SERIAL NO. **SSC-37**

Considerations

of

WELDED HATCH CORNER DESIGN

by

SHIP STRUCTURE COMMITTEE

Convened by

The Secretary of the Treasury

Member Agencies—Ship Structure Committee

Bureau of Ships, Dept. of Navy
Military Sea Transportation Service, Dept. of Navy
United States Coast Guard, Treasury Dept.
Maritime Administration, Dept. of Commerce
American Bureau of Shipping

Address Correspondence To:

Secretary
Ship Structure Committee
U. S. Coast Guard Headquarters
Washington 25, D. C.

October 1, 1952

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(Project SR-117)

This report has been prepared and published by the Ship Structure Committee in accordance with the duties and responsibilities vested in the Committee by the Secretary of the Treasury, United States of America.

SHIP STRUCTURE COMMITTEE
WASHINGTON 25, D. C.
October 1, 1952

FOREWORD

1. The large number of welded ship failures early in World War II focused attention upon the destructive potential of structural notches. Complete elimination of notches from a ship is impossible. However, elimination of the destructive effects originating at structural notches is generally possible through design. This has been demonstrated by successive stages of development of satisfactory all welded hatch corners.

2. The original hatch corner of the Liberty Vessel proved to be one of the worst crack initiators. As a result this hatch corner was modified and those of later Liberties were redesigned.

In the Victory class of vessels, and other vessels subsequently constructed, additional design improvements were incorporated into the hatch corner.

3. Because of the importance of the problem, complete service and fracture records have been analyzed and full scale laboratory tests of hatch corners, duplicating as closely as possible construction and service conditions, were performed. Results of these tests have been analyzed for correlation with actual service performance.

4. In view of the significant volume of accumulated service data and associated laboratory test data available, the Ship Structure Committee has undertaken to evaluate and interpret these data in terms of design features intended to produce crack-resistant hatch corners in welded steel vessels. The results of such undertaking are contained in this report.

We urge that this material be used in the development of new hatch corner designs.

K. K. Cowart

K. K. COWART, Rear Admiral, U.S.C.G.
Engineer-in-Chief, United States Coast Guard
Chairman, Ship Structure Committee

W. H. Von Dreele

W. H. VON DREELE, Captain, U.S.N.
Director, Maintenance and Repair
Military Sea Transportation Service
Member, Ship Structure Committee

E. W. Sylvester

E. W. SYLVESTER, Rear Admiral, U.S.N.
Assistant Chief for Ships, Bureau of Ships
Department of the Navy
Member, Ship Structure Committee

D. P. Brown

D. P. BROWN, Senior Vice Pres. and Tech. Mgr.
American Bureau of Shipping
Member, Ship Structure Committee

R. L. Hicks

R. L. HICKS, Rear Admiral, U.S.N. (Retired)
Chief, Office of Ship Construction
Maritime Administration
Member, Ship Structure Committee

TABLE OF CONTENTS

CONSIDERATIONS OF WELDED HATCH CORNER DESIGN

The purpose of this report is to assemble and summarize such portions of the available information relating to hatch corner failures and tests as are significant in the actual design of a welded hatch corner for a typical cargo vessel. Attention will be paid principally to the matter of the geometry and size of the structure. For this reason such factors as temperature, notch sensitivity of the material, and strain rate, which are known to be contributory causes of failures are not discussed. The hatch corners particularly referred to in the report are those on the weather deck of a cargo vessel and located in the mid-ship 3/5 length. The design principles given here apply also to corners located elsewhere but to a lesser degree. It is not to be considered that this report presents the final word with reference to hatch corner design. It represents merely the best advice that can be given at the present time, based on the available Ship Structure Committee data on this subject.

I. GENERAL CONSIDERATIONS

A. Homogeneous Structure Concept

The ultimate objective of structural design is to obtain, if possible, a homogeneous structure. That is, at all loads up to failure, component parts of the structure behave in a parallel manner with regard to stress and elongation. It is only in this way that an approach to the full strength characteristics of the material can be realized. These general statements are particularly true with respect to hatch corners. Let us suppose that a hatch corner exhibits high ultimate nominal stress but low energy absorption. This means that its total elongation to rupture is low. The resisting stresses in other parts of the structure are a function of the load-elongation properties of the material. Since all components must elongate together, the hatch corner in question possesses the characteristic of accumulating higher stress in proportion to its elongation than do adjacent components, and therefore will be subject to early destruction because it will attract more than its fair share of the load to be resisted.[1*] Conversely, a hatch corner that exhibits low ultimate nominal stress but high energy absorbing ability, through high elongation properties, would shirk its share of the applied loads.

Thus it appears that neither the ultimate failure load of a hatch corner, nor its energy absorbing qualities may be considered singly as a suitable criterion for hatch corner design. Ideally, both these qualities of a hatch corner should be considered in association with similar characteristics for the surrounding structure. From a practical design standpoint this approach to the problem leads to no solution, for several reasons, among them the fact that no simple analytical means is available for determining the load-strain relationship for a particular hatch corner design. Hatch corner design must, therefore, be a process involving the intelligent use of good basic practice coupled with constant reference to successful previous designs.

B. Geometrical Arrangement

There is a large number of possible geometrical arrangements for the design of a hatch corner. In the choice of the geometry to be used, attention must be given to two factors: (a) Structural Adequacy, and (b) Method of Fabrication. In structural design, neither of these factors can be ignored, and a suitable compromise must be adopted. From past experience with welded hatch corners, it is clearly evident that in the conflict between these two factors the structural adequacy of the corner must be considered first. The original corner used in Liberty vessels, Figure 1, was an example of over-emphasis on ease of fabrication, while the Kennedy type corner, Figure 2, probably exemplifies the opposite approach.

In the choice of the geometry to be used, primary consideration should be given to the location and severity of the unavoidable notches. A notch may be defined as any discontinuity. Notches vary in size from small imperfections in the weld up to the hatch corner which is itself a large notch. The serious effect of notches is two-fold, involving first the stress magnification which always exists; and second the fact that the material is under consider-

*For references see page 14.

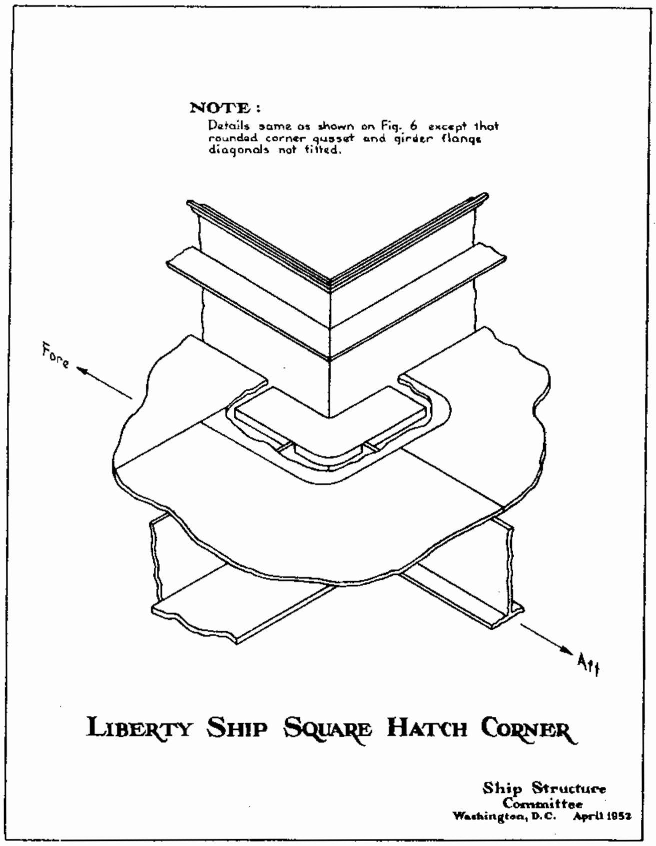


Figure 1

able constraint which prevents normal yielding, and causes the material to react in a brittle manner. In addition, the possibility of compounding notches should be avoided. By compounding is meant the location at the same point of separate notches in two members of the structure or the creation of a notch within a notch such as the formation of a weld cavity in a region of multi-axial stress.

C. Thickness of Plating

It is always desirable in structural design to limit plate thickness to the minimum acceptable value in order to obtain an economical structure. In the case of relatively large structures containing stress concentrations (such as hatch corners), it has been found that a fairly definite relation exists between the thickness of steel plate and its notch sensitivity. The heavier gages of ship plate are usually more notch sensitive than lighter plates of the same class of steel. For these reasons it is important that plate thickness be limited to the minimum acceptable values.

D. Location of Stanchions

By far the largest number of cargo vessels constructed in recent years have been fitted with centerline stanchions. This arrangement is preferred by some operators in the belief that for certain trades the centerline location causes less interference with the loading of cargo into tween decks and holds than the arrangement with corner stanchions. Thus the greater part of service experience data which are available apply to the centerline stanchion arrangement. A lesser number of cargo vessels, however, have been constructed with stanchions located under the hatch corner. There is no factual evidence to indicate any superiority of one arrangement over the other, insofar as the performance of the hatch corner is concerned.

E. Deck Corner Reinforcement

It has been common practice in shipbuilding to reinforce the corners of the deck openings where stress concentrations were known to occur. The recent experience with the Liberty vessels as well as the hatch corner test program has afforded an opportunity to study the effect of such corner reinforcement. It has been found that corner reinforcement improved the nominal stress at failure of the laboratory test specimens and reduced the incidence of fracture in vessels under service conditions.[2]

It is therefore considered desirable to reinforce the deck corner by the use of heavier deck plating or by the addition of doublers. The area of increased thickness should be of relatively large size and carried well around the corners of the opening. There is little factual information to indicate the optimum amount of extra thickness. Since the use of doublers for corner reinforcement increases the amount of welding necessary in the corner area, insert plates are considered preferable.

II. HATCH CORNER DETAIL AND TESTS

The full scale hatch corner tests, as conducted under the direction of the Ship Structure Committee, and the performance of the Liberty and Victory vessels in operation, offer the best means available for making a study of various designs of hatch corners. Figures 1, 2, and 3 show the three most important types of hatch corner design which have been included in the series tested. Taken as a whole the tests show the efficacy of various attempts to alleviate the critical condition

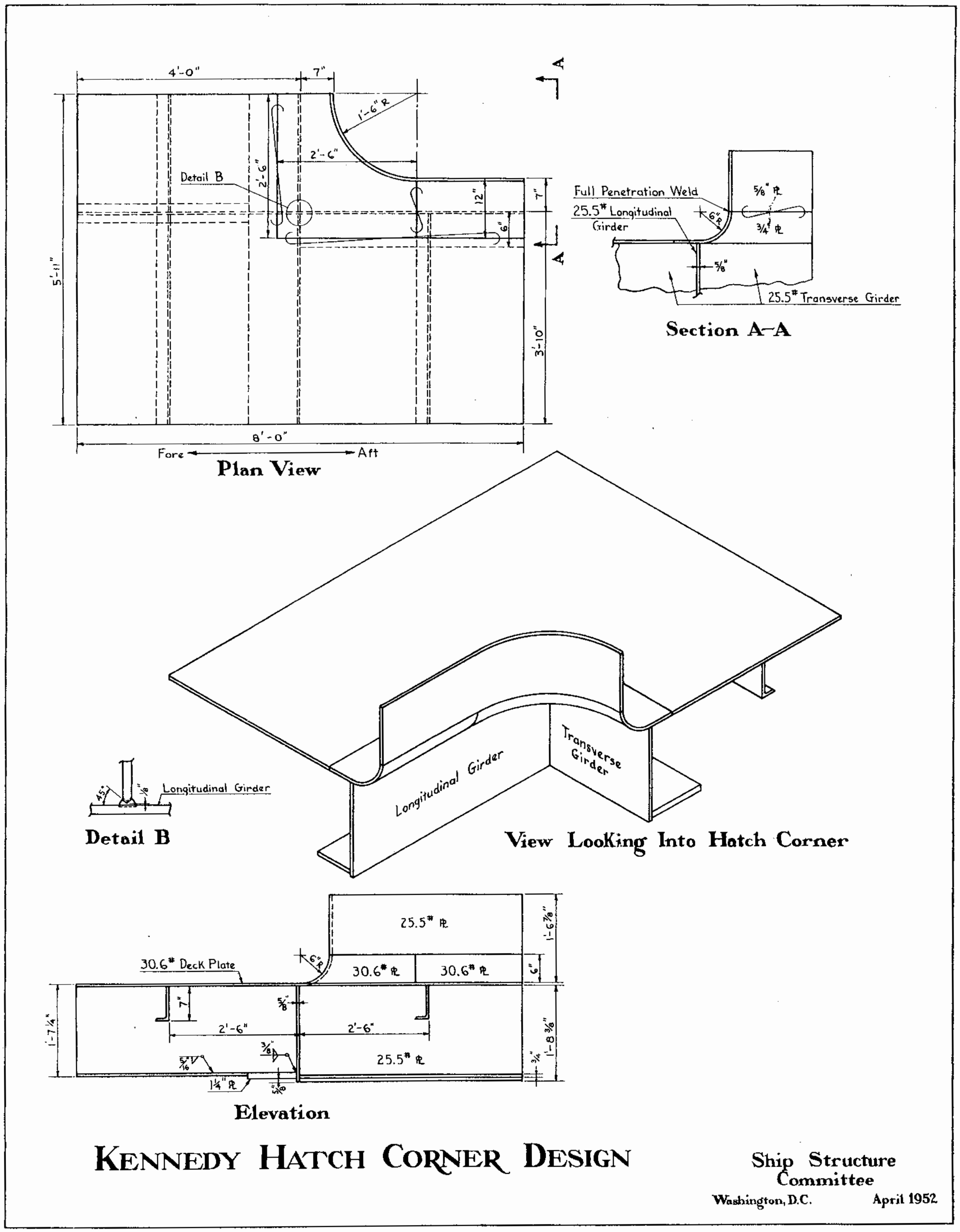

4'-0"
7"
1'-6" R
2'-6"
2'-6"
Detail B
12"
7"
6"
5'-11"
3'-10"
8'-0"
Fore
Aft
Plan View
A
A
Full Penetration Weld
25.5# Longitudinal Girder
6" R
5/8" PL
3/4" PL
5/8"
25.5# Transverse Girder
Section A–A
Longitudinal Girder
Transverse Girder
View Looking Into Hatch Corner
45°
1/8
Longitudinal Girder
Detail B
25.5# PL
30.6# Deck Plate
6" R
30.6# PL
30.6# PL
1'-6 7/8"
6"
7"
5/8"
2'-6"
2'-6"
1'-7 1/4"
3/8"
5/16"
25.5# PL
1'-8 3/8"
3/4"
1 1/4" PL
5/8"
Elevation
KENNEDY HATCH CORNER DESIGN
Ship Structure Committee
Washington, D.C.
April 1952

Figure 2

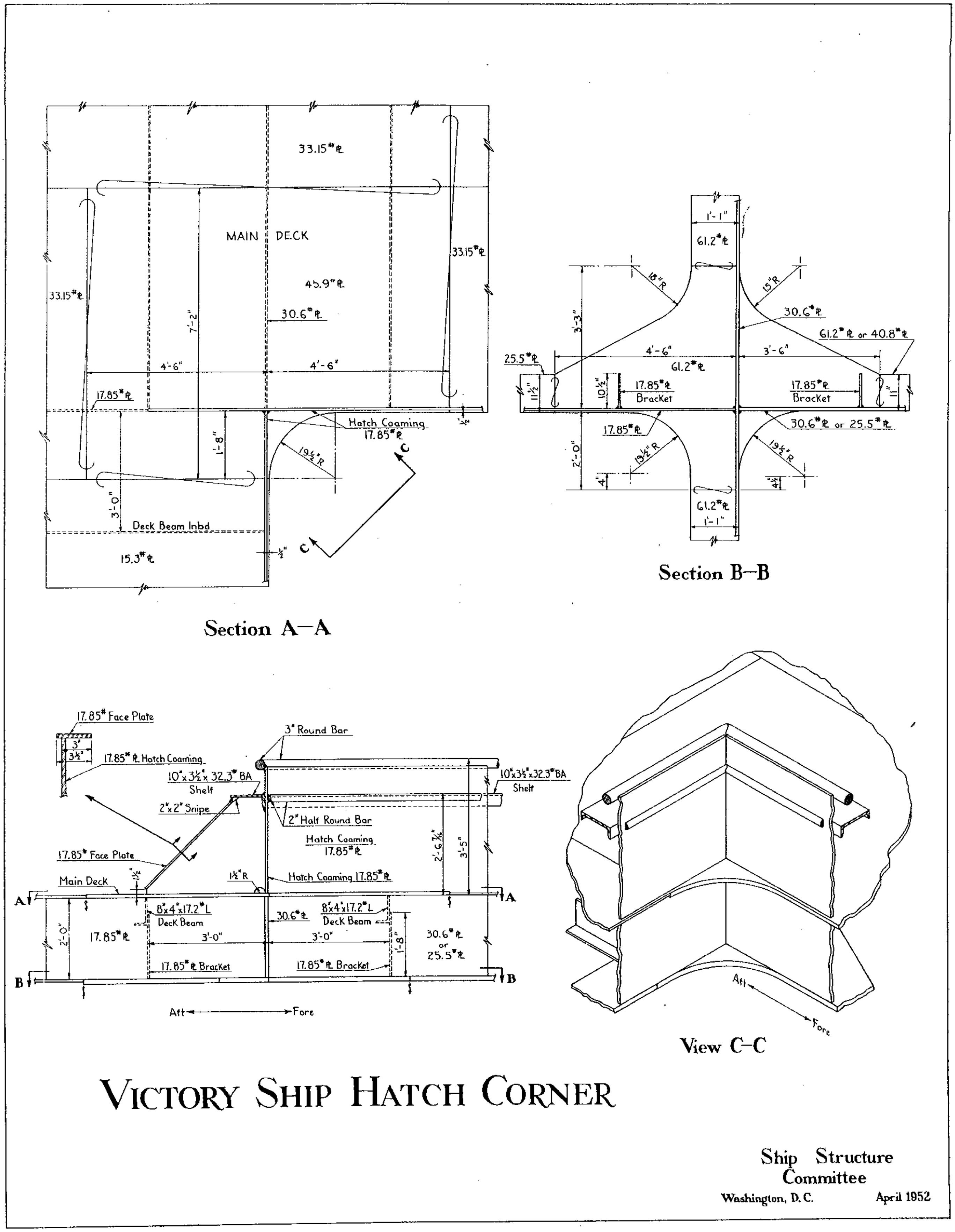

MAIN DECK
33.15# Pl
45.9# Pl
30.6# Pl
7'-2"
4'-6"
17.85# Pl
Hatch Coaming 17.85# Pl
1'-8"
19½"R
3'-0"
Deck Beam Inbd
15.3# Pl
Section A—A
1'-1"
61.2# Pl
18"R
15"R
3'-3"
30.6# Pl
61.2# Pl or 40.8# Pl
25.5# Pl
3'-6"
17.85# Pl Bracket
30.6# Pl or 25.5# Pl
2'-0"
Section B—B
17.85# Face Plate
17.85# Pl Hatch Coaming
3" Round Bar
10"x3½"x 32.3# BA Shelf
2"x2" Snipe
2" Half Round Bar
Hatch Coaming 17.85# Pl
2'-6 7/16"
3'-5"
Main Deck
8"x4"x17.2# L Deck Beam
3'-0"
17.85# Pl Bracket
30.6# Pl or 25.5# Pl
Aft
Fore
View C—C
VICTORY SHIP HATCH CORNER
Ship Structure Committee
Washington, D. C.
April 1952

Figure 3

found to exist in the original Liberty ship hatch corner design.

A. Liberty and Victory Types

The original hatch corner, Figure 1, represented a compounding of severe notches resulting in triaxial stress conditions which restrict natural plastic flow and cause the material to act in a brittle manner. Four severe notches are concentrated around the point of intersection of the deck, longitudinal girder and hatch end beam. These four notches are shown schematically in Figure 4. The details of the design prevented complete penetration of the welds at the corner. The resulting cavities constituted notches within the four notches illustrated in Figure 4. These additional notches are not readily illustrated.

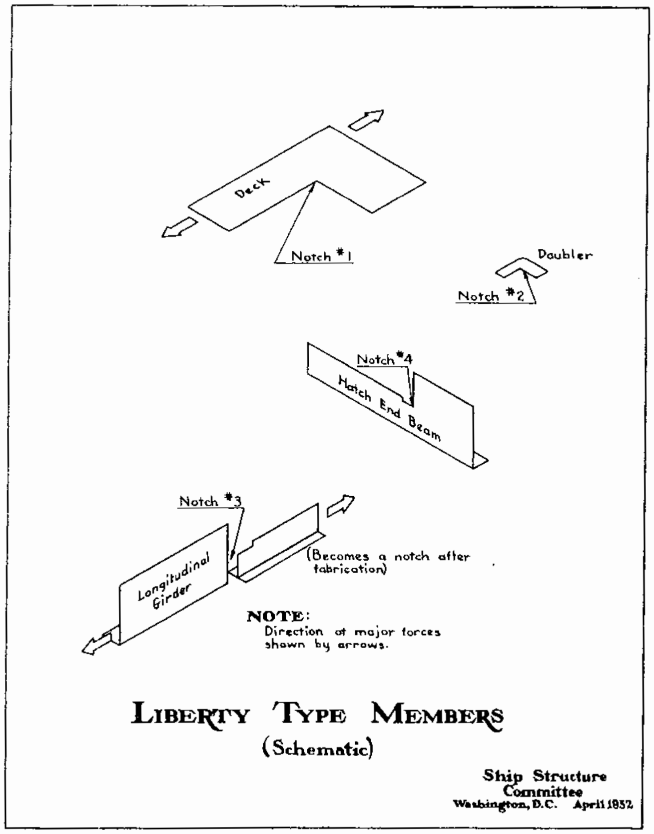


Figure 4

An informative comparison can be made between this original hatch corner and the successful corner, Figure 3, employed in the construction of the Victory vessel. The manner in which the difficulties encountered in the Liberty design were avoided, or minimized, in this design will be apparent from Figure 5 and the following discussion.

The improvements consist in easing the notches in tensile members (deck and longitudinal girder)

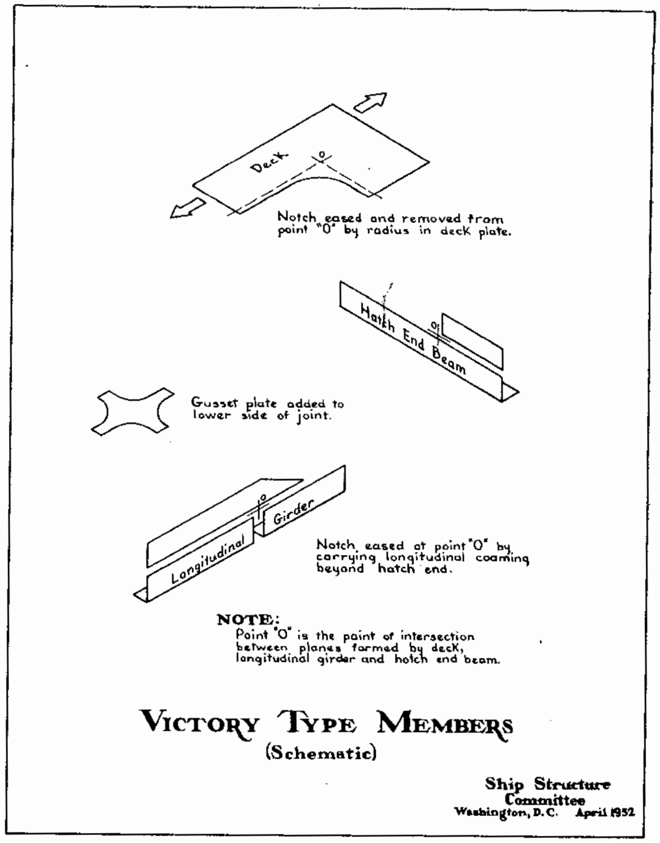


Figure 5

and in moving the remnants of these stress concentrators to new and separate locations. Added continuity of structure and improved local welding conditions were provided by the addition of a radiused gusset plate at the level of the flange of the girders below deck.

Figures 6 and 7 illustrate two of the modifications applied to the original Liberty ship hatch corner design. These modifications have been included in the test series.

Figures 6, 7, and 3 are not considered to represent optimum hatch corner designs but rather successive stages of design improvement which still include some undesirable notches.

B. Kennedy Type

The Kennedy hatch corner shown in Figure 2 represents the design which gave the best performance under laboratory test conditions. This corner showed superiority in ultimate unit stress as well as energy absorption over other types of hatch corner specimens tested. Due to the difficulty of establishing the effective area of metal in tension, the test results are not directly comparable with those of other types.

Since the design requires rolled coamings, with hot-formed corner pieces, it is more difficult to repair or renew than other types.

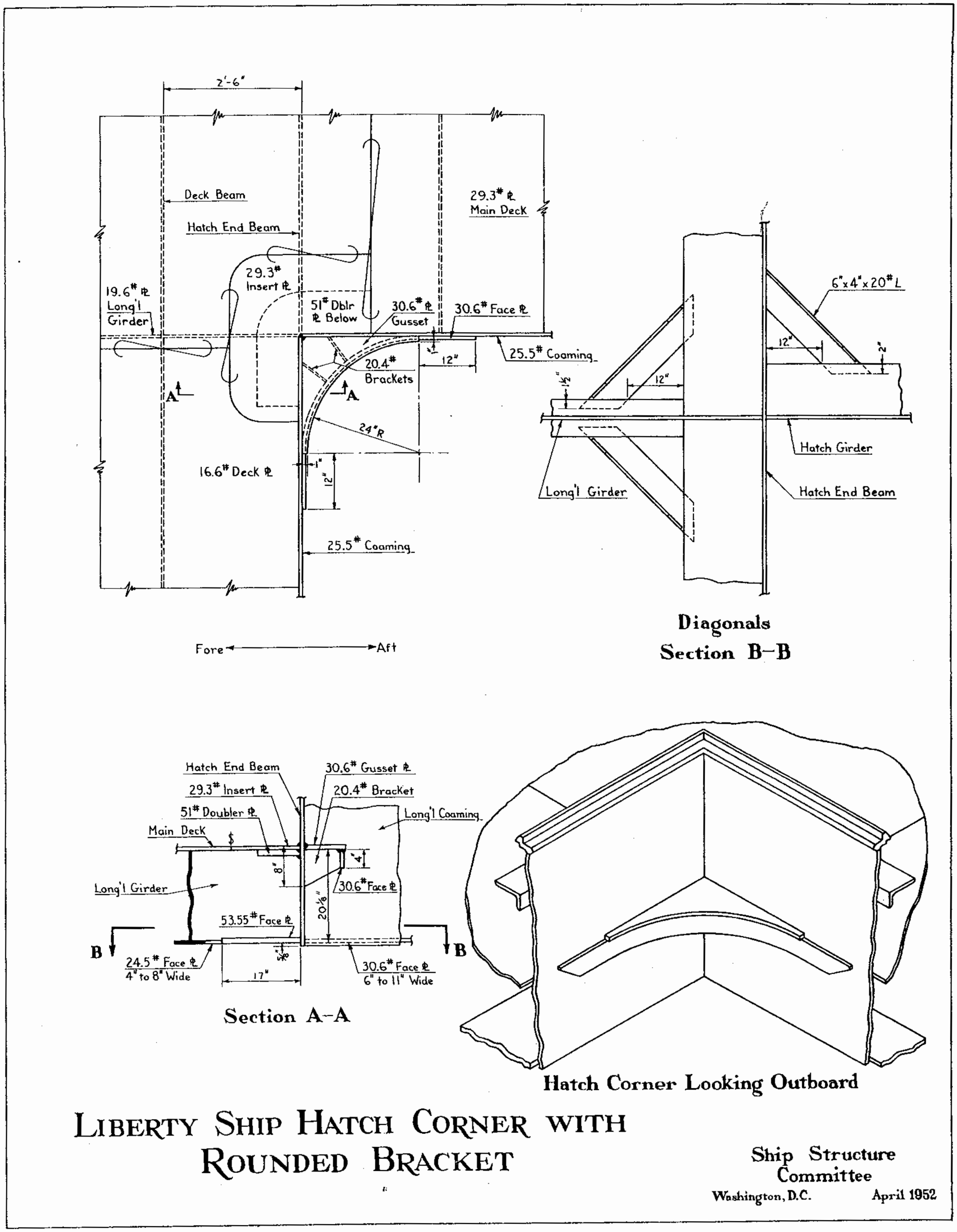
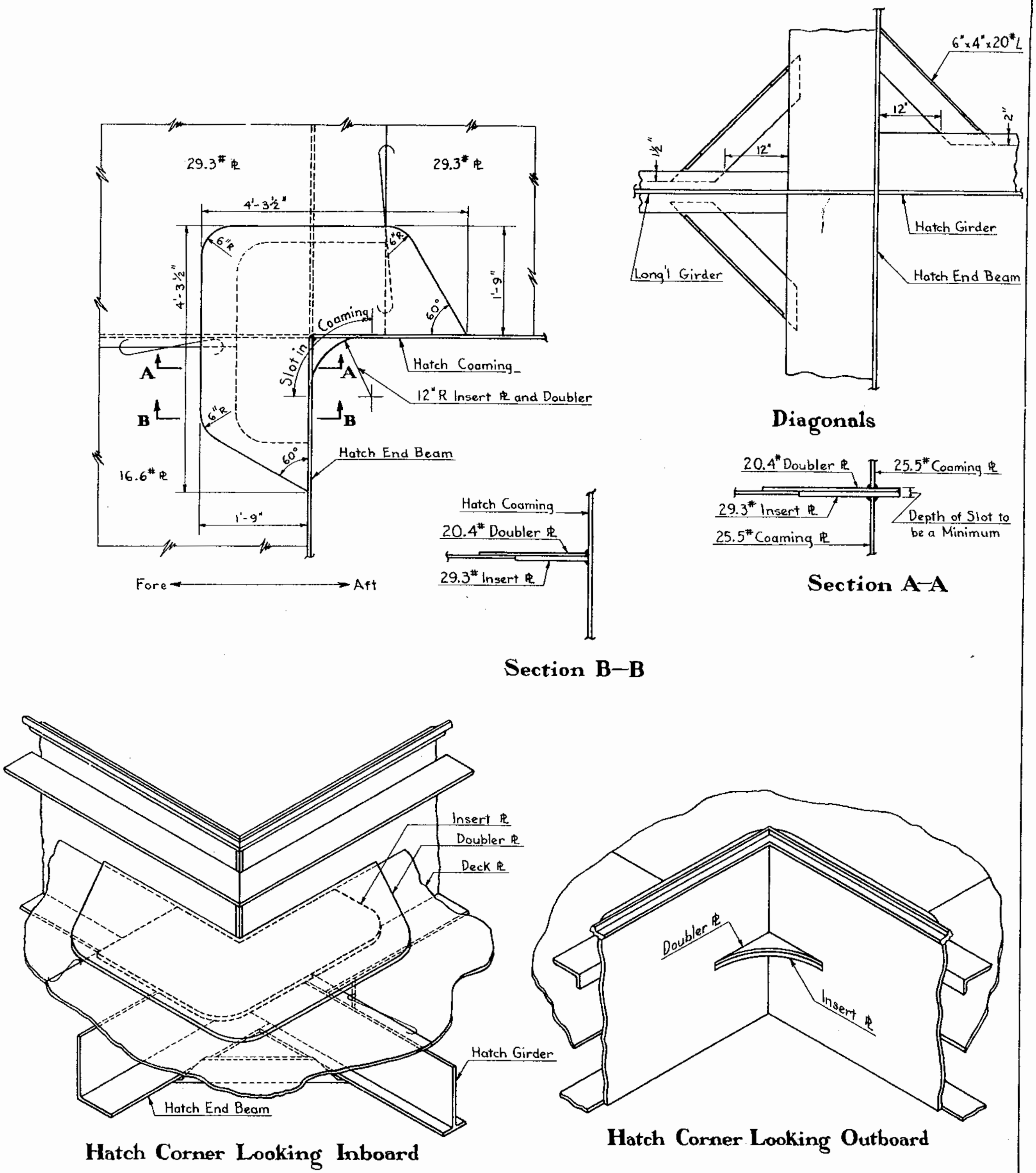

2'-6"
Deck Beam
Hatch End Beam
29.3# ℄ Main Deck
19.6# ℄ Long'l Girder
29.3# Insert ℄
51# Dblr ℄ Below
30.6# ℄ Gusset
30.6# Face ℄
25.5# Coaming
12"
20.4# Brackets
A
A
24"R
16.6# Deck ℄
1"
12"
25.5# Coaming
Fore Aft
6"x4"x20# L
12"
2"
1½"
12"
Hatch Girder
Long'l Girder
Hatch End Beam
Diagonals
Section B-B
Hatch End Beam
30.6# Gusset ℄
29.3# Insert ℄
20.4# Bracket
51# Doubler ℄
Long'l Coaming
Main Deck
8"
4"
30.6# Face ℄
Long'l Girder
20⅝"
53.55# Face ℄
B
B
24.5# Face ℄
4" to 8" Wide
17"
30.6# Face ℄
6" to 11" Wide
Section A-A
Hatch Corner Looking Outboard
Liberty Ship Hatch Corner with Rounded Bracket
Ship Structure Committee
Washington, D.C.
April 1952

Figure 6



Liberty Ship Hatch Corner with Rounded Deck Plate and Doubler

Ship Structure Committee

Washington, D.C. April 1952

Figure 7

C. Rounded-coaming Type

From an arrangement standpoint, the Victory corner has a disadvantage in the fact that the hatch-side coaming extends one frame space beyond the end of the hatch. This might be an awkward arrangement, limiting access around the end of the hatch, and possibly influencing winch locations and other fittings in that area.

As an alternative to the Victory corner, the rounded-coaming hatch corner shown in Figure 8 has been used successfully on a number of vessels of the C3 type since 1947. It was designed to eliminate the right angled coaming intersection at the corner with the intent that the longitudinal coaming stresses taper gradually down into the deck and girder. Rectangular hatch covers may be used by squaring the corner at the level of the top of the coaming. No laboratory tests of the design have been made, nor has any investigation been made of the service extremes to which these vessels have been subjected.

D. Hatch Corner Test Data and Service Records

The results of laboratory tests[3] and an analysis of the service records[2] of the various types of hatch corners described previously are contained in Table I. It is important to note that the material, welding influences, and test temperatures for the laboratory test specimens, were the same. As a result, the test data demonstrate the very considerable benefits that can accrue from careful attention to design. That the test data correctly reflect the performance of the hatch corners in service is shown by the fracture record contained in Table I.

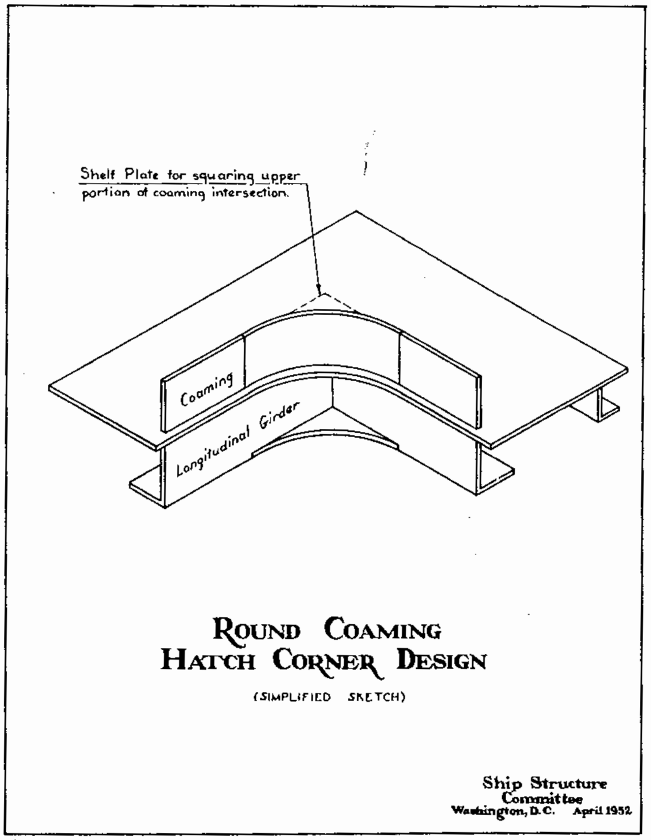


Figure 8

TABLE I

RESULTS OF LABORATORY TESTS AND ANALYSIS OF SHIP SERVICE RECORDS (APPROXIMATELY TO END OF 1950) OF VARIOUS HATCH CORNER DESIGNS

Figure Number	Type	Record of Structural Performance in Service			Data from Laboratory Tests (*)	
		Ship Years in Service	Fractures Reported at Hatch Corners	Hatch Corner Fractures per 100 Ship-Years	Energy Absorpt. at Failure Inch-Pounds	Nominal Stress at Failure Pounds/Sq. In.
Figure 1	Liberty Ship with Square Hatch Corner	2,110	224	10.60	230,000	24,000
Figure 6	Liberty Ship as altered with rounded bracket	4,400	31	0.70	921,000	31,450
Figure 7	Liberty Ship with rounded Deck Plate and Doubler	3,750	1	0.03	3,627,000	35,500
Figure 3	Victory Type	2,100	0	0.00	5,800,000	33,200
Figure 2	Kennedy Type	—	—	—	6,786,000	54,100 (**)

(*) Laboratory specimens varied somewhat from the actual ship detail to permit practical fabrication and testing procedure.

(**) Failure started from a notch resulting from an arc struck inadvertantly where no weld was intended.

III. HATCH CORNER DESIGN PRINCIPLES

It is evident from the foregoing discussion that, among the many contributory causes for failures of hatch corners, one of the most significant factors is the choice of the geometrical arrangement. In order to emphasize the important basic points to be considered in hatch corner design, they are summarized and restated as hatch corner design principles.

A. GENERAL PRINCIPLES

(1) Ease notches in all members and especially those carrying main longitudinal stresses.

(2) Avoid coincidences of notches.

(3) Avoid the intersection of welded joints as far as possible, especially at points of stress concentration.

(4) Minimize welding defects by proper design for welding.

B. SPECIFIC SUGGESTIONS

Selection of specific suggestions listed below must depend upon the ship design. Effective hatch corner reinforcement need not incorporate all of the features listed below. The judgment of the designer must prevail.

(1) At the corner provide a heavier deck plate with a generous radius. (For main hatches in typical cargo ships such as the Liberty a radius = 1/20 of the transverse dimension of the opening was satisfactory.)

(2) Taper hatch side coaming beyond hatch end.

(3) Ease longitudinal girder to hatch end beam connection at flange level as by radiused gusset.

(4) Specify full penetration welds for joining deck to coaming in way of the hatch corner and for such joints as are subject to direct loading, in order to avoid cavities or piping in such welds, especially those perpendicular to the principal tensile stresses.

REFERENCES

1. MacCutcheon, E. M., Discussion of paper "Tests of Various Designs of Welded Hatch Corners for Ships" by E. P. DeGarmo; *The Welding Journal,* Welding Research Supplement, Pages 69-s and 70-s, February 1948.

2. Technical Progress Report (First) of the Ship Structure Committee, March 1, 1948.

3. DeGarmo, E. P. and Boodberg, A., "Causes of Cleavage Fracture in Ship Plate: Hatch Corner Design Tests," Ship Structure Committee Report Serial No. SSC-16, December 4, 1947.

4. "The Design and Methods of Construction of Welded Steel Merchant Vessels," Report of an Investigation, Government Printing Office, 1947.

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