

OPTIONAL SNIPE

5T

S

S

1"
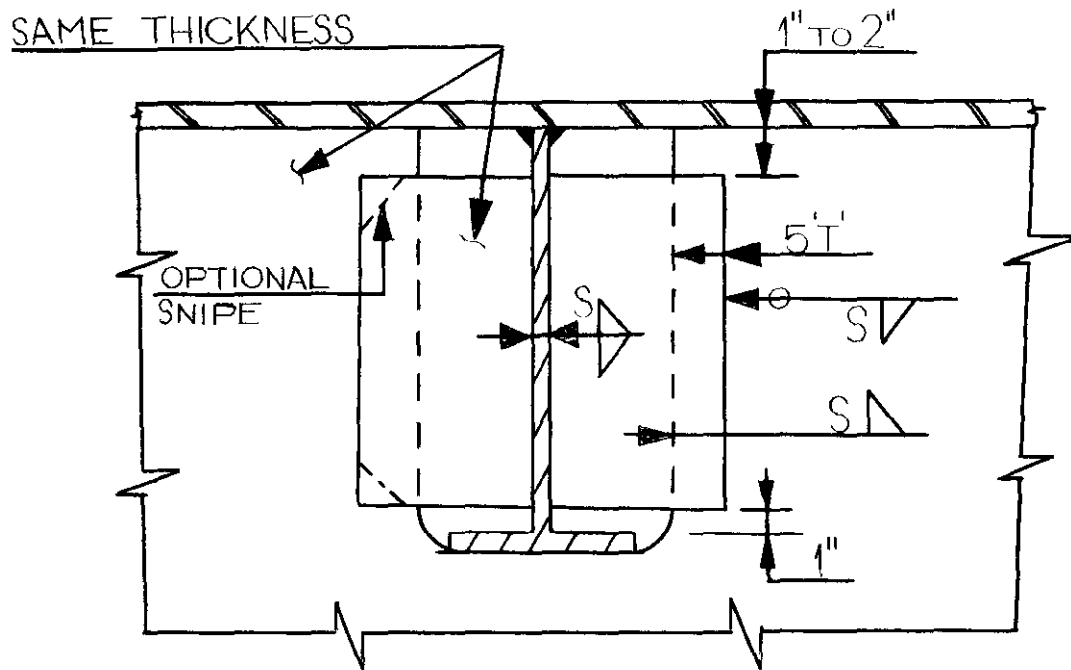
FOR CUT DETAILS SEE CC-10

NC - 12

Detail Type: STRUCTURAL INTERSECTION (NON-TIGHT LAPPED COLLAR)

Comments: This detail is used by Shipyards "U", "W" and "Z" on ship types
"A", "C", "D", "G" and "K" for collaring rolled or fabricated
Tee sections penetrating non-tight structure. To facilitate
welding the collar plate should have radiused corners. Provides
flange support and partial web area replacement.

Detail Count Ship Type "A":   70

Manhours Required to Complete Typical Detail: 2.6

Typical Scantlings: 18-13/16" x 1/2"-12-1/2" x 3/4" Tee penetrating 5/8" Plate.

3-49
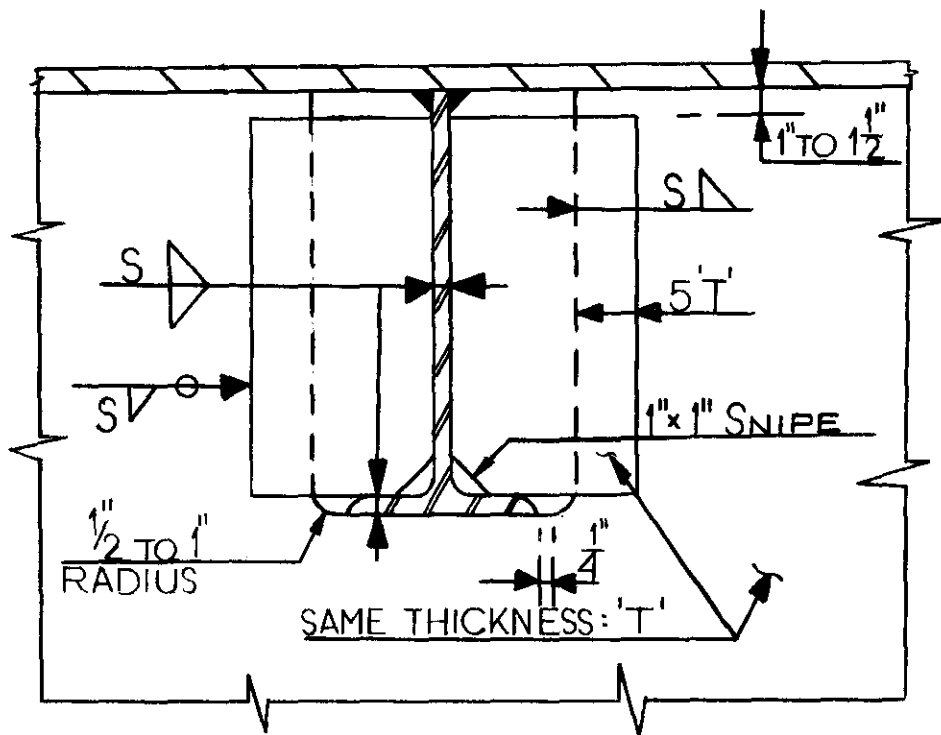
$$\underline{NC - 13}$$

Detail Type: STRUCTURAL INTERSECTION (NON-TIGHT LAPPED COLLAR)

Comments: This detail is used by Shipyard "U" on ship types "A" and "C" for collaring rolled or fabricated Tee sections penetrating non-tight structure. For other comments see NC-12.

SNIPE $1\frac{1}{2}" \times 1\frac{1}{2}"$

DECK PLATING

$30°$

$O"$ TO $1"$

$1\frac{1}{2}"$ RADIUS

$5'T'$

$\frac{1}{2}"$ TO $1\frac{1}{2}"$

$\frac{1}{2}"$ TO $1\frac{1}{2}"$ RADIUS

PLATE THICKNESS: 'T'

NC-14
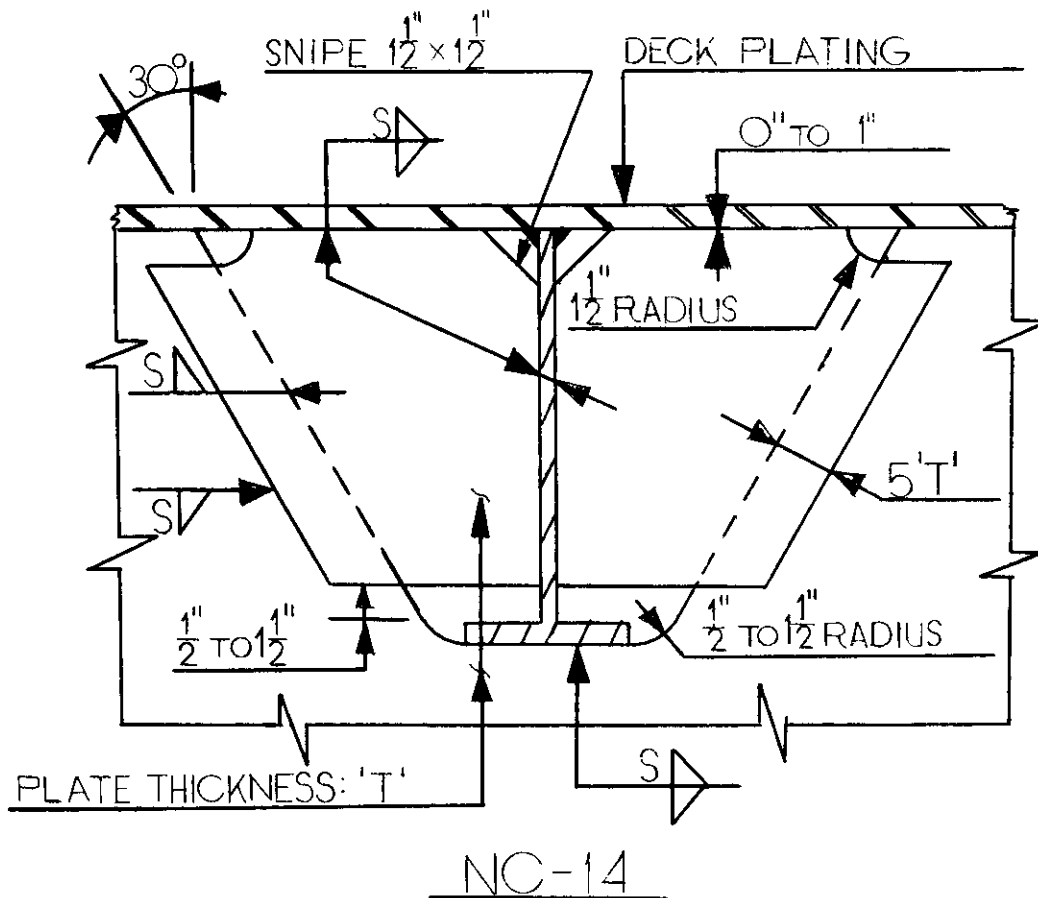
Detail Type: STRUCTURAL INTERSECTION (NON-TIGHT LAPPED COLLAR)

Comments: This detail is common to Navy ships and is included in the standard details library of the CASDOS program. To facilitate fabrication of collar plates they should be modified similar to MTC-1.
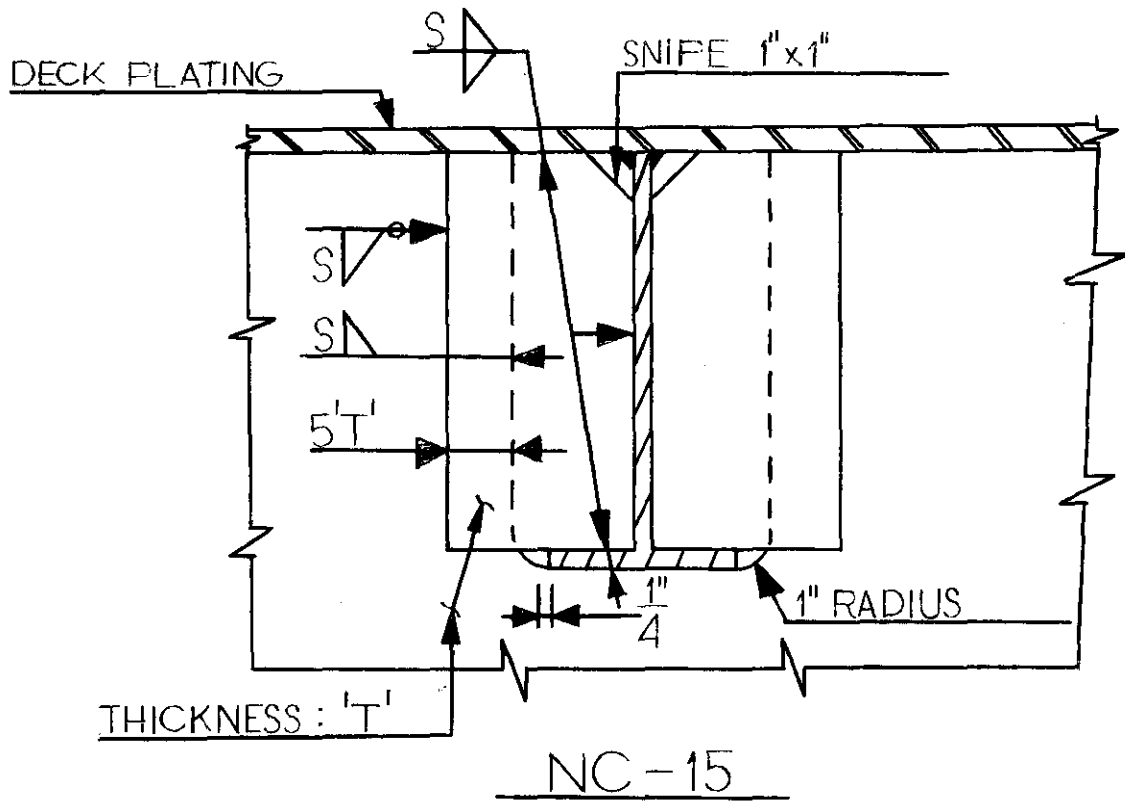
DECK PLATING

S

SNIFE 1"x1"
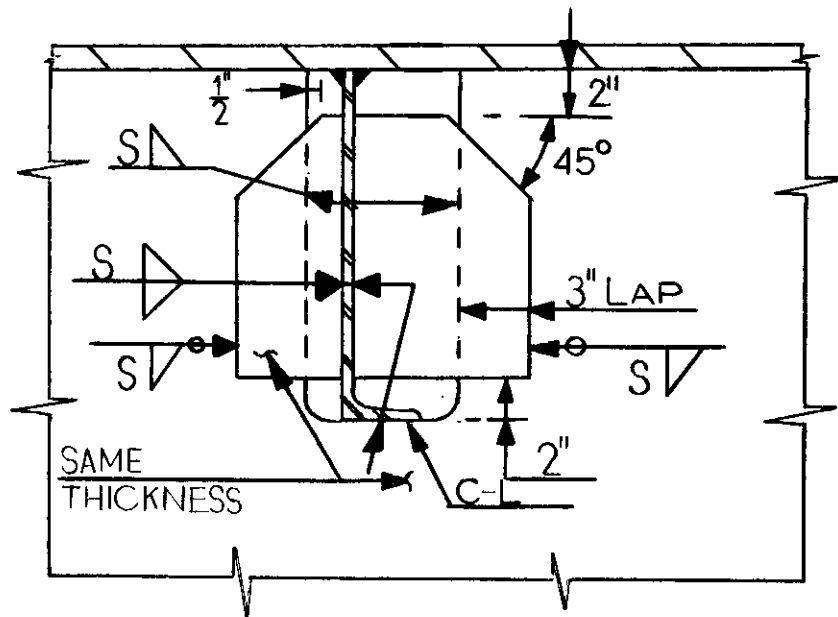
S

S

5'T'

1"
4

1" RADIUS

THICKNESS : 'T'

NC-15

Detail Type: STRUCTURAL INTERSECTION (NON-TIGHT LAPPED COLLAR)

Comments: This detail is used by Shipyard "U" on ship types "A" and "D" for collaring rolled or fabricated Tee sections penetrating non-tight structure. This detail is used when the girder is carrying a large lateral load and transfer of shear stress is desired. To facilitate welding this detail should be modified similar to MTC-1. Cutting the collar plate 1/16" undersize will facilitate fit-up.
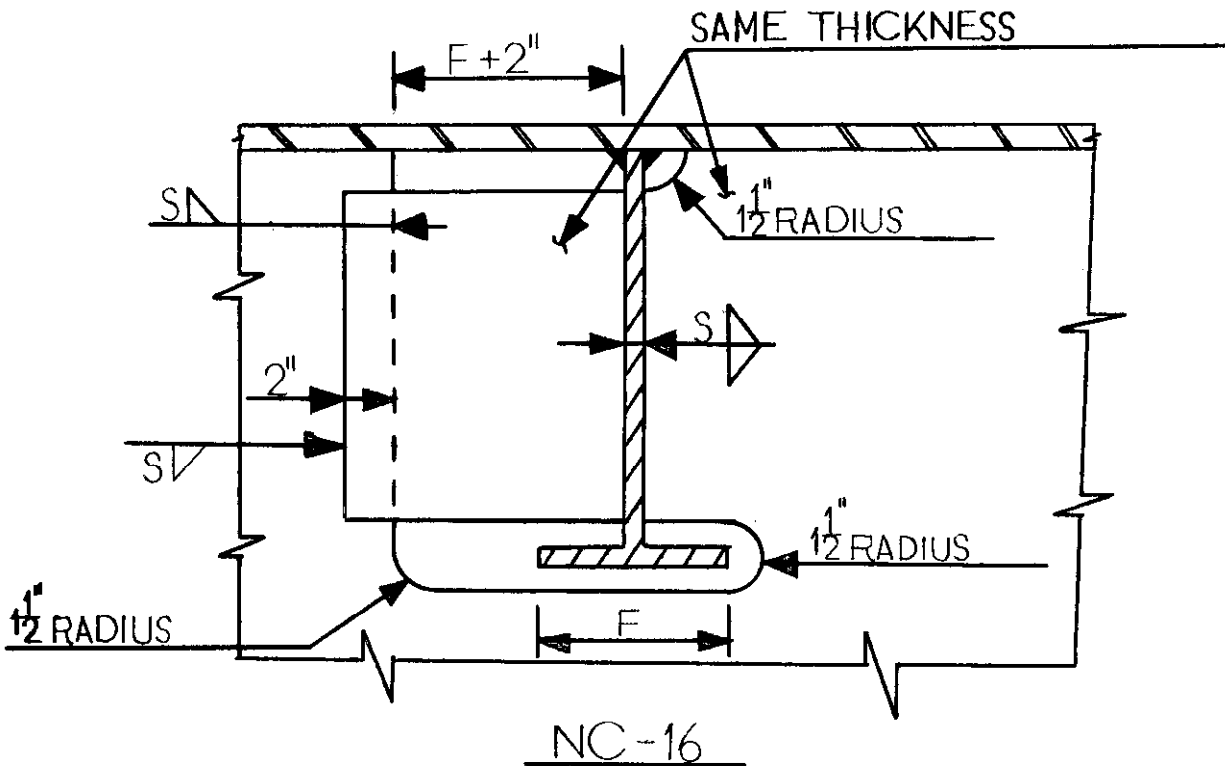
SAME THICKNESS

F+2"

S

2"

S

$1\frac{1}{2}$"RADIUS
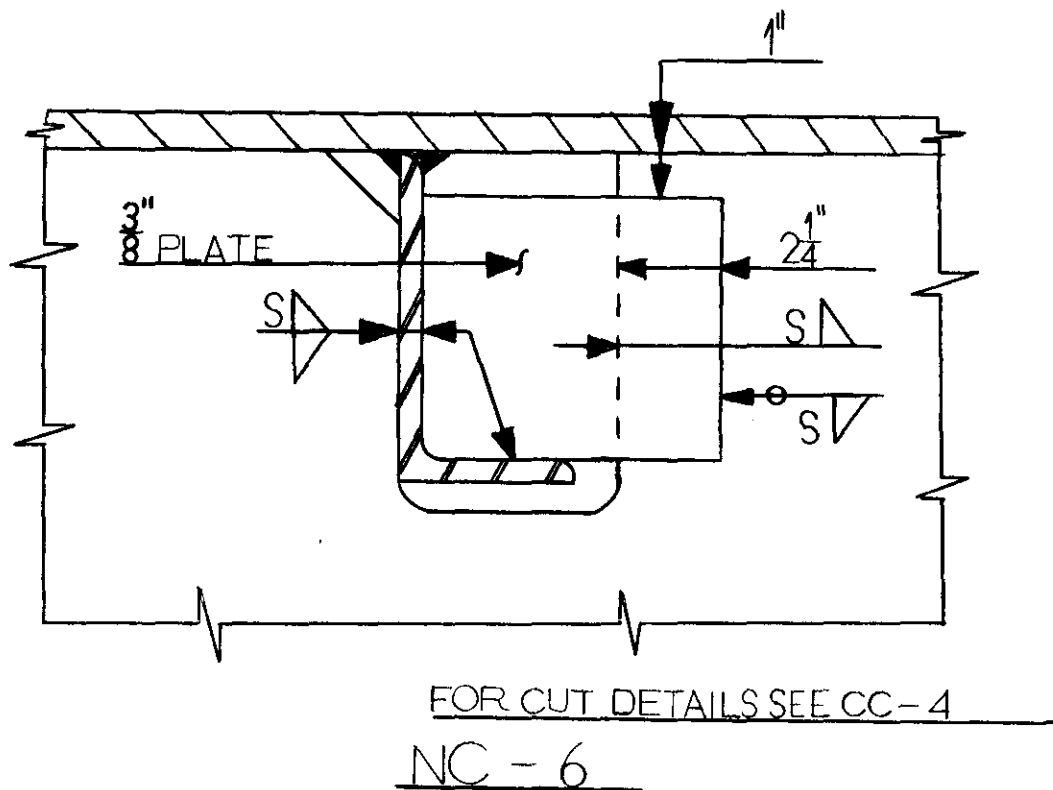
S

$1\frac{1}{2}$RADIUS

$1\frac{1}{2}$ RADIUS

$1\frac{1}{2}$ RADIUS

F

NC-16

Detail Type: STRUCTURAL INTERSECTION (NON-TIGHT LAPPED COLLAR)

Comments: This detail is used Shipyard "Y" on ship type "J" for collaring rolled or fabricated Tee sections penetrating non-tight structure. To facilitate welding, the corners of collar plate should be radiused. This detail does not provide flange support. This is a good detail that reduces welding, material handling and stress concentrations. It does require lateral as well as vertical movement of components to be assembled.

$1\frac{1}{2}$" RADIUS

$\frac{1}{2}$"

$1\frac{1}{2}$"

$1\frac{1}{2}$"

SN

2" LAP MIN.

SV

SNIPE $1\frac{1}{2}$" X $1\frac{1}{2}$"

SN

S

1"

SV

SN

6"

SHELL PLATING
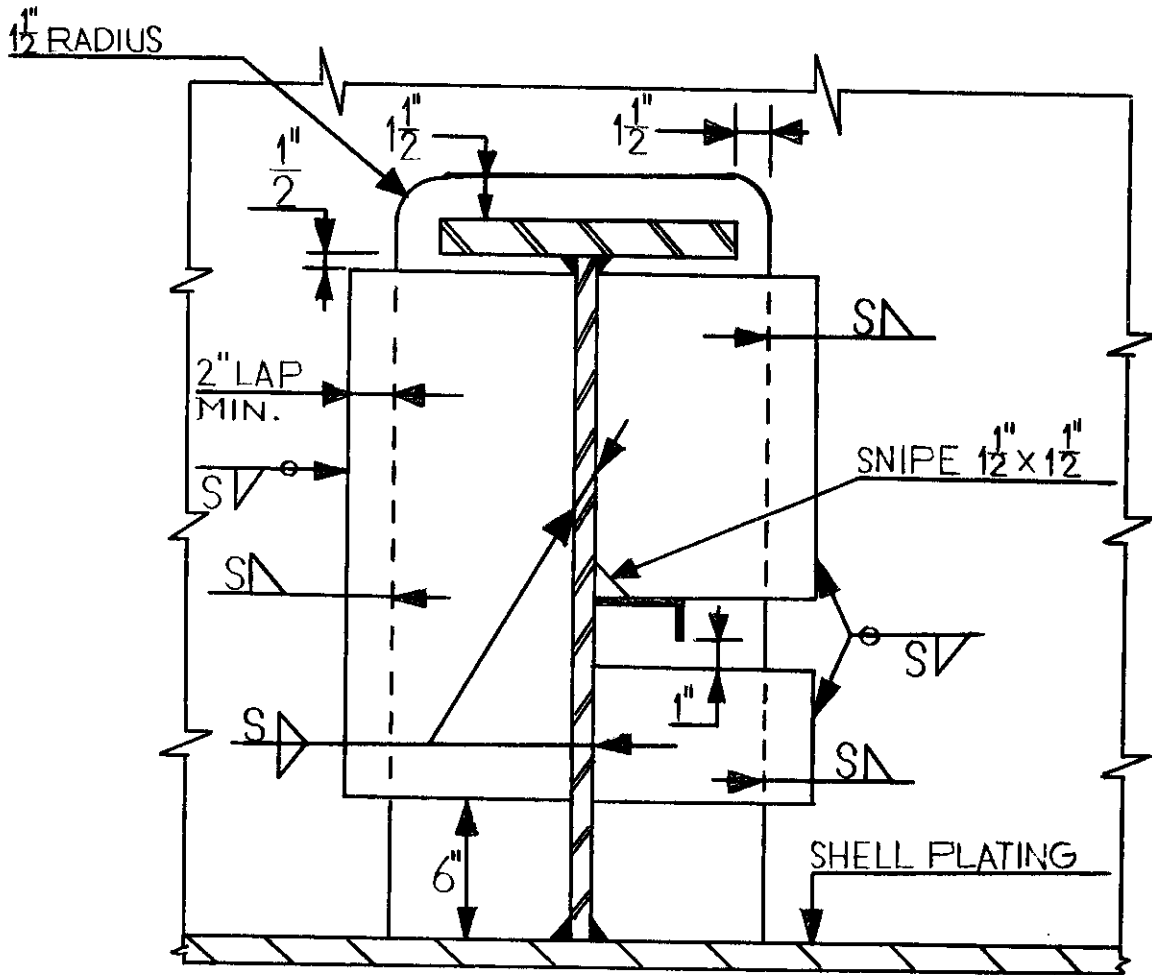
NC-17

Detail Type: STRUCTURAL INTERSECTION

Comments: This detail is used by Shipyard "Y" exclusively on single bottom ships where center and side keelsons penetrate non-tight floors and bulkheads. The thickness of the collar plate is sized according to load on member. To improve shear flow, the two right side clips should be a single clip with a cutout for the web stiffener. To facilitate welding, the lapped corners of the collar plate should be radiused.

3-54

CVK OR LONG'L
BULKHEAD OR
SHELL LONG'L

1½" RADIUS

3"

3"

SEAL WELD TO BE
CARRIED AROUND
EDGE OF CUT.
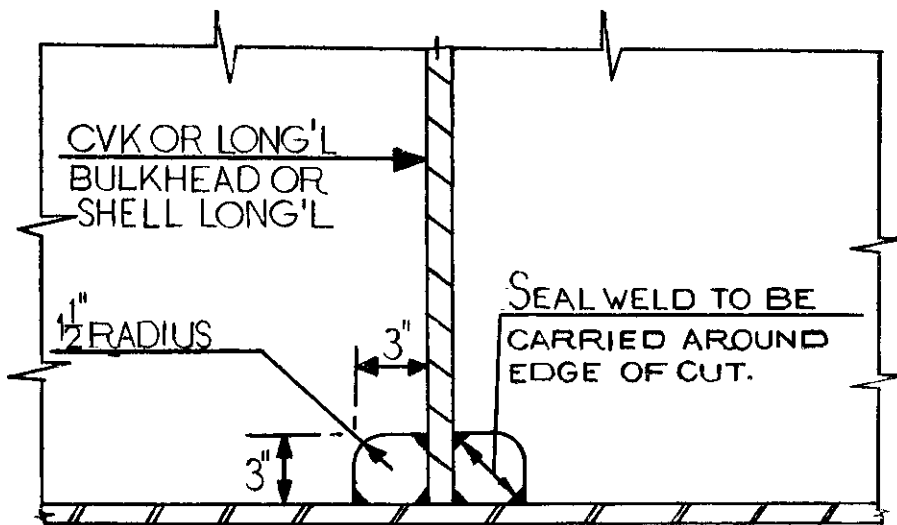
MH - 1

Detail Type: MISCELLANEOUS CUTOUT

Comments: This detail is used by Shipyard "U" on ship type "A" as
drain and limber hole at the shell in the midship area. The
purpose of these cutouts is to provide access to the
continuous weld and to eliminate corners in wet spaces that
could trap corrosive liquids and lead to a weakening of the
section.
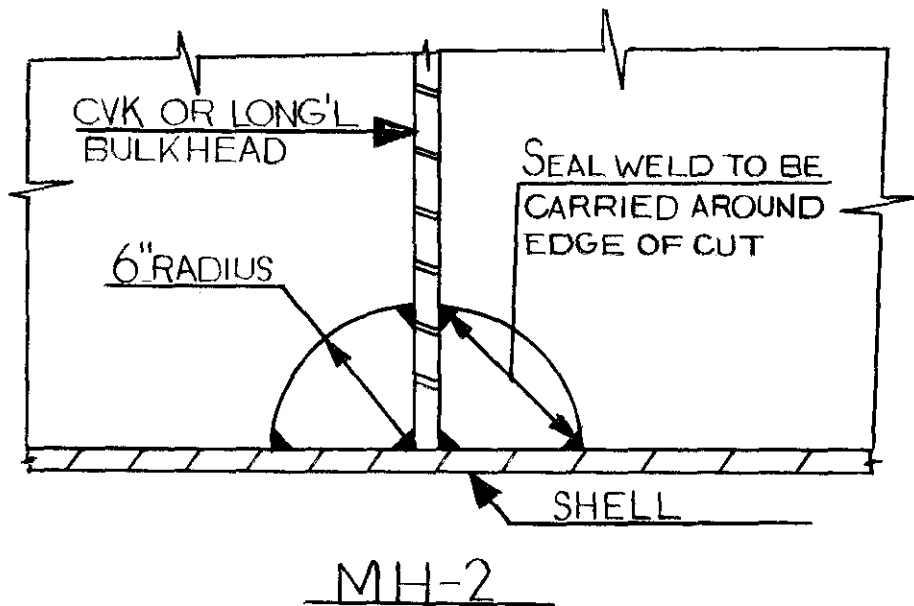
CVK OR LONG'L BULKHEAD

6" RADIUS

SEAL WELD TO BE CARRIED AROUND EDGE OF CUT

SHELL

MH-2

Detail Type: MISCELLANEOUS CUTOUT

Comments: This detail is used by Shipyards "U" and "X" on ship types "B", "C", "D", "E" and "H" as drain and limber holes at the shell. For additional comments see MH-1.

HOLES TO BE SMOOTH

CONTINUOUS MEMBER

$1\frac{1}{2}'' - 4''$

$2''$ TO $4''$

$\frac{5''}{8}$ TO $1''$
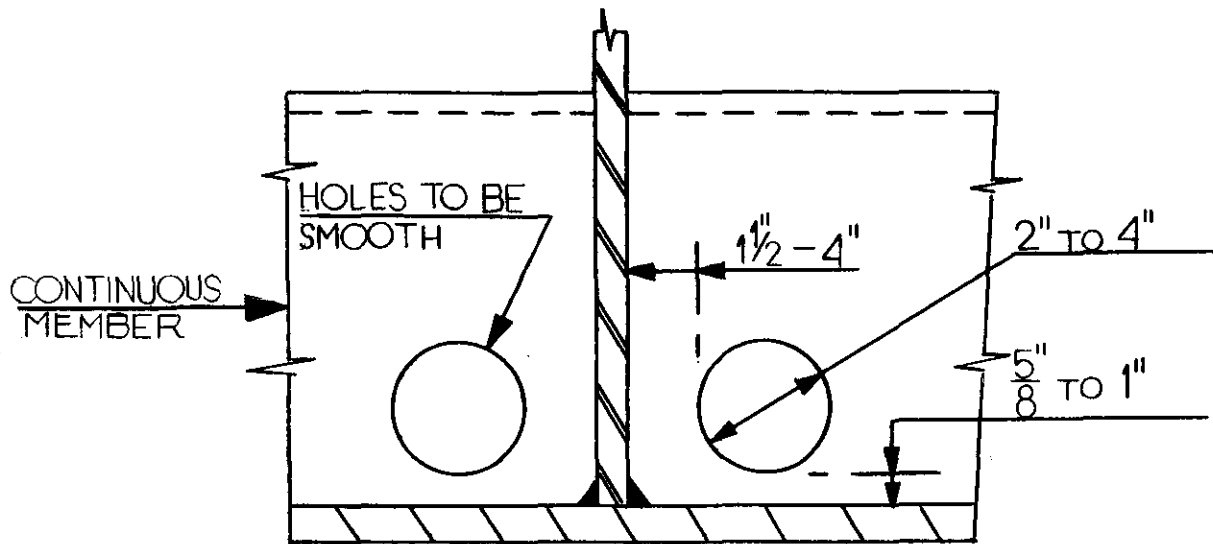
MH - 3

Detail Type: MISCELLANEOUS CUTOUT

Comments: This detail is used by Shipyard "U" on ship types "A" and "B" as
drain holes in lieu of MH-1 or MH-2. The diameter of the drain
hole is a function of member depth. Up to a depth of 12" the
diameter of the hole is 1/4 of the depth and above 12" the diameter
is constant at 4". If this detail is used and the continuous member
is penetrating a tight boundary, a welded oil or water stop is
required on one side of the structure being pierced. If used in
longitudinal members, sectional area lost should be considered.

Detail Count Ship Type "B":   100

Manhours Required to Complete Typical Detail: 0.3

Typical Scantlings: 3" Diameter, 5/8" Plate.

CONTINUOUS MEMBER

BHD OR WEB

$1\frac{1}{2}$" MIN.

$1\frac{1}{2}$" TO 3"
RADIUS

WRAP WELD
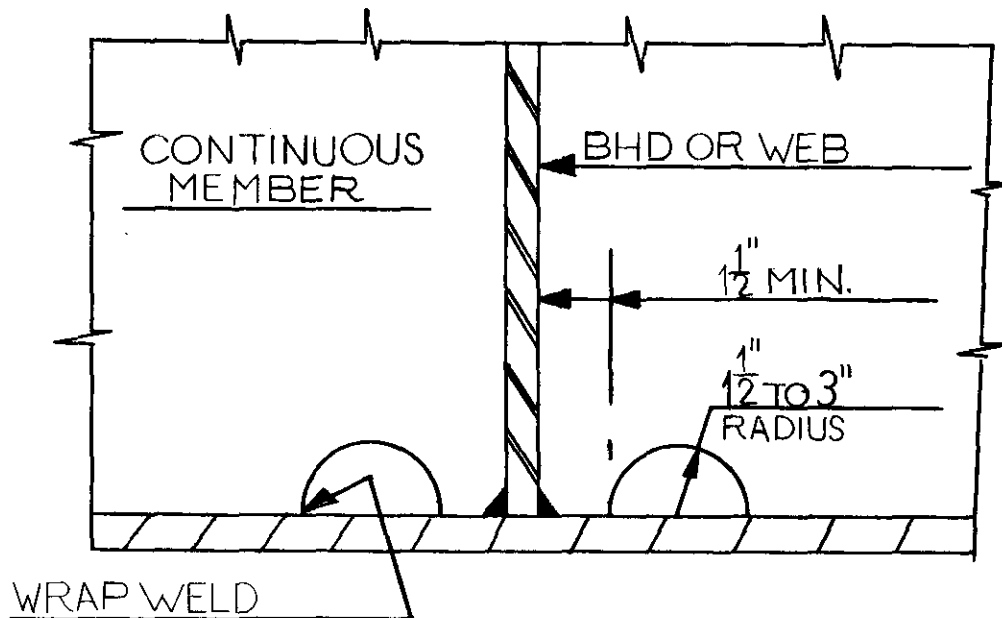
MH-4

Detail Type: MISCELLANEOUS CUTOUT

Comments: This detail is used by Shipyards "U", "W", "Y" and "Z" on ship types "A", "B", "C", "D", "E", "G", "J" and "K", as a drain or air hole in high or low corners in tank. This detail also acts as a water or oil stop adjacent to tight structure.when the weld is wrapped around the edges. The weld is often wrapped to minimize corrosion between plate and web edge in non-tight structure. The radius of the cutout is a function of member depth: for depth 9" or less, R = 1-1/2" to 2"; for depth greater than 9", R = 3".

Detail Count: Ship Type "A" = 220; Ship Type "B" = 5700

Manhours Required to Complete Typical Detail: 0.3

Typical Scantlings: 3" Radius, 5/8" Plate

3-58

$\frac{1}{2}$" TO 1$\frac{1}{2}$"

1" TO 3" DIAMETER

1$\frac{1}{2}$" TO 4"

D

NON-TIGHT STRUCTURE
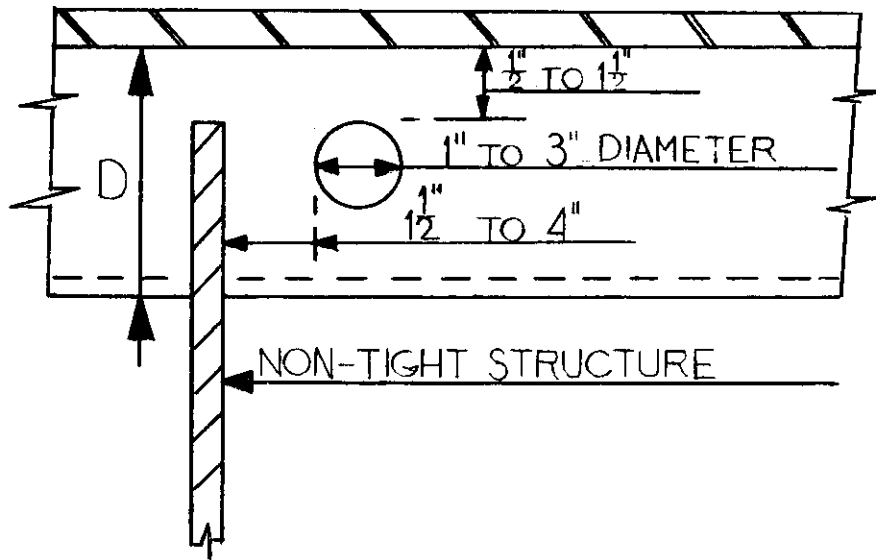
MH - 5

Detail Type: MISCELLANEOUS CUTOUT

Comments: This detail is used by Shipyards "U", "W" and "X" on ship types "A", "B", "C", "E", "G" and "H" as a typical air hole drilled in high corner in way of tight structure. Use in longitudinal stringers or stiffeners or in highly stressed areas. The size of the hole is based on the following rationale: For areas with special coatings, if "D" is less than 9", use 2" diameter; if "D" = 9" and over use 3" diameter. Elsewhere use 1" diameter.

The detail seems superfluous in view of the fact that water or oil stops such as MH-4 are required and will also function as air vents. Furthermore "high-corner" is not adjacent to non-tight structure.

$1\frac{1}{2}''$ RADIUS

3" MIN.

NON-TIGHT STRUCTURE
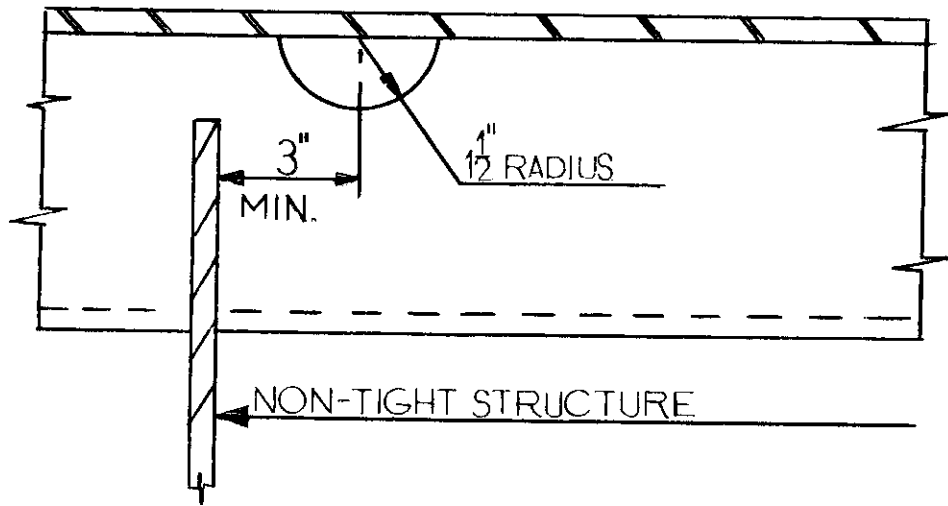
MH - 6

Detail Type: MISCELLANEOUS CUTOUT

Comments: This detail is used by Shipyards "U" and "Z" on ship types "D"
                 and "K" as air holes in high corners in way of non-tight structure.
                 Hole should be cut with a template, or by the ABM to insure no
                 ragged edges. Detail should properly be adjacent to tight
                 boundary (high corner).
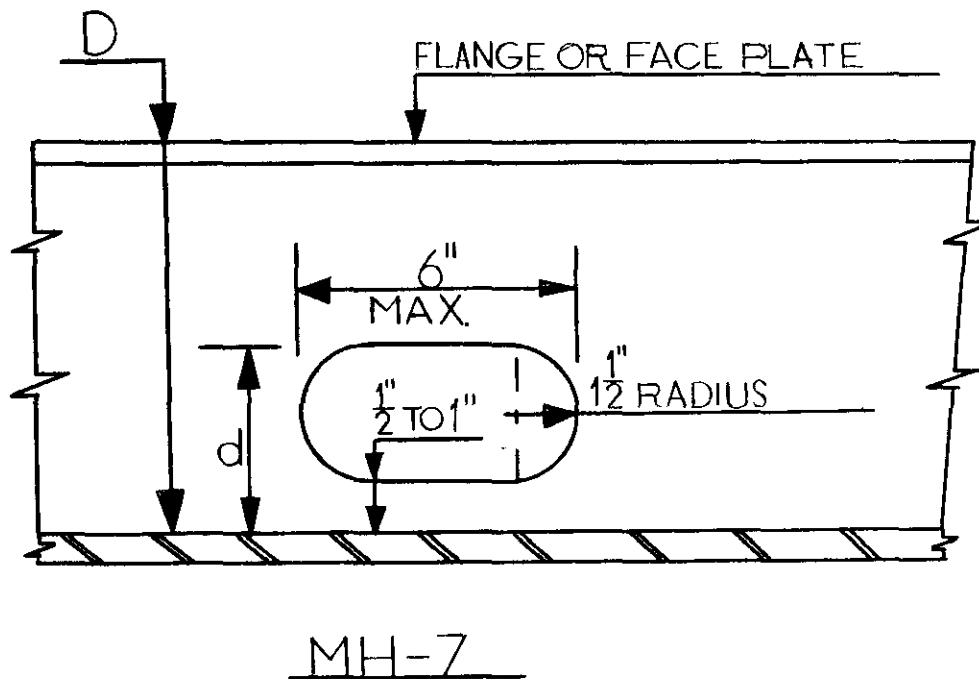
D

FLANGE OR FACE PLATE

6"
MAX.

$1\frac{1}{2}$" RADIUS

$\frac{1}{2}$" TO 1"

d

MH-7

Detail Type: MISCELLANEOUS CUTOUT

Comments: This detail is used by Shipyards "U" and "Y" on ship types "A" and
               "J" as an alternate drain hole in inner bottom structure. This
               detail cannot be used if d/D exceeds 1/3. Holes should be machine
               cut or burned from a template. Provides good drainage for
               limited loss of web depth.
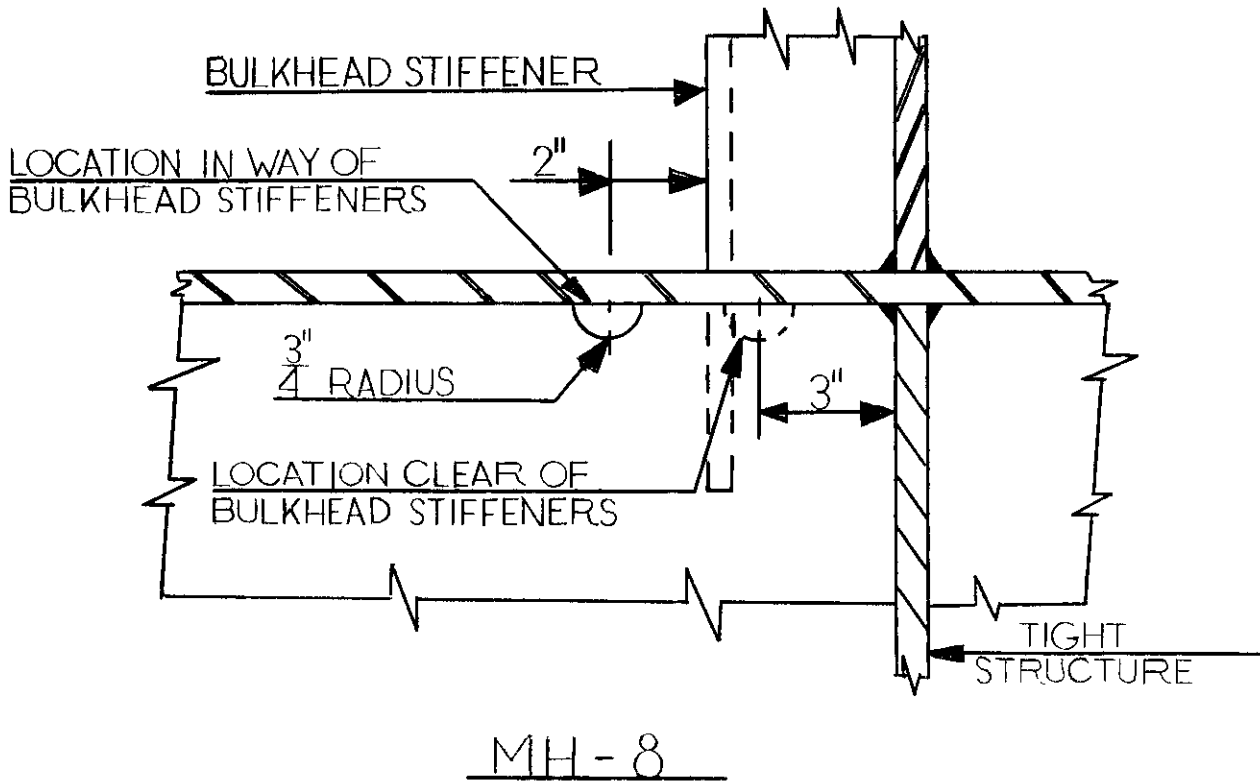
BULKHEAD STIFFENER

LOCATION IN WAY OF
BULKHEAD STIFFENERS

2"

$\frac{3}{4}$" RADIUS

3"

LOCATION CLEAR OF
BULKHEAD STIFFENERS

TIGHT
STRUCTURE

MH-8

Detail Type: MISCELLANEOUS CUTOUT

Comments: This detail is used by Shipyards "U", "W" and "X" on ship types
"D", "E", "G" and "H" as air holes in non-tight structure below
bulkhead stiffeners.

3-62

PATCH TO BE USED
WHEN CLEARANCE CUT
RADIUS ≥ 2"

BULKHEAD, LONGITUDINAL OR
TRANSVERSE MEMBER

1"

S

1"

S

S

S
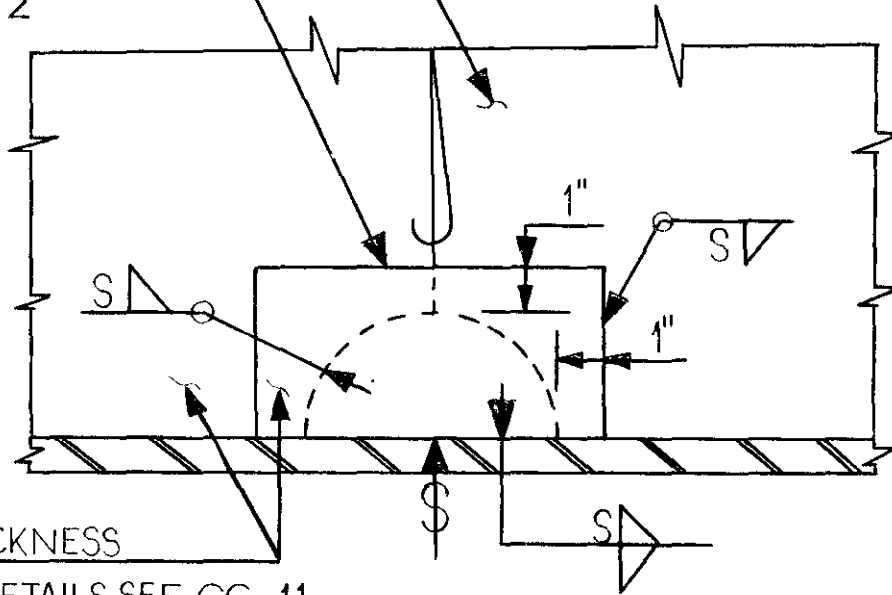
SAME THICKNESS

FOR CUT DETAILS SEE CC-11

TP-1

Detail Type: PATCH

Comments: This detail is used by Shipyards "U", "V", "W",
              "X" and "Z" on ship types "A", "B", "C", "E", "F", "G", "H"
              and "K", to patch clearance cut CC-11 in way of airtight, oil-
              tight or watertight structure, or to repair ragged cuts in non-
              tight structure. If clearance cut is in horizontal web, fit patch
              on top side. To facilitate welding, the corners should be radiused.
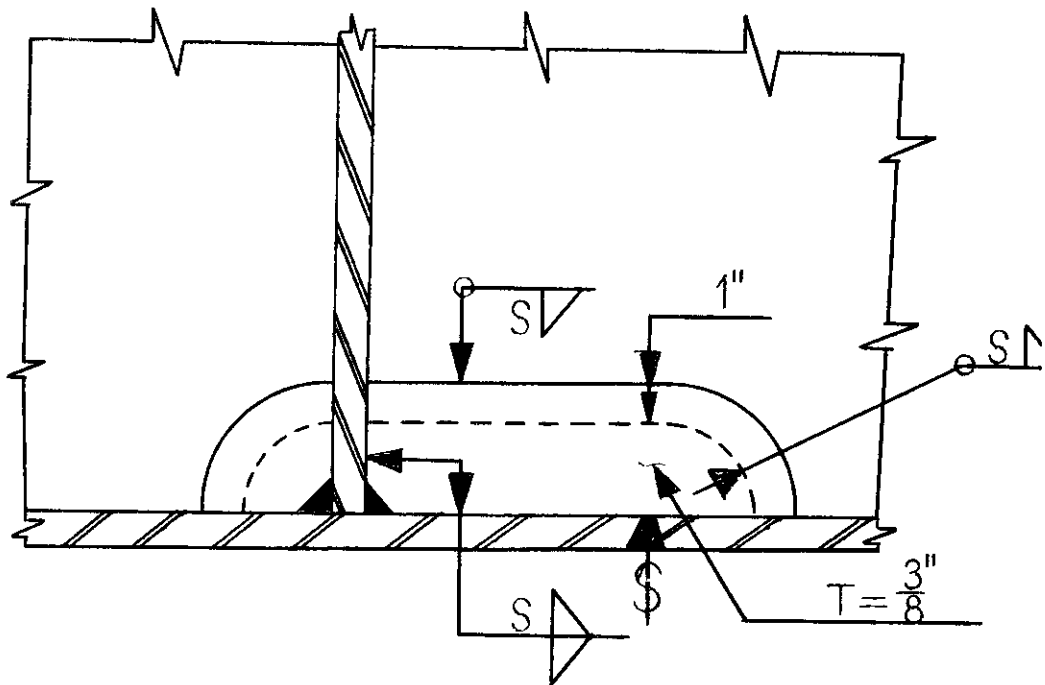
FOR CUT DETAILS SEE CC-13

TP-2

Detail Type: PATCH

Comments: This detail is used by Shipyards "U" and "X" on ship
types "B" and "H", to patch clearance cut CC-13 in way of air-
tight, oiltight, or watertight framing members, and to repair
ragged cuts in non-tight structure.

1" 1" S S

THICKNESS : $T = \frac{3}{8}"$

S

FOR CUT DETAILS SEE CC -13
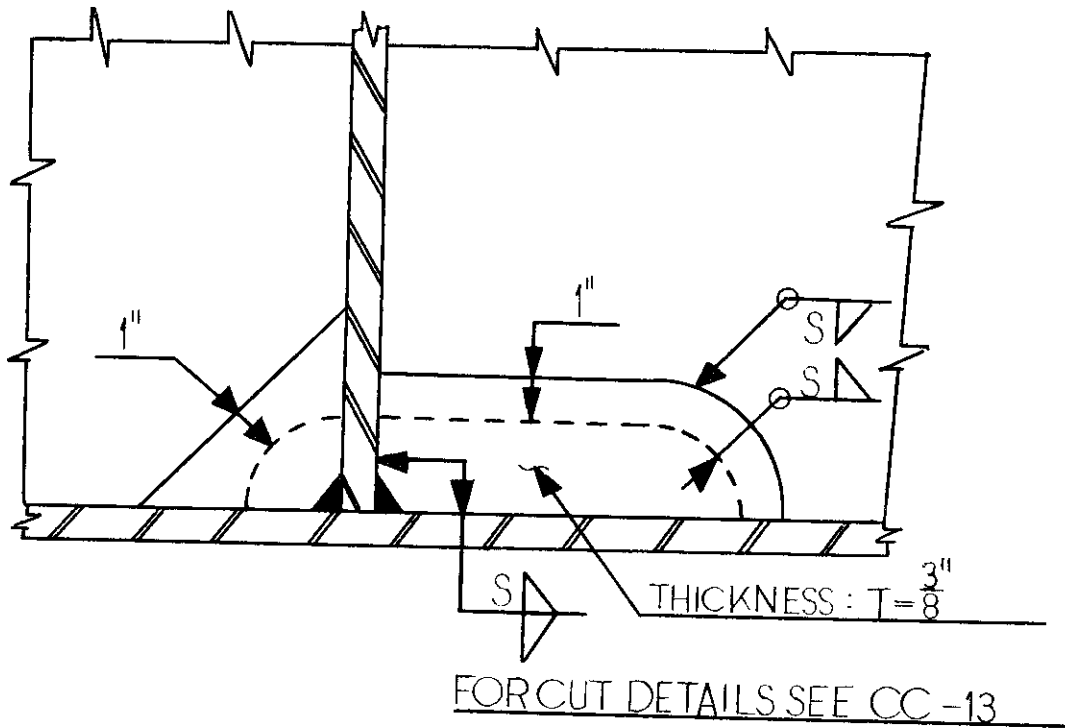
TP - 3

Detail Type: PATCH

Comments: This detail is used by Shipyards "U" and "W" and on
types "A" and "G", to patch clearance cut CC-13 in way of air-
tight, oiltight, or watertight in framing members, and to repair
ragged edges. No significant difference from TC-2.

PATCH TO BE USED WHEN
SNIPE ≥ 2"×2

THICKNESS: $T = \frac{3}{8}$"

FOR SNIPE DETAILS SEE S-4

TP-4
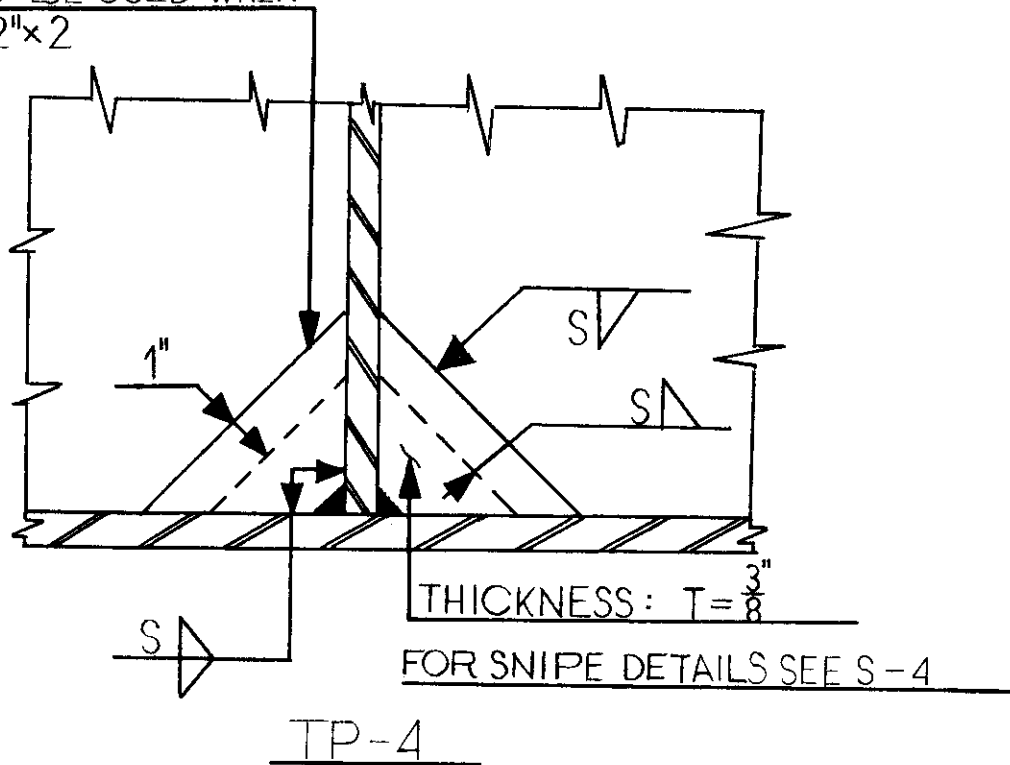
Detail Type: PATCH

Comments: This detail is used by Shipyards "U", "V", "W"
                and "Z" on ship types "A", "C", "E", "F", "G" and "K" to patch
                snipes in framing members at miscellaneous airtight, oiltight, or
                watertight structure. Used in lieu of S-3.

$\frac{3}{8}"$ PLATE

1"

D

d

S

S

S

S

FOR CUT DETAILS SEE CC-14

TP-5
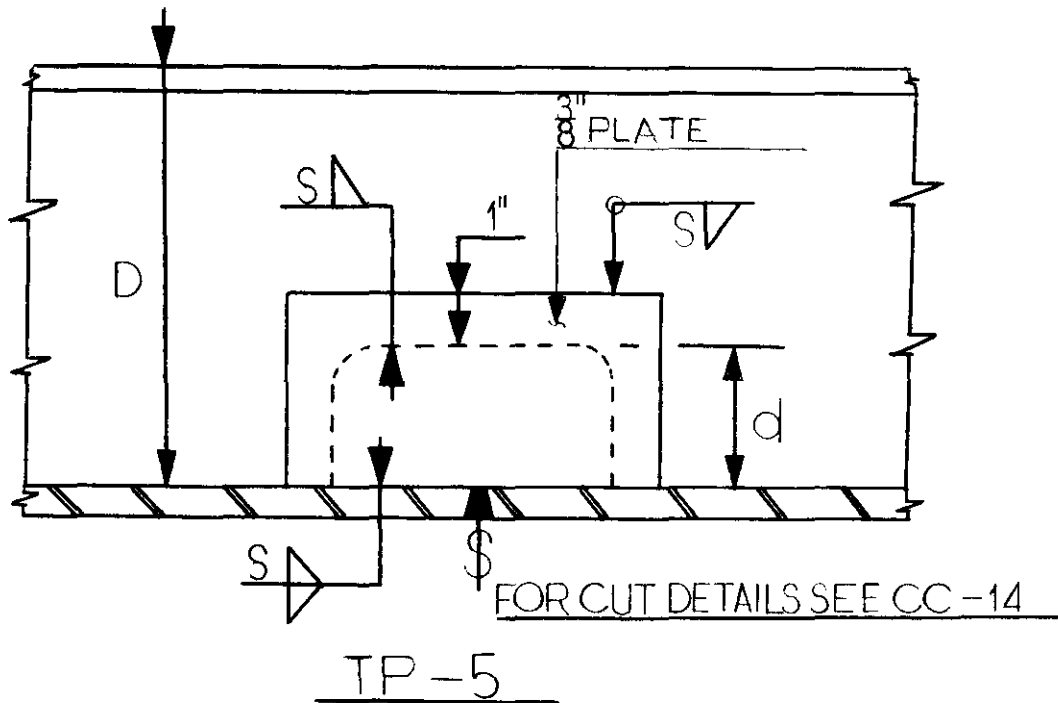
Detail Type: PATCH

Comments: This detail is used by Shipyard "U" on ship types "A" and
              "B", to patch clearance cut CC-14 in way of airtight, oiltight,
              or watertight structure, or when depth of clearance hole, "d"
              is greater than permissible cut, in non-tight structure.

WF SECTION

S ▷

CHOCK

CHOCK
4 Pcs: THICKNESS:
SAME AS FLANGE
OF STANCHION

FILL WITH WELD

WF SECTION
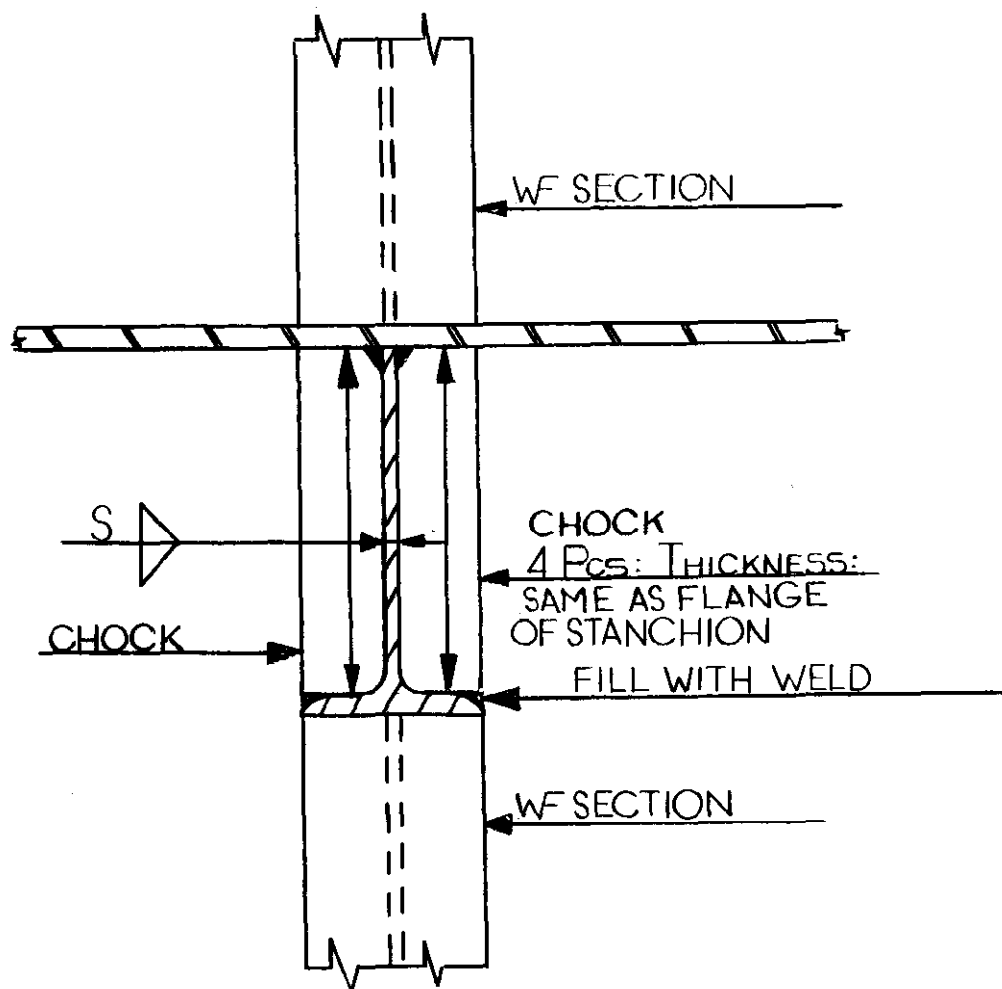
SS - 1

Detail Type: STANCHION END CONNECTION

Comments: This detail is used by Shipyards "V", "Y" and "Z" on ship types
"F", "J" and "K" to insure structural continuity between wide
flange stanchions in the machinery space. No snipes are allowed
in the chocks. Thickness of chock to be equal to the thickness of
the greater flange. Chocks may be sloped to align stanchion
flanges.
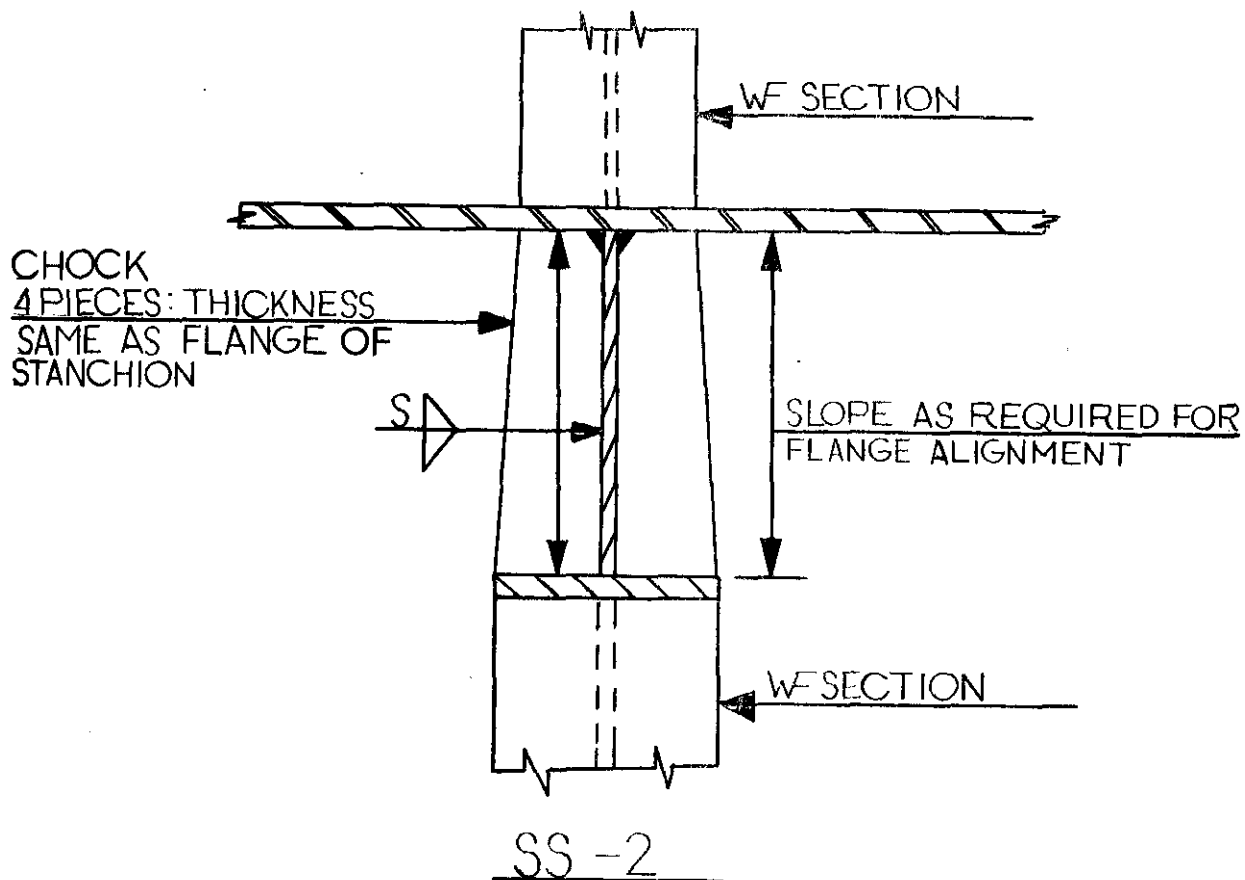
WF SECTION

CHOCK
4 PIECES: THICKNESS
SAME AS FLANGE OF
STANCHION

S

SLOPE AS REQUIRED FOR
FLANGE ALIGNMENT

WF SECTION

SS-2

Detail Type: STANCHION END CONNECTION

Comments: This detail is used by Shipyards "U" and "V" on ship types "A",
"B" and "F" to insure structural continuity between wide flange
stanchions in the machinery space. No snipes are allowed in the
chocks. Thickness of chock to be equal to the thickness of the
greater flanges. Chocks are to be sloped to align stanchion
flanges.

Detail Count: Ship Type "A" = 30; Ship Type "B" = 170

Manhours Required to Complete Typical Detail: 12. 4

Typical Scantlings: 3/4" chocks from 12" to 8" wide flanges.
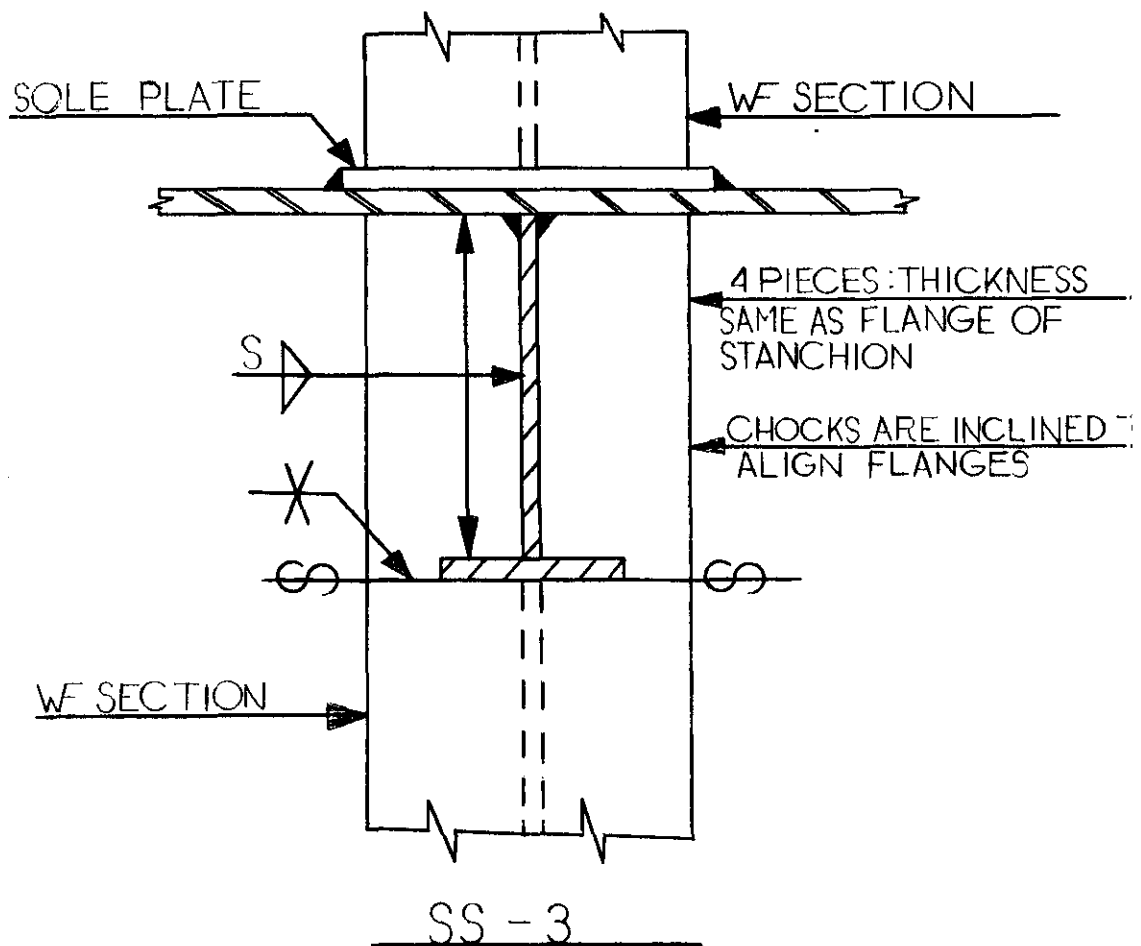
3-69

SOLE PLATE

WF SECTION

4 PIECES THICKNESS
SAME AS FLANGE OF
STANCHION

CHOCKS ARE INCLINED
ALIGN FLANGES

S

WF SECTION

SS - 3

Detail Type: STANCHION END CONNECTION

Comments: This detail is used by Shipyard "U" on ship type "A" to insure
structural continuity between wide flange stanchions in the lower
levels of the machinery space. For comments see SS-2.
Use of sole plate is limited to areas where deck plating is
thin, or where chocks may be slightly out of alignment.

Detail Count Ship Type "A":   50

Manhours Required to Complete Typical Detail: 12. 2

Typical Scantlings: 1" chock plate, 14" wide flange section.
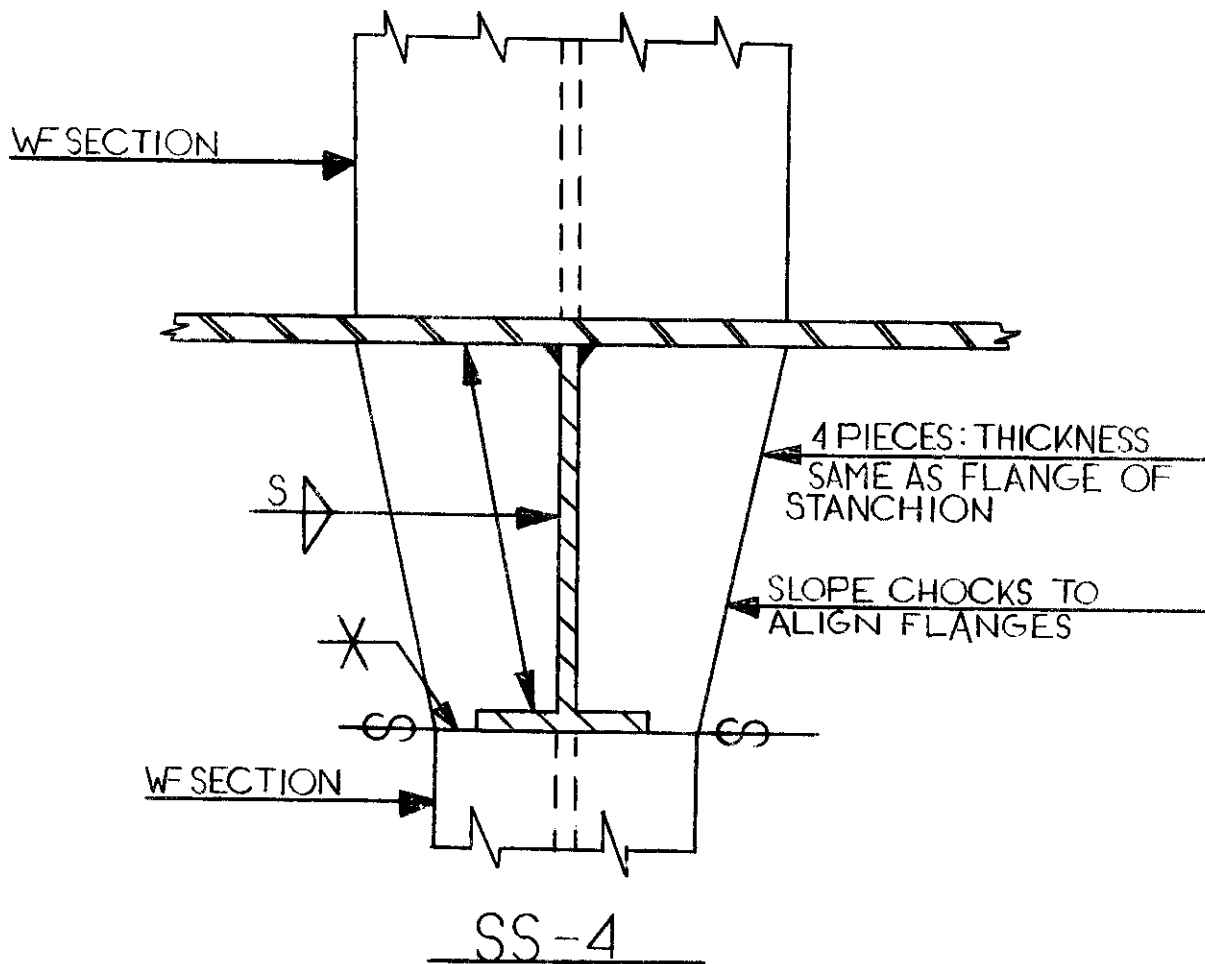
WF SECTION →

4 PIECES: THICKNESS
SAME AS FLANGE OF
STANCHION

S

SLOPE CHOCKS TO
ALIGN FLANGES

WF SECTION →

SS-4

Detail Type: STANCHION END CONNECTION

Comments: This detail is used by Shipyard "Z" on ship type "K" to insure structural continuity in areas of the machinery space. For additional comments see SS-2.
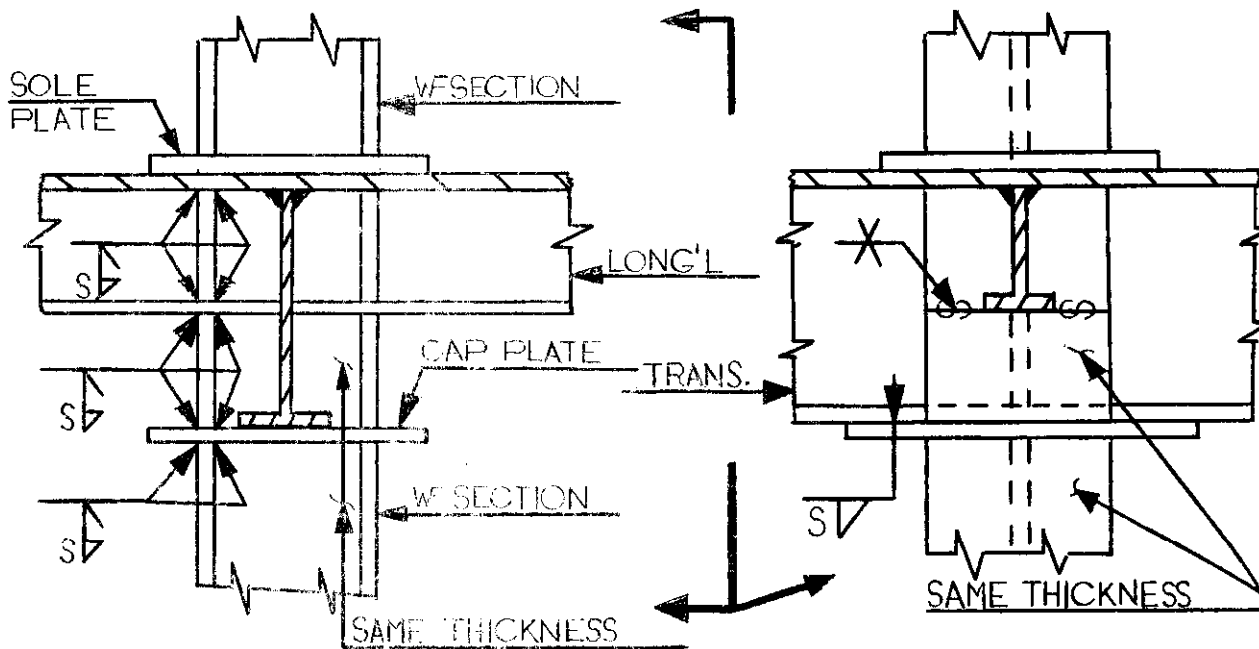
SS-5

Detail Type: STANCHION END CONNECTION

Comments: This detail is used by Shipyard "U" on ship type "D" for wide flange
stanchion end connection details.   No snipes are allowed in the
chock plates.   Thickness of chock plates are based on the stanchion
scantlings.   Weld accessibility is poor for this detail.   To ease
the problem, the flanges of the stanchions should be aligned with
the girder web.
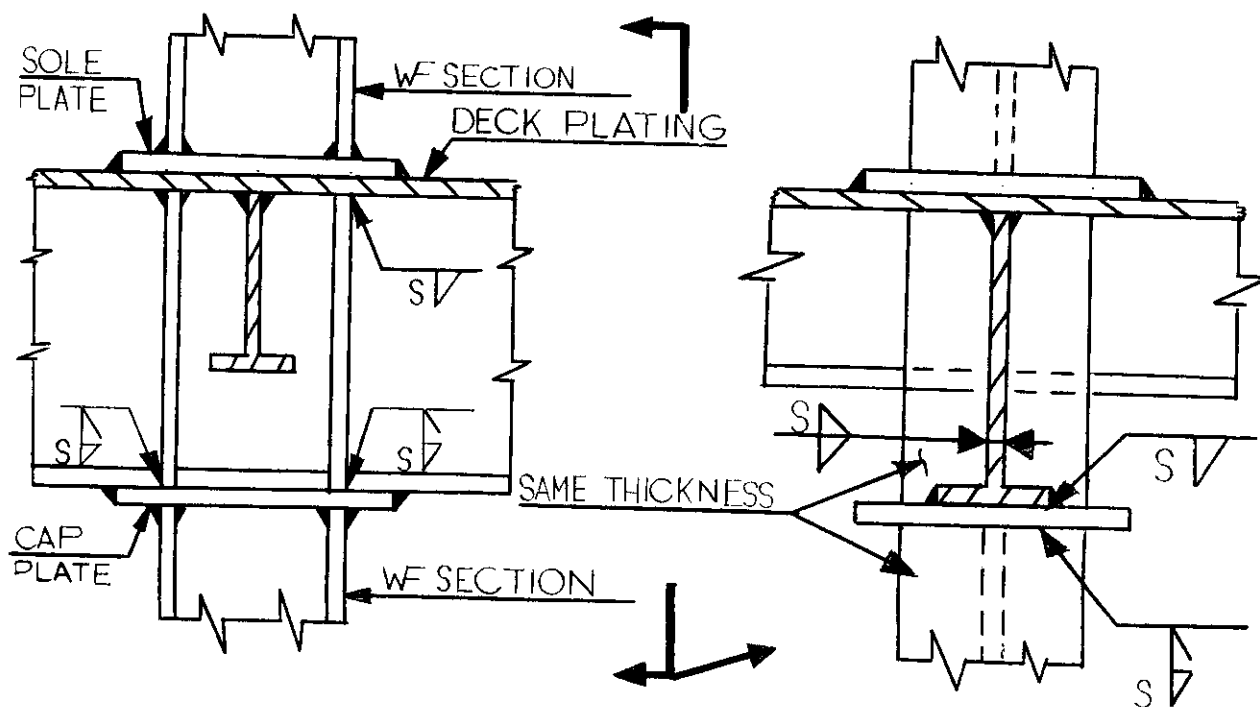
3-72

SOLE PLATE

W^F SECTION

DECK PLATING

S

S

S

SAME THICKNESS

S

S

CAP PLATE

W^F SECTION

S

SS-6

Detail Type: STANCHION END CONNECTION

Comments: This detail has the same characteristics as SS-5.

SOLE PLATE

W^F SECTION

DECK PLATING

S

S

S

SAME THICKNESS

S

S

CAP PLATE

W^F SECTION

S

SS-6

Detail Type: STANCHION END CONNECTION

Comments: This detail has the same characteristics as SS-5.

DECK PLATING

18"

1"

SAME THICKNESS

SAME THICKNESS

S

$1\frac{1}{2}$"

WF SECTION

$\frac{1}{2}$"

$\frac{1}{2}$" TO 1"

$\frac{1}{2}$"

30°

$1\frac{1}{2}$"

$1\frac{1}{2}$"

S

$\frac{1}{2}$" TO 1"

FOR COMMENTARY SEE
PG. 3-75

SS-7

3-74
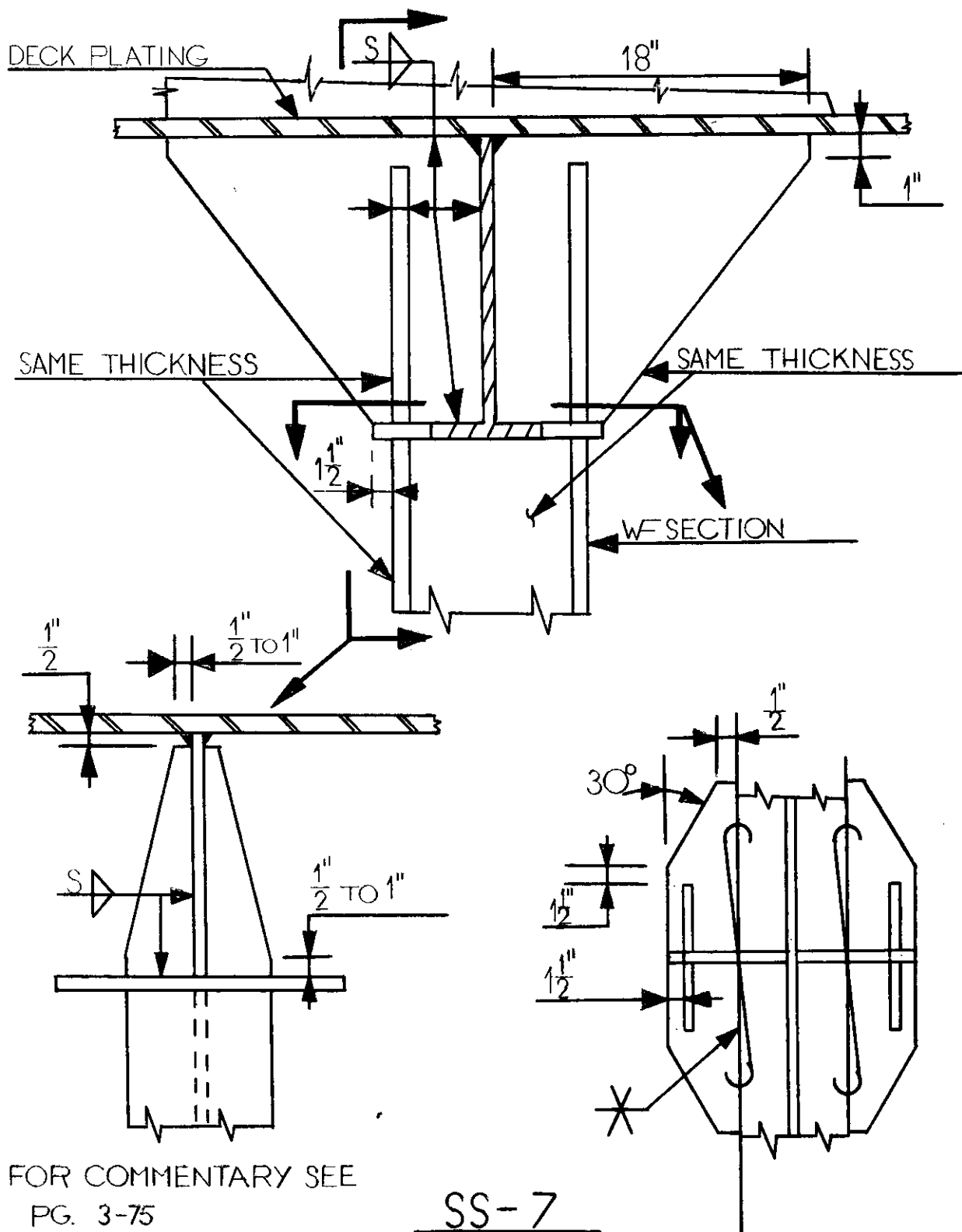
Detail Type: STANCHION END CONNECTION

Comments: This detail is used by Shipyard "U" on ship types "B" and "D"
for wide flange stanchion end connections under heavy equipment
foundations or under areas subject to high mobile loads. Used
only when supporting structure in line with the stanchion web.
For additional comments see SS-2 and SS-5.

Detail Count Ship Type "B":   100

Manhours Required to Complete Typical Detail: 18.0
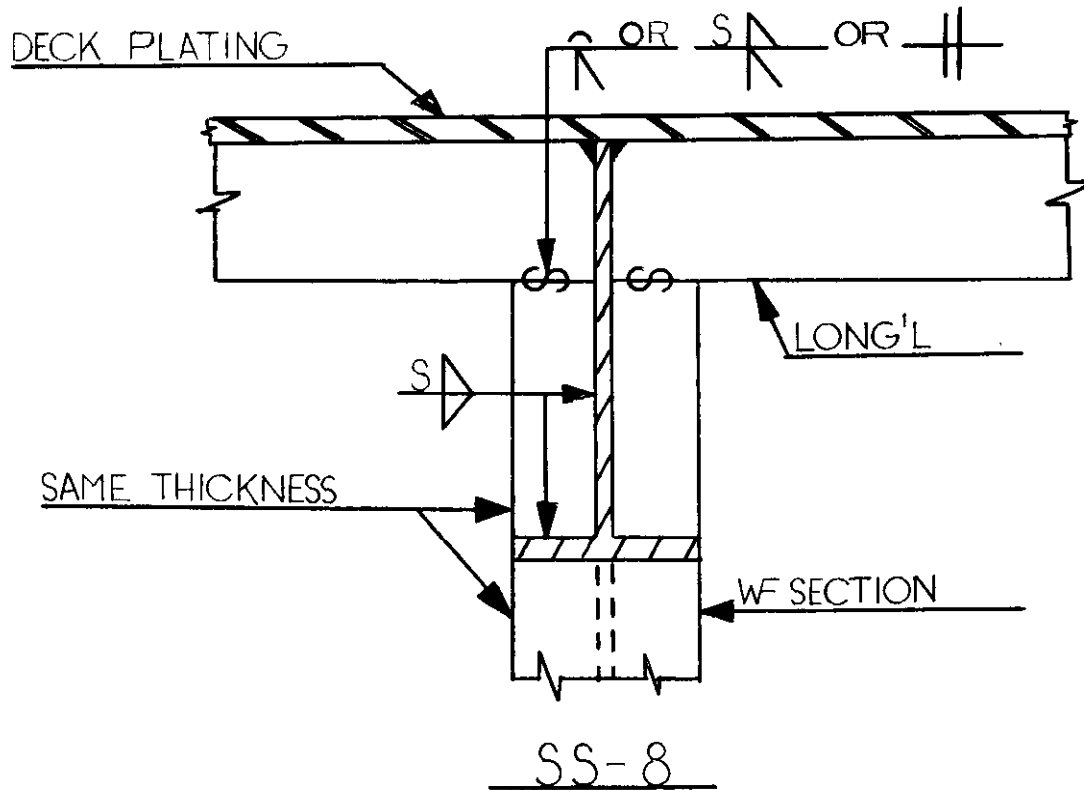
DECK PLATING

∧ OR S⋀ OR ─╫─

LONG'L

S▷

SAME THICKNESS

WF SECTION

SS-8

Detail Type: STANCHION END CONNECTION

Comments: This detail is used by Shipyard "U" on ship types "A", "B" and
                "D" for wide flange stanchions below the weather deck except in
                forward sections, and for stanchions below the house top. This
                detail is not applicable to stanchions in the forward sections of
                the ship because the head and heel connections may be subject
                to tensile loading. Chocks in way of other stanchion flange similar
                to SS-7. For additional comments see SS-2.

Detail Count Ship Type "B":   120

Manhours Required to Complete Typical Detail: 4. 9

Typical Scantlings: Chock plates 4" x 12" x 1/2".

WF SECTION

DECK PLATING

4 PCS: THICKNESS SAME AS FLANGE

1.5W

S

1½"

BULKHEAD OR DEEP WEB
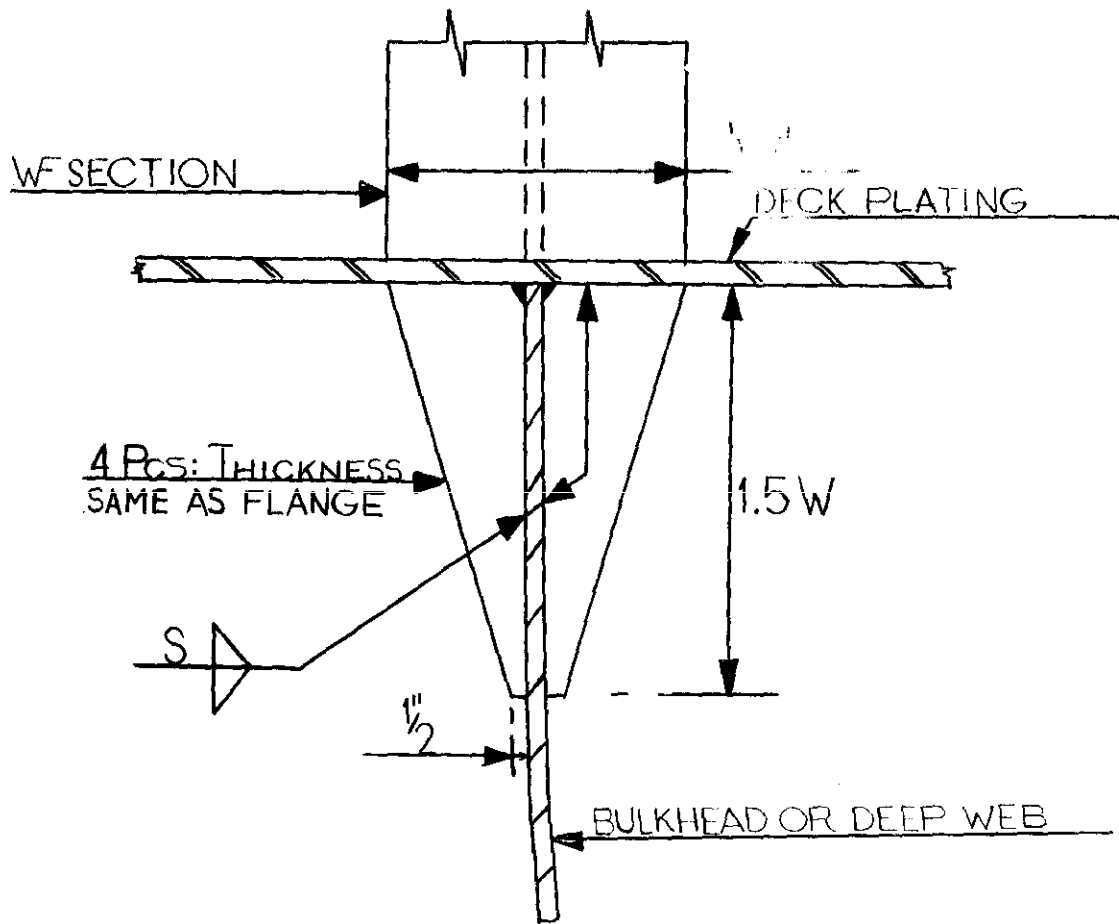
SS- 9

Detail Type: STANCHION END CONNECTION

Comments: This detail is used by Shipyards "U", "V", "Y" and "Z" on ship types "A", "B", "F", "J" and "K" for wide flange stanchions ending on bulkheads, deep webs, or floors. No snipes are to be used; thickness of chock to be same thickness as flange.
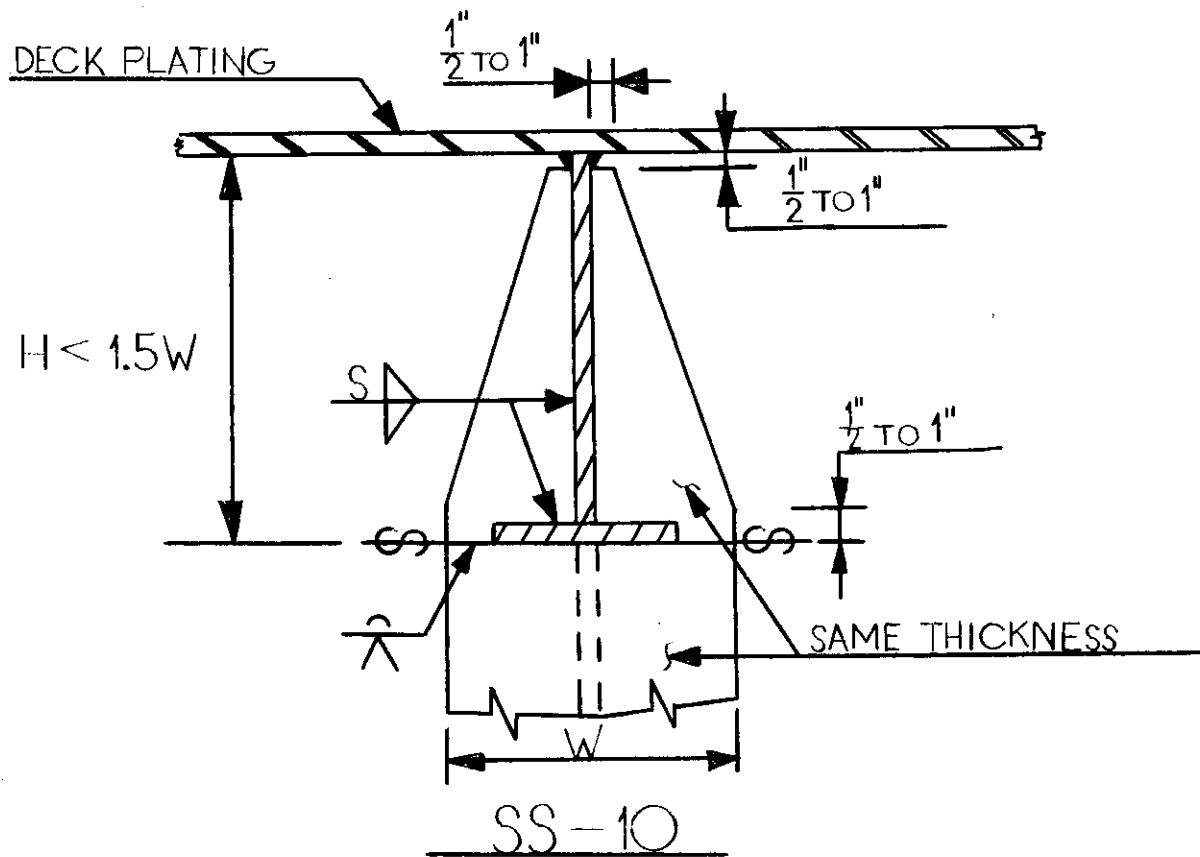
DECK PLATING

$\frac{1}{2}$" TO 1"

$\frac{1}{2}$" TO 1"

$H < 1.5W$

S

$\frac{1}{2}$" TO 1"

SAME THICKNESS

W

SS-10

Detail Type: STANCHION END CONNECTION

Comments: This detail is used by Shipyards "U" and "V" on ship types "B" and
"F" for wide flange section end connections. This detail is used on
stanchions ending against a transverse or longitudinal girder. For
additional comments see SS-2. When H $\geq$ 1.5 W detail SS-9 is
employed.

DECK PLATING

W⁻ SECTION

W

SAME THICKNESS

4 PCS REQ'D TO
BACK-UP STANCHION
FLANGES

S

$H < 1.5$

SS – 11
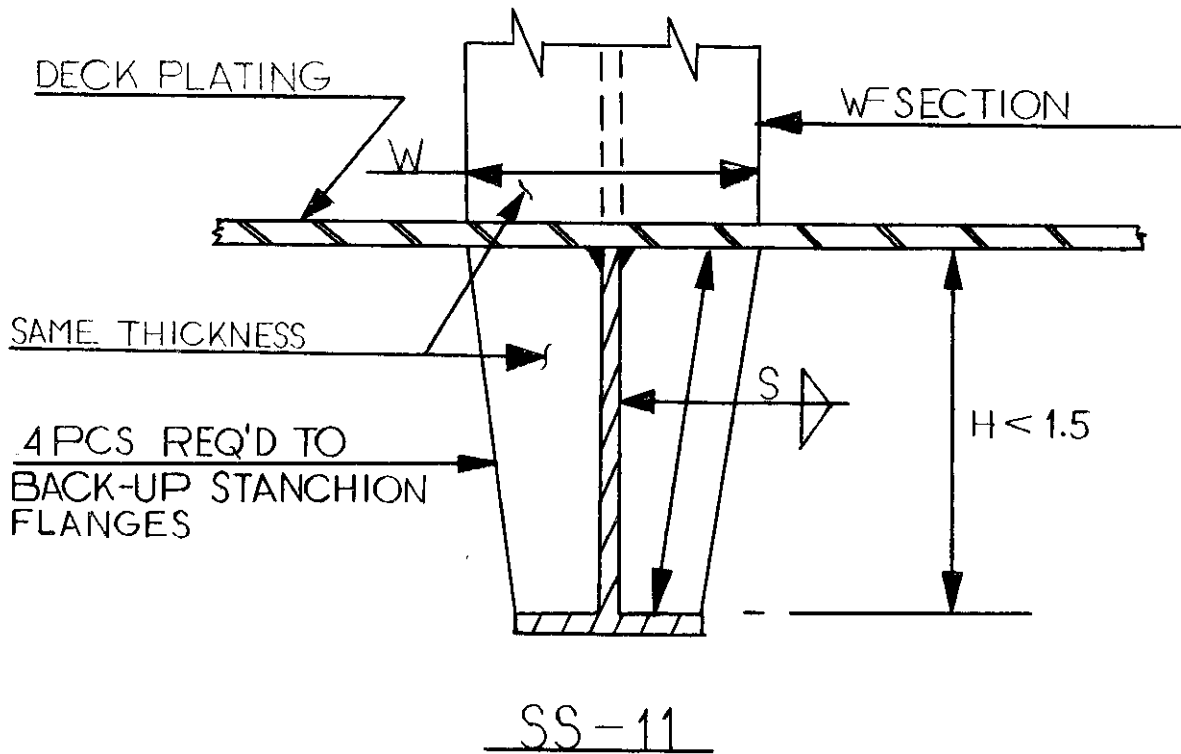
Detail Type: STANCHION END CONNECTION

Comments: This detail is used by Shipyard "V" on ship type "F" for a wide
flange stanchion ending on a longitudinal or transverse girder.
This detail insures a good transfer of load from the stanchion to
the girder.   For additional comments see SS-2.
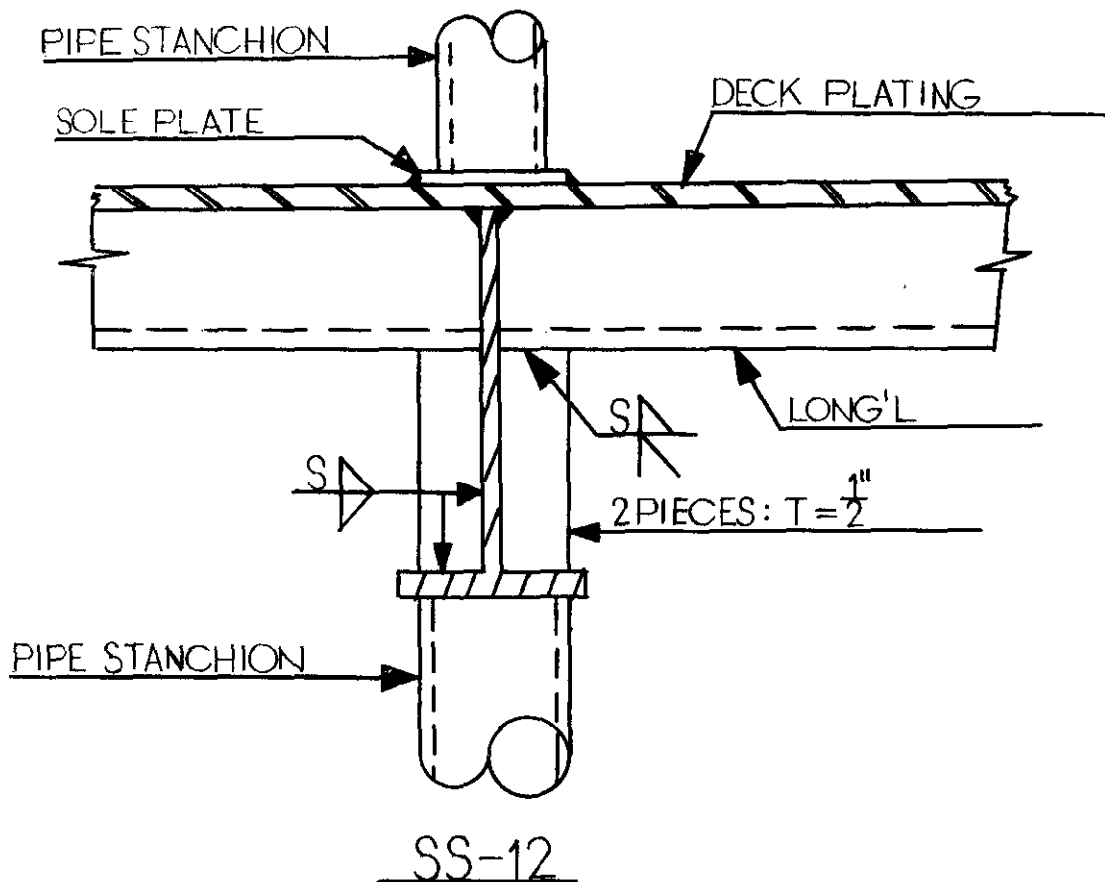
PIPE STANCHION

SOLE PLATE

DECK PLATING

LONG'L

S

S

2 PIECES: T = $\frac{1''}{2}$

PIPE STANCHION

SS-12

Detail Type: STANCHION END CONNECTION

Comments: This detail is used by Shipyard "U" on ship types "A", "D" and
"E" for insuring structural continuity between pipe stanchions in
the superstructure or in crews quarters. This chock does not
provide optimum end support. A bracket arrangement would be
preferable.

Detail Count Ship Type "A":   50

Manhours Required to Complete Typical Detail: 4.9

Typical Scantlings: Chock plate 4" x 12" x 1/2".
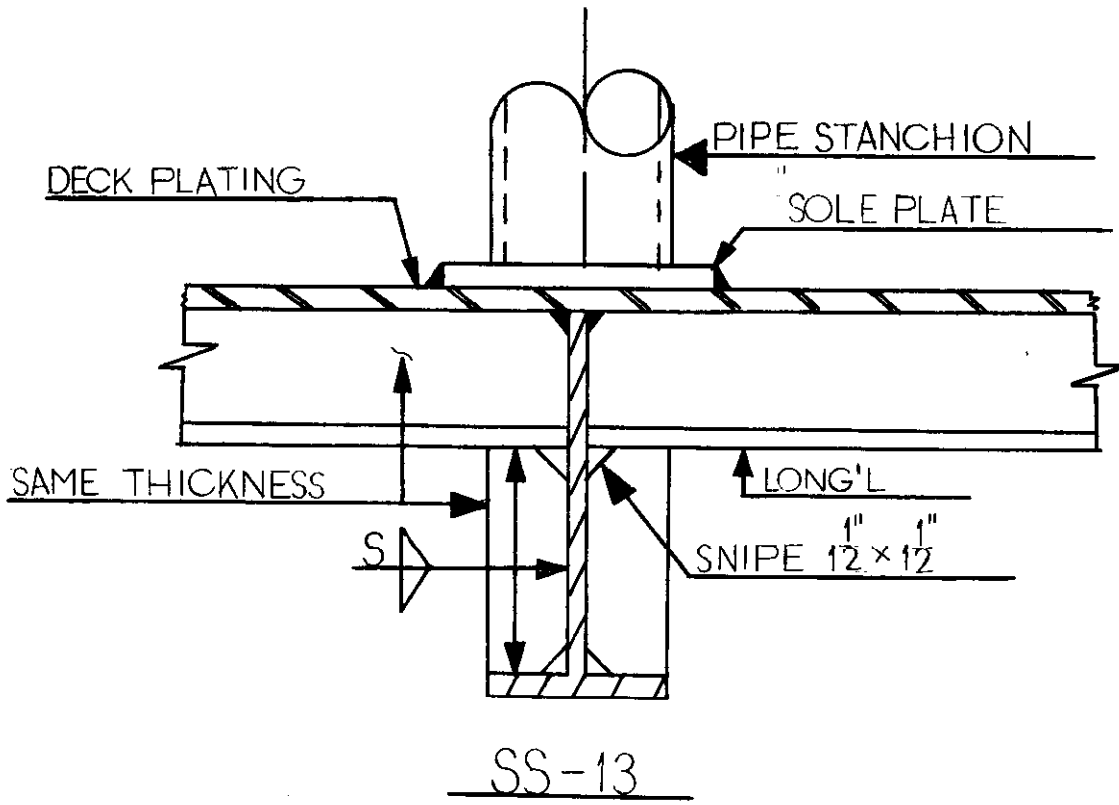
DECK PLATING

PIPE STANCHION

SOLE PLATE

SAME THICKNESS

LONG'L

S

SNIPE $1\frac{1}{2}" \times 1\frac{1}{2}"$

SS-13

Detail Type: STANCHION END CONNECTION

Comments: This detail is used by Shipyard "U" on ship type "D" and it is also
included in the CASDOS library.   This detail insures an effective
transfer of load from the pipe stanchion to the girder.   The detail
may be modified to resemble SS-9, thus easing fitup.
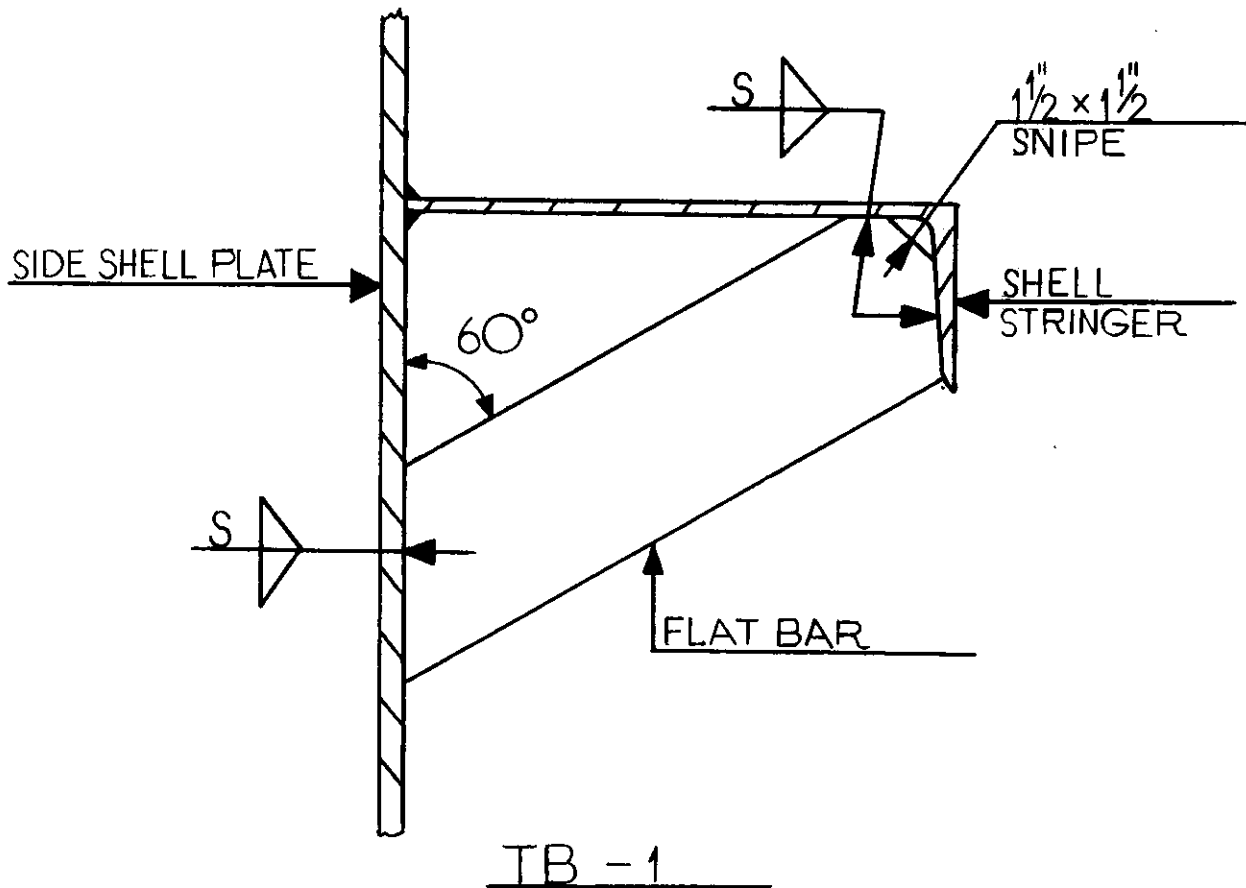
S

$1\frac{1}{2}'' \times 1\frac{1}{2}''$
SNIPE

SIDE SHELL PLATE

60°

SHELL
STRINGER

S

FLAT BAR

TB - 1

Detail Type: TRIPPING BRACKET

Comments: This detail is used by Shipyard "Y" on ship type "J", to provide flange stability to side shell stringers. This bracket effectively provides torsional rigidity, but landing bracket against unstiffened plating is undesirable. Not a commonly used detail.
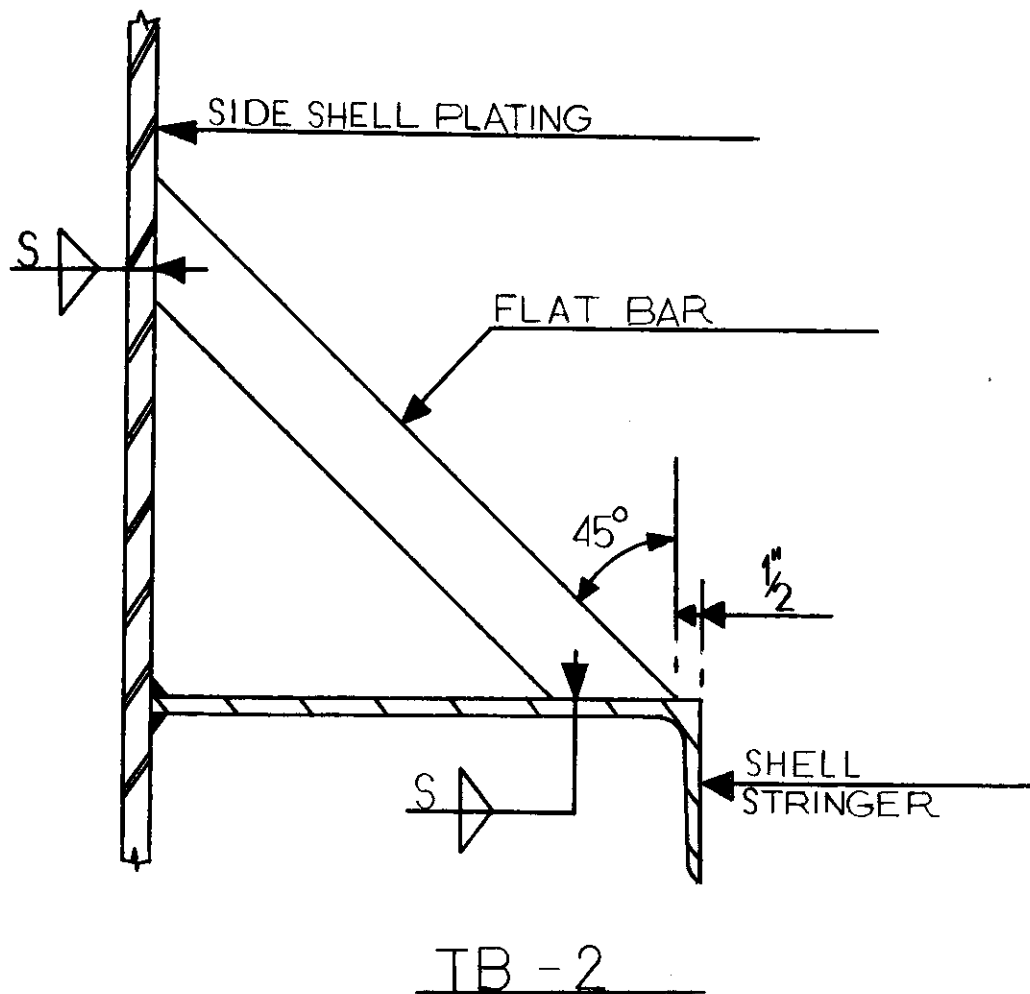
SIDE SHELL PLATING

S

FLAT BAR

45°

$1\frac{1}{2}"$

SHELL
STRINGER

S

TB - 2

Detail Type: TRIPPING BRACKET

Comments: This detail is used by Shipyard "Y" on ship type "J" to provide torsional rigidity to side shell stringers. This detail does not support the flange as does TB-1. Other comments of TB-1 apply.
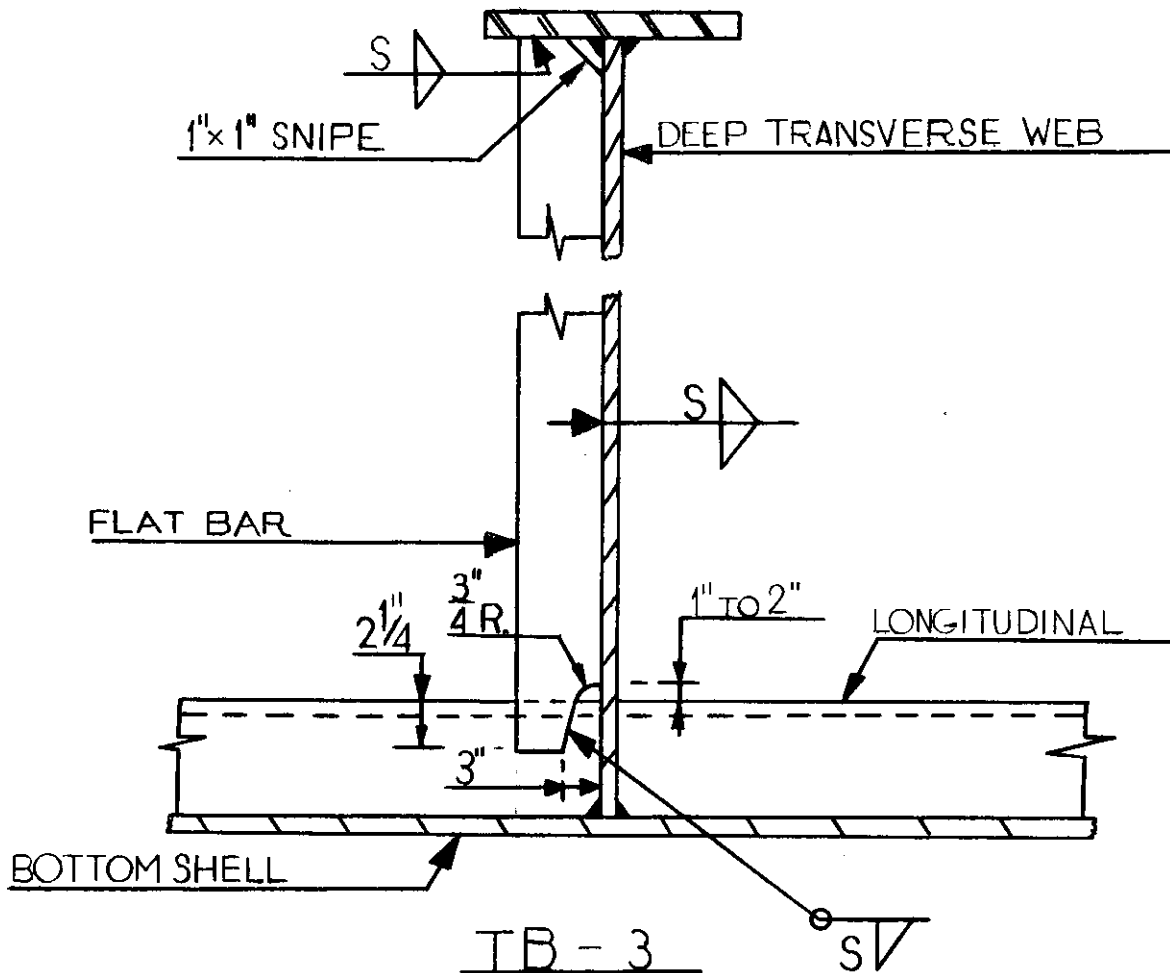
S

1"×1" SNIPE   DEEP TRANSVERSE WEB

FLAT BAR

S

$2\frac{1}{4}$"

$\frac{3}{4}$" R.

$\frac{3}{4}$"

1" TO 2"

LONGITUDINAL

3"

BOTTOM SHELL

TB - 3   S

Detail Type: TRIPPING BRACKET (WEB STIFFENER)

Comments: This detail is used by Shipyard "U" on ship types "A" and "B" to provide some degree of torsional rigidity to the flange and to stiffen the web against web crippling. The detail is used to stiffen deep web frames anywhere in the ship. Where it is necessary to provide flange stability, a second bracket should be added similar to TB-4. A lap as shown is preferred to butting the flat bar to the longitudinal.

Detail Count: Ship Type "A" = 430; Ship Type "B" = 4260

Manhours Required to Complete Typical Detail: 3.0

Typical Scantlings: 6" x 1/2" flat bar 40" long.
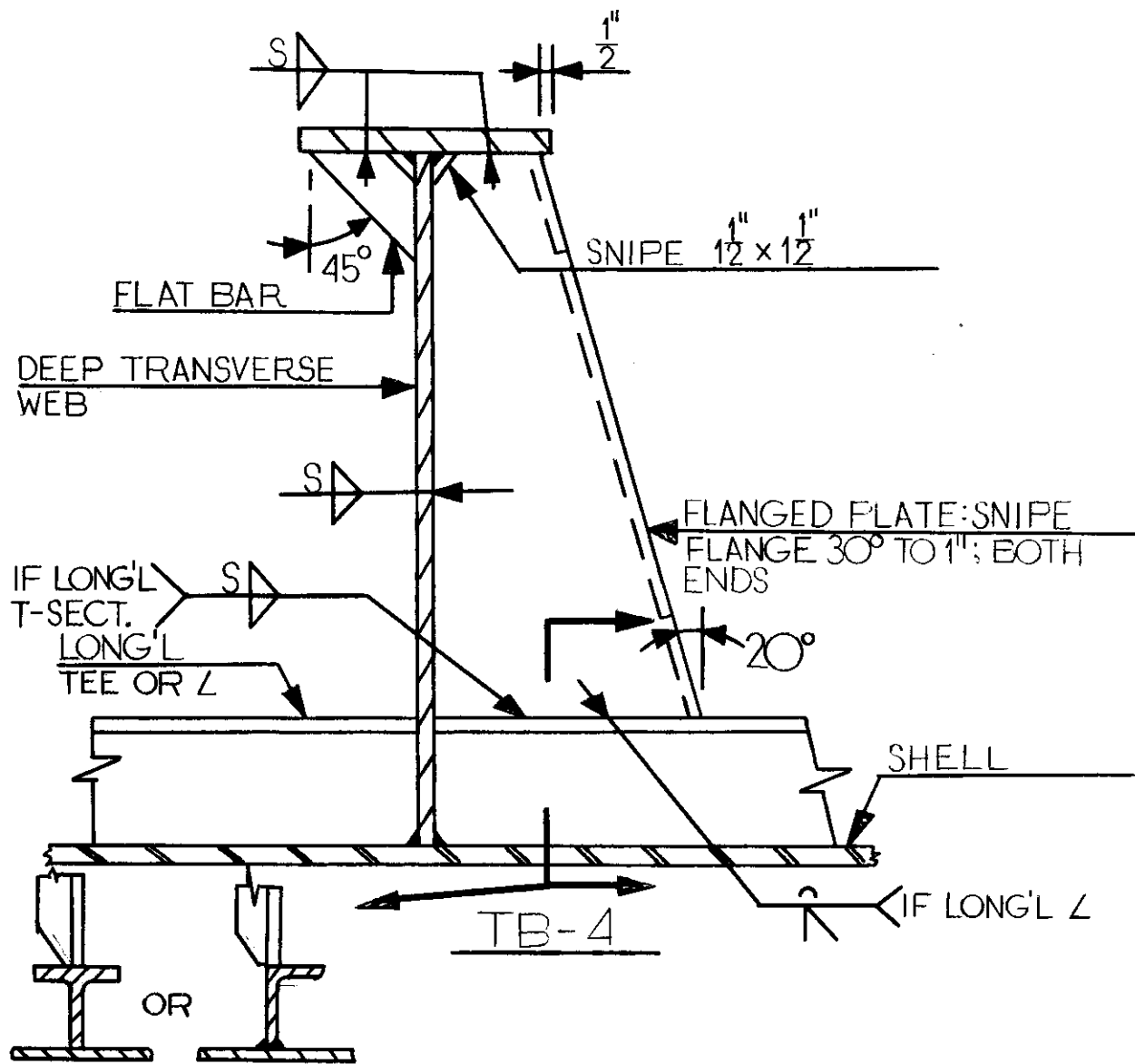
3-84

Detail Type: TRIPPING BRACKET (WEB STIFFENER)

Comments: This detail is used by Shipyard "Y" on ship type "J" to stabilize web and flange of deep transverse or longitudinal girders. Minimum bracket dimensions, spacing and scantlings are determined from ABS rules (See Appendix A).

TB-5
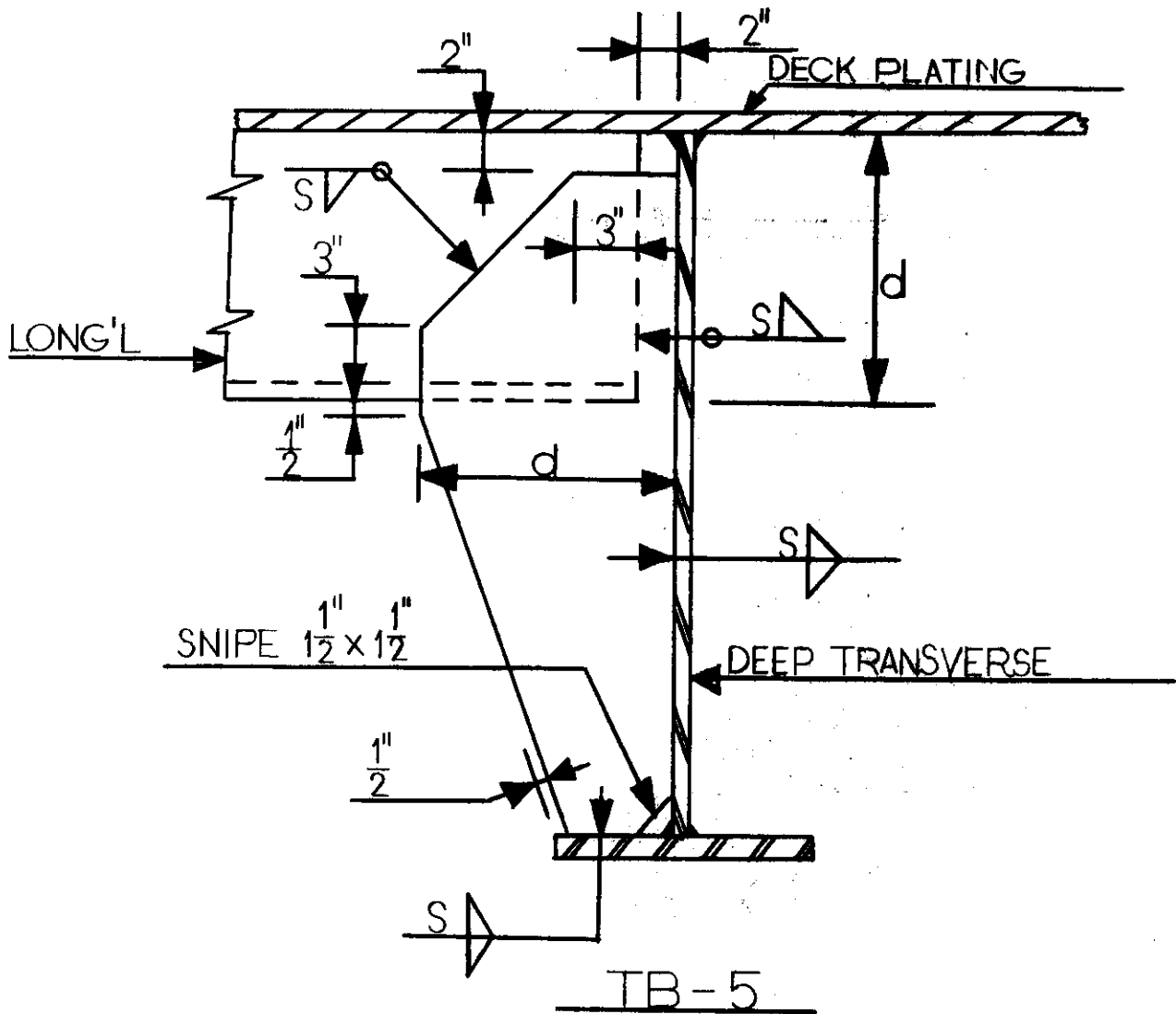
Detail Type: TRIPPING BRACKET (BEAM BRACKET)

Comments: This detail is used by Shipyard "Y" on ship type "J" to stabilize
web and flange and provide an end connection at the juncture of a
continuous transverse girder and a shallow intercostal longitudinal.
This detail might be found in way of hatch or deck openings.

Radiusing of bracket corners is recommended to facilitate welding.
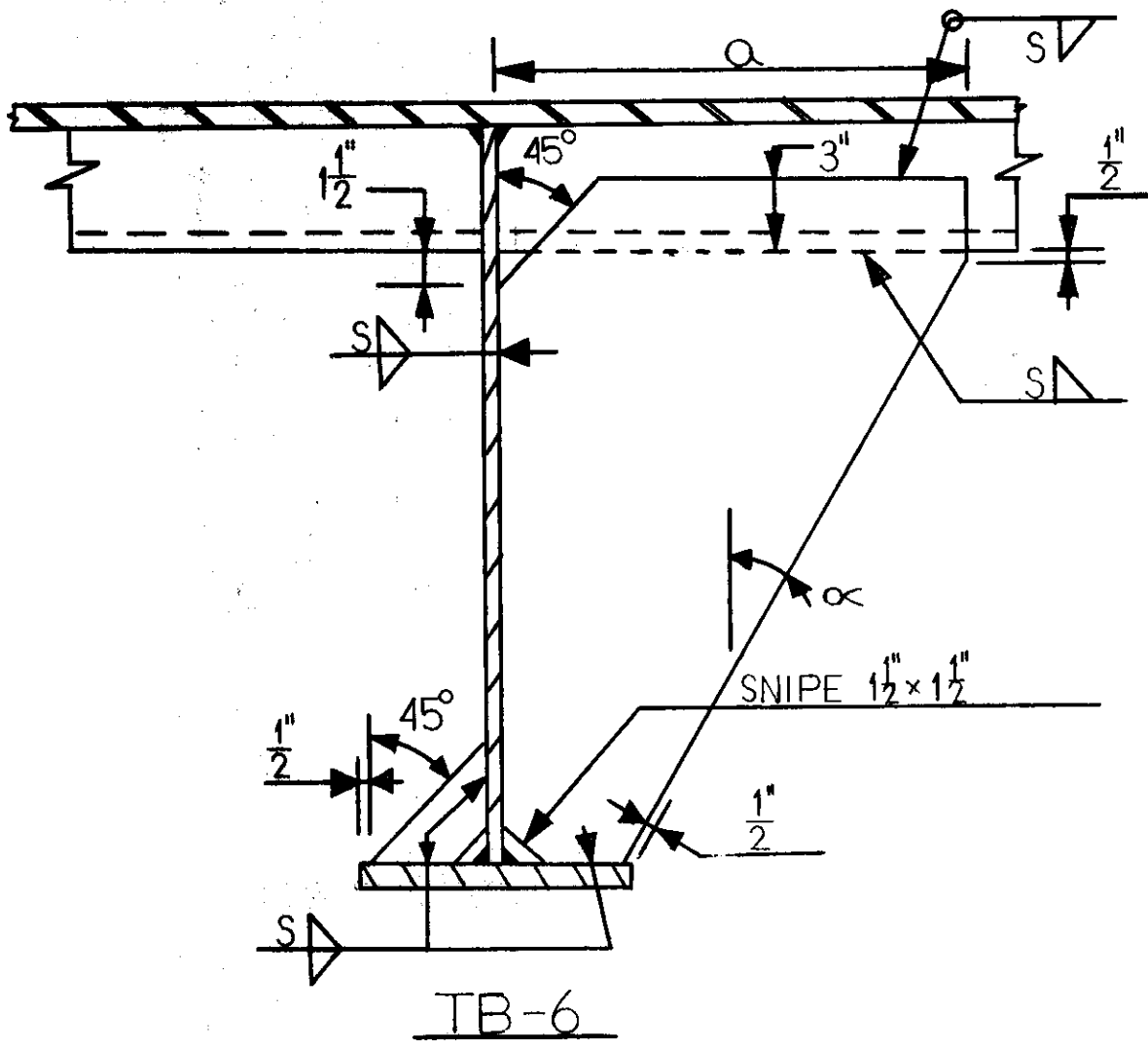
$\underline{\text{TB-6}}$

Detail Type: TRIPPING BRACKET (WEB STIFFENER)

Comments: This detail is used by Shipyards "U" and "Y" on ship types "C" and "J" to stabilize flanges against rotation and to stiffen the web plate against crippling.   Used on transverse or longitudinal girders. The angle $\propto$ is normally in range of 18° to 30°.

If dimension "a" is at least equal to one-eighth the span of the shallow member, the bracket will also be considered to be an effective bracket connection when calculating the required section modulus of the shallow member.   Scantling must satisfy ABS Rules (see Appendix A).
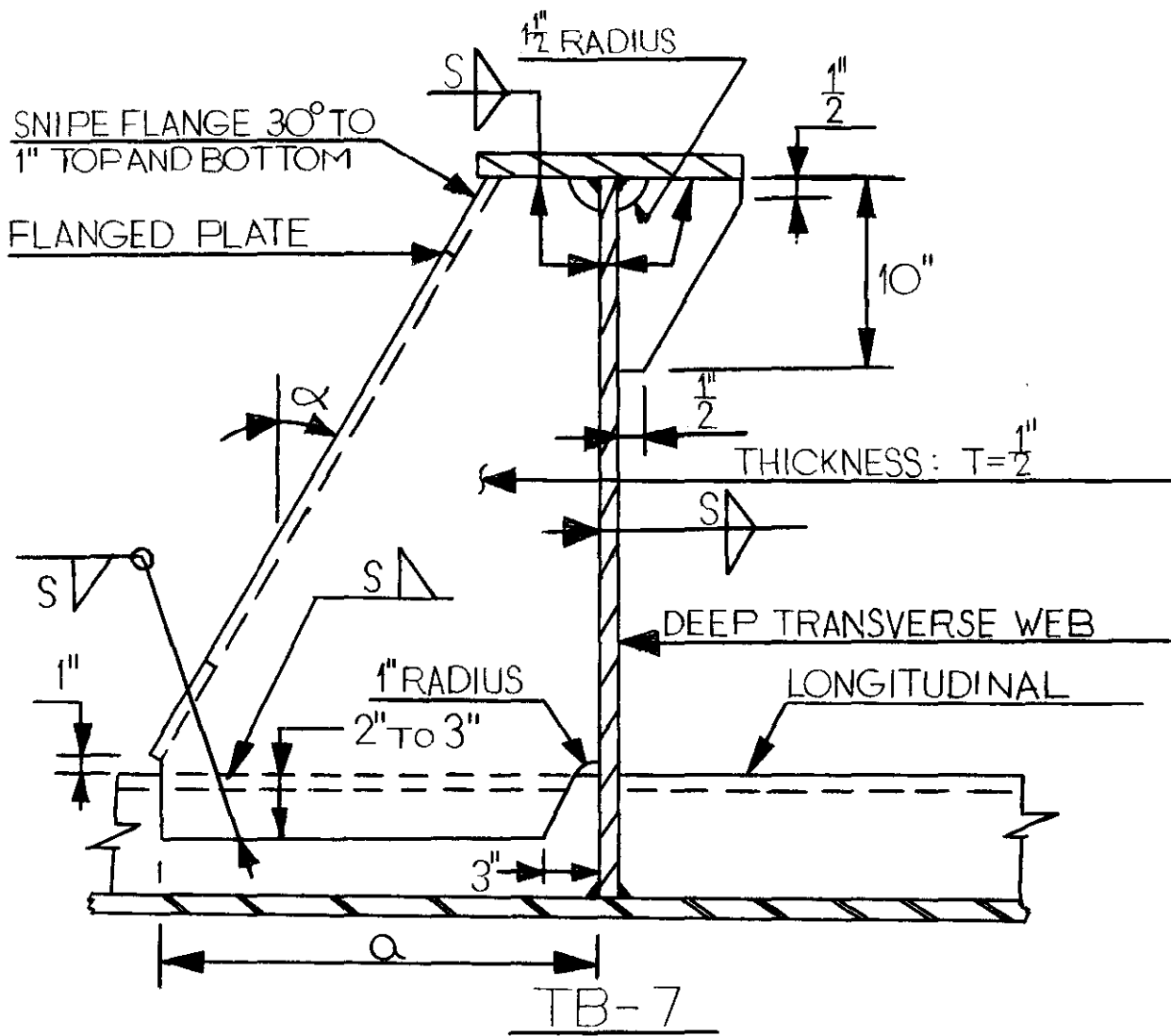
3-87

$1\frac{1}{2}$" RADIUS

S

SNIPE FLANGE 30° TO
1" TOP AND BOTTOM

$\frac{1}{2}$"

FLANGED PLATE

10"

α

$\frac{1}{2}$"

THICKNESS : $T=\frac{1}{2}$"

S

S

S

DEEP TRANSVERSE WEB

1"

1" RADIUS

LONGITUDINAL

2" TO 3"

3"

a

TB-7

Detail Type: TRIPPING BRACKET

Comments: This detail is used by Shipyards "U" and "Y" on ship types "A" and
"J", for the same purpose as TB-4. Producibility would be
improved by cutting back flange at top of bracket similar to base.
For comments on angle α and dimension a, see TB-6.

Detail Count Ship Type "A":   1200

Manhours Required to Complete Typical Detail: 10. 6

Typical Scantlings: 1/2" plate, 25-1/8" x 72" w/6" x 1/2" flange.

DECK PLATING

18-13/16"

S

2" RADIUS

1"

2"

S

S

THICKNESS: T = 1/2"

α

2" RADIUS

TB - 8
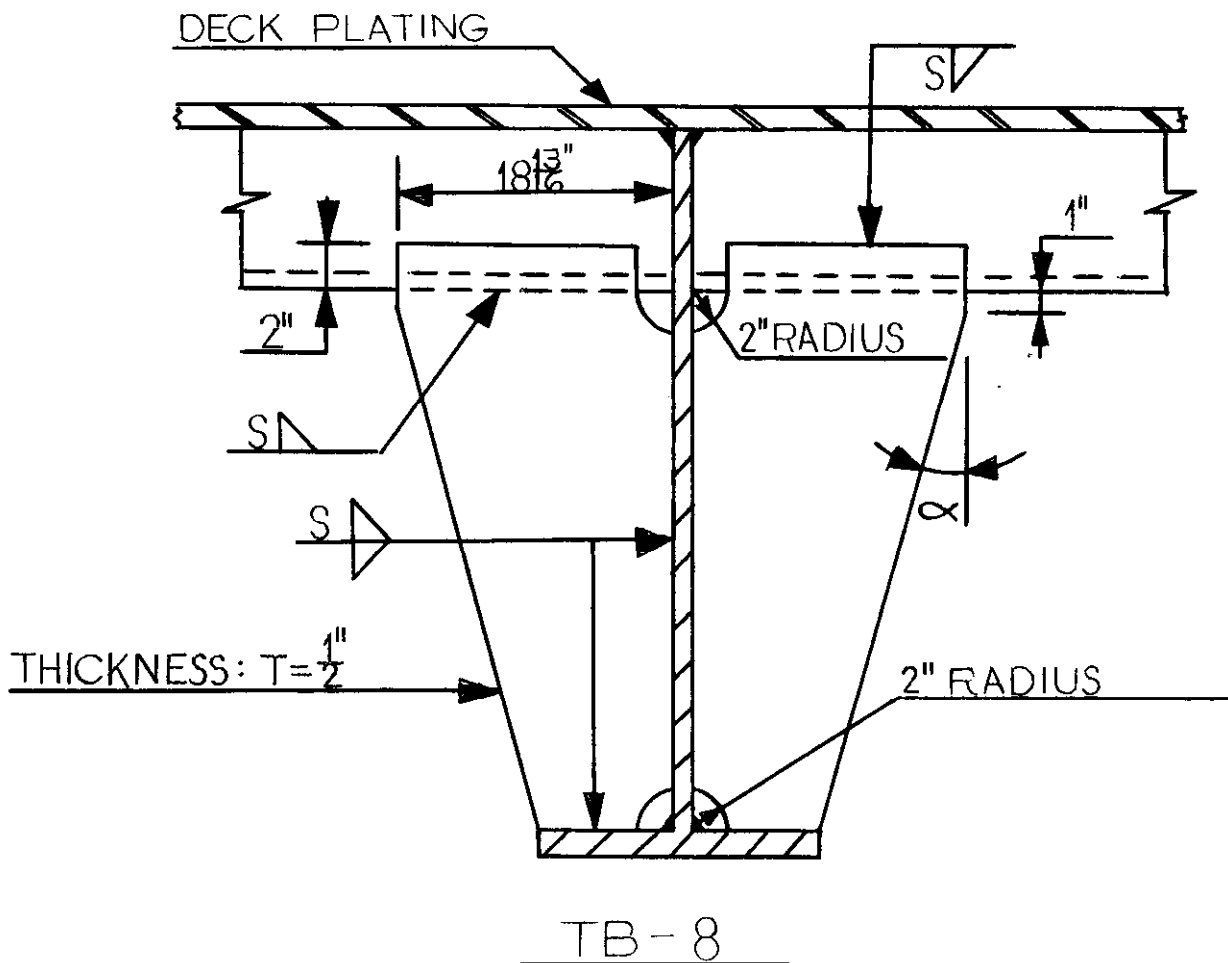
Detail Type: TRIPPING BRACKETS (WEB STIFFENERS)

Comments: This detail is used by Shipyard "U" on ship types "A" and "C" to provide flange and web stability to transverse or longitudinal girders. The width of this bracket is dictated by a standard strip width. The resulting angle α attains a minimum of about 15°.

Detail Count Ship Type "A": 170

Manhours Required to Complete Typical Detail: 4.3

Typical Scantlings: 1/2" plate - 36" x 18-13/16" (2 pieces).
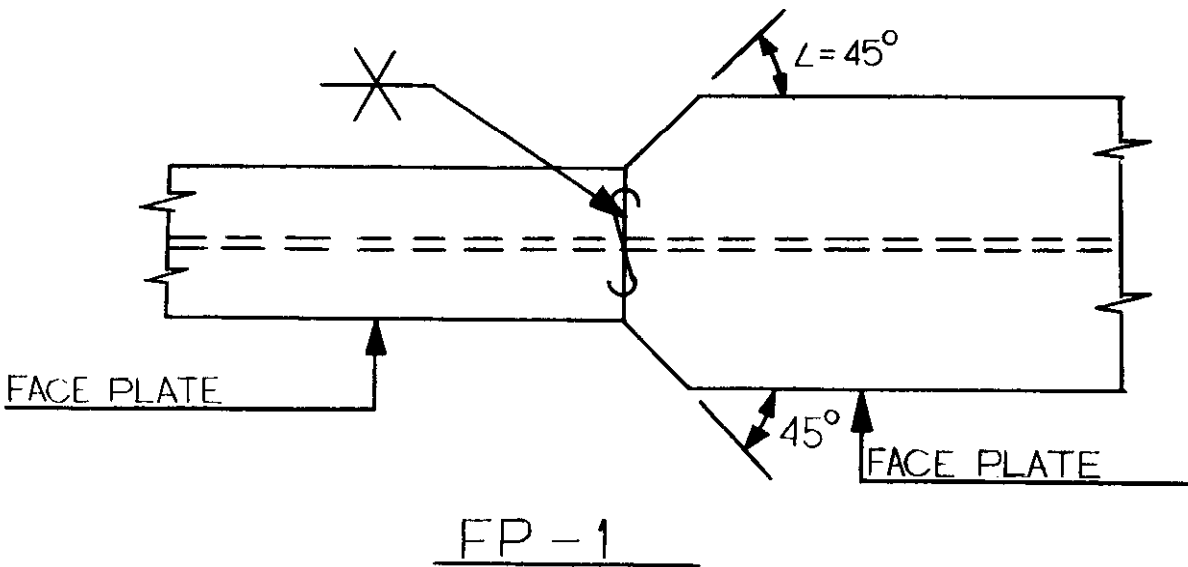
FP - 1

Detail Type: FACE PLATE DETAIL

Comments: This detail is used by Shipyard "Y" on ship type "J" for connections
between face plates or flanges of different widths.   The bevel
shown should be reduced to about 20° to minimize the effect at
change of section.
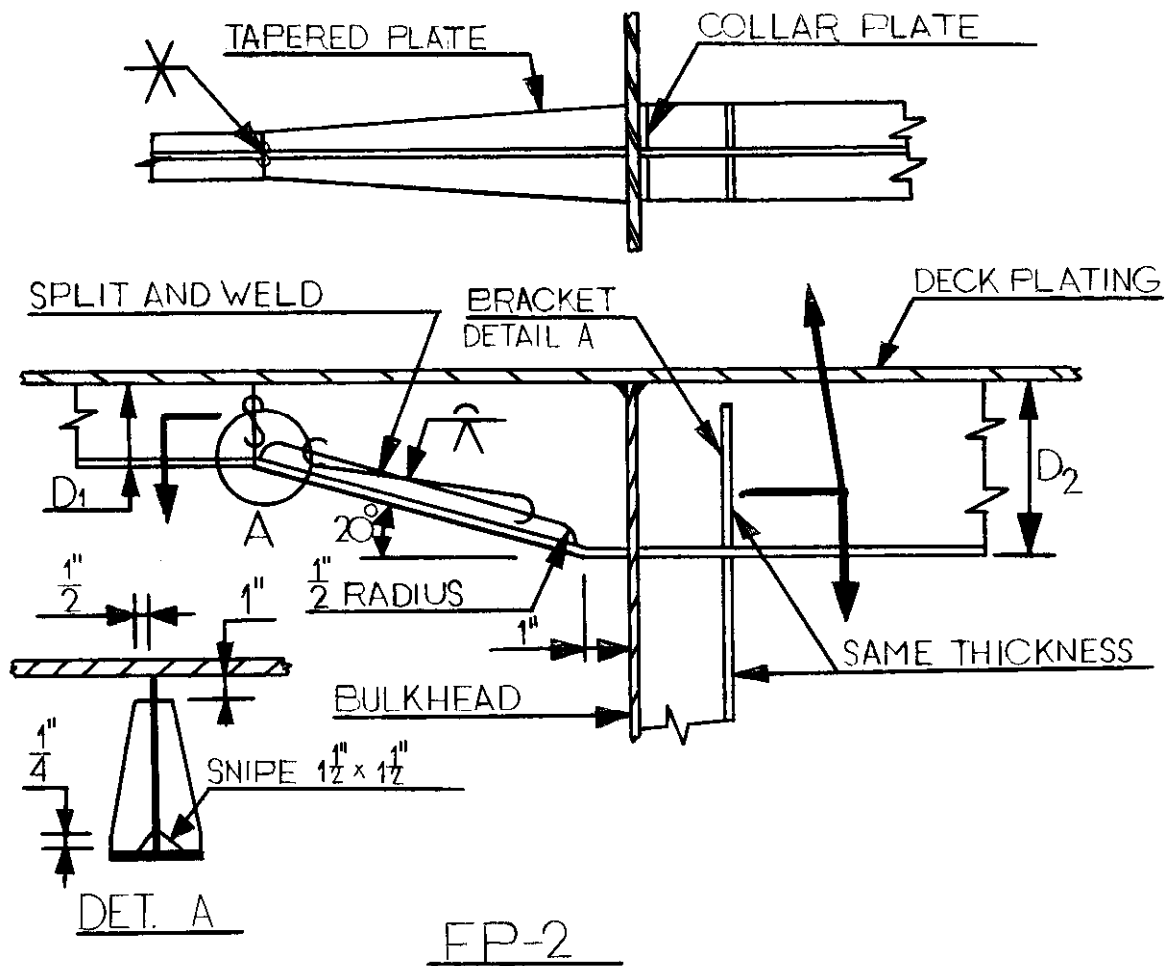
TAPERED PLATE

COLLAR PLATE

SPLIT AND WELD

BRACKET
DETAIL A

DECK PLATING

D_1

D_2

A

20°

$\frac{1}{2}"$

$1"$

$\frac{1}{2}"$ RADIUS

$1"$

SAME THICKNESS

BULKHEAD

$\frac{1}{4}"$

SNIPE $1\frac{1}{2}" \times 1\frac{1}{2}"$

DET. A

FP-2

Detail Type: FACE PLATE DETAIL

Comments: This detail was prepared for the CASDOS library of standard
structural details for use on Navy ships.   It provides an effective
transition detail of deck beam through a bulkhead, while maintaining
structural continuity.   No snipes should be permitted in members
less than 3" in depth.   The 1/2" radius shown in circle should be
eliminated and seam extended into the web butt to simplify
fabrication. Navy practice requires tangency brackets at change
of section (see FP-3) that are not shown in this detail.
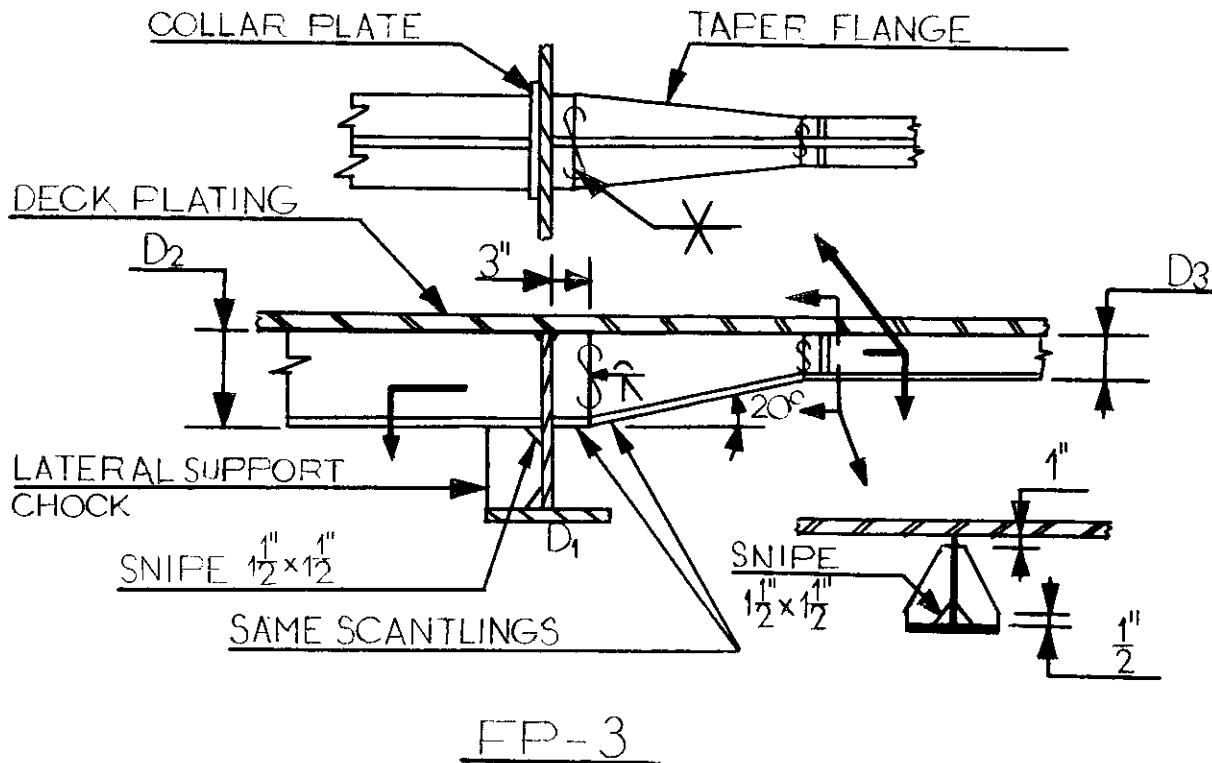
COLLAR PLATE   TAPER FLANGE

DECK PLATING

D_2 3" D_3

LATERAL SUPPORT
CHOCK

SNIPE $1\frac{1}{2}"\times1\frac{1}{2}"$ D_1

20°

1"

SNIPE
$1\frac{1}{2}"\times1\frac{1}{2}"$

$\frac{1}{2}"$

SAME SCANTLINGS

FP-3

Detail Type: FACE PLATE DETAIL

Comments: This detail was prepared for the CASDOS library of standard
                structural details for use on Navy ships. It provides an effective
                transition detail for a continuous deck beam to reduce or increase
                the depth of the member. No snipes should be permitted in members
                less than 3" in depth.
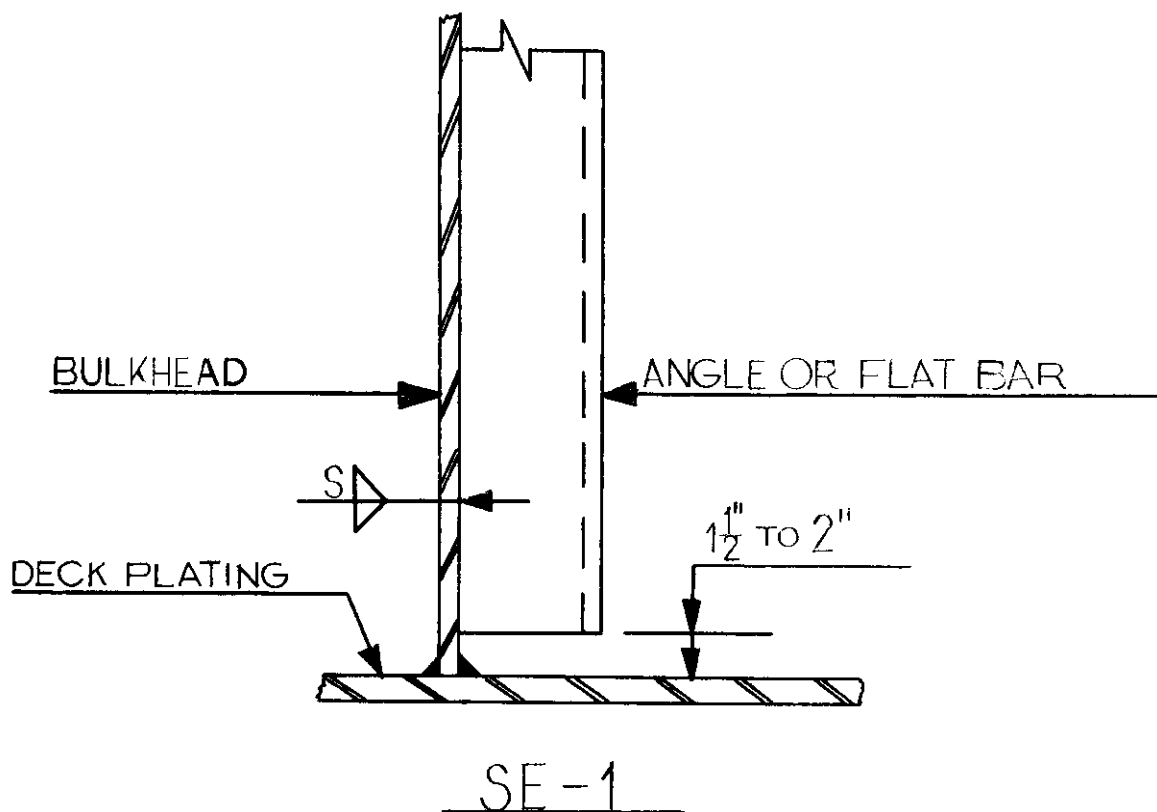
3-92

BULKHEAD

ANGLE OR FLAT BAR

S

DECK PLATING

$1\frac{1}{2}"$ TO $2"$

SE-1

Detail Type: STIFFENER END CONDITION

Comments: This detail is used by Shipyards "U", "W" and "X" on ship types
"A", "B", "E", "G" and "H" as a stiffener ending for stiffeners on
watertight or non-tight bulkheads or floors, where no rigidity at the
end is required. This detail is not recommended for deep tanks,
or where end shear load is large. The detail is applicable to flat
bars, rolled angles, and built-up angles.

If access to plate intersection is desired in living or working spaces,
the flange may be sniped or use made of detail SE-2.

3-93

BULKHEAD

S

30°

1" TO 2"

$\frac{1"}{8}$ TO 1"

OR

30°

ANGLE OR
T-STIFFENER

RADIUS OR SNIPE WHERE
EXPOSED IN LIVING OR WORKING
SPACES
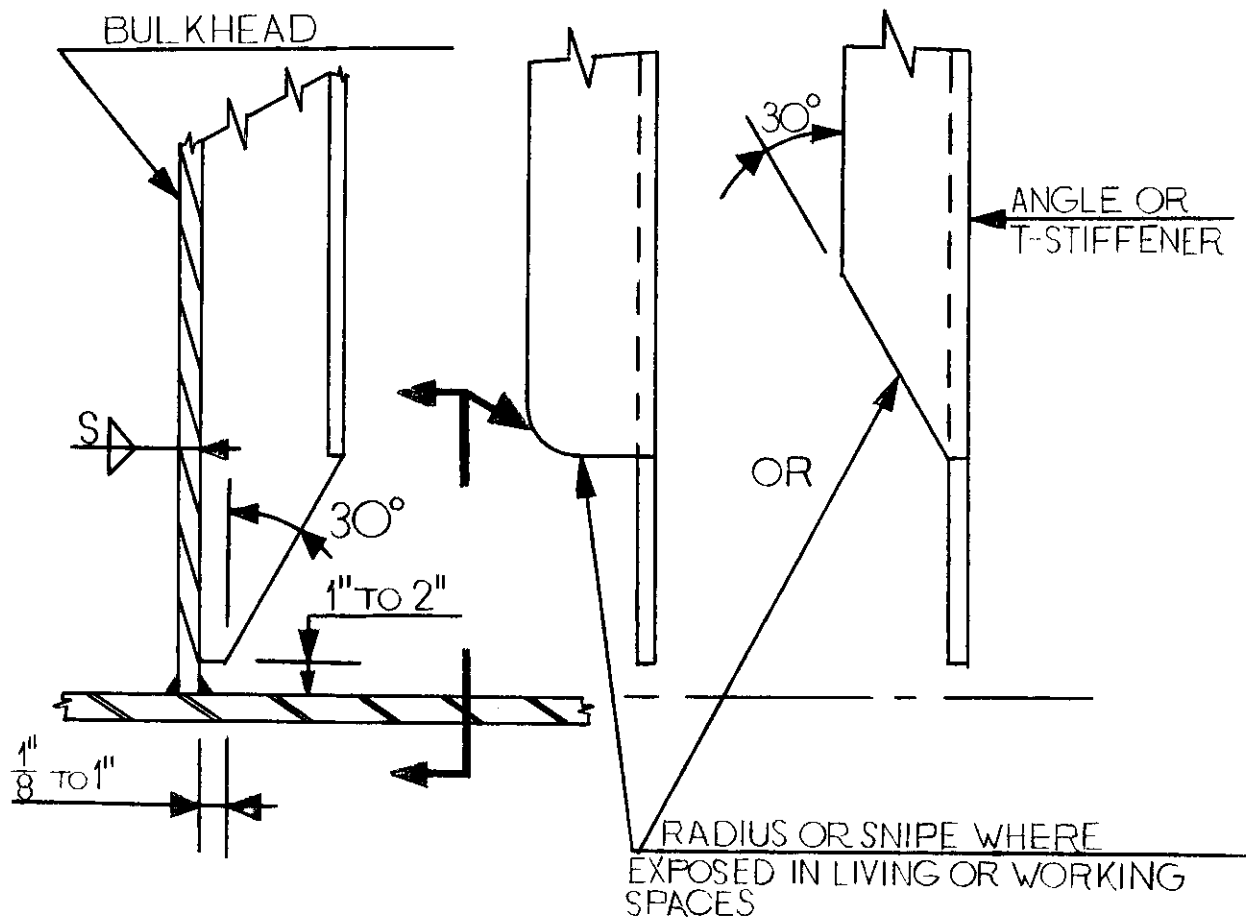
SE-2

Detail Type: STIFFENER END CONDITION

Comments: This detail is used by Shipyards "U", "W", "X" and "Y" on ship types "A", "B", "C", "D", "G", "H" and "J" as a stiffener ending for stiffeners on watertight or miscellaneous non-tight bulkheads where back-up structure is not available. This detail is not recommended for deep tanks, or where end shear load is large. The detail is applicable to rolled or fabricated angles and Tees.

BULKHEAD →

$D > 5"$

$30°$

DECK PLATE →

SNIPE $\frac{1}{2}" \times \frac{1}{2}"$
FILL WITH WELD

$\frac{D}{2} + \frac{1}{2}"$

S

$30°$

$3T_w + 1"$

T_w

SE—3
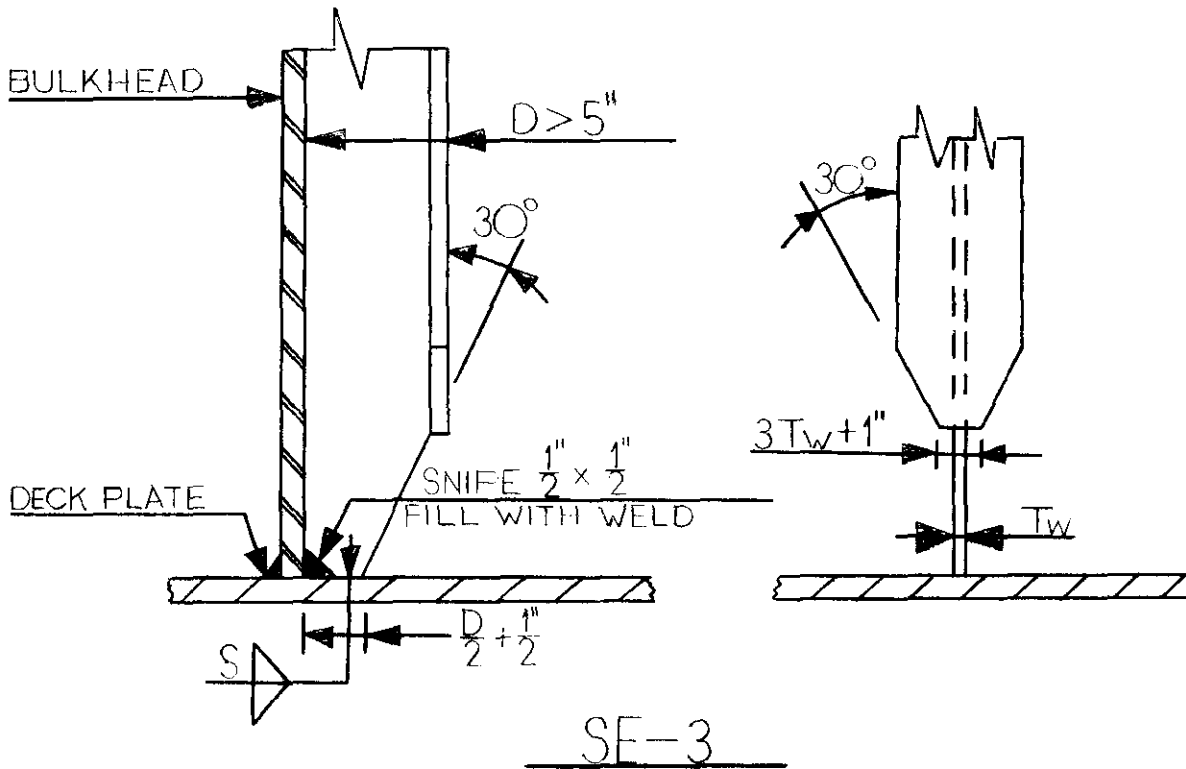
Detail Type: STIFFENER END CONDITION

Comments: This detail is used by Shipyards "V" and "Z" on ship types "F" and
"K" and is in the CASDOS library. This detail is used where little
or no end restraint is required and preferably in the presence of
back-up structure or heavy deck plating. Not recommended for
deep tanks, or where end shear load is large.

ANGLE OR T-BAR

BULKHEAD

SNIPE $1\frac{1}{2}" \times 1\frac{1}{2}"$

DECK PLATE

SNIPE FLANGE
30° TO 1"

30°

1"

LONG'L

S

SE—4
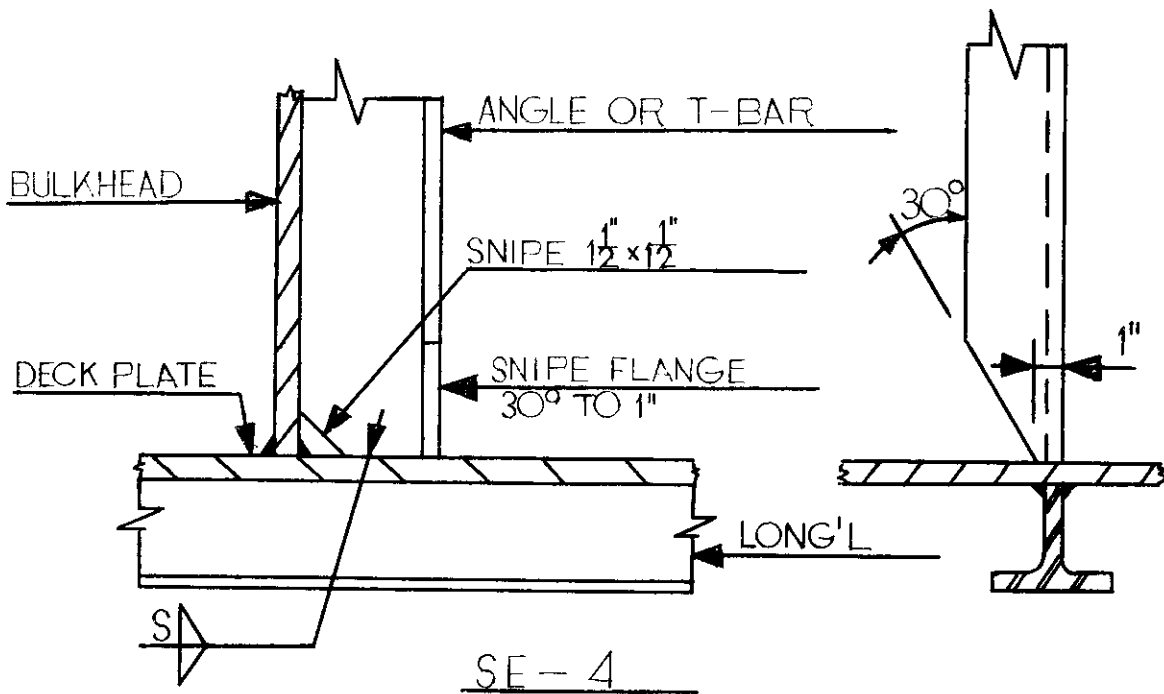
Detail Type: STIFFENER END CONDITION

Comments: This detail is used by Shipyards "U", "V", "W" and "X" on ship
types "A", "B", "D", "E", "F", "G" and "H" and in the CASDOS
library.   This detail is used on watertight and deep tank bulkhead
stiffeners for which end fixity is not required.   The detail should
be backed up by another member, when the intersecting
member is less rigid and the stiffener is designed as the
end being supported by a horizontal girder.   Although Navy
practice generally allows stiffeners 6" or less in depth to land
on 3/4" plate or thicker without modification.

BULKHEAD

DECK PLATE

SNIPE $1\frac{1}{2}" \times 1\frac{1}{2}"$

$\frac{1}{2}"$ PLATE

S

SE-5

$1\frac{1}{4}"$

S

$1"$

$1"$

$1"$ RADIUS
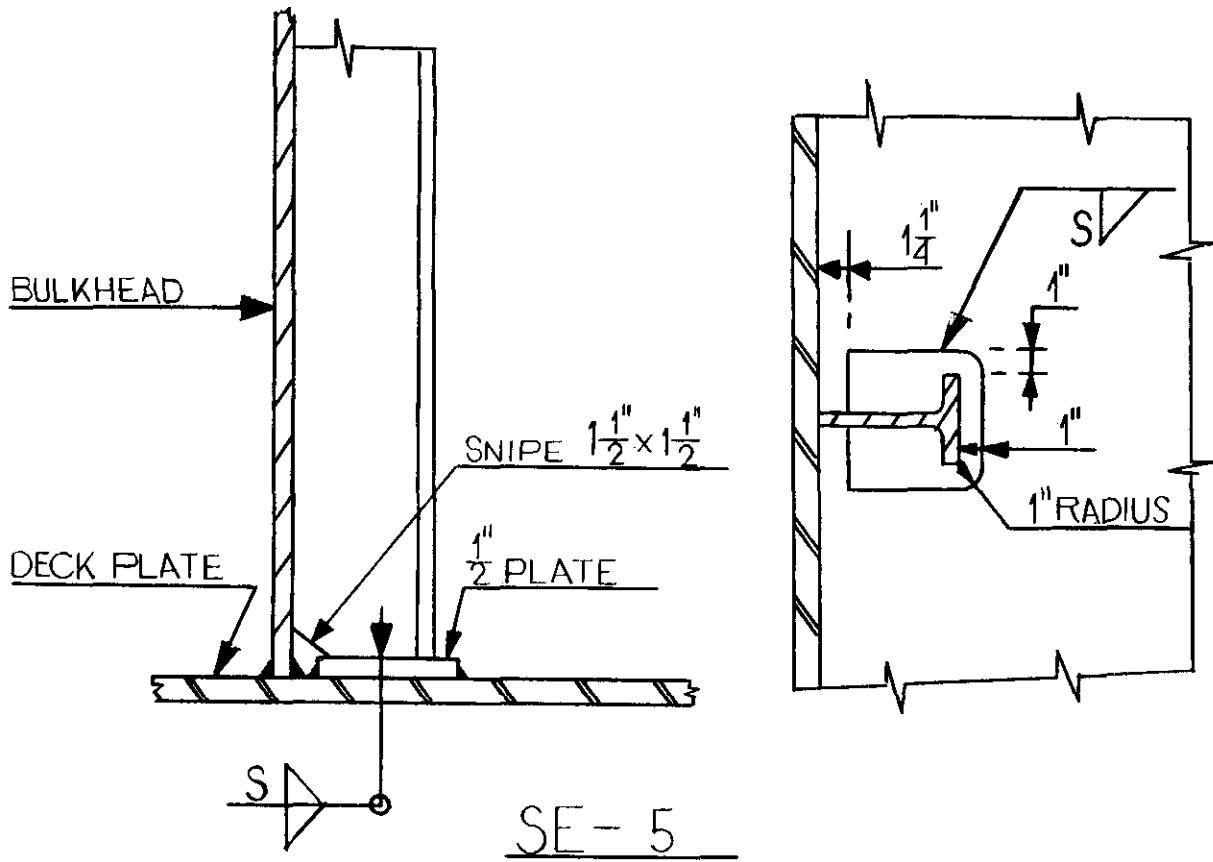
Detail Type: STIFFENER END CONDITION (SOLE PLATE)

Comments: This detail is used by Shipyards "U" and "Z" on ship types "A",
"B", "D" and "K" and in the CASDOS library. This detail is used
where some degree of end support is required by the shear load,
where backing structure is not fitted, and where the deck plating
is less than 3/4". Sole plate should have all rounded corners
to facilitate welding.

Detail Count Ship Type "B":   20

Manhours Required to Complete Typical Detail: 1.4

Typical Scantlings: 6" x 6" x 1/2" Plate.

DECK PLATING   FLAT BAR OR ANGLE

SE-6
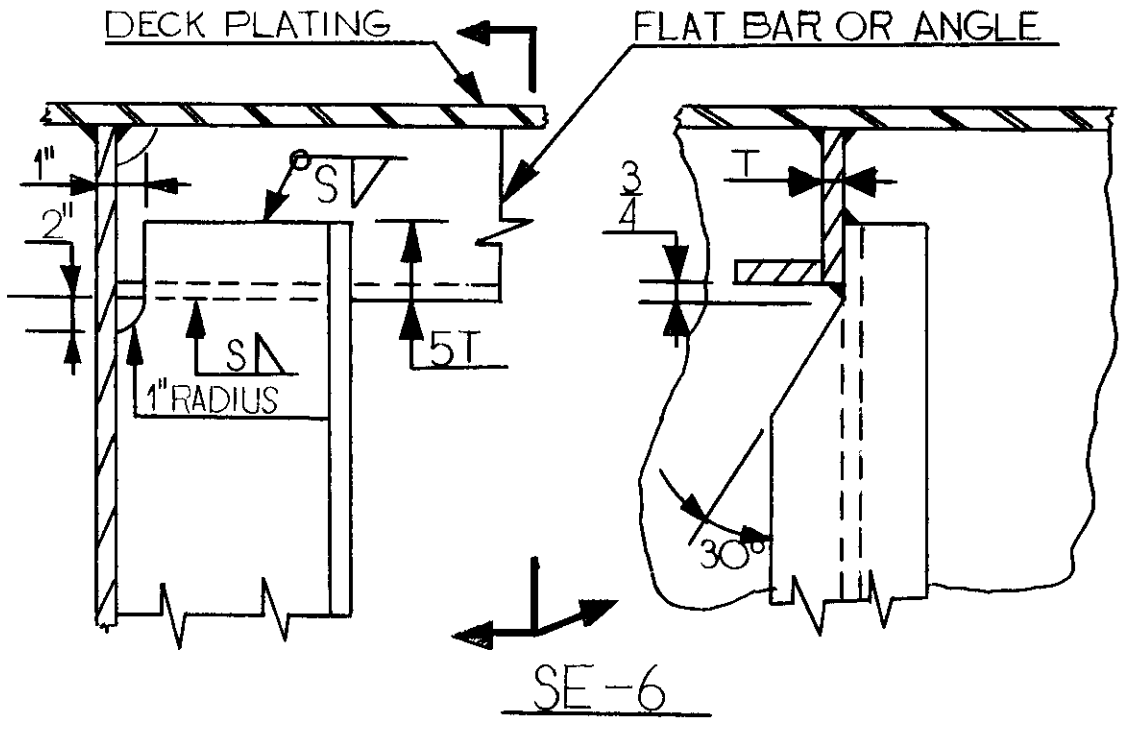
Detail Type: STIFFENER END CONDITION (LAPPED CONNECTION)

Comments: This detail is used by Shipyard "U" on ship type "C" for the top
connection of watertight or deep tank bulkhead tee or angle
stiffeners joined to continuous deck longitudinals. Welding
accessibility is improved by adding a 30° snipe to the 1" radius.
Removal of the flange limits the degree of end support.

3-98

DECK PLATING

0° TO 30°

S∇

$1\frac{1}{2}"$ TO $2"$

$2"$ TO $2T+1"$

$\frac{3"}{4}$ RADIUS

S⊿

BULKHEAD

T = WEB THICKNESS
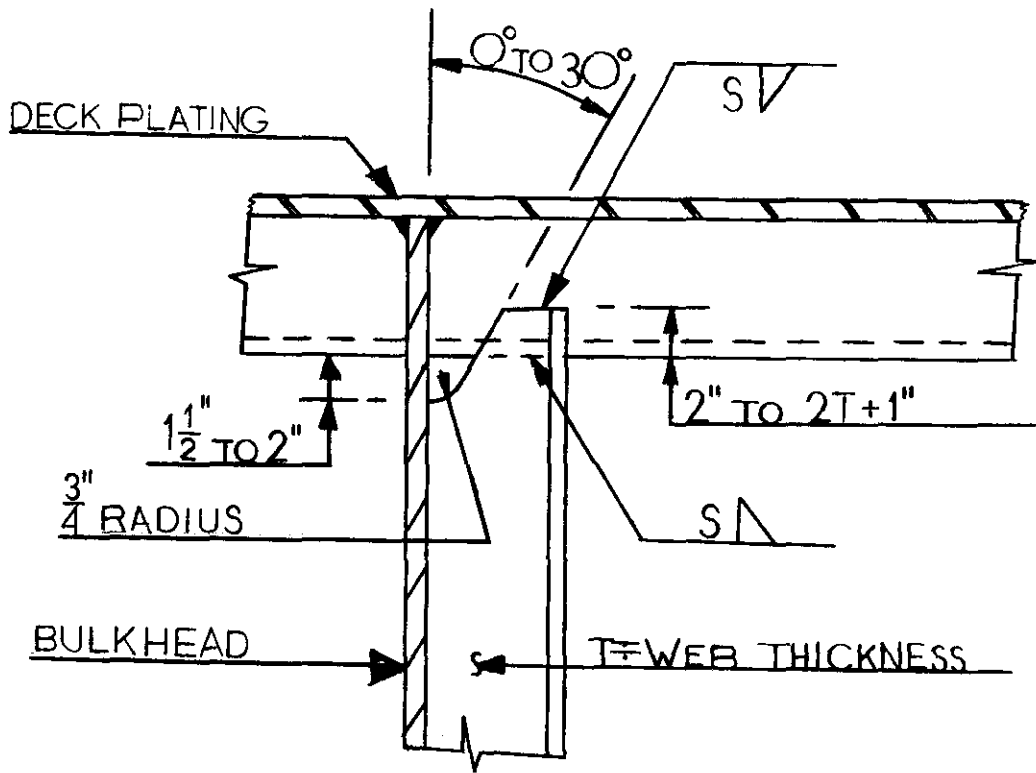
SE - 7

Detail Type: STIFFENER ENDING (LAPPED CONNECTION)

Comments: This detail is used by Shipyards "U", "V" and "X" on ship types
"A", "B", "G" and "H" for the top connection of watertight or
deep tank bulkhead rolled or fabricated angle stiffeners.   To
improve weld accessibility the snipe should always be made with
a 30° angle.

Detail Count: Ship Type "A" = 720; Ship Type "B" = 1600

Manhours Required to Complete Typical Detail: 0.8

Typical Scantlings: 10" x 1/2"-6-3/16" x 1/2" ⌐
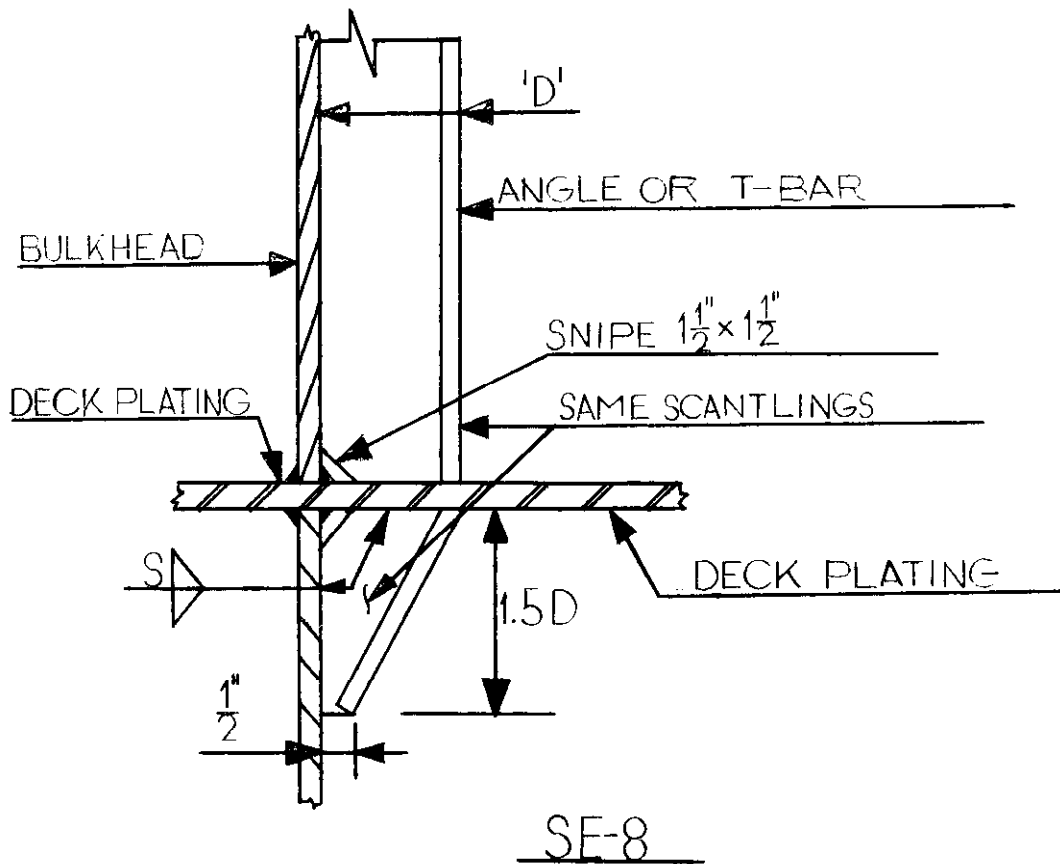
3-99

BULKHEAD

DECK PLATING

'D'

ANGLE OR T-BAR

SNIPE $1\frac{1}{2}" \times 1\frac{1}{2}"$

SAME SCANTLINGS

DECK PLATING

S

$\frac{1"}{2}$

1.5D

SE-8

Detail Type: STIFFENER END CONDITION

Comments: This detail is used by Shipyards "V" and "Z" on ship types "F" and "K" and it is in the CASDOS library. This detail is used primarily on Navy ships for watertight and deep tank bulkhead rolled or fabricated angle or tee beam stiffeners when support is required at the ends.

Some type of back-up structure on the opposite side of the bulkhead is desirable. This is preferable to SE-5 for large stiffener depths or thin deck plating.
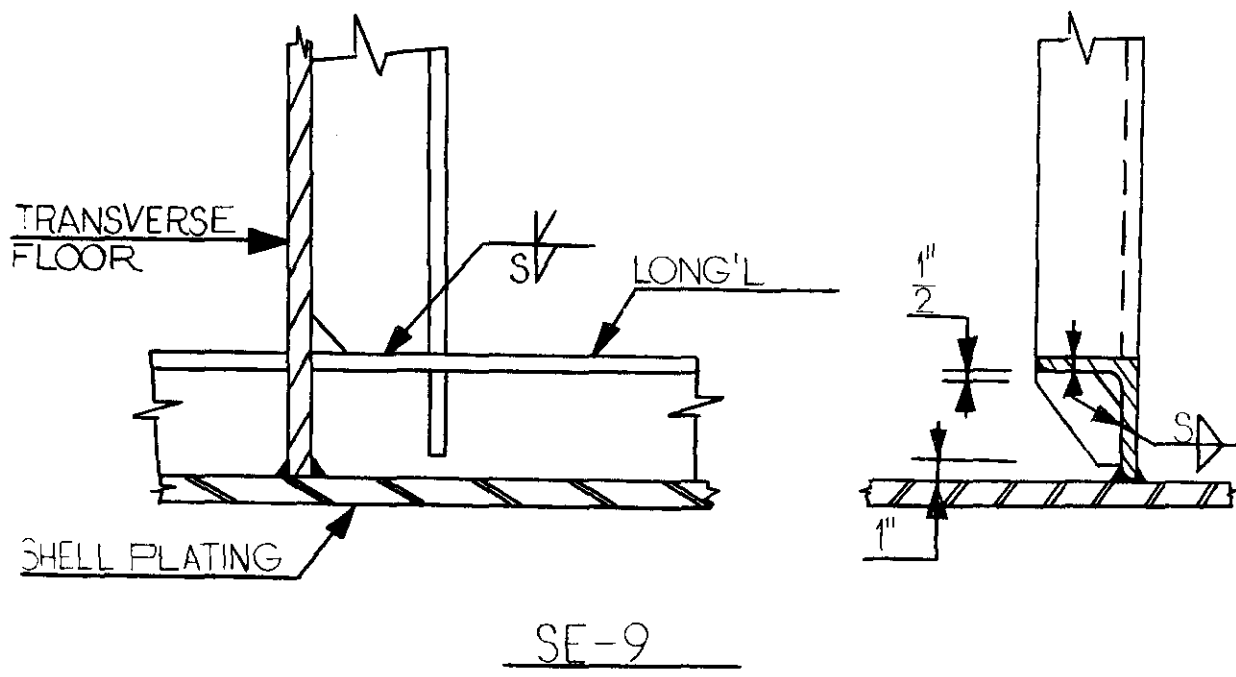
TRANSVERSE FLOOR

S

LONG'L

SHELL PLATING

$\frac{1''}{2}$

S

1"

SE-9

Detail Type: STIFFENER END CONDITION

Comments: This detail is used by Shipyard "U" on ship types "A" and "B" for rolled or fabricated angle stiffeners of transverse floors, supported by bottom shell longitudinals. This detail provides continuity at the end to resist shear and bending to the extent permitted by the intersecting shell longitudinal.
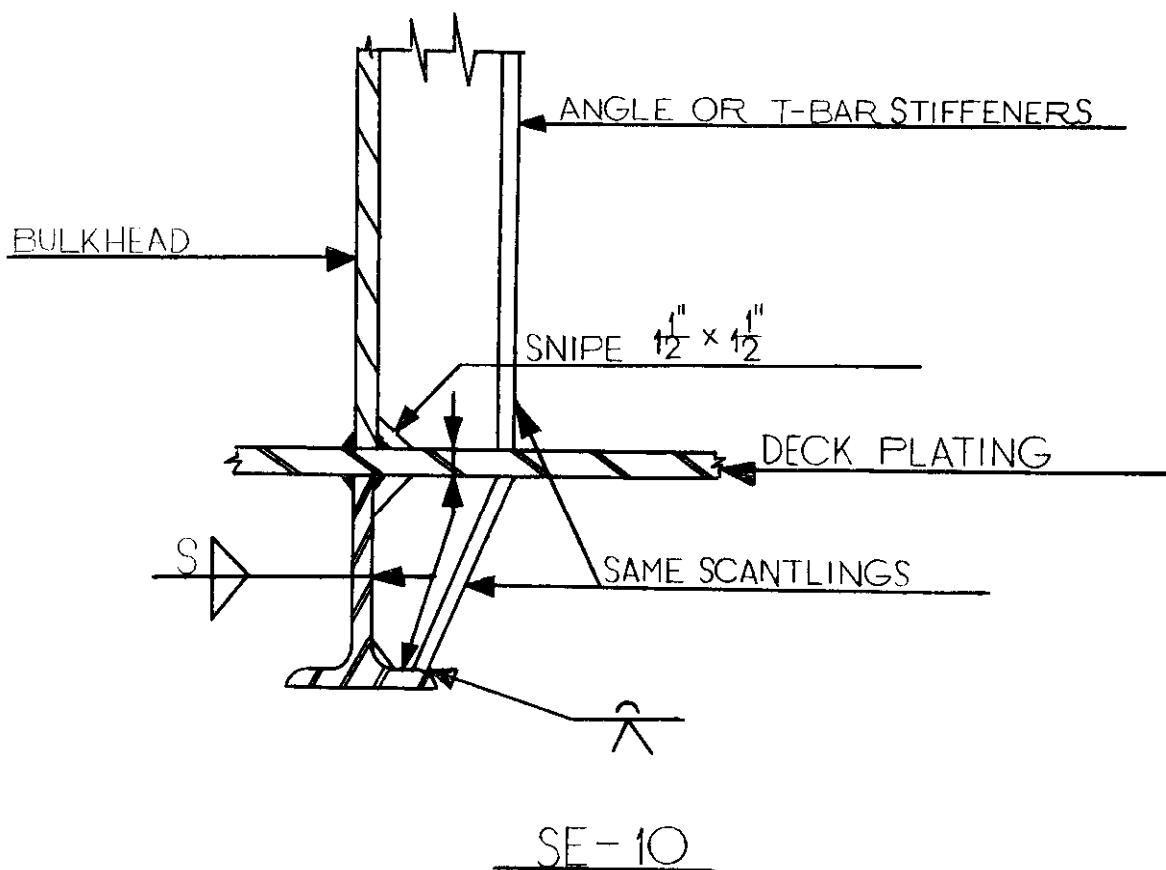
ANGLE OR T-BAR STIFFENERS

BULKHEAD

SNIPE $1\frac{1}{2}"$ × $1\frac{1}{2}"$

DECK PLATING

SAME SCANTLINGS

SE-10

Detail Type: STIFFENER END CONDITION

Comments: This detail is used by Shipyards "V" and "Z" on ship types "F" and "K" for watertight and deep tank bulkheads on Navy vessels. Detail provides good shear connection, and end fixity dependent on torsional rigidity of the bottom member.
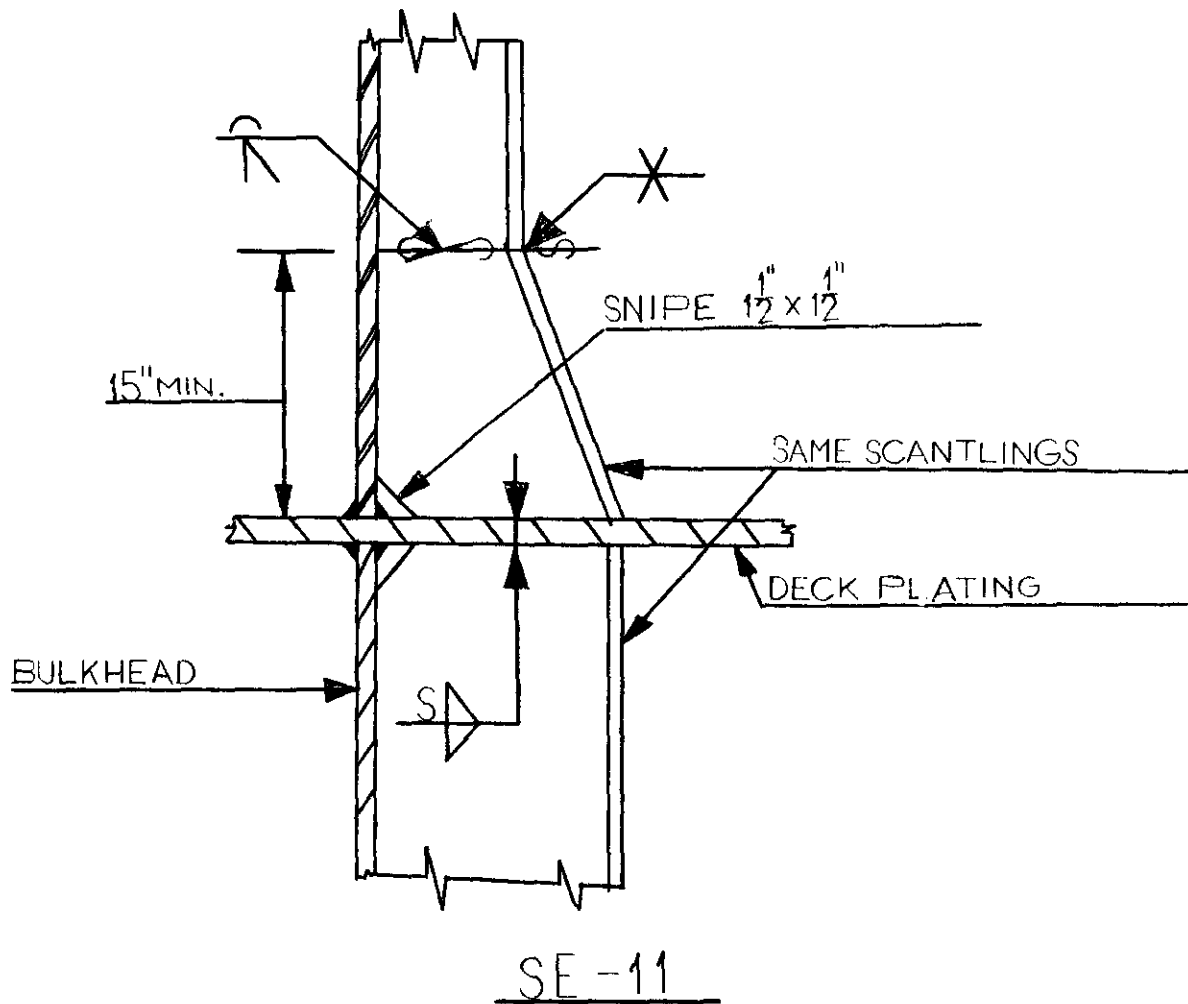
SNIPE $1\frac{1}{2}'' \times 1\frac{1}{2}''$

SAME SCANTLINGS

DECK PLATING

15" MIN.

BULKHEAD

SE-11

Detail Type: STIFFENER END CONDITION

Comments: This detail is used by Shipyards "V" and "Z" on ship types "F" and "K" for watertight and deep tank bulkhead rolled or fabricated angle and tee stiffeners where structural continuity must be maintained. This detail is common to Navy ship design. The flange of the make-up piece may have to be tapered to assure continuity.
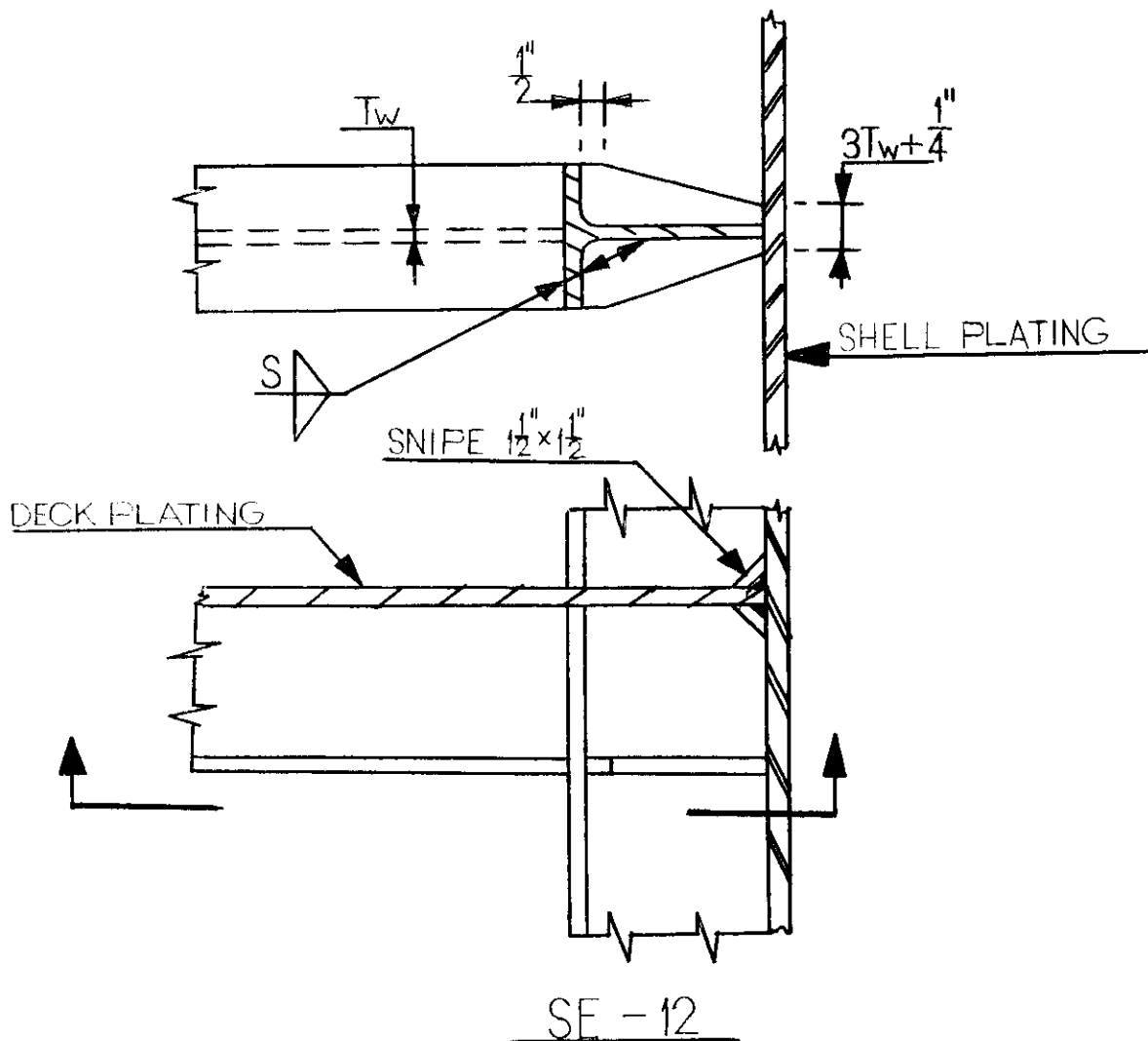
$\frac{1}{2}''$

T_W

$3T_W + \frac{1}{4}''$

SHELL PLATING

S

SNIPE $1\frac{1}{2}'' \times 1\frac{1}{2}''$

DECK PLATING

SE - 12

Detail Type: STIFFENER END CONDITION

Comments: This detail is used by Shipyards "V" and "Z" on ship types "F" and
                "K" for the intersection between longitudinal deck beams and
                vertical stiffeners on transverse bulkheads or vice versa. The
                detail is used on Navy vessels with rolled or fabricated tee beam
                sections where continuity must be maintained.

                Chock would be easier to fit if configured as in SE-9.

3-104

BHD

S

T_w

60°

THICKNESS: T_w

$\frac{1}{2}$"

FLANGE + $\frac{3}{4}$"

W

$\frac{1}{2}$"

1"
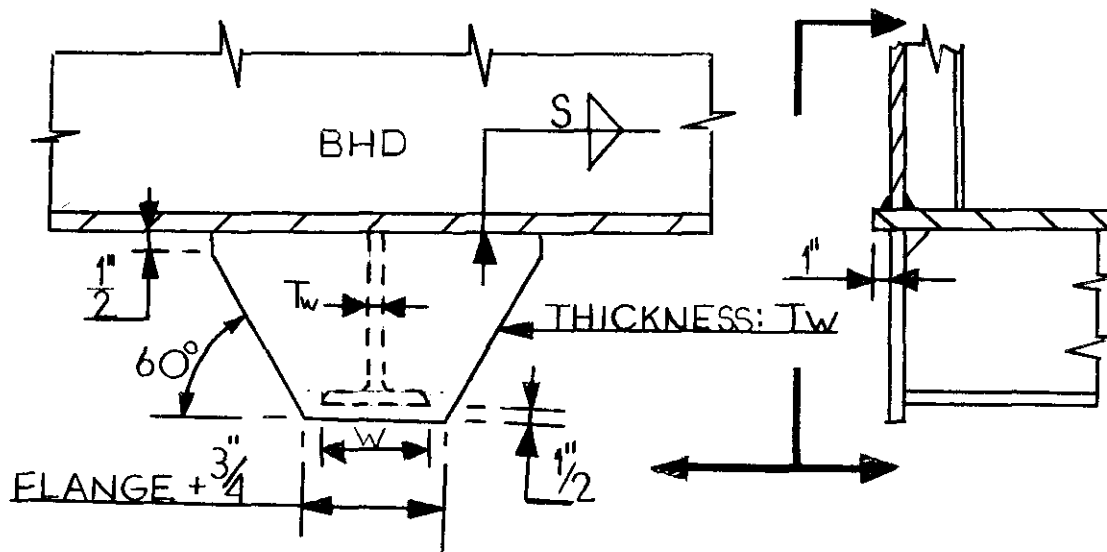
SE-13

Detail Type: STIFFENER END CONDITION (TERMINAL BRACKET)

Comments: This detail is used by Shipyard "Z" on ship type "K" for the
termination of a deck girder in way of a deck opening. This
detail is employed when hatch side girders and deck coamings
have been excluded, and the bracket must be under a bulkhead
or other structure capable of supporting the end shear reaction.

SAME SCANTLINGS

1"

DECK PLATING

S

½

1"
½

A

A

S

1½" × 1½"

A

45°

½"

½"

BULKHEAD

SAME SCANTLINGS

A-A
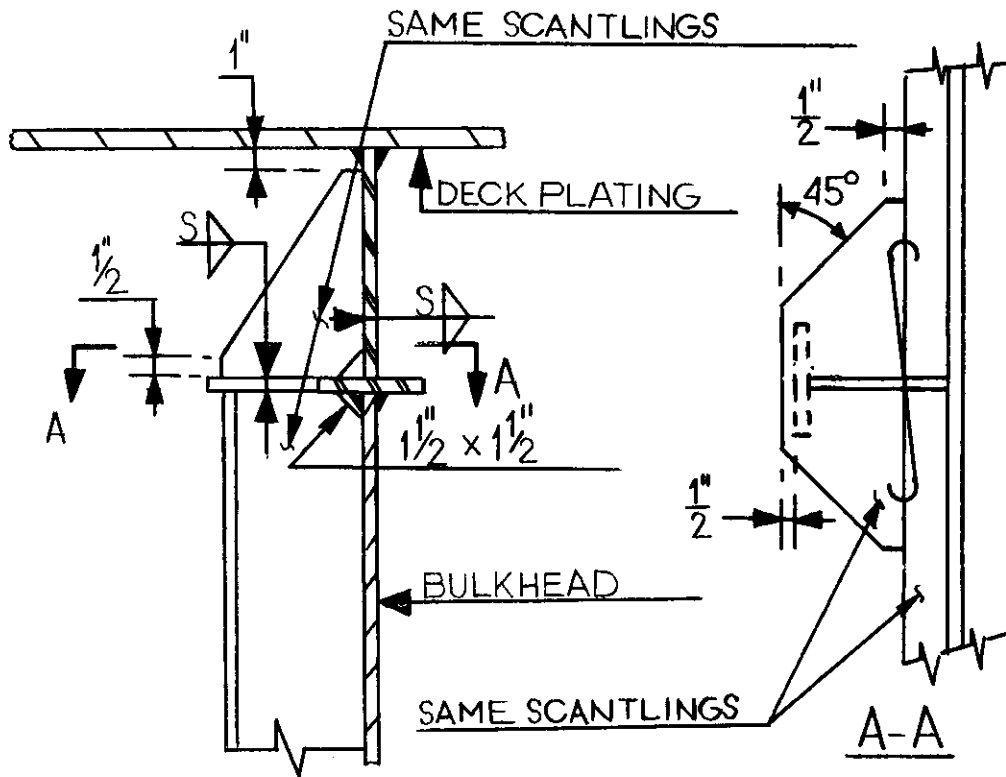
SE-14

Detail Type: STIFFENER END CONDITION

Comments: This detail was prepared for the CASDOS library for use on Navy
vessels. The detail is used for rolled or fabricated tee section
bulkhead stiffeners. This detail occurs where bulkheads are
installed below deck girders, but provides limited shear transfer
or end fixity.
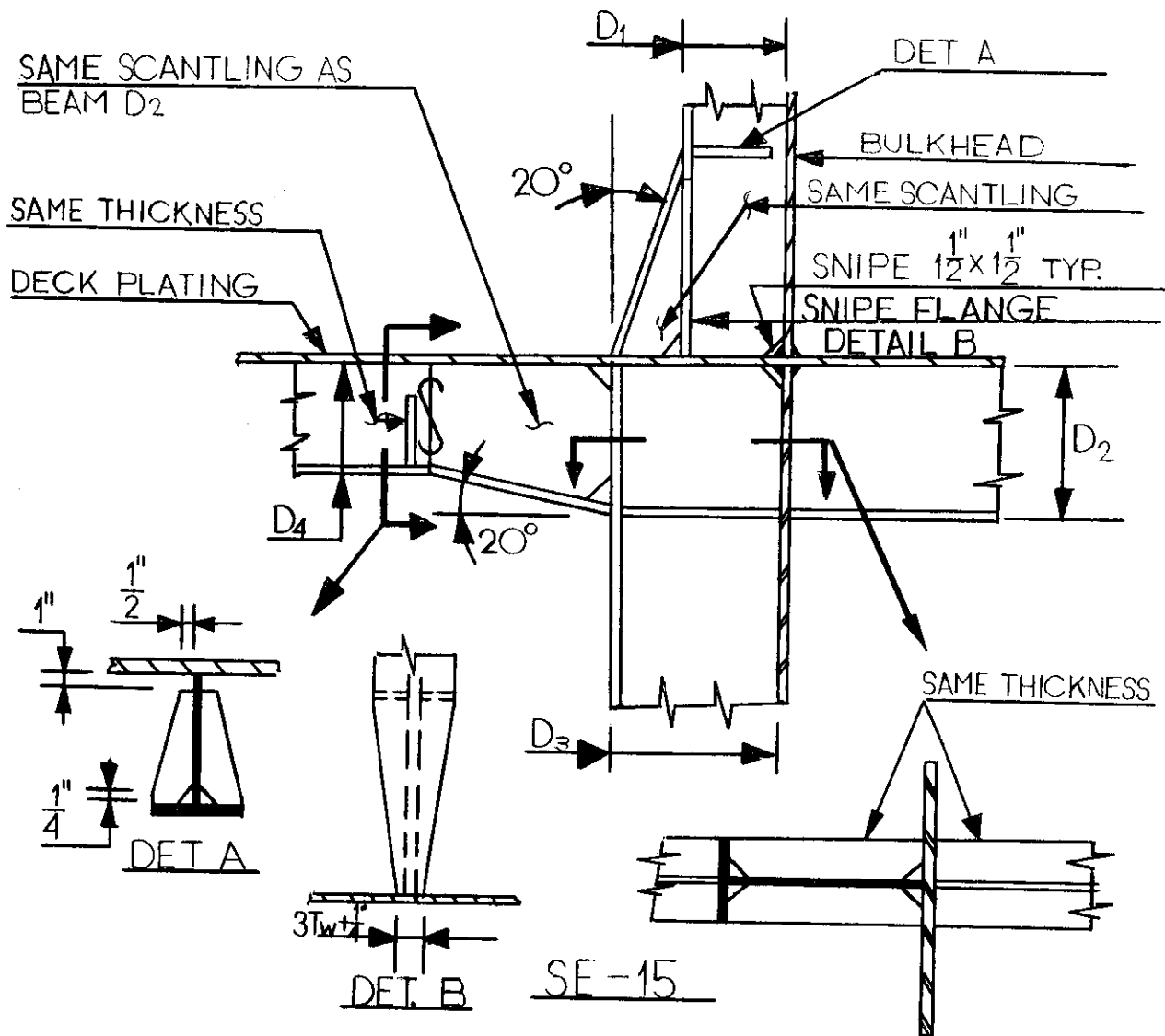
SAME SCANTLING AS
BEAM D_2

SAME THICKNESS

DECK PLATING

D_1

DET A

$20°$

BULKHEAD

SAME SCANTLING

SNIPE $1\frac{1}{2}" \times 1\frac{1}{2}"$ TYP.

SNIPE FLANGE
DETAIL B

D_2

D_4

$20°$

$\frac{1"}{2}$

$1"$

$\frac{1"}{4}$

DET A

$3T_w + \frac{1}{4}"$

D_3

SAME THICKNESS

DET B

SE-15

Detail Type: STIFFENER END CONDITION

Comments: This detail was prepared for the CASDOS library of standard details for use on Navy vessels. It is used in way of intercostal deck members and intercostal bulkhead stiffeners.
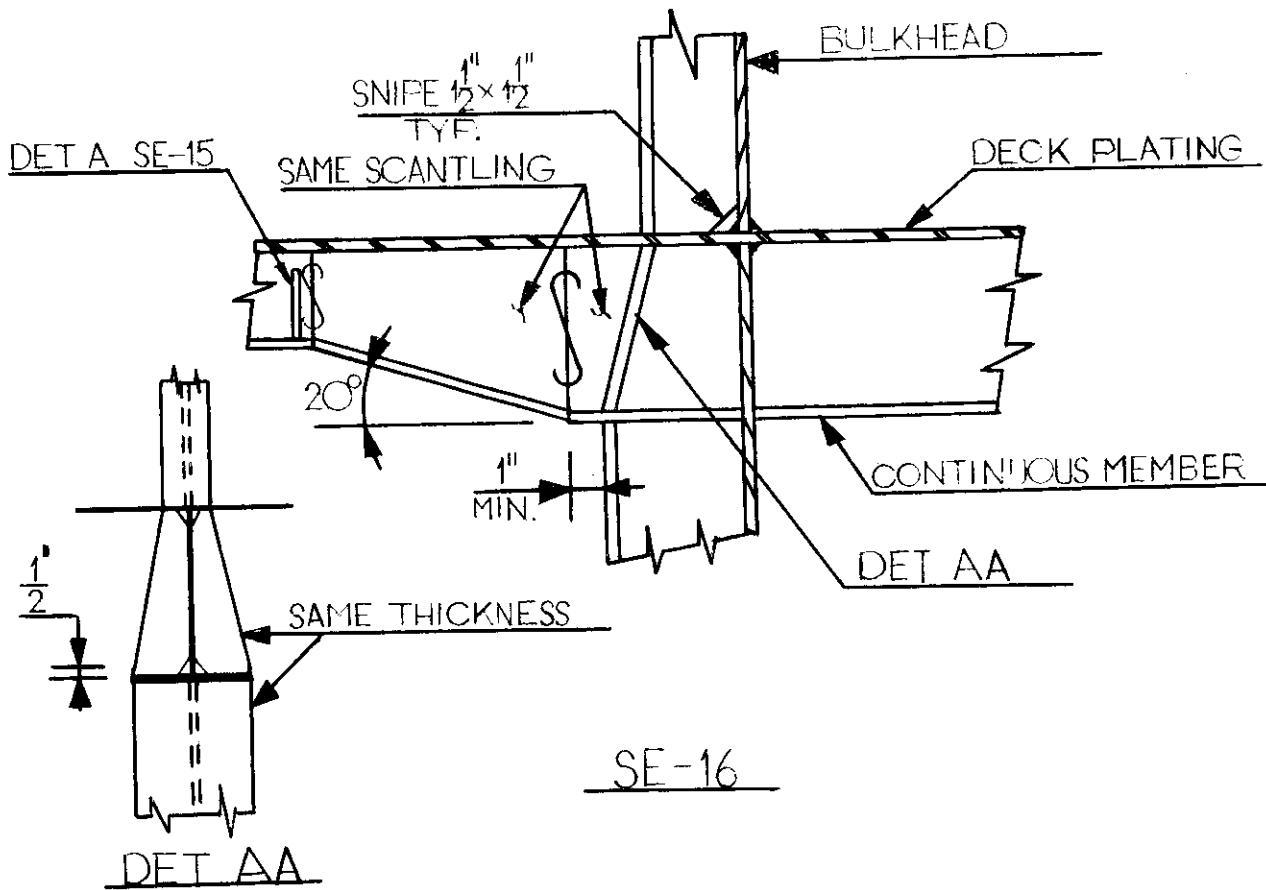
DET A SE-15

SNIPE $1\frac{1}{2}$" × $1\frac{1}{2}$" TYP.

SAME SCANTLING

BULKHEAD

DECK PLATING

20°

1" MIN.

CONTINUOUS MEMBER

DET AA

$\frac{1}{2}$"

SAME THICKNESS

SE-16

DET AA

Detail Type: STIFFENER END CONDITION

Comments: This detail was prepared for the CASDOS library of standard details for use on Navy vessels. This detail is used in way of continuous deck members and intercostal bulkhead stiffeners.
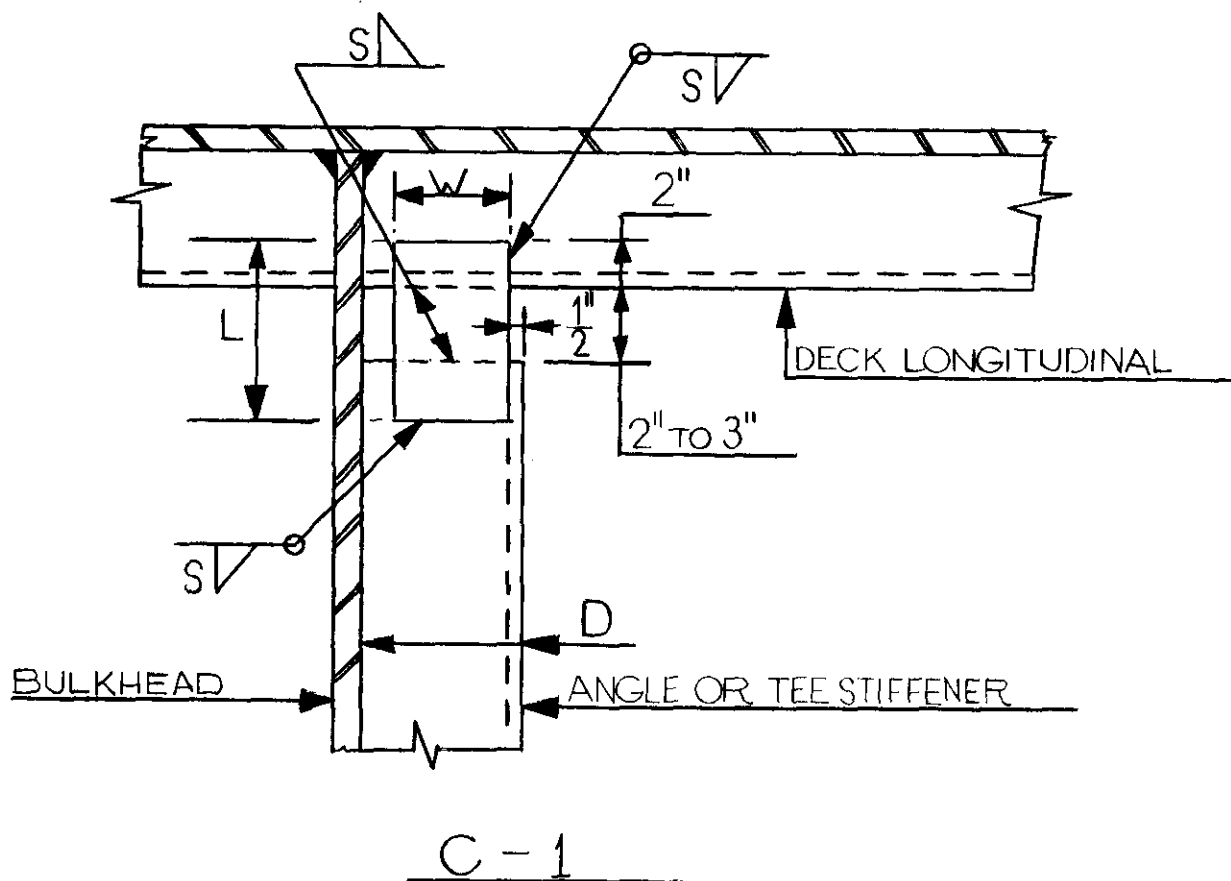
C – 1

Detail Type: CLIP CONNECTION

Comments: This detail is used by Shipyards "U", "W" and "X" on ship types
                "A", "B", "G" and "H" for rolled or fabricated angle or tee
                stiffeners for watertight or deep tank bulkheads. Clips are
                utilized when a small degree of fixity is required at the ends.
                This detail occurs at the top of the bulkhead stiffener, where it
                is attached to a longitudinal deck member. The thickness of the
                clip is dependent on the shear, but the thickness must be no less
                than the web thickness. Clip dimensions are determined by the
                following method: L = 8", W = D - 3".

Detail Count: Ship Type "A" = 240; Ship Type "B" = 4540

Manhours Required to Complete Typical Detail: 1. 2

Typical Scantlings: Clip Size - L = 8", W = 5"; Stiffener - 8" x 4" x 1/2"∠
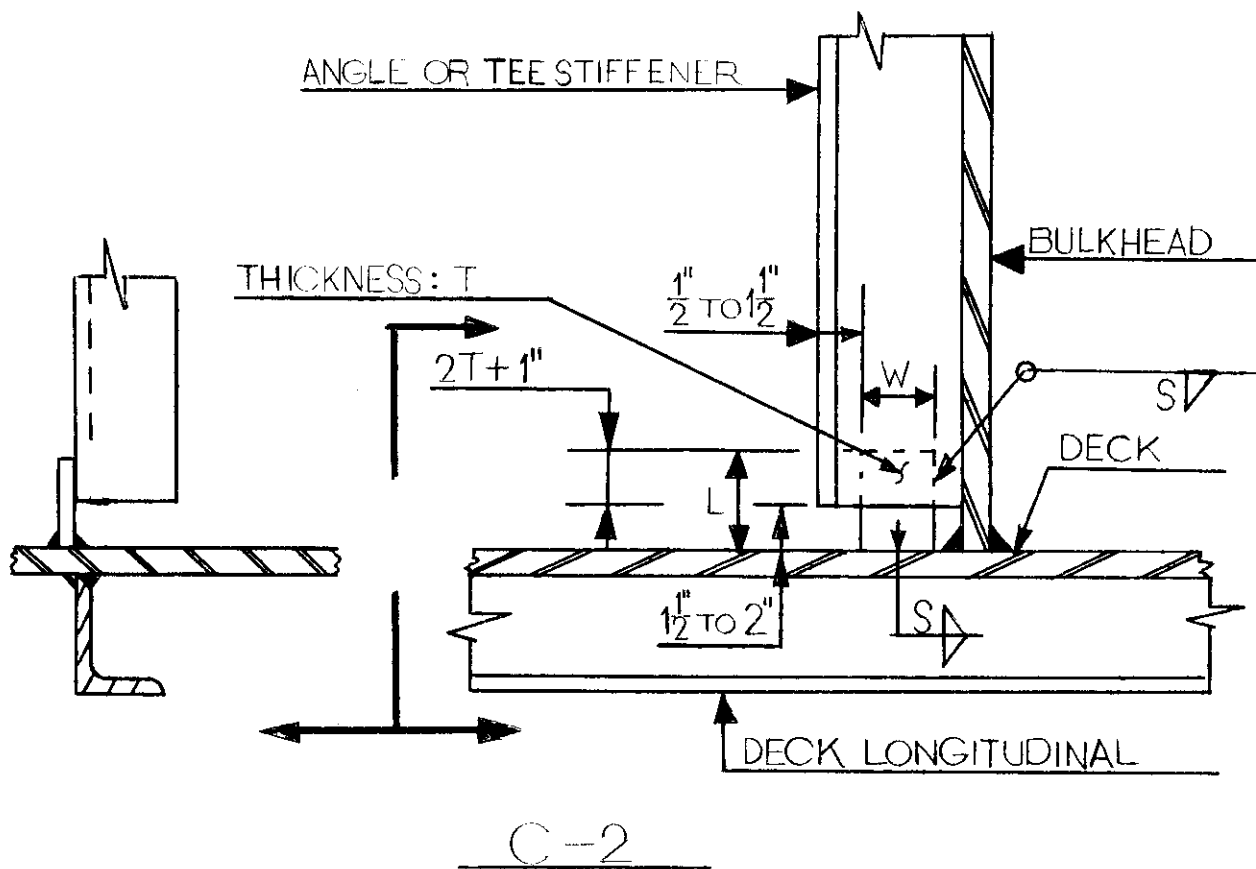
ANGLE OR TEE STIFFENER

THICKNESS: T

BULKHEAD

$\frac{1}{2}''$ TO $1\frac{1}{2}''$

W

$2T+1''$

S

DECK

L

$1\frac{1}{2}''$ TO $2''$

S

DECK LONGITUDINAL

C-2

Detail Type: CLIP CONNECTION

Comments: This detail is used by Shipyards "U", "W", "X" and "Y" on ship
types "A", "B", "G", "H" and "J" for rolled or fabricated angle
and tee stiffeners for watertight or deep tank bulkheads.   This
detail is similar to C-1, except that the clip is welded to the deck
and L = 6". This detail eases fit-up, however, the clip is not backed
up by the deck longitudinal.

Detail Count: Ship Type "A" = 400; Ship Type "B" = 2550

Manhours Required to Complete Typical Detail: 0. 7

Typical Scantlings: Clip Size - L = 6", W = 5"; Stiffener - 8" x 4" x 1/2" /.

C-3
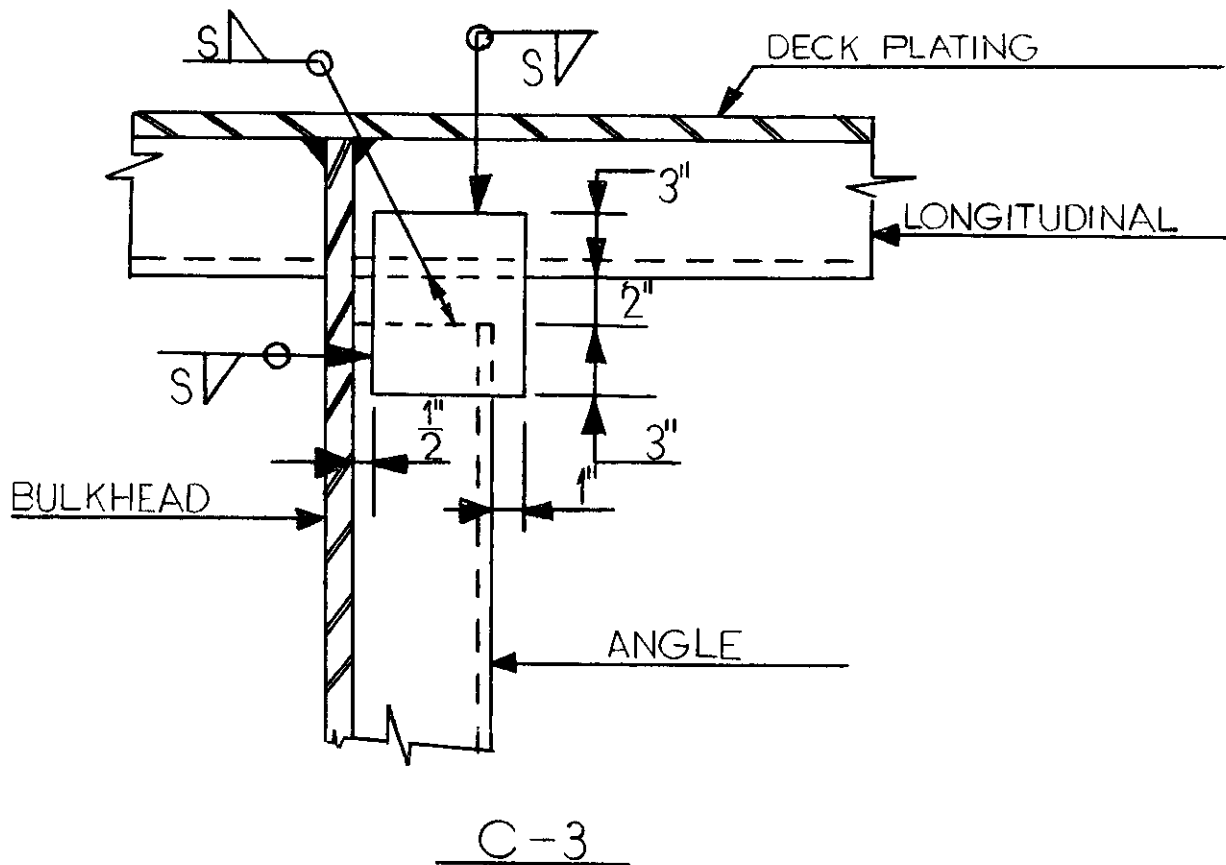
Detail Type: CLIP CONNECTION

Comments: This detail is used by Shipyard "Y" on ship type "J" for upper end of rolled or fabricated angle stiffeners on watertight or deep tank bulkheads, where shear carrying capacity is a major design consideration.   For additional comments see C-1.   The 1/2 in. space is too narrow for easy welding.   Modification to the shape shown in detail B-11 would improve weldability.

SNIPE $1\frac{1}{2}" \times 1\frac{1}{2}"$ TO $2" \times 2"$

CH-1
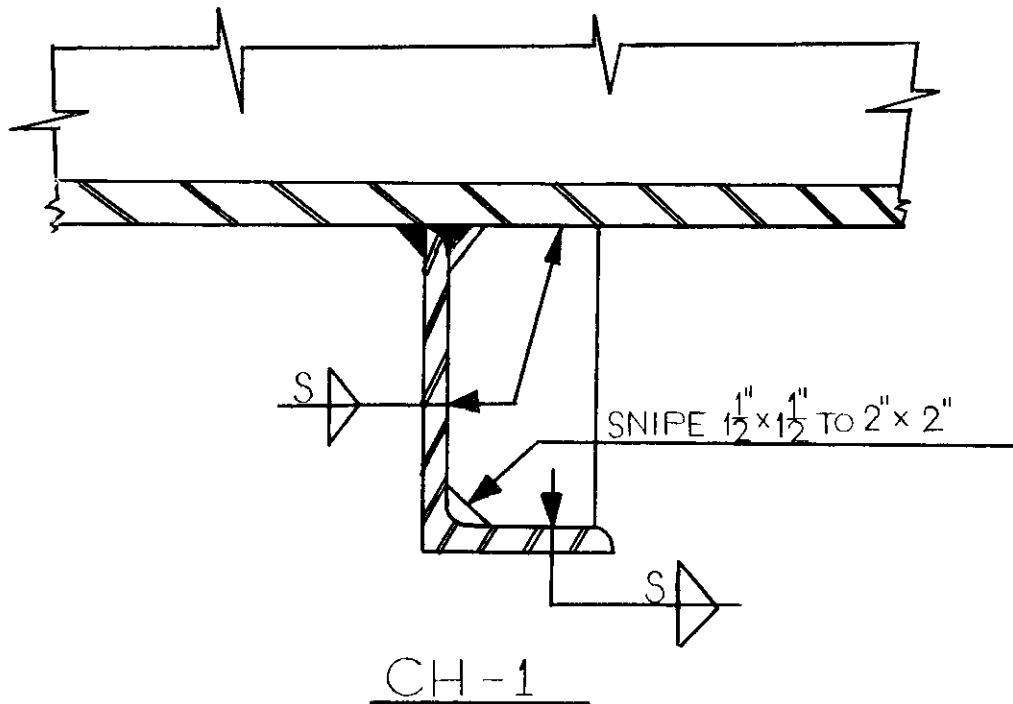
Detail Type: CHOCK

Comments: This detail is used by Shipyards "U", "W" and "X" on ship types "A", "B", "G" and "H" and is in the CASDOS library of standard details.   This detail is used on deck, shell and bulkhead long-itudinals as a tripping bracket or as a support point in way of equipment foundations.   For rolled or fabricated angles.
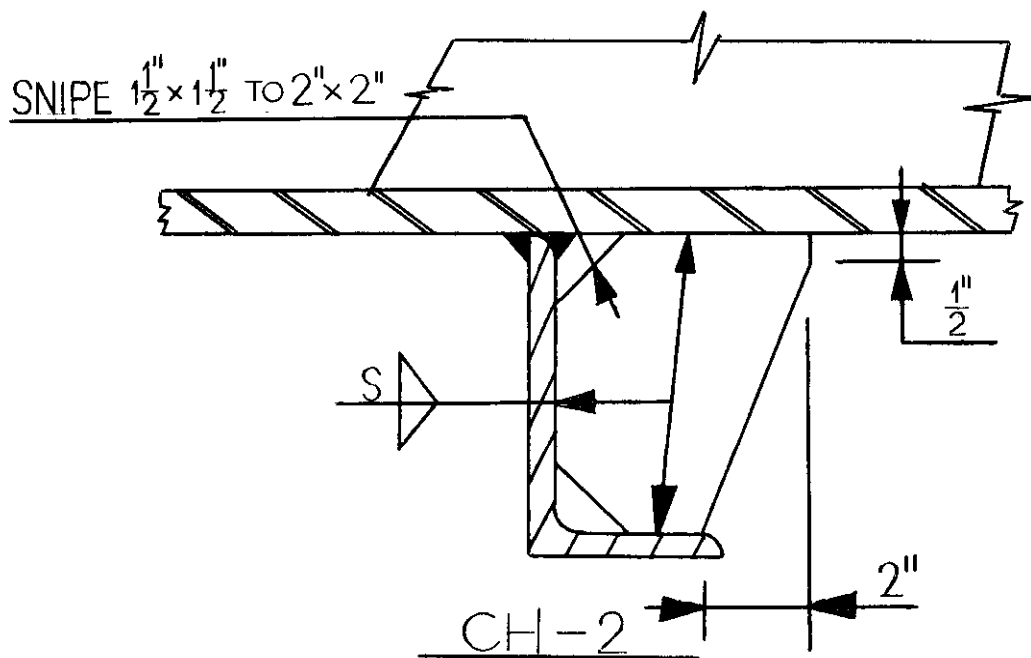
SNIPE $1\frac{1}{2}'' \times 1\frac{1}{2}''$ TO $2'' \times 2''$

$\frac{1}{2}''$

S

CH-2

$2''$

Detail Type: CHOCK

Comments: This detail is used by Shipyards "U", "W" and "X" on ship types "A", "B", "G" and "H".   For additional comments see CH-1.

Detail Count: Ship Type "A" = 120;   Ship Type "B" = 2070

Manhours Required to Complete Typical Detail: 2. 0

Typical Scantlings: 10" x 1/2" - 6-3/16" x 1/2" ∠

3-113

DECK PLATING

2T+1"

THICKNESS: T

S

SNIPE 1½" × 1½"

C-L

S

CH-3
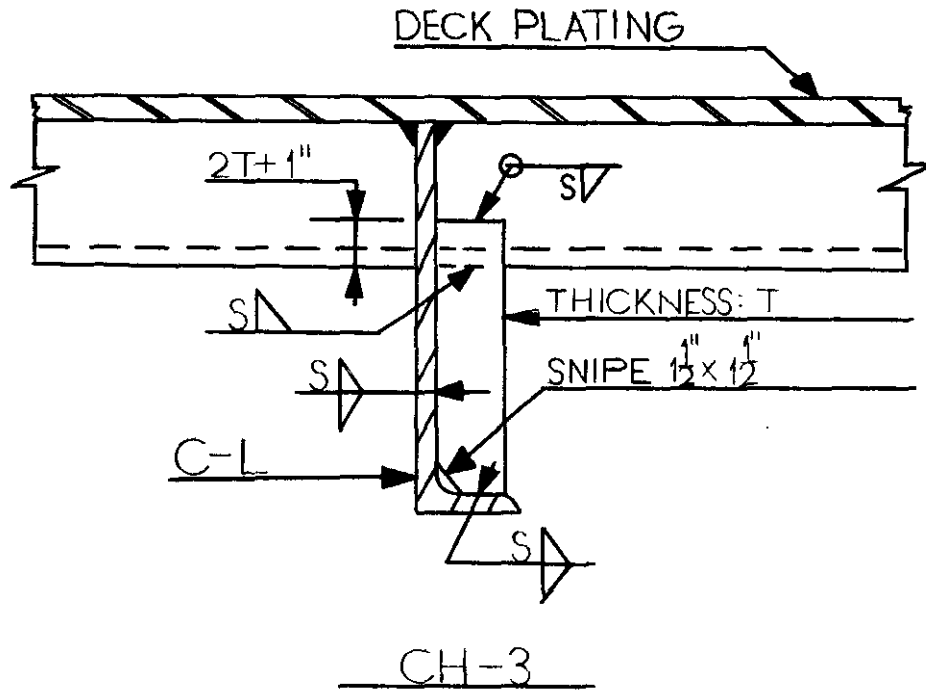
Detail Type: CHOCK

Comments: This detail is used by Shipyard "Z" on ship type "K" for longitudinal
             and transverse framing member intersections. This detail may be
             used on rolled or fabricated angles or tee sections, as a tripping
             bracket. Detail CH-5 is recommended in lieu of above detail
             because of possible fitting and welding problems.

3-114

DECK PLATING

$S\nabla$

$2T + 1''$

$1\frac{1}{2}''$ RADIUS

$S\triangle$

$S\triangleright$

THICKNESS : T

C-L

SNIPE $1\frac{1}{2}'' \times 1\frac{1}{2}''$

CH-4
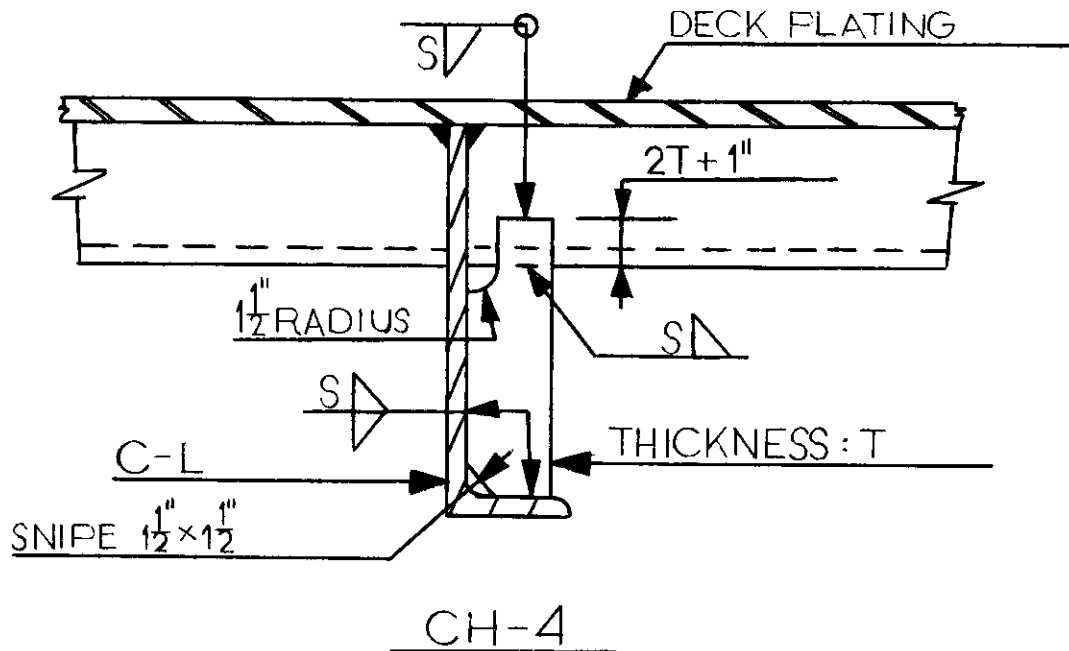
Detail Type: CHOCK

Comments: This detail is used by Shipyards "U" and "Z" on ship types "A" and
               "K" for longitudinal and transverse framing member intersections.
               For additional comments see CH-3. CH-5 is a better detail.

Detail Count Ship Type "A":   430

Manhours Required to Complete Typical Detail: 2.0

Typical Scantlings: 12" x 6" x 1/2" Chock.

DECK PLATING

3"

S

ANGLE OR FLAT BAR   1" TO 2"

S

2$\frac{1}{4}$"

$\frac{3}{4}$" RADIUS

SNIPE 1$\frac{1}{2}$"x1$\frac{1}{2}$" TO 2"x2"

S

S

CH-5
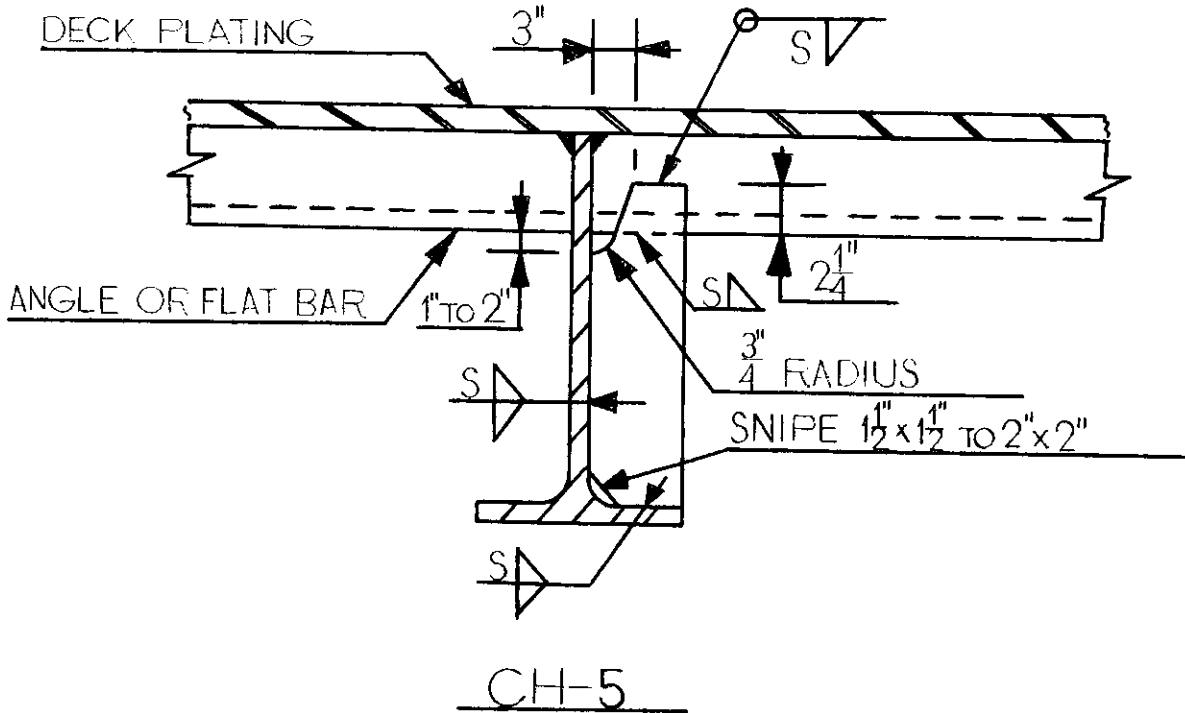
Detail Type: CHOCK

Comments: This detail is used by Shipyard "U" on ship type "B" as a web stiffener and flange stability chock for rolled or fabricated tee sections.   Used for longitudinal or transverse deck girders.   This detail has better weld accessibility than CH-3 and CH-4

DECK PLATING

CH-6
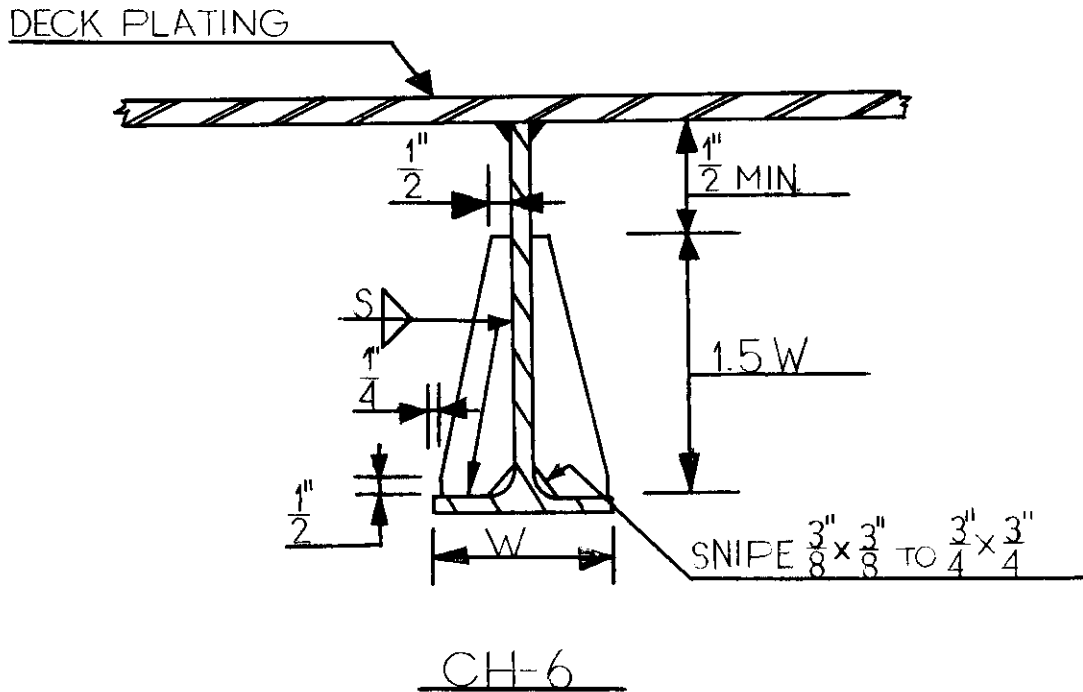
Detail Type: CHOCK

Comments: This detail is used by Shipyards "U", "V" and "Z" on ship types
               "A", "B", "F" and "K".   It is the same as CH-8 except it is used
               when the depth of the member is 1-1/2 times or greater than the
               width of the flange.   For additional comments see CH-8.

Detail Count: Ship Type "A" = 1050; Ship Type "B" = 3700

Manhours Required to Complete Typical Detail: 3.8

Typical Scantlings: Chock plate, 18" x 6" x 3/4".

3-117

DECK PLATING

SNIPE 1½"×1½" TO 2"× 2"

S ▷

¼" TO ½"

S ▷

CH-7
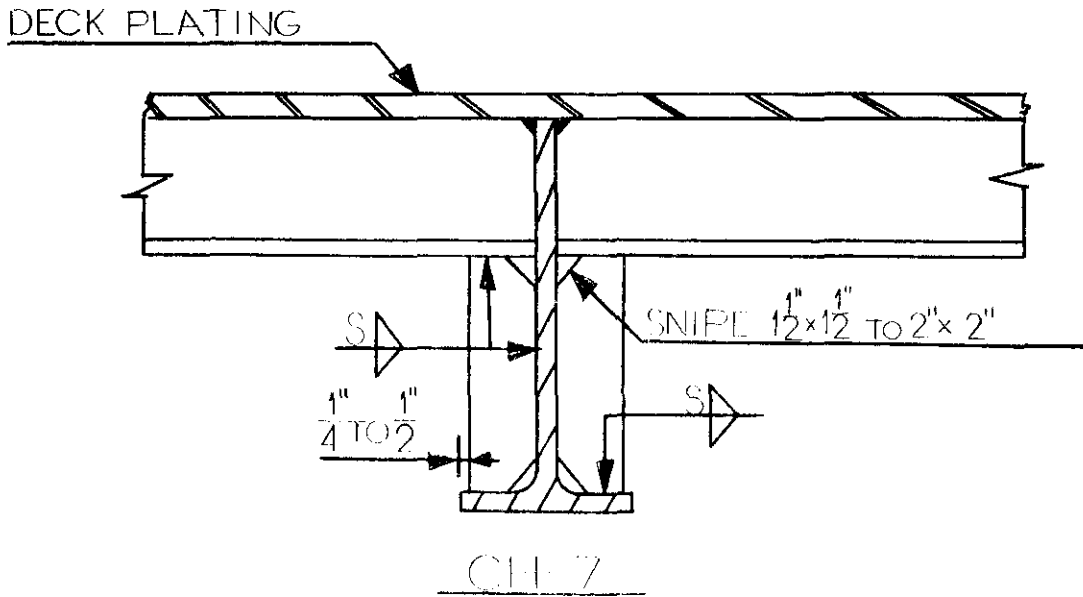
Detail Type: CHOCK

Comments: This detail is used by Shipyards "U", "V" and "Z" on ship types
                "A", "B", "D", "F" and "K" for longitudinal and transverse
                framing member intersections. This detail is applicable to rolled
                or fabricated tee sections.

Detail Count: Ship Type "A" = 120; Ship Type "B" = 10

Manhours Required to Complete Typical Detail: 3.5

Typical Scantlings: Chock plates, 7" x 6" x 1/2".

DECK PLATING

$\frac{1}{8}$" TO $\frac{1}{2}$"

$\frac{1}{2}$" TO 1"

$\frac{1}{4}$" TO $\frac{1}{2}$"

S

D < 1.5H

H

SNIPE 1$\frac{1}{2}$"×1$\frac{1}{2}$" TO 2"×2"

CH-8
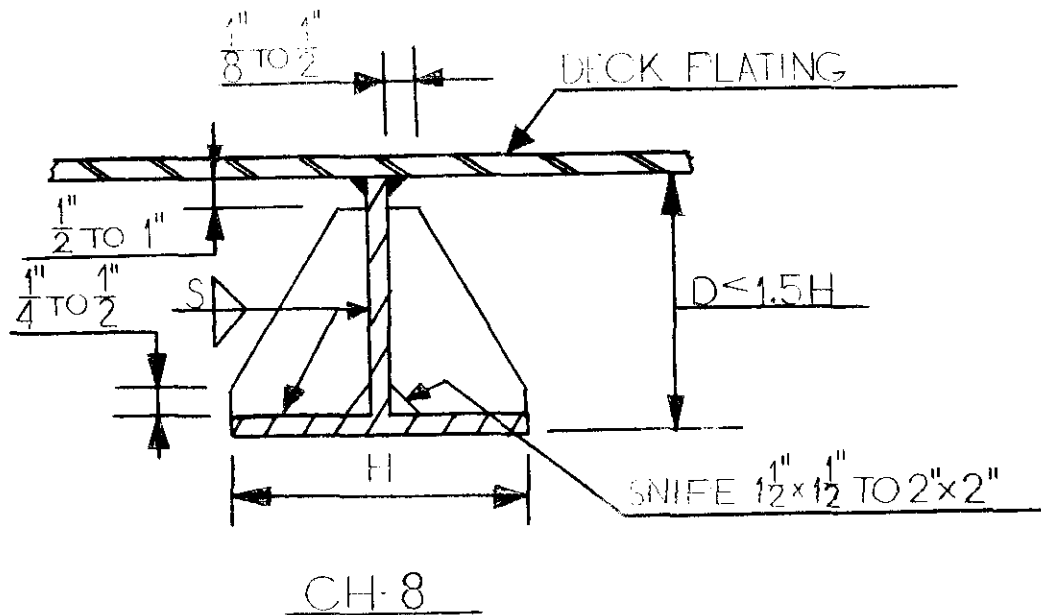
Detail Type: CHOCK

Comments: This detail is used by Shipyards "U", "W" and "X" on ship types
"B", "D", "A", "G" and "H" and it is in the CASDOS library. The
detail is used as a flange stability chock for longitudinal and
transverse deck girders, for both rolled and fabricated tee sections.
This detail is used when the depth of the member is less than
1-1/2 times the flange width.

3-119

BULKHEAD

ANGLE, FLAT
BAR OR TEE

DECK PLATING

W

$\frac{1"}{2}$

S

SNIPE $1\frac{1"}{2} \times 1\frac{1"}{2}$

1.5 TO 2W

S

CH-9
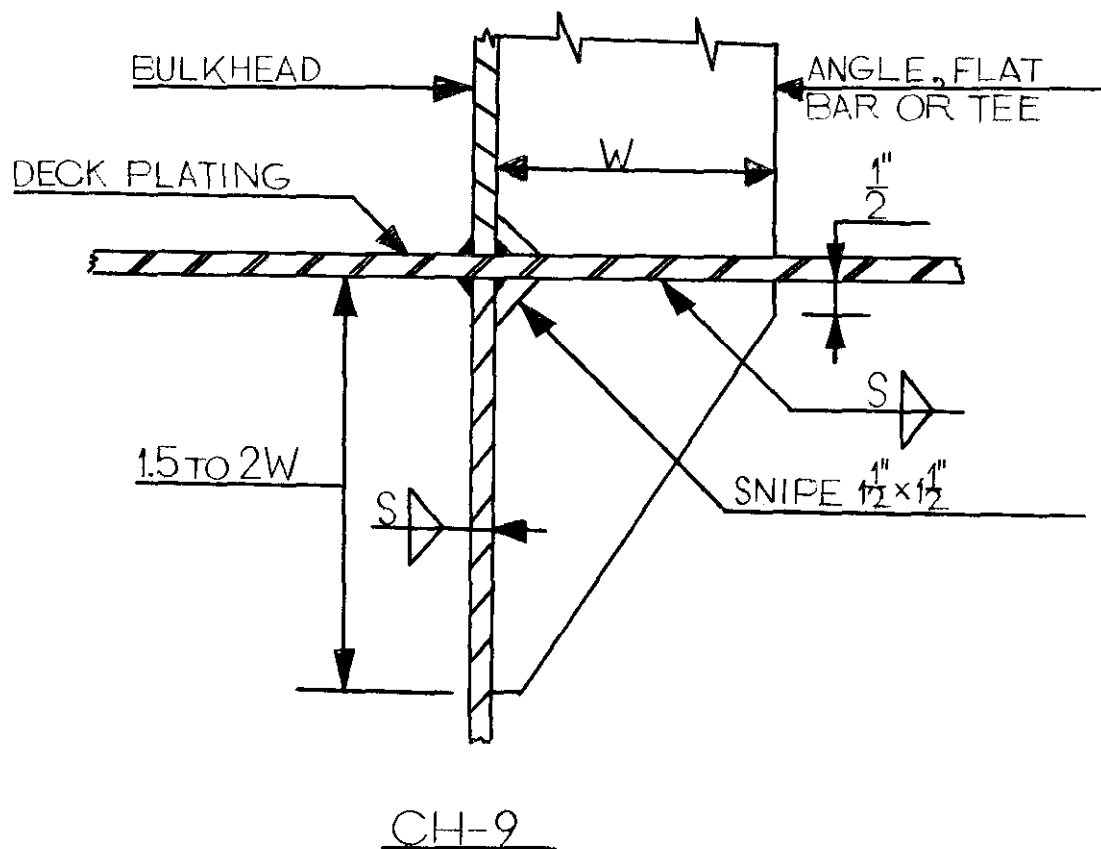
Detail Type: CHOCK (BRACKET)

Comments: This detail is used by Shipyards "U", "W" and "X" on ship types
"A", "B", "G" and "K" for bulkhead stiffener web endings. It is
applicable to flat bars, and rolled and fabricated angles and tee
sections with sniped flanges which end on plating with non back-up
structure.

Detail Count: Ship Type "A" = 230; Ship Type "B" = 800

Manhours Required to Complete Typical Detail: 1.8

Typical Scantlings: Chock, 15" x 10" x 1/2" Plate.

SHELL PLATING

DECK PLATING

SNIPE $1\tfrac{1}{2}" \times 1\tfrac{1}{2}"$

$\tfrac{1}{2}"$

$\tfrac{1}{2}"$ MIN.

$\tfrac{1}{8}"$ TO $\tfrac{1}{2}"$

$\tfrac{1}{8}"$ TO $\tfrac{1}{2}"$

W

1.5W

CH-10
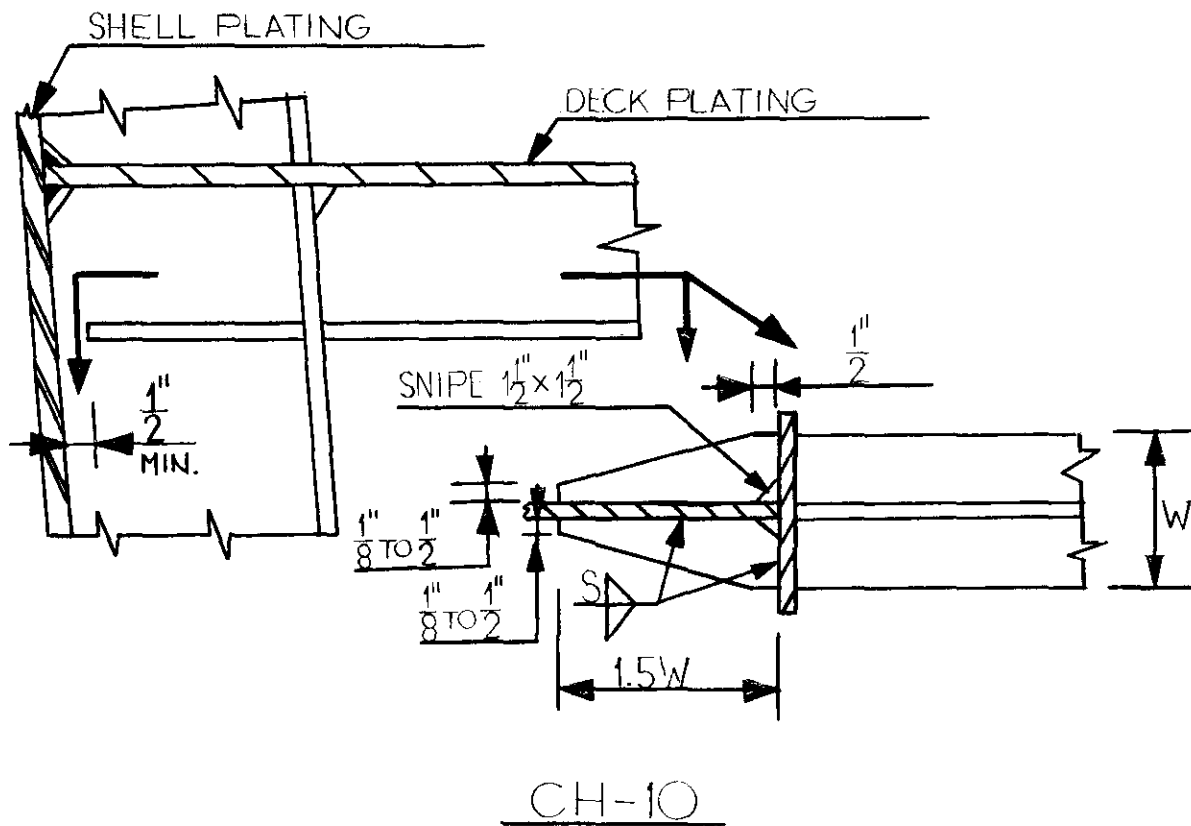
Detail Type: FLANGE CHOCK

Comments: This detail is used by Shipyards "U", "V", "W", "X" and "Z" on
ship types "A", "B", "D", "F", "G", "H" and "K" and is in the
CASDOS library of standard structural details. This detail occurs
at the intersection of a shell frame and a transverse deck girder.
A plate bracket is often fitted in the corner of the intersecting
members to eliminate the possibility of joint failure.

3-121

$$\underline{CH-11}$$
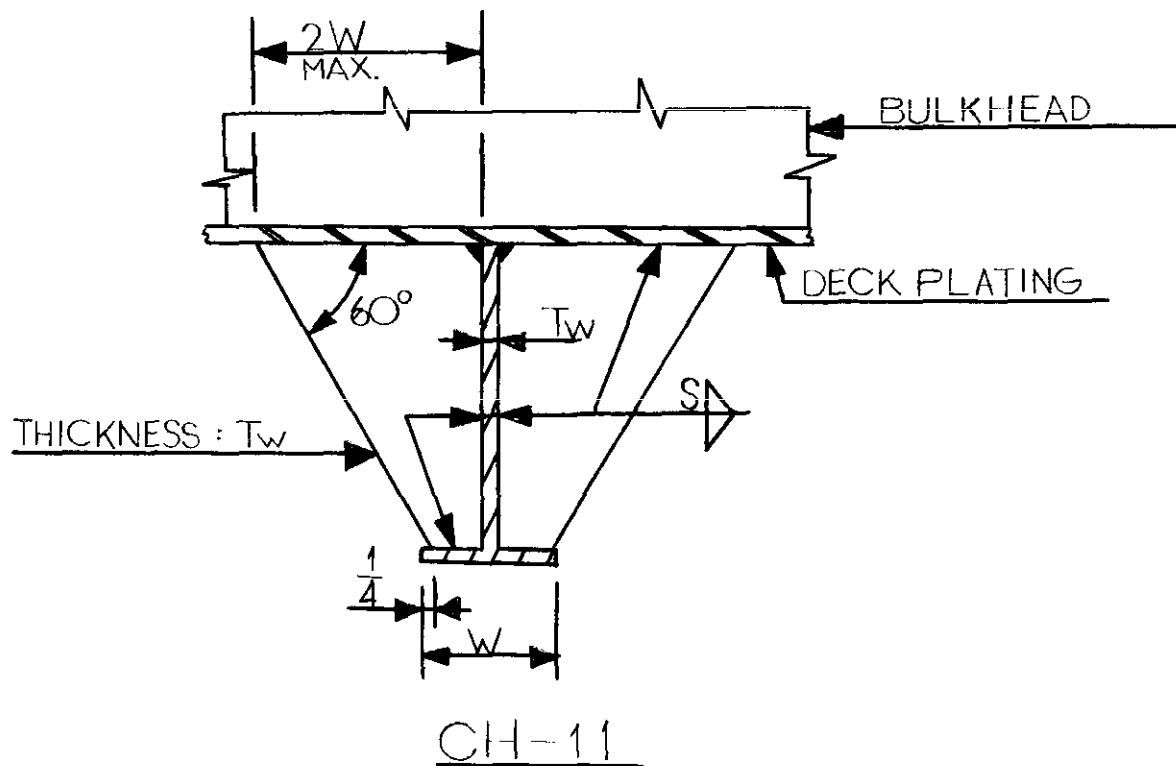
Detail Type: CHOCK (TRIPPING BRACKET)

Comments: This detail is used by Shipyard "U" on ship type "C" when a
longitudinal or transverse deck girder passes under a bulkhead.
This detail is applicable to rolled or fabricated tee sections.

INNER BOTTOM PLATING

1" TO 2"

0" TO 2"

CVK OR FLOOR

FLAT BAR

S

45°

BOTTOM SHELL PLATING

PS — 1

INNER BOTTOM PLATING

0" TO 2"

S

FLAT BAR OR ANGLE

CVK OR FLOOR

SNIPE $1\frac{1}{2}" \times 1\frac{1}{2}"$

S

0" TO 2"

PS — 2

FOR COMMENTARY SEE PG 3-124

Detail Type: PANEL STIFFENER: PS-1

Comments: Detail PS-1 is used by Shipyards "U", "V", "W" and "Y" on ship types "A", "G", "H" and "J" as panel stiffeners fitted on double bottom floors and center and side girders to prevent panel buckling. The scantlings of the stiffener must be a flat bar.

Detail Count Ship Type "A":   2450

Manhours Required to Complete Typical Detail: 3.4

Typical Scantlings: Flat bar - 6" x 1/2", length 84".

PS-2

Detail Type: PANEL STIFFENER (see pg. 3-123 for detail)

Comments: Detail PS-2 is used by Shipyards "U", "V", "W", and "Y" on
              ship types "A", "B", "G", "H" and "J" as panel stiffeners
              on tight double bottom floors to prevent panel buckling and to
              support lateral loading. The stiffener may be a flat bar or
              a rolled or fabricated section. Detail PS-2 (with no bottom
              gap) is based on civil engineering practice which recommends
              welding to the compression flange and eliminates the weld to
              the tension flange to improve fatigue life.

Detail Count Ship Type "A":   300

Manhours Required to Complete Typical Detail: 3.4

Typical Scantlings: Flat bar - 6" x 1/2", length 74".

INNER BOTTOM PLATING

1"

SNIPE $1\frac{1}{2}" \times 1\frac{1}{2}"$

ANGLE OR TEE

FLOOR

S

FLAT BAR

1"

45°

SHELL PLATING
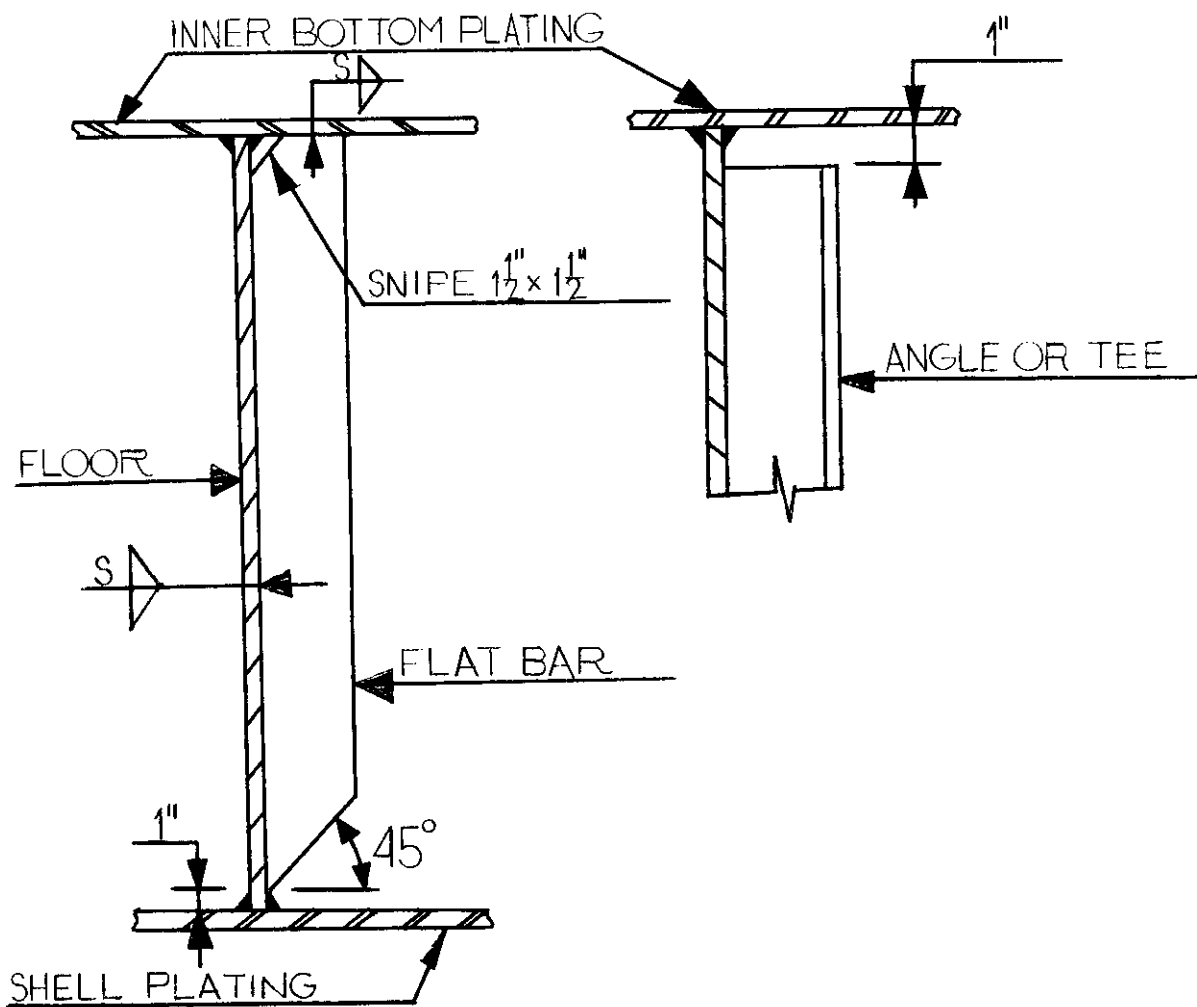
PS - 3

Detail Type: PANEL STIFFENER

Comments: This detail is used by Shipyard "Y" on ship type "J" as a panel
                     stiffener for double bottom floors. This detail is applicable to
                     flat bars, rolled or fabricated tee sections or angles. See PS-2
                     for additional comments.

BULKHEAD

0" TO 2"

C-L

SNIPE FLANGE
(30° TO 1") TO (45° TO 1½)

ANGLE OR TEE

S

PS-4
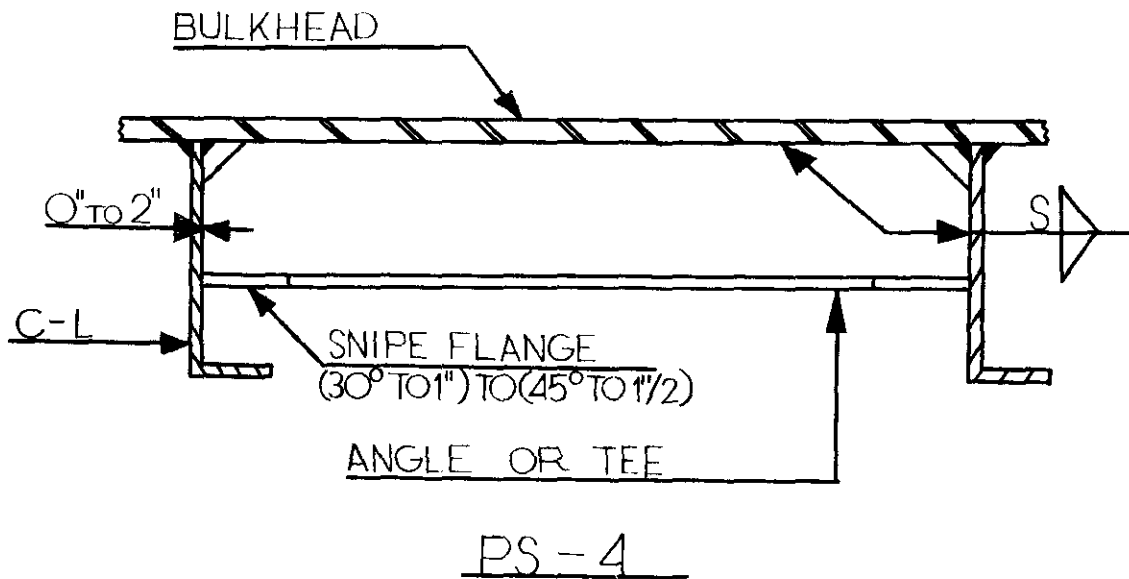
Detail Type: PANEL STIFFENER

Comments: This detail is used by Shipyards "U", "X", "W" and "Y" on ship
                types "A", "B", "D", "E", "G", "H" and "J" for rolled or fab-
                ricated tee sections or angles. Seldom used as a panel stiffener
                in commercial practice. When used as a header in way of bulk-
                head or deck openings it is the same depth as mating members.
                Commonly used as backup in way of foundations. Designed as a
                simply supported beam.

Detail Count Ship Type "A":   400

Manhours Required to Complete Typical Detail: 4. 0

Typical Scantlings: Header - 6" x 4" x 1/2" ∠ , 33" long.

3-126

SNIFE $1\frac{1}{2}" \times 1\frac{1}{2}"$

S

S

D>6"

SAME SCANTLING

PS-5

T_w

$3T_w + \frac{1}{4}"$

$\frac{1}{2}$

A-A

A

A

SNIPE $1\frac{1}{2}" \times 1\frac{1}{2}"$

S

D

A

D

SAME SCANTLING

USE WHERE W IS D/2 OR LESS

W

PS — 6
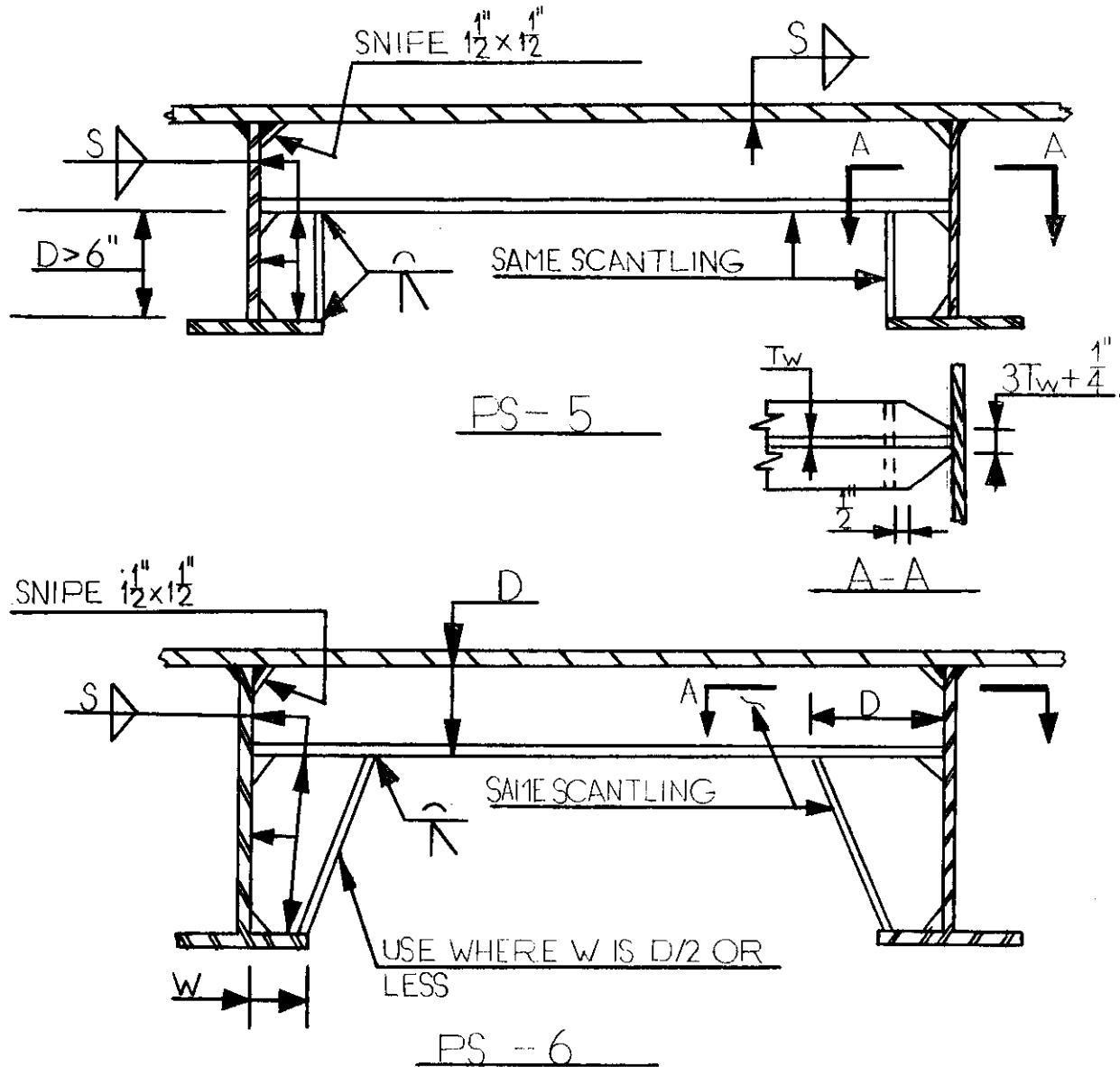
Detail Type: PANEL STIFFENER

Comments: These details are used by Shipyard "Z" on ship type "K" as supports under heavy equipment foundations. They are used primarily on Navy ships. The brackets at the end of the stiffeners will provide flange stability.

3-127

SNIPE $1\frac{1}{2}'' \times 1\frac{1}{2}''$ SAME THICKNESS

S

FLAT BAR OR TEE

OR
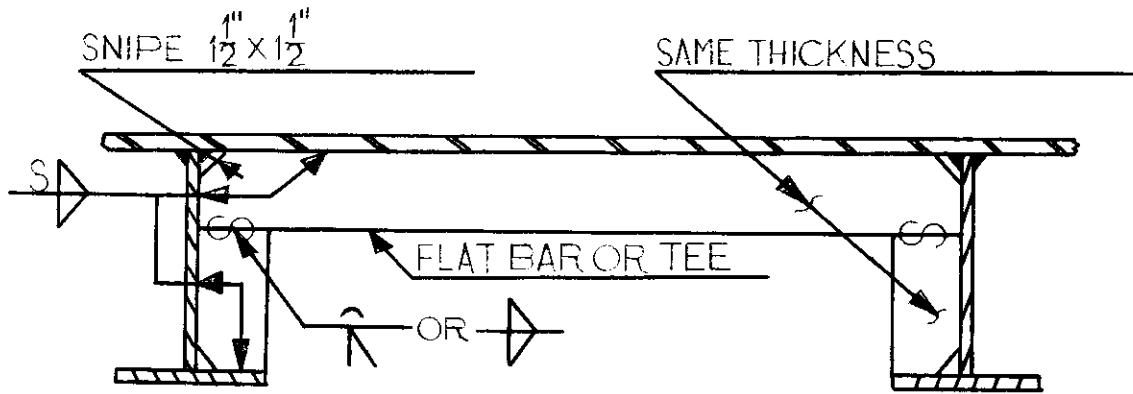
PS - 7

Detail Type: PANEL STIFFENER

Comments: This detail is used by Shipyard "Z" on ship type "K" to stabilize
                 compression panels and provide support for light loads or
                 foundations.
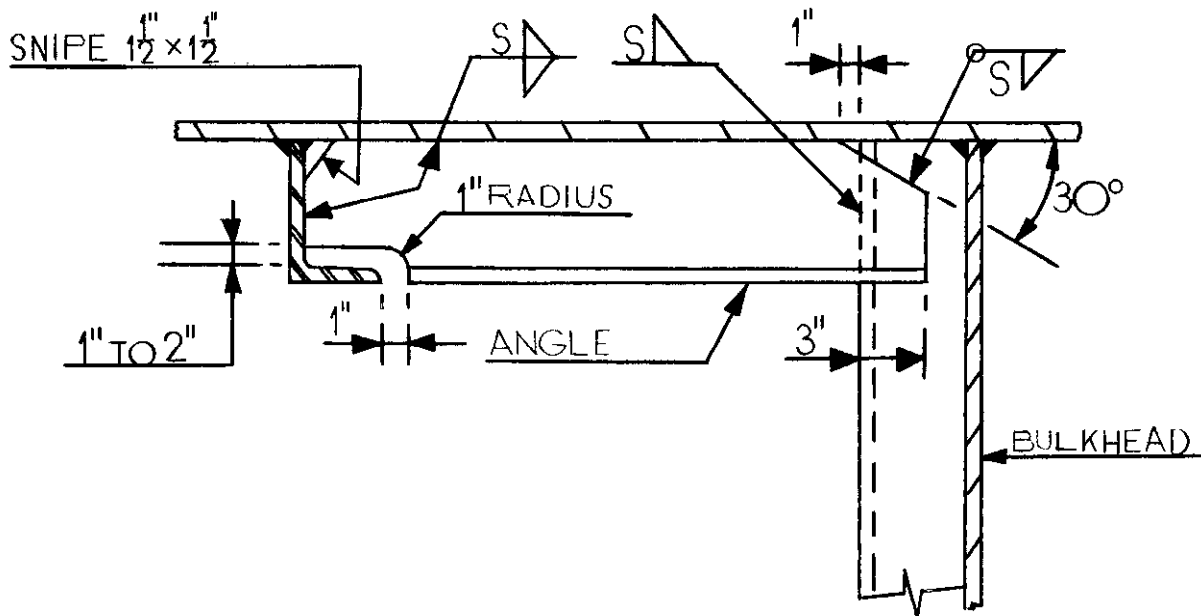
PS - 8

Detail Type: PANEL STIFFENER

Comments: This detail is used by Shipyard "Y" on ship type "J" to support
              large lateral loads such as in way of equipment foundations.   This
              detail is applicable to rolled or fabricated angles.

DECK PLATING

SNIPE $1\frac{1}{2}'' \times 1\frac{1}{2}''$

S

ANGLE OR TEE

S

PS-9

SNIPE $1\frac{1}{2}'' \times 1\frac{1}{2}''$

DECK PLATING

1" RADIUS

ANGLE OR TEE

S

SNIPE FLANGE
30° TO 1"

PS-10

SNIPE $1\frac{1}{2}'' \times 1\frac{1}{2}''$

DECK PLATING

SNIPE FLANGES
30° TO 1"

ANGLE OR TEE

S

PS-11
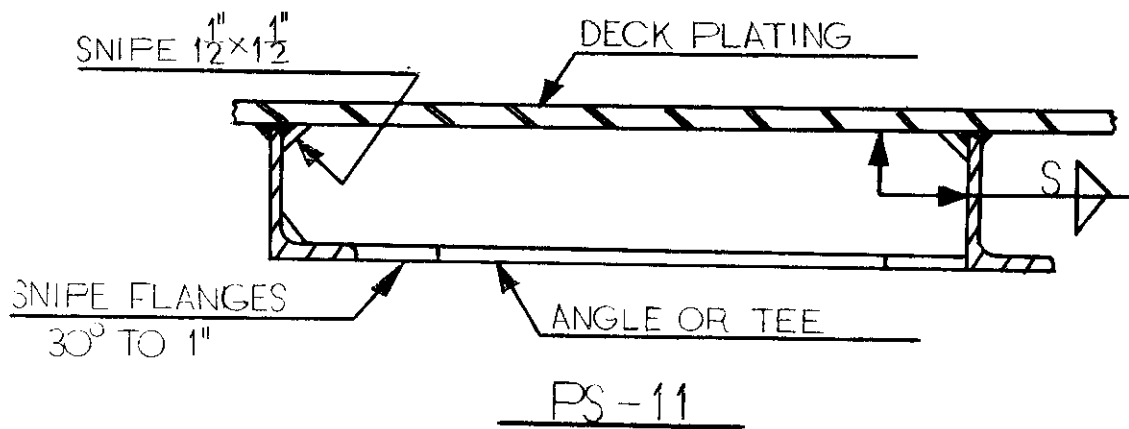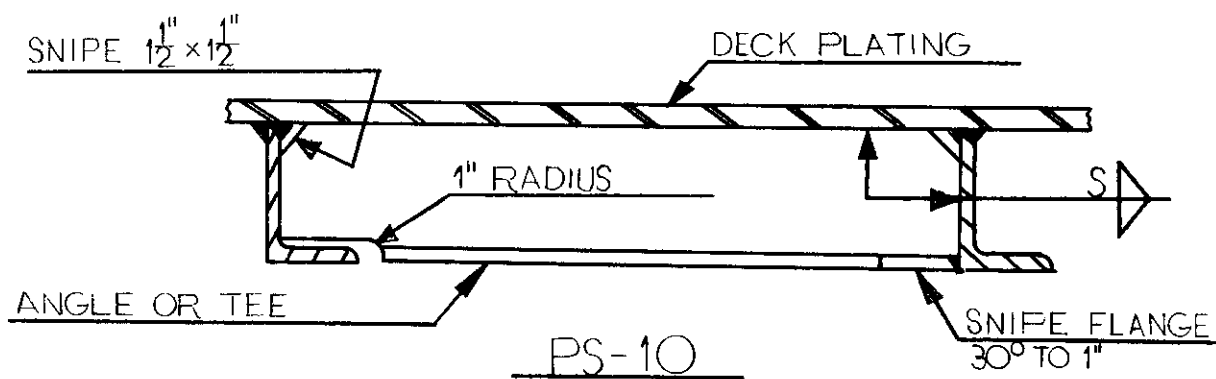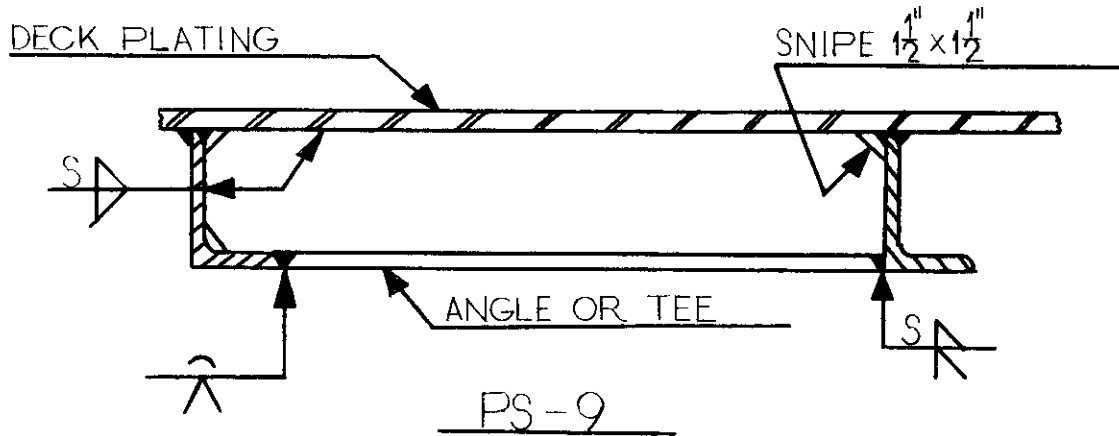
FOR COMMENTARY SEE PG 3-131

3-130

Detail Type: PANEL STIFFENER (see pg. 3-130 for detail)

Comments: This detail is used by Shipyards "U", "W", "X" and "Y"on
ship types "B", "G", "H" and "J" to support large lateral
loads such as in way of machinery foundations and to stiffen
plating around openings. This detail is applicable to rolled
or fabricated angles or tee sections.

Detail Count Ship Type "B":   2450

Manhours Required to Complete Typical Detail: 2.8

Typical Scantlings: Header - 6" x 4" x 1/2" $\angle$, Length - 60".

Detail Type: PANEL STIFFENER (see pg. 3-130 for detail)

Comments: This detail is used by Shipyard "Y" on ship type "J" as a
support in way of deck or bulkhead openings and under
machinery foundations. Left side flange snipe permits
simpler fit-up to stiffener with no noticeable sacrifice in
end shear area. End bending stress not significant due to
local load and weak rotational end support. Same applicability
as PS-9.

Detail Type: PANEL STIFFENER (see pg. 3-130 for detail)

Comments: This detail is used by Shipyard "Y" on ship type "J" as a
support in way of bulkhead or deck openings and in way of
equipment foundations. This detail is easier to fabricate,
than PS-9, not as easy as PS-10. Same applicability as
PS-9.

2"

2"

S

S

ANGLE OR TEE

SNIPE: $1\frac{1}{2}'' \times 1\frac{1}{2}''$

No Snipe to Snipe
$30°$ to $1''$

S

PS - 12
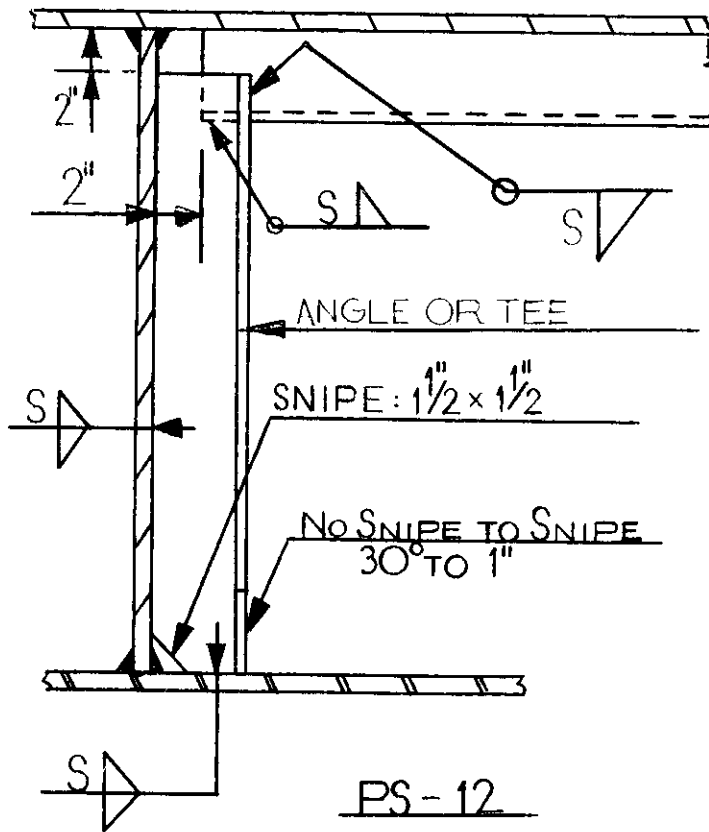
Detail Type: PANEL STIFFENER

Comments: This detail is used by Shipyard "Y" on ship type "J" as the
                attachment of a panel stiffener on a floor to an inner bottom
                longitudinal.   This detail is applicable to rolled or fabricated
                angles.   Fixity of upper joint improve with increasing depth
                of members.
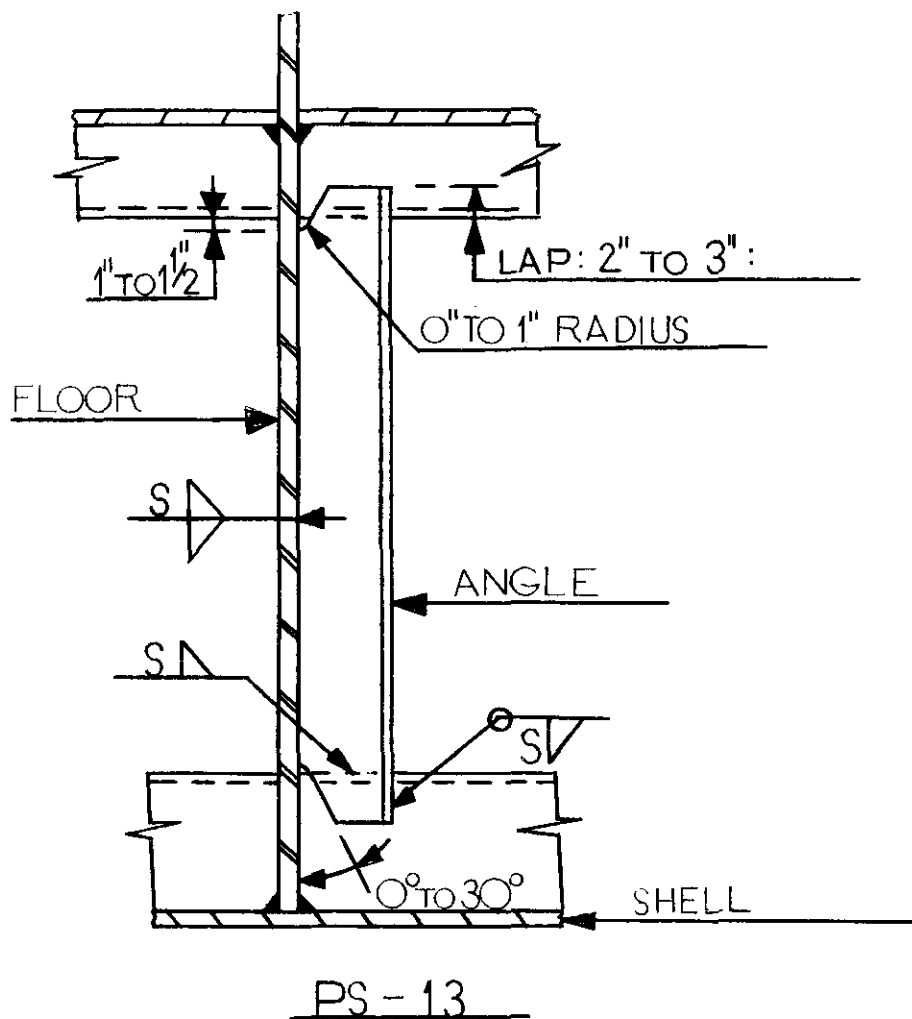
FLOOR

LAP: 2" TO 3":

0" TO 1" RADIUS

1" TO 1½"

S

ANGLE

S

S

0° TO 30°

SHELL

PS - 13

Detail Type: PANEL STIFFENER

Comments: This detail is used by Shipyards "U" and "Y" on ship types "A", "B" and "J" for panel stiffeners applied to tight floors. The 30° web snipe at stiffener ends facilitates welding. Overlap is small compared to flange width, consequently the latter should not be considered effective when calculating the stiffener end section modulus. If end moment is critical, overlap should be increased. This detail is applicable to rolled or fabricated angles.

Detail Count: Ship Type "A": 2300; Ship Type "B": 1000

Manhours Required to Complete Typical Detail: 3.0
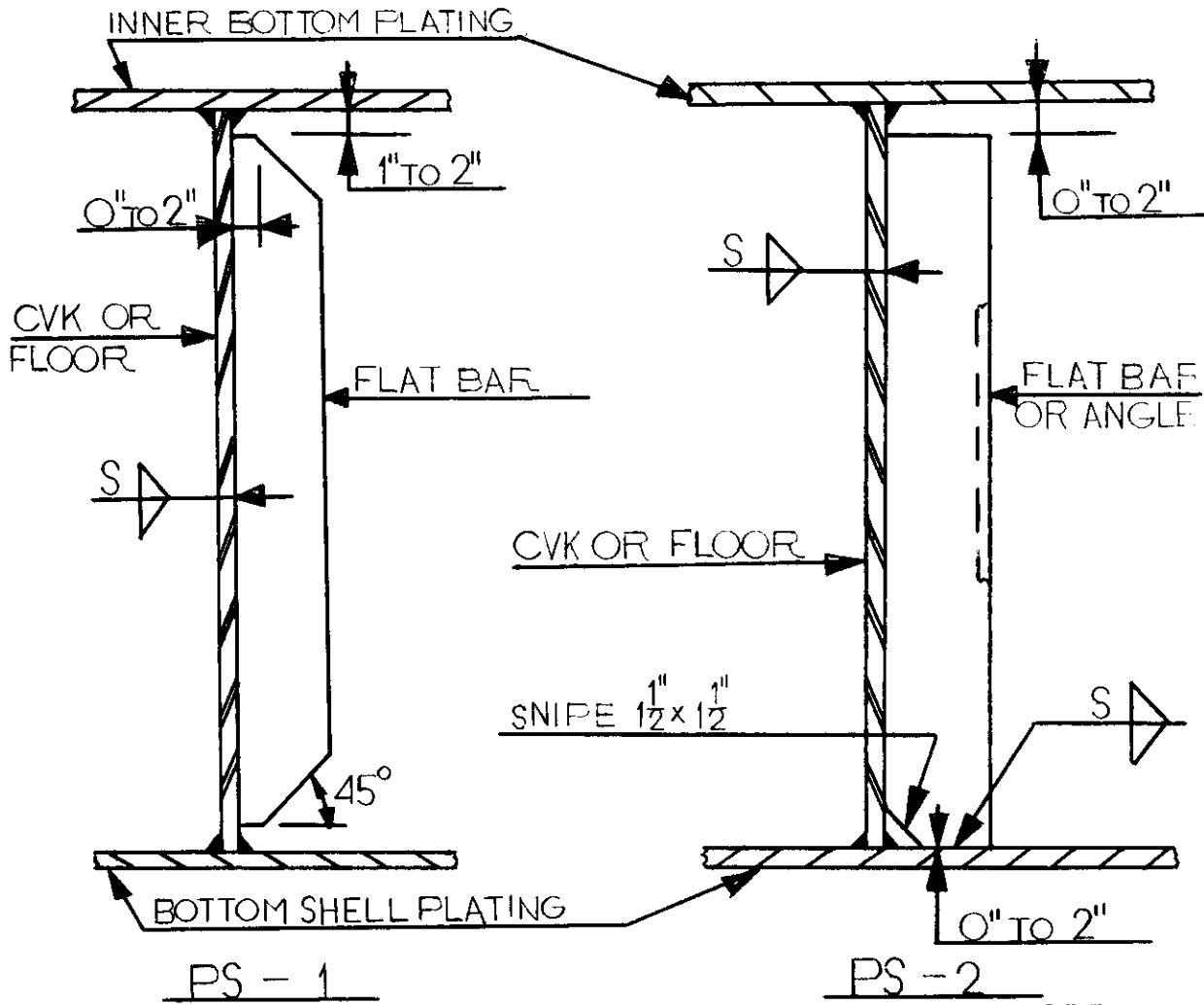
Typical Scantlings: 6" x 4" x 1/2" $\angle$, Length - 60".
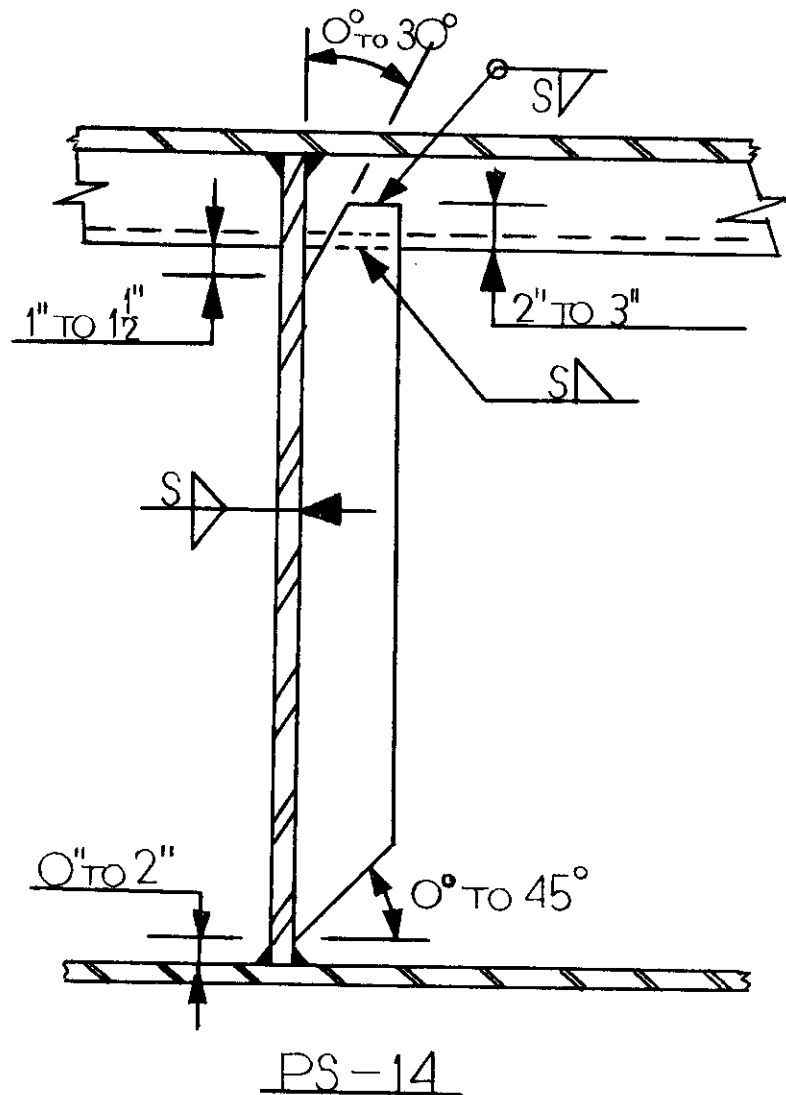
PS-14

Detail Type: PANEL STIFFENER

Comments: This detail is used by Shipyards "U" and "Y" on ship types "A",
"B" and "J" as flat bar panel stiffeners for transverse or
longitudinal girders.   For additional comments see PS-4.

Detail Count Ship Type "A":   5520

Manhours Required to Complete Typical Detail: 4.0

Typical Scantlings: 6" x 1/2" Flat bar, length - 74".
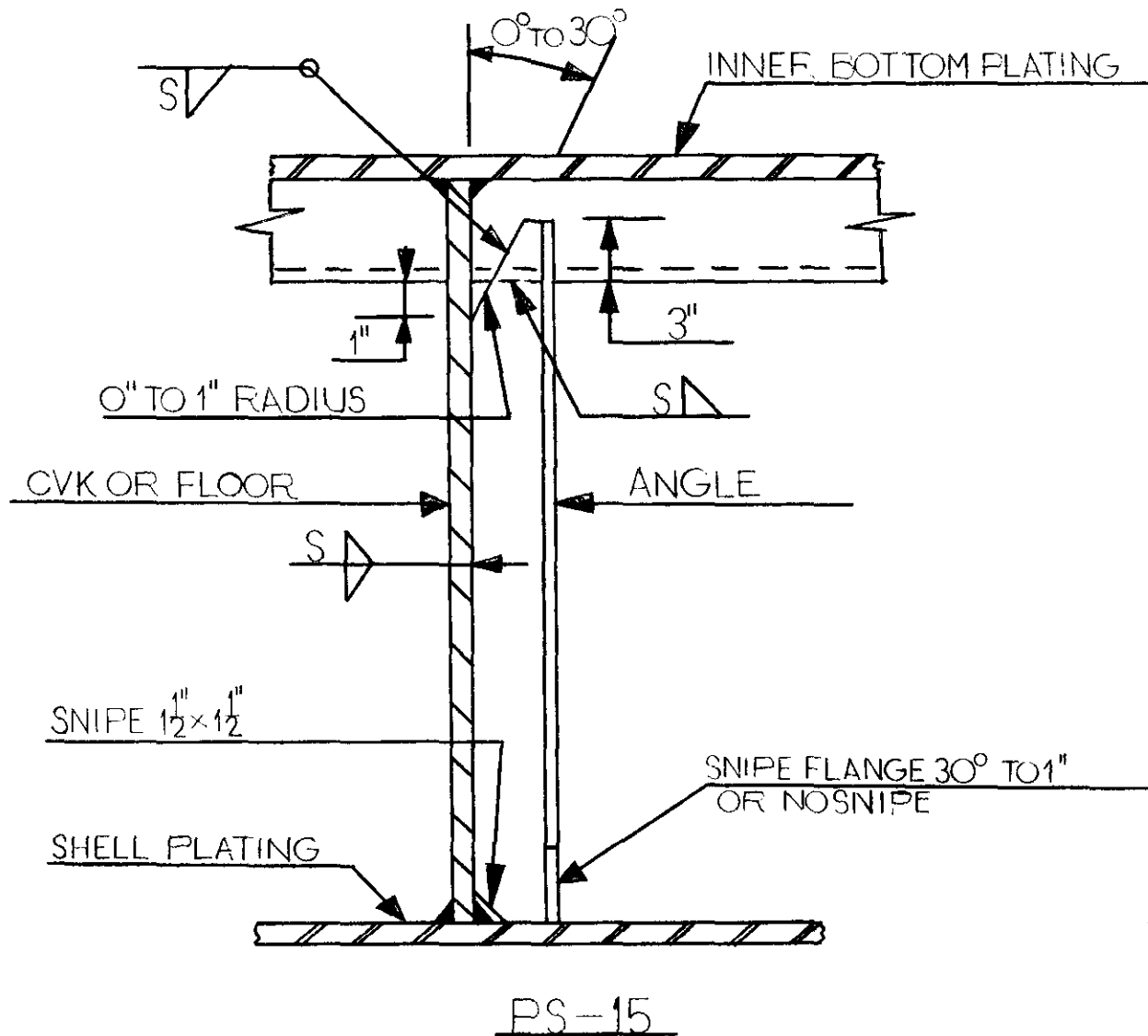
3-134

$0°$ TO $30°$

INNER BOTTOM PLATING

S

$1''$

$3''$

$0''$ TO $1''$ RADIUS

S

CVK OR FLOOR

ANGLE

S

SNIPE $1\frac{1}{2}''\times 1\frac{1}{2}''$

SNIPE FLANGE $30°$ TO $1''$
OR NO SNIPE

SHELL PLATING

PS-15

Detail Type: PANEL STIFFENER

Comments: This detail is used by Shipyards "U" and "Y" on ship types "A" and "J", as panel stiffeners on double bottom structure. The $30°$ web snipe is desirable because of weld accessibility. This detail is applicable to rolled or fabricated angles.

Detail Count Ship Type "A":   110

Manhours Required to Complete Typical Detail: 4.4

Typical Scantlings: 7" x 4" x 1/2" $\angle$, length - 72".

3-135

INNER BOTTOM PLATING

CVK OR FLOOR

SNIPE FLANGE 30° TO 1"

SHELL PLATING

SNIPE 1½" × 1½"

PS - 16
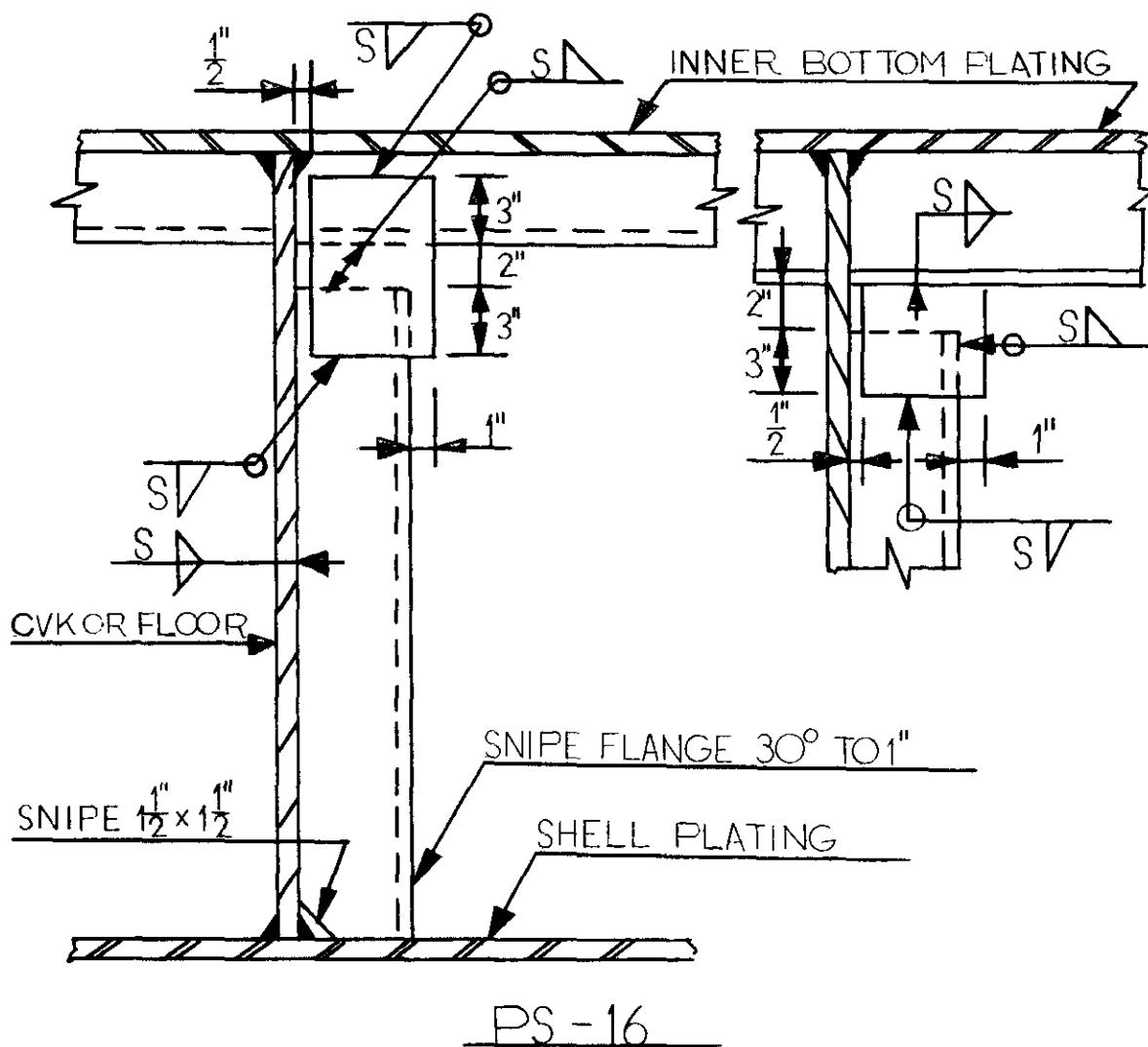
Detail Type: PANEL STIFFENER

Comments: This detail is used by Shipyard "Y" on ship type "J" as rolled or fabricated angle panel stiffeners on tight double bottom structure. Two alternate lapped connection details are presented, their application depends on the type of inner bottom longitudinals. See PS-2 for end connection comments. Welding accessibility is poor; clip should be modified to provide better access along the edge of the clip closest to the bulkhead and across the top.
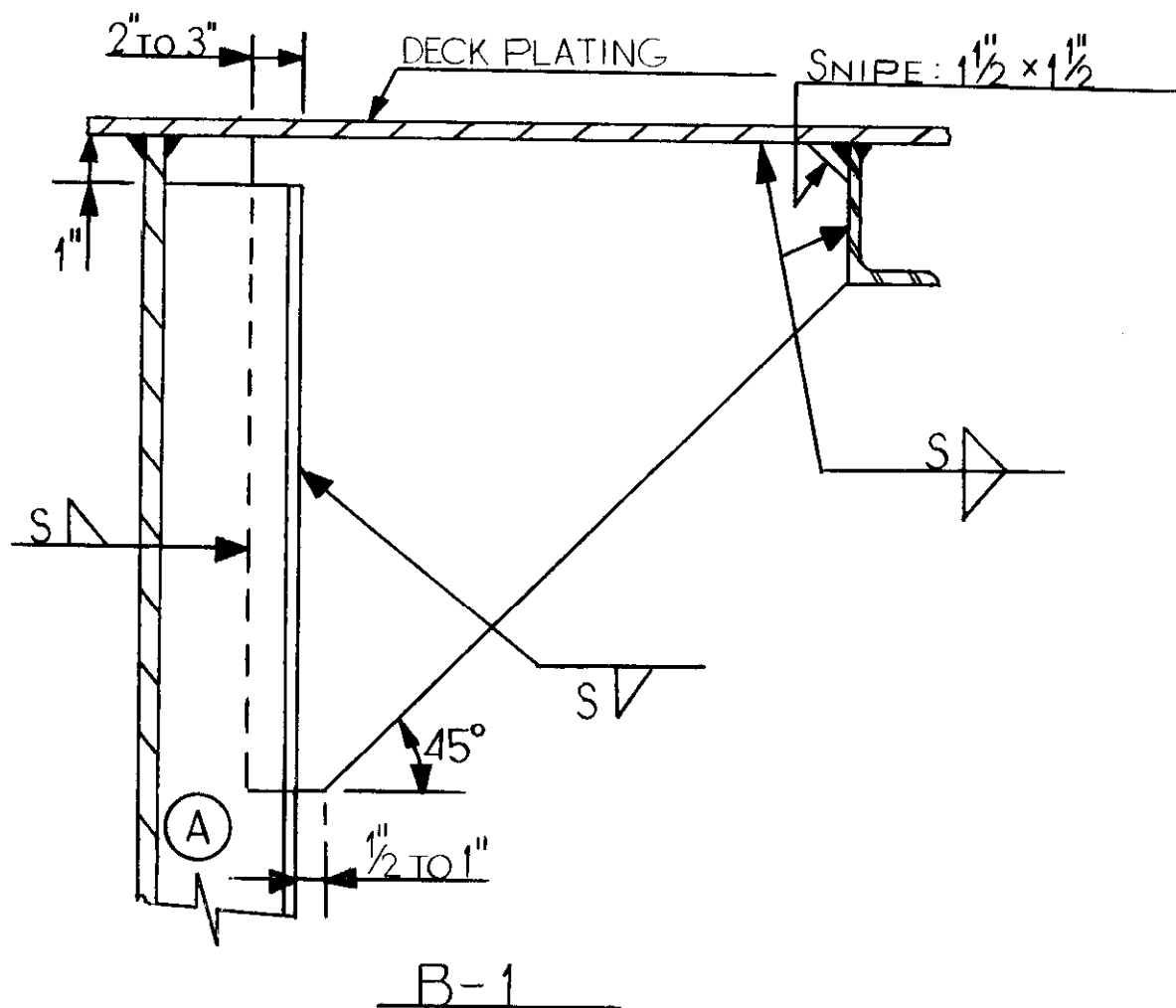
2" TO 3"

DECK PLATING

SNIPE: $1\frac{1}{2}$ × $1\frac{1}{2}$

1"

S

S

S

45°

$\frac{1}{2}$ TO 1"

(A)

B-1

Detail Type: BEAM BRACKET (UNFLANGED)

Comments: This detail is used by Shipyards "U", "W", "Y" and "Z" on ship
types "B", "G", "J" and "K" as end connection for a bulkhead
stiffener or longitudinal deck beam requiring end fixity.   Bracket
length and thickness determined by ABS Rules, see Appendix A,
Section A2. 1. 1.   For the bracket to be considered effective,
i. e. providing end restraint leading to reduction in required
section modulus, the leg length must be equal to one-eighth the
span of member A.

Detail Count Ship Type "B":   10

Manhours Required to Complete Typical Detail: 2. 4

Typical Scantlings: Equal legs = 30", Thickness = 1/2"

3-137

DECK PLATING

SNIPE $1\frac{1}{2}" \times 1\frac{1}{2}"$

$1"$

S

$1\frac{1}{2}"$

$3"$ RADIUS

S

$1\frac{1}{2}"$

S

BULKHEAD

$\frac{1}{2}"$ TO $1"$

A

$2\frac{1}{4}"$

B - 3

Detail Type: BEAM BRACKET (UNFLANGED)

Comments: This detail is used by Shipyards "W" and "X" on ship types "G" and
"H" as an end connection for a bulkhead stiffener or deck beam
requiring fixity at ends.   Rigidity at joint of bracket to supporting
stiffener should be checked in terms of end moment.   Bracket
length and thickness determined from ABS Rules, see Appendix
A, Section A2.1.1.   For additional comments see Detail B-1.
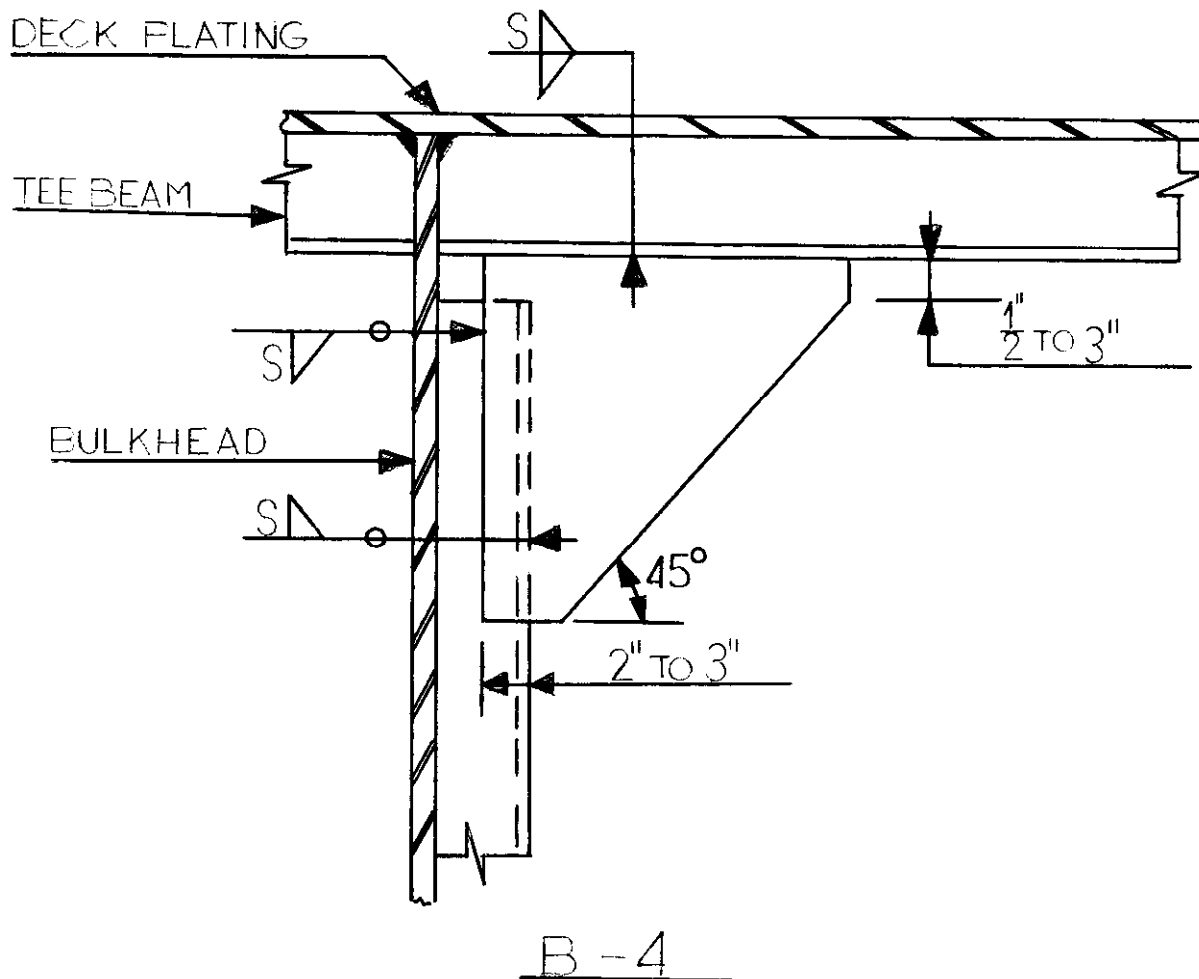
DECK PLATING

TEE BEAM

BULKHEAD

45°

2" TO 3"

$\frac{1}{2}$" TO 3"

B - 4

Detail Type: BEAM BRACKET (UNFLANGED)

Comments: This detail is used by Shipyards "U", "W", "X" and "Y" on ship
              types "B", "G", "H" and "J" to provide end support for bulkhead
              stiffeners and deck beams. Bracket length and thickness to be
              determined from ABS Rules, see Appendix A, Section A2.1.1.
              For the bracket to be considered effective for both members, the
              bracket leg length should be equal to one-eighth the value of the
              larger of the member spans.

Detail Count Ship Type "B":   20

Manhours Required to Complete Typical Detail: 2.1

Typical Scantlings: Equal legs = 24", Thickness = 1/2".

3-140

TEE BEAM

$\frac{1}{2}$"

SNIPE $1\frac{1}{2}$" x $1\frac{1}{2}$"

S

X

THICKNESS = $\frac{3}{4}$"

BULKHEAD

RADIUS: 1.25 X

B - 5
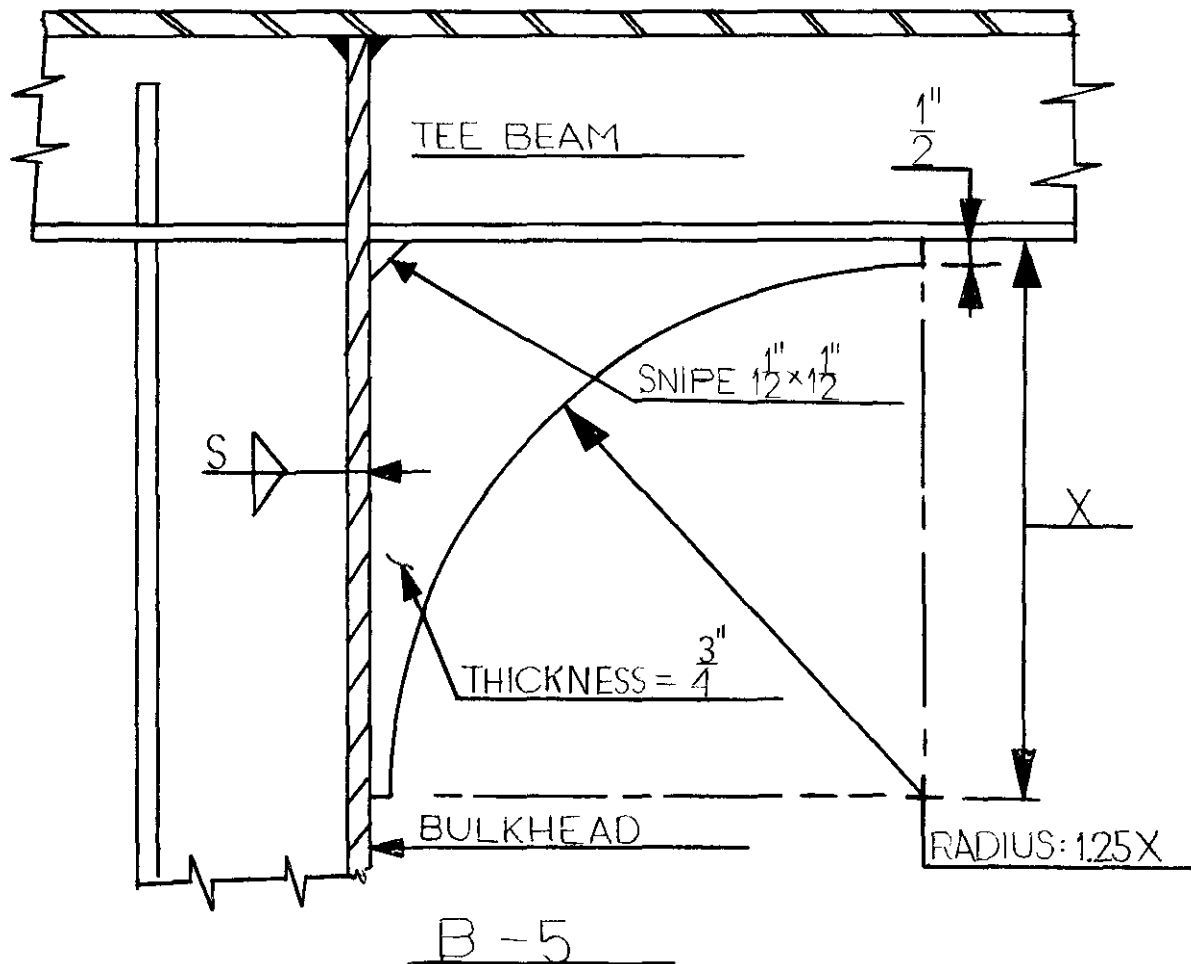
Detail Type: KNEE BRACKET

Comments: This detail is used by Shipyards "U" and "Y" on ship types "B" and "J" for minimizing stress concentrations at the intersection. Maximum leg length from ABS Rules, see Appendix A, Section A2.1.1. This detail is a softening, not an effective, bracket.

Detail Count Ship Type "B":   810 '

Manhours Required to Complete Typical Detail: 2.7

Typical Scantlings: Radius = 30", Thickness = 3/4".
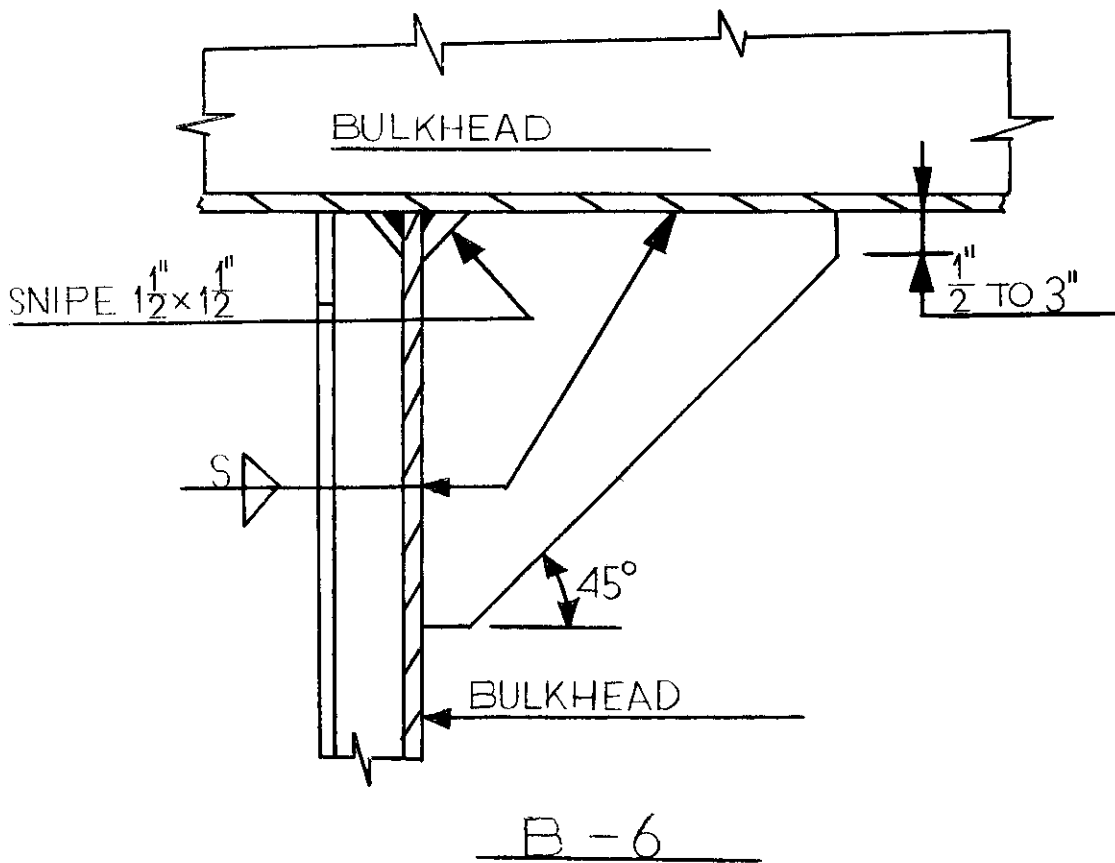
3-141

BULKHEAD

SNIPE 1½" × 1½"

S

45°

BULKHEAD

½" TO 3"

B – 6

Detail Type: BEAM BRACKET (UNFLANGED)

Comments: This detail is used by Shipyards "U", "W", "X" and "Y" on ship types "A", "B", "G", "H" and "J" to reduce stresses at discontinuities and corners. Maximum leg length and bracket thickness to be determined from ABS Rules. See Detail B-1 for bracket effectiveness criteria.

Detail Count: Ship Type "A" = 130; Ship Type "B" = 530

Manhours Required to Complete Typical Detail: 2. 1

Typical Scantlings: Equal legs = 24", Thickness = 1/2".

B - 7
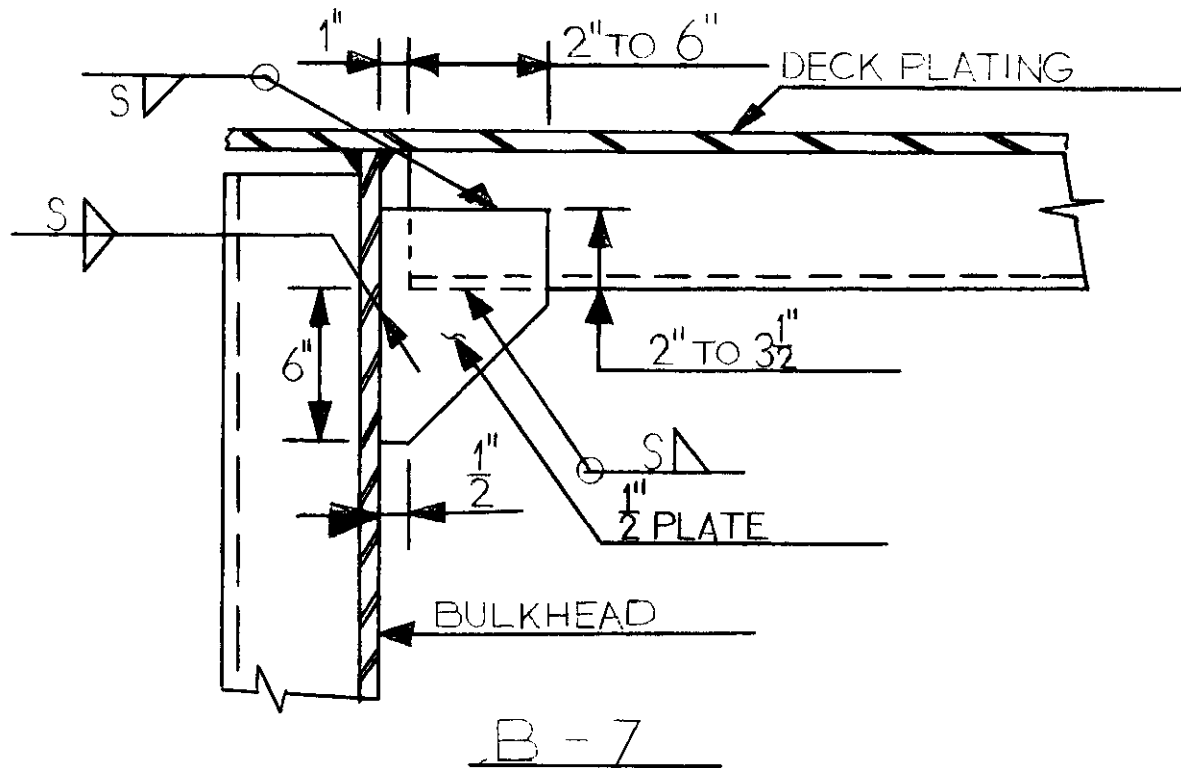
Detail Type: BEAM BRACKET

Comments: This detail is used by Shipyards "U", "W" and "X" on ship types
"B", "G" and "H" for end connections of deck longitudinals to
transverse bulkhead stiffeners.   Bracket may not necessarily be
in line with supporting stiffener.   Purpose of bracket is to
facilitate end connection rather than to obtain reduced scantling.

Detail Count Ship Type "B":   130

Manhours Required to Complete Typical Detail: 2.0

Typical Scantlings: 8" x 8" x 1/2" Plate.
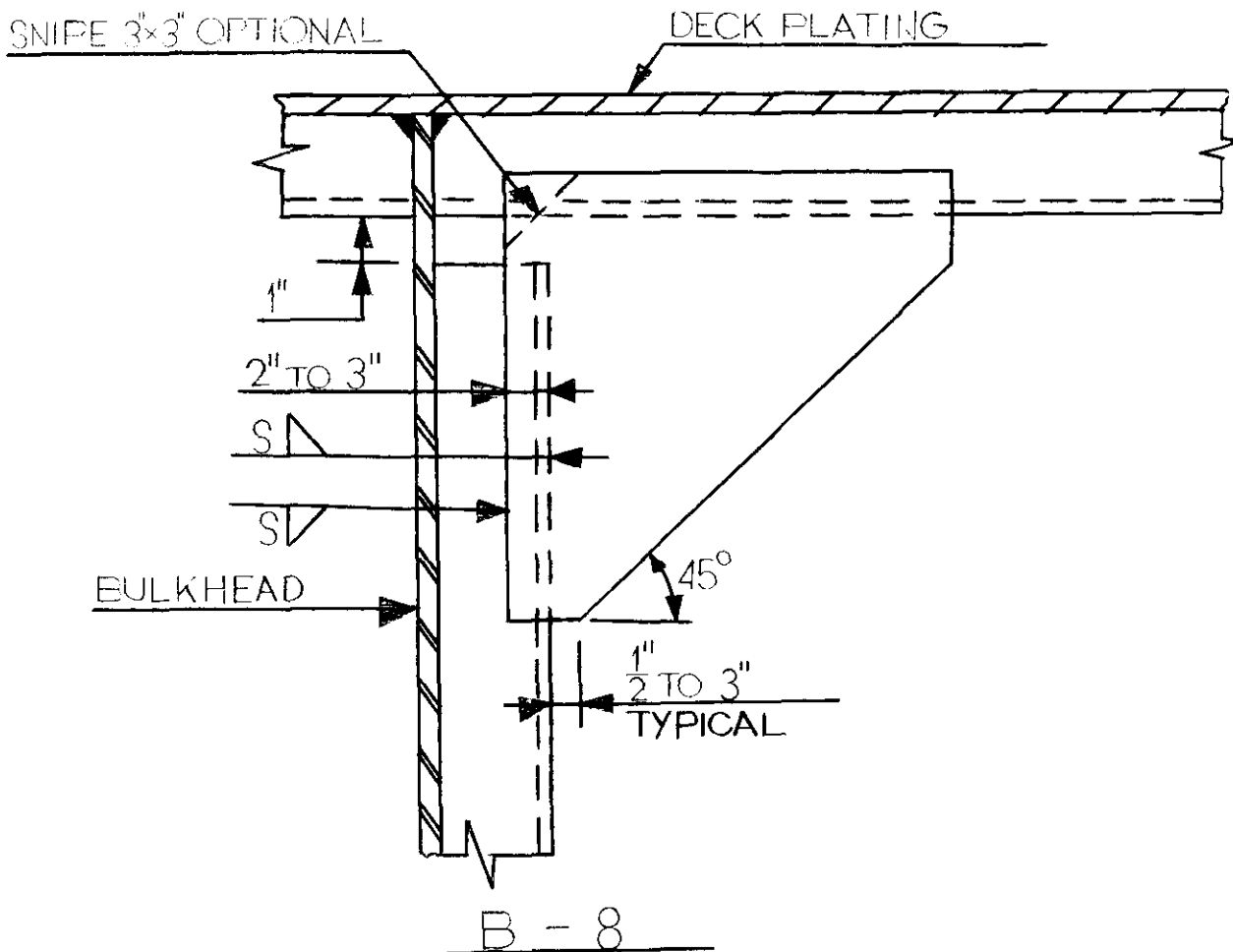
SNIPE 3"x3" OPTIONAL   DECK PLATING

1"

2" TO 3"

S ◁

S ▽

BULKHEAD

45°

$\frac{1"}{2}$ TO 3"
TYPICAL

B - 8

Detail Type: BEAM BRACKET (UNFLANGED)

Comments: This detail is used by Shipyards "U", "W", "X" and "Y" on ship
                types "B", "G", "H" and "J" to join a continuous longitudinal deck
                beam to an intercostal bulkhead stiffener where full fixity is
                required.   Maximum leg length and thickness to be determined
                from ABS Rules, see Section A2.1.1, Appendix A.   See Detail
                B-4 for bracket effectiveness criteria.

Detail Count Ship Type "B":   490

Manhours Required to Complete Typical Detail: 2.1

Typical Scantlings: Equal legs = 24", Thickness = 1/2".

3-144

SEE CH-5

DECK PLATING

1"

BULKHEAD

TEE BEAM

45°

FACE PLATE CENTERED

SNIPE FACE PLATE
30° TO 1" NEAR & FAR

$1\frac{1}{2}$"

B-9
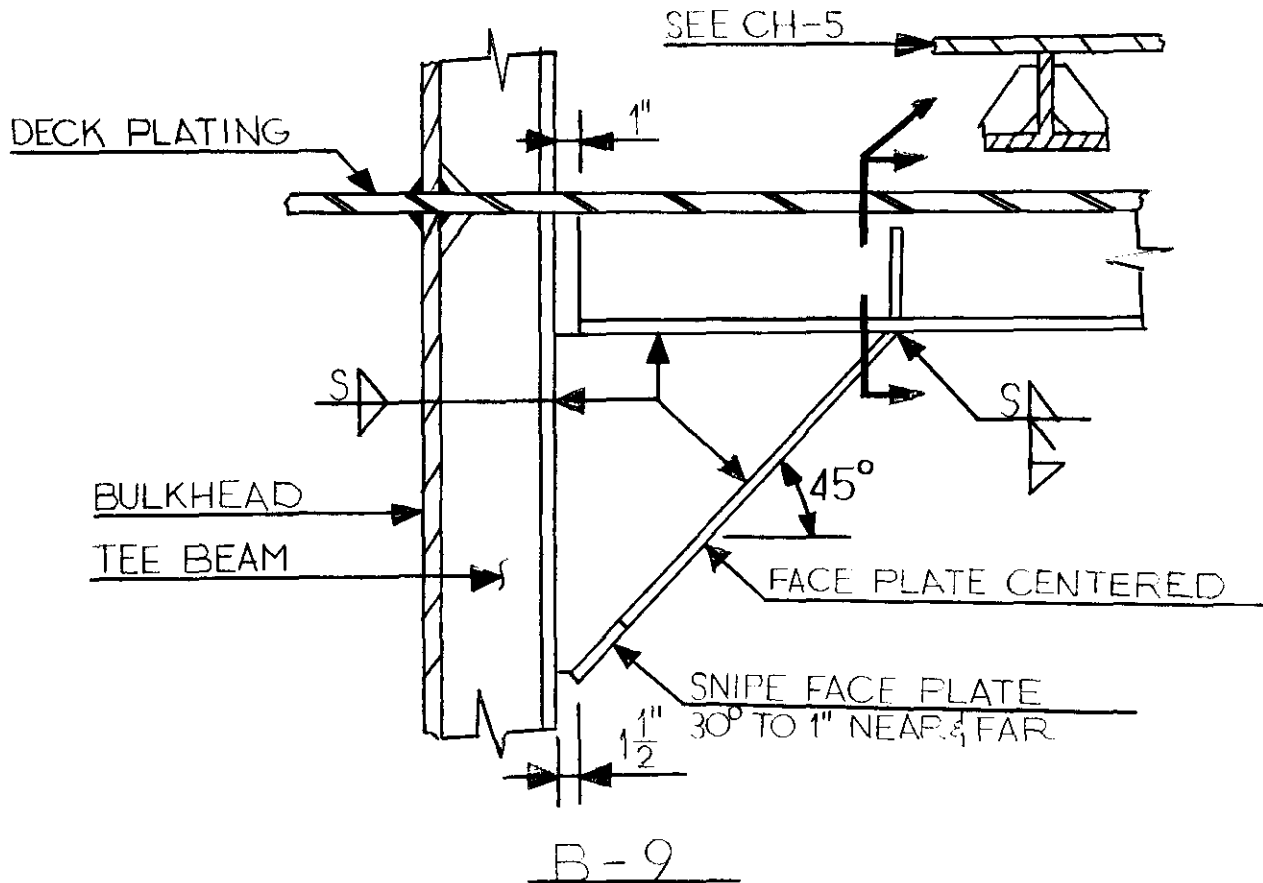
Detail Type: BEAM BRACKET (FLANGED)

Comments: This detail is used by Shipyards "Y" and "Z" on ship types "J" and "K" to connect bulkhead stiffeners and longitudinal deck beams to obtain full fixity. Maximum leg length, face plate scantlings and bracket thickness to be determined from ABS Rules, see Appendix A, Section A2.1.1. For bracket effectiveness criteria, see bracket Detail B-4.

3-145

DECK

$1\frac{1}{2}$"

1"

S ▷

$\frac{1}{2}$"

S ▷

FLANGED PLATE: SNIPE 30° TO 1" BOTH ENDS

S ▷

60°

$1\frac{1}{2}$"

3"

BULKHEAD

B-10
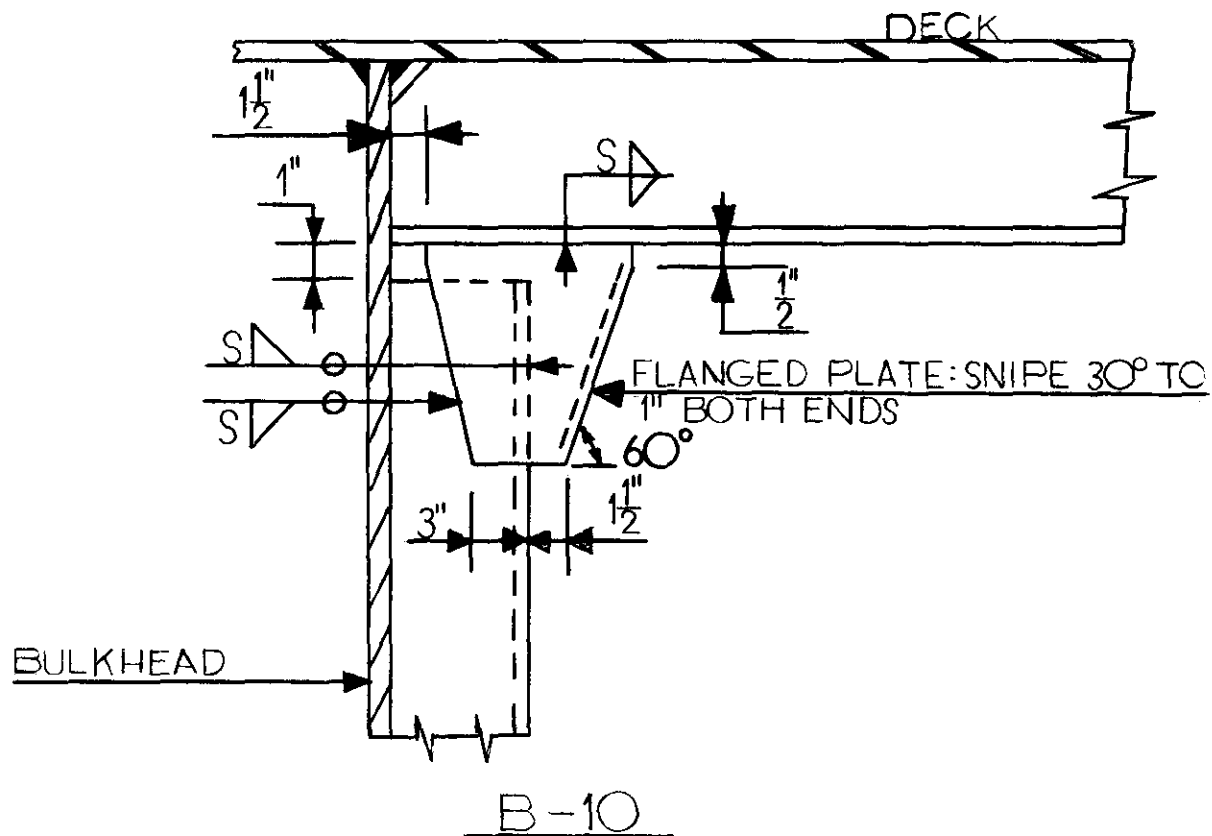
Detail Type: BEAM BRACKET (STIFFENER END CONNECTION)

Comments: This detail is used by Shipyard "Y" on ship type "J" to connect an intercostal bulkhead stiffener and an intercostal deck member; primarily to resist shear. The need for flanging is questionable. This is not a common detail.
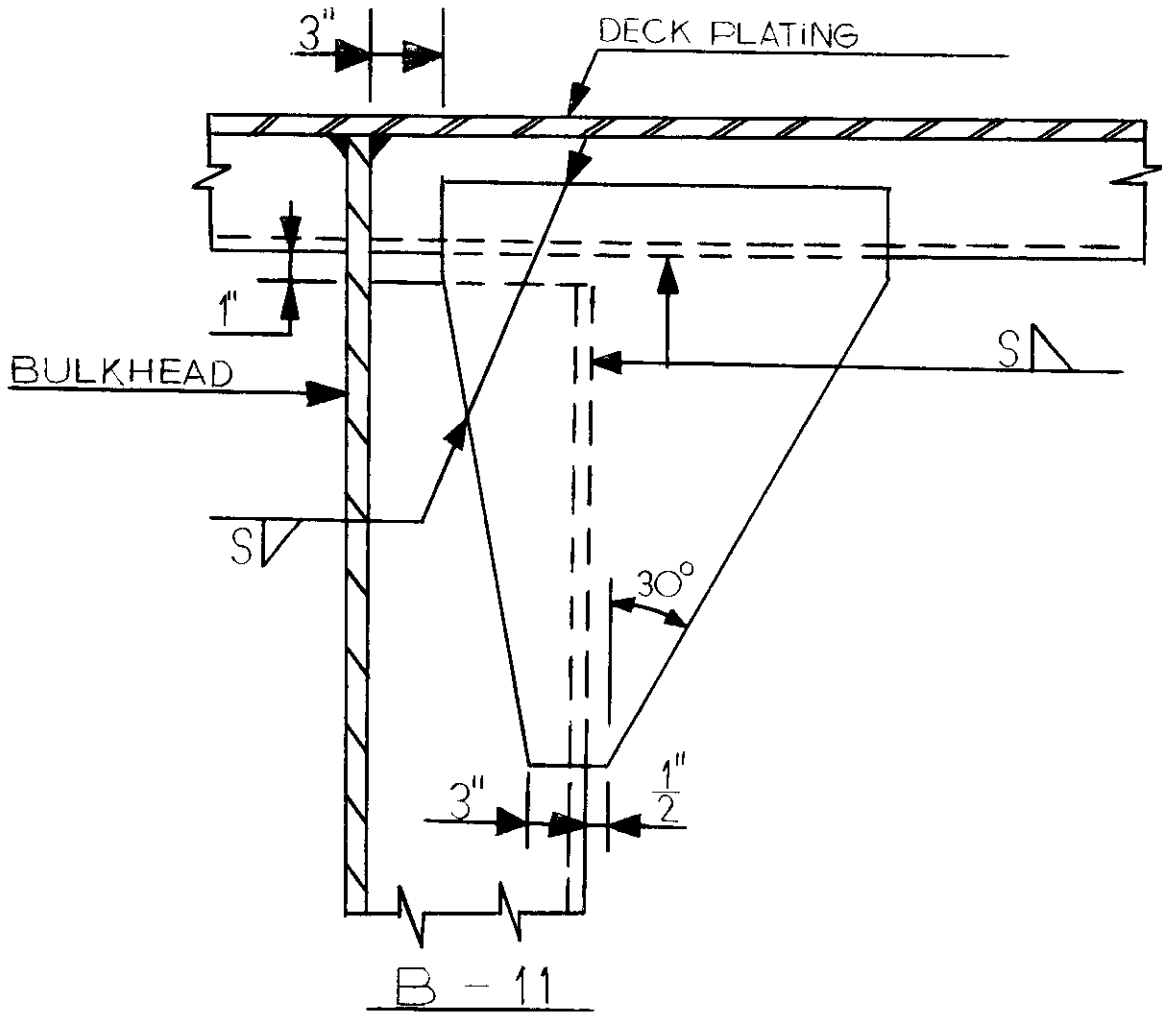
3" DECK PLATING

1"

BULKHEAD

S

S

30°

3" 1/2"

B - 11

Detail Type: BEAM BRACKET (UNFLANGED)

Comments: This detail is used by Shipyard "Y" on ship type "J" to connect a shallow continuous deck longitudinal to a deep intercostal bulkhead stiffener, primarily to resist shear. This is not a common detail. Bracket thickness to be determined from ABS Rules, see Appendix A, Section A2.1.1. See Detail B-4 bracket effectiveness criteria.
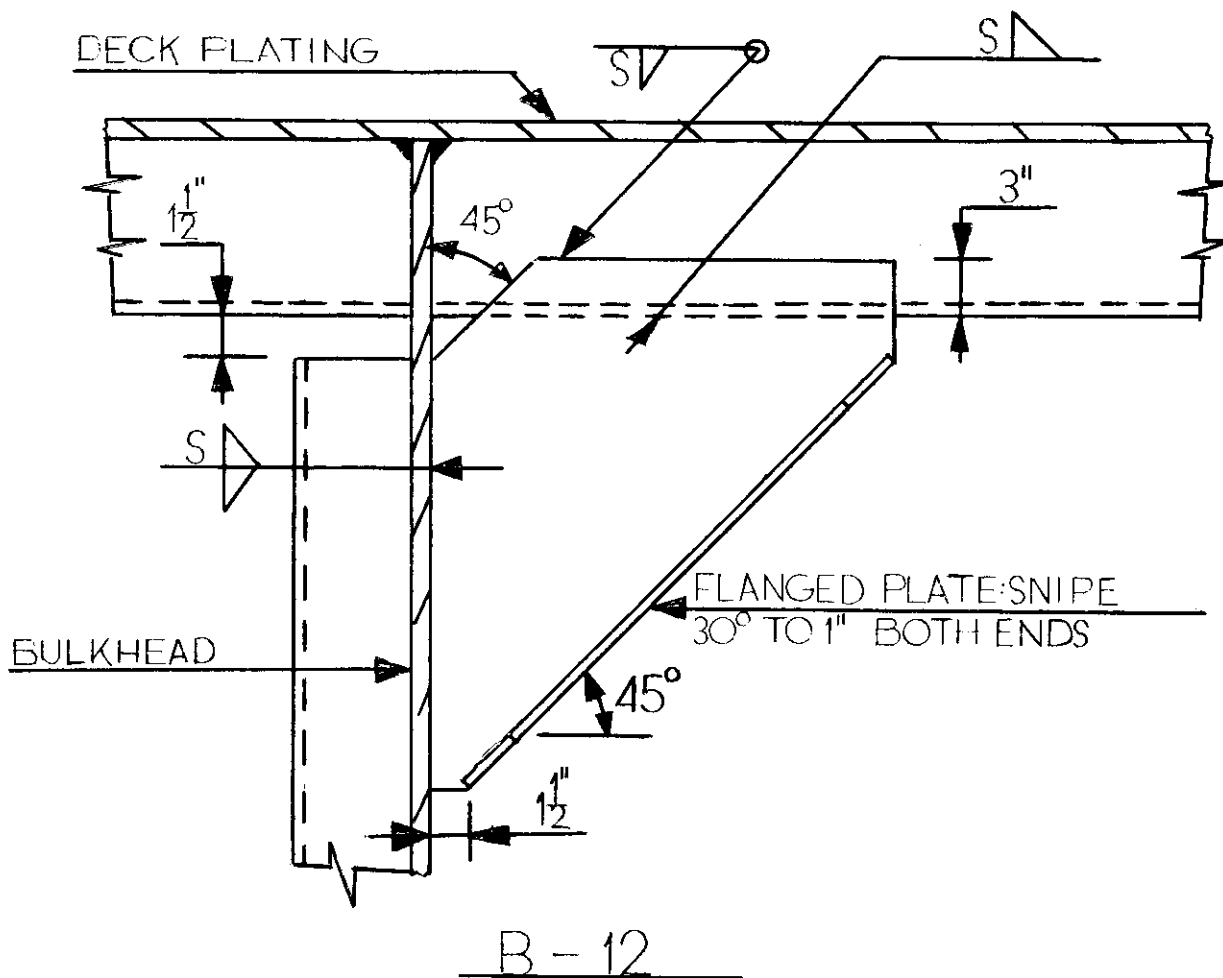
DECK PLATING

45°

3"

$1\frac{1}{2}''$

S

BULKHEAD

FLANGED PLATE SNIPE
30° TO 1" BOTH ENDS

45°

$1\frac{1}{2}''$

B - 12

Detail Type: BEAM BRACKET (FLANGED)

Comments: This detail is used by Shipyard "Y" on ship type "J" to provide end
support for continuous deck members penetrating bulkheads or
floors.   Maximum leg length, bracket thickness, and flange area
are to be determined from ABS Rules, see Appendix A, Section
A2.1.1.   For bracket effectiveness criteria, see bracket Detail
B-4.   Bracket more commonly on stiffener side of bulkhead, see
Detail B-13.
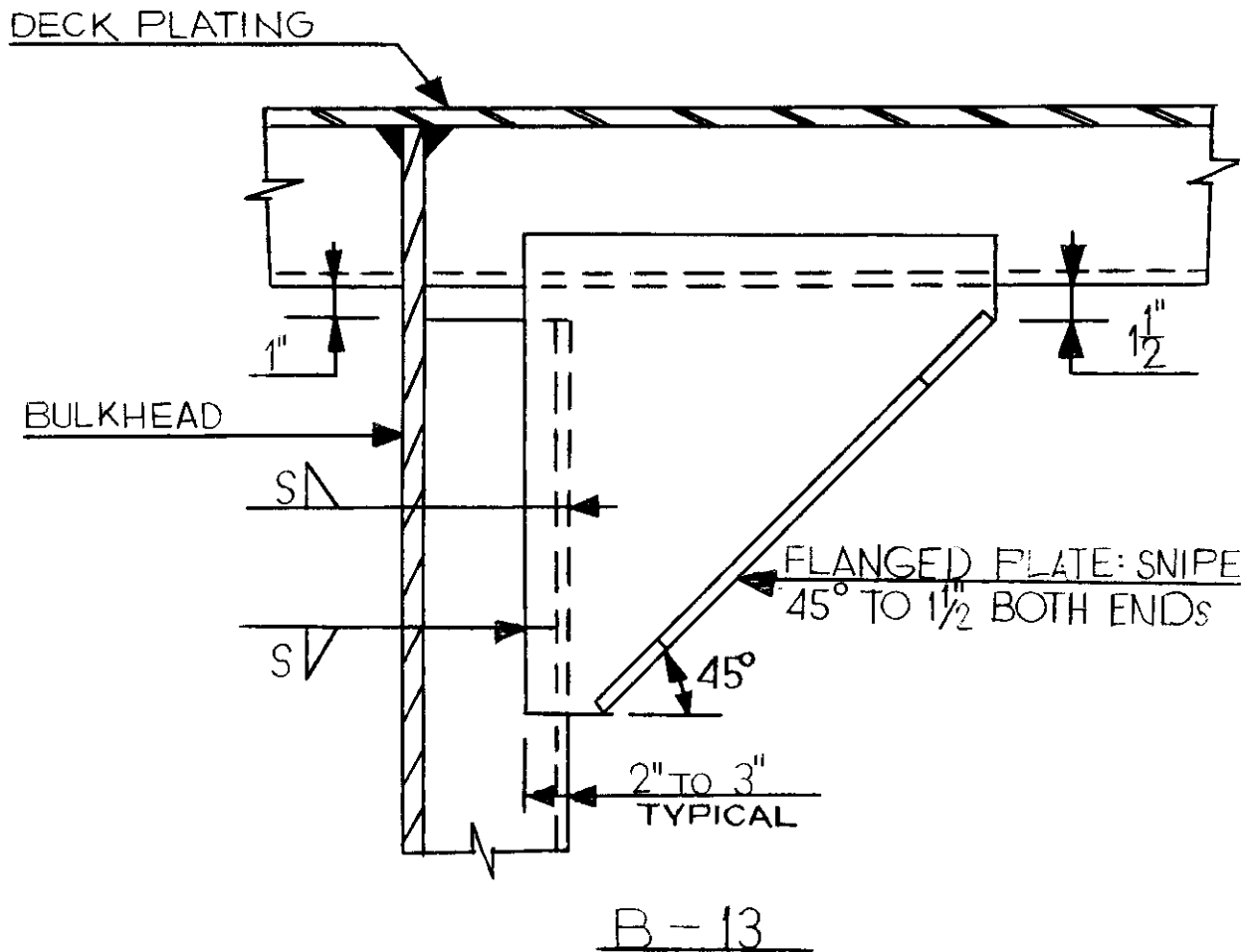
3-148

DECK PLATING

BULKHEAD

S

S

1"

1½"

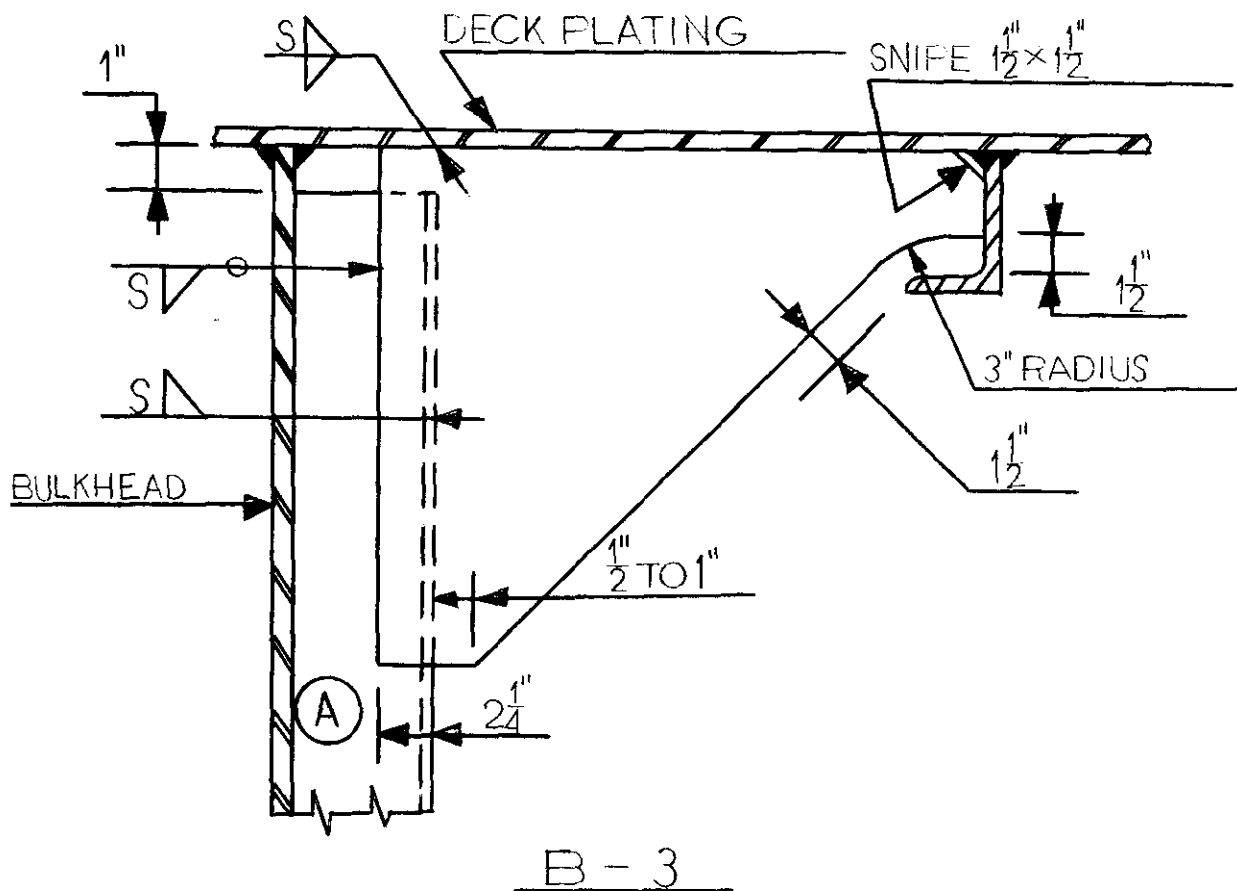FLANGED PLATE: SNIPE
45° TO 1½" BOTH ENDs

45°

2" TO 3"
TYPICAL

B - 13

Detail Type: BEAM BRACKET (FLANGED)

Comments: This detail is used by Shipyards "U", "W", "X" and "Y" on ship
types "B", "G", "H" and "J" to provide end connections for an
intercostal bulkhead stiffener to a continuous deck member. For
additional comments see B-12.

3-149

LONGITUDINAL BULKHEAD

1"

$\frac{1"}{2}$

S

FLAT BAR STIFFENER

INNER BOTTOM PLATING

a

3" RADIUS

RADIUS = $\frac{a}{4}$

S
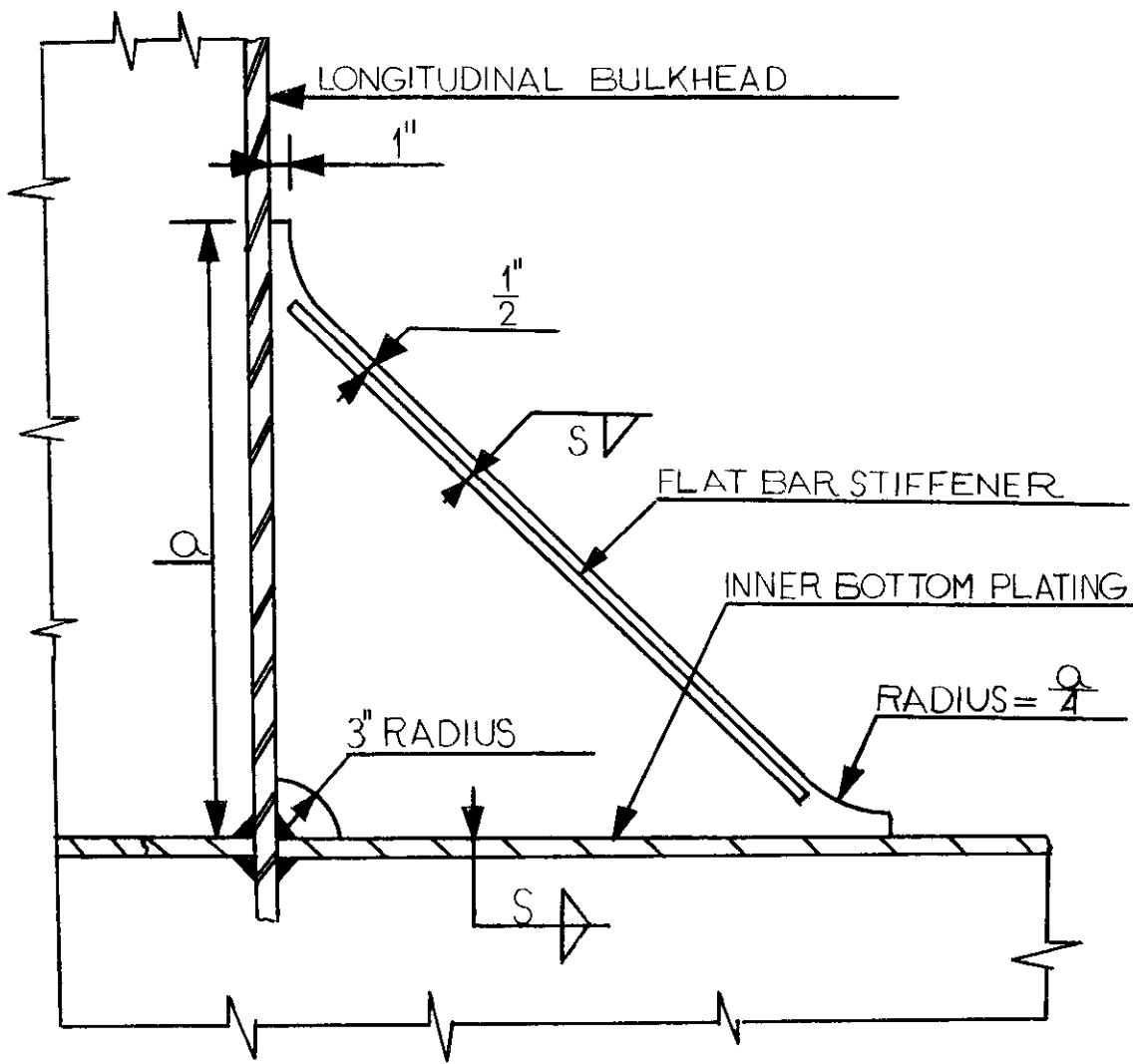
B-14

Detail Type: KNEE BRACKET

Comments: This detail is used by Shipyard "Y" on ship type "J" to reduce stress
concentrations at corners and to reduce the span length of the
members depending on the flange or face plate area. Primarily
used on oil tankers. For span reduction criteria see Appendix A,
Section A2.1.1. Bracket thickness to be the same as the thickness
of the supported member.

BULKHEAD   SHELL

SNIPE $1\frac{1}{2}" \times 1\frac{1}{2}"$

3"

1"

S

2D

SD

FLANGED
PLATE

S

$\frac{1}{2}"$ 3"

D
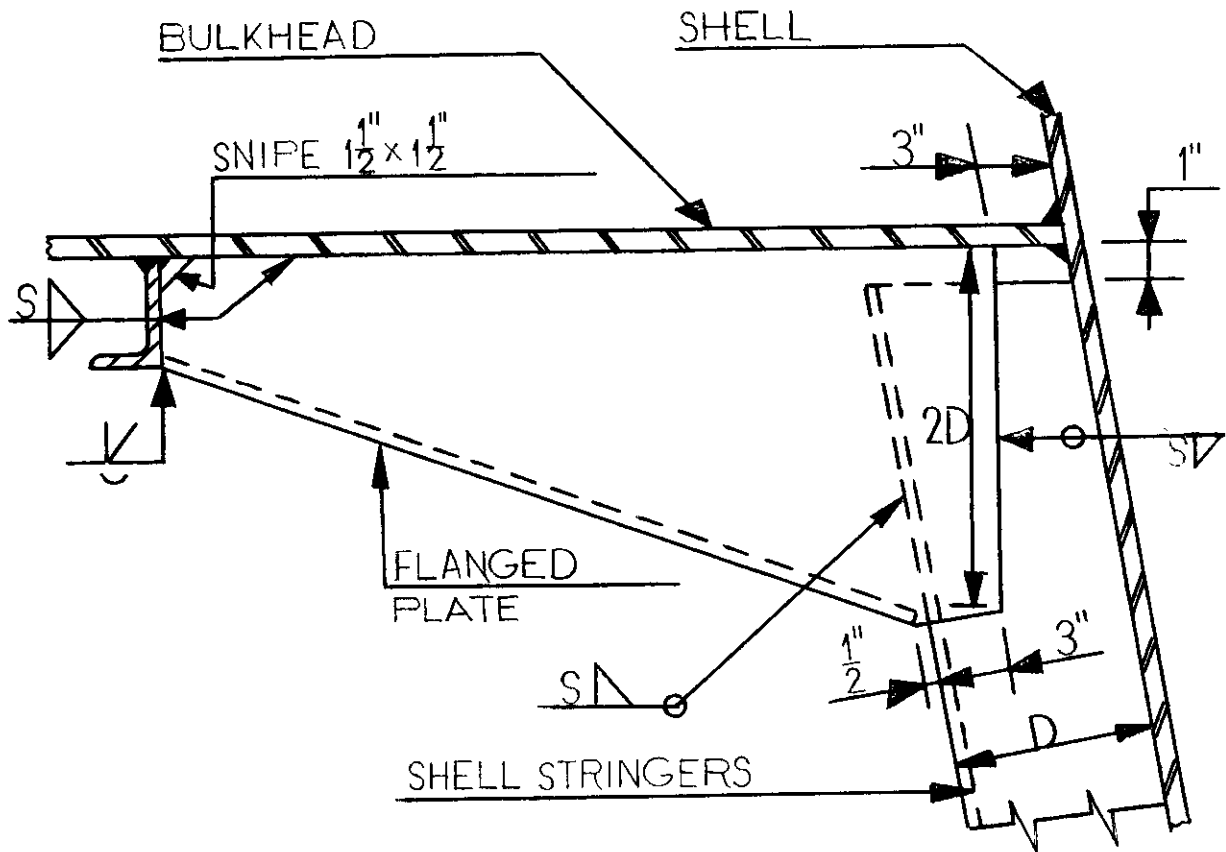
SHELL STRINGERS

B—15

Detail Type: BEAM BRACKET (UNFLANGED)

Comments: This detail is used by Shipyard "Y" on ship type "J" for end
connections where shell stringers terminate at a bulkhead or
tank boundary.   This detail provides end fixity for shear and
moment.

DECK FLATING

D

LONGITUDINAL BEAM

45°

3"

$\frac{1}{2}$

$1\frac{1}{2}$

TRANSVERSE GIRDER

S

S

1"

1"

B - 16
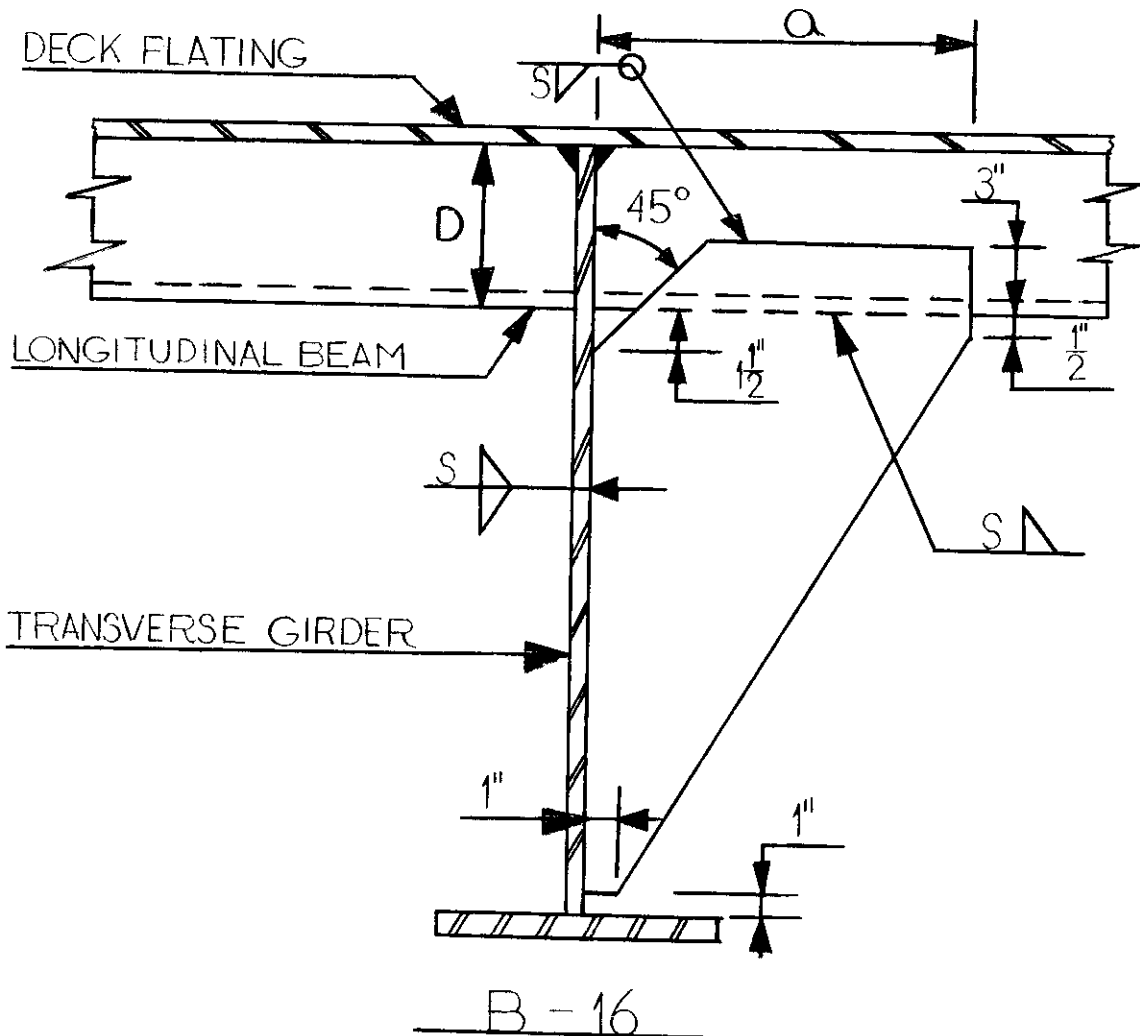
Detail Type: BEAM BRACKET (WEB STIFFENER)

Comments: This detail is used by Shipyard "Y" on ship type "J" to provide
web plate stiffening for a deep transverse girder and end support
for longitudinal deck beams carrying large lateral loads.   Size
of bracket is dependent on scantlings of supported members. Can be
used as beam bracket if used on both sides of web to effectiveness
criteria of Detail B-4.   When used as web stiffener a = 2D.

DECK PLATING

SNIPE $1\frac{1}{2}'' \times 1\frac{1}{2}''$

S

1"

30°

S

SAME
THICK.

3"

1"

S

1"

S

SNIPE $1\frac{1}{2}'' \times 1\frac{1}{2}''$

1"

HATCH SIDE GIRDER

S

B - 17
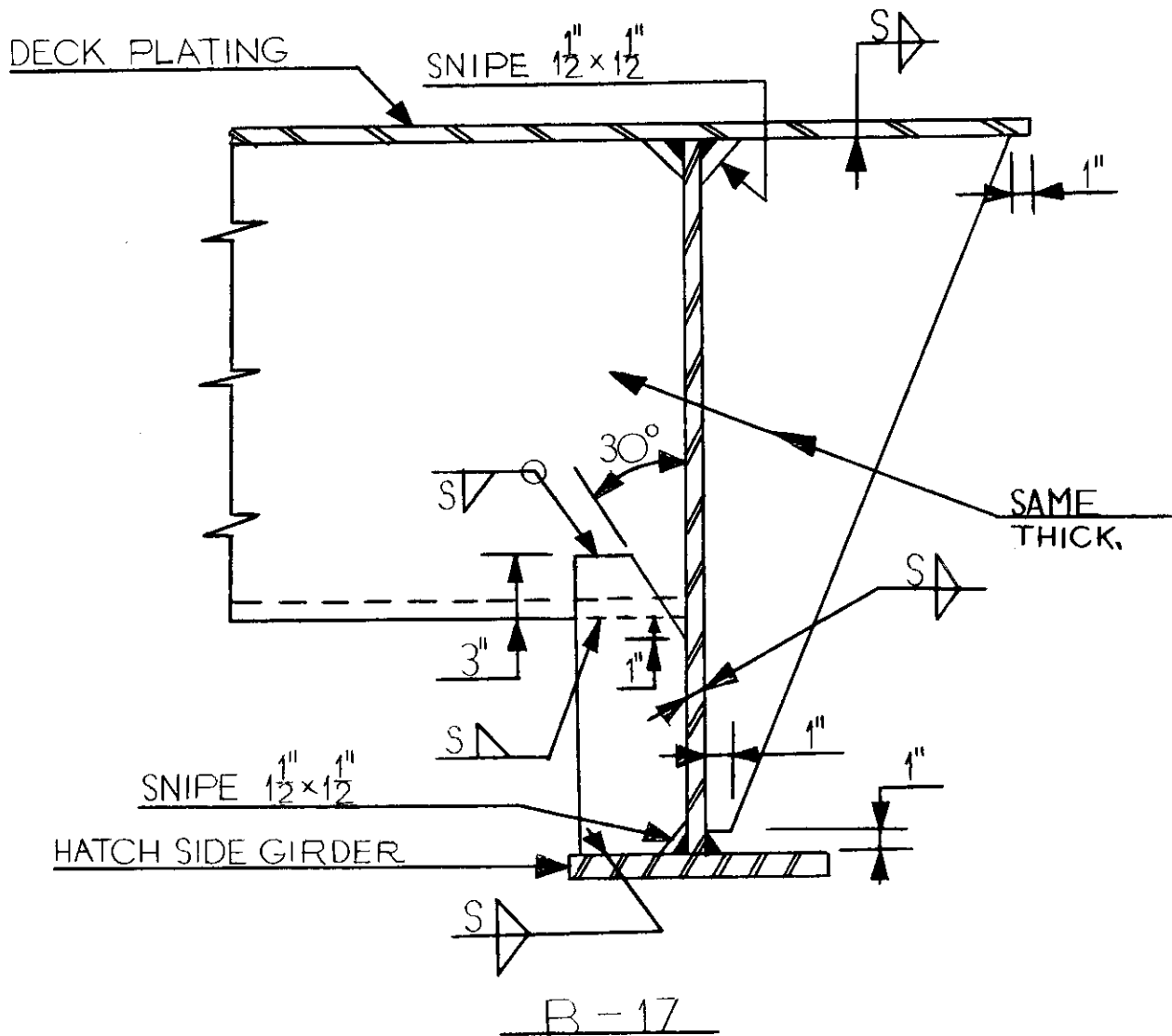
Detail Type: BRACKET

Comments: This detail is used by Shipyard "Y" on ship type "J" to provide deck plating support around deck openings and to provide an end connection for a deck member. The flange of the hatchside girder receives support from the small chock. Not a commonly used detail.

SPAN LENGTH = L

$L/8$ OR $2D$ USE GREATER

$2D + 1''$

DECK

CH-5

A

A

D

S

S

SNIPE $1\frac{1}{2}'' \times 1\frac{1}{2}''$
TYPICAL

Tw

$1\frac{1}{2}''$

$3Tw + \frac{1}{4}''$

A-A

B-18
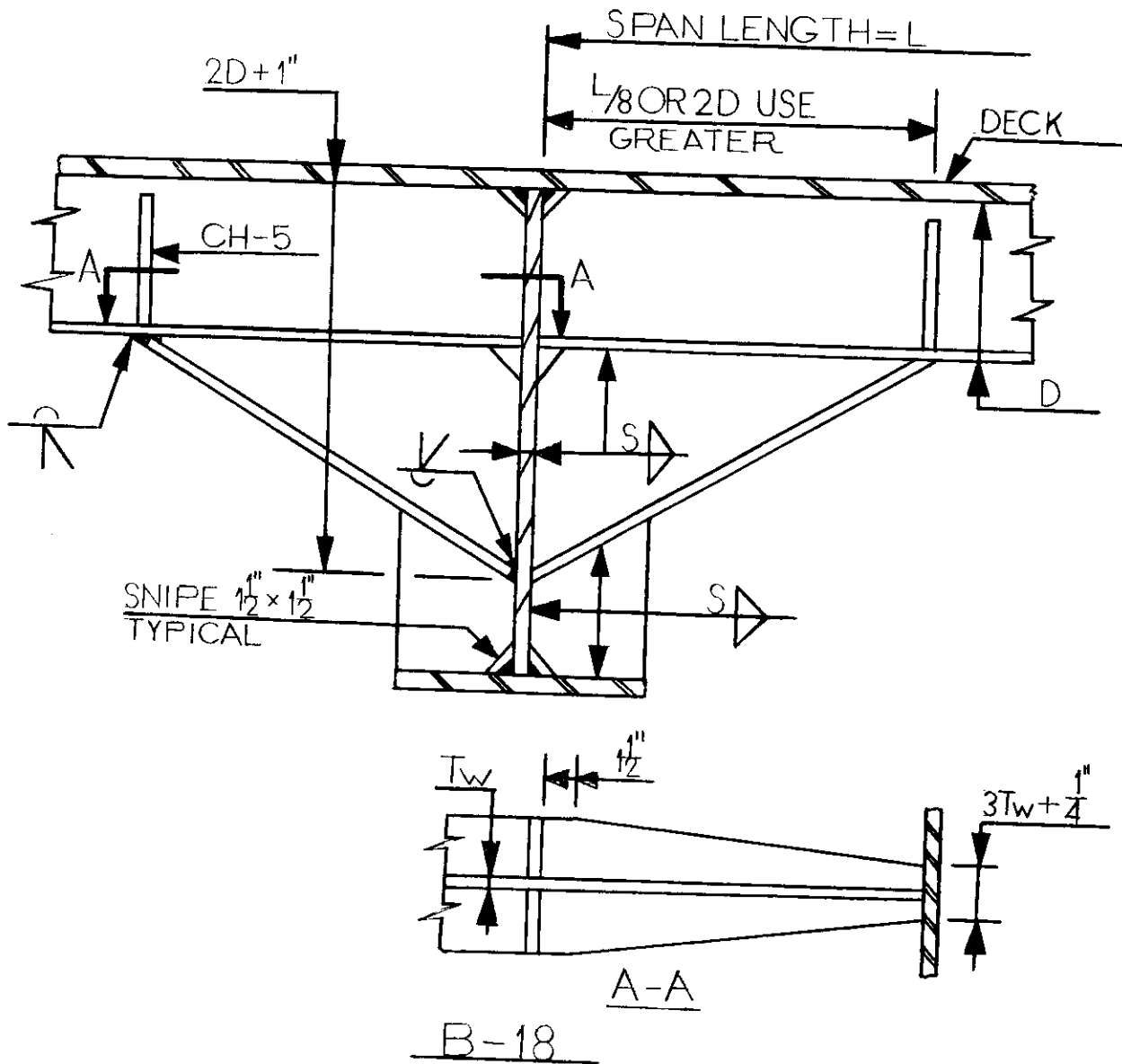
Detail Type: BEAM BRACKET

Comments: This detail is used by Shipyards "U" and "V" on ship types "D" and "F" and it is in the CASDOS library of standard details. This detail is used primarily on Navy vessels where deck beams carrying large lateral loads are supported by a deep girder. Brackets develop a moment resisting connection, which reduces the scantlings of the deck beams.
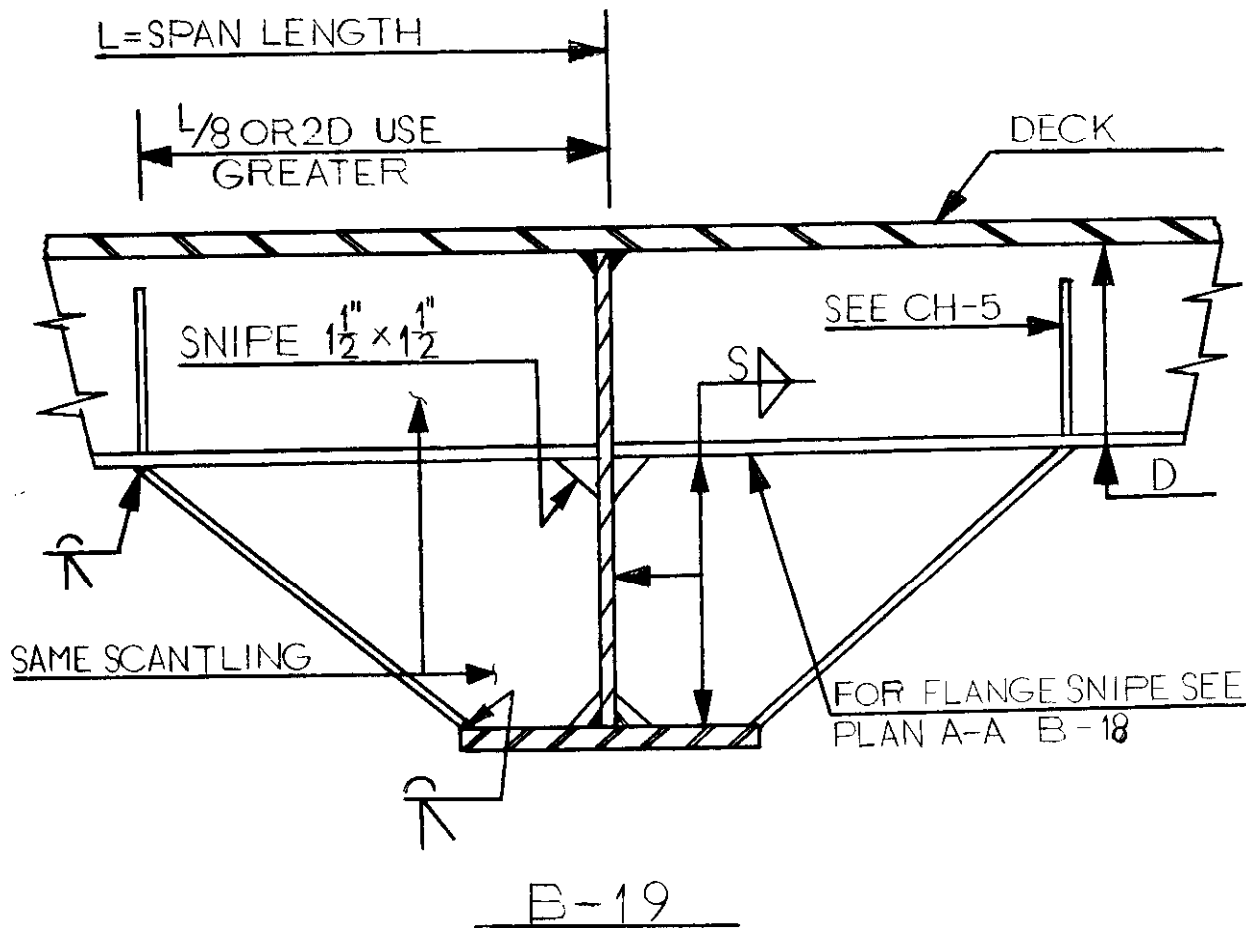
L=SPAN LENGTH

$L/8$ OR 2D USE GREATER

DECK

SEE CH-5

SNIPE $1\frac{1}{2}" \times 1\frac{1}{2}"$

S

D

SAME SCANTLING

FOR FLANGE SNIPE SEE PLAN A-A B-18

B-19

Detail Type: BEAM BRACKET

Comments: This detail is used by Shipyards "U", "V" and "Z" on ship types
                "D", "F" and "K" and is in the CASDOS library of standard details.
                This detail is used primarily on Navy vessels where deck beams
                are supported by shallow girders.

DECK PLATING

2D+1" WHEN
D IS 6" TO 20"
2D IN OTHER
CASES

SNIPE $1\frac{1}{2}" \times 1\frac{1}{2}"$

SEE CH-5

L= SPAN LENGTH

L/8 OR 2D USE
GREATER

S

SNIPE FLANGE SIMILAR B-18

SAME SCANTLINGS

SEE CH-5

D

BULKHEAD

B-20
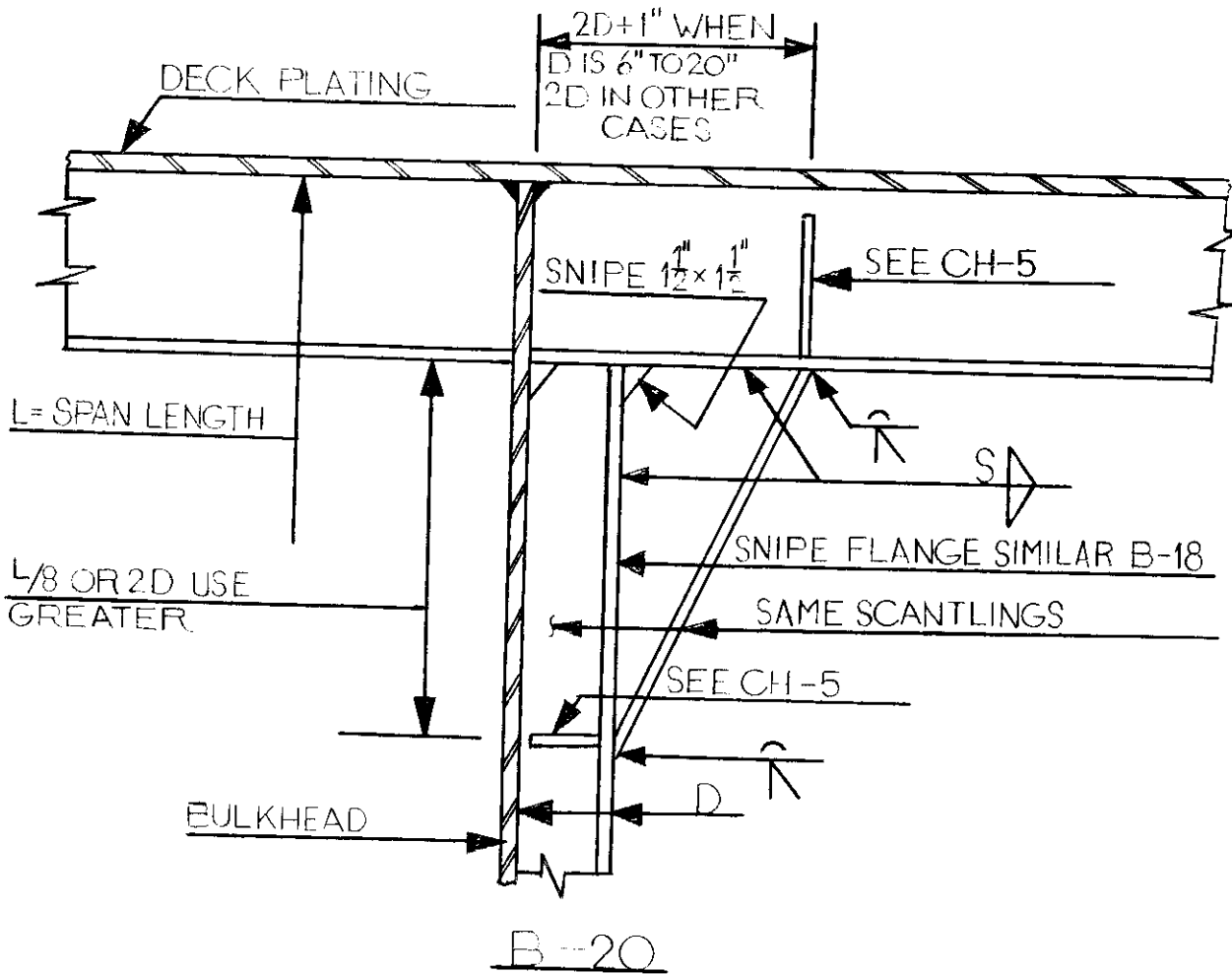
Detail Type: STIFFENER BRACKET

Comments: This detail is used by Shipyards "U", "V" and "Z" on ship types
"D", "F" and "K" and is in the CASDOS library of standard details.
This detail is used primarily on Navy vessels where a deep deck
beam intersects a shallow bulkhead stiffener, where a rigid
connection is desired.   Bracket is effective for bulkhead member.
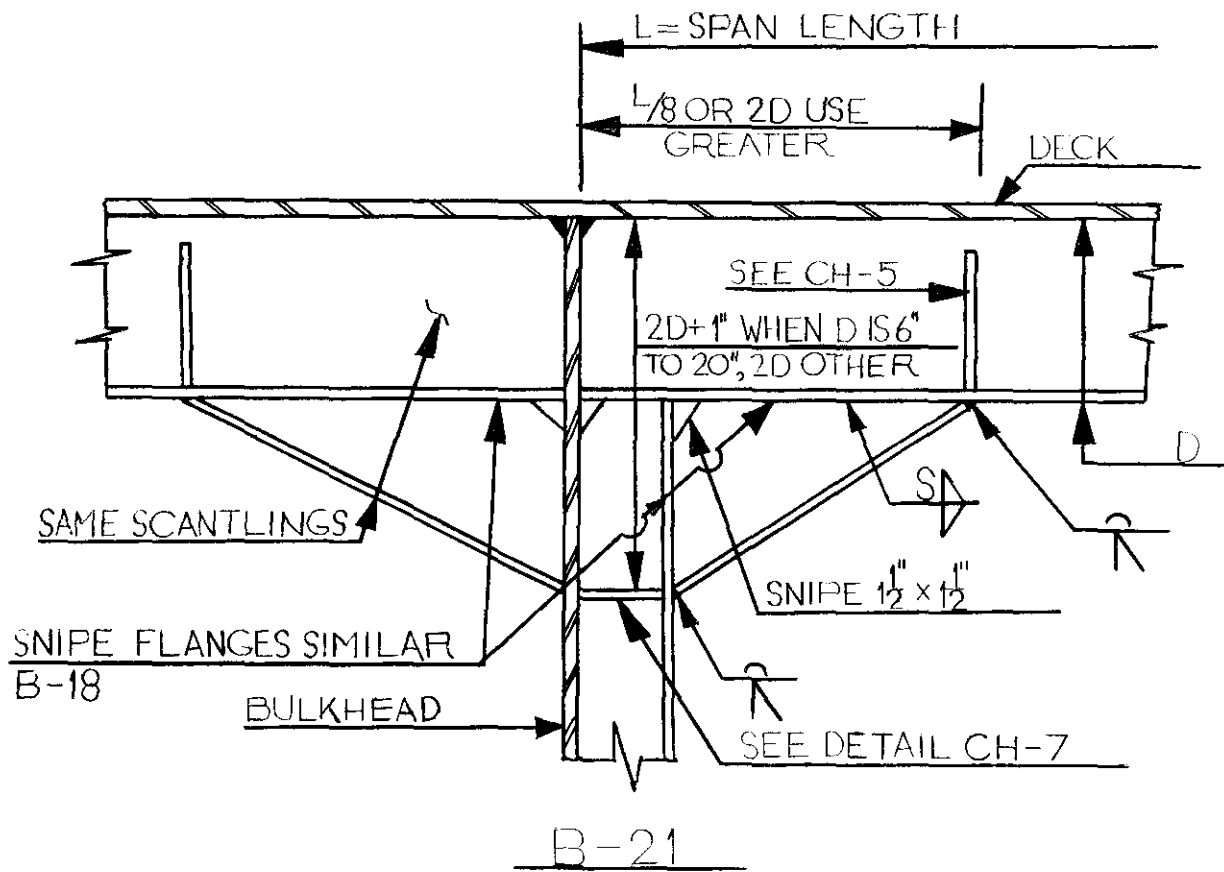
L = SPAN LENGTH

L/8 OR 2D USE GREATER

DECK

SEE CH-5

2D+1" WHEN D IS 6" TO 20", 2D OTHER

D

SAME SCANTLINGS

SNIPE 1½" X 1½"

SNIPE FLANGES SIMILAR B-18

BULKHEAD

SEE DETAIL CH-7

B-21

Detail Type: BEAM BRACKET

Comments: This detail is used by Shipyards "U" and "Z" on ship types "D" and "K" and is in the CASDOS library of standard details. This detail is used primarily on Navy vessels where a shallow bulkhead stiffener and shallow deck beam, both carrying large lateral loads, intersect, and a moment resisting connection is desired.

3-157

$2D_3+1''$ WHEN D_3 IS 6" TO 20" $2D_3$ OTHER

L_2 = SPAN LENGTH OF D_2

$L_2/8$ OR $2D_2$ USE GREATER

SAME SCANTLINGS

CH-5

CH-5

L_1

CH-6

SAME SCANTLINGS

SNIPE $1\frac{1}{2}'' \times 1\frac{1}{2}''$ TYP.

D_1

SNIPE FLANGE SIMILAR B-18

$2D_2+1''$ WHEN D_2 IS 6" TO 20": $2D_2$ IN OTHER CASES

$L_1/8$ OR $2D_1$ USE GREATER

S ⊳ TYP.

CH-5

D_3

B -22
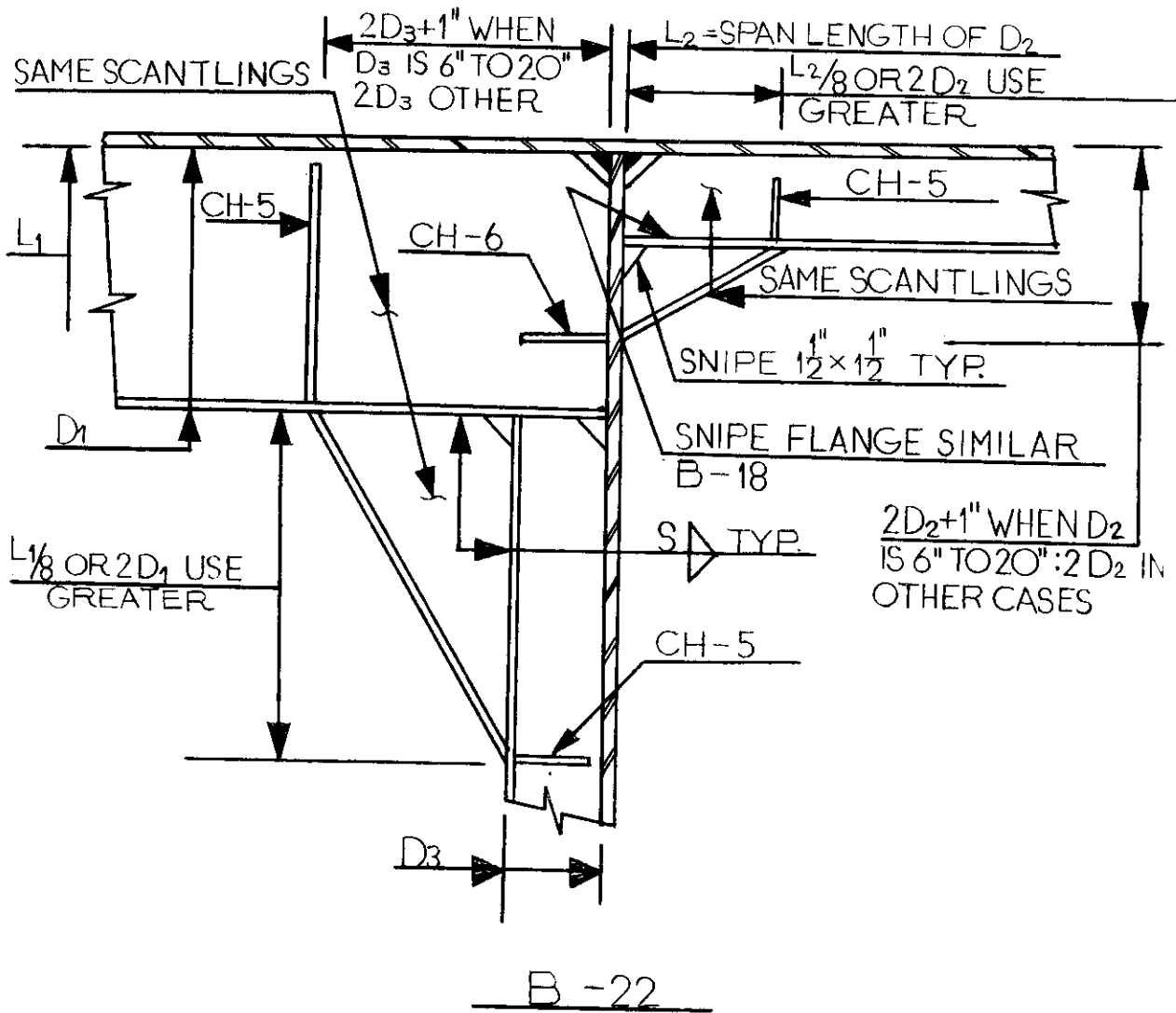
Detail Type: BEAM BRACKET

Comments: This detail is in the CASDOS library of standard details, primarily used on Navy ships where a longitudinal deck beam, deck girder and bulkhead stiffener, all carrying large lateral loads, intersect. Note that this detail uses ten pieces.

3-158

Section 4

DETAIL DESIGN GUIDELINES

4.1 GENERAL

Appendix A is an attempt to list all guidelines applicable to structural detail
design contained in the rules of the world's major classification societies
and other applicable rule-making technical societies. This section reproduces
only those rules which are considered the most applicable available guidelines
for each particular detail. Rules are supplemented by common ship design
practice where the latter is generally accepted.

In general agreement with the overall objective of reviewing the state of the
art in regard to structural details, the aim of this section is to display the
most explicit guidelines currently in use, rather than to attempt the formula-
tion of new design rules.

The benefit of this approach is that the immediate application of such guide-
lines is sanctioned by either a technical organization or by common usage.
The shortcoming is that it fails to facilitate the choice between many of the
detail configurations shown in Section 3, and does not necessarily always
represent either a rational or optimum solution.

This section is background for future theoretical and rule making activites
in this important field of ship structures.

4.2 OPENINGS IN SHIP HULL STRUCTURE

Openings in ship hull structure are made for access, passage of piping,
ventilation ducts and electrical cables, cargo handling, air escape, lightening
of structure, etc. Stress concentrations in structural members are a direct
result of the introduction of holes in a member. Poor design procedures in
combination with poor workmanship may result in serious structural failures
of penetrated members.

Guidelines have been assembled from the classification and technical society
rules and experience.

Because of the complexity of modern ships, it is recommended practice to
develop a set of holes record prints which maintain a composite and current
record of all penetrations through structural members. These prints may also
be used for checking and anticipating interferences, and for influencing design
and engineering decisions related to the location of service systems with respect
to the structural arrangement, as well as monitoring the effect of holes on the
structural design.

The ideal situation is when all required penetrations are identified in the design stage, before steel fabrication begins: then cutouts can be made by the automatic burning machine (ABM) which assures a smooth hole. Frequently the system's design lags behind steel fabrication for the first ship in a series, thus many of the penetrations which should be cut by the ABM must be cut by hand, aboard ship. This practice frequently results in a poor cut, necessitating the addition of a patch plate or coaming where one should normally not be required.

Openings in hull structure are discussed in relation to specific items of such structure.

4.2.1 Shell Plating

4.2.1.1 General

There are two main types of shell openings: sea chest and discharge. Sea chest openings and openings greater than 24 inches are compensated for by increasing the thickness of the strake of plating containing the opening. The discharge openings are compensated for by the pipe itself. Sea chest openings are reviewed and approved by the classification society. Ballast discharge overflows of up to 24 inches are approved by the classification society shipyard representative. Small penetrations are inspected by the classification society shipyard representative since they do not appear on the working plans sent to the approval agency.

4.2.1.2 Sheerstrake (Pertains to the top full course of side shell plating)

Openings in the sheerstrake are to have well-rounded corners. In general, compensation will not be required for holes in the sheerstrake which are clear of any deck openings outside the line of the main hatchways, where the longitudinal strength of the hull is not critical, and whose depth does not exceed 20% of the depth of the sheerstrake or 15 inches, whichever is less. When the longitudinal strength of the hull is critical, or the size of the opening is greater than the aforementioned limiting dimension, then some compensation of area in judicious combination of the following will be required.

    a.   Increased plate thickness.

    b.   Use of insert plates or doubler plates.

    c.   Increase the area of the adjacent girders or longitudinals.

    d.   Flat bar reinforcement along the edge of the opening. See Figure 4-1.

    e.   Flat bar reinforcement around the inside of the opening. See Figure 4-2.
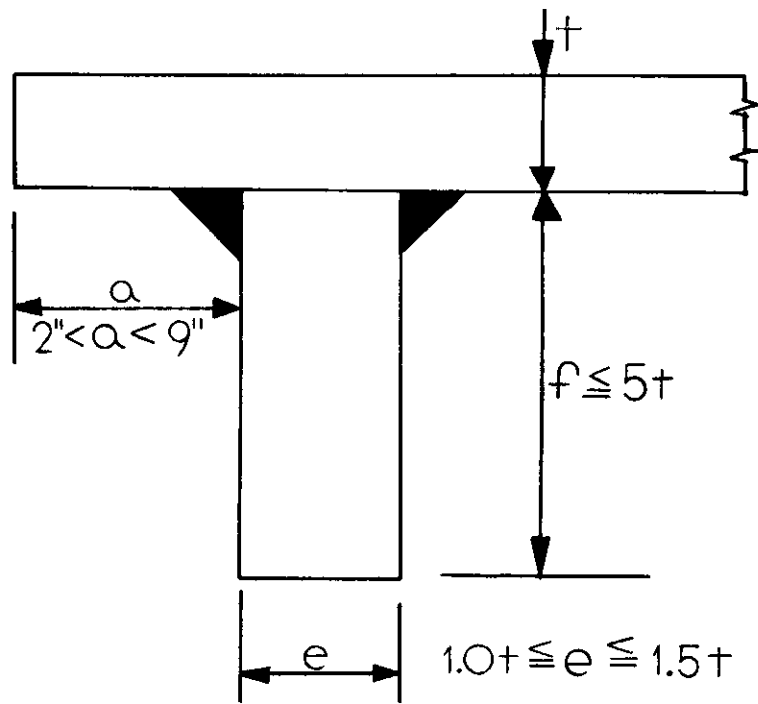
Fig.4-1: Flat Bar Reinforcement Along the Edge of an Opng
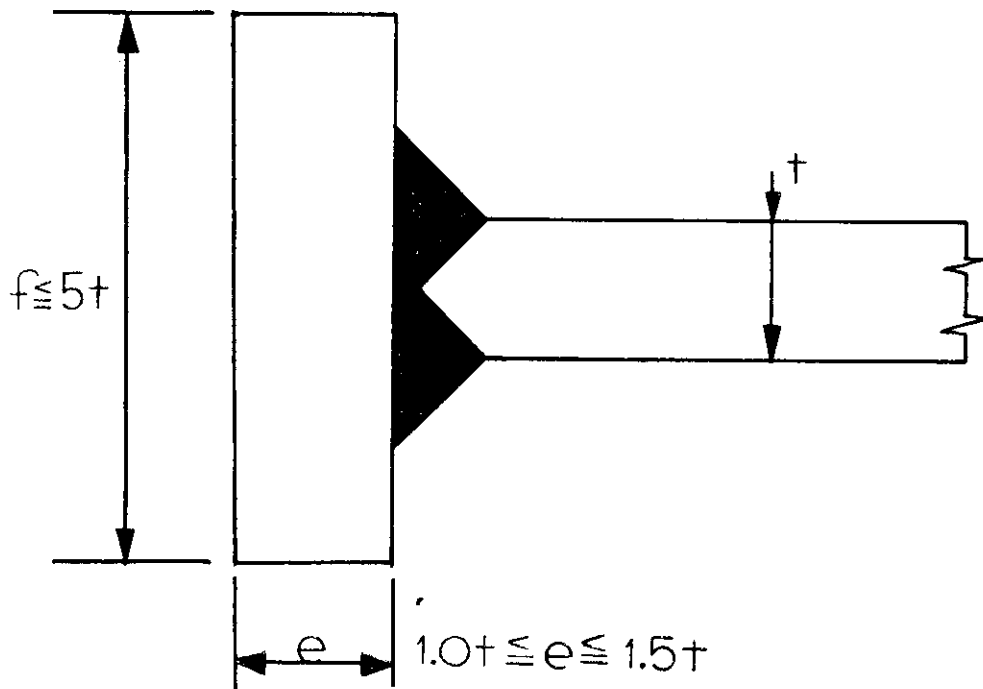
Fig.4-2: Flat Bar Reinforcement Around the Inside of an Opng

4.2.1.3 Side Shell Plating

Openings in the side shell; such as cargo doors, freeing ports, side scuttles, etc., are to have well-rounded corners. Side shell openings are to be kept clear of discontinuities in the hull girder. Compensation will be required for all openings, except for circular openings with a diameter less than 12 inches. Compensation may be made as described in Section 4.2.1.1.

4.2.1.4 Bilge Strake Plating (plating between the bottom shell and side shell)

Openings for sea inlets are to have well-rounded corners, and so far as possible should be kept clear of the bilge radius. Openings on or near the bilge radius should be elliptical in shape with the major axis in the longitudinal direction.

4.2.1.5 Bottom Shell Plating

Openings in the bottom shell are to have well rounded corners, and are to have adequate compensation so as to maintain the longitudinal and transverse strength of the hull. Considerations for compensation requirements will be based on the following guidelines for 0.6 L amidships.

TABLE 4-1

GUIDELINES FOR OPENINGS IN THE BOTTOM SHELL PLATING

	Deduction-free Openings Within the same Transverse Section	
Bottom Shell	Elliptical	Circular
	$\Sigma a \leqq 0.03 B$	$\Sigma a \leqq 0.02 B$

The transverse section is any strip measured along the bottom whose width is B/15 (see Figure 4-3).

Σa = sum of transverse dimensions of all openings.

Strengthening for openings exceeding the limits of Table 4-1 shall use compensation as described in Section 4.2.1.1.
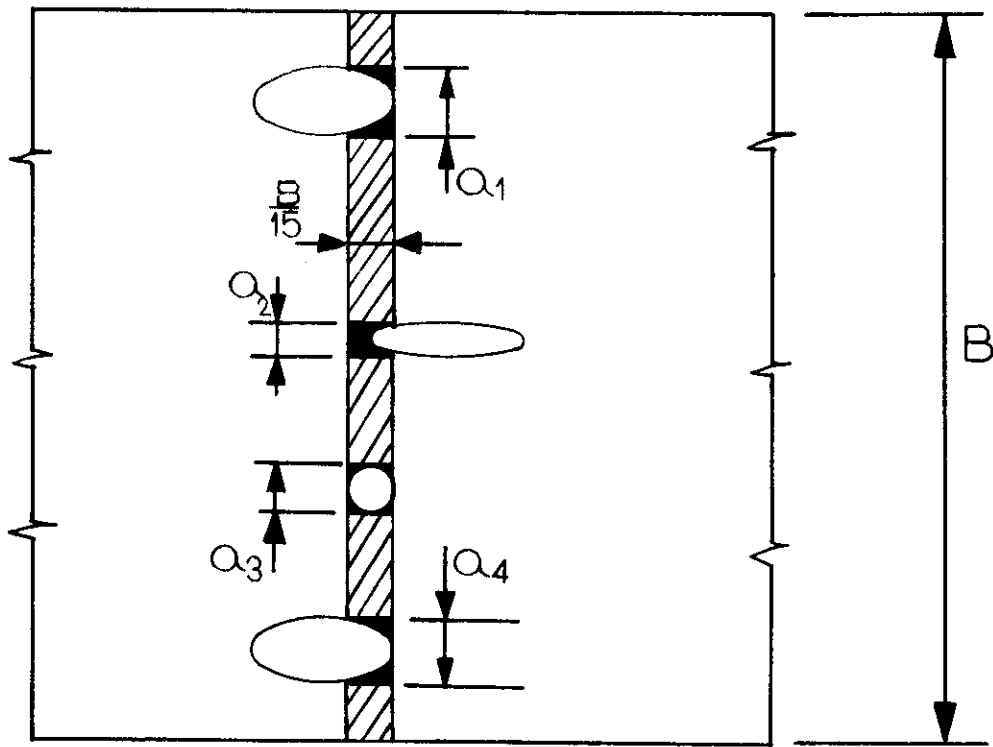
FIG.4-3 OPENINGS IN THE BOTTOM SHELL
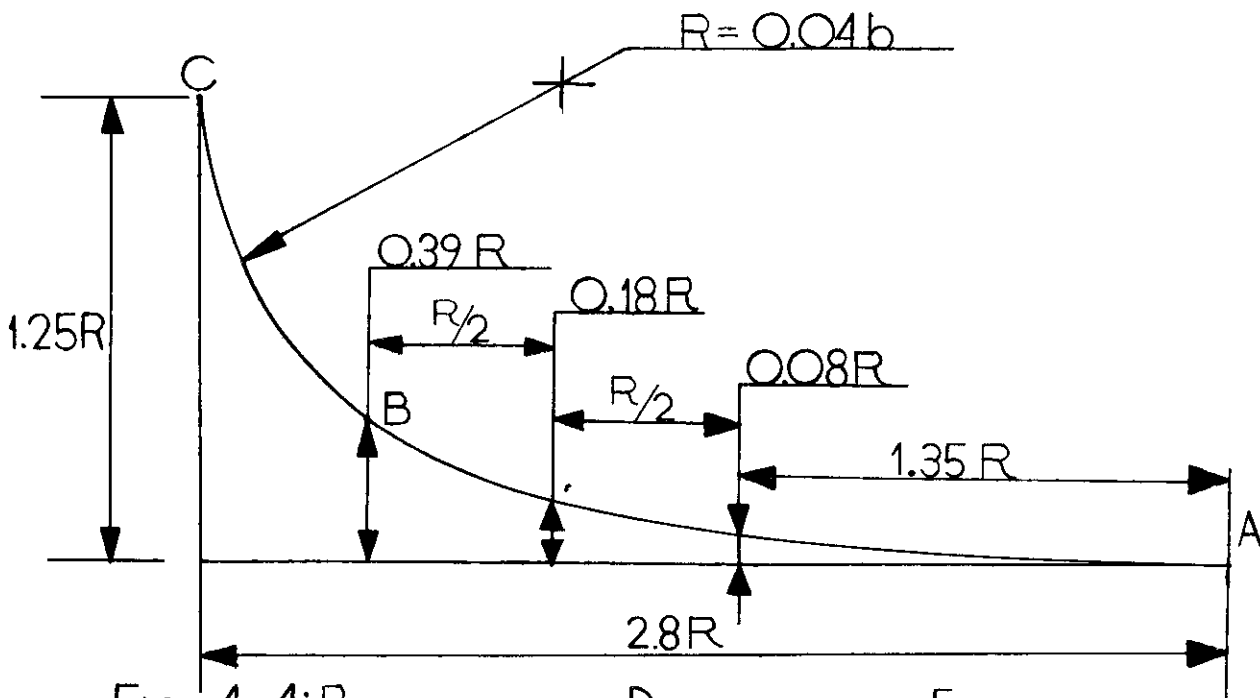
FIG. 4-.4: RECOMMENDED DIMENSIONS FOR ELLIPTIC OR PARABOLIC CORNERS OF HATCHWAYS

4.2.2 Strength Deck Plating

4.2.2.1 Plating Within the Line of Openings

Within the line of openings, the thickness of exposed plating, t_{ph}, is not to be less than:

    tplt = 0.01Sb + 0.035 in., where Sb $\leqq$ 30 in.
    tplt = 0.00067Sb + 0.134 in., where Sb > 30 in.
    Sb = spacing of transverses or longitudinals, (inches.)

4.2.2.2 Hatch Corners

The corners of main hatchways are to be surrounded by strengthened plates which are to extend over at least one frame space fore and aft and athwartships. Within 0.5 L amidships, the thickness of the strengthened plates is to be equal to the deck thickness abreast of the hatchway plus the deck thickness between the hatchways. At the ends, the strengthened plates need not exceed 1.6 times the thickness of the deck plating abreast of the hatchway. Where the hatchway corners are elliptic or parabolic, strengthening is not required, provided that no greater thickness results from the strength calculation of hatchway girders at the corners. The recommended dimensions of the elliptical or parabolic corners should be as shown in Figure 4-4. In the event that radiused corners are used at hatchway corners, that radius is not to be less than:

    $r = 0.1\ b_L(1 - {}^{b_L}/B)$ in.
    r max. = $0.06 b_L$
    r min. = 4 in.
    b_L = breadth of hatchway or hatchways

4.2.2.3 Openings

Shipyard practice generally does not require compensation for openings in the strength deck less than 9 inches in diameter. The normal procedure of locating deck penetrations is a minimum of $2D_p$ (D_p mean diameter) center to center.

Elliptical openings, although not generally employed by U.S. Shipyards, are used because they cause less severe stress concentrations than circular or rectangular openings do.

The centerline of pipe penetrations shall not be less than one diameter away from plate butts or seams.

Openings in deck plating are to have well-rounded corners, the distance between the outer edge of the openings for pipe, etc., and the ship's side is not to be less than the opening diameter. Strength deck openings are to be of suitable shape and design so as to minimize stress concentrations. The following table will provide guidelines for compensation of openings in deck plating.

TABLE 4-2

GUIDELINES FOR OPENINGS IN THE STRENGTH DECK

	Deduction-free Openings Within the same Transverse Section	
	Elliptical-I	Circular-II
Decks, Tankers	$a \leqq 0.05B$ $0.05\ B \leqq 80$ in. $a \leqq 35$ in.	$a \leqq 0.03\ B$ $0.03\ B \leqq 40$ in. $a \leqq 16$ in.
Decks, dry cargo ships	$a \leqq 0.03\ (B-b_L)$ $a \leqq 14$ in.	$a \leqq 0.03\ (B-b_L)$ $a \leqq 4$ in.

b_L = hatch breadth

Strengthening for openings exceeding the limits of Table 4-2 shall use compensation as described in Section 4.2.1.1.

4.2.3 Bulkhead Plating

4.2.3.1 Main Longitudinal Bulkheads

Openings in the main longitudinal bulkhead should be avoided as much as possible. However, when openings are unavoidable, the corners are to be well-rounded. Care should be taken to maintain the tightness of the bulkhead, and adequate compensation should be provided to maintain the longitudinal strength of the hull. Openings in the bulkhead are to be effectively framed so as to facilitate proper fitting, and to guarantee perfect tightness. Compensation of area will be accomplished as discussed in Section 4.2.1.1.

4.2.3.2 Main Transverse Bulkheads

Openings in the main transverse bulkhead are to be restricted to cutouts for watertight doors and cuts for piping. Cuts for pipes, vent ducts and wireways may be kept to a minimum by employing pipe tunnels or utility trunks. Where openings do exist in the bulkhead, the corners are to be well-rounded and care should be taken to maintain the tightness of the bulkhead. Openings in the bulk-head are to be effectively framed to facilitate proper fitting and guarantee perfect tightness.

4.2.3.3 Miscellaneous Structural Bulkheads

Openings in miscellaneous structural bulkheads above doors and arches should be avoided where possible, since this is a high stress area. Any vent spool, pipe or sleeve passing through a structural bulkhead, but not designed for compensation need only be welded one side.

4.2.3.4 Non-Tight Bulkheads

Compensation for non-tight bulkhead openings will generally not be required

4.2.4 Girders and Other Strength Members

4.2.4.1 Inner Bottom Floors and Side Girders

Manholes and other openings in floors and girders are to be cut smooth along a well-rounded design. Holes inside girders and floors should be cut at mid-depth, their length should not exceed one-half the web depth and their height should be so limited as to provide a plate strip at least equal to one-quarter the depth of the double bottom.

4.2.4.2 Longitudinal and Transverse Girders

Girders with openings exceeding the limits of Table 4-3 are to have the hole areas deducted when calculating the member section moduli, or the openings are to be compensated for by a judicious combination of the following:

    a.   Increased plate thickness.
    b.   Flat bar reinforcing rings.
    c.   Insert plates and doubler plates.

TABLE 4-3
GUIDELINES FOR OPENINGS IN TRANSVERSE AND LONGITUDINAL GIRDERS

Arrangement of Openings	Deduction-free Openings
Long openings or groups of long openings all in the same section. Figure 4-5	$b \leq 0.5s$ and $L_A \geq 10a$; $a \leq 0.2s$ $\Sigma atw \leq 0.02A$
Long openings or groups of openings shifted in relation to each other. Figure 4-6	$b \leq s$ and $b \leq L_A$ $L_A \geq 10a$ and $L_A \geq 600$ mm $\Sigma atw = 0.03A$
Short openings with relatively large spacing in the same section or shifted. Figure 4-7	$b \leq 0.25s$ and $L_A \geq 10a$ $\Sigma atw \leq 0.03A$

where:

    b = major axis of opening
    a = minor axis of opening
    L_A = distance between openings
    tw = thickness of web plate
    s = longitudinal spacing
    A = total area of the members in the bottom or strength deck
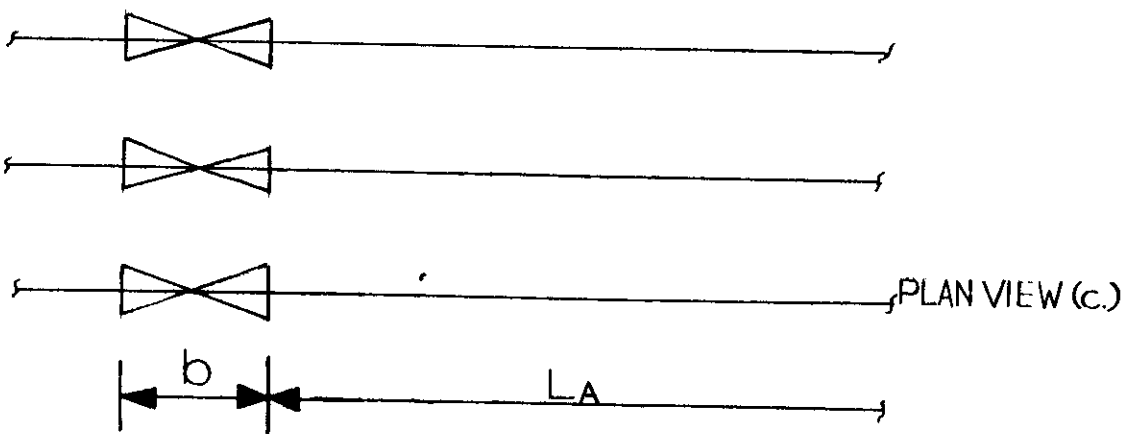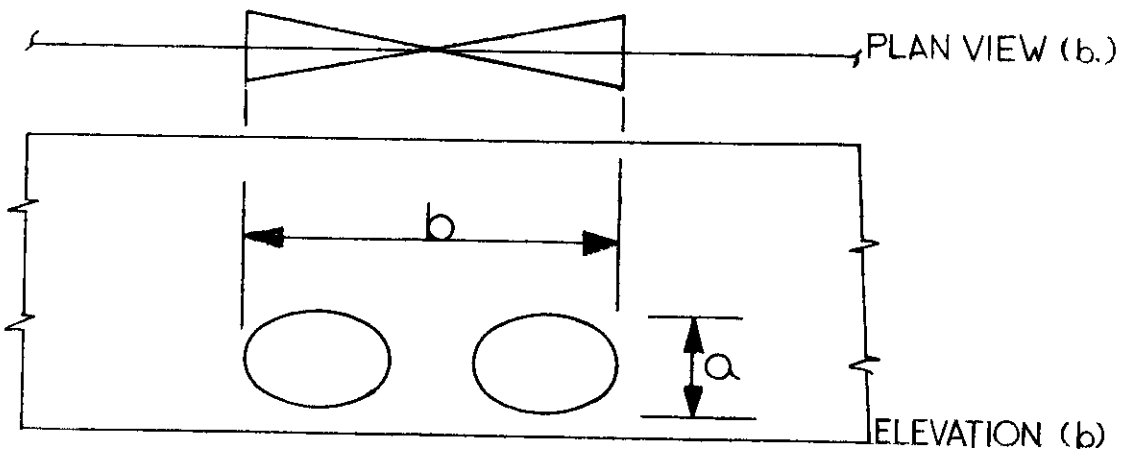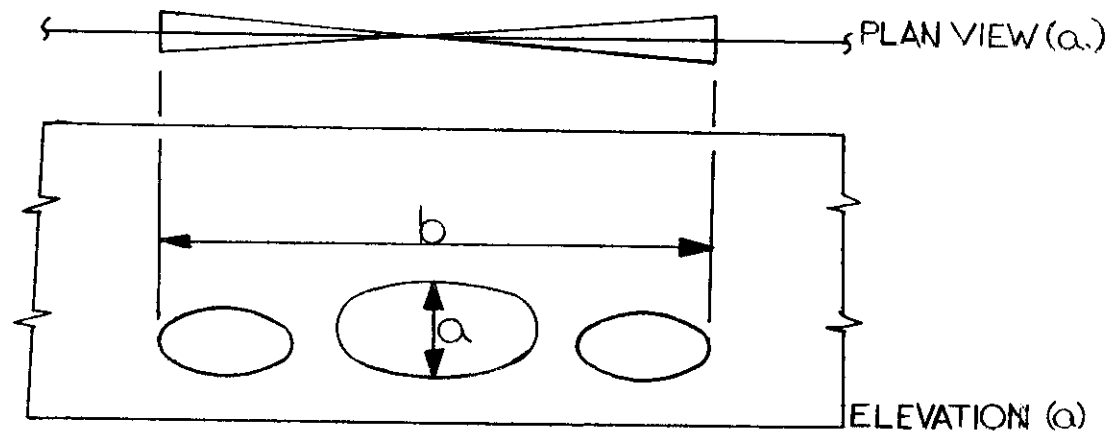
FIG.4-5: LONG OPNGS OR GROUPS OF LONG OPNGS ALL IN THE SAME SECTION
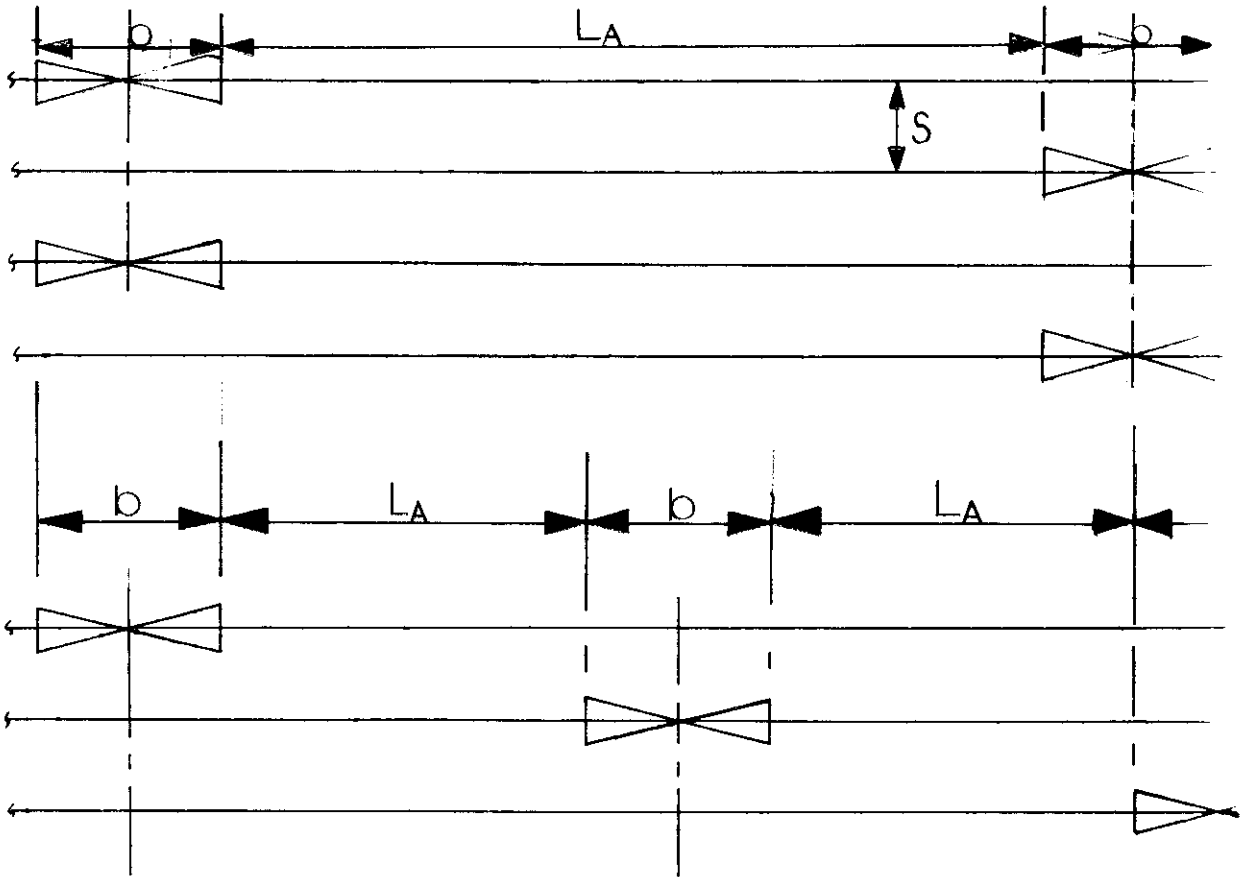
FIG. 4-6: LONG OPNGS OR GROUPS OF LONG OPNGS SHIFTED IN
RELATION TO EACH OTHER
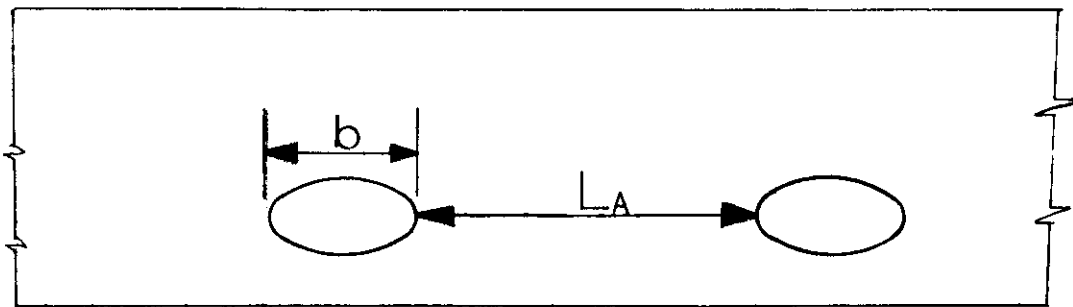
FIG. 4-7: SHORT OPNGS WITH RELATIVELY LARGE SPACING IN THE
SAME SECTION OR SHIFTED

Openings in beams, girders, longitudinals, and stiffeners should be located in the web near the neutral axis of the member. No cuts in the flanges of beams and stiffeners should be made without compensation.

4.3 KNEE AND BEAM BRACKETS

4.3.1 Brackets for Girders and Deep Webs

In vessels constructed with deep webs, girders and transverses, it may be desirable to reduce the scantlings of these members by introducing brackets at the member ends. These brackets are fitted on the girders or webs to reduce the unsupported span of the members, to eliminate stress concentrations at the joint of two members or to assist in steel erection. The following guidelines have been formulated to assist in the design of these brackets.

a. Where brackets are employed, they are to have a thickness that is at least equal to the thickness of the web of the member supported.

b. By varying the area of the face plate of the bracket, the unsupported span Lu of the member is defined as follows:

Case 1: When the area of the bracket face plate is at least equal to one-half the area of the face plate or flange on the girder or deep web and the girder flange is carried to the bulkhead or base, the unsupported span of the member may be measured to a point 6 in. onto the bracket (see Figure 4-8).

Case 2: When the area of the bracket face plate is less than one-half the area of the face plate or flange of the girder or deep web and the girder flange is carried to the bulkhead or base, the value of the unsupported span is measured to a point on the bracket where the area of the bracket and its flange outside the line of the girder or deep web, is equal to the area of the flange on the girder. (see Figure 4-9).

Case 3: When the area of the face plate or flange of the supported girder or deep web is carried along the face of the bracket, which may be curved for this purpose, the unsupported length of the member is measured to the toe of the bracket (see Figure 4-10).

c. Brackets on girders and deep webs cannot be considered effective beyond the point where the arm on the girder or deep web is one and one-half times the length of the arm on the bulkhead or base. In no case is the allowance in the unsupported length at either end to exceed one quarter of the overall span of the girder or deep web.

4-11

GIRDER SPAN : L_S (IN.)

ABRKT FLG (IN^2)

UNSUPPORTED SPAN : L_U (IN.)

AGIRD. FLG (IN^2)

d_A (IN.)

t BRKT (IN.)

t GIRD. (IN.)

a_L (IN.)

6"
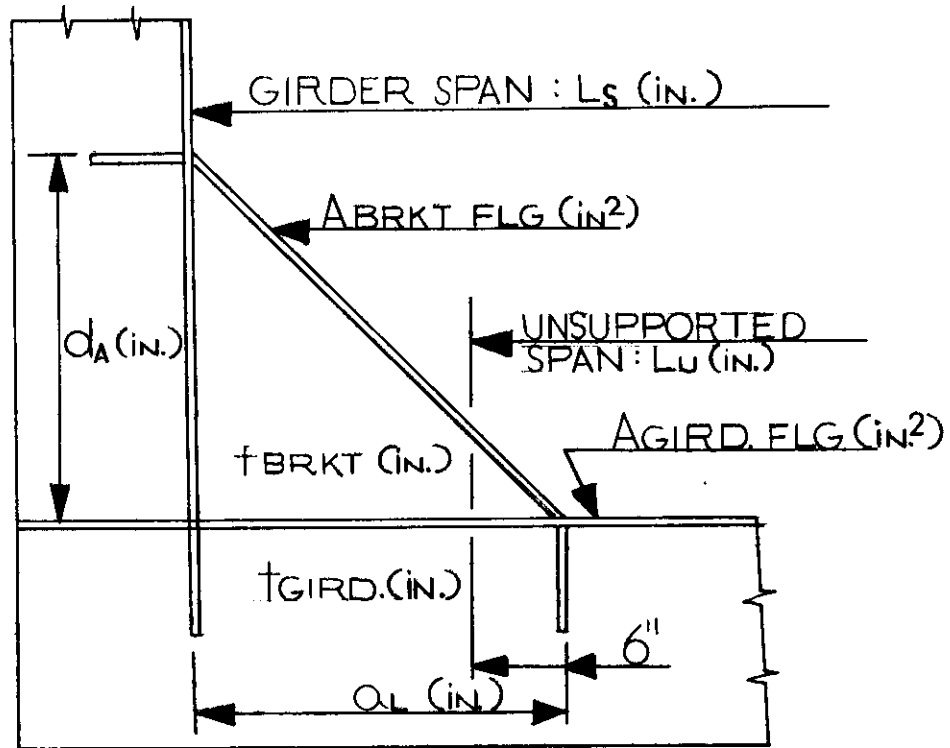
ABRKT FLG $\geqq$ (AGIRD. FLG) $\div 2$ IN^2

t BRKT $\geqq$ t GIRD. IN.

$a_L \leqq 1.5 d_A$ IN.

$a_L \leqq L_S / 4$ IN.

$L_U = L_S 2 (6 - a_L)$ IN.

FIG. 4-8: KNEE BRACKET : CASE 1

GIRDER SPAN: Ls (IN.)

ABRKT FLG (IN.²)

UNSUPPORTED SPAN : Lu : (IN.)

AGIRD FLG (IN.²)

d_A(IN.)

t_{BRKT}(IN.)

t_{GIRD}(IN.)

d_L (IN.)

a_L (IN.)
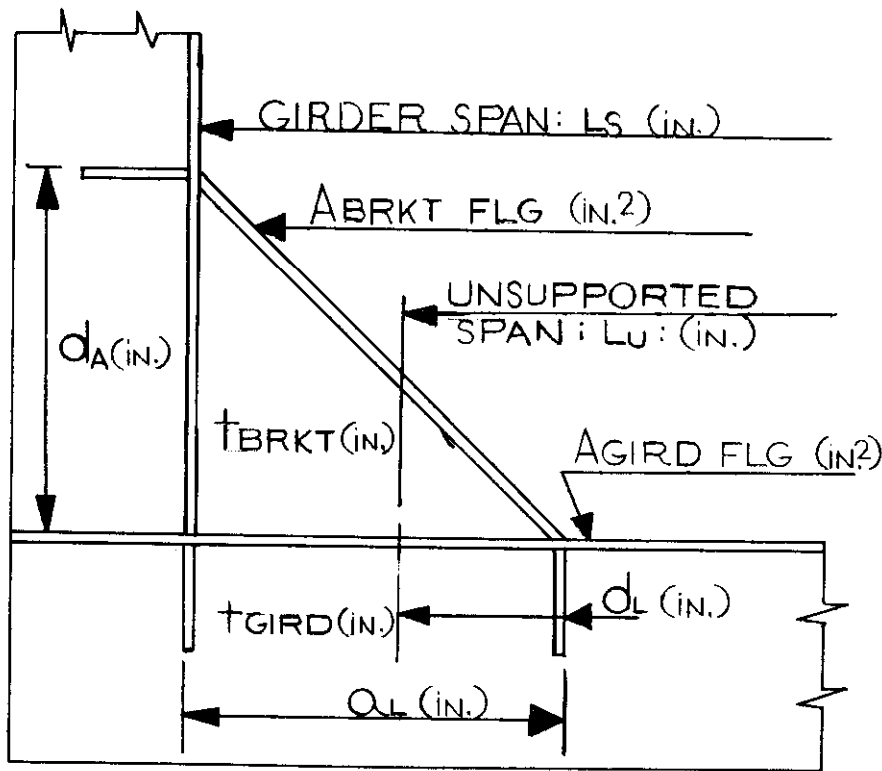
$A_{BRKT\ FLG} < (A_{GIRD\ FLG})/2 \quad IN.^2$

$t_{BRKT} \geqq t_{GIRD.} \quad IN.$

$a_L \leqq 1.5\, d_A \quad IN.$

$a_L \leqq L_S/4 \quad IN.$

$d_L = \dfrac{[A_{GIRD.FLG} - A_{BRKT\ FLG}]\, a_L}{d_A\, t_{BRKT}} \quad IN.$

$L_U = L_S - 2\,(a_L - d_L) \quad IN.$

FIG. 4-9: KNEE BRACKET : CASE 2

4-13

GIRDER SPAN: L_S

$A_{BRKT\ FLG}$ (in²)

a_L (in.)

d_A (in.)

UNSUPPORTED SPAN: L_U (in.)

$A_{GIRD\ FLG}$ (in²)

t_{BRKT} (in.)

a_L (in.)
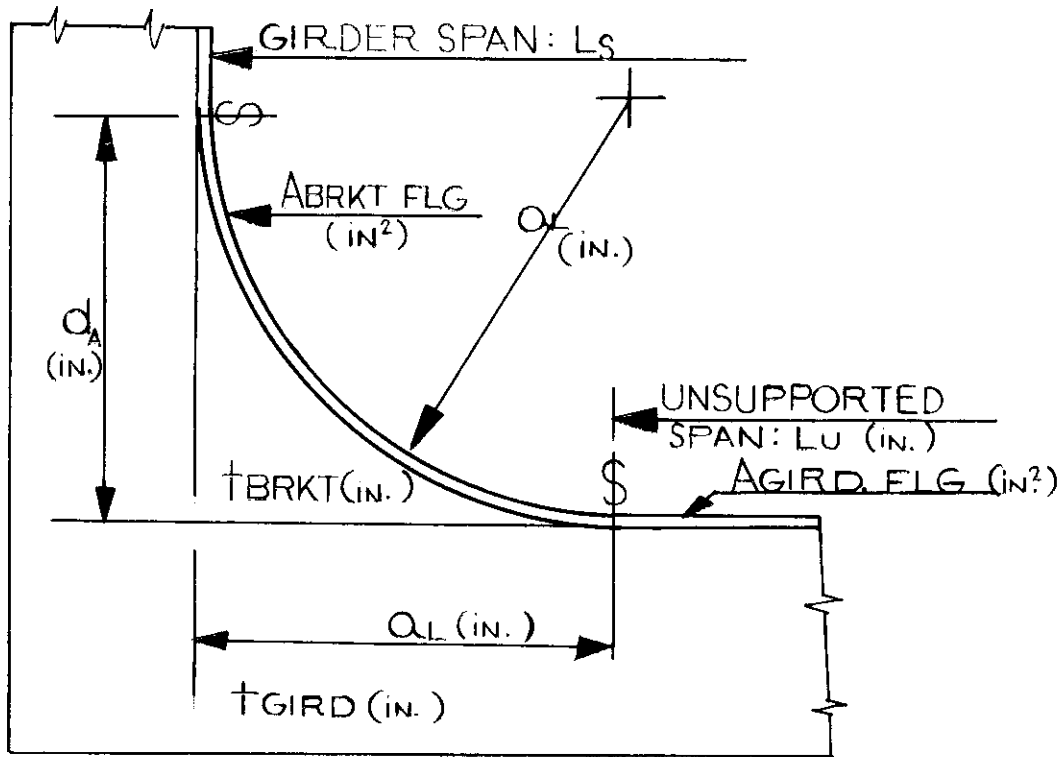
t_{GIRD} (in.)

$A_{BRKT\ FLG} = A_{GIRD\ FLG}$ in²

$t_{BRKT} \geq t_{GIRD}$ in.

$a_L \leq 1.5 d_A$ in.

$a_L \leq L_S/4$ in.

$L_U = L_S - 2a_L$ in.

FIG. 4-10: KNEE BRACKET: CASE 3

4.3.2 Brackets Connecting Rolled Sections

This section pertains to brackets connecting rolled sections, with the exception of brackets interconnecting members participating in the overall strength of the hull. Brackets are to be either butt welded or lapped. Straight brackets are to have equal legs.

The scantlings of connecting brackets will depend on a factor, W, which is considered to be the reference modulus. This reference modulus is dependent upon the section moduli of the connected members.

Figures 4-11 thru 4-15 detail the more common brackets used in hull structure. By utilizing the guidelines for determining the reference section modulus as presented in these figures, it is then possible to obtain the geometric characteristics for a particular bracket from Table 4-4. Any bracket that does not conform to the aforementioned guidelines should be considered on an individual basis.

4.4 TRIPPING BRACKETS, LATERAL SUPPORT

4.4.1 Unbraced Length of Compression Flange

The allowable bending stress and resultant allowable load carrying capacity of a longitudinal or transverse beam or girder is dependent upon the lateral support of its compression flange in addition to its section properties. In the design of a transverse or longitudinal member, it is often necessary to provide flange support to the member by introducing tripping brackets along the compression flange. The following paragraphs will outline the procedure for locating and sizing tripping brackets:

a. The notation, Lu, represents the maximum unbraced length of the compression flange, assuming the compressive stress is less than or equal to 0.6 Fy (Fy = yield stress, Ksi). For ordinary strength hull structural steel (Fy = 33.0 Ksi).

$$Lu = 606/\left[12(d_W/Af)\right] \text{ ft.}$$

where:
d_W = depth of member (in.)
Af = area of compression flange (in.^{2})

For other grades of steel, the value of Lu is calculated as follows:

$$Lu = 20000/\left[12(d_W/Af) \cdot Fy\right] \text{ ft.}$$

(The use of this formula is limited to sections whose compression flange area is at least as great as the tension flange.)

$$W = W_2 \text{ IF } W_2 \leqq W_1$$
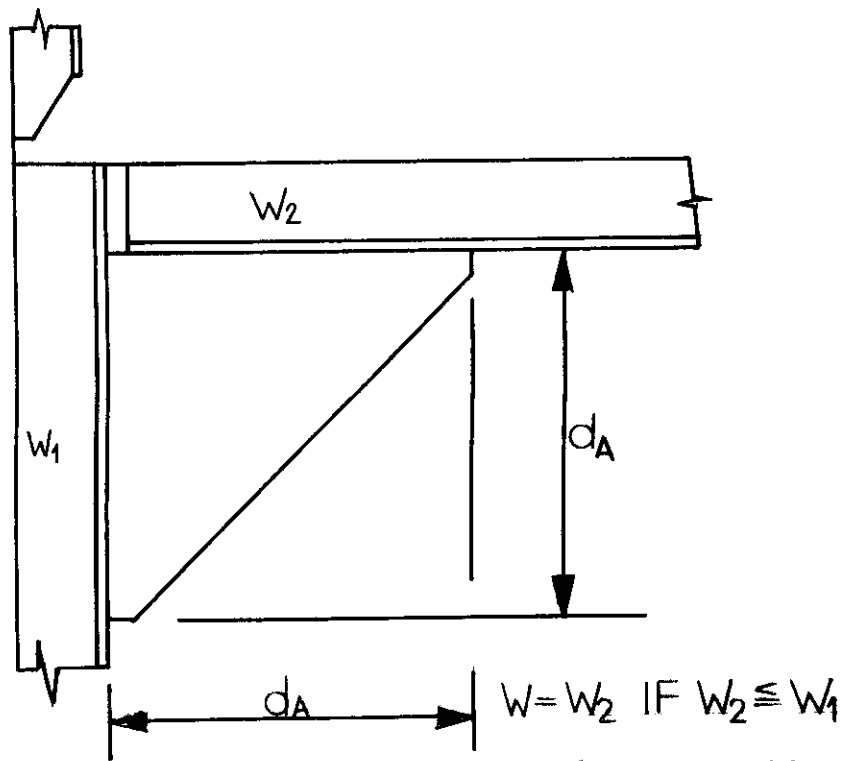
Fig. 4-11: Beam Bracket Connecting Two Sections Neither of Which Extend Beyond the Assembly

THEORETICAL BRKT LINE

ACTUAL BRKT LINE

$$W = W_2 \text{ IF } W_2 \leqq W_1$$
$$W = W_1 \text{ IF } W_2 > W_1$$
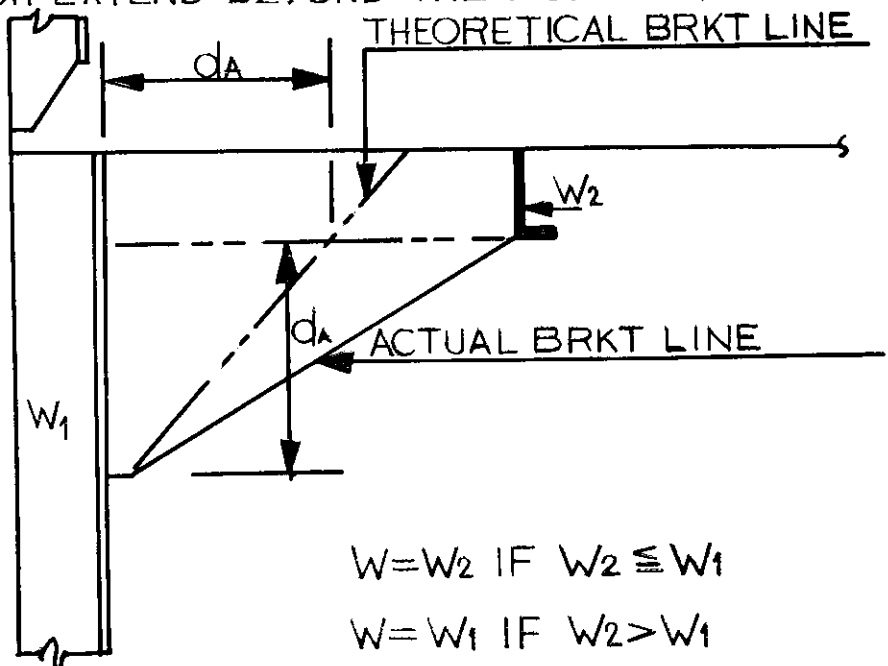
Fig. 4-12: Beam Bracket Connecting Two Sections Lying in Perpendicular Planes

$$W = W_2 \text{ IF } W_2 \lesseqgtr W_1 + W_1'$$
$$W = W_1 + W_1' \text{ IF } W_2 > W_1 + W_1'$$
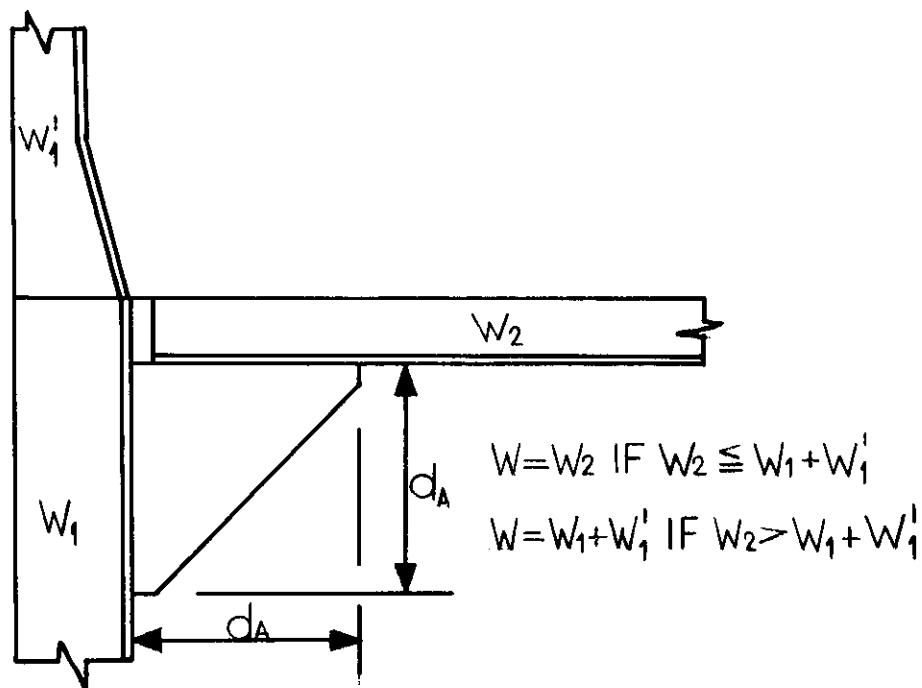
Fig. 4-13: Intermediate Beam Bracket Connecting Members with Direct Continuity

$$W = W_1 \text{ IF } W_1 \gtreqless W_2$$
$$W = W_2 \text{ IF } W_1 < W_2$$
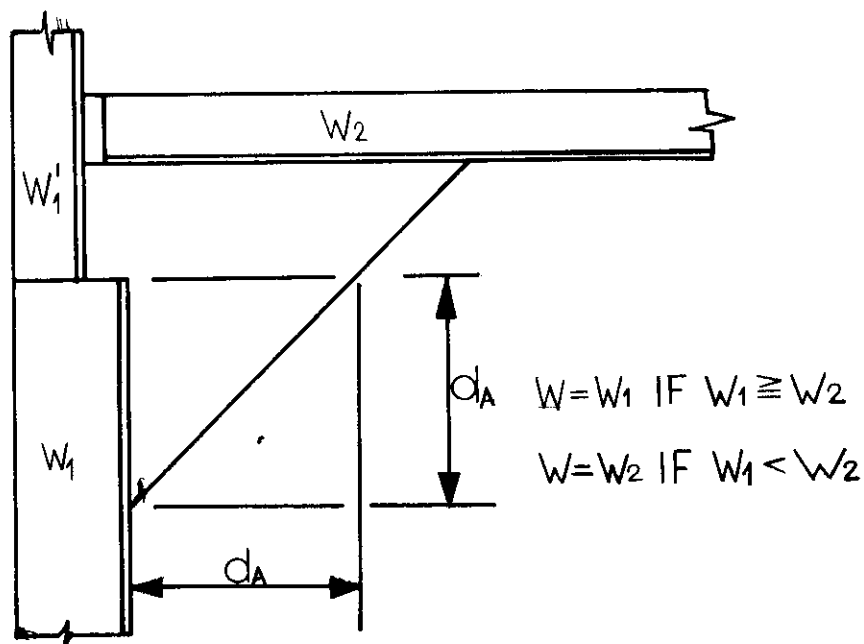
Fig.4-14: Intermediate Beam Bracket Providing Continuity of Members

$$W_A = W_1 \quad \text{IF} \quad W_1 \geqq W_2$$

$$W_A = W_2 \quad \text{IF} \quad W_1 < W_2$$

$$W_B = W_1'$$
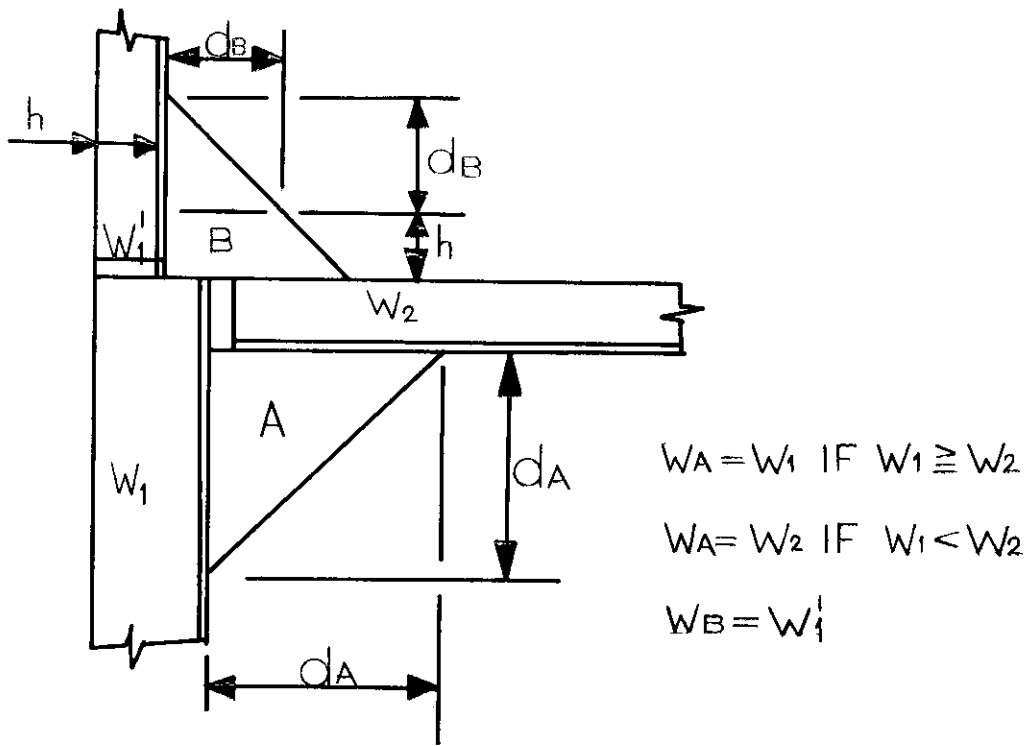
FIG. 4-15: INTERMEDIATE BEAM BRACKETS PROVIDING CONTINUITY OF MEMBERS

TABLE 4-4

GUIDELINES FOR BRACKETS CONNECTING ROLLED SHAPES

Reference Modulus in.^{3} W	Minimum Bracket Thickness in.		Minimum Width and Height d_A in.	Minimum Required Flange Area in.^{2}
	Unflanged	Flanged		
5	5/16		8	
10	5/16		10	
15	3/8		11	
20	7/16		12	
25	7/16		13	
30	7/16		14	
35	1/2		15	
40	1/2	7/16	15	1.0
45	1/2	7/16	16	1.0
50	9/16	7/16	16	1.1
55		1/2	17	1.2
60			17	1.2
65			18	1.2
70			18	1.2
75			19	1.3
80			19	1.3
85			20	1.3
90			21	1.4
100			22	1.5
110			22	1.5
120			23	1.6
130			24	1.7
140			25	1.7
150			26	1.8
160			27	1.9
170			28	2.0
180			28	2.1
190			29	2.2
200		↓	30	2.3
210	↓		30	2.4

Since only the compression flange is subject to tripping, the location of tripping brackets should be selected to suit the actual loading condition.

b. Tripping brackets on girders are to be stiffened by a flange or stiffener along the free edge. If the length of that edge exceeds 24 inches, the area of the stiffening is not to be less than $0.1\ell_b$ in.^{2}, where ℓ_b = length of bracket free edge (inches).

c. The width to thickness ratio of compression flanges should not exceed $95/\sqrt{Fy}$, i.e., 16.5 for ordinary ship steel.

$$b_f/t_f \leq 95/\sqrt{Fy}$$

d. Unstiffened compression elements whose width to thickness ratio exceeds the limit in section c. shall be subject to a reduction factor Qs. The value of Qs shall be determined by the following formulas. When such elements comprise the compression flange of a flexural member the maximum allowable bending stress shall not exceed:

$$Fb = 0.6\ Fy\ Qs$$

When $95/\sqrt{Fy} < (b_f/t_f) < 176/\sqrt{Fy}$:

$$Qs = 1.415 - 0.00437\ (b_f/t_f)\ \sqrt{Fy}$$

When $b_f/t_f \geq 176/\sqrt{Fy}$:

$$Qs = 20000/\left[Fy\ (b_f/t_f)^2 \right]$$

Tripping brackets are normally placed on both sides of a tee-beam to insure that one is always in tension.

4.5 PANEL AND WEB STIFFENERS

4.5.1 Center and Side Girders

Where longitudinal framing is used in the double bottom, transverse brackets are to be fitted at a maximum spacing of 72 inches between solid floors. When the bracket spacing exceeds 48 inches, additional stiffeners will be required.

The thickness of the brackets shall be the lesser of the following:

a. center girder thickness
b. $0.0131\sqrt{L} + 0.10$ (in.)

The additional stiffeners are to be flat bars with the same strength as those with the same thickness as the center girder and a depth equal to 0.08 (depth of the center girder.)

4-20

For Side Girders, vertical stiffeners are to be provided at every open floor. The scantlings for the vertical stiffeners are obtained using the same rationale as those for the center girder.

4.5.2 Floors

In vessels of 280 feet and above, stiffeners are to be fitted on solid floors. Stiffeners fitted on plate floors may consist of flat bars having a width of 0.10 times the floor depth and a thickness not to be less than:

$$t = 0.0354 \sqrt{L} \text{ in.}$$

L = length of ship in feet.

4.5.3 Web Plate Stiffeners

Stiffeners on web plates are to be located not more than 4 in. from the free edge of cutouts for intersecting longitudinals, frames or stiffeners. If web stiffeners are fitted in line with intersecting members, they are to be attached to the intersecting members. Stiffeners on the web plates that are perpendicular to the flange may be sniped toward the deck, side shell, or bulkhead plating. Web plate stiffeners for tankers may be sized per Table 4-5, which may also serve as overall guidance for web plate stiffening. Note that for deep girders a choice may be made between vertical and longitudinal web stiffening.

4.6 STANCHION SUPPORTS AND END CONNECTIONS

4.6.1 General

Although stanchions and pillars are primarily employed as compression members, it is possible for these members to experience an occasional tensile loading. Because of this occurrence, care must be taken in the design of end connections.

When stanchions are employed, it is recommended that they line up and not be staggered.

4.6.2 Compression and Bearing End Connections

4.6.2.1 Tubular and Hollow Square Pillars

Tubular and hollow square pillars are to be attached at the head to plates, supported by brackets, flanged where necessary, in order to transmit loads effectively. Doublers or insert plates are to be fitted to inner bottom under heels of tubular or hollow square pillars, and to decks under pillars greater than 6 inches in diameter. Pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding.

4.6.2.2 Pillars From Built-up or Rolled Sections

At head and heel connections of pillars built of rolled sections, loads are to be well distributed by means of transverse and longitudinal brackets.

4.6.3 Tensile End Connections

Attachments of stanchions or pillars under bulkhead recesses, tunnel tops, or deep tank tops which may be subject to tensile loads are to be specially developed to provide sufficient welding to withstand the tensile stress. Allowable tensile stress in the weld should not be greater than 15,600 psi.

SYMBOL DEFINITION - TABLE 4-5

* – the distance from bottom and deck to the nearest stiffener is not to exceed 55 t_w. For each successive stiffener $\left(\dfrac{\text{above bottom}}{\text{below deck}}\right)$ the spacing may be increased by 10%.

Iv = required moment of inertia of stiffeners perpendicular to girder flange - including 16 in. of plate flange.

Ih = required moment of inertia of stiffener parallel to girder flange - including 16 in. of plate flange.

Sv = maximum permissible spacing of stiffeners perpendicular to girder flange.

Sh = maximum permissible spacing of stiffeners parallel to girder flange.

S_1 = actual stiffener spacing (in.)

b_f = flange breadth (in.)

A_s = sectional area (in.^{2}) of stiffener including 16 in. plate flange.

ℓ = length of stiffener (in.)

S_b = spacing of transverses (in.)

H = web plate depth (in.)

τm = mean shear stress in the web plate in Ksi. τm is not to be taken less than 8.53 Ksi. If τm has not been calculated, it is to be taken as 12.8 Ksi.

t_w = web thickness (in.)

TABLE 4-5

GUIDELINES FOR SIZING WEB PLATE STIFFENERS FOR TANKERS

Girder Type	Iv (in.^{4})	Ih in.^{4}	Sv (in.)	Sh (in.)
Bottom Transv.	$\dfrac{cS_1 (t_w+t_c)^3}{16.4}$	$\dfrac{A_s \ell^2}{4000}$	$\dfrac{768\, t_w}{\tau\, m}$	$\dfrac{853\, t_w}{\tau\, m}$
Side and Long'l Bulkhead Verticals	$\dfrac{cS_1 (t_w+t_c)^3}{16.4}$	$\dfrac{A_s \ell^2}{2000}$	$\dfrac{768 t_w}{\tau\, m}$	$\dfrac{853\, t_w}{\tau\, m}$
Long'l Bottom Girder	——	$\dfrac{A_s \ell^2}{3000}$	——	*
Long'l Deck Girder	——	$\dfrac{A_s \ell^2}{3000}$	——	*
Deck Trans.	$\dfrac{cS_1 (t_w+t_c)^3}{16.4}$	$\dfrac{A_s \ell^2}{4000}$	$\dfrac{768\, t_w}{\tau\, m}$	$\dfrac{853\, t_w}{\tau\, m}$
Transv. Bulkhead Vertical	——	$\dfrac{A_s \ell^2}{2000}$	——	——
Stringers	$\dfrac{cS_1 (t_w+t_c)^3}{16.4}$	$\dfrac{A_s \ell^2}{4000}$	$\dfrac{768\, t_w}{\tau\, m}$	$\dfrac{853\, t_w}{\tau\, m}$

The spacing of web plate stiffeners for very large crude carriers (VLCC's) is a critical condition and should be specially considered to avoid possible failure of the transverse. The following guidelines are only minimum standards and each case should be individually considered. For bottom transverses, web plate stiffeners are to be fitted for the full depth of the member and are to be spaced at each longitudinal frame, for side transverses, vertical webs and horizontal girders stiffeners are to be fitted on alternate longitudinals and on every third longitudinal frame for deck transverses. Special attention is to be given to the stiffening of web plate panels close to changes in contour of the web, and for ships over 650 feet in length.

tc = 0.08 in. if no effective corrosion protection provided, = 0.04 in. if corrosion protection provided.

c is given in the following table:

$\dfrac{Sv}{H}$	0.8 or Greater	0.7	0.6	0.5	0.4	0.3
c	0.8	1.4	2.75	5.5	11.0	20.0

4.7 CUTOUTS

4.7.1 General

The material presented here applies in general to miscellaneous nonstructural openings such as lightening holes, scallops, and snipes. The guidelines already presented may also be applied to these cutouts.

Wrapping of welds in way of drain holes, erection and clearance holes, chocks, etc., is desirable because this eliminates a point of probable corrosion.

Erection butt cutouts conform to an unwritten rule allowing removal of up to 1-1/2 in.[2] of material without reduction of section properties.

4.7.2 Lightening Holes

Lightening holes are to be cut in all non-tight members, except in way of widespread pillars, to insure accessibility and adequate ventilation. Holes in side girders and transverse floors should be cut at mid-depth, their length should not exceed 50 percent of the web depth and their height should be so limited as to provide a plate strip of at least one-quarter of the double bottom depth wide. Lightening holes are to be kept well clear of end brackets and areas of high shear. The holes are to be well-rounded with a minimum radius of about one-third of the depth of the hole.

4.7.3 Scallops and Snipes

Air and drainage holes are to be cut in all parts of the structure to insure free escape of air to vents and free drainage of liquids to suction pipes. Air holes are to be placed as near to the inner bottom as possible. The total area of air holes is to be greater than the area of the filling pipes. Drain holes and welding scallops in longitudinal girders are to be arranged as far away from the centers of lightening holes as possible. Scallops for frames, longitudinals or stiffeners deeper than 20 inches, are to be stiffened at their free edge.

4.8 STRUCTURAL INTERSECTIONS

4.8.1 End Connections

1. End connections of all girders, webs, and stringers should be balanced by effective supporting members on the opposite side of bulkheads, tank tops, etc., and their attachments are to be effectively welded. End connections are to be for the full depth of the web plate. Where stringers are the same depth as the web frame, the standing flanges of the side stringers are to be attached.

2. Where the face bar of floor plates extend to the center keelson plate, the face plate is to be continuously welded to the center keelson's face plate and web plate. Where the face bar of the floor plate only extends to the face plate of the center girder, these are to be connected by welding. Furthermore, on both sides of the face bar, horizontal brackets are to be attached, the leg length of which is about the breadth of the face bar and the thickness of which is that of the face bar.

3. Structural continuity is to be maintained at the junction of primary supporting members of unequal stiffness by fitting well-rounded brackets.

4. In ships with double bottoms, the following guidelines have been provided for determining the minimum required weld area necessary for structural continuity:

    a. Bottom shell and inner bottom longitudinals are to be connected to the floors by a weld area of not less than:

    $$A_w = 0.0088sd \ (\ell - s_1) + 0.75 \ \text{in.}^2$$

    Where:

    s = stiffener spacing (ft)
    s_1 = calculated frame spacing (ft)

    d = ship draft (ft)
    ℓ = span of longitudinal (ft)

    b. If the expression $0.0001 \ H_A Ks/_t^2$ is greater than 0.2, or if the floor forms part of a sea chest, the end connection of stiffeners on plate floors is to have a weld area not less than:

    $$A_w = 0.0035 \ H_A Ks/_t^2 \ \text{in.}^2$$

    H_A= vertical distance from the middle of k to the top of the air pipe (ft)

    K= depth of center line (ft)

s = stiffener spacing (ft)

t = floor thickness (in.)

c. If the pressure head (h) on the inner bottom is greater than the draft (d.), the weld area between the inner bottom longitudinals or frames and floor plates or side girders is not to be less than:

$$A_w = 0.004 \ (\ell_1 + \ell_2)sh + 0.75 \text{ in.}^2$$

ℓ_1, ℓ_2 = span of frame on each side of the girder (ft)

h = pressure head to the mid-point of ℓ.

s = stiffener spacing (ft)

d. The weld area between inner bottom frames and transverse brackets at the CVK and margin plate is not to be less than:

$$A_w = 0.0044 \ell sh + 0.75 \text{ in.}^2$$

e. The weld area between inner bottom longitudinals or frames and vertical struts is not to be less than:

$$A_w = 0.004 \ell sh + 0.75 \text{ in.}^2$$

5. For ship's sides and tank bulkheads not covered by item 6, the following apply:

a. In holds, frames and stiffeners supported by girders are to be welded to the girders with a weld area not less than:

$$A_w = 0.004 \ (\ell_1 + \ell_2)sh + 0.75 \text{ in.}^2$$

(see 4c. for symbol definition)

b. If, in areas with great shear stresses, both sides of the frames are connected to the web of the girder, only the weld area on one side of the frame will be accepted as an effective connection area.

c. The lowest frames in the peaks are to be welded to the floors with an area not less than:

$$A_w = 0.0066 s \ell h + 1.2 \text{ in.}^2$$
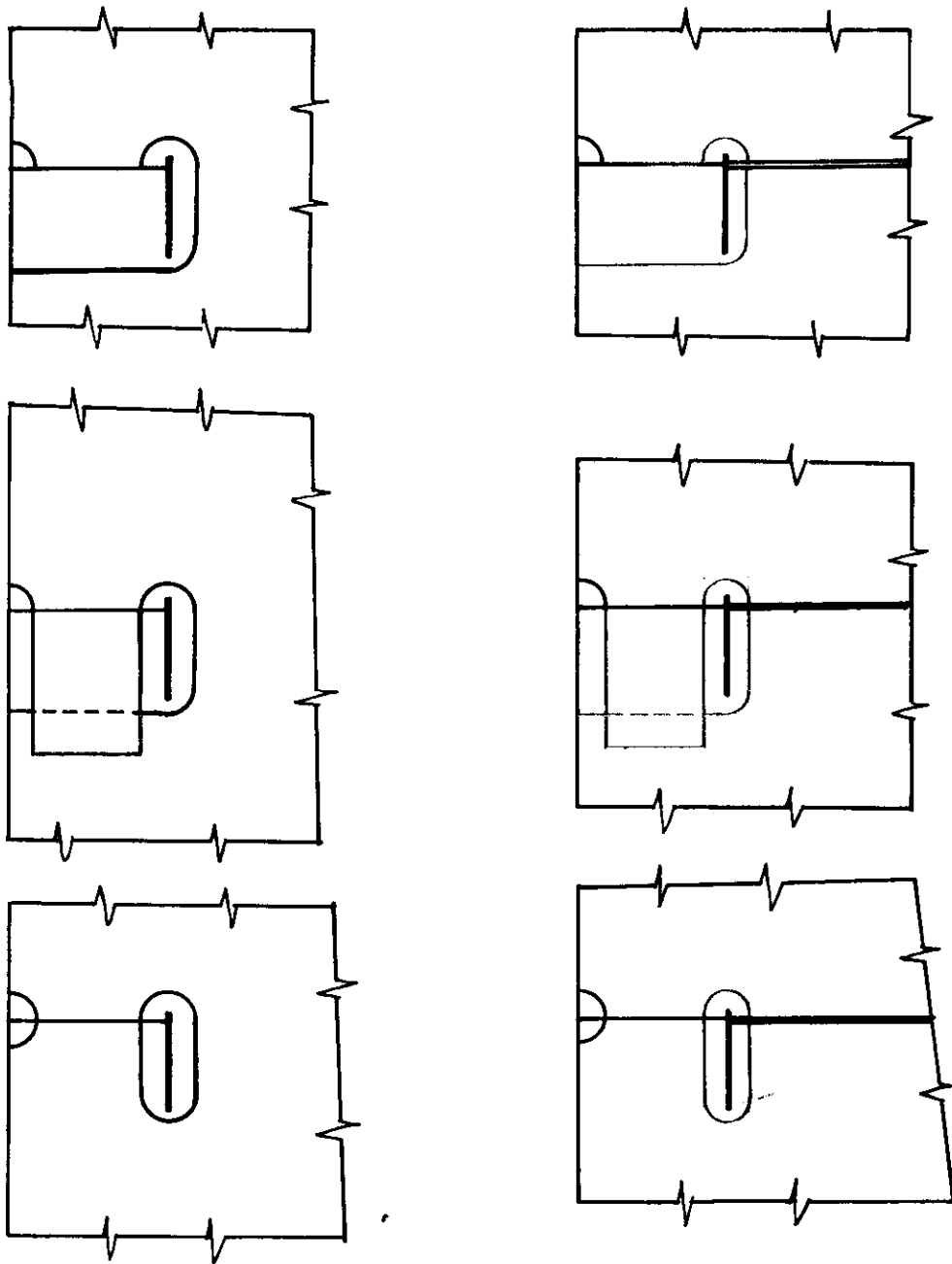
FIG.4-16: CONNECTION DETAILS OF LONGITUDINALS TO GIRDERS
AND/OR WEB FRAMES

4-27

6. Longitudinals, frames and bulkhead stiffeners in cargo tanks may be connected to the web plate of girders and web frames in the following ways (see Figure 4-16):

    Welded directly to the web plate on one or both sides of the frames.

    Connected by single or double-sided collars.

    With stiffener or bracket welded on top of frame.

    A combination of the above.

    In locations with great shear stresses in the web plate, a double-sided connection is required. The connection may then be taken into account when calculating the effective web area. Only one side of the connection, however, may then be included in the effective connection area between frame and web plate.

    If the necessary area is not obtained by using a side connection only, a stiffener or bracket is to be provided on top of the frame.

    Minimum connection area:

    $$A_w = 0.0055 \, \ell sh \text{ in.}^2$$

    ℓ = span (ft)
    s = spacing (ft)
    h = pressure head (ft)

7. For bulkhead stiffeners not covered by item 6, the following apply:

    a. The upper end of stiffeners which support deck beams or longitudinals, is to be connected to the deck beam or longitudinal by a weld area not less than:

        $$A_w = 0.0079 s \ell h \text{ in.}^2$$

        h = head on deck beam

    b. The lower end of stiffeners which support deck beams or longitudinals, is to be connected to deck or tank top by a weld area not less than:

        $$A_w = \ell^2/19.36 \text{ in.}^2 \geqq 2.4 \text{ in.}^2$$

    c. The end connection area at both ends of stiffeners is to be at least:

        $$A_w = 2.1 \frac{z}{\ell} \text{ in.}^2$$

        z = required section modulus of stiffener (in.^{3})
        ℓ = span of stiffener (ft)

8. For decks and single bottoms the following applies:

a. Continuous deck longitudinals in holds are to be connected to transverse bulkheads, transverses and other transverse structural parts with a weld area not less than:

$$a = 0.0044 s \ell h + 0.75 \text{ in.}^2$$

b. Where beams are supported by deck girders or hatchway coamings, the connection to girder or coaming is not to be less than given in the following table:

Depth of Beam	Connection Area
< 7.5 in.	1.0 in.^{2}
< 9.5 in.	1.6 in.^{2}
> 9.5 in.	2.0 in.^{2}

4.9   LIST OF COMMON SYMBOLS

a =   transverse dimension, or minor axis of an opening (in.)

a_L =   bracket arm length (in.)

A =   total area of the members in the bottom shell or strength deck (in^2).

ABRKT FLG   =   area of bracket flange (in^2).

AGIRD FLG   =   area of girder flange (in^2).

As   =   sectional area of stiffener including 16 in. plate flange (in^2).

b =   dimension, major axis of an opening (in.).

b_f =   flange breadth (in.)

bl   =   breadth of hatchway or hatchways (in.).

B =   ship breadth (ft.).

c =   end condition reduction factor

d =   ship draft (ft.), measured from the baseline to the summer loadline.

da, db   =   bracket arm length (in.)

dl   =   span reduction for case 2 brackets (in.).

dw   =   member web depth (in.)

D =   depth of ship, measured at ship centerline from the baseline to the bulkhead deck (ft.).

Dp   =   mean diameter of deck penetrations (in.).

e =   thickness of flat bar reinforcement ring (in.).

f =   depth of flat bar reinforcement ring (in.).

Fy   =   yield stress of material (Ksi).

h =   pressure head to the midpoint of ℓ (ft.).

hdb   =   head from top of the innerbottom to the top of the overflow (ft.).

Iv   =   required moment of inertia of stiffeners perpendicular to girder flange – including 16 in. of plate flange (in^4).

Ih   =   required moment of inertia of stiffener parallel to girder flange – including 16 in. of plate flange (in^4).

K   =   depth of centerline girder (in.).

ℓ =   length of stiffener (in., ft.).

ℓb =   length of bracket free edge (in.).

L   =   distance measured along the summer loadline, from the fore side of the stem to the after side of the rudder post or sternpost (ft.).

La   =   distance between openings (in.).

Ls   =   girder span (ft.).

Lu   =   unsupported span or maximum unbraced length of a member (ft.).

Qs   =   allowable stress reduction factor.

r =   radius of hatchway corners (in.).

R   =   fairing radius for elliptic or parabolic hatchway corners (in.).

s =   spacing of longitudinals (in.).

Sb   =   spacing of transverses or longitudinals (ft.).

S_l =   actual stiffener spacing (in.).

Sh   =   maximum permissible spacing of stiffeners parallel to the girder flange (in.

Sm   =   section modulus of panel or web stiffeners (in^3).

Sv   =   maximum permissible spacing of stiffeners perpendicular to girder flange (in^3).

t =   plating thickness (for deck, shell, bulkhead, etc.) (in.).

t_f = flange thickness (in.).

t plt = thickness of exposed plating (in.).

tw = web plate thickness (in.)

W = reference modulus used in determining bracket size and scantlings (in^3).

Z = section modulus of deck longitudinals (in^3).

Σa = summation of transverse dimensions of all openings in the bottom shell plate (in.).

NOTES

Section 5

DAMAGE HISTORY OF STRUCTURAL DETAILS

5.1 GENERAL

Haaland in his excellent paper on ship structural design (Ref. 1) indicates tha
many structural detail failures have very elementary causes. This is a gene
and true observation of practicing surveyors: usually the deficiencies of a
detail resulting in local failure are readily recognized, without need for
extensive analysis. The bulk of failure examples and accompanying descripti
is taken from a booklet by Lloyd's Register of Shipping (Ref. 2).

Discussions with representatives of the American Bureau of Shipping and of
the U. S. Salvage Association confirmed the damage descriptions in Refs. 1
and 2.

5.2 BRACKETS

When a bracket is fitted between a stiff member and unstiffened plating (as
shown in Figure 5-1, the latter may flex about the toe of the bracket and
cracks appear in the plating. This effect is not removed by fitting a second
bracket since the hard spot remains unaffected. Figures 5-2, 5-3, and 5-4
show examples of this failure. The problem may be corrected by aligning
the toes of the bracket with a stiffener, by adding a doubler plate, or by fittin
a stiffener to spread the load (see Figure 5-5 and 5-6). Whenever a
bracket is fitted, the structure to which it is attached should be strong enough
to transmit forces exerted by the bracket. Figure 5-7 shows examples of
inadequate brackets. Figure 5-8 gives an improved detail that will eliminate
the problem.

5.3 MISCELLANEOUS OPENINGS

5.3.1 Ratholes

Figure 5-9 shows a serious fracture which originated from a rathole made
in the web of a hatchside girder in way of a butt weld in the web.

Such ratholes are commonly made to facilitate welding after erection, but
can be a source of fracture unless special care is taken in design and
fabrication. In this case the girder web butt weld probably broke due to the
difficulty in providing good endings to the welds at "X", causing a high stress
concentration at the rathole. It is recommended that scallops and ratholes
be kept to a minimum but, if they are necessary for assembly, special care
is required to avoid crater cracks, particularly at "X" in Figure 5-9.

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FIG.5-1: FLEXURE OF UNSTIFFENED PLATING ABOUT BRACKET
TOE LEADING TO CRACKS (FROM REF.2)
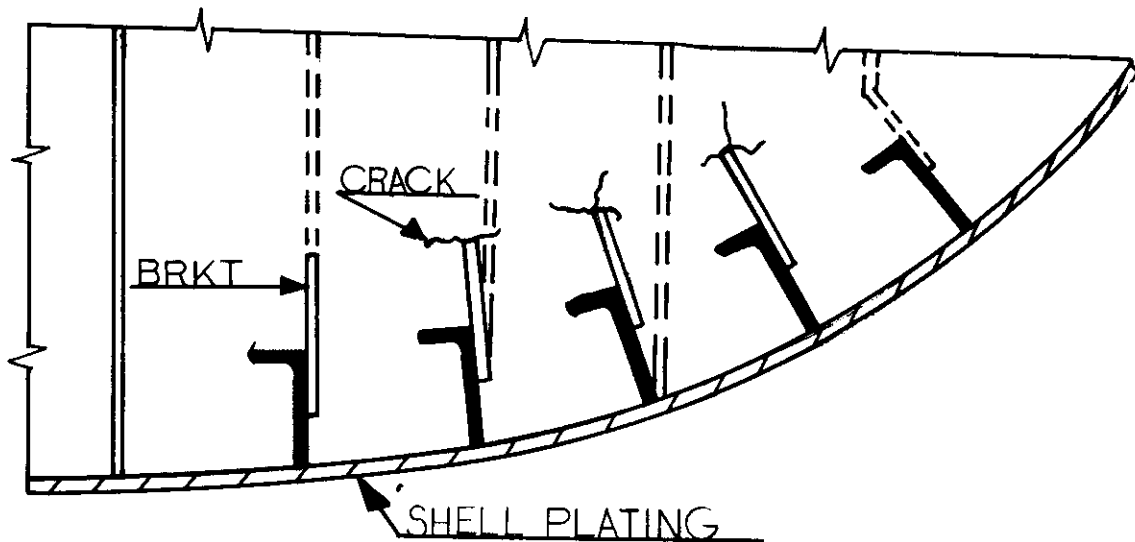
FIG.5-2: CRACKS INITIATING AT BRACKETS INSTALLED ON
BOTTOM LONGITUDINALS (FROM REF.2)

5-2
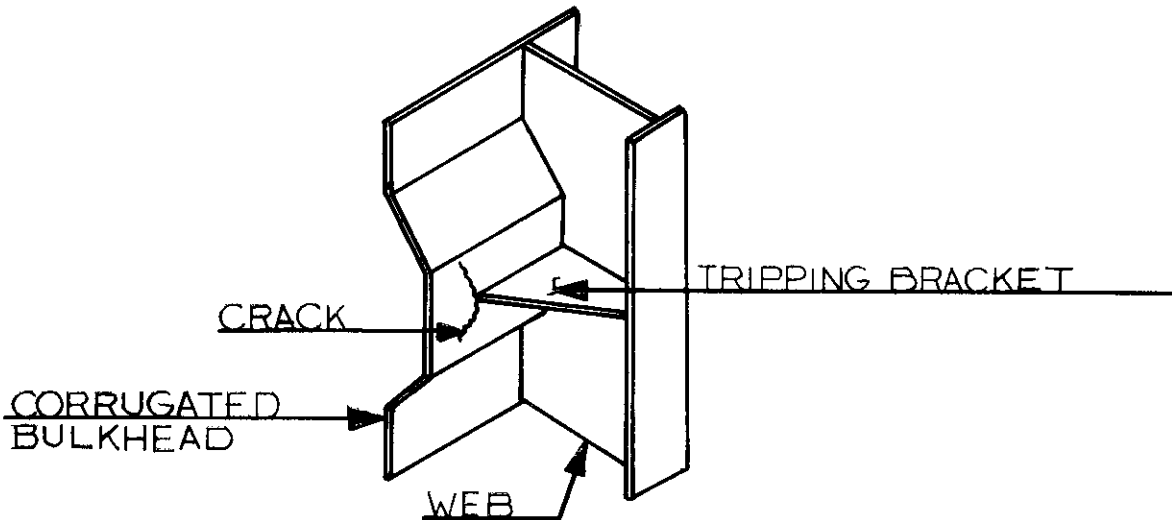
FIG. 5-3: CRACKS OCCURRING IN CORRUGATED BULKHEADS AT
THE TOES OF TRIPPING BRACKETS (FROM REF. 2)
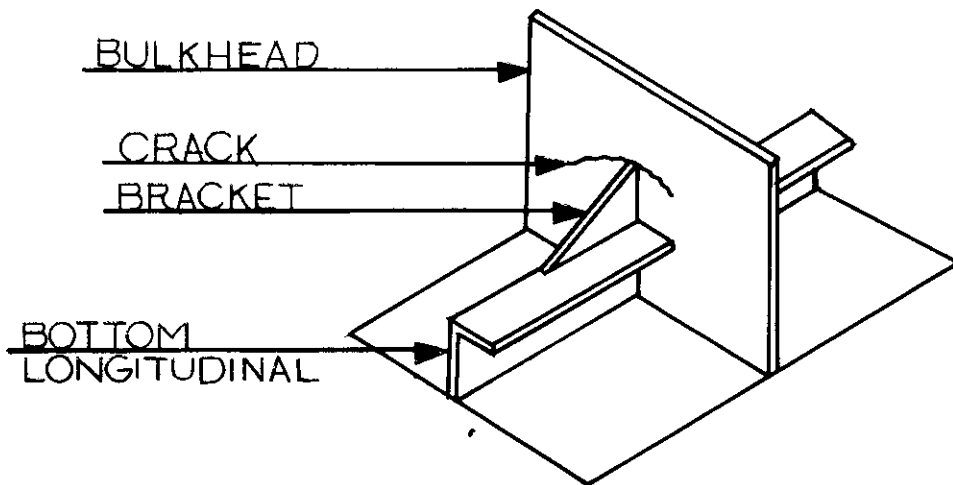
FIG 5-4: CRACKS CAUSED BY FLEXURE OF UNSTIFFENED
PLATING AT BRACKET DETAILS (FROM REF. 2)

HORIZONTAL
STIFFENER
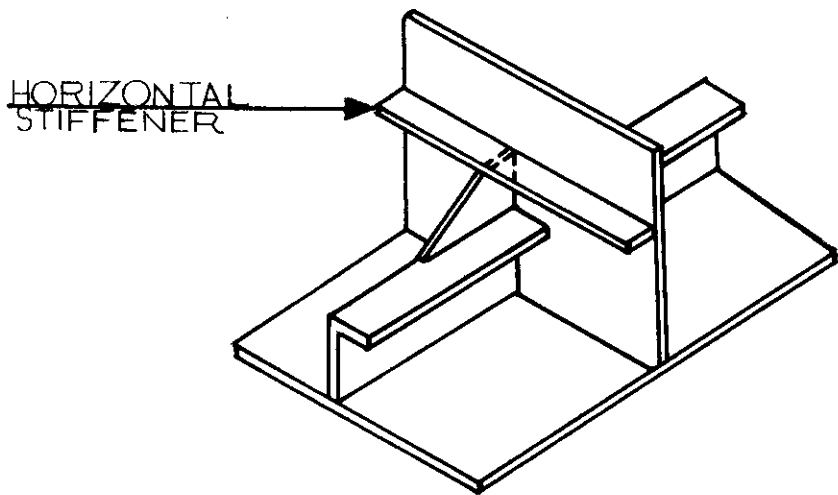
FIG. 5-5: USE OF HORIZONTAL GUSSET OR STIFFENER TO
STIFFEN BULKHEAD PLATING AT POINTS OF FLEXURE
(FROM REF. 2)

DOUBLER FAR SIDE
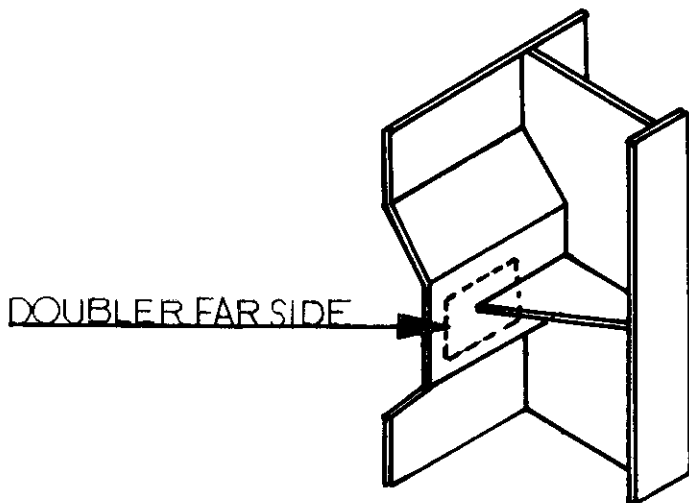
FIG. 5-6: USE OF DOUBLER PLATES TO ELIMINATE CRACKS AT
TRIPPING BRACKETS ON CORRUGATED BULKHEADS
(FROM REF. 2)

5-4

CRACK IN DECK

DECK

DECK LONGITUDINAL

BRACKET

SIDE FRAME

DECK

SHELL

BRACKET

SCALLOPS

CRACK

FRAME

SIDE SHELL

CRACK

WELD CRACKED

FACE PLATE CRACK

BULKHEAD
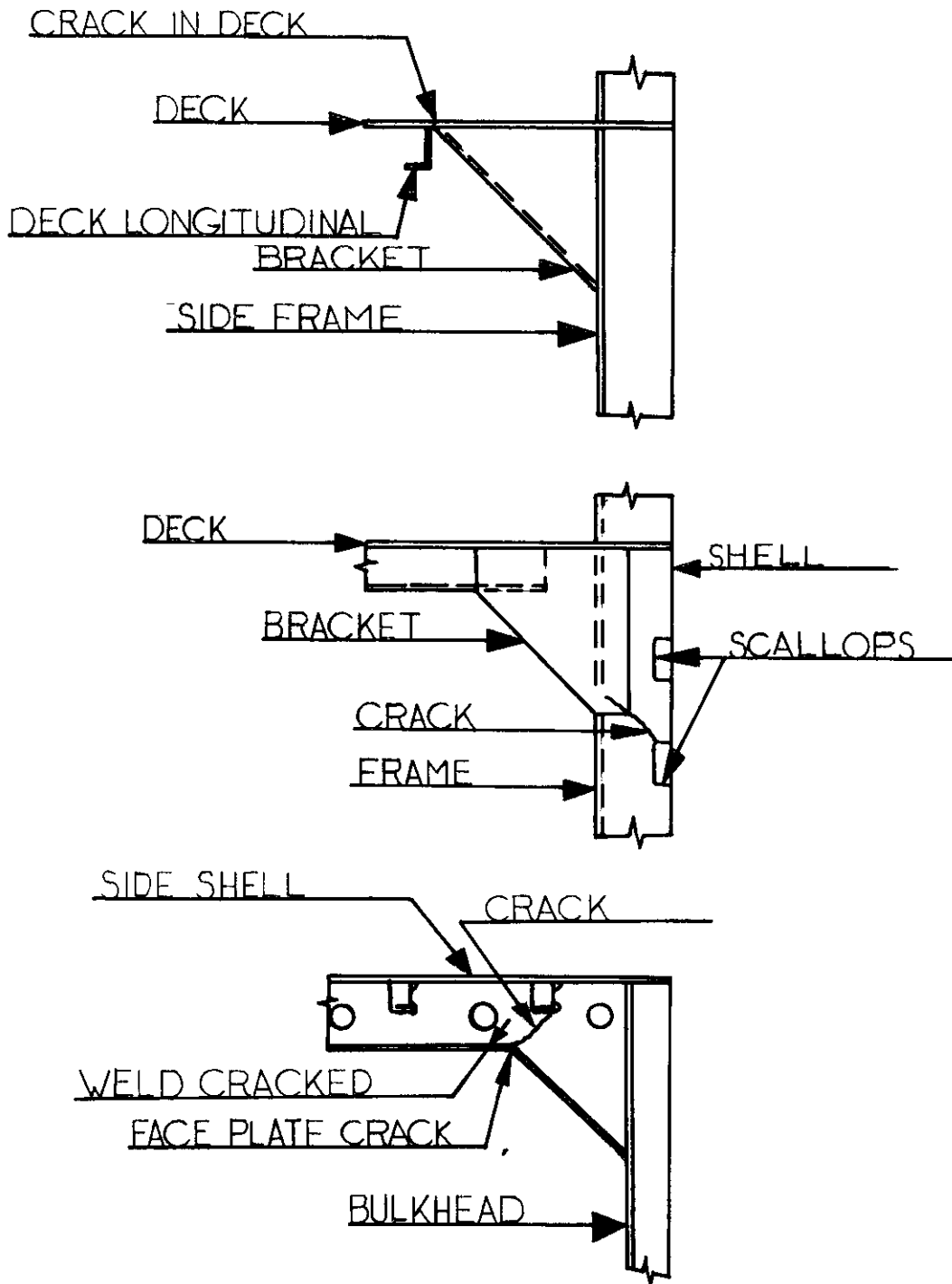
FIG. 5-7: POOR BRACKET DETAILS THAT HAVE LED TO CRACKS IN SUPPORTED MEMBERS (FROM REF. 2)

5-5

WELD BRACKET TO LONG'L

BEAM CONTINUED TO FRAME

NO SCALLOPS

COLLAR CUTOUT

REMOVE HOLES
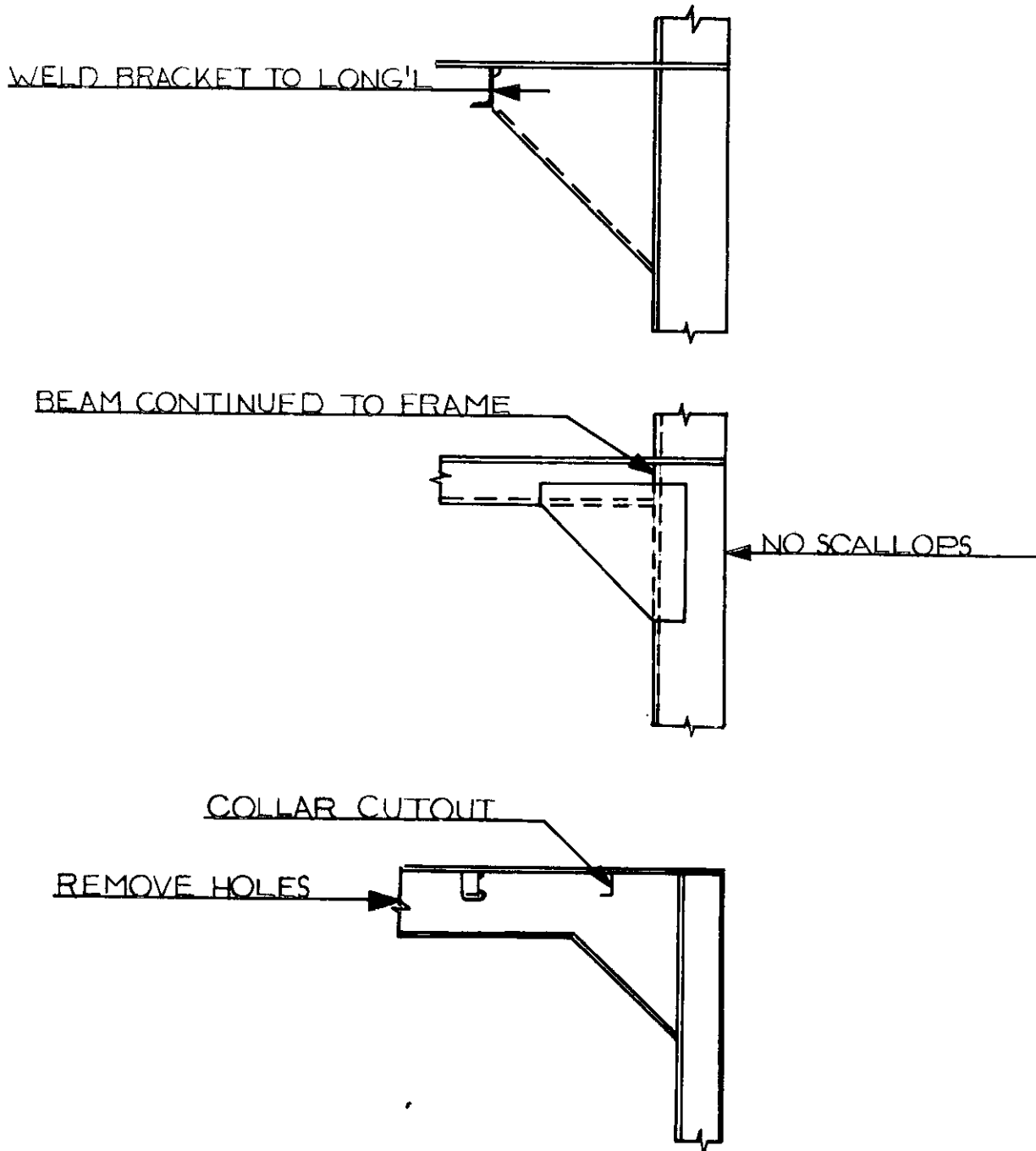
Fig. 58: Improved Bracket Details for Figure 5.7
(From Ref. 2)

5-6

SECOND DECK

CRACK IN DECK RAN
ABOUT 15 FEET

BUTT IN GIRDER WEB
WITH RATHOLES

"X"

BUTT IN DECK
PLATE WITH
RATHOLE IN
GIRDER WEB

CRACK

"X"

HATCH-SIDE GIRDER

BUTT IN GIRDER FACE PLATE WITH
RATHOLE IN GIRDER WEB
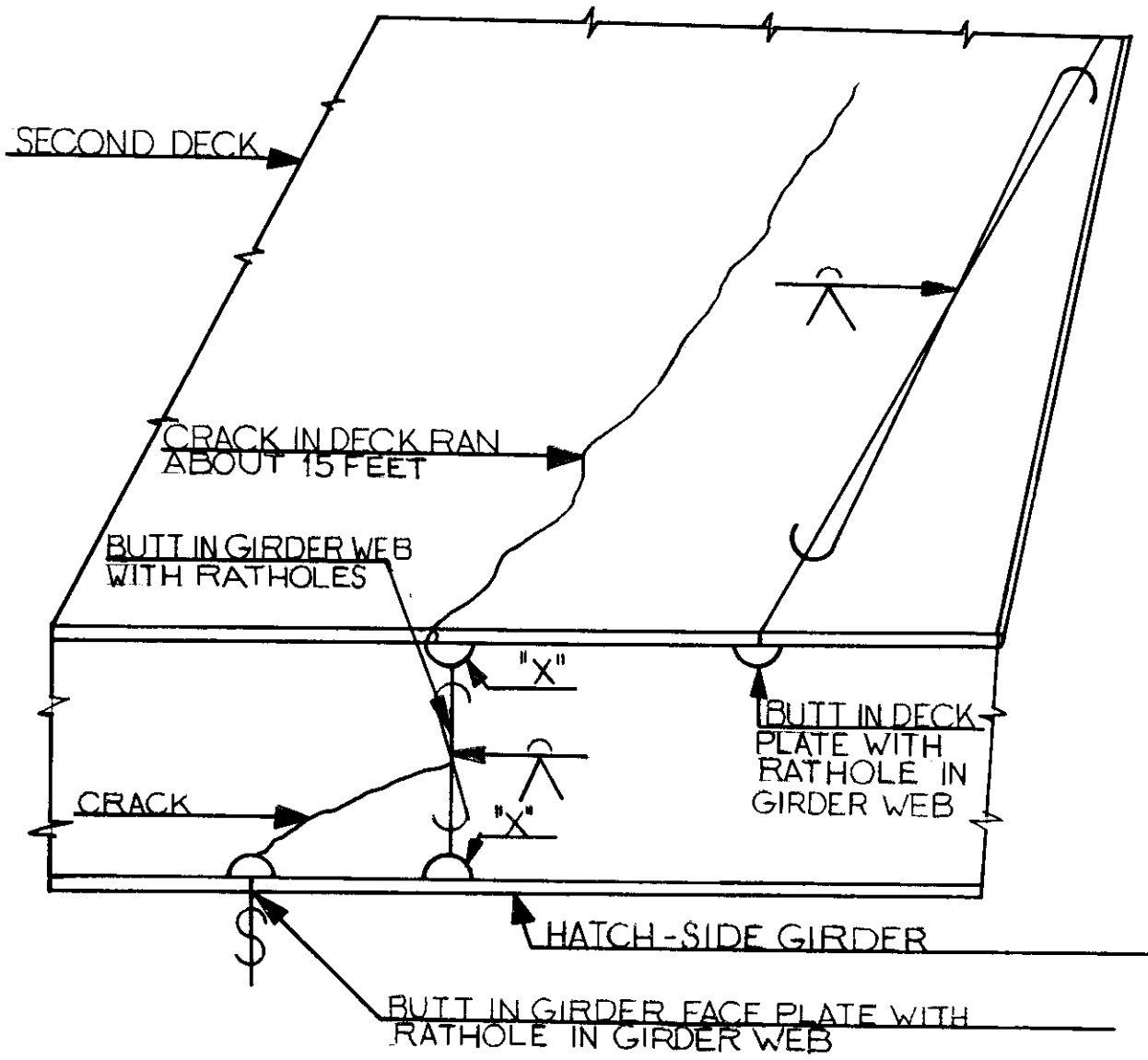
FIG. 5-9: FRACTURE OF HATCH SIDE GIRDER AND DECK PLATE
AT "POOR RATHOLE" CUTOUT (FROM REF. 2)

5-7

5.3.2 Manholes and Lightening Holes

Manholes and lightening holes cut in the diaphragm plates of cofferdam bulk-
heads have led to severe buckling of the plate. Figure 5-10 depicts the
buckled plate at the lowest strake of a transverse cofferdam bulkhead.

The recommended improvement of this situation is not to allow holes to be
cut in the bottom or top third of vertical web plates in cofferdam bulkheads.

5.3.3 Slots and Scallops

Another common location of damage is shown in Figures 5-11, 5-12, 5-13,
5-14 and 5-15. Figure 5-11 shows cracks occurring at the junction between
side shell longitudinals and transverse web frames because the cross-sectional
area of the connection is too small, thus causing high shear stresses at the
support. Normally cracks occur in the fillet weld, and when the connection
has first been broken secondary cracks will appear in the shell at the edge of
the scallop in the vertical web for the longitudinal and at the weld connection
between the web and the shell.

This problem may be eliminated by increasing the cross-sectional area of
the connection with brackets, collar plates or lapped stiffeners.

Figure 5-12 shows cracks in a deep tank stringer. The cracks have appeared
at the end of the span where the shear force is greatest and where the cross-
sectional area of the web plate is greatly reduced because of deep cutouts. In
these sections the shear stresses should be determined and the cutout closed
if necessary.

Figures 5-13 and 5-14 show the results of damages occurring where concentrated
loads have been applied in way of cutouts. It is advisable that all slots be cleanly
cut with rounded corners and should be collared in way of concentrated loads.

Figure 5-15 is taken from Reference 3 and depicts a typical bottom longitudinal
and bottom transverse intersection where cracks have developed (points A
through I). Investigation reveals that approximately 75% of the total number of
fractures found around slots are of Type G, H and I. Since most the webs
having D, E, and F type fracture also have G, H and I type fracture, it is
considered that the fractures around slots may have begun at the lower end of
the web stiffener as type G, H and I and then developed to type D, E and F type
fractures. Type A, B and C occur rarely and may be a result of vibration of
the transverse webs.

5.4 LOCAL DISCONTINUITIES

5.4.1 Face Plate Transition Pieces

Figure 5-16 shows cracks that have developed because the transition from the

WEBS SPACED 36 in. TRANSV.

STIFF.

WEB BUCKLED 3 in.

BUCKLED 1 in.
BULKHEAD PLATING

STIFF

STIFF

TANK TOP

DOUBLE BOTTOM
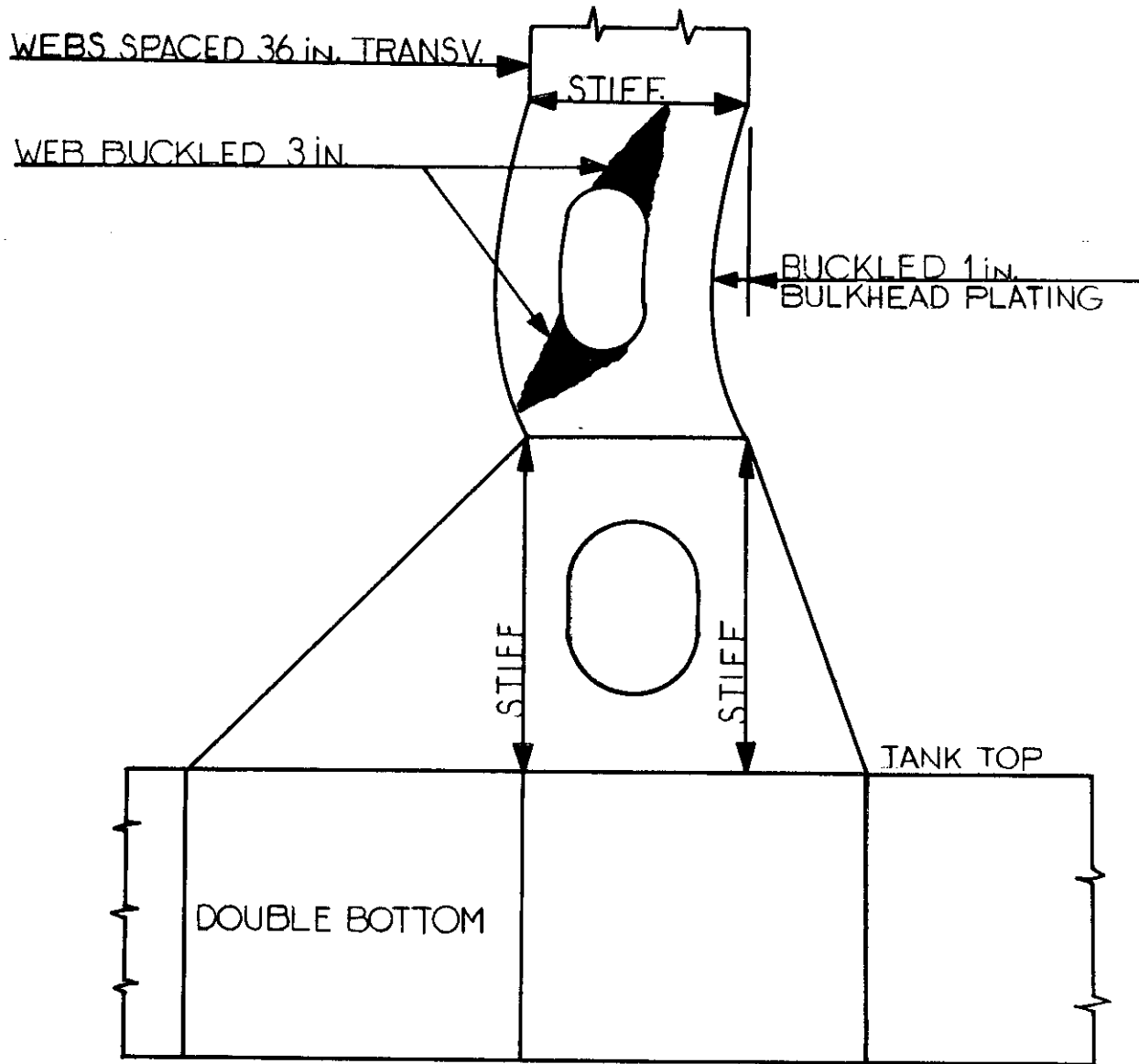
FIG. 5-10: BUCKLED PLATING OF TRANSVERSE COFFERDAM
(FROM REF. 2)

5-9
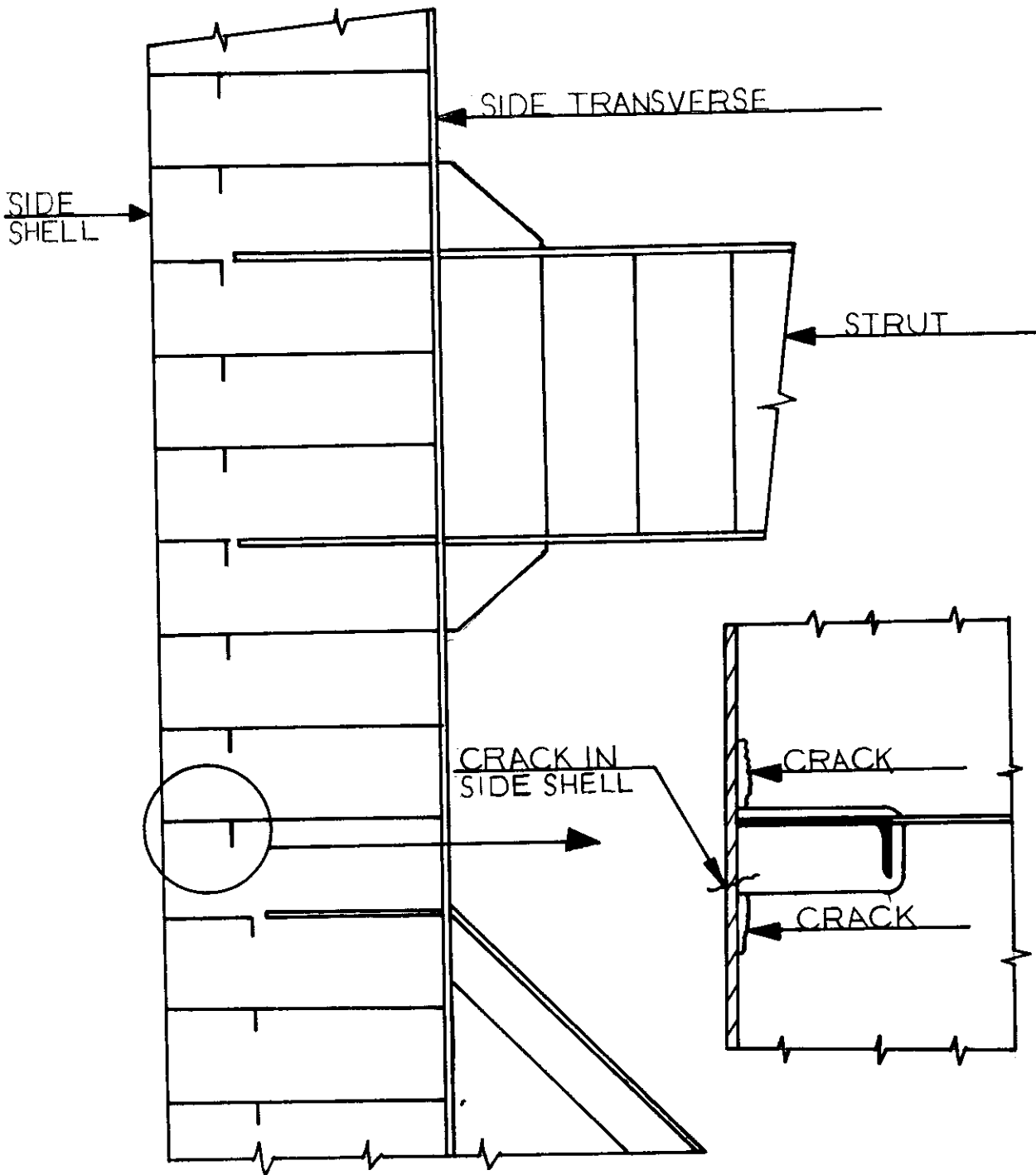
FIG. 5-11: CRACKS OCCURRING IN LARGE TANKERS AT THE JUNCTION OF SIDE LONGITUDINALS AND WEB FRAMES (FROM REF. 1)
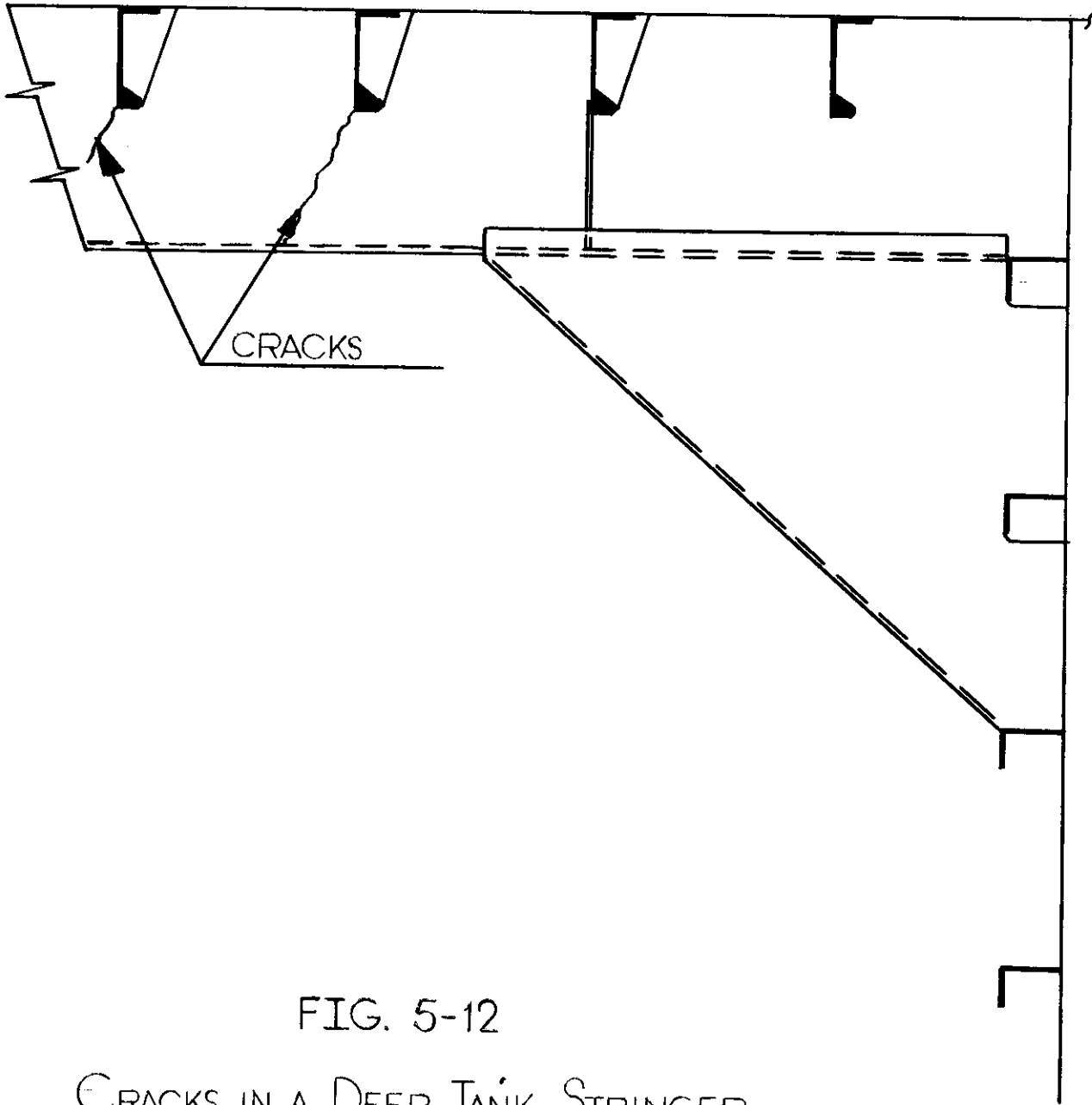
CRACKS

FIG. 5-12

CRACKS IN A DEEP TANK STRINGER
(FROM REF. 1)

LOAD

BRACKETS N&F

DECK

CRACKS

PILLAR

USE TIGHT COLLARS

ADD BRACKETS

BETTER LOCATION
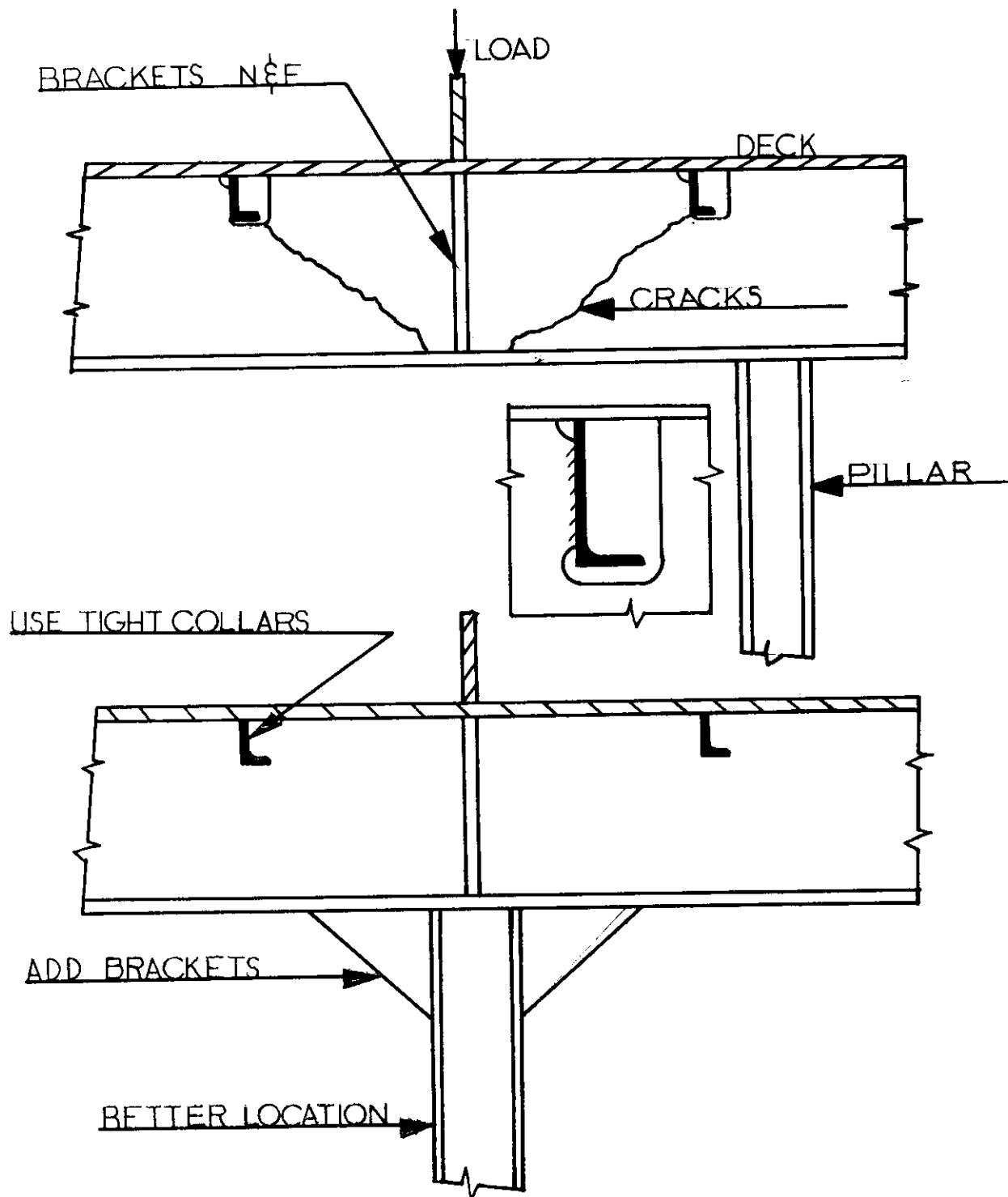
Fig.5-13: Cracks in Deck Girder due to Poor Positioning of a Pillar (from ref.1)
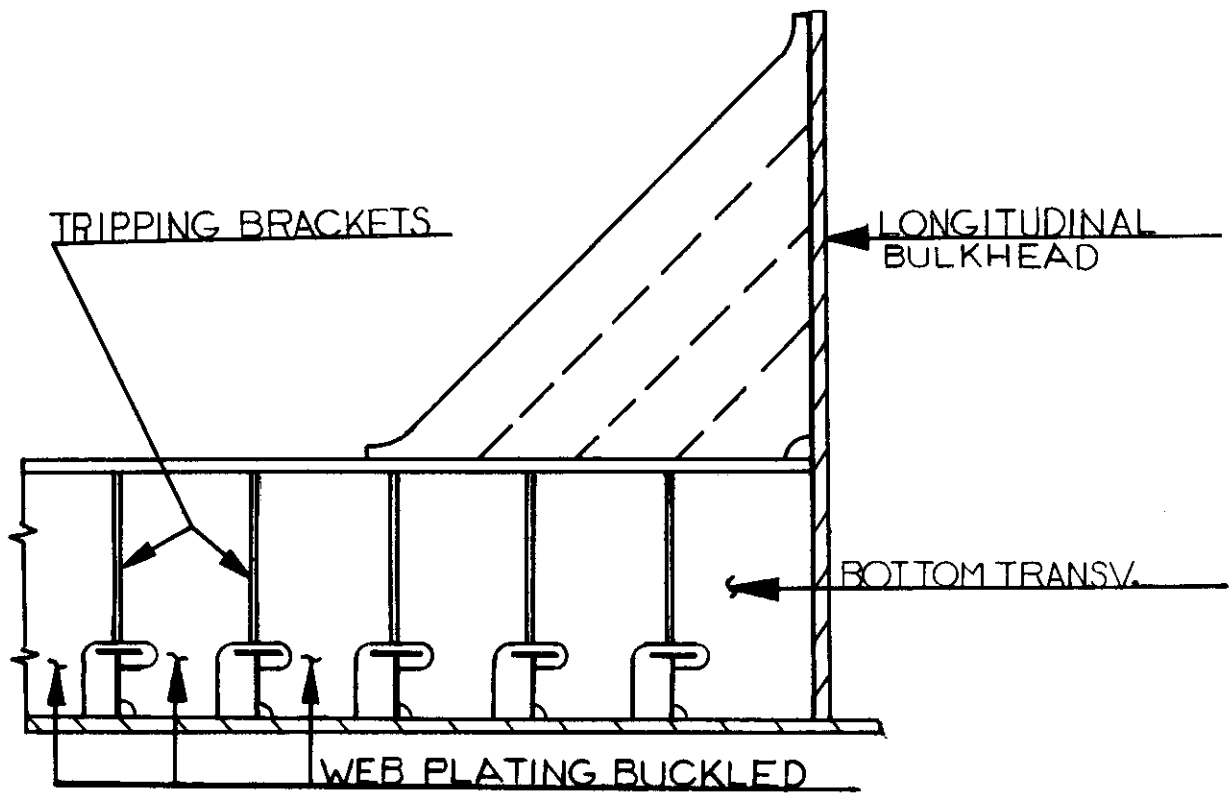
FIG. 5-14: BUCKLING OF BOTTOM TRANSVERSE WEB FRAME
(FROM REF. 2)
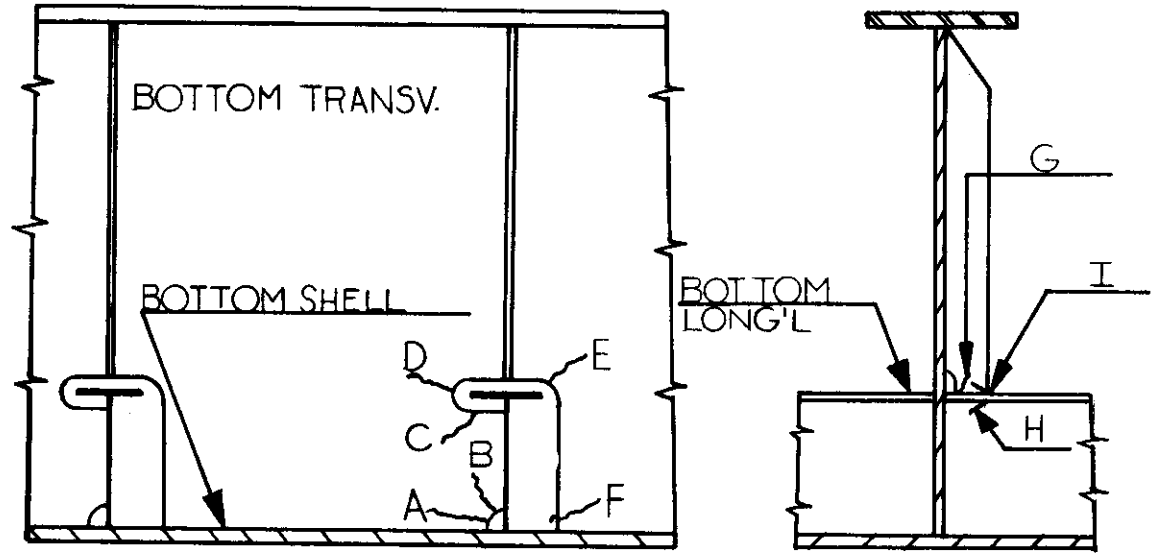
FIG. 5-15: CRACKS OCCURRING AT THE JUNCTION OF BOTTOM
LONGITUDINALS AND BOTTOM TRANSVERSES (FROM REF. 3)

HATCHWAY

HATCH END GIRDER

TRANSITION PIECE

LONG'L GIRDER

$1\frac{1}{2}''$ DIAMOND PLATE

CRACKS EXTENDING INTO WEB OF GIRDER

TRANSITION PIECE

LONGITUDINAL GIRDER
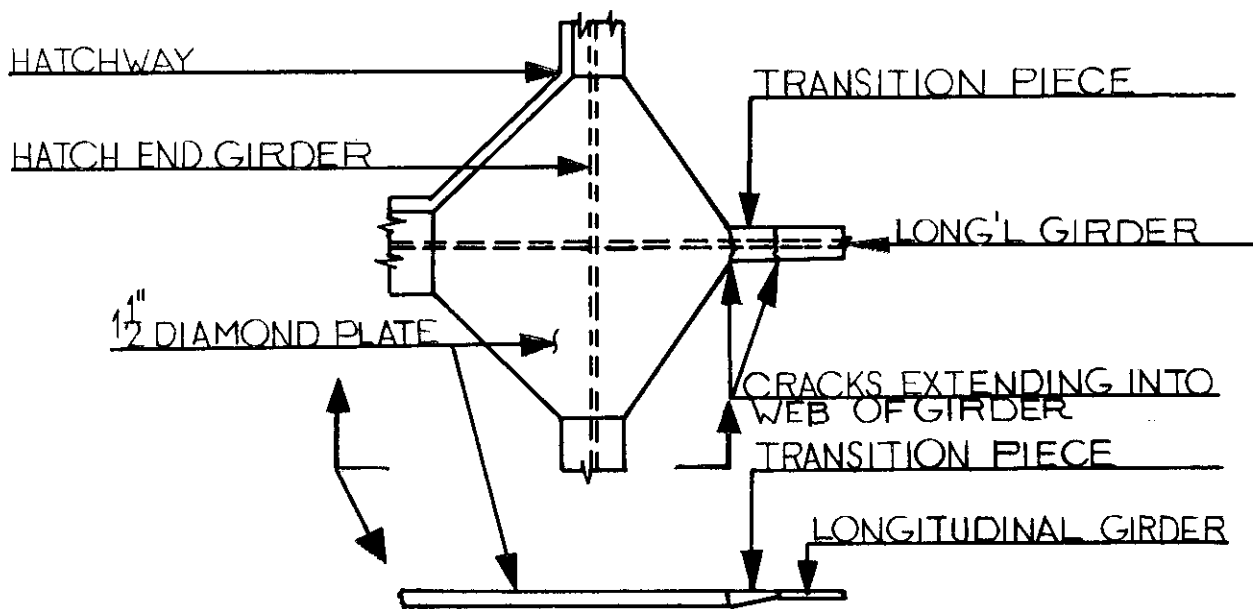
FIG. 5-16: CRACKS OCCURRING AT AN INADEQUATE TRANSITION PIECE (FROM REF. 2)

LONGER TRANSITION

$1\frac{1}{2}''$

$1''$
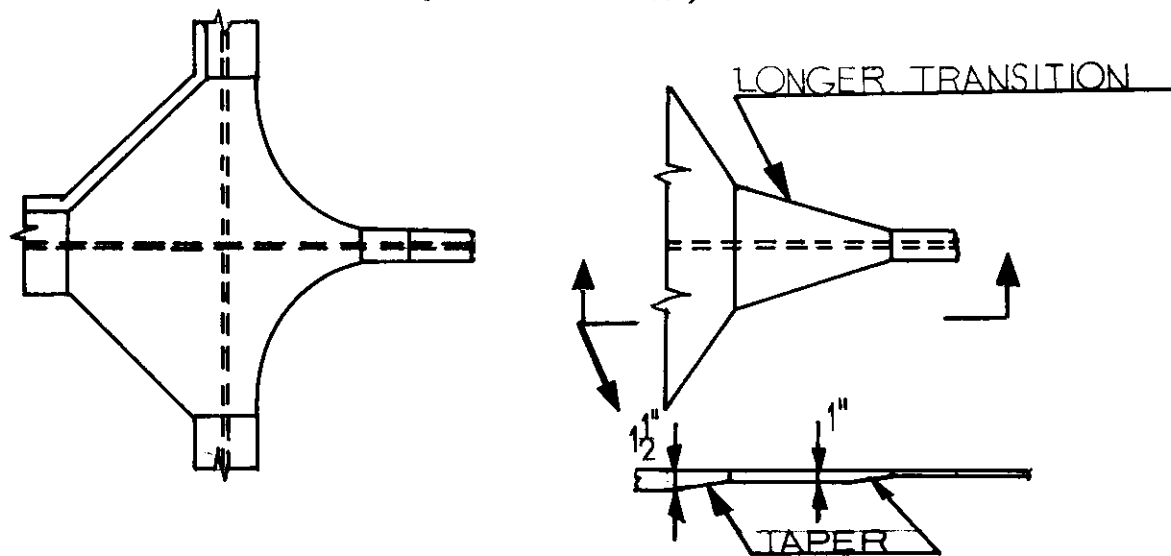
TAPER

FIG. 5-17: RECOMMENDED IMPROVEMENTS FOR FACE PLATE TRANSITION PIECES (FROM REF. 2)

heavy member to the light longitudinal girder is too abrupt. Possible solutions to this problem could be as follows:

a. Longer transition pieces (Figure 5-17).

b. Taper the thickness of the transition pieces

Figure 5-18 shows a type of fracture which occurred at a number of positions on several ships. The problem here was the discontinuity of the upper flange of the transverse girder at the intersection with the center girder where there was little difference in the height of the two girders. Joining the two face-plates with a full penetration weld will correct this problem.

5.4.2 Hatchway Corners

Badly designed or constructed hatchway corners are a frequent source of fracture. Fractures have occurred even in well rounded hatchway corners, where some detail of design has introduced a stress concentration or possibly a weld defect. Figure 5-19 shows such a case. In Figure 5-19 the source of fracture was at the corner of the part of the deck plate which extended through the coaming. This is not only a point of stress concentration, but a difficult position in which to produce a sound weld. It should be noted that in rounded hatchway corners the highest level of stress concentration occurs at about the point where the corner radius meets the longitudinal side of the hatchway and that fractures almost invariably begin at this point.

When designing hatchway corners the following guidelines are suggested:

a. Detail design should be simple, avoiding multiple connections resulting in an accumulation of difficult welds.

b. Attachments should not be welded to free deck edge.

c. Elliptical corners in the deck are preferred to circular corners.

5.5 MISCELLANEOUS

Yamaguchi in Reference 4 discusses a survey conducted by the Ship Classification Society of Japan on the inner structural members of 97 oil tankers. Figure 5-20 gives the damage occurence rate by age of the vessel. Figures 5-21 and 5-22 are sketches of details prone to early fatigue cracks. Yamaguchi concludes that the most likely locations for fatigue cracks are:

a. Welded joints near structural discontinuities.

b. Welded joints in highly stressed areas, such as corners.

c. Areas of extremely high stress concentration, such as notched longitudinals.

NO WELD   SMALL SCALLOP HERE

CRACK

TRANSV. GIRDER   CENTER GIRDER
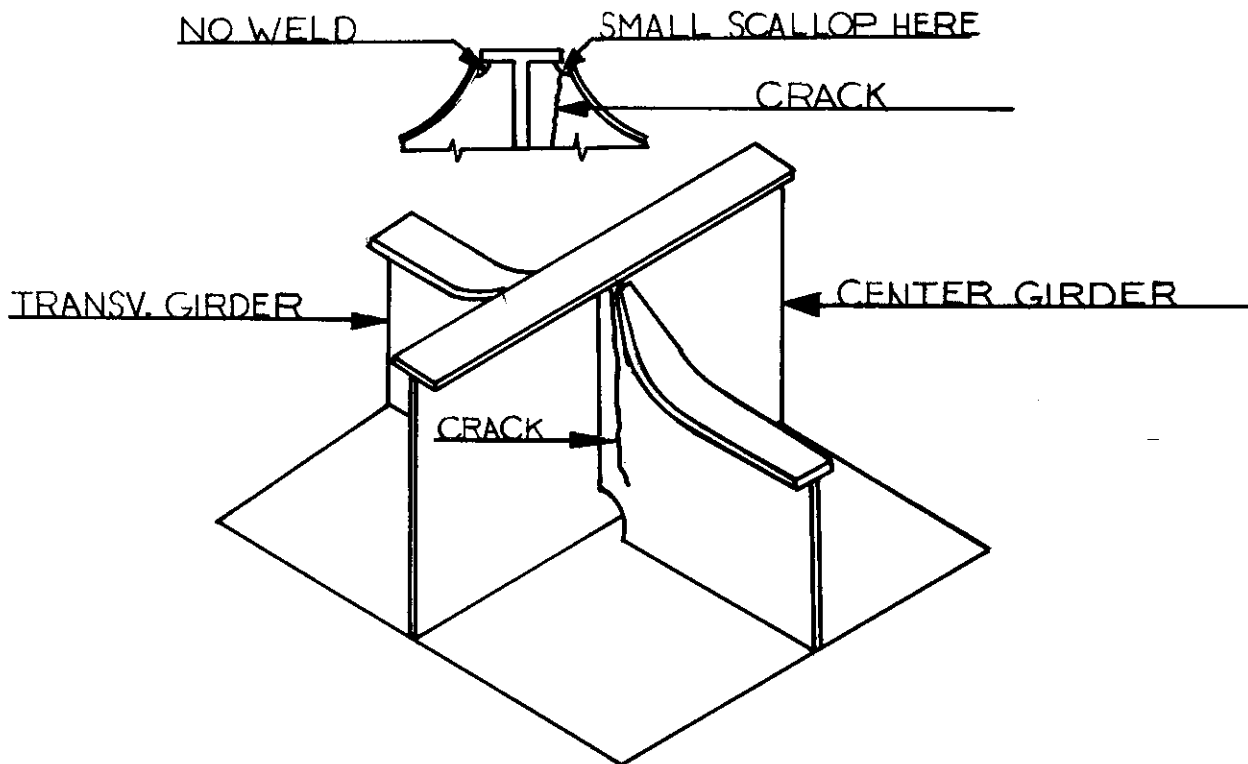
CRACK

FIG. 5-18: CRACK INITIATING AT THE INTERSECTION OF A
TRANSVERSE GIRDER AND CENTER GIRDER
(FROM REF. 2)

CURVED INSERT IN COAMING

CONTINUATION OF HATCH
SIDE UNDER DECK

CRACK

WELD BUTT

HATCH END

HATCH SIDE

DECK PLATE EXTENDED INTO
HATCHWAY

CRACK STARTED HERE
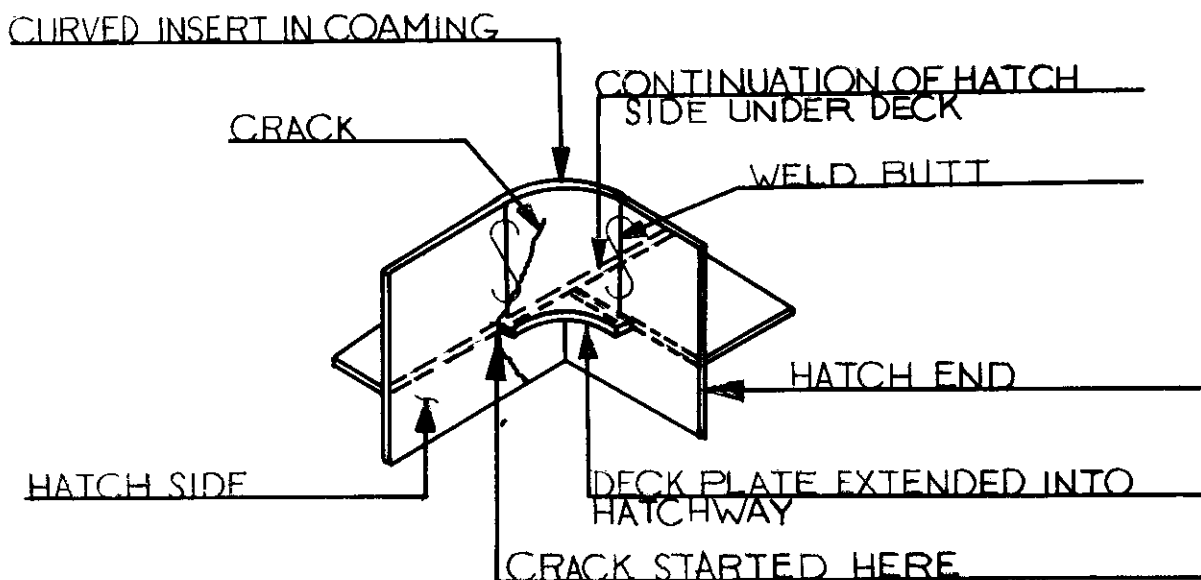
FIG. 5-19: FRACTURES OCCURRING IN HATCHWAY COAMINGS
(FROM REF. 2)

OCCURRENCE RATE (%)

VESSEL AGE.
LESS THAN ONE YR.

1 YEAR - 2 YEAR

2 YEAR - 3 YEAR

3 YEAR - 4 YEAR

4 YEAR - 5 YEAR

5 YEAR - 6 YEAR

6 YEAR - 7 YEAR

7 YEAR - 8 YEAR

8 YEAR - 9 YEAR

OCCURRENCE RATE

CUMULATIVE RATE

CUMULATIVE RATE (%)

FIGURE 5-20 (FROM REF. 4)
DAMAGE OCCURRENCE RATE BY AGE OF VESSEL

5-17
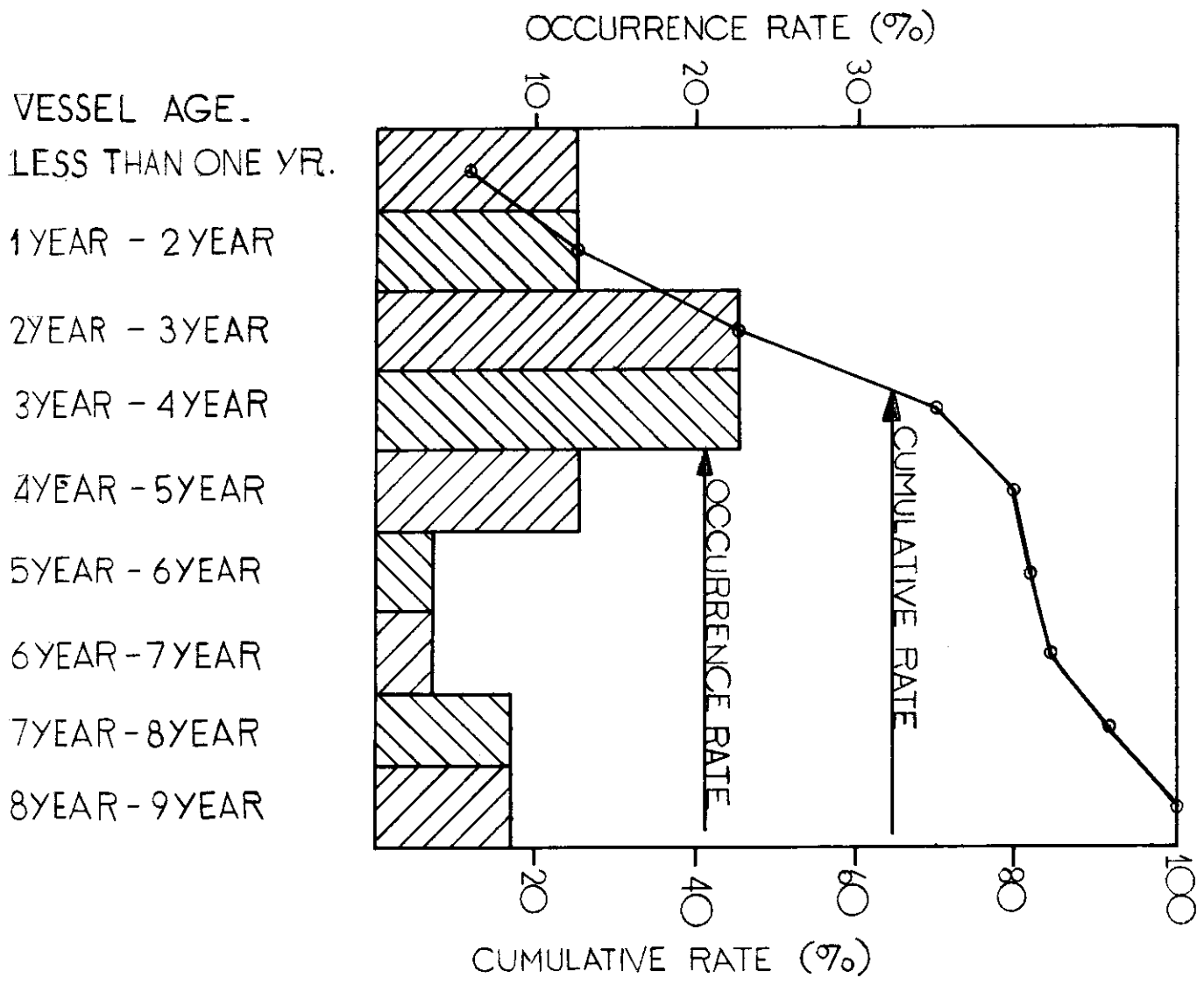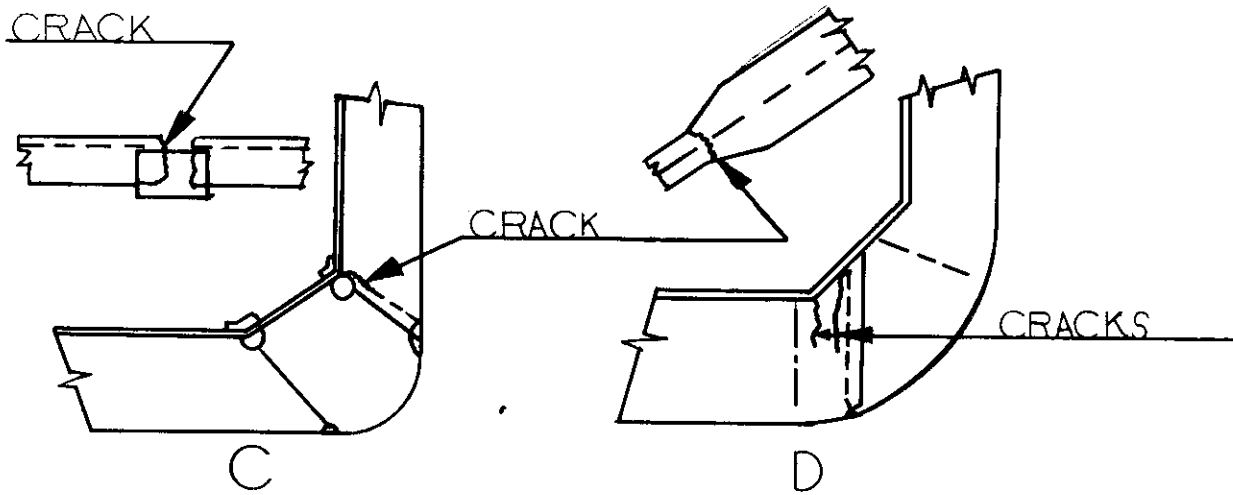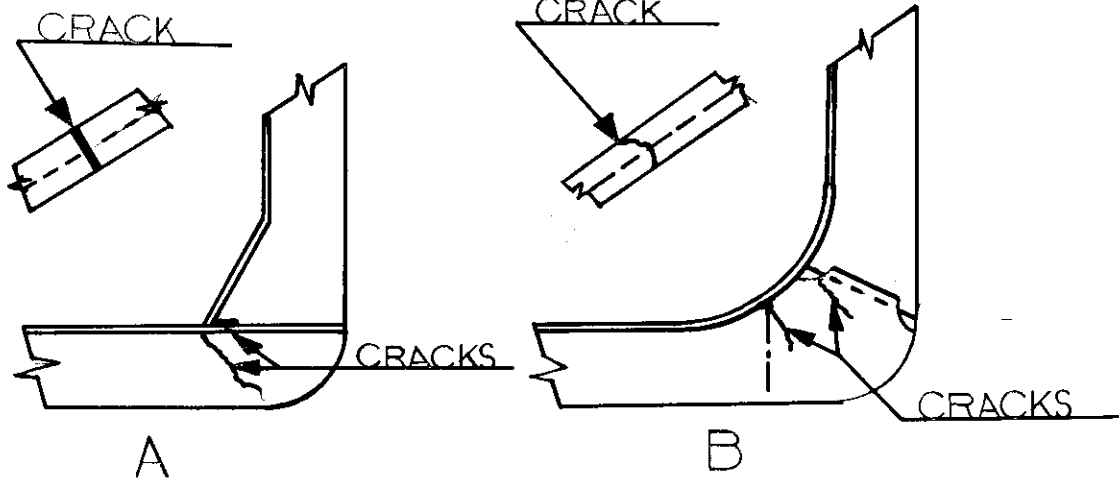
FIG. 5-21: CRACKS IN TRANSVERSE RINGS (FROM REF. 4)

5-18
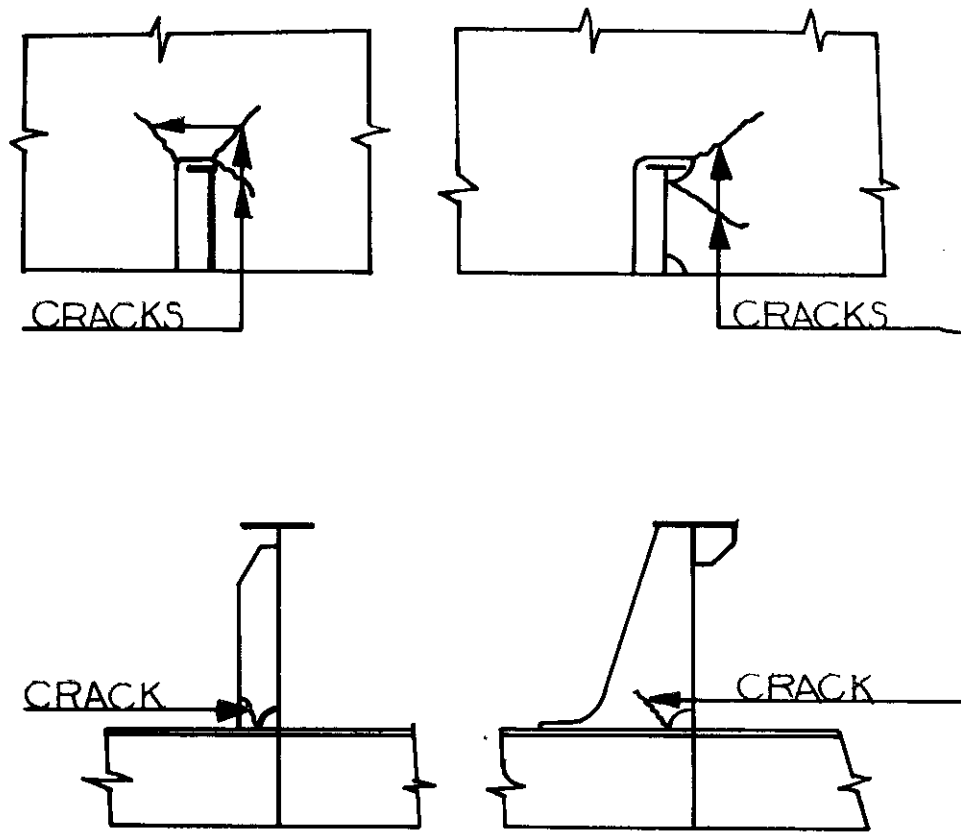
FIG. 5-22: CRACKS IN NOTCHES THROUGH LONGITUDINALS
(FROM REF. 4)

All of the above implies that the common sense guidelines for sound detail design recommended by D'Arcangelo in 1964 (Ref. 5) are and will continue to remain valid.

Haaland in Reference 1 shows how the problem of buckling at the edge of lightening holes is compounded by stress corrosion along an axis of high stress. The example cited is a web in an ore carrier, where protective coatings take constant abuse.

Section 6

STRENGTH CRITERIA

6.1 GENERAL

Abrahamsen in Reference 5 has suggested that based on ship experience over
the last fifteen years one may conclude that the longitudinal strength standards
now applied are reasonable, provided that the detail design and the workmanship
are above a certain minimum standard.

That statement effectively describes the status of ship structural design today:
there are adequate techniques and guidelines for establishing overall hull
girder strength requirements and the strength requirement of such major   –
structural components as stiffened panels, but as discussed in Section 1 there
is little if any systematic quantitative approach leading to the design of structural
details.

The strength criteria required for structural details differ from other structural
criteria only in emphasis. Before elaborating on this observation, it is
desirable to list the types of structural damage that could result from inadequate
detail design:

1. Failure of the detail to perform its intended function. For example:

    Web buckling due to inadequately sized or spaced web
    stiffeners.

    Collapse of a deck beam due to inadequate end bracket
    support.

2. Failure of a detail or of adjacent material by ductile tearing as a
    result of excessive stresses at the detail.

3. Fatigue cracks originating at a structural detail.

4. Brittle fracture starting at a fatigue or other crack at a structural
    detail.

Prevention of the first two categories of damage listed above requires knowledge
of the state of stress at or near the detail, and the assignment of allowable or
permissible values of stress.

It is not the purpose of this discussion to propose universal methods of stress
analysis applicable to structural details: the analysis of compressive stress
in a web frame may be obtained by a simple strength of materials analysis,
whereas the state of stress around a complex cutout may require a fine mesh

That suggestion is unlikely to be implemented in the near future because of related theoretical and practical reasons. Accepting that the prediction of crack growth rate is more important than the prediction of crack initiation, it is clear that the complex state of stress in ship structure, particularly in the presence of a crack, makes the calculation of propagation to critical length extremely difficult. This is compounded by the fact that the responsibility for the decision on whether to require crack repair will rest with the classification societies' field surveyors, who have neither the time nor the tools for the detailed analysis such a decisiion would require.

Proponents of crack tolerant design point to aircraft experience, but the prevalent riveted airframe construction makes it far simpler to provide the dual load paths required for fail-safe design than it is for welded ship structures. Such monolythic structures must rely on a combination of safe-metal and safe-life design philosophy. Fatigue damage criteria are required to aim at the safe-life design.

6.2 FATIGUE CRITERIA

In proposing a framework for establishing fatigue criteria it has been considered important to adhere to proven standards wherever possible. In the marine field one of the few, if not the only, fatigue criterium is that developed by Det Norske Veritas for design of certain classes of shipborne containers for liquefied gases.

The stress histogram, Figure 6-1, is plotted on semilog paper to a life of 10^8 cycles, which is generally conceded to be the number of wave-induced load cycles over approximately 20 years of ship life. Still water stress level at some average service load distribution is the mean stress, and maximum and minimum stresses can best be based on the most probable maximum amplitude of varying stress in 10^8 cycles (probability of 10^{-8}). That maximum stress variation will be some combination of primary (hull bending) and secondary (pressure on plating panels) effects. Estimation of these amplitudes is aided by ship motion analysis or by standard series seakeeping data such as provided by Loukakis and Chryssostomidis (Ref. 8). Engineering judgement is required in establishing these amplitudes.

The histogram is completed by connecting maximum to mean and minimum to mean with straight lines. This is at best an approximation justified by a generally similar pattern of probability distribution of all linearized ship responses to the sea spectrum. That trend is demonstrated by the histogram used by Kline in Reference 6.

In addition to the load spectrum due to seaway loads it is also necessary to consider cyclic stresses due to major changes of ship loading. On bulk carriers and tankers this could be taken as a multiple of the number of trips expected in the ship's lifetime.
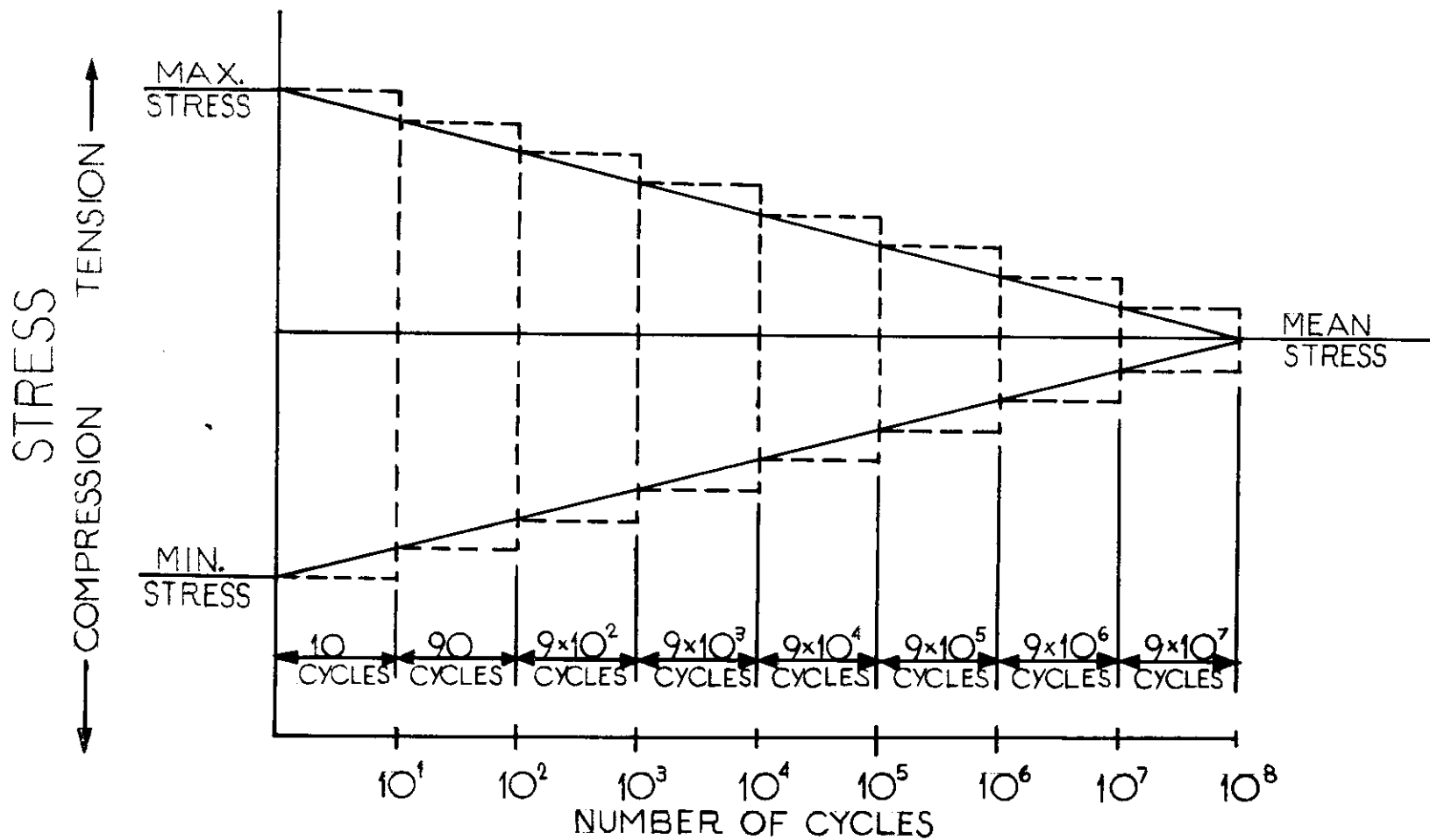
FIGURE 6-1: SIMPLIFIED STRESS HISTOGRAM

The one common theory for cumulative fatigue damage is that due to Palmgren-Miner, which in terms of the above discussion can be written as:

$$\sum_{i=1}^{P} \frac{n_i}{N_i} + \frac{k}{N_j} \leq 1.0$$

where

n_i = number of cycles at stress level i

N_i, j = fatigue life at stress level i, j

P = number of stress increments into which total stress range is divided

k = number of cycles at stress level j

To simplify the summation it is proposed to subdivide the stress histogram into the eight equal blocks shown in Figure 6-1.

To apply the cumulative fatigue damage theory it is necessary to have the fatigue data for the material and structure in question. A great many such data have been collected in recent years. Those generally applicable to shipbuilding have been well summarized in each of the five ISSC (International Ship Structures Congress) Proceedings dating from 1961 to 1973. Tests have been performed on a variety of ship steels, with various configurations, welding procedures, surface conditions and loading ranges. Yet out of this large body of data has not yet appeared the skeleton of a shipbuilding fatigue design criterion.

Professional societies such as the AWS, AASHO, and AISC have formulated rules for fatigue design. These as well as many foreign organizations have generally based the allowable fatigue stress on the number of cycles at a given stress and stress ratio or within a given stress range. Notice that these organizations are not concerned with a stress spectrum, although British Standard 153, which we have been unable to review, does apparently take a spectral load distribution implicitly into account.

The above rules generally give an allowable fatigue stress for discrete numbers of stress cycles, i.e., 100,000, 5 or 600,000 and 2,000,000. A factor of safety of about 1.5 is implicit in the allowable stress. Different values are provided for various welding configurations and grades of steel. For example, and to illustrate the format of the specification, quoting from the AWS Bridge Specifications (Ref. 9), for A36 base metal connected by fillet welds, the allowable fatigue stress at 2,000,000 cycles is given by:

$$\sigma = \frac{7500}{1 - 0.67\,k} \text{ psi}$$

where

k = stress ratio

More recently, and as a direct result of work sponsored by the Transportation Research Board (Refs 10 & 11), it has been concluded that stress range is more important than magnitude of stress, stress ratio, or base metal. Current specifications of AASHO and the AISC reflect this thinking. An additional improvement brought about by Refs 10 and 11 is the conclusion that 2,000,000 cycles does not correspond to the fatigue limit of the material, consequently a fourth loading cycle category (over 2,000,000) has been included. Five categories of structural configuration (from plain material to fillet-welded connections) are defined by Reference 11. The AISC Manual of Steel Construction lists seven categories of structures, and provides 27 illustrative examples to help establish the correct category.

An excellent comparison of all major international fatigue standards has been presented by Gurney (Ref. 12).

The preceding serves to point out that there are two approaches available for formulating shipbuilding fatigue criteria based on stress spectra: one based on the S-N diagram of the particular material and structural configuration at a specific stress ratio, the other one where only structural configuration and stress range are relevant.

Complete S-N diagrams over a large range of stress ratios are not generally available. Therefore to illustrate the application of the first approach above, an S-N diagram was produced by extrapolating the data for 100,000 and 600,000 cycles given by Reference 13 for allowable stresses in groove welds with the reinforcement in place.

These expressions are:

No. of cycles	Allowable stress
2,000,000	$\dfrac{19,000}{(1-0.73\,k)\ \text{FS}}$
600,000	$\dfrac{24,000}{(1-0.60k)\ \text{FS}}$
100,000	$\dfrac{28,000}{(1-0.75k)\ \text{FS}}$

where

FS = factor of safety

6-6

Table 10.1 in Reference 13 indicates that details involving short lap or fillet welds will experience a reduction in fatigue limit of about 50 percent (from 41 to 59 percent), consequently the numerator in the tabulated expressions was divided by 2. The artificial S-N diagram, with factor of safety FS = 1.5, is shown in Figure 6-2.

For any value of mean stress other than zero the stress ratio varies for each computational block along the stress histogram. Consequently design rules should be based on a permissible stress range centered about various arbitrary levels of mean stress. Figure 6-3 shows the result of the application of

$$\sum \frac{n_i}{N_i} \leq 1$$ for a mean stress of 0 and 10 ksi. The maximum allowable stress ranges are 14 and 12 ksi, respectively.

If this method were to be pursued to formulate fatigue guidelines, it would be necessary to do calculations for values of mean stress within the range defined by ± (yield stress/factor of safety).

At least three structural configurations should be considered: base metal, groove or butt welds, and short fillet welds.

Because it is generally agreed that yield stress is a more important factor in fatigue strength than the exact chemistry of the steel, the design rules should also encompass the principal yield stress values used in shipbuilding, i.e., 33, 50, 60, 80 and 100 ksi.

Although Figure 6-3 demonstrates theoretical fatigue life dependence on stress ratio (at a particular number of cycles the ratio of fatigue strength at R = - ∞ to that at R = +0.75 is in the order of 2.5), it was earlier pointed out that Reference 11 concludes that stress range is the sole practical variable. The explanation for this observed experimental phenomenon is that welding of small details introduces residual tensile stresses which in the actual structure prevent the occurrence of low stress ratios.

Consequently a shipbuilding fatigue criterium analogous to that proposed by References 10 and 11 would simply specify the maximum stress range allowed for the simplified assumed spectrum. Note that at 2,000,000 cycles and R = -1 the modified equation used to plot the S-N diagram of Figure 6-2 predicts an allowable stress range of 8.4 ksi, which compares favorably to a range of 8.0 ksi allowed by the proposed specification of Reference 11.

The use of a simplified ship stress spectrum increased that allowable range to 14 ksi, suggesting that the application of a multiplier 14/8.4 ≃ 1.7 to the AASHO permissible stress ranges could be used at least as a tentative guideline for application to fatigue design of ship structural details.

FIGURE 6-2: Assumed S-N Diagram for a 36 ksi Yield Stress Steel

MAX. STRESS = 7 KSI
MIN. STRESS = -7 KSI
MEAN STRESS = 0 KSI
MAX. STRESS RANGE = 14 KSI
STRESS RATIO = -1

MAX. STRESS = 16 KSI
MIN. STRESS = 4 KSI
MEAN STRESS = 10 KSI
MAX. STRESS RANGE = 12 KSI
STRESS RATIO = (0.25 TO 0.86)
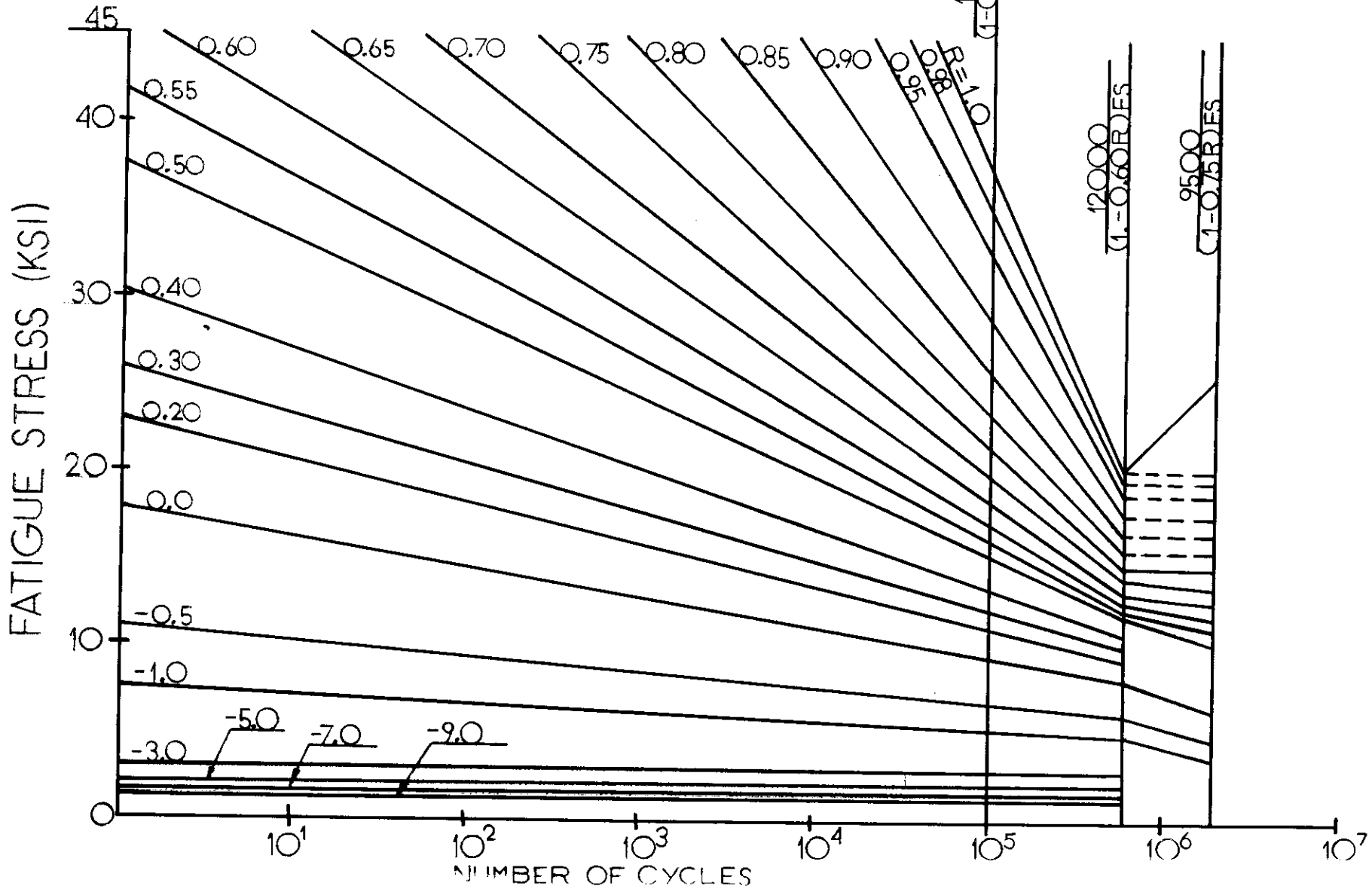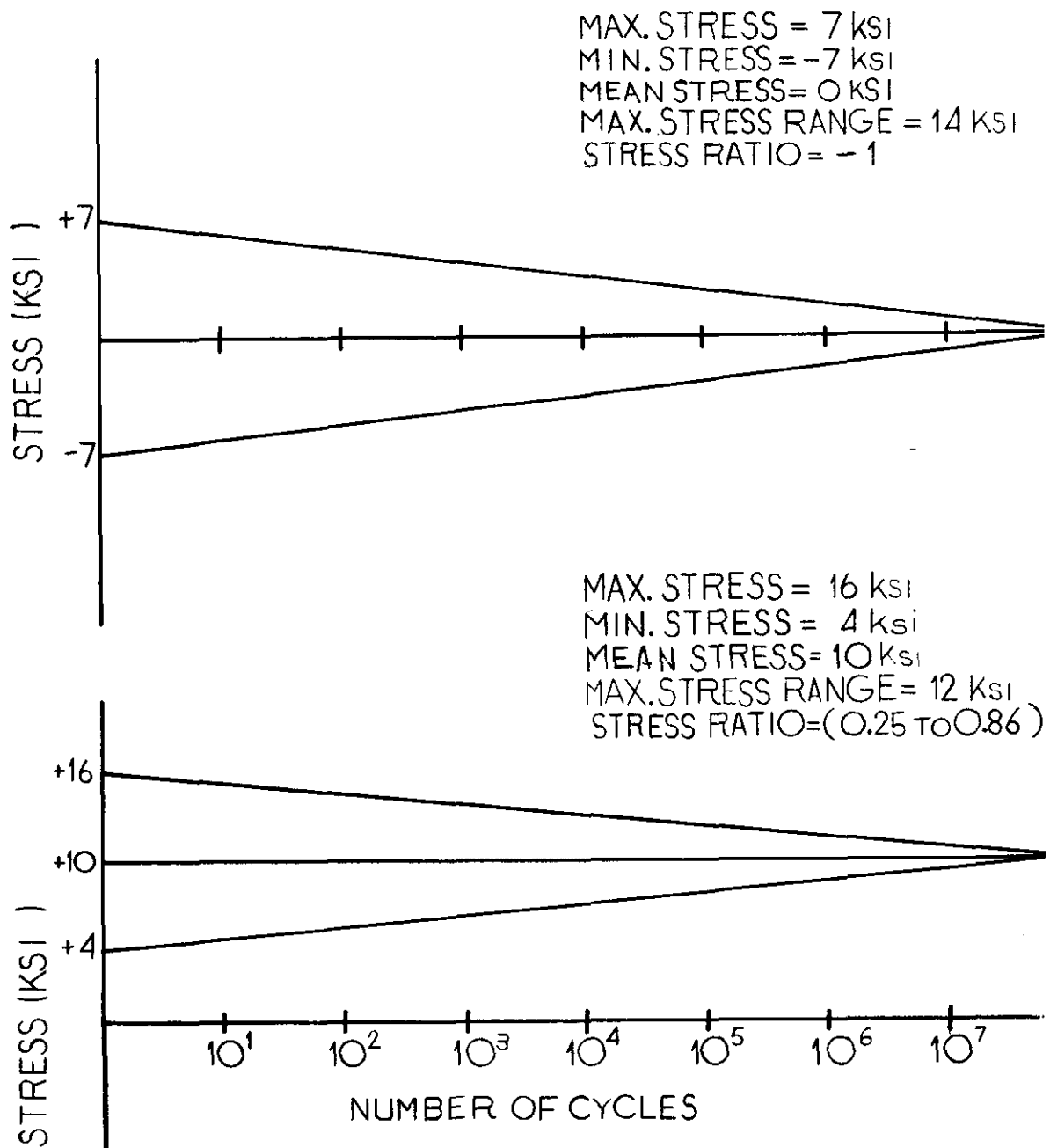
FIGURE 6-3

PERMISSIBLE STRESS HISTOGRAMS BASED ON
S-N CURVES OF FIG. 6.2

In the formulation of standards it will be necessary to establish not only the safety factor on allowable fatigue stress, but on the Palmgren-Miner cumulative damage criterium. The Det Norske Veritas Rules referred to earlier require that:

$$\sum \frac{n_i}{N_i} \leq 0.5 \, .$$ Aircraft practice is to require a scatter factor of 4.0,

which is equivalent to a four-fold extension of service life or, approximately,

$$\sum \frac{n_i}{N_i} \leq 0.25 \, .$$ It should be noted that aircraft acceptance is based on

testing of components and assemblies, rather than on approval of calculations based on any given method or standard.

This discussion of fatigue criteria applicable to structural details would not be complete without a mention of low cycle fatigue, which some authorities consider of paramount importance to ship structural analysis. The reason for this belief is that so many cracks appear very early in the life of the ship. This has been partially explained as the growth of cracks resulting from welding defects or due to excessive residual stresses. In the latter case the problem is more one of a ductile tensile failure than low cycle fatigue.

In the application of the cumulative failure criterium to various assumed stress spectra it is clear that the low cycle properties (to about 100,000 cycles) are as likely to be dominant as are the higher cycle properties. For the stress spectra shown in Figure 6-3 the first 100 cycles were decisive for the spectrum with mean stress = 0, whereas the 100,000 to 10,000,000 cycle blocks were dominant for the other spectrum shown.

Section 7

LITERATURE SURVEY ON DETAIL DESIGN

7.1 GENERAL

Using, for example, the five sets of International Ship Structures Congress (ISSC) Transactions as a guide, it is possible to construct an extensive bibliography indirectly related to the design of ship structural details. Relevant subjects would be stress concentrations at openings and other discontinuities, effect of residual stresses, limit design, fatigue testing of structural components and stability analysis of stiffened and unstiffened plates.

During the course of this Project it became clear that the large extent of that bibliography is very misleading regarding the amount of published research with relatively direct applicability to the design of ship structural details. Therefore, in the paragraphs which follow, only those reports with some direct relevance to structural detail design are reviewed.

7.2 OPENINGS

The Ship Structure Committee of Japan (References 14 and 15) proposes rules for the allowable size of lightening holes in girders and provides justifying theoretical background. The proposed rules are reproduced as Tables 7-1, 7-2 and 7-3, which specify allowable size of lightening holes, minimum length between holes, and strength ratio of girders with holes to girders at ends without holes. The supporting calculations in Reference 15 are based largely on plastic design criteria.

Reference 7 has a succinct discussion of buckling failures in large ships, many in the vicinity of cutouts or lightening holes. The buckling characteristics of a specific configuration can now be established by finite element calculations, but no general data suitable for design guidance have been developed.

7.3 KNEES AND BRACKETS

Jaeger and Nibbering (Ref 16) ran an extensive series of static, buckling and dynamic tests on ten basic configurations of knees and brackets. They suggest that assymetrical brackets date back to riveting, when a function of the bracket was to maintain the angle between stiffeners. That function is no longer required, and emphasis should be placed on a second function, i.e., to lead the stresses smoothly around the corner.

The results of the test series are reproduced in Table 7-4, taken from the above reference. Note that all specimens were annealed after welding, thus residual stresses were not a factor in the results.

Table 7-1

GUIDANCE FOR ALLOWABLE SIZE OF LIGHTENING HOLES

		Depth of hole/Depth of web				High stress region (C)
		Low stress region (A)		Intermediate stress region (B)		
		No reinforcement	With reinforcement	No reinforcement	With reinforcement	
Girder Web	Cargo oil tanks	0.2* (0.25)*	0.5**	0.1* (0.125)*	0.25	-
	Cargo holds, engine room or other sect.	0.25 (0.33)	0.5	0.125 (0.165)	0.25	-
	Living quarter Weather decks	0.33 (0.5)	0.5	0.165 (0.25)	0.25	-
Solid floor and webs in cof. d.		0.4	0.5	0.25	0.2	-
Side girders in double bottom and various diafragms		0.6	0.66	-	-	-

Note 1. Figures in ( ) are for NK and ABS.

2. *: max. 300 mm **: max. 600 mm

3. In case there are two holes in the depth of girder the sum of the size of these holes shall be within the limit specified above.

4. The length of hole shall be normally less than twice the depth.

5. At the corner of holes there should be roundness with radius at least 1/10 of depth or min. 25 mm.

6. The indication of region (A), (B) and (C) are given for the strength member according to the intensity of stress. In case of girders the part within a distance of 0.1 from the end thereof belongs to region (B) (intermediate stress region). The other part belongs to region (A) (low stress region).

Table 7-2

MINIMUM LENGTH BETWEEN HOLES (S)

S		
Low stress region (A)	Intermediate region (B)	High stress region (C)
$\dfrac{d_1 + d_2}{2}$	$d_1 + d_2$	——
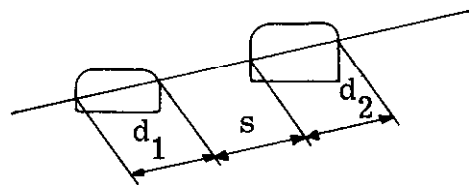
Table 7-3

PROPOSED GUIDANCE AND STRENGTH RATIO OF GIRDERS WITH HOLES
TO RESPECTIVE GIRDERS AT ENDS WITHOUT HOLES

Section	Region	"Standard of Lightening Holes"		Strength ratio %
		Allowable depth hole d/D	Allowable l/d length	
Cargo oil tanks	A	0.2	2	86
	B	0.1	2	88
Cargo holds	A	0.25	2	89
	B	0.125	2	99
Living quarter	A	0.33	2	104
	B	0.165	2	142

TABLE 7-4

	2	3	ELASTIC STRESSES		RELATION BETWEEN LOG n OF IDEAL KNEE AND LOG n OF OTHER CONSTRUCTIONS. THE IDEAL STRUCTURE IS INDICATED BY 1. n=number of cycles		MOMENT OF LOAD		QUALIFICATION OF CONSTRUCTION			
SUB DIVISION SYMBOLS INDICATE CONSTRUCTIONS IN FIG. 42	Nº	K ($\frac{\Delta f}{\Delta f}=K$)	RELATION BETWEEN STRESSES IN ALL TYPES OF KNEES AND IN IDEAL STRUCTURE FOR EQUAL MOMENTS	RELATION BETWEEN STRESSES IN ALL TYPES OF KNEES AND IN IDEAL STRUCTURE FOR EQUAL FORCES	TENSION	COMPRESSION	TENSION AND COMPR. AT FLOW LIMIT	COMPRESSION AT COLLAPS	STATIC TENSION AND COMPR AT FLOW LIMIT	STATIC COMPRESSION AT COLLAPS	DYNAMIC TENSION	DYNAMIC COMPRESSION
I	1.9 A	1,2	1	1'	1	$\gg 1$	1	1	1	1	1	1
	21 A	2,85	2,74	2,74	0,81	$\gg 1$	0,61	0,92	}3	1	2	1
	21 B^{ab}	2,4	2,32	2,32	0,66	$\gg 1$				1	4	1
	21 B^{K}	2,4	2,32	2,32	0,61	$\gg 1$					2	1
	24 A	2,2	3,92	3,92	0,70	$\gg 1$	0,66	0,70	}3	3	3	1
	24 B^{ab}	2,8	5,08	5,08	0,54	$\gg 1$				2	5	1
	24 B^{K}	2,8	5,08	5,08	0,77						3	1
	31	4,2	4,75	6,08	0,76	$\gg 1$	0,58	0,71	4	3	3	1
	35	3,4	6,86	8,78	0,63	$\gg 1$	0,49	0,71	4	3	4	1
	41 A	1,3	2,20	2,20	0,80	$\gg 1$			}4	2	3	2
	„ B	1,3	2,20	2,20	0,79	$\gg 1$	0,56	0,83				
	„ B		2,75	2,75								
	„ C		2,54	2,88		0,92						
	41ss A	1,2	1,28	1,28					}4	2	3	2
	„ C						0,56					
	„ D		1,01	1,16				0,85				
	44 A	1,2	2,09	2,09	0,96	$\gg 1$			}4	2	2	3
	„ B	1,2			>1	$\gg 1$						
	„ C		1,70	1,70	0,91	>1	0,56					
	„ D		2,71	3,10	0,94	$\gg 1$		0,77				
	„ E		1,58	1,83	$\gg 1$	0,87						
	46' A	1,0	2,09	2,09					}5	4	3	3
	„ C		3,39	3,95	0,79		0,31					
	„ D		2,58	3,10				0,66				
FACE SIDE C₁ E₁ F₁	47 A	1,2			>1	$\gg 1$			}4	3	2	3
	„ B	1,2	2,12	2,12	0,88	$\gg 1$						
	„ C₁		1,74	2,03	$\gg 1$	0,96						
	„ D		1,85	2,16			0,56					
	„ F₁		1,95	2,28	$\gg 1$	0,88						
REVERSE SIDE C₂ E₂ F₂	„ C₂		1,33	1,56	0,98	$\gg 1$						
	„ F₂		3,56	4,18	0,83	$\gg 1$		0,73				

OBSERVATIONS: a) IN COLUMNS 4,5,6,7,8,9 THE RELATIONS BETWEEN VALUES OF ALL TYPES OF KNEES AND THE IDEAL STRUCTURE ARE GIVEN. FRAMED VALUES IN COLUMNS 6 AND 7 ARE MEASURED; SMALL FIGURES INDICATE ESTIMATIONS

$\gg 1$ LOG n > 7 , >1 LOG n = 6,5 TO 7

b) IN COLUMNS 10,11,12,13 FIGURES OF QUALIFICATIONS ARE GIVEN VARYING FROM 1 TO 5   1 INDICATING THE BEST STRUCTURE.

Shama in Reference 17 extends Schade's effective breadth design charts to cover symmetrical and assymetrical curved face plates, as found on various knee and bracket designs. The charts are reproduced here as Figure 7-1 and 7-2.

7.4 STRUCTURAL INTERSECTIONS

Clarkson in Reference 18 reports on the relative structural stiffness of various types of T-beam intersections. Clarkson defines an efficiency N_1 as the percentage of load required to produce a certain amount of overall plastic deformation at the intersection in question, with respect to the load required for equal deformation in a fully collared reference intersection. The efficiency N_2 is defined as the percentage of load required to produce a given relative deflection between the members at the intersection with respect to that of the reference intersection. The results are shown in the table below:

Structural Efficiency of Welded Connections

Efficiency	Main member, N_1		Joint, N_2	
$\dfrac{\text{Depth passing member}}{\text{depth main member}} \times 100\%$	75	56	75	56
Joint A: no lug plus bracket or direct weld	75	90	75	85
Joint B: one lug	75	75	35	50
Joint C: one lug plus bracket or direct weld	75	90	80	90
Joint D: two lugs	90	90	50	80
Joint E: two lugs plus bracket or direct weld	90	—	95	—
Joint F: two-piece insert collar --reference beam	100	100	100	100
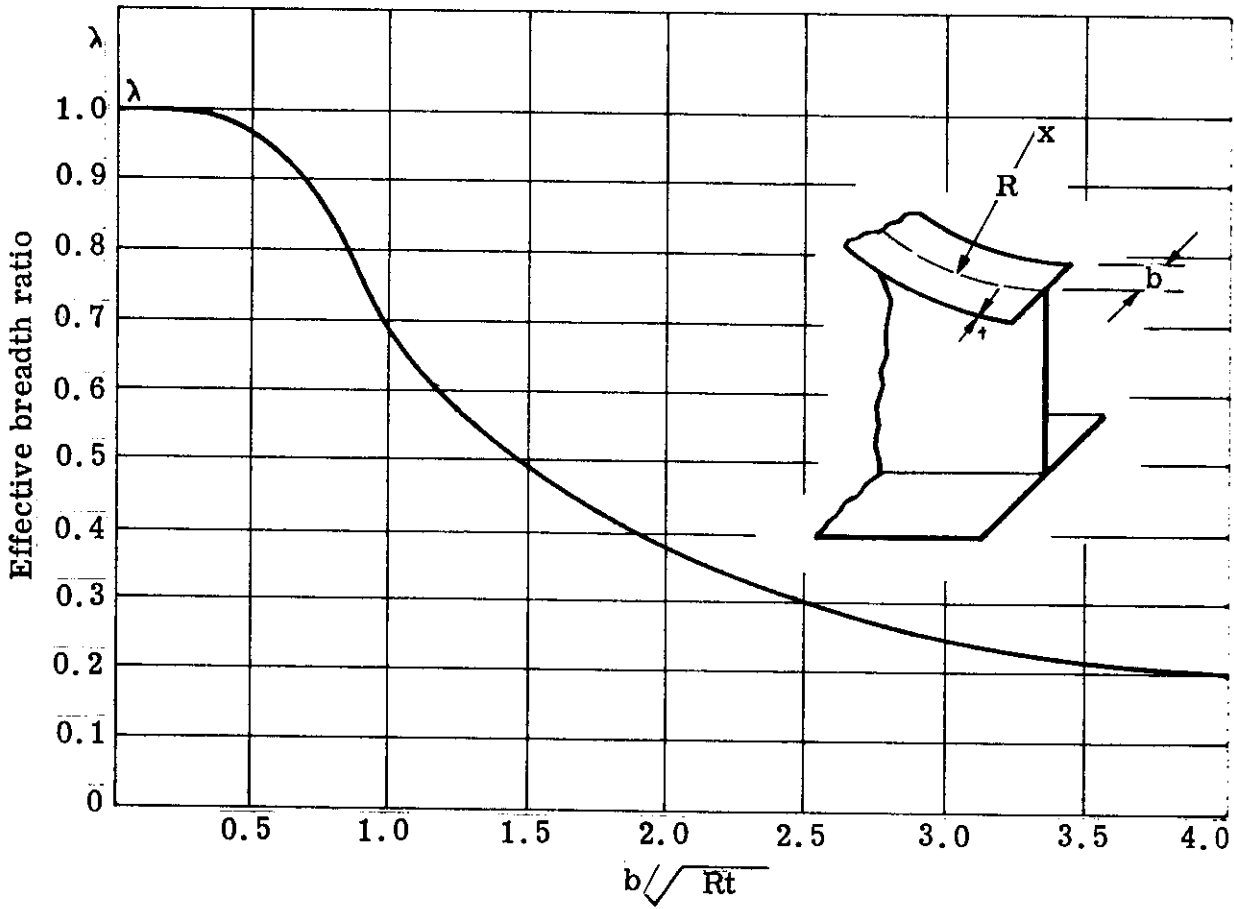
Figure 7-1 Effective Breadth Ratio for Symmetrical Curved Face Plates
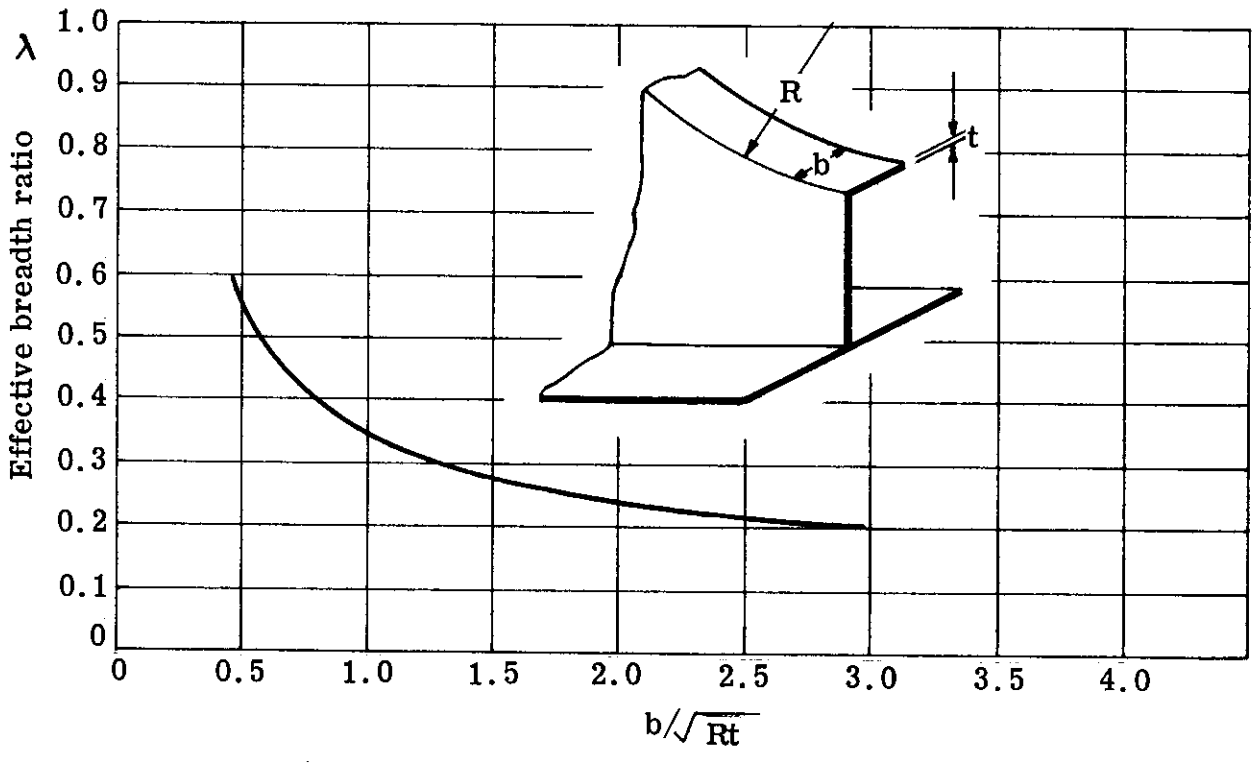
Figure 7-2 Effective Breadth Ratio for Asymmetrical Face Plates

Clarkson also includes a table providing guidelines for sizing lugs and brackets as a function of web area of the penetrating member:

Cross-Sectional Areas of Lugs and Brackets for
Connections with Two Lugs plus Bracket or Direct Weld

(A_w = area of web of piercing member)

	Depth of piercing member/depth of main member		
	≥ 0.65	0.65 to 0.40	≤ 0.40
Each lug (vertical area)	$0.5A_w$	$0.4A_w$	$0.3A_w$
Bracket (in way of weld to main member web)	$0.8A_w$	$0.65A_w$	$0.5A_w$

The work described does not consider stress concentrations or fatigue, being limited entirely to gross static stiffness.

Higuchi, et al, (Ref. 19) discuss extensive experimental (photoelastic) and theoretical (finite element) analysis of T-beam longitudinal intersections with deep tanker webs. Two types of slots were considered: one as shown in Detail NC-16 of Section 3, the second consisting of a modification whereby the stiffener flange bears against the web (called a "crab-eye" slot, Fig. 7-3b). Calculations and tests for both slots were made with and without the lug, and with and without a bracket backing up the web stiffener in line with the T-beam web.

The paper claims very good agreement between theory and experiment. Peak stresses (usually at the open lower end of the slot) were reduced by about 30% by the presence of the lug. At the base of the web stiffener, which in Section 5 was seen to be a frequent source of cracks, the presence of the lug reduced stresses by about 50%.

Reference 19 concludes that the crab-eye slot without lug is equivalent to the conventional slot with lug. That conclusion is not made clear by the numeric results listed.

The above paper makes the interesting observation that, where shear and compressive loads are largely unidirectional, the peak stress in the slot can be minimized by proper orientation of the slot.

Full scale tests and confirming finite element analysis are reported by Örge (Ref. 20) for fabricated angle longitudinals intersecting deep webs. Use of a lug as in detail NC-7 decreased stresses in the stiffener. Adding a stiffener
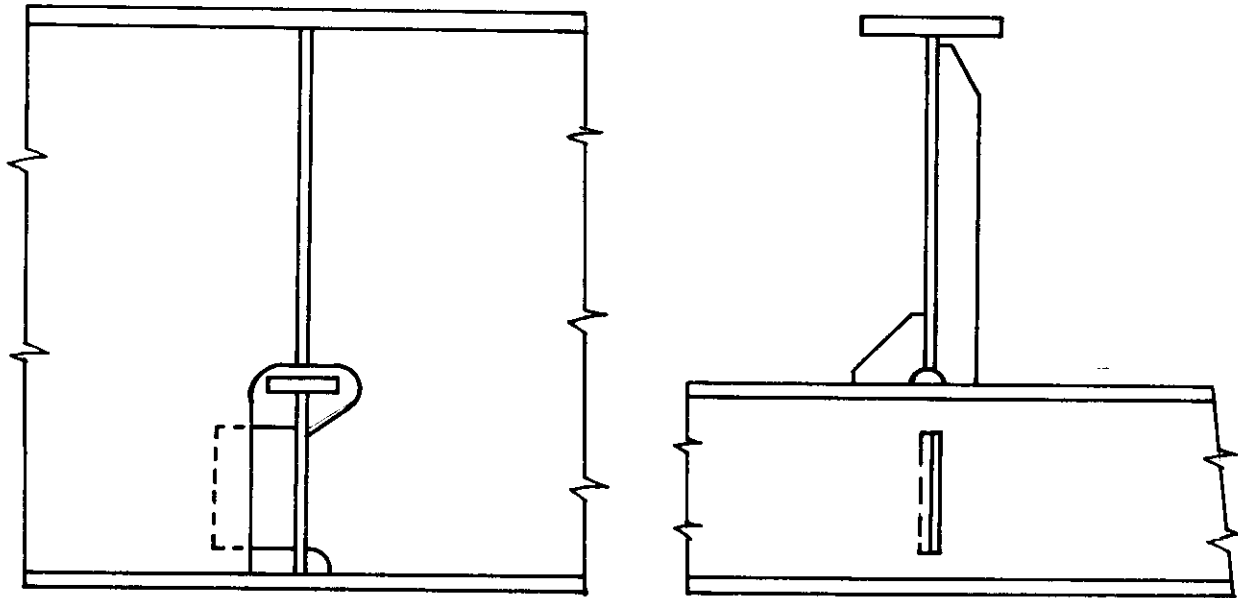
(a) CONVENTIONAL SLOT
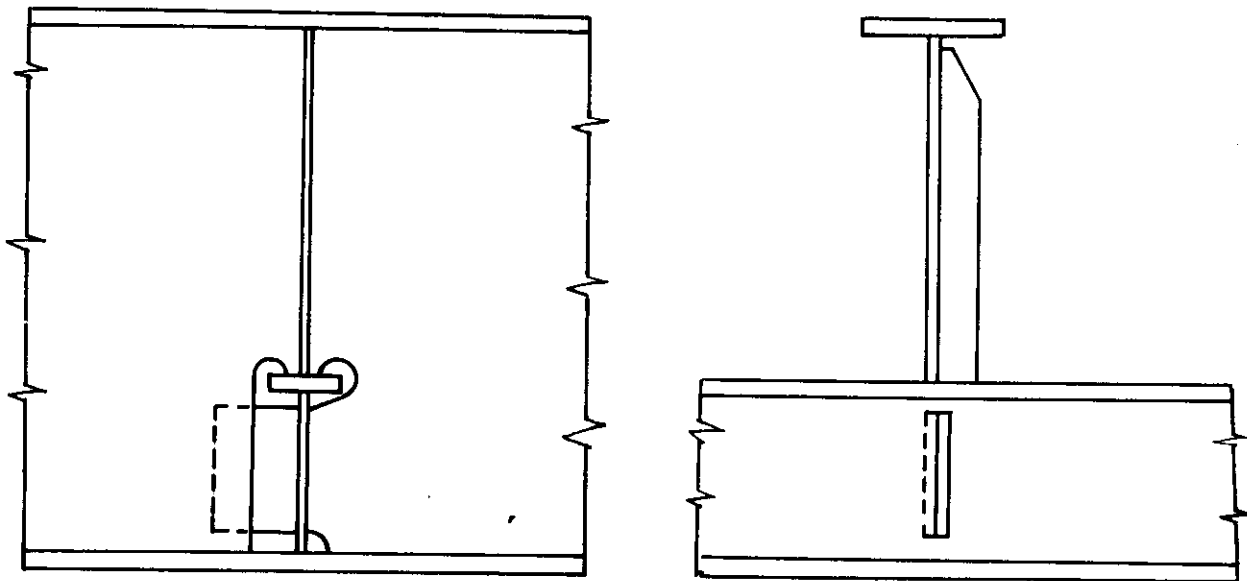
(b.) CRAB-EYE SLOT

FIG. 7-3: DETAIL OF CONVENTIONAL AND CRAB-EYE SLOT

on top of the longitudinal decreased stresses in the lug but increased stresses in the longitudinal.

Discontinuous longitudinals are treated in several references. This is no longer a common detail and is therefore not discussed herein.

Section 8

CONCLUSIONS AND RECOMMENDATIONS

With few exceptions, the Ship Classification Societies do not define the configuration and scantlings of structural details. Guidelines from other Technical Societies are equally vague. That is probably a permanent state of affairs as it is not practical to generalize the results of varied and individual stress analyses.

The capability for theoretical stress analysis of details exists in terms of known conditions of loading. The capability for prediction of structural integrity based on such structural analysis is also possible in theory, and a discussion of a proposed fatigue analysis methodology is included herein. Yet the reliability of such analyses will remain in question unless the contributions of residual stresses due to fabrication and welding can be quantitatively established.

A certain amount of structural detail standardization has taken place as a possible result of professional migration and the attendant distribution of proprietary booklets of structural details. Additional standardization in this field is, in principle, simpler than in other areas of shipbuilding: designers would welcome details accompanied by analytical and experimental confirmation of proposed design guidelines.

It is suggested that interested researchers do not hesitate unduly in selecting for analysis one or another of several duplicate details as catalogued in this report. The promulgation of such guidelines should best be left to an ad-hoc technical committee rather than a Classification Society, whose legal responsibilities would inhibit promulgation of highly qualified rules.

No readily accessible damage records of structural details are maintained in the United States. It is recommended that a long range program be initiated to monitor service performance of structural details. This could take the form of periodic surveys of selected locations aboard particular ships.

Initial observations should be made of detail configuration, workmanship, corrosion protection and expected load cycles. Subsequent observations should monitor condition of details with emphasis on crack initiation, crack propagation, corrosion and buckling of detail or adjacent structure.

Surprisingly little performance feedback is currently available to the designer.

Damage to structural details is generally the result of obvious design or fabrication deficiencies. They could largely be avoided by consistent and diligent quality control and inspection.

This common observation implies that if sound detail design practice is possible with the scant analytical or experimental backup currently available to the designer, there must remain a significant potential for hull girder scantling reduction based on more thorough detail design procedures.

Detail standardization potentially serves the dual purpose of minimizing analysis and simplifying the material handling problems attendant to structural diversity. In practical terms the degree of structural standardization currently employed is often of primary benefit to the drafting room in terms of providing a short cut notation.

The study reported herein also included review of the standards of related industries, particularly aerospace. Although a great deal of data were compiled on the latter, the final conclusion was that their practices are not applicable to shipbuilding. This is due primarily to the types of materials used, their method of joining (riveting and Huck-bolting) and the extensive full-scale testing of components.

The conflicts between theory and practice are particularly evident in the area of structural details. As an example, technical papers on brackets and stiffeners advocate symmetrical flanges because of improved structural efficiency. The use of such sections, as in tanker bottoms, dictates panel stiffeners that butt end on the stiffener flange and are the cause of many failures. An assymetrical flange permits a more favorable lap weld of the web stiffener.

The conclusion from the above is that all detail design must concern itself with the most simple and common sense aspects of producibility, including permissibl tolerances and misalignment.

The availability and increasing use of nesting programs and automatic burning machines eliminates all practical objections to relatively complex shapes of brackets, cutouts, etc.

Judging from published data reviewed herein, the most significant damage potential is exhibited by structural intersections. It is recommended that any follow-on studies emphasize this type of detail.

(Huck-bolts = mechanical fasteners, used in lieu of rivets, utilizing a pre-tensioned pin that swages a collar into a series of grooves on the pin and creates a watertight connection.)

Failures of details can be minimized by the obvious means of reducing stress concentrations and providing adequate backup to components. Such stress concentrations arise due to inadequate analysis, design or construction.

Typical example of excessive stress due to faulty analysis is the absence of partial or full collars at intersections subject to high shear stresses.

Poor design can lead to weld inaccessibility, which in turn results in cracks and craters. Brackets, chocks, collars and other details should have good welding accessibility and should be configured to minimize the number of arc strikes. Shapes with gentle radii are to be preferred.

Construction is responsible for problems arising due to poor fitup of mating components requiring field changes to clearance cuts and attachments. Such field changes are often made by casual manual burning or chipping resulting in a ragged cut outline. Design can minimize field adjustment errors by being aware of intended assembly operations. Clips or collars should be provided at intersections where a neat fit against webs or flanges of structural members is impractical because it would require dimensional control incompatible with the procedures used.

The presence of deeper clearance cuts intended to facilitate fitup or to ease stress concentrations should be considered when selecting the depth of the member. Complex arrangements of beam brackets can be minimized by increasing the scantlings of joining members, a practice whose weight implications makes it more applicable to merchant than to naval vessels.

Section 9
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ACKNOWLEDGEMENT

Appendix A

CLASSIFICATION SOCIETY RULES APPLICABLE TO STRUCTURAL DETAILS

This Appendix contains excerpts of the 1973 Rules of the major Ship Classification
Societies applicable to ship structural details. The Societies reviewed and the
abbreviations used are:

American Bureau of Shipping - ABS.
Bureau Veritas - BV.
Det Norske Veritas - DNV.
Germanisher Lloyd - GL.
Lloyd's Register of Shipping - LR.
Nippon Kaiji Kyokai - NKK.

Section A1. OPENINGS

A1.1 SHELL PLATING

A1.1.1 ABS: Section 15.9

Compensation is to be made where necessary for holes in shell plates. All
openings are to have well rounded corners; those for cargo, gangway, fueling
ports, etc., are to be kept well clear of discontinuities in the hull girder;
local provision is to be made to maintain the longitudinal and transverse strength
of the hull.

A1.1.2 BV: Section 6-26

Openings such as cargo doors, freeing ports, side scuttles, sea inlets are to
have well rounded corners. Compensation should be required except for
circular openings not greater than 300 mm in diameter.

A1.1.3 DNV: II Section 4.E: Table 102 (A-1)

Table A-1 is valid within 0.6 L amidships for bottom and ship's side in a
height of 0.15 D from bottom and deck.

TABLE A-1

	Deduction-free Openings within the same Transverse Section	
	Elliptical-I	Circular-II
Bottom-any inner bottom included:	$\Sigma\, a \leqq 0.03\,B$	$\Sigma\, a \leqq 0.02\,B$

A-1

III - Strengthening for openings exceeding the limits of I, II;

Compensation of area in arbitrary combination of:

- increased plate thickness,
- increased area of longitudinals or girders,
- flat bar along the edge of the openings,
- edge reinforcement of openings having $\Sigma a \leqq 1500$ mm
(Σa = sum of transverse dimensions of all openings)
- elliptical openings are supposed to have an axis ratio not less than 2:1.
In the ship's side below the sheer strake and above the bilge plate, circular openings are considered to be elliptical.

Total deduction for openings in plating in a transverse section is not to exceed 0.03A where A=bottom or deck area, i.e., total area of the members in bottom.

A1.1.4 GL: Section 6-G

Where openings are cut in the shell plating for windows or side scuttles, hawses, scuppers, sea valves, etc., they are to have well-rounded corners. If they exceed 500 mm in width in ships up to L=70m and 700 mm in ships having a length L>70 m, the openings are to be surrounded by framing, doubling, or a thicker plate.

A1.1.5 LR: D514

Cargo door openings are to have well-rounded corners. Sea inlets, or other openings, are to have well-rounded corners, and so far as possible, should be kept clear of the bilge radius. Openings on or near the bilge radius should be elliptical. In general, compensation will not be required for holes in the sheer-strake which are clear of any deck openings outside the line of the main hatch-ways, and whose depth does not exceed 20% of the depth of the sheer strake or 380 mm whichever is less.

A1.1.6 NKK: Part 15, Section 7; Article 16, 18.

All openings in the shell plating are to have well-rounded corners and to be compensated as necessary. Openings for cargo ports, gangway ports, coaling ports, etc., are to be kept well clear of discontinuities in the hull construction, and they are to be locally compensated so as to maintain the longitudinal and transverse strength of the hull.

A1.2 STRENGTH DECK PLATING

A1.2.1 ABS: Section 16.5.1&3

Within the line of openings the thickness of exposed plating is not to be less than:

$T_{PLT} = 0.01Sb + 0.035$ in. where: $Sb \leqq 30$ in.
$T_{PLT} = 0.0067 Sb + 0.134$ in. where: $Sb > 30$ in.
* Sb = stiffener spacing

At the corners of hatchways or other openings in effective decks, generous radii are to be provided.

A1.2.2 BV: Section 6-26

Within 0.75 L amidships, the corners of hatchways are to be strengthened by insert plates; the thickness of these will be that of the deck plating increased by: $(40\frac{a}{b} -20)$ percent, without exceeding 38 mm, where a is the distance between consecutive hatchways and b is the breadth of the hatchways; the value a/b is not to be less than 0.5 and not more than 2. Hatch corners are to be rounded. The ratio of the blending radius to the breadth of the hatchway is to be about 0.05. Where no continuous deck girder is fitted in way of hatch coamings, this ratio may be increased to 0.08. The opening may also have a streamlined design as shown in Figure A-1, it is determined by the radius R which is equal to 0.04 times the breadth of the hatchway. For the extreme corners of end hatchways, a streamlined design may be required. The thickness of insert plates is to be 60% greater than that of adjacent deck plating.

A1.2.3 DNV: II Section 4

Table A-2 is valid within 0.6 L amidships for strength deck.

TABLE A-2

	Deduction-free Openings Within the same Transverse Section	
	Elliptical-I	Circular-II
Deck, Tankers	at the same time: $\Sigma a \leqq 0.05B$ and $\Sigma a \leqq 2000$ mm and $a \leq 900$ mm	at the same time: $\Sigma a \leqq 0.03B$ and $\Sigma a \leqq 1000$ mm and $a \leqq 400$ mm
Deck, dry cargo ships	$\Sigma a \leqq 0.03(B-b_L)$ $a \leqq 350$ mm	$\Sigma a \leqq 0.03 (B-b_L)$ $a \leqq 100$ mm

Strengthening of openings exceeding the limits of I, II - compensation of area in arbitrary combination of:

- increased plate thickness
- increased area of longitudinals or girders
- flat bar reinforcement

a = transverse dimension of greatest opening

Σa = sum of transverse dimensions of all openings

b_L = hatch breadth

A-3

FROM A TO B, THE STREAMLINED CURVE IS AS DEFINED
BY THE SKETCH. FROM B TO C THE CURVE IS AN ARC OF A
CIRCLE WITH A RADIUS R EQUIVALENT TO THE RADIUS
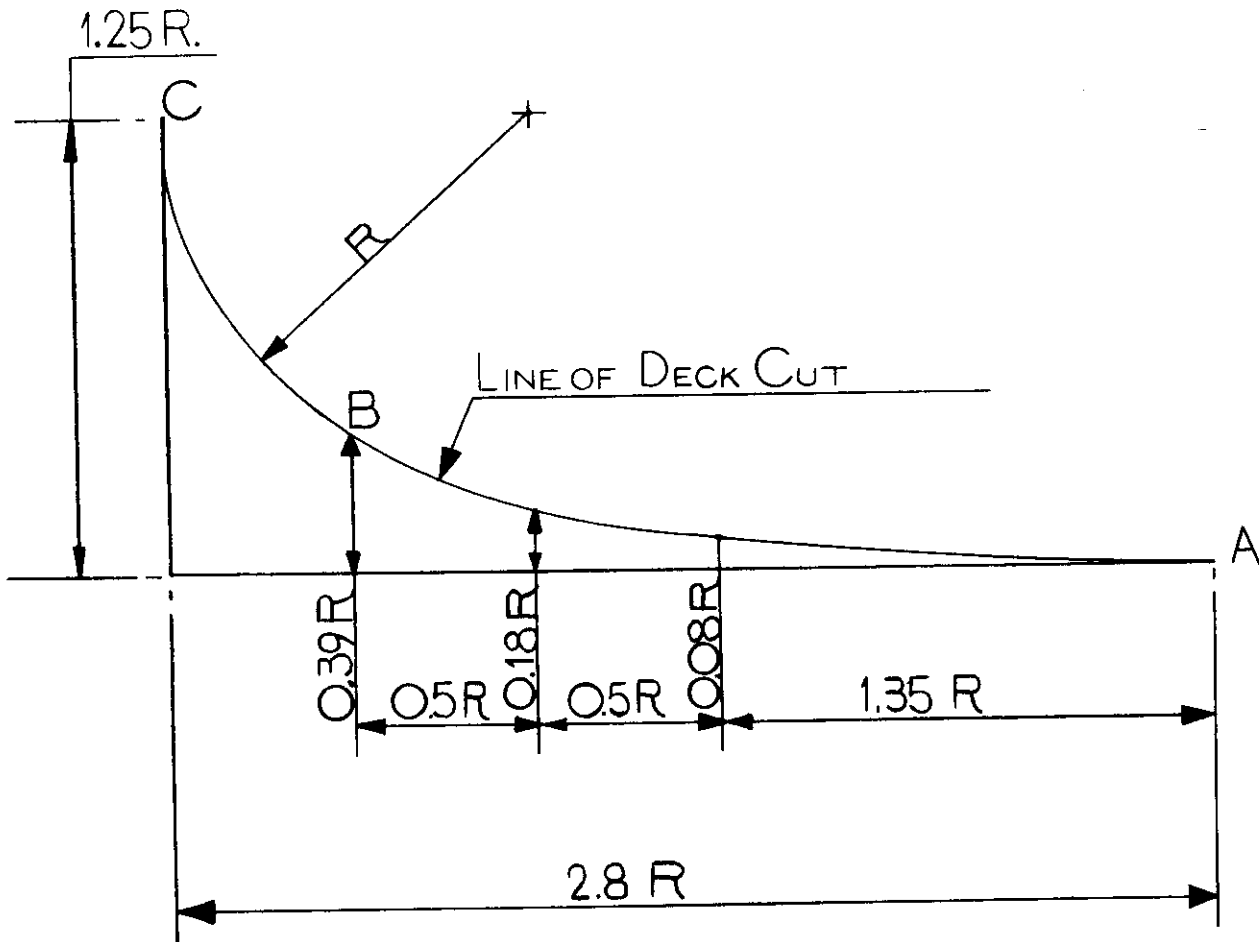OF CURVATURE AT B.

FIGURE A-1

STREAMLINED HATCHWAY CORNER – RECOMMENDED BY B.V.

A1.2.4 GL: Section 7.A

All openings in the strength deck are to have well-rounded corners. Circular openings are to be edge reinforced. The sectional area of the face bar is not to be less than: $f=0.25$ ds CM^2 (d=dia. of opening, s=deck thickness). The reinforcing face bar may be dispensed with, where the diameter is less than 300 mm and the smallest distance from another opening is not less than 5 times diameter of the smaller opening. The distance between the outer edge of openings for pipes, etc., and the ship's side is not to be less than the opening diameter. The hatchway corners are to be surrounded by strengthened plates which are to extend over at least one frame spacing fore and aft and athwartships. Within 0.5 L amidships, the thickness of the strengthened plate is to be equal to the deck thickness abreast of the hatchway plus the deck thickness between the hatchways. At the ends, the strengthened plate need not exceed 1.6 times the thickness of the deck plating abreast the hatchway. The hatchway corner radius is not to be less than: $r=0.1$ $b(1-b/B)$: r max = 0.06b, r min = 100 mm: b=breadth of hatchway or hatchways. Where the hatchway corners are elliptic or parabolic, strengthening is not required, provided that no greater thickness result from the strength calculation of hatchway girders at the corners. The dimensions of the elliptical and parabolic corners shall be as shown in Figure A-2. Thickness of strength deck plating inside a line of hatchways is not be less than than:

> SL1 = 12a (mm); SL2 = 5+0.03 L (mm)
> SL1 = SL2 = deck plating thickness

A1.2.5 LR: D409-D412

Strength deck openings are to be of suitable shape and design to minimize stress concentrations. The corners of main hatchways are to be elliptic or parabolic or are to be rounded with a radius which, for openings within 0.6 L amidships, is generally not to be less than 1/24 of the breadth of the openings with a minimum of: 12 in. if the deck plating extends inside the coamings, or 6 in. if the coaming is welded to the inner edge of the plating. If elliptical corners are arranged, the major axis should not be less than 2:1, and the minimum half-length of the major axis is defined as a in Figure A-2. Where two or more hatchways are arranged abreast, the corner arrangements will be specially considered. Where corners of large openings in the strength deck are parabolic or elliptic, insert plates are not required. Required thickness of insert plates is to be 0.2 in. greater than deck thickness up to a deck thickness of 1.0 in. At a deck thickness of 1.5 in. the increase is to be 0.15 in. Circular openings and square or rectangular openings with well-rounded corners will generally be required to be reinforced, but reinforcement may be omitted for circular openings having a diameter of less than 325 mm, provided that they are situated at a distance from any other opening such that there is an intervening width of plating of not less than five times the diameter of the smaller of the two openings. Where holes in the strength deck are required to be reinforced, the vertical ring area is equal to: dt/4: Openings with squares corners or other similar
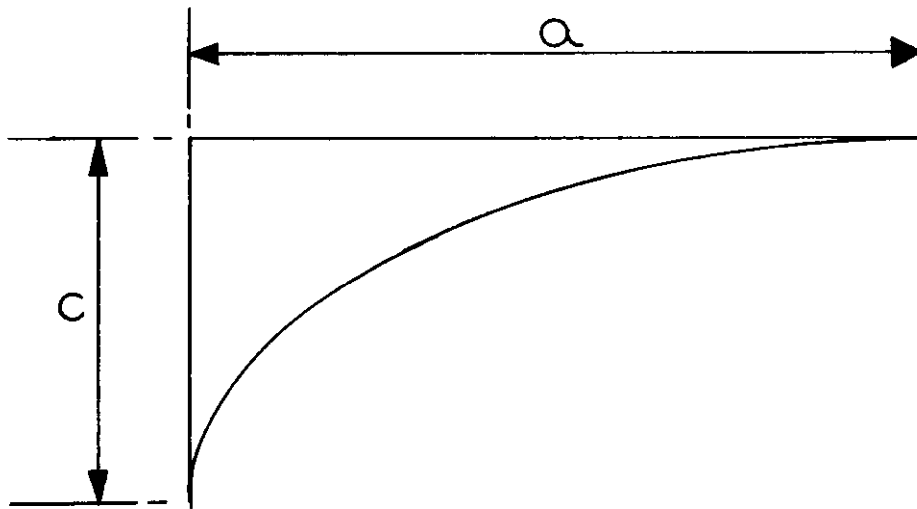
$a \geq 2c$; $C = r$ (ACCORDING TO 3.3:

WHERE SMALLER VALUES OF a AND C ARE ADOPTED REINFORCED INSERT PLATES ARE REQUIRED WHICH WILL BE CONSIDERED IN EACH INDIVIDUAL CASE.

FIGURE A-2

DIMENSIONS OF ELLIPTIC OR PARABOLIC CORNERS – RECOMMENDED BY G.L.

stress risers will not generally be acceptable. d=diameter of opening, t=deck thickness.

A1.2.6 NKK: Part 16, Article 6

Hatchways or other openings on strength or effective decks are to have well-rounded corners, and suitable compensation is to be provided as necessary.

A1.3 BULKHEAD PLATING

A1.3.1 ABS: No Comment

A1.3.2 BV: No Comment

A1.3.3 DNV: II Section 4

For longitudinal bulkheads Table A-3 for openings in the shell applies.

TABLE A-3

	Deduction-free openings within the same Transverse Section	
	Elliptical-I	Circular-II
Bottom, any innerbottom included	$\Sigma a \leqq 0.03 B$	$\Sigma a \leqq 0.02 B$

Strengthening of openings exceeding the limits allowed in I and II: Compensation of area in arbitrary combination of: increased plate thickness, increased area of longitudinals or girders, flat bar reinforcing rings.

A1.3.4 GL: Section 11.3

Openings in the bulkhead are to be effectively framed so as to facilitate proper fitting and to guarantee perfect watertightness. Where bulkhead fittings are penetrating watertight bulkheads care is to be taken to maintain watertightness.

A1.3.5 LR: No Comment

A1.3.6 NKK: No Comment

A1.4 GIRDERS AND OTHER STRENGTH MEMBER OPENINGS

A1.4.1 ABS: Section 9.5.2; 13.3.4

Hold stringers are to have a depth of not less than 1.5 in. per foot of span plus 1/4 of the depth of the slot for frames, but need not exceed the depth of the web

frames to which they are attached; in general, the depth is not to be less than 3 times the depth of the slots (in the web frame, Ed.) or the slots are to be fitted with filler plate;

Girders, except deck girders, and webs are to have depths not less than 1.75 in. per foot of span, where no struts or ties are fitted, and 1 in. per foot of span, where struts are fitted, plus 1/4 of the depth of the slots for frames or stiffeners; in general, the depth is not to be less than 3 times the depth of the slots.

A1.4.2 BV: Section 6.33

Manholes and openings in the floors and girders are to be cut smooth along a well-rounded design: Holes in side girders and floors should be cut at mid-depth, their length should not exceed half the web depth and their height should be so limited as to provide around, as far as possible a plate strip at least 1/4 the depth of the double bottom.

A1.4.3 DNV: Table 103 (A-4): II Section 4

TABLE A-4

Arrangement of Openings	Deduction-free Openings-I	Opening exceeding Requirements in I.
Long openings or groups of openings all in the same section.	$b \leq 0.5s$ and $L \geq 10a$ $a \leq 0.2s$ $\Sigma\ ae \leq 0.02A$	Opening areas exceeding the allowed, is to be deducted when calculating the SM, or to be compensated by an arbitrary combination of: increased plate thickness, increase longitudinal scantlings, flat bar reinforcing rings.
Long openings or groups of openings shifted in relation to each other.	$b \leq s$ and $b \leq L$ $L \geq 10a$ and $L \geq 600mm$ $\Sigma\ ae \leq 0.03A$	
Short openings with relatively large spacing in same section or shifted.	$b \leq 0.25s$ and $L \geq 10a$ $\Sigma\ ae \leq 0.03A$	

If b, L, and a do not comply with the requirements in I, the total opening area is to be deducted when calculating the SM, or compensation is to be provided for the total opening area. Shear stress in the web plate and weld attachment to plating is to be examined.

b - major axis of opening
a - minor axis of opening
L - distance between openings
e - thickness of web plate
s - longitudinal spacing

A-8

A1.4.4 GL: No Comment

A1.4.5 LR: D933

Sufficient holes are to be cut in the inner bottom floors and side girders, to provide adequate ventilation and access to all parts of the double bottom. The edges of all holes are to be smooth. The size of the opening should not, in general, exceed 50% of the double bottom depth, unless edge reinforcement is provided. In way of ends of floors and fore and aft girders at transverse bulkheads, the number and size of holes should be kept to a minimum and the openings are to be circular or elliptic. Edge stiffening may be required in these positions.

A1.4.6 NKK: No Comment

Section A2.   GIRDER AND PANEL STIFFENING

A2.1   KNEE AND BEAM BRACKETS

A2.1.1   ABS: Section 9.3.2, 12.7.2

Where brackets are fitted having thicknesses not less than the girder or web plates, the value of the unsupported span is as follows:

a.   Where the face area on the bracket is not less than 1/2 that on the girder or web and the face plate or flange on the girder or web is carried to the bulkhead or base, the length may be measured to a point 6 in. onto the bracket.

b.   Where the face area on the bracket is less than 1/2 that on the girder or web and the face plate or flange on the girder or web is carried to the bulkhead or base, L may be measured to a point where the area of the bracket and its flange outside the line of the girder or web, is equal to the flange area of the girder.

c.   Where the face plate or flange area of the girder or web is carried along the face of the bracket, which may be curved for the purpose, L may be measured to the point of the bracket.

d.   Brackets are not to be considered effective beyond the point where the arm on the girder or web is 1-1/2 times the length of the arm on the bulkhead or base; in no case is the allowance in L at either end to exceed 1/4 of the overall length of the girder.

An effective beam bracket is to have the scantlings shown in the following table and is to extend on to the stiffener for a distance equal to one-eighth of the length ℓ of the stiffener.

Table A-5A

Depth of Longer Arm (in)	Thickness		Width of Flange (in)
	Plain (in)	Flanged (in)	
6	0.26		
7.5	0.28		
9	0.30	0.26	1 1/4
10.5	0.32	0.26	1 1/4
12	0.34	0.28	1 1/2
13.5	0.36	0.28	1 1/2
15	0.38	0.30	1 3/4
16.5	0.40	0.30	1 3/4

Table A-5A (Continued)

Depth of Longer Arm (in)	Thickness		Width of Flange (in)
	Plain (in)	Flanged (in)	
18	0.42	0.32	2
19.5	0.44	0.32	2
21	0.46	0.34	2 1/4
22.5	0.48	0.34	2 1/4
24	0.50	0.36	2 1/2
25.5	0.52	0.36	2 1/2
27	0.54	0.38	2 3/4
28.5	0.56	0.38	2 3/4
30	0.58	0.40	3
33		0.42	3 1/4
36		0.44	3 1/2
39		0.46	3 3/4
42		0.48	4
45		0.50	4 1/4

A2.1.2   BV: Section 5-54

The requirements below cover brackets for connecting rolled sections, with
the exception of brackets interconnecting members participating in the overall
strength of the structure. Brackets are either butt or overlap welded. The
end of one of two sections is always to be inside the extension of the other.
The width and depth of straight brackets are measured from the inner edges
of assembled sections. With straight brackets, the depth and width are to
have the same minimum value d. Straight brackets may therefore have equal
sides.

Curved brackets are to be treated like the largest equal-sided bracket that
may be entirely contained in a curved brakcet. The scantlings of connecting
brackets depend on W-reference section modulus. Corner brackets connect
two sections none of which extends beyond the assembly, as shown in Figure
A-3. The reference modulus is equal to: W=W2 if W2 $\leq$ W1 or W-W1 if
W2 >W1. Where brackets connect two sections lying in perpendicular planes,
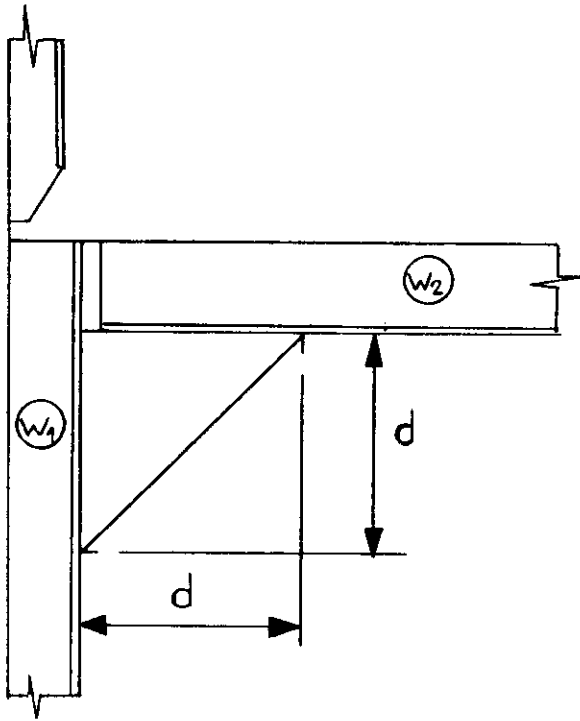
FIG. A-3: BEAM BRACKET CONNECTING TWO SECTIONS NONE OF WHICH EXTEND BEYOND THE ASSEMBLY – B.V.
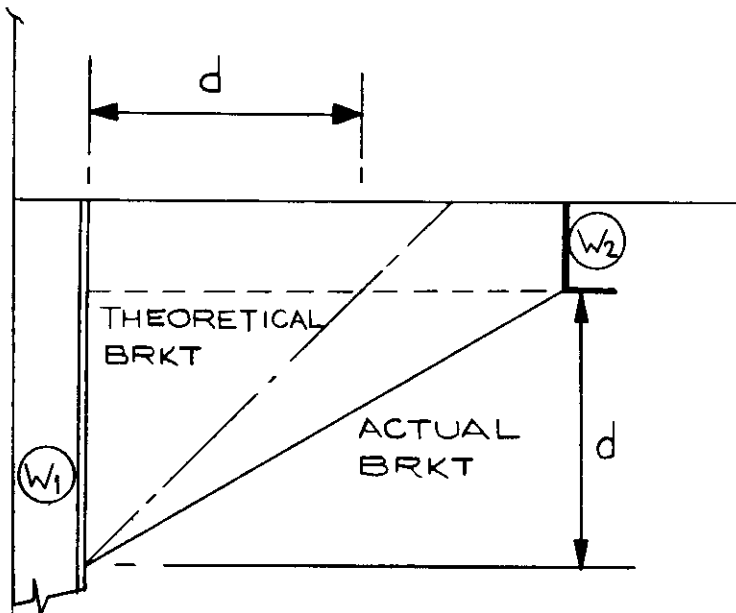

FIG. A-4: BEAM BRACKET CONNECTING TWO SECTIONS LYING IN PERPENDICULAR PLANES – B.V.

A-12

the arm lengths of brackets are to be measured from the inner edge of the assembled sections, but the bracket is to extend up to the section perpendicular to the plane of the bracket as shown in Figure A-4. The reference modulus is equal to: W=W2 if W2 $\leq$ W1 or W=W1 if W2 $\geq$ W1. Intermediate brackets connect two sections of which at least one extends beyond the assembly by means of construction measures in such a way as to ensure whole or partial continuity of such section with the one located along its extension. The reference modulus may differ according to the section moduli of the assembled sections, depending on whether the continuity between the sections located in each others extension is wholly or partially insured either directly or by means of another bracket, as shown in Figures A-5, A-6, and A-7. The width or depth of a bracket in mm is not to be less than: $d=\psi \sqrt{(W+30)}/e$ (mm)
ψ flanged = 43.5; unflanged = 48.0; e = thickness of brackets.

The bracket thickness, in mm, is not to be less than the rule value shown in Table A-5: in terms of the reference modulus. Where the thickness of the bracket equals the rule thickness e_0, the minimum value of its arm lengths may be read directly from the Table. All straight brackets in which the arm length-to-thickness ratio exceeds 32 are to be provided with a flange. The minimum width of a flange is shown in the table against the reference modulus, whatever the bracket thickness.

A2.1.3 <u>DNV: II Section 5. F</u>

The free edge of brackets in girder frames should be circular in shape to insure a smooth transition to adjoining structural members. The radius of curvature is not to be less than the depth of the largest adjoining member. The thickness of brackets on girders is not to be less than that of the girder web plate. The thickness of brackets on frames or stiffeners not taking part in the longitudinal strength, is not to be less than shown in Table A-6. Flanges on girder brackets are to have a cross-sectional area not less than $A=0.1L\,t$ cm^2. L=Length of free edge of brackets in cm. If L exceeds 150 cm, 40% of the flange area is to be in a stiffener fitted parallel to free edge and maximum 150 mm from the edge, (t = thickness of brackets in cm). Where A is less than the flange area of the girder and the flange is continuous, the girder flange is to be tapered. If the flange is discontinuous, the free flange of the girder is to extend well beyond the toe of the bracket. The general requirement to arm length is given by: $a=C\sqrt{Z}/t$ cm.

Z=Rule section modulus in cm^3 of the strength member to which the member is attached.

t = thickness of bracket (cm)
C=2.0 for brackets on bottom and deck girders.
=2.8 for brackets on girders other than bottom and deck.
=2.1 for brackets on longitudinals discontinuous at transverse bulkheads in cargo tanks.
=1.4, 1.5 for brackets; flanged and unflanged respectively, on stiffeners and frames not taking part in the longitudinal strength.

<div align="center">A-13</div>

DIRECT
CONTINUITY:

THE REFERENCE MODULUS IS
EQUAL TO:

$W = W_2$ IF $W_2 \leq W_1 + W_1'$
$W = W_1' + W_1$ IF $W_2 > W_1 + W_1'$

WITHOUT EXCEEDING $2W_1$

W_1'

W_2

W_1

d

d
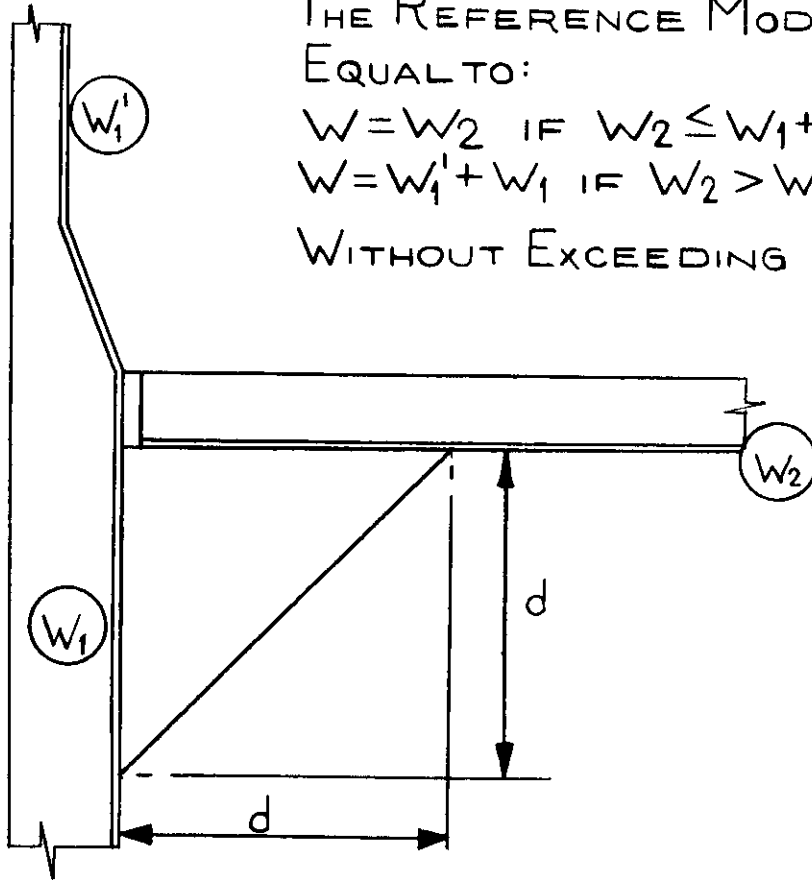
FIGURE A-5

INTERMEDIATE BEAM BRACKET: CONNECTING MEMBERS TO
INSURE DIRECT CONTINUITY - B.V.

CONTINUITY BY ONE BRACKET:
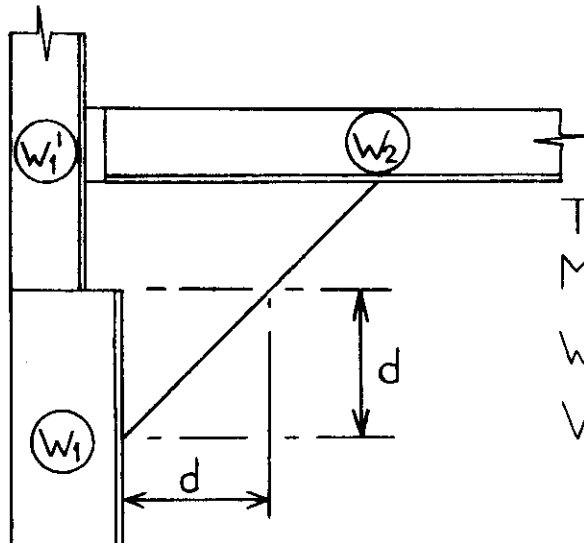
THE REFERENCE MODULUS IS EQUAL TO:

$W = W_1$ IF $W_1 \geq W_2$

$W = W_2$ IF $W_1 < W_2$

FIG. A-6: INTERMEDIATE BEAM BRACKET INSURING CONTINUITY OF MEMBERS - B.V.

CONTINUITY BY TWO BRACKETS:
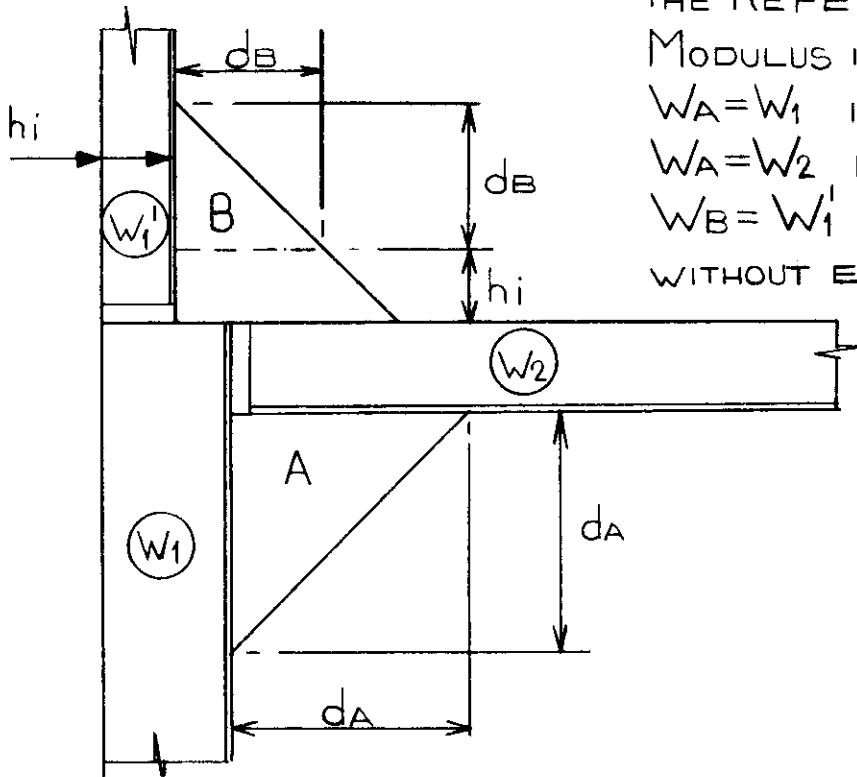
THE REFERENCE MODULUS IS EQUAL:

$W_A = W_1$ IF $W_1 \geq W_2$

$W_A = W_2$ IF $W_1 < W_2$

$W_B = W_1'$

WITHOUT EXCEEDING W_1

FIG. A-7: INTERMEDIATE BEAM BRACKETS PROVIDING CONTINUITY OF MEMBERS - B.V.

TABLE A-5

Reference Modulus W_3 (cm^3)	Minimum Thickness e_O		Minimum Width and height d_O corresponding to e_O (mm)	Minimum Width of flange (mm)
	Unflanged (mm)	Flanged (mm)		
10	7.0	6.0	110	
20	8.0	7.0	120	
30	8.5	7.0	130	
50	8.5	7.0	150	
80	9.0	7.5	170	
100	9.5	7.5	180	
150	10.0	8.0	210	
200	10.0	8.0	230	
250	10.5	8.5	250	
300	11.0	8.5	270	
350	11.0	9.0	285	
400	11.5	9.0	300	60
450	11.5	9.0	315	60
500	12.0	9.5	330	60
550	12.0	9.5	340	60
600	12.0	9.5	350	65
700	12.5	10.0	370	65
800	13.0	10.5	390	70
900	13.5	10.5	405	70
1000	13.5	11.0	420	75

TABLE A-6

Z cm^3		100	200	300	400	500
t min. mm	Unflanged	7.5	8.5	9.5	10.5	11.5
	Flanged	6.5	7.5	8.5	9.0	9.0
Width of Flange		50	50	50	60	60
Arm Length at Rule thickness (mm)		180	240	270	300	330
Z cm^3		600	700	800	900	1000
t min. mm	Unflanged	12.0	12.5	12.5	13.0	13.0
	Flanged	10.0	10.5	10.5	11.0	11.0
Width of Flange		65	65	70	70	75
Arm Length at Rule Thickness (mm)		350	370	390	410	430

The depth (a-H) see Figure A-8, of brackets on girders other than bottom and deck girders need not exceed 0.5H and L'/9 provided the bracket flange area is not less than the greater of the flange of the adjoining girders. L'-span of adjoining girder.

A2.1.4 GL: Section 3.2

For the scantlings of brackets the required SM of the section is decisive. Where sections of different section moduli are connected to each other, the scantlings of the brackets are generally governed by the smaller section. The thickness of brackets is not to be less than: Smin=6.5 mm

for unflanged brackets: $S1 = 1.26\sqrt[3]{W} + 1$ (mm)
for flanged brackets: $S2 = 1.26\sqrt[3]{W} - 1$ (mm)
W=section modulus of small section:

The arm length of welded brackets is not to be less than:
Lmin = 100(mm); $L=16\sqrt{W}/S1$ (mm)
L=is the length of the welded connection.

Where flanged brackets are used the width of flange is to be determined:
$50(mm) \leqq b=40+30/W) \leqq 90(mm)$
The thickness of tank side brackets and bilge brackets is not to be less than: $S=0.5H+5(mm) \leqq 15(mm)$

For ships with 3 decks and more H need not be taken greater than L/12. For single deck ships the thickness is to be increased by 10%. If the section modulus of the frame exceeds $30cm^3$, the bracket is to be flanged. The width of the flange is to be at least 75mm. Where longitudinals abut at the transverse bulkheads, brackets are to be passed through the transverse bulkheads. Within the upper and the lower girth the sectional area of the bracket at the bulkheads is to be 1.25 times the sectional area of longitudinals.

A2.1.5 LR: D726; D732; D733; D729

In ships having more than 3 tiers of beams and where large areas of deck are arranged for accommodations, or where particular conditions of loading are contemplated, the requirements for beam knees will be considered with a view to their omission in certain areas without an increase in modulus. When the effective arm of the knee or bracket; L a, differs from the Rule arm; L, the frame modulus is to be multiplied by the following factors:

L a < L: factor = 1.2-0.2 (La/L)
L a > L: factor = 1.1-0.1 (La/L)

For a beam knee the Rule length of arm L, measured as indicated in Figure A-9.

a=b $(21\sqrt{I/Y} - 51$ (mm) with a minimum of 165 mm, where I/Y is the Rule section modulus in cm^3 and is taken as follows:
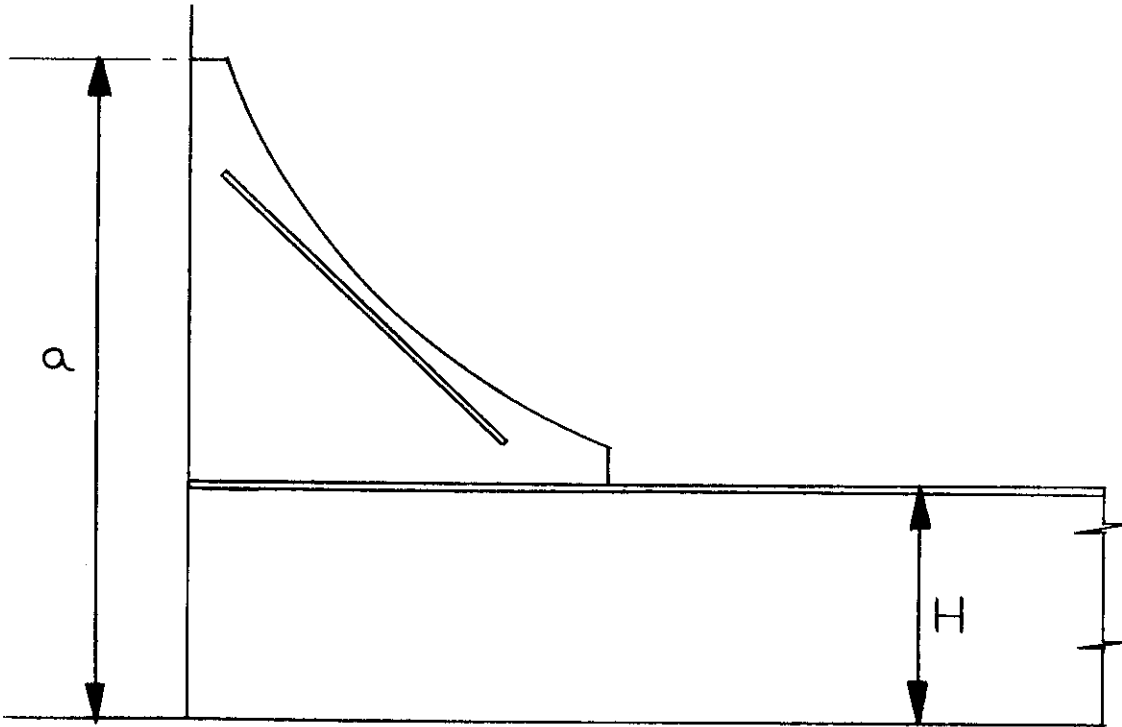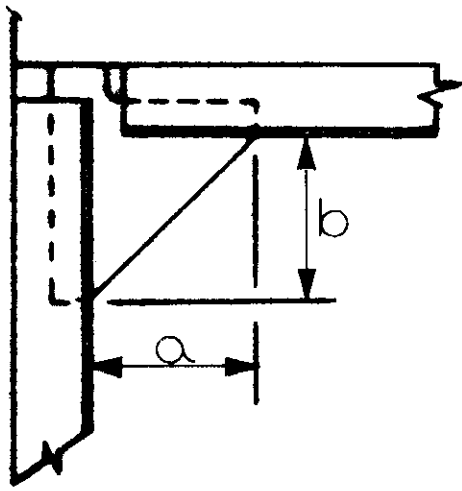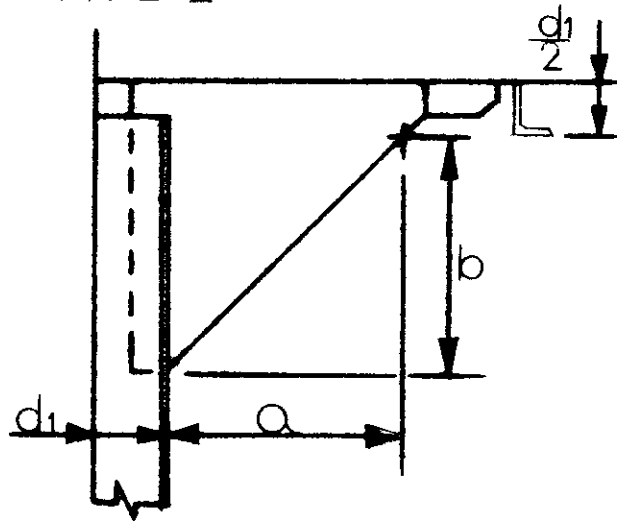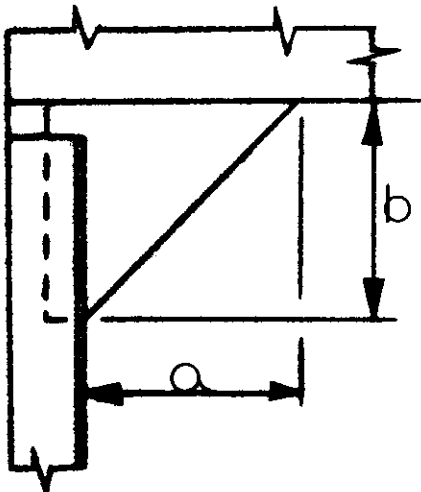
Fig. A-8: Knee Bracket Configuration - DNV

TYPE 1:

TYPE 2:

$\dfrac{d_1}{2}$

b

a

d1

b
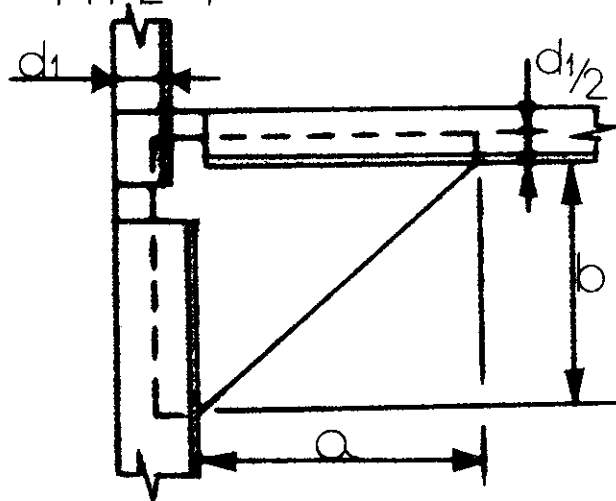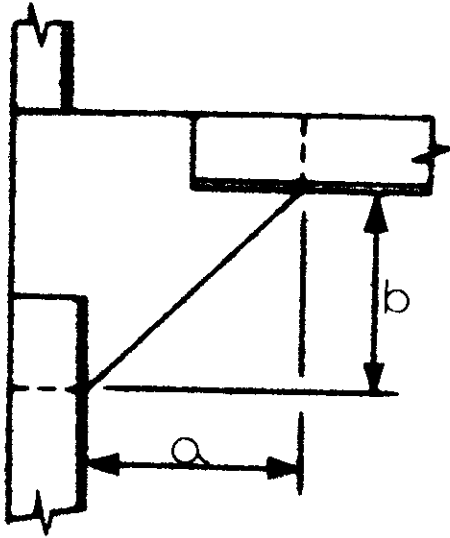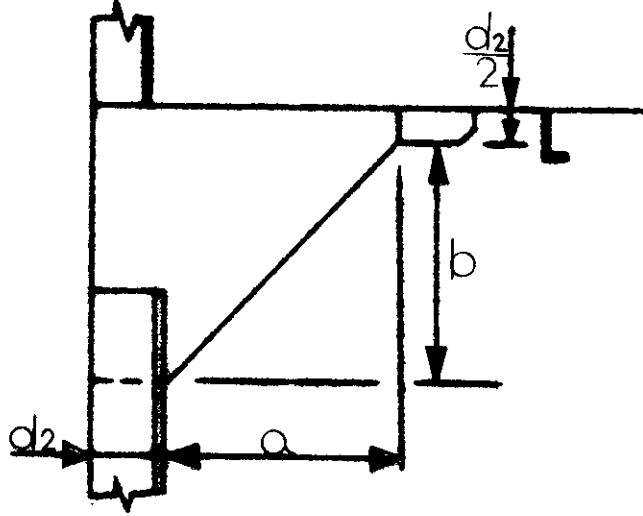
a

TYPE 3:

TYPE 4:

b

a

d1

$d_1/2$

b

a

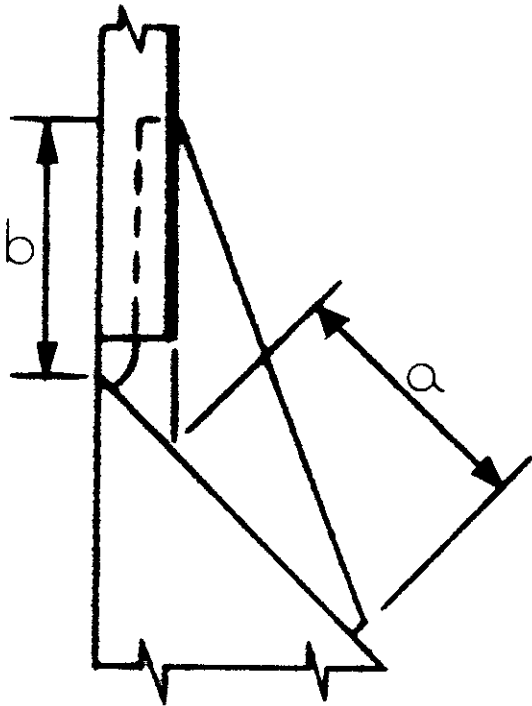Fig. A-9: Beam and Knee Bracket Configurations — L.R.
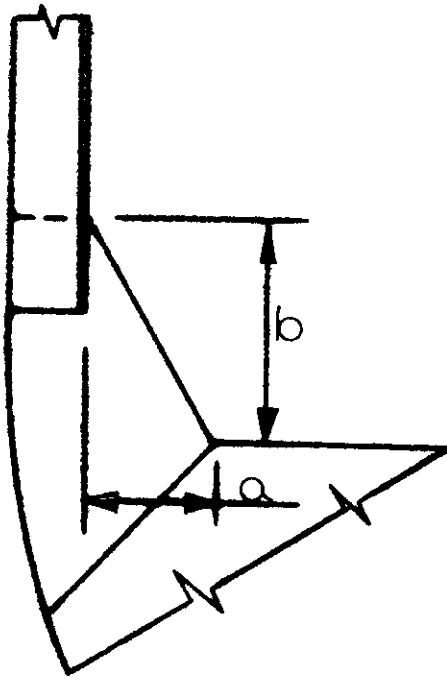
A-20

TYPE 5:

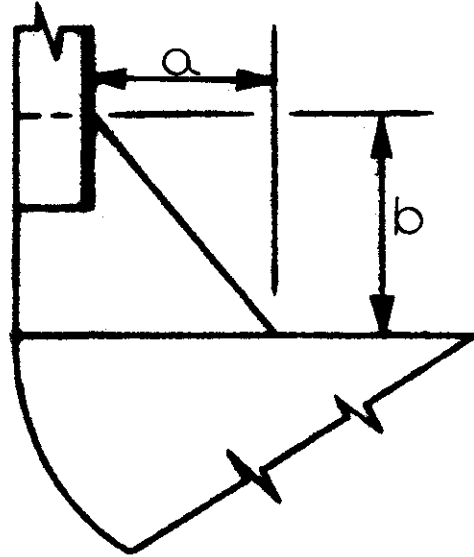TYPE 6:

TYPE 7:

TYPE 8:

FIG. A-9: CONT'D

TYPE 9

FIG. A-9 CONT'D

At decks where the hold frame terminates and at the lower deck in the panting region, I/Y is to be that of the frame or beam, whichever is greater. At all other decks, the dimension is to be based on the modulus of the beam. If the frame is continuous, the I/Y to be used in the above formula is that of the beam. Where the modulus of the beam is less than 590 cm^3 and the knee is flanged, L may be reduced by 15%.

Where tank side brackets are connected to a double bottom, L is to be taken not less than 20% greater than that required for the beam knee, 0.4 times the Rule height of double bottom, whichever is greater. Where $I/Y>590$ (cm)^3 a flange of width not less than: $2.1\sqrt{I/Y}$ (mm) is to be fitted. A flange will also be required when $I/Y<590$ (cm)^3 where the length of the bracket free edge exceeds 50t, where t is the bracket thickness. In no case should the width of the flange be less than 50 (mm). The thickness of the knee or bracket is not to be less than:

Unflanged: $4+(\sqrt{I/Y}/3)$ mm; flanged: $2+(\sqrt{I/Y}/3)$mm

With a minimum of 7 mm for beam knees, 8.5 mm for tank side brackets and a maximum of 14 mm. Girders, deck transverses, and hatch end beams are to have stiffened end brackets having the same thickness as the girder web plate. The distance from the deck to the toe of the bracket is not to be less than: $150+(\sqrt[3]{I/Y})$ 52 (mm): Where I/Y is the Rule section modulus of the girder. The horizontal arm of the bracket is not to be less than the depth of the bracket below the girder.

A2.1.6 NKK: Section 7.13

Where longitudinal framing is adopted in the double bottom, transverse brackets are to be provided between solid floors with spacing not more than 1.825 m connecting the center girder plates to bottom shell plating, as well as adjacent bottom longitudinals. Where the spacing of these brackets exceeds 1.25 m, additional stiffeners are to be provided for the center girder plates. The thickness of the foregoing brackets is not to be less than obtained from the following formula. However, it need not be greater than that of solid floors in the same location. $0.6\sqrt{L}+2.5$ (mm). The bracket stiffeners are not to be of less strength than that of a flat bar having the same thickness as that of the girder plates and having the depth not less than $0.8d_o$, where d_o is the depth of the center girder.

A2.2 TRIPPING BRACKETS

A2.2.1 ABS: Section 9.3.5; 11.7.4; 11.13.4; 12.7.4

Stiffeners or tripping brackets are to be fitted on deep webs as may be required, where the width of the flange on either side of the web exceeds 8 in., the brackets are to be arranged to support the flanges at intervals of about 10 feet.

Tripping brackets arranged to support the flanges of deck girders are to be
fitted at every third frame where the breadth of the flanges on either side of
the web exceeds 8 in., at every second frame where it exceeds 16 in., and
at every frame where it exceeds 24 in. Tripping brackets arranged to support
the hatch end beams are to be located at intervals of about 10 feet. Tripping
brackets are to be fitted at intervals of about 10 feet and where the width of
the flange exceeds 8 in. for bulkhead girders.

A2.2.2 BV: No Comment

A2.2.3 DNV: Section 5.13

Tripping brackets on girders are to be stiffened by a flange or stiffener along
the free edge if the length of the edge exceeds 60 cm. The area of the stiffening
is not to be less than $A=0.1\,L cm^2$, where L is the length of the free edge in
cm. The tripping brackets are to have a smooth transition to adjoining
longitudinals or stiffeners exposed to large longitudinal stresses. Tripping
brackets are to be fitted near the toes of brackets, near the rounded corners
or girders, and in line with cross ties. The tripping brackets are to be
fitted in line with longitudinals or stiffeners, and are to extend the whole height
of the web plate. For longitudinal girders within 0.5L amidships outside the
line of hatchway openings and for deck transverses between hatches, tripping
brackets are to be fitted at distances not exceeding 14 x flange width, max. 4m.
Otherwise, the distance between tripping brackets is not to exceed 20 x flange
width, max. 4m. The web plate of low hatch side coamings is to be stiffened
over the entire height at every frame. Tripping brackets are to be fitted on
every second frame.

A2.2.4 GL: Section 3H; 9F; 10B

For preventing the face plates from tripping, adequately spaced stiffeners
or tripping brackets are to be provided. The spacing of these tripping brackets
should not exceed 12 b(b=flange width). Between the point of greatest depth
of the ship at maximum draft and the collision bulkhead, tripping brackets
spaced not more than 2.6m are to be fitted. In the same range in between
decks and superstructures of 3m and more in height, tripping brackets are to
be fitted. At every second deck beam the face bars are to be stiffened by
tripping brackets. At girders of symmetrical section they are to be arranged
alternately on both sides of the web.

A2.2.5 LR: D1314; D1916

Girders of unsymmetrical section are to be supported by tripping brackets
at alternate beams or equivalent, if the section is symmetrical the brackets
may be 4 frame spaces apart. Where the ratio of the unsupported width of
the girder face flat or flange to its thickness is 16 or greater, the tripping
brackets are to be connected to the face flat or flange. On girders of symmetrical
section tripping brackets are to be fitted on both sides when they are required

to be connected to the flange. Girders are to be supported by tripping
brackets at the toes of the end brackets and elsewhere at every third frame
stiffener or frame. Stiffeners or frames intermediate between these
brackets are to be effectively connected to the girders.

A2.2.6 NKK: Parts 8; 9; 11

Web frames are to be provided with tripping brackets at intervals of about
3m and stiffeners are to be provided on the webs at each longitudinal except
for the middle part of the span of web frames where they may be provided
at alternate longitudinals. Side transverses are to be provided with intervals
of about 3m and with stiffeners at every longitudinal, except that these
stiffeners may be provided at alternate longitudinals in the middle part of the
spans other than the lowest spans. Bottom transverses are to be provided
with tripping brackets at intervals of about 3m and stiffeners are to be provided
on the webs at every longitudinal. Stiffeners or tripping brackets are to be
provided on deep webs as may be required. Tripping brackets are to be
arranged at intervals of 3m. Tripping brackets arranged to support flanges
are to be provided at every third frame where the breadth of flanges on either
side of the web exceeds 200 mm, at every second frame where it exceeds
405 mm, and at every frame where it exceeds 610 mm.

A2.3 PANEL AND WEB STIFFENERS

A2.3.1 ABS: Sections 7.3.7; 9.5.3

Stiffeners spaced not more than 5 feet apart are to be fitted on solid floors
forward and on every solid floor in ships of 280 feet and above. Where the
depth of the floor exceeds 3 feet, stiffeners on tank-end bulkheads spacing
is not to exceed 3 feet. Stiffeners are to extend for full depth of the stringer
on alternate frames at intervals of about 10 feet.

A2.3.2 BV: Sections 6.33; 6.35

Stiffeners fitted on plate floors, may consist of flat bars having a width of
1/10 of the floor depth and a thickness not less than $0.9\sqrt{L}$mm or of sections
of equivalent strength. The section modulus of vertical web stiffeners fitted
on watertight floors is not to be less than: $W_1 = 8.4C_1E\ell^2$:

C_1 = depth of ship
E = spacing of floor web stiffeners
ℓ = length of stiffeners
W_1=is for transverse framing or longitudinal framing when stiffeners
are not welded to longitudinals. For longitudinal framing when longitudinals
are welded to the stiffeners. $W_2 = 5.6C_1E\ell^2$.

In ships over 80 m in length or where the floor depth exceeds 0.85m, for
double bottoms built on the transverse system, the floors are to be fitted with
vertical stiffeners not spaced more than 1m.

Stiffeners on web plates are to be located not more than 100 mm from free edges of scallops for intersecting longitudinals, frames, or stiffeners. If the web stiffeners are fitted in a line with the intersecting longitudinals, frames or stiffeners then are to be welded to the intersecting member. Stiffeners on the web plate perpendicular to the flange may be sniped toward deck, side, or bulkhead plating. The web plate is to be especially stiffened at openings when the mean sheer stress exceeds $600Kp/cm^2$. Stiffeners are to be fitted along the free edges of the opening parallel to the vertical and horizontal axes of the opening. Stiffeners may be omitted in one direction if the shortest axis is less than 400 mm and in both directions is less than 300 mm. Edge reinforcement may be used as an alternative to stiffening.

Table A-7 lists the requirements for stiffening of different girder types.

TABLE A-7

GIRDER STIFFENING:

Girder Type	Iv cm^4	Ih cm^4	Sv cm	Sh cm	St cm
Bottom Transv.	$aS_1(t+0.2)^3$	$\dfrac{AL^2}{4000}$	$\dfrac{54000t}{\tau m}$	$\dfrac{60000t}{\tau m}$	20f Max. 400
Side and Long'l Bhd Vert.	$aS_1(t+0.2)^3$	$\dfrac{AL^2}{2000}$	$\dfrac{54000t}{\tau m}$	$\dfrac{60000t}{\tau m}$	12f
Long Bottom Girder	——	$\dfrac{AL^2}{3000}$	——	*	14f Max S**
Long'l Deck Girder	——	$\dfrac{AL^2}{3000}$	——	*	14f Max S
Deck Transv.	$aS_1(t+0.2)^3$	$\dfrac{AL^2}{4000}$	$\dfrac{54000t}{\tau m}$	$\dfrac{60000t}{\tau m}$	20f
Trans. Bhd Vertical	——	$\dfrac{AL^2}{2000}$	——	——	9f wash bhd 12f others
Stringers	$aS_1(t+0.2)^3$	$\dfrac{AL^2}{4000}$	$\dfrac{54000t}{\tau m}$	$\dfrac{60000t}{\tau m}$	20f Max. 400

* - distance from bottom and deck to the nearest stiffener is not to exceed 55t. For each successive plate stiffener($\frac{\text{above bottom}}{\text{below deck}}$) the spacing may be increased by 10%:

** - for center girder, St is not to exceed $^S/2$:

Iv - required moment of inertia of stiffeners perpendicular to girder flange, including 400 mm plate flange.

Ih = required moment of inertia of stiffener parallel to girder flange.
Sv = maximum permissible spacing of stiffeners perpendicular to
     girder flange.
Sh = maximum permissible spacing of stiffeners parallel to girder flange.
St = maximum permissible spacing of tripping brackets.
L = length of stiffener.
S_1 = actual stiffener spacing.
f = flange breadth
A = sectional area of stiffener
S = spacing of transverses
H = web depth
τm = mean shear stress in the web plate in Kp/cm^2
τm is not to be taken less than 600 Kp/cm^2. If τm has not been calculated,
it is to be taken as 900 $Kp/cm2$.

$\frac{Sv}{H}$	0.8	0.7	0.6	0.5	0.4	0.3
a	0.80	1.40	2.75	5.50	11.0	20.0

A2.3.4 GL: Section 7.3.2; 8.2.6

Where the depth of the floors exceeds 900 mm, watertight floors are to be
stiffened by vertical stiffeners, the section modulus of which is not to be
less than: $W = 5.5\ ahL^2 cm^3$:

   a = stiffener spacing
   L = length of stiffener (m)
   h = height of top of overflow pipe above the inner bottom (m).

Plate floors are to be stiffened at every longitudinal by a vertical strut with
the scantlings of the inner bottom longitudinals. The depth of the stiffener
need not exceed 150 mm.

A2.3.5 LR: D914; D929

If the depth of the center girder exceeds 915 mm the floors are to be fitted
with stiffeners spaced not more than 915 mm and having a section modulus
not less than: $I/Y = (Ddb)^2\ (hdb)\ (Sdb)/600,000$ in.^{3}

   Ddb = depth of center girder
   Sdb = stiffener spacing
   hdb = head from top of inner bottom to top of overflow.

The ends of stiffeners are to be sniped. On side girders a vertical stiffener
is to be arranged midway between floors when these are spaced more than 2
frame spaces apart. The stiffeners are to have a depth not less than 100 mm
and a thickness equal to the girder thickness.

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A2.3.6 NKK: Part 7; Part 8

Where the spacing of transverse brackets exceeds 1.25 m, additional stiffeners
are to be provided for the center girder. The stiffeners are not to be of less
strength than that of a flat bar having the same thickness as that of the girder
plates and having the depth not less than 0.08 dv, where dv is the depth of the
center girder in meters. Vertical stiffeners are to be provided to side girders
at every open floor or at a suitable distance if the double bottom is framed
longitudinally, and vertical struts are to be provided on half-height girders at
every floor. Vertical stiffeners are to be provided on the solid floors at
suitable spacing except where the double bottom is framed longitudinally, they
are to be provided at every longitudinal. Web frames are to be provided with
tripping brackets at intervals of about 3m and stiffeners are to be provided on
the webs at each longitudinal except for the middle part of the span of web
frames where they may be provided at alternate longitudinals.

A2.4 FACE PLATES

A2.4.1 ABS: Sections 7.1.1; 7.1.2

All single bottom vessels are to have center keelsons formed of continuous
or intercostal center girder plates with horizontal top plates.
Top-plate area at ends: $A=0.0033\sqrt{L^3} -0.15$ in.^{2}
Top-plate area at amidships: $A=0.000440\sqrt{L^3} -1.3$ in.^{2}
For side keelsons, the area of the horizontal top-plate is to be:
$\quad A=.001\sqrt{L^3} = 2.6$ in.^{2}: Amidships:
$\quad A=.00065\sqrt{L^3} + 3.1$ in.^{2}: Ends

A2.4.2 BV: No Comment

A2.4.3 DNV: II Section 5.D

Buckling of flanges on angles and T-sections:

$\quad \sigma_e=0.8\text{x}10^6 (tf/b)^2$ Kp/cm^2=critical buckling stress

$\quad$ tf = flange thickness in (cm)
$\quad$ b = flange width in (cm) for angles; half the flange width for T-sections.

Flanges on girders are to have a thickness not less than 1/30 of the flange
width when the flange is symmetrical and 1/15 if the flange is asymmetrical.

A2.4.4 GL: Sections 3.2; 3.3; 7.2

Buckling strength of face plates of girders and transverses, the thickness
of the face plate is not to be less than: $s=b/27\sqrt{K}$

$\quad$ b = unsupported width of face plate
$\quad$ K = material factor = 1.0

Buckling strength of longidutinals; angles or T-sections: $bf = 19.5tf/\sqrt{K}$

    bf = flange width
    tf = flange thickness

The sectional area of the top plate for the Center Keelson within the 0.7L amidships is not to be less than: $f = 0.7L + 12$ cm^2.

Towards the ends, the sectional area of the top plate may be reduced by 10%. The sectional area of the top plate for the side keelson within the 0.7L amidships is not to be less than: $f = 0.2L + 6$ cm^2:

A2.4.5 LR: No Comment

A2.4.6 NKK: Part 6, Article 5: Part 8; Article 15

Rider plates are not to be of less breadth than: $b = 16.6L - 200$ mm

Section A3. STANCHION SUPPORTS

A3.1 ABS: Section 11.3.7

Wide-spaced tubular or solid pillars are to bear solidly at head and heel, and are to be attached by welding, properly proportioned on the size of the pillar. The attachments of stanchions or pillars under bulkhead recesses, tunnel tops, or deep tank tops which may be subjected to tension loads are to be specially developed to provide sufficient welding to withstand the tension load.

A3.2 BV: No Comment

A3.3 DNV: II Section 4D; II Section 5G

Plates of increased thickness are to be fitted at inner bottom, deck, etc., under the base of large pillars, if no brackets to distribute the load are fitted. Doubling plates may be fitted instead of thicker plates, except where the pillar may be subjected to tensile forces.

The requirements to end connection of pillars are given in the following table:

TABLE A-8

Pillar Dia.	Conn. Area
Under 89 mm	6.5 cm^2
Under 115 mm	10 cm^2
Under 140 mm	15 cm^2
Under 150 mm	22 cm^2
Above 150 mm	34 cm^2

Table A-8 values apply to solid pillars. Hollow pillars are to have equivalent end connections.

A3.4 GL: Section 10.C

Structural members at the heads and heels of pillars as well as the stiffening of the structure at heads and heels are to be constructed according to the forces they are subjected to. At the head and heel of tubular pillars, plates are generally to be arranged. The pillars are to have a weld connection to be so dimensioned that at least 1cm^2 sectional area is available for 1 ton of load.

A3.5 LR: D1406-D1410

Tubular and hollow square pillars are to be attached at their heads to plates supported by brackets, flanged where necessary, in order to transmit the load

effectively. Doubling or insert plates are to be fitted to the inner bottom under the heels of tubular or hollow square pillars, and to decks under large pillars. The pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding. At the head and heels of pillars built of rolled sections, the load is to be well distributed by means of longitudinal and transverse brackets. Where pillars are to be fitted inside tanks or under watertight flats, the tensile stress in the pillar and its end connections is not to exceed 1100 Kg/cm^2.

A3.6 NKK: Part 11: Section 8

The head and heels of built-up pillars are to be efficiently connected by means of angles, brackets or foundation plates according to the form of the pillar. Where pillars are connected to the deck plating, the deck is to be properly strengthened as necessary. The head and heel of pillars may be subjected to tensile loads such as under bulkhead recesses, tunnel tops or deep tanks are to be efficiently welded to withstand the tensile loads.

Section A4. PADS AND DOUBLERS

A4.1 ABS: No Comment

A4.2 BV: Section 6.24

Where the sectional area of top face plate of deck girders, is relatively
important, doubling plates or increased plates are to be provided in way
of these girders.

A4.3 DNV: No Comment

A4.4 GL: Section 6.G

Above openings in the shear strake within the 0.4L amidship length, generally
a strengthened plate or a continuous doubling is to be provided compensating
the omitted plate sectional area. Under each sounding tube the shell plating
is to be provided with a strengthened plate or doubling plate.

A4.5 LR: No Comment

A4.6 NKK: No Comment

Section A5. CUTOUTS: LIGHTENING HOLES, SNIPES, SCALLOPS

A5.1 ABS: Section 7.1.7; 7.3.2

Where the girders are not required to be intact, manholes may be cut in every frame space outside the midship 0.75L in vessels under 90m in length provided the depth of the hole does not exceed 1/3 the depth of the center girder; manholes within the midship 0.75L in vessels 90m and above are to be compensated for and specially approved. Manholes and lightening holes are to be cut in all non-tight members, except in way of widespaced pillars to insure accessibility and ventilation. Air and drainage holes are to be cut in all parts of the structure to insure the free escape of air to the vents and the free drainage to the suction pipes.

A5.2 BV: Sections 6-32; 6-33

Drain holes are to be cut in the floors at centerline or on each side, according as the center keelson is continuous or intercostal. In flat bottom ships, drain holes should be cut at the lower turn of the bilge, over 0.5L at least amidships. side keelsons too are to be provided with drain holes for allowing for free running of water towards the pump suction. Holes in side girders and floors should be cut at mid depth; their length should not exceed 1/2 the web depth and their height should be so limited as to provide around, as far as possible, a plate strip at least 1/4 the double bottom depth wide.

A5.3 DNV: II Section 4E; II Section 5D; II Section 10A

Lightening holes may be cut in girders, except the centerline vertical on transverse bulkheads, and only in exceptional cases in the centerline bottom and deck girder. The distance from the edge of the lightening hole to the edge of the face plate or other holes is not to be less than 0.3 times the depth of the member. Lightening holes are to be kept well clear of end brackets and locations of high shear. Scallops for longitudinals, frames, or stiffeners deeper than 500mm are to be stiffened at their free edge. The vertical extension of lightening holes in the bracket floors is not to be greater than 1/3 the breadth of the bracket. To insure the escape of air and water from each frame space to the air pipes and suctions, holes are to be cut in the floors and side girders. The air holes are to be placed as near to the inner bottom as possible. The drain holes are to be placed at the upper edge of the solid cement. The total area of the air holes is to be greater than the area of the filling pipes.

A5.4 GL: Sections 3.2.3; 3.2.4; 8.2; 8.3

Lightening holes in the side girders are to be of such size as to leave a remainder of web plate around the hole not less than 0.2 of the height of side girder or of frame spacing respectively. Where the holes are fitted with flat bars the above value may be reduced to 0.15. In way of the strengthening of the bottom forward, any scalloping in the side girders is to be restricted to

holes required for welding and for limbers. The location of lightening holes
shall be such that the distance from hole edge to the face plate is not to be
less than 0.3 times web plate. Lightening holes in the center girder are
generally permitted only outside the 0.75 L amidships. Their depth is not
to exceed 1/2 the depth of the center girder, and their lengths are not to be
more than half the frame spacing. Lightening holes in the side girders are
to be of such size as to leave a remainder of web plate around the hole not
less than 0.2 of the height of side girder or of frame spacing respectively.
Where the holes are fitted with flat bars the above value may be reduced by
0.15. Plate floors may have lightening holes. The length of each hole should
not exceed 0.75 of the web depth and the total length of the holes is not to
exceed 1/2 the breadth of the floor between center girder and margin plate.
The depth of lightening holes is not to exceed 1/2 the depth of the floor. Its
distance from center girder and margin plate respectively is not to be less
than 0.4 of the depth of the center girder. The holes will be well rounded
and will have a minimum radius of about 1/3 of the depth of the hole. In
areas of high shear, lightening holes shall be avoided. It is recommended
to adopt lightening holes with an elliptical shape in the longitudinal girders.
Where the spacing of the plate floors exceeds 3 transverse frame spaces two
lightening holes should be provided. Drain holes and welding scallops in
the longitudinal girders are to be arranged as far away from the centers of
the lightening holes as possible.

A5.5 LR: D933

Sufficient holes are to be cut in the inner bottom floors and side girders, to
provide adequate ventilation and access to all parts of the double bottom. The
edges of all holes are to be smooth. The size of openings, should not in
general exceed 50% of the double bottom depth, unless edge reinforcement is
provided in way of ends of floors, fore and aft girders at transverse bulkheads,
the number and size of holes is to be kept to a minimum, and the openings are
to be circular or elliptical.

A5.6 NKK: Sections 6.20; 7.2, 7.18, 7.22

Limber holes are to be provided above the frames in all floor plates on each
side of the centerline, and in addition, at the turn of the bilge in flat bottom
ships. Lightening holes may be provided in floor plates. Where the holes are
provided, appropriate strength compensation is to be made by increasing the
floor depth or by some other suitable means. Manholes and lightening holes
are to be provided in all non-watertight members to insure traffic and ventilation,
except in way of pillars and where such openings are not permitted by the Rules.
Air and drainage holes are to be provided in all non-watertight members. Within
10% of the length of a hold from its end bulkheads, the diameter of lightening
holes in the side girder is not to exceed 1/3 the depth of the girders. This
requirement may, however, be modified in a short hold and outside 0.75 L amid-
ships and where suitable compensation is made to the compensating plate. Within
0.1 B from the side shell plating, the diameter of lightening holes provided in

the solid floors in the middle half length of a hold is not to exceed about 1/5 the floor depth. This requirement may, however, be suitably modified at the end parts of ship and in exceptionally short holds and where the solid floors are suitably compensated for.

Section A6. STRUCTURAL INTERSECTIONS - INCLUDING COLLARS

A6.1 ABS: Sections 9.3.6; 9.5.4

End connections of all girders, webs and stringers should be balanced by effective supporting members on the opposite side of bulkheads, tank tops, etc., and their attachments are to be effectively welded. End connections are to be for the full depth of the web plate. Where the stringers are the same depth as the web frame, the standing flanges of the side stringers are to be attached.

A6.2 BV: Sections 6.32; 6.33; 6.55

The face plates of keelsons are to be connected to those of floors. Where the bottom and inner bottom longitudinals are cut at floors, their continuity is to be insured by means of rectangular brackets connecting the bottom longitudinals. The connection length of these brackets should be 0.5 times the double bottom depth, but need not exceed 3 times the bottom longitudinal depth. Deck girders are to be securely connected to strong hatch end beams, are also to be provided with diamond plates attaching the face plates of girders to those of beams.

A6.3 DNV: II Section 4D; II Section 5G

Structural continuity is to be maintained at the junction of primary supporting members of unequal stiffness by fitting well rounded brackets. In double bottoms the following apply:

a. The bottom and inner bottom longitudinals are to be connected to the floors by a weld area not less than: $a = 5 + 2sd(\ell - S_1)$ cm^2
   s - Spacing of longitudinals (m)
   ℓ - Span (m)
   S_1 - Rule frame spacing (m)
   d - Draft (m)

b. If the expression $2.5 \, H_a \ell s / t^2$ cm^2 is greater than 0.2 or the floor forms part of a sea chest, the end connection of stiffeners on plate floors is to have an area not less than: $a = H_a \ell s$ cm^2

   ℓ - depth of center line girder (m)
   s = stiffener spacing (m)
   t - floor thickness (mm)
   H_a = vertical distance from middle of 1 to top of the air pipe. (m)

c. If the pressure head (h) on the inner bottom is greater than d: The weld area between inner bottom longitudinals or frames and floor plates on side girders is not to be less than: $a=5+0.9(\ell_1+\ell_2)$ sh cm^2 and the weld area between inner bottom frames and transverse brackets at center girder and margin plate is not to be less than: $a=5+\ell$ sh cm^2 and the weld area between inner bottom longitudinals on frames and vertical struts is not to be less than: $a=5+0.9\ell$ sh cm^2

ℓ_1, ℓ_2 = are the longitudinal or frame spans in (m) on each of the floor plates on side girders.
ℓ = span (m)
s = spacing (m)

d. For ship's side and tank bulkheads not covered by e, the following apply:

In holds, frames and stiffeners supported by girders are to be welded to girders with a weld area not less than: $a=5+0.9(\ell_1+\ell_2)$ sh cm^2

If, in areas with great shear stresses, both sides of the frames are connected to the web of the girder, only the weld area on one side of the frame will be accepted as an effective connection area.

The lowest frames in the peaks are to be welded to the floors with an area not less than: $a=7.5 + 1.5\ell$ sh cm^2

e. Longitudinals, frames, and bulkhead stiffeners in cargo tanks may be connected to the web plate of girders in the following ways:

Welded directly to the web plate on one or both sides of the frame.
Connected by single-or-double-sided lugs.
With stiffener or bracket welded on top of frame.
A combination of the above.

In locations with great shear stress in the web plate, a double-sided connection is required. The connection may be taken into account when calculating the effective web area. Only one side of the connection, however, may then be included in the effective connection area between frame and web plate.

If the necessary area is not obtained by using a side connection only, a stiffener or bracket is to be provided on top of the frame.

Minimum connection area: $a=1.25\ \ell$ sh$_t$ cm^2

h$_t$ = pressure head

If a stiffener or a bracket is welded to top of the frame, the net sectional area of stiffener may be included in the connection area, limited upwards to 50% of the required area.

f. For bulkhead stiffeners not covered by e, the following apply:

The upper end of stiffeners which support deck beams or longitudinals, is to be connected to the deck beam or longitudinal by a weld area not less than: $a = 1.8 \ell sh \; cm^2$

h = head on stiffener

The lower end of stiffeners which support deck beams or longitudinals, is to be connected to deck or tank top by a weld area not less than: $\sqrt[3]{\ell 2} \; cm^2 \geqq 6 \; cm^2$

The end connection area at both ends of stiffeners is to be at least: $a = 0.25 Z/\ell \; cm^2$

Z = rule section modulus of stiffener in cm^3

ℓ = span of stiffener (m)

g. For decks and single bottoms, the following applies:

Continuous deck longitudinals in holds are to be connected to transverse bulkheads, transverses and other transverse structural parts with a weld area not less than: $a = 5 + s \ell h \; cm^2$

h = deck load

Where beams are supported by deck girders or hatchway coamings, the connection to girder or coaming is not to be less than given in the following table:

Depth of beam in mm	Connection Area in cm^2
Less than 190	6.5
Less than 240	10
More than 240	13

For cargo tank bottom and deck longitudinals, which are discontinuous at transverse bulkheads, the total connection area to bottom and deck plating for 20% of the span from the ends is not to be less than: $a = 0.1 Z/\ell \; cm^2$

ℓ = span of longitudinal (m)
Z = rule section modulus of longitudinal (cm^3)
Minimum throat thickness of weld = 4mm

For cargo tank bottom and deck longitudinals which are continuous through transverse bulkheads, the connection area to the plating for 20% of the span from the ends is not to be less than that of a double continuous fillet weld with a throat thickness: $t = 1.5 + Z/100 \ell^2 \; mm$

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For the remainder of the span in the cargo tanks, the connection area is not to be less than that of a double continuous fillet weld with a throat thickness: $t = 1 + Z/150\ell^2$ mm

Transverse frames and beams in cargo tanks may for the complete span be connected to the plating according to the latter formula, with the following exceptions:

- Where the frame spacing exceeds 760mm, the connection area of transverse side frames to the shell plating is to be increased by 10%.

- For built sections, the connections to the flange and plate are to be equal.

A6.4 GL: Section 8.1.1

Where the face bar of the floor plates extend to the center keelson plate, the floor plate is to be continuously welded to the keelson face plate and to the center keelson. Where the face bar of the floor plate only extends to the face plate of the center keelson, those are to be connected by welding. Furthermore, on both sides of the face bar horizontal brackets are to be attached, the leg length of which is about the breadth of the face bar and the thickness of which is that of the face bar.

A6.5 LR: No Comment

A6.6 NKK: No Comment

Section A7. SHEAR STRAKE CONNECTIONS

A7.1 <u>ABS: No Comment</u>

A7.2 <u>BV: No Comment</u>

A7.3 <u>DNV: II Section 9.A</u>

The upper edge of the shear strake is not to extend above top of the stringer plate.

A7.4 <u>GL: Sections 6.4.3; 7.2.1</u>

Where the conrection of the deck stringer with the shear strake is rounded, the radius is to be at least 15 times the plate thickness. For the welded connection between strength deck and shear strake use a fillet weld where t = 20mm, where the plate exceeds 20mm a fully welded connection shall be provided.

A7.5 <u>LR: D511</u>

Where a rounded shear strake is adopted, the radius should in general, not be less than 15 times the thickness.

A7.6 <u>NKK: No Comment</u>

Section A8. HATCH COAMINGS

A8.1 ABS: Section 18.3.2

Coaming plates are not to be less than 0.34 in. thick in vessels not exceeding 100 ft and 0.44 in. thick, in vessels 250 feet and above.

A8.2 BV: Section 6.83.12

The thickness of hatch coamings is not to be less than: $e=0.082L+6mm$:
This thickness is in no case less than 8mm or more than 11mm.

A8.3 DNV: II Section 4

Compensation by flat bar rings: Figures A-10 and A-11.

A8.4 GL: Section 17.B.1

The thickness of hatchway coamings on exposed decks is to be 8.5mm where the length L does not exceed 30m, and not less than 11 mm where the length $L \geqq 60$m.

A8.5 LR: D411

Compensation: See Figure A-12

A8.6 NKK: Section 18.5

The thickness of hatchway coamings is not to be less than:

$L \leqq 100$m: $t = 6+0.05L$
$L > 100$m: $t = 11$mm

* In all cases, L is the ship length, as previously described.
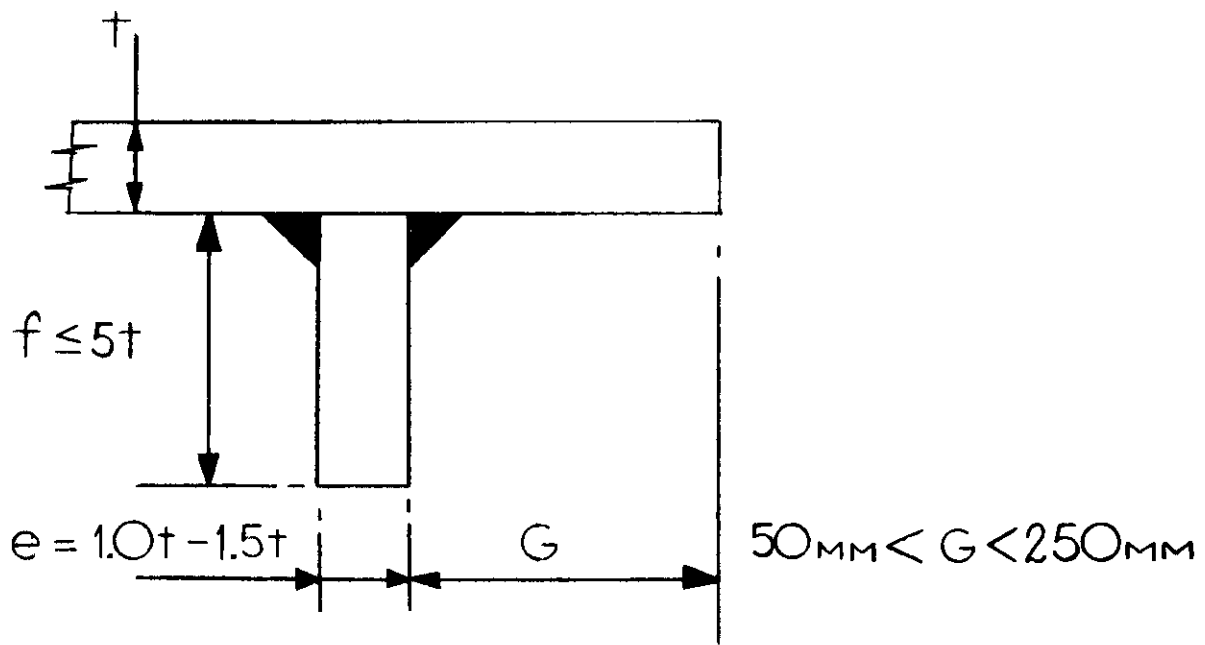
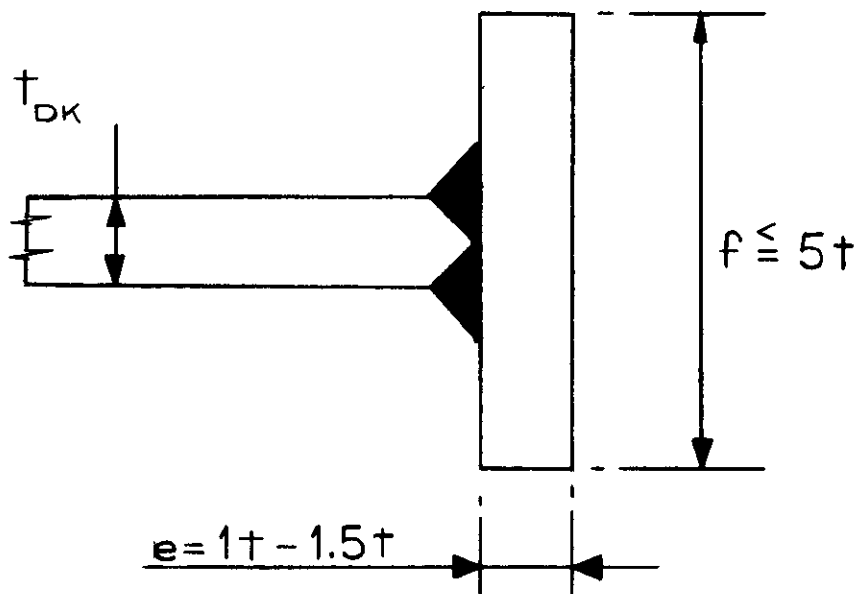Fig. A-10: Flat Bar Reinforcement Along the Edge of an Opening - DNV

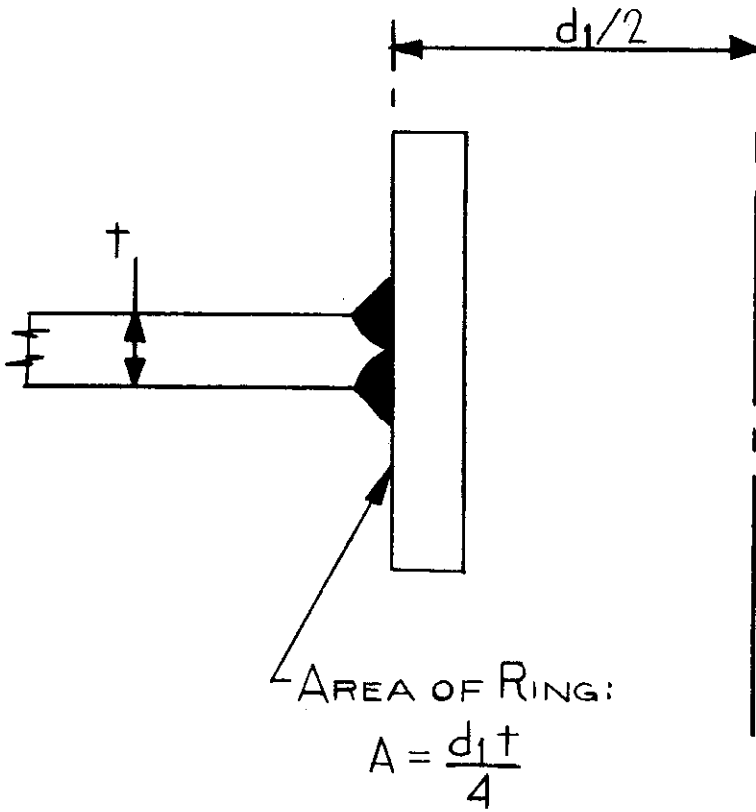Fig. A-11: Flat Bar Reinforcement Around the Inside of an Opening - DNV

$$d_1/2$$

$$t$$

Area of Ring:

$$A = \frac{d_1 t}{4}$$

FIGURE A-12

Flat Bar Reinforcement Around the Inside of an Opening - L.R.

Section A9. STIFFENER ENDINGS

A9.1 ABS: Sections 10.3, 12.7, 13.3

a. Deck beams: Req'd $Sm = 0.0041 chsL^2$ in.^{3}

   s = spacing of beams: (ft)
   L = span of deck beams: (ft)
   h = loading

   End attachment factor: c:

   =0.54 for half beams, for beams with center line support only, for beams between longitudinal bulkheads, and for beams over tunnels or tunnel recesses.

   = 0.585 for beams between longitudinal deck girders, for longitudinal beams of platform decks and between all hatches.

   = 0.855 for longitudinal beams of effective second and third decks.

   = 0.945 longitudinal beams of strength decks.

   = 0.99 for beams at deep tank tops supported at one end or both ends at the shell or on longitudinal bulkheads.

   = 1.17 for beams at deep tank tops between longitudinal girders.

b. Watertight and (Deep Tank) Stiffeners: Req'd $Sm = 0.0041 chsL^2$ in.^{3}:

   c-Factor:

   = 0.3, (0.594) - efficient brackets at both ends.

   = 0.43, (0.747): effective bracket at one end and supported by clip connections or by horizontal girders at the other end.

   = 0.56, (0.90): clip connections at both ends, or clip connections at one end and supported by a horizontal girder at the other end.

   = 0.60, (1.17): no end attachments, or supported by horizontal girders at both ends.

A9.2 BV: No Comment

A9.3 DNV: No Comment

A9.4 GL: Section 11.B.1

Bulkhead Stiffeners Req'd: $Sm = KCs\, ahL^2$ cm^3

K=1, material factor

   h = head in $^t/m^2$;
   L = unsupported span (m).
   Cs = attachment factor:

Restrained:

      3.25 - Collision bhd

      2.60 - all others

Simply supported:

      4.30 - collision bhd

      3.50 - all others.

A9.5 <u>LR: No Comment</u>

A9.6 <u>NKK: Section 12.13</u>

Bulkhead Stiffeners: Required section modulus: $Sm = ChsL^2 cm^3$:

L = distance between adjacent supports of stiffeners including the length of connection (m)

s = stiffener spacing (m)

h = vertical distance (m), from the midpoint of L for vertical stiffeners, and from the midpoint of the supported panel for a horizontal stiffener, to the top of the bulkhead deck at center line.

Where h<6m: use h'=0.8h + 1.2 m

C = attachment factor:

=2.8 - effective bracket connections at each end.

=3.6 - bracket at one end and clip at one end, or girder at one end.

=4.4 - clips at both ends, clip at one end, girder at the other end or girders at both ends.

=5.5 - no end connections.

NOTES

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NOTES

APPENDIX B

COMPARISON OF RULE APPLICATION

The sections that follow serve to illustrate the difference in scantlings, if any, obtained by applying the classification society rules regarding ship structural details that were discussed in Appendix A.

Only those cases are considered where two or more Classification Societies have applicable Rules. Where the Rules are silent or give insufficient data to define scantlings or configuration, the abbreviation ID will follow the Society's initials.

The following arbitrary main ship characteristics were chosen to guide application of the Rules:

Length	L	=	840 ft.	= 256 m.
Beam	B	=	145 ft.	= 44.2 m.
Depth	D	=	75 ft.	= 22.9 m.
Draft	d	=	36 ft.	= 11.0 m.

Stiffener Spacing = 29.5 in. = 74.9 cm.

B1.0 OPENINGS

B1.1 SHELL OPENINGS: Figure B-1

a. **ABS**: (ID)

b. **BV**:

Some compensation is required for holes A, B, C, D, and F. No compensation is required for hole E. (Section 6.26: compensation required except for circular openings not greater than 12 in. in diameter)

c: **DNV**:

Some compensation is required for holes A, B, C, D. (Compensation required when $\Sigma a > 0.03$ B. $\Sigma a = 11.0$ ft., 0.03 B = 2.25' ft.)

Compensation may take the form of:

- increased plate thickness
- increased area of stiffeners or girders
- flat bar reinforcement
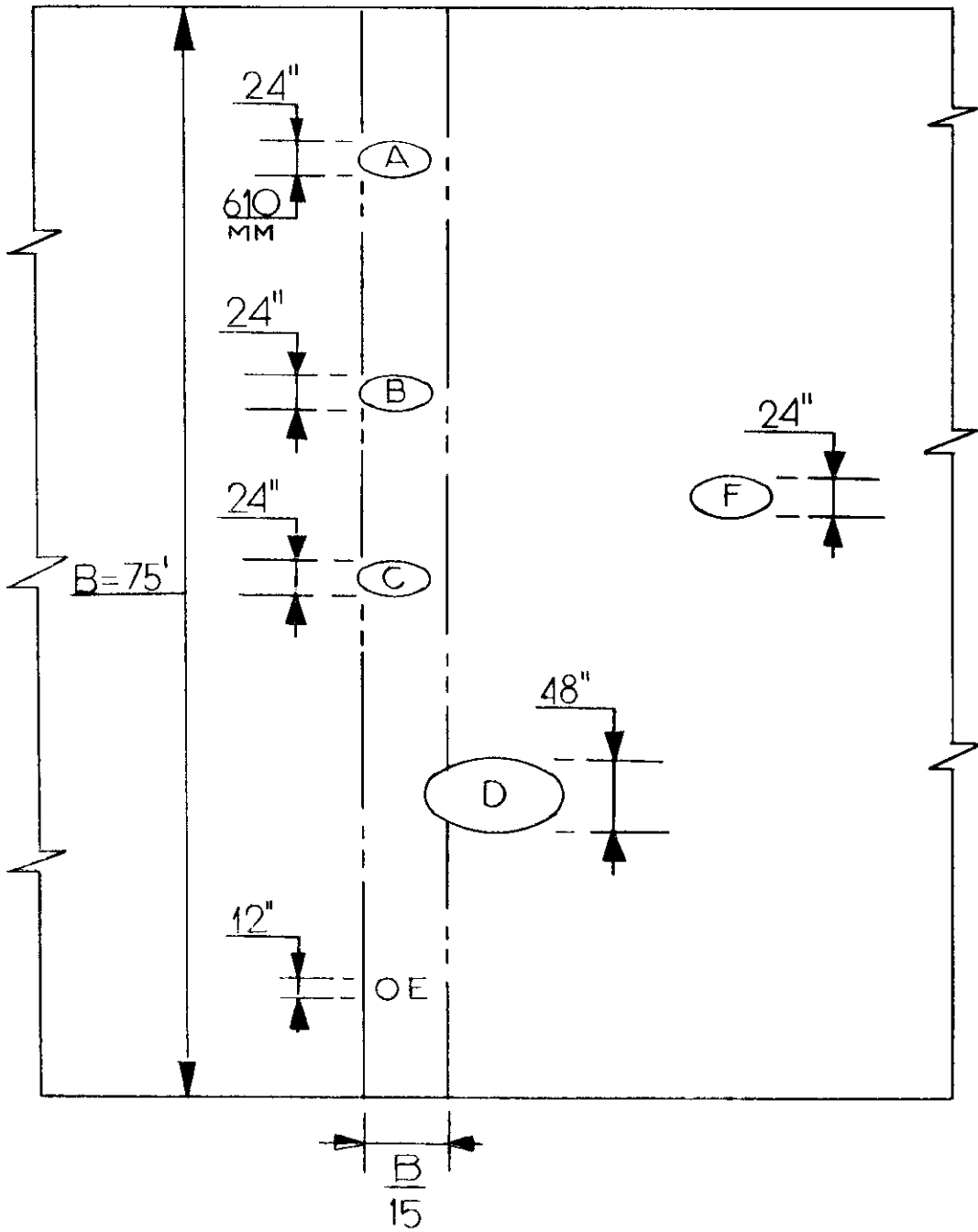
No compensation is required for holes E and F.

Fig. B-1: Hypothetical Example - Openings in the Shell

d. GL:

No compensation is required for holes A, B, C, E, and F. (No compensation when width of hole less than 700 mm). Hole D must be compensated for. Compensation may take the form of doublers, increased plate thickness, reinforcing framing members.

e. LR: (ID)

f. NKK: (ID)

B1.2 STRENGTH DECK OPENINGS: Figures B2 & B3

a. ABS:

For Tankers: (ID)

For Dry Cargo Ships: Area between the cargo hatches, minimum plating thickness: tplt = 0.01 (29.5) + 0.035 = 0.33 in.

b. BV:

For Tankers: (ID)

For Dry Cargo Ships: The corners of the hatchway are to be radiused, $R = 0.05b = 0.05 (70 \times 12) = 42$"

c: DNV:

For Tankers: Compensation will be required for openings A, B_1, B_2, B_3 and C, since they all exceed the limits of Table 102, Section 4. Reinforcement must be added in the form of: increased plating thickness, flat bar reinforcing, additional deck framing. No compensation is required for hole D.

For Dry Cargo Ships: All holes exceed the limits of Table 102, Section 4. Reinforcement must be provided as mentioned above.

d. GL:

For Tankers: No compensation required for opening D. Openings A, B_1, B_2, B_3, and C are to be edge reinforced. Required flat bar reinforcement of area $f = 0.25$ ds:
$A = 6.75$ in.^{2}
$B = 4.50$ in.^{2}
$C = 6.75$ in.^{2}

For Dry Cargo Ships: No compensation required for opening D. Openings A, B,

C require edge reinforcement, as calculated above. The hatchway corner radius, $r = 0.1 \, b \, (1 - b/B) = 0.1(840) \, (1 - 70/140) = 42"$. The thickness of strength deck plating inside the line of hatchways is not to be less than
$t = 5mm + 0.03 \, L$
$\quad t = 1/2$ in. plate

e. **LR:**

For Tankers: Same as GL, Paragraph d.

For Dry Cargo Ships: For compensation details see GL, paragraph d. Corners of main hatchways are to be rounded with a radius not less than $(1/24)b = 840/24 = 35$ in. Where corners of large openings are radiused an insert plate is required whose thickness is 0.2" greater than the deck plating thickness:
$t = 0.75 + 0.20 = 0.95"$

f. **NKK:**

For Tankers: (ID)

For Dry Cargo Ships: (ID)

B1.3 BULKHEAD OPENINGS: Figure B-4

a. **ABS:** (ID)

b. **BV:** (ID)

c. **DNV:**

Openings A and B exceed the limits of Table 102; some form of strengthening is required. No reinforcement is required for Opening C.

d. **GL:** (ID)

e. **LR:** (ID)

f. **NKK:** (ID)

B1.4 OPENINGS IN GIRDERS AND OTHER STRENGTH MEMBERS

Table B-1 provides a comparison of the relevant design guidelines. The following hypothetical structure has been used to establish the results shown in the table:
$\quad$ Member depth $= 1524$ mm $= 60$ in. $= H$
$\quad$ Web thickness $= 13$ mm $= 0.512$ in. $= e$
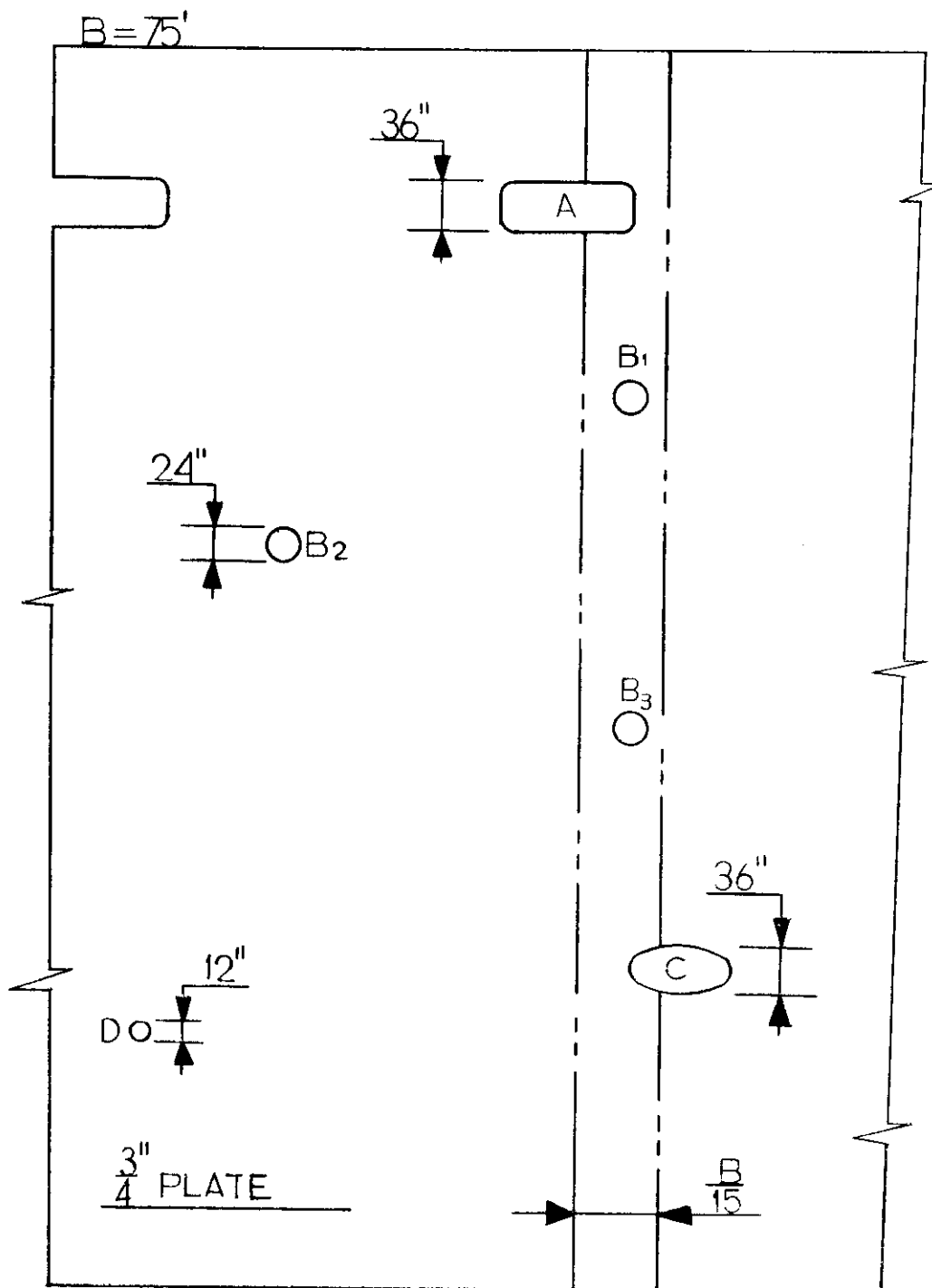$\quad$ Stiffener spacing $= 76 \, 2$ mm $= 30$ in. $= s$

FIGURE B-2

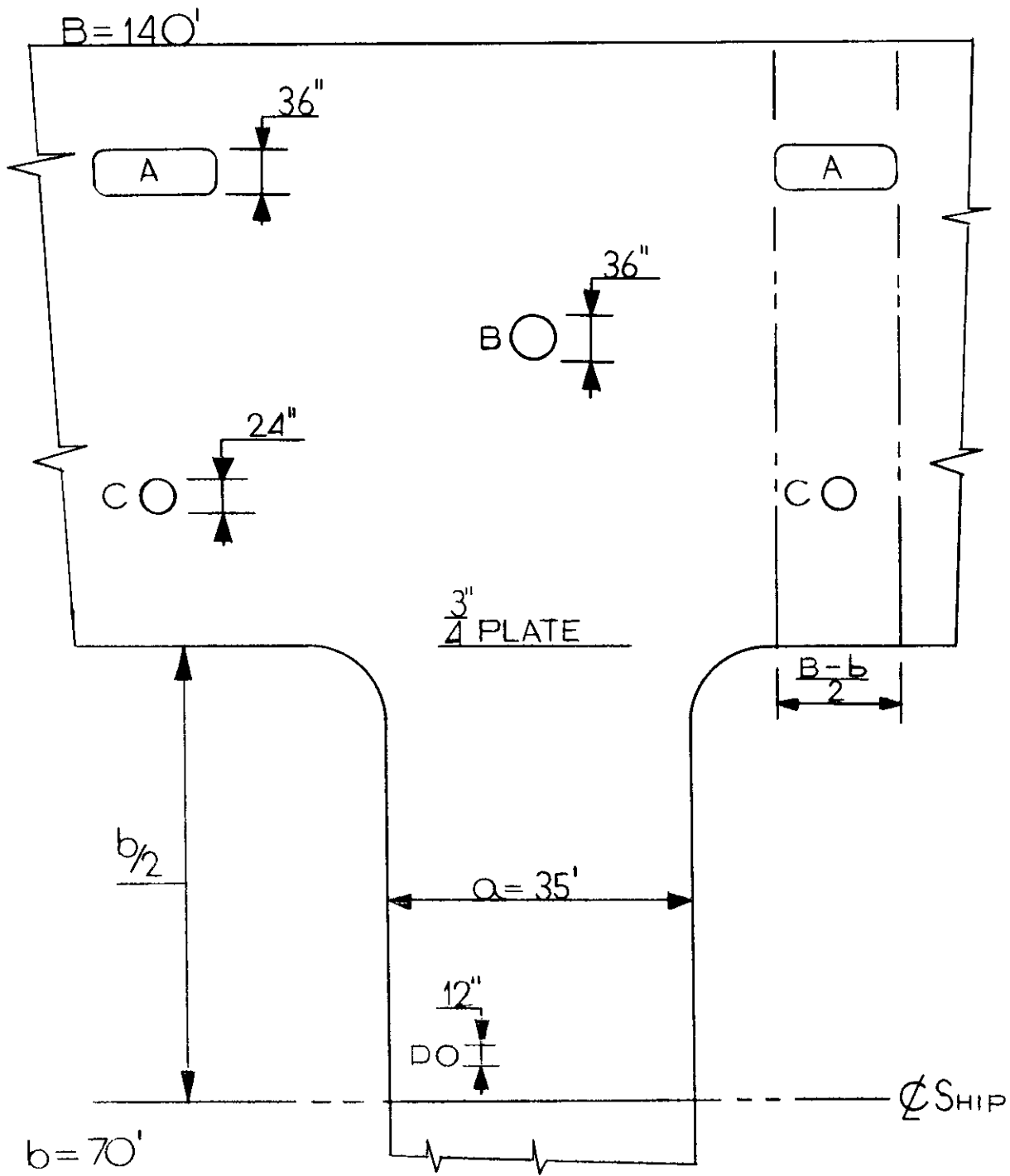HYPOTHETICAL EXAMPLE-OPENINGS IN THE STRENGTH DECK OF A
TANKER

B-5

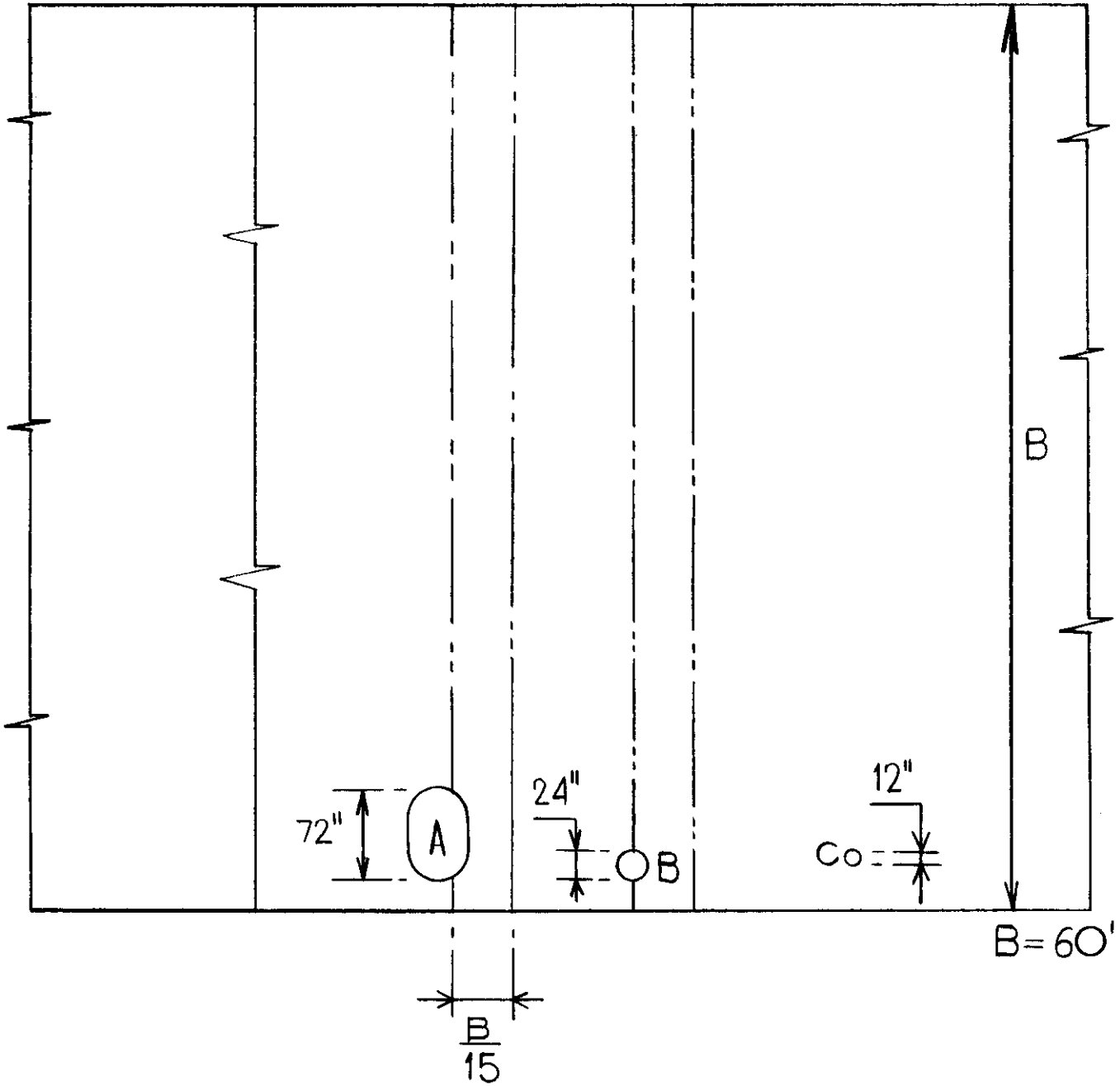FIG. B-3: HYPOTHETICAL EXAMPLE - OPENINGS IN THE STRENGTH DECK OF A DRY CARGO SHIP

FIGURE B-4
HYPOTHETICAL EXAMPLE - OPENINGS IN A MAIN TRANSVERSE BULKHEAD

TABLE B-1

CLASSIFICATION SOCIETY	HOLE DEPTH (a)	HOLE LENGTH (b)	MINIMUM HOLE SPACING (1)
ABS	——	——	——
BV	762 mm	762 mm	——
DNV*			
Type 1	304 mm	762 mm	3040 mm
Type 2	152 mm	1524 mm	1524 mm
Type 3	$^1\!/10$	381 mm	10 a
GL	——	——	——
LR	762 mm	762 mm	——
NKK	——	——	——

* Type 1: Long openings or groups of openings, all in the same section (see Figure 4-5).

  Type 2: Long openings or groups of openings shifted in relation to each other (see Figure 4-6).

  Type 3: Short openings with relatively large spacing in same section or shifted. (see Figure 4-7).

B2.0 BRACKETS

B2.1 KNEE BRACKETS

Table B-2 provides a comparison of Rule guidelines for the design of Knee
Brackets. Figure B-5 shows a hypothetical transverse web frame intersection
that requires bracketing to reduce the span of the bottom member. Scantlings
and spans are recorded on Figure B-5, and the design calculations will
assume an equal-leg bracket. The brackets will be sized with the intent of
reducing the span by 10'-0".

B2.2 BEAM BRACKETS

Table B-3 provides a comparison of Rule guidelines for the design of Beam
Brackets. Figure B-6 shows an intersection between a vertical bulkhead
stiffener and longitudinal deck beam. Scantlings are noted on the figure, and
the design will assume an equal-leg bracket. The purpose of these brackets
is to insure rigidity at the member ends.

B2.3 TRIPPING BRACKETS

a. ABS:

Figure B-7 will be used to locate tripping brackets on the four designated
spans:

    Span 1 - 30 feet; Transverse deck girder: add two pairs equally
             spaced tripping brackets (both sides).

    Span 2 - 26 feet; Transverse deck girder: add two pairs equally
             spaced tripping brackets (both sides).

    Span 3 - 26 feet; Side transverses: add two pairs equally spaced
             tripping brackets (both sides)

    Span 4 - 30 feet; Side transverse: add two equally spaced tripping
             brackets, both sides.

b. BV: (ID)

c. DNV:

    Span 1 - add two pairs of equally spaced tripping brackets (both sides)
             with a flange area equal to 1.4 in.^{2}

    Span 2 - add one pair tripping brackets both sides equal distance from
             each end, with a flange area of 1.4 in.^{2}

    Span 3 - Add one pair of tripping brackets (both sides) that is equal
             distance from both ends, with a flange area of 1.4 in.^{2}.

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TABLE B-2

Classification Society	Bracket Leg Length (a)	Bracket Thickness (t)	Bracket Flange Area	Reduced Span
ABS				
Type 1 (Fig. 4-8)	66"	0.75"	$\geqq 9.0$ in.^{2}	L -10'
Type 2 (Fig. 4-9)	depends on flange area	0.75"	< 9.0 in.^{2}	L -10'
Type 3 (Fig. 4-10)	60"	0.75"	18.0 in.^{2}	L -10'
BV	——	—	—	——
DNV	——	0.75"	—	——
GL	120"	0.50"	——	L -10'
LR	—	—	—	——
NKK	——	——	—	——

TABLE B-3

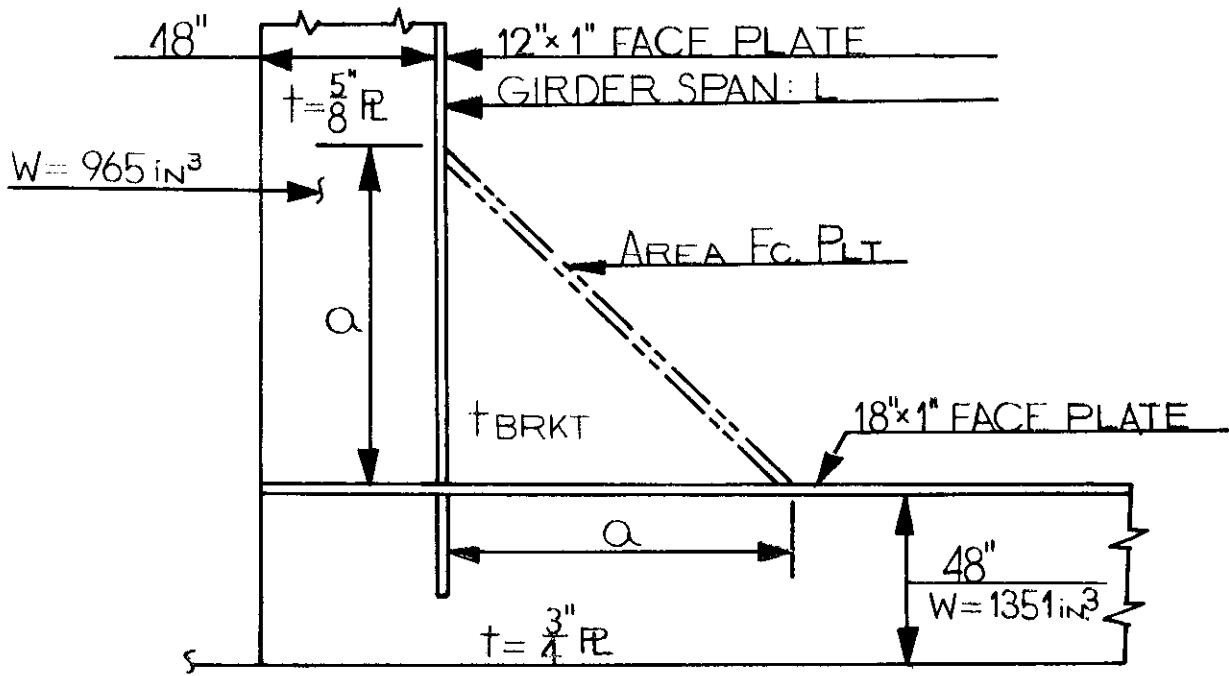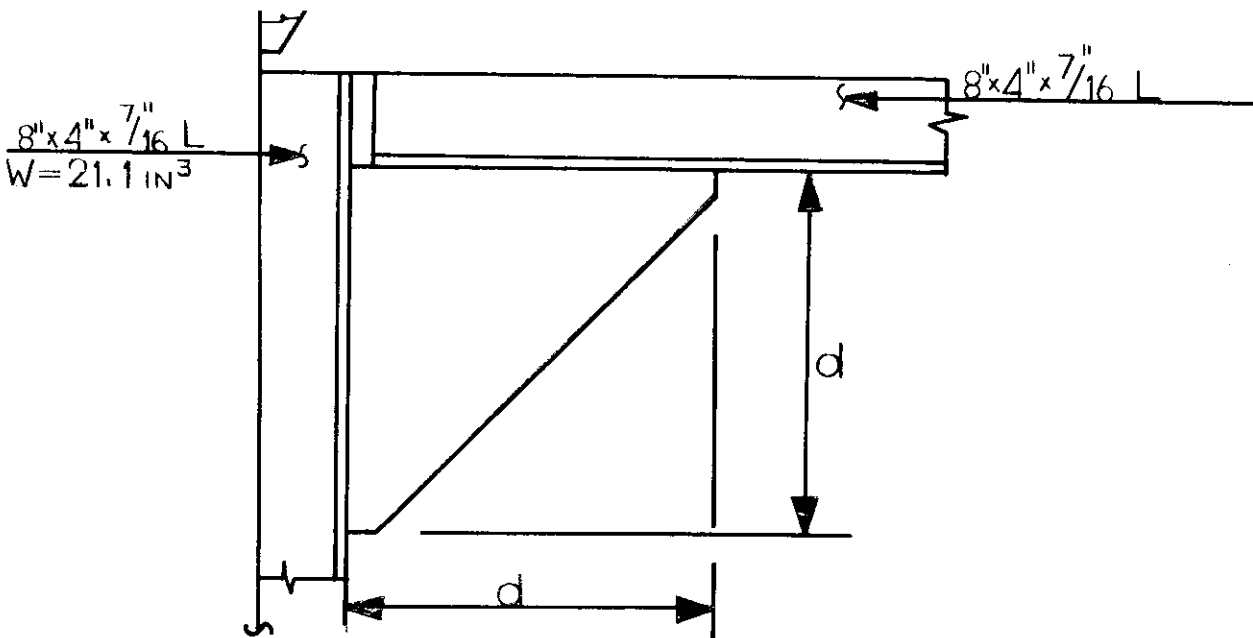| Classification Society	Bracket Arm Length	Bracket Thickness	Bracket Flange Width
ABS	18 in.	0.32 in.	2.0 in.
BV	12 in.	0.35 in.	2.2 in.
DNV	12 in.	0.35 in.	2.2 in.
GL	12 in.	0.31 in.	2.0 in.
LR	——	0.32 in.	1.6 in.
NKK	——	——	——

Fig. B-5: Hypothetical Example - Knee Bracket Detail

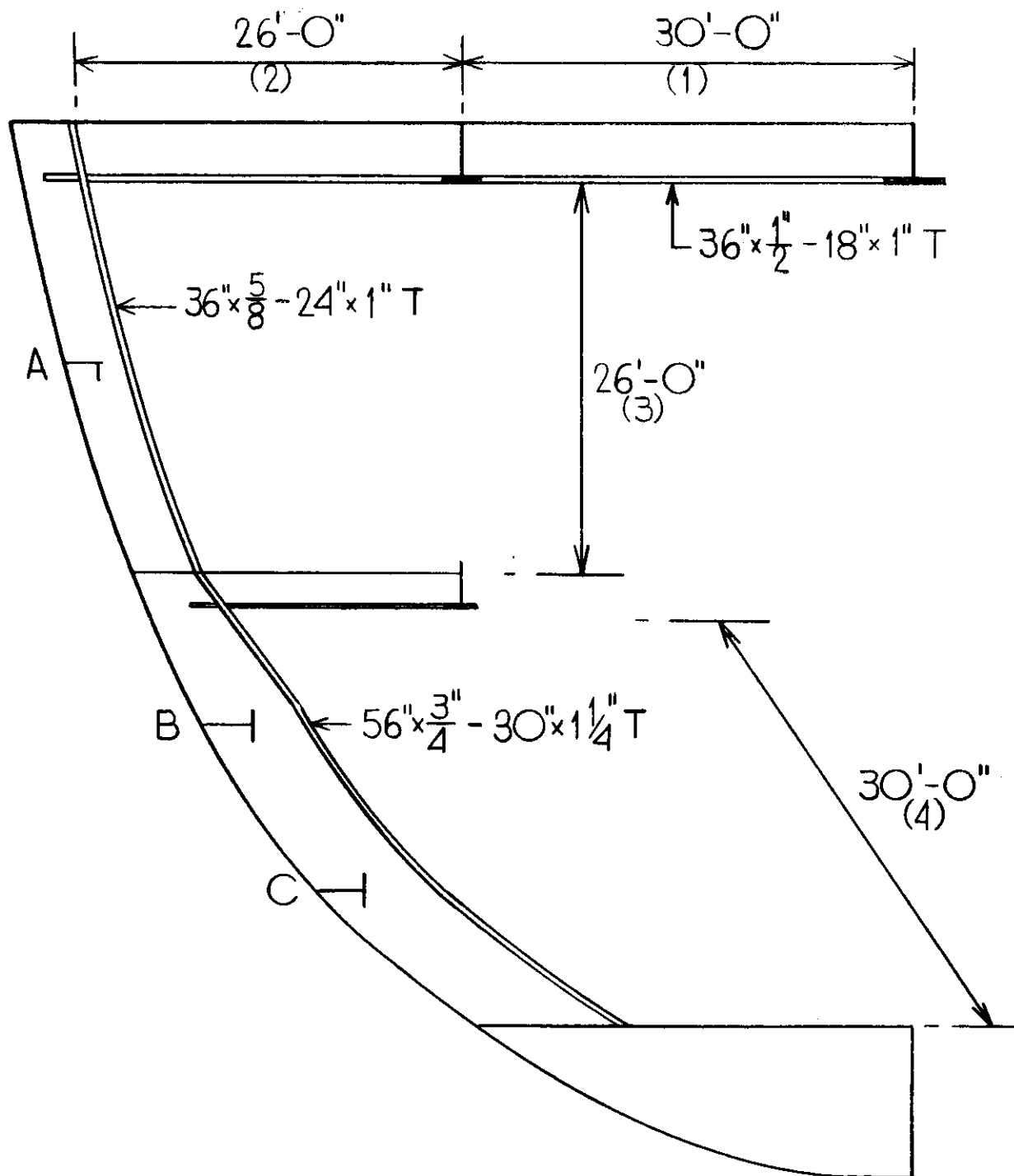Fig. B-6: Hypothetical Example - Beam Bracket Detail

FIG. B-7: TRANSVERSE SECTION USED FOR THE COMPARISON OF TRIPPING BRACKET DESIGN GUIDELINES

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Span 4 - add two equally spaced pairs of tripping brackets (both sides)
Flange area = 2.2 in.[2].

d. <u>GL</u>:

Span 1 - add three equally spaced pairs of tripping brackets (both sides).

Span 2 - add two equally spaced pairs of tripping brackets (both sides).

Span 3 - add two equally spaced pairs of tripping brackets (both sides).

Span 4 - add three equally spaced pairs of tripping brackets (both sides).

e. <u>LR</u>: (ID)

f. <u>NKK</u>: same locations as ABS.

B3.0 <u>PANEL AND WEB STIFFENERS</u>

Calculations for comparison of web and panel stiffener Rule guidelines have been made for (a) a plate floor with a depth of 10 feet and a stiffener spacing of 30 inches and (b) for a transverse deep girder with a depth of 8 feet and a stiffener spacing of 30 inches.

a. <u>ABS</u>:

Plate floor stiffeners: (ID)

Web stiffeners: (ID)

b. <u>BV</u>:

Plate floor stiffeners:

depth $=(\ell/10)$ (floor depth) = 12"

thickness = $0.9\sqrt{L}$ mm = 0.574"   use: 12" x 5/8" Flat bar

Web stiffeners:

Toes of web stiffeners welded to longitudinals (longitudinal framing).

Section modulus= $W = 5.66C_1EL = 327$ cm^3 = 20 in.^{3} use: 8"x4"x7/16" L

c. <u>DNV</u>:

Plate floor stiffeners:

Floors are to be stiffened at every longitudinal with a 6" flat bar.

Web plate stiffeners:

$Iv = aS_1(t + 0.2)^3 = 153$ in.^{4} use: 8"x4"x7/16" L

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d. GL:

Plate floor stiffeners: (see DNV for details)

Web Stiffeners:

Section Modulus: $= W = 5.5\, ahL^2\ cm^3 = 19.6\ in.^3$ use: 8"x4"x7/16" L

e. LR:

Plate floor stiffeners:

Vertical stiffeners are to be fitted on each longitudinal, having a depth of 6" and a thickness equal to floor thickness.

Web stiffeners:

Section Modulus: $= SM = D^2 hs/600000 = 21.0\ in.^3$ use: 8"x4"x 7/16" L

f. NKK:

Plate floor stiffeners:

Use a flat bar 10" deep and the same thickness as the floor.

Web stiffeners:

Use a flat bar 8" deep and a thickness equal to the girder web.

B4.0 STANCHION SUPPORTS

Figure B-8 details a 4-inch pipe stanchion with a tensile load of 25 kips. The following is a comparison of the classification design guidelines for determining the type of stanchion end connection detail required to resist the load.

a. ABS: (ID)

b. BV: (ID)

c. DNV:

An end connection must be provided with a minimum end connection area of 13 cm^2 (tabulated value). This can be accomplished by providing brackets at the head and heel.

d. GL:

An end connection must be provided with a minimum end connection area of 12.5 cm^2. This will be accomplished by providing brackets at the head and heel

e. LR:

An end connection must be provided with a minimum end connection area of 11.4 cm^2. This will be accomplished by providing brackets at the head and hee
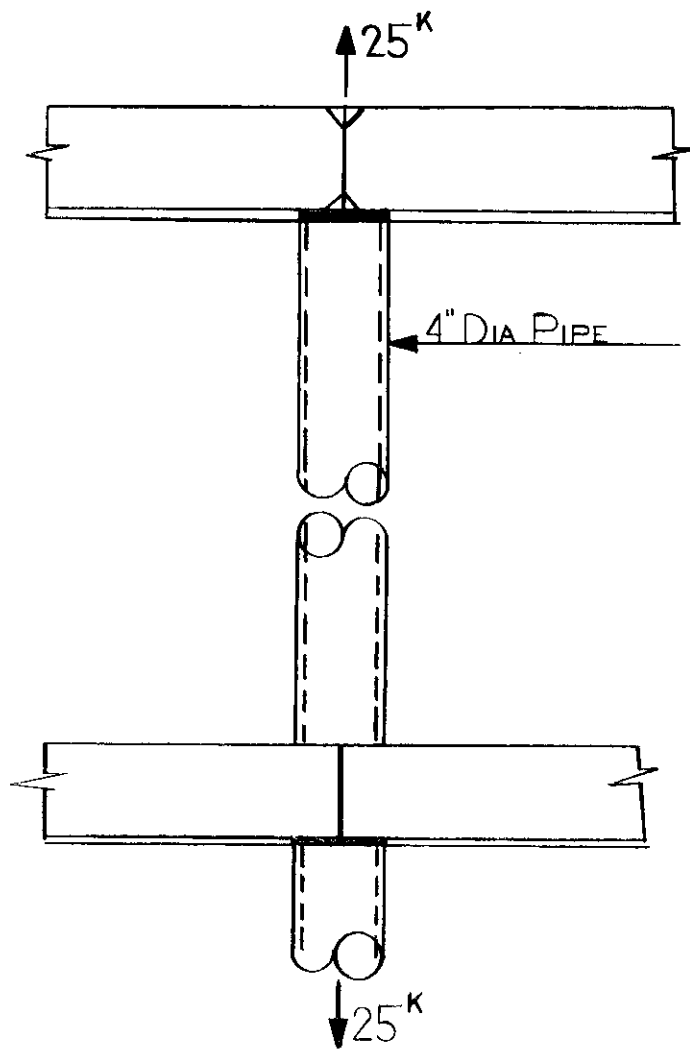
FIG. B-8: TENSILE CONNECTION PILLAR DESIGN

25^K

4" DIA PIPE

25^K

f.   NKK: (ID)

B5.0 FACE PLATES

Table B-4 presents a comparison of the classification society guidelines for establishing the face plate area amidships for center and side keelsons.

TABLE B-4

| | FACE PLATE AREA | |
CLASSIFICATION SOCIETY	CENTER KEELSON	SIDE KEELSON
ABS	106.0 in.^{2}	27.0 in.^{2}
BV	——	——
DNV	——	——
GL	80.0 in.^{2}	19.0 in.^{2}
LR	——	——
NKK	——	——

B6.0 CUTOUTS: LIGHTENING HOLES, SCALLOPS, SNIPES

Figure B-9 depicts a hypothetical nontight longitudinal or transverse girder with lightening holes, welding scallops, and snipes. The critical dimensions for cutout size and location in Figure B-9 are represented by the symbols a, b, c, d, e, and f. The dimension L represents the girder depth, a known quantity. The following is a comparison of classification society guidelines to be used in determining the critical dimensions.

a.   ABS: (ID)

b.   BV:

Dimensions: $a = d = L/4$, $c = L/2$

c.   DNV:

Dimensions: $a = d = L/4$, $f = 10c = 5L$, $b \leq 10$ in., $c = L/2$

d.   GL:

For side girders: $a = d = 0.2L$, $c = 0.5L$
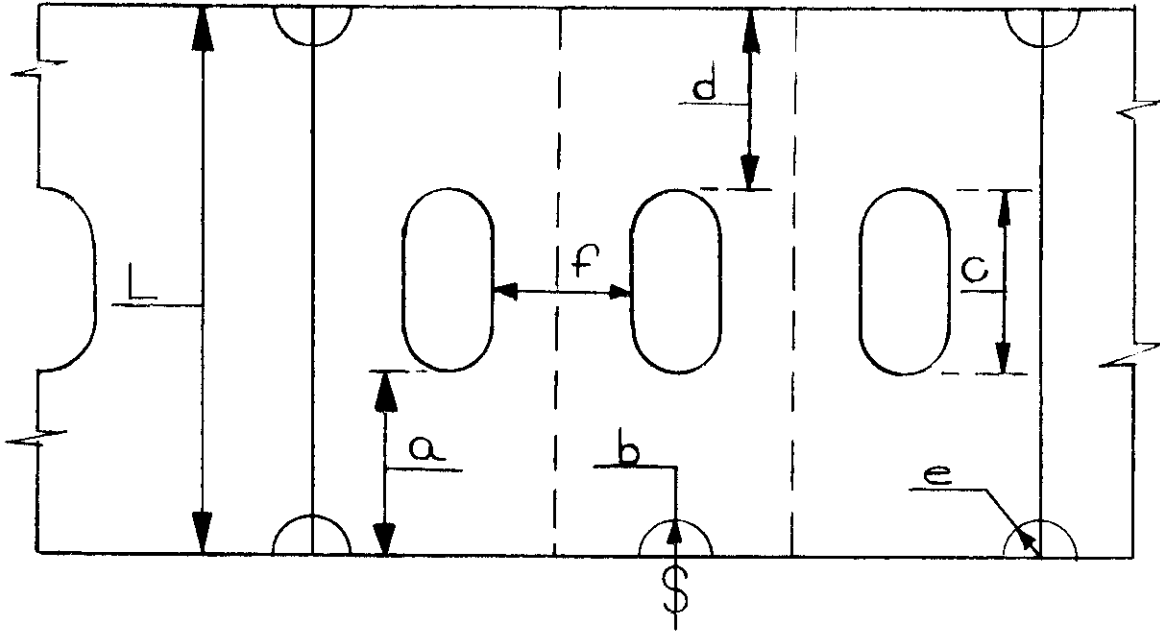
FIG. B-9: MISCELLANEOUS CUTOUTS IN A NON-TIGHT
LONGITUDINAL GIRDER

e. LR:

Dimensions: c = 0.5 L

f. NKK:

Dimension: $c = {}^L/3$

B7.0 SHEAR STRAKE CONNECTIONS

a. ABS: (ID)

b. BV: (ID)

c. DNV: (ID)

d. GL:

The radius of a rounded shearstrake connection is equal to 15 times the plating thickness.

e. LR:

Same as GL

f. NKK: (ID)

B8.0 HATCH COAMINGS

Hatch coamings support the hatch cover and provide some stiffening of the deck. The minimum thickness allowed for a hatch coaming by the classification societies follows:

a. ABS:

Coaming plate minimum thickness required: t = 7/16 in.

b. BV:

Same as ABS

c. DNV: (ID)

d. GL:

Same as ABS

e. LR:

Same as ABS

f.   NKK:

Same as ABS.

B9.0 STIFFENER ENDINGS

The following section presents Rule calculations that determine the required section moduli based on the end connection. These calculations where performed assuming a watertight bulkhead with a stiffener spacing of 30", stiffener length = 10' and a head of 50'. Various end conditions have been investigated and the results are recorded below.

a.   ABS:

   L = 10'-0"
   H = 50'-0"
   s = 30"

Required section modulii:

   Case a: efficient brackets at both ends. $Sm = 0.0041(0.3)(50)(2.5)(10)^2$
            $= 15.4$ in.^{3}

   Case b: bracket at one end, clip connection at the other end.
            $Sm = 0.0041(0.43)(50)(2.5)(10)^2 = 22.0$ in.^{3}

   Case c: clip connections at each end: $Sm = 0.0041(0.56)(50)(2.5)(10)^2$
            $= 28.7$ in.^{3}

   Case d: no end connections: $Sm = 0.0041(0.6)(50)(2.5)(10)^2 = 30.75$ in.^{3}

b.   BV: (ID)

c.   DNV: (ID)

d.   CL:

Required Section Modulii: $Sm = kC_s \, ahl^3 \, cm^3$

   Case a: Restrained: $Cs = 2.60$ $Sm = 1(2.6)(.76)(15.2)(3.05)^2 = 17.1$ in.^{3}

   Case c: Simply supported: $Cs = 3.50$ $Sm = 1(3.5)(0.76)(15.2)(3.05)^2$
            $= 23.0$ in.^{3}

e.   LR: (ID)

f. NKK:

Required Section Modulii: $Sm = ChsL^2 \ cm^3$

Case a: efficient bracket at both ends. $Sm = 2.8(15.2)(0.76)(3.05)^2$
= 18.43 in.^{3}

Case b: bracket at one end and clip at the other end.
$Sm = 4.4(15.2)(0.76)(3.05)^2 = 29.0$ in.^{3}

Case c: no end connections: $Sm = 5.5(15.2)(0.76)(3.05)^2 = 36.25$ in.^{3}

Appendix C

GLOSSARY

ABM: (AUTOMATIC BURNING MACHINE): - a multi-headed burning machine, controlled by a punched tape.

ACCESS HOLES: - holes cut in the ship's structure to permit entering or leaving various compartments.

AIR HOLES: - cuts provided in the upper part of floor plates and longitudinals in double bottom structure so that when the water in the tank rises above the lightening holes, the air contained in the tank may still have ample means to escape.

AVA: (AUTOMATIC VERTICAL ARC) WELDING MACHINE: - an automatic welding machine which is used to weld vertical erection butts with a consummable copper shoe.

BEAM, DECK: - a transverse or longitudinal structural member, usually a shallow rolled shape, supporting a deck or flat.

BEAM KNEE: - connections used in tying beams or girders to frames, making the ship more rigid at deck corners, and reinforcing the frames.

BILGE STRAKE: - course of shell plates at the turn of the bilge.

BRACKET, BEAM: - plate, flanged or unflanged, used to rigidly connect deck beams, bulkhead stiffeners and secondary members to frames. By ABS Rules beam brackets must extend onto the stiffener for a distance equal to one-eighth of the length of the stiffener.

BRACKET, KNEE: - flanged plates used to rigidly connect deep transverse and longitudinal girders to side frames. Use of knee brackets on deep transverses allows for a reduction in span of the girder.

CASDOS: (COMPUTER-AIDED STRUCTURAL DETAILING SYSTEM): - A computer program developed for the U. S. Navy that produces instructions which are used for constructing the ship, material ordering and weight control, plate fabrication, stiffener fabrication and assembly.

CHOCK: - a small piece of plate used primarily to backup load carrying members. The chock can be a filler plate in a load path and can also be used to provide flange stability.

CLIP: - a short length of angle or plate to attach webs of beams and stiffeners to plating or to other beams and stiffeners.

COAMING: - the vertical plating bounding a hatch, hatchway, or other opening for the purpose of stiffening the edge of the opening.

COFFERDAM: - the narrow void space between two tight bulkheads.

COLLAR (TIGHT OR NONTIGHT): - welded plate used to close a frame or beam penetration through plating and webs of structural members. Collars are used to insure tightness, replace cutout material, and/or provide flange stability.

DEEP TANKS: - tanks extending from the bottom or inner bottom up to or higher than the lowest deck.

DOUBLE BOTTOM: - compartments at the bottom of the ship between the inner bottom and the shell plating, used for ballast or fresh water, fuel oil, etc.

DOUBLER PLATE: - a plate fitted outside or inside of and faying against another to give additional local strength or stiffness.

FRAME: - the closely spaced transverse stiffening members of the shell plating.

GIRDER: - a continuous member, usually running fore and aft under a deck for the purpose of supporting deck beams and plating. Also the vertical fore and aft plate members on the bottom of single or double bottom ships.

HATCH: - openings in the deck for the passage of cargo, etc.

HATCHWAY: - opening in a deck through which passes a stairway or an inclined ladder.

HEADER: - member added for local strength which is not parallel to main strength members of the vessel. Headers are used to provide stiffening to large panels, replace area removed by structural cuts, and to transfer load to main members.

INNERBOTTOM: - plating forming the upper surface of the double bottom, also called the tank top.

INTERCOSTAL: - noncontinuous structural member between frames, floors or beams.

LIGHTENING HOLES: - holes cut in structural members for reducing weight.

LIMBER HOLE: - small hole or slot in a frame or plate for the purpose of preventing water or oil from collecting; a drain hole.

LINER: - a flat or tapered strip of steel placed under a plate or shape to bring the member in line with another which it overlaps; a filler.

LONGITUDINALS: - fore and aft structural shape or plate members attached to the underside of decks and flats, to the inner bottom or to shell plating.

MANHOLES: - holes, round or oval, cut in decks, tanks, etc. for the purpose of providing access.

OILSTOP: - rathole modified by wrapping the weld around the plate edge. Located in continuous members on both sides of a tight boundary to prevent liquid from passing out of a tank by way of the root gap in the member.

PILLAR: - vertical member or column giving support to deck girders, flat or similar structure.

RATHOLE: - clearance cuts in continuous members for butt welds in adjacent shell and deck plating.

REEVING SLOT: - clearance cut for continuous member passing through a bulkhead or deep girder where the penetrated member is welded to the continuous members, thus eliminating collar plates.

SCALLOPS: - clearance cuts for members or welds passing through bulkheads, decks, etc. (foreign usage).

SEA CHEST: - compartment through which sea water is admitted or discharged.

SHEER STRAKE: - the top full course of side shell plating.

SIDE SCUTTLES: - openings in the side shell for the overboard discharge of water.

SNIPES: - small cuts made in the web of intercostal members at the junction of intercostal and continuous members and plating to clear the weld of the continuous member.

C-3

STANCHION: -   see pillars.

STIFFENERS: -   sections or shapes used for increasing the rigidity of plating, such as bulkhead plating.

STRINGERS: -   fore and aft girders running along the side of the ship at the shell.

TRIPPING BRACKETS: -   flat bars, chocks or brackets placed along the compression flange of girders, stiffeners or beams as reinforcement to prevent their free flanges from tripping.

DOCUMENT CONTROL DATA - R & D

Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)	2a. REPORT SECURITY CLASSIFICATION
General Dynamics Corporation Quincy Shipbuilding Division Quincy, MA 02169	Unclassified
	2b. GROUP

3. REPORT TITLE

REVIEW OF SHIP STRUCTURAL DETAILS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final Technical Report

5. AUTHOR(S) (First name, middle initial, last name)

R. Glasfeld
D. Jordan
M. Kerr, Jr.,
D. Zoller

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
	305	20

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
N00024-74-C-5230	
b. PROJECT NO.	SF 422306 Task 02022
c. SR-216	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT

Distribution of this document is unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Naval Sea Systems Command

13. ABSTRACT

The review of structural detail design is intended to serve as a summary of the state of the art and a guide to development of tools for design and analysis of these details.

The report includes a count of common structural details aboard two modern commercial vessels, and labor estimates for representative sizes of those details intended to provide a total cost per type of detail ranking for those ships.

Current shipyard practice is reported with sketches and application description of about 160 ship structural details. Design improvements related to shipyard producibility are suggested.

The most relevant rules promulgated by technical and classification societies are excerpted, and comparison of rules is illustrated by application to specific examples.

Damage induced by poor design or fabrication of details is reviewed and illustrated.

The relatively sparse technical literature related to analysis and design of structural details is reviewed and summarized.

A framework for fatigue criteria is developed as a suggestion for possible detail strength criteria, and recommendations for future work in the area of detail design are presented.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in²	square inches	6.5	square centimeters	cm²
ft²	square feet	0.09	square meters	m²
yd²	square yards	0.8	square meters	m²
mi²	square miles	2.6	square kilometers	km²
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft³	cubic feet	0.03	cubic meters	m³
yd³	cubic yards	0.76	cubic meters	m³
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm²	square centimeters	0.16	square inches	in²
m²	square meters	1.2	square yards	yd²
km²	square kilometers	0.4	square miles	mi²
ha	hectares (10,000 m²)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m³	cubic meters	35	cubic feet	ft³
m³	cubic meters	1.3	cubic yards	yd³
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

°F
-40   0   32   80   98.6   120   160   200   212
-40   -20   0   20   37   40   60   80   100
°C

*1 in = 2.54 cm (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures Price $2.25 SD Catalog No. C13.10:286.

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