SSC-331

DESIGN GUIDE FOR SHIP STRUCTURAL DETAILS

SHIP STRUCTURE COMMITTEE

1990

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Ship Structure Committee

An Interagency Advisory Committee
Dedicated to the Improvement of Marine Structures

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DESIGN GUIDE FOR SHIP STRUCTURAL DETAILS

Over the years we have accumulated extensive service histories of unsuccessful designs for the structural details of ships. What is lacking, however, are data concerning how well the modified or improved details have performed and the cost of these changes.

This guide is intended to aid the designer of commercial and naval ships in specifying sound and cost-effective structural details. The details shown in this guide represent a combination of satisfactory service experience and reasonable fabrication costs. Numerous tables, graphs and, illustrations are included to assist the designer in selecting structural details.

J. D. SIPES
Rear Admiral, U. S. Coast Guard
Chairman, Ship Structure Committee

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16. Abstract

This report provides a designer with a guide to the selection of structural details for both naval and commercial ships. The details in the guide combine good service experience with reasonable construction costs. A simple method for determining approximate construction time for a wide range of detail sizes is presented. Details which have not performed well are also discussed to illustrate problem areas to avoid.

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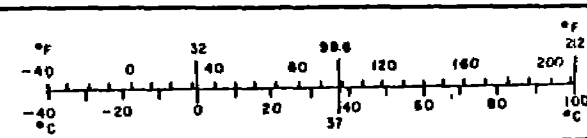
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	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
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (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.

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		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	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
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



METRIC CONVERSION FACTORS

1. INTRODUCTION

Ship structural details are subject to various loads and combinations of loads: axial, bending, shear, cyclic, and dynamic. They connect structure that is part of the basic hull girder, structure that is designed for overload, and structure of secondary importance. Ship structural details are important because:

- their layout and fabrication represent a sizable fraction of hull construction costs;
- details are often the source of cracks and local failure which can lead to serious damage to the hull girder;
- the trend towards decreasing ship hull scantlings has the potential of increasing the frequency and seriousness of cracks and failures at details;
- analysis of structural details has been neglected, partly because of large numbers of configurations, functions, etc.; and
- details influence the performance of the primary structural components.

The Ship Structure Committee has supported research on structural details since its inception in 1946 as a successor to a "Board of Investigation to Inquire into the Design and Methods of Construction of Welded Steel Merchant Vessels" (Ref. 1). Many of the early studies (Refs. 2 and 5 thru 8) cover details which are rarely specified on new construction today but may still be found on older ships remaining in service.

The most recent work on structural details sponsored by the Ship Structure Committee is reported in Refs. 49, 55, 59, and 66. The first study (Ref. 49) is an extensive review of ship structural details in which current practice is reported, with descriptions of about 160 details. This study also described damage induced by poor design and fabrication of details, reviewed the literature on analysis of details, and included proposals for a fatigue criterion which would support the analysis of structural details. Additional analysis work on structural intersections sponsored by the Maritime Administration is reported in Ref. 53.

Ref. 55 reports on the structural details of 50 different ships, classifying these details into 12 families. Failures in these details are described, and causes such as design, fabrication, maintenance, and operation, are postulated as an aid to designers. This work is summarized in Refs. 50 and 51. Ref. 59 reports on a continuation of the program described in Ref. 55

in which the midships portions of an additional 36 ships were surveyed. The results were combined with the results of Ref. 55 to provide data on failure of details for use by design and repair offices. Ref. 73 summarizes this data and ranks the details in each family sub-group in order of observed successful performance.

Ref. 66 is the most recent continuing project to characterize the fatigue of fabricated ship details. This program includes assembly of fatigue information for a large number of structural members, joints, and details; a selection of details which, in service, have exhibited fatigue problems; a compilation of ship loading histories; and an examination of ship structure fatigue criteria. The program will lead to the development of fatigue design criteria for ship details, and an experimental program will be conducted to provide additional data. Ref. 65 provides a brief summary of this work. All this work, along with that reported in the other publications listed, has provided a wealth of background data on the operational experience of a large variety of structural details.

From these data, the project reported here has developed a guide to assist a designer in selecting sound, cost-effective details. The guide is a selection of the best details (i.e., the least expensive details which have given adequate service) from the many arrangements currently in use. This report also provides the designer with a simple method for determining the approximate construction cost (in terms of man-hours) of a wide range of detail sizes.

2. REVIEW OF SHIP STRUCTURAL DETAIL LITERATURE

There exists a large amount of published material related to the design and adverse service experience of ship structural details. The features which have caused ship structural details to fail are well illustrated and discussed along with the features which would improve the performance of the details. What has been lacking is data on how well the improved details have performed and what they cost to construct. Refs. 55 and 59 provide valuable data which the current project uses to rank details in order of service performance before addressing the cost of structural details. A selection from the many good descriptions of structural detail failures will be included in the following section.

2.1 SAMPLE FAILURES

Ref. 49 includes many sketches of failures in ship structural details. The bulk of failure examples were taken from a booklet by "Lloyd's Register of Shipping" (Figs. 2-1, 2-2, 2-3 and 2-4) and a paper by Mr. A. Haaland on ship structural design (Figs. 2-5 and 2-6). Figs. 2-1 and 2-2 illustrate a typical problem when installing brackets on stiffeners in way of a watertight or oiltight bulkhead. The bulkhead plating is relatively flexible and tends to bend over the hard spot caused by the relatively stiff bracket. The high stresses produced in the bulkhead frequently lead to cracks in the bulkhead. Fig. 2-3 illustrates similar problem areas and improved details which should reduce the potential for failures. Sound structural design considerations such as continuity and proper reinforcement can solve most of the problems shown in Fig. 2-3. Similar suggested improvements to typical ship structural details are presented in Refs. 30, 53, 58, 62, and 68. Fig. 2-4 shows that serious fractures can occur from very simple details if special care is not taken in design and construction. In this case, the girder web butt weld probably failed first due to the difficulty in providing good endings to the weld at "X". In general, scallops should be kept to a minimum.

Structural intersections have been the source of many failures (Refs. 10, 11, 20, 24, 30, 32, 33, 36, and 45). Fig. 2-5 shows cracks near the end of a deep tank stringer where the shear force is greatest. The cross-sectional area of the girder web has been reduced by the large cutouts.

Fig. 2-6, ". . . 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." (Ref. 49)

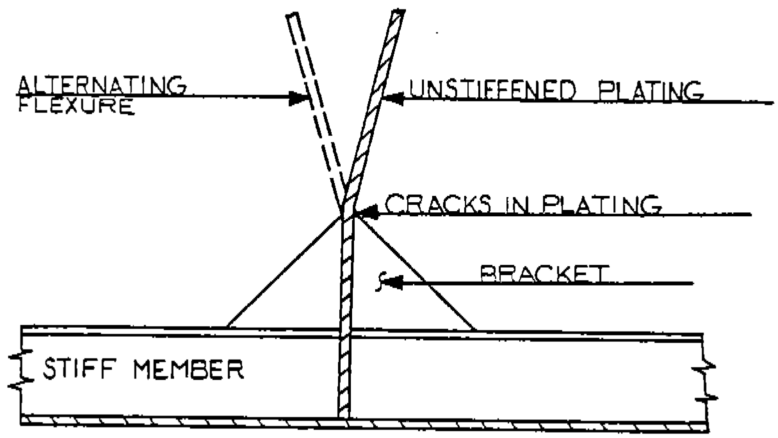


FIGURE 2-1

FLEXURE OF UNSTIFFENED PLATING ABOUT BRACKET TOE LEADING TO CRACKS (REF.49)

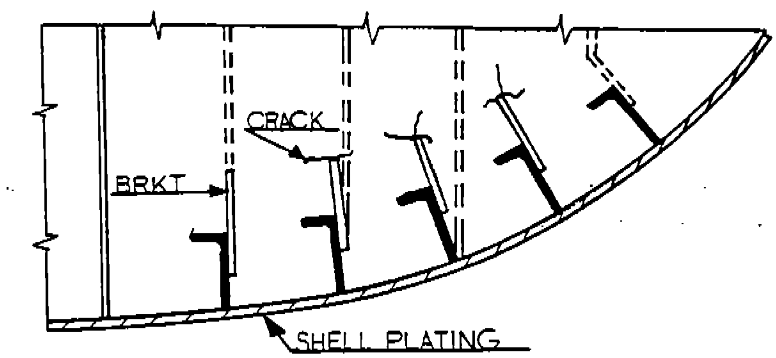


FIGURE 2-2

CRACKS INITIATING AT BRACKETS INSTALLED ON BOTTOM LONGITUDINALS (REF. 49)

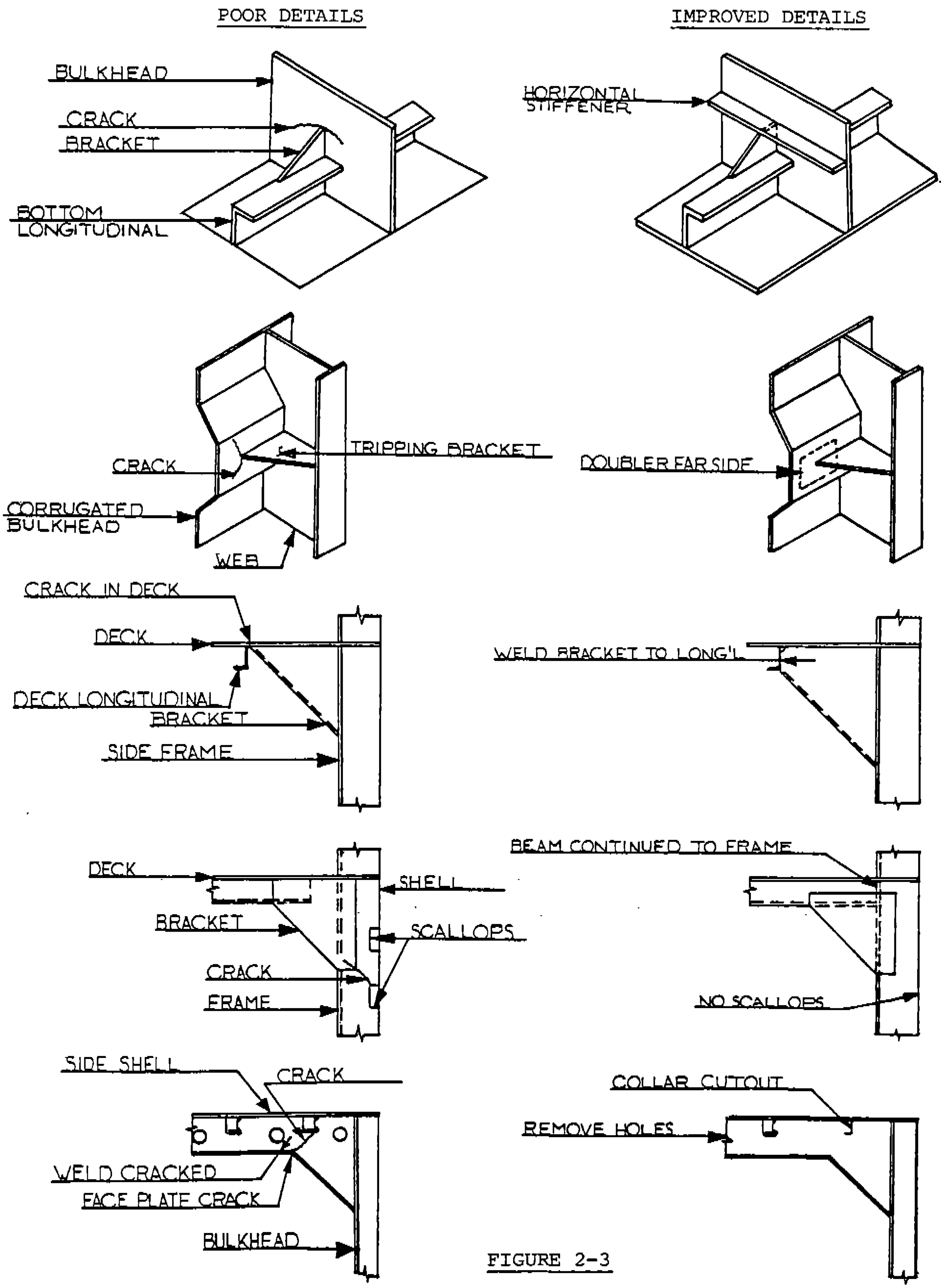


FIGURE 2-3

EXAMPLES OF FAILURES IN BEAM BRACKETS (REF. 49)

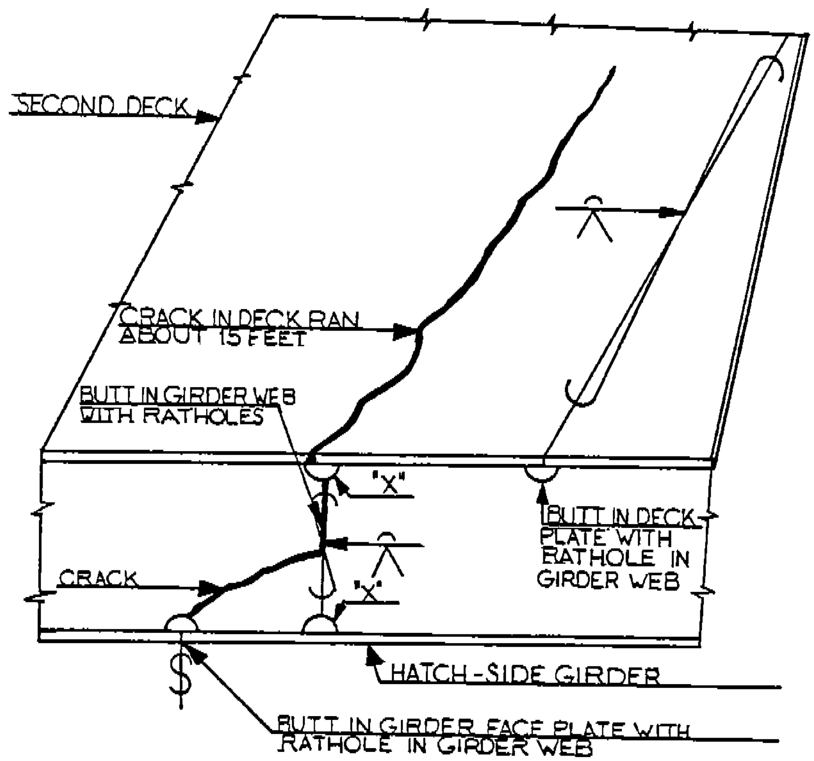


FIGURE 2-4

FRACTURE OF HATCH SIDE GIRDER AND DECK PLATE
AT "POOR RATHOLE" CUTOUT (REF. 49)

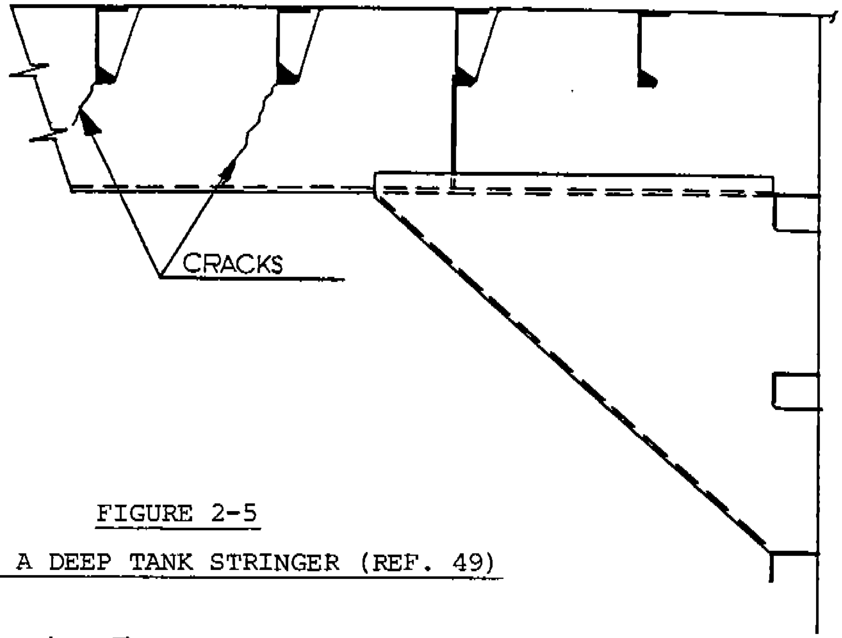


FIGURE 2-5

CRACKS IN A DEEP TANK STRINGER (REF. 49)

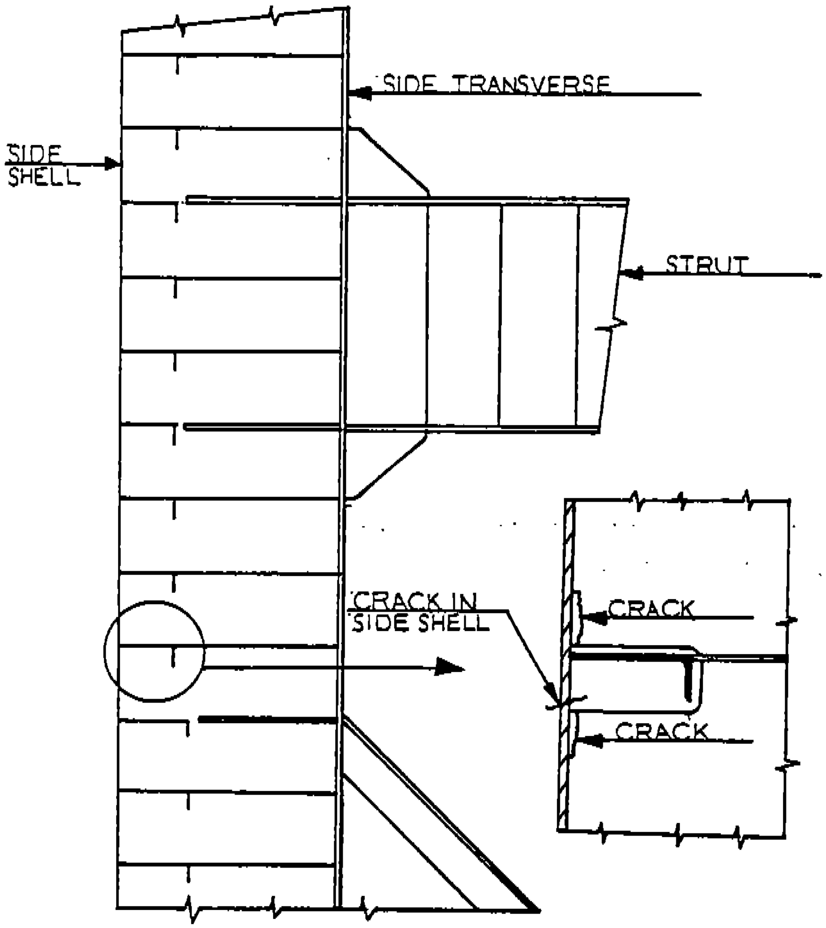


FIGURE 2-6

CRACKS OCCURRING IN LARGE TANKERS AT THE JUNCTION OF SIDE LONGITUDINALS AND WEB FRAMES (REF. 49)

As drawn in Fig. 2-6, there is no direct connection of the longitudinal to the web frame. Consequently, the end reaction of the longitudinal must first be transferred to the flat bar stiffener and then into the web frame. This connection between the longitudinal and the flat bar stiffener has been a source of cracks in heavily loaded members even when a direct web to longitudinal stiffener connection is provided as described in the next paragraph.

Fig. 2-7 illustrates both cracking and buckling failures in way of structural intersections. As stated in Ref. 49: "Investigation reveals that approximately 75% of the total number of fractures found around slots are of Type G, H and I [cracks in or in way of the flat bar attached to the longitudinal flange]. Since most [of] the webs having D, E, and F type fracture [cracks in the girder web plate] 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 [additional cracks in the girder web plate] occur rarely and may be a result of vibration of the transverse webs." Fig. 2-8 shows the configuration of a typical side shell longitudinal connection to a web frame and the sequence of crack initiation most commonly observed. Figs. 2-7 and 2-8 appear to be in general agreement on the sequence of crack initiation. "Although these details were used successfully for many years with smaller vessels, the increased draft, web frame spacing, and size of the larger tankers were probably not fully considered in designing the details." (Ref. 60)

Ref. 45 provides a list of design recommendations covering structural intersections which is presented in Fig. 2-9.

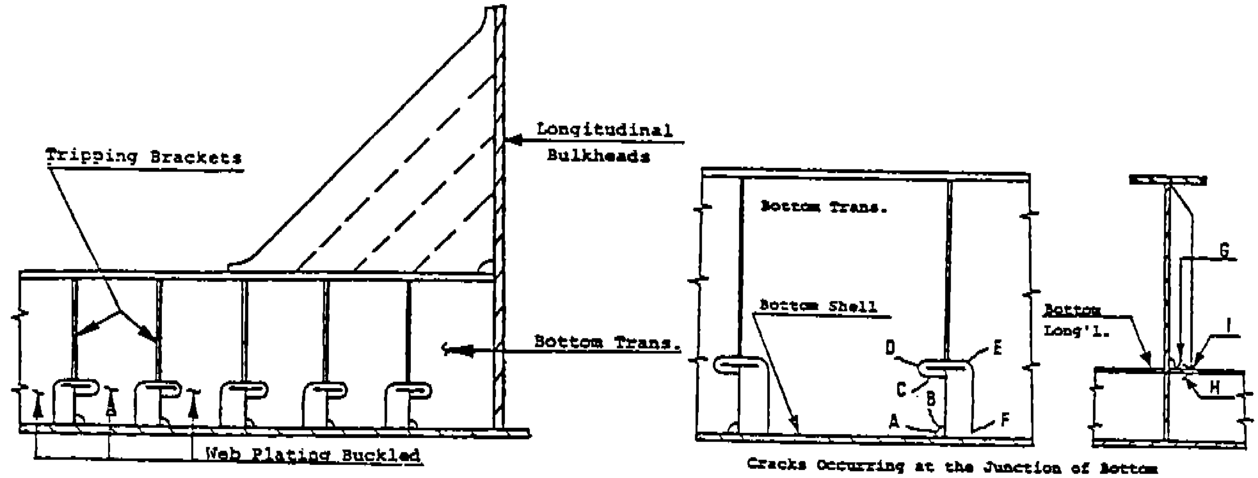
2.2 FATIGUE

Fatigue has been identified as the cause of many of the failures in ship structural details. Of the 6,856 failures observed in Refs. 55 and 59, approximately 4,050 involved cracking of welds or base materials; the remainder were buckling failures. Consequently, fatigue probably was involved in about half of the failures observed.

Ref. 66 is the most recent of a continuing series of Ship Structure Committee projects to characterize the fatigue of fabricated ship details. The factors that influence fatigue can be separated into three general categories:

- geometry,
- stresses or loading condition, and
- material.

Discontinuities in geometry are inevitable whenever various structural members are joined. These discontinuities may be in the general configuration of the members, the local configuration of weld details, angular distortions

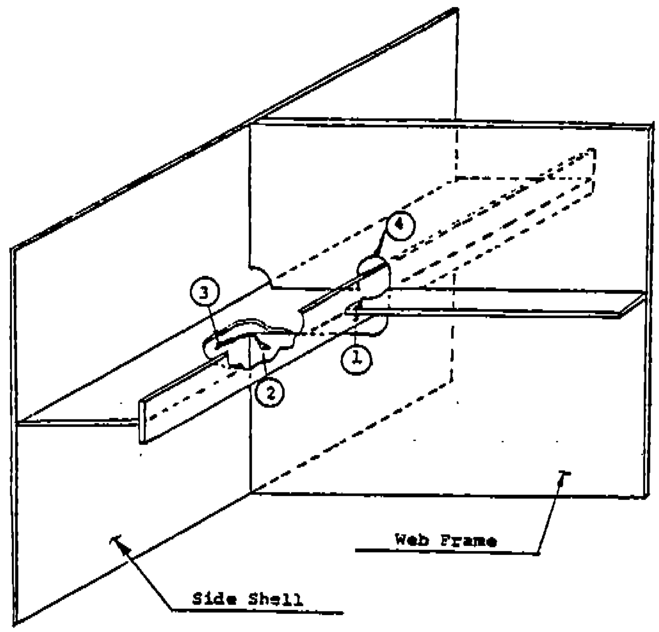


Buckling of Bottom Transverse Web Frame

Cracks Occurring at the Junction of Bottom Longitudinals and Bottom Transverses

FIGURE 2-7

FAILURES IN CONNECTION DETAILS (REF. 49)



1 Initiation of Crack in Flat Bar Stiffener
2 Crack at Free Edge of Cut-out
3 Crack in Side Shell Plating
4 Crack at Radius of Cut-out

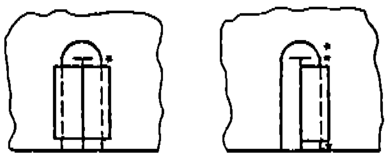
FIGURE 2-8

SEQUENCE OF CRACK INITIATION (REF. 60)

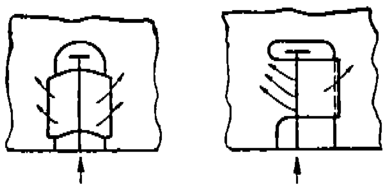
FIGURE 2-9

DESIGN RECOMMENDATIONS FOR STRUCTURAL INTERSECTIONS FROM REF. 45

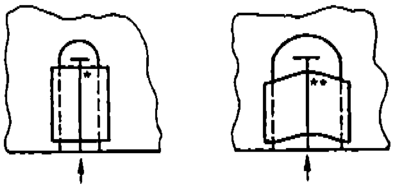
KEY: * = Maximum stress
** = Maximum stress twice as large as *



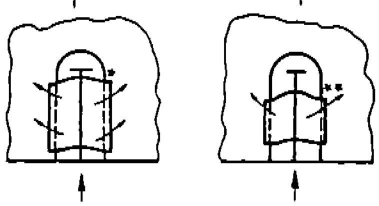
A double-sided lug connection has a maximum stress that is considerably less than half of that in a connection with only one lug.



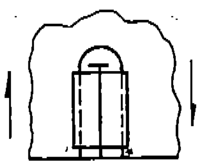
A symmetrical design gives a better transfer of forces to the girder, and therefore has smaller stresses than an asymmetrical one.



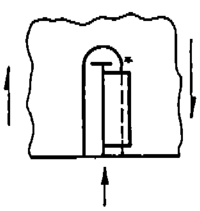
A large cutout breadth results in relatively large bending stresses in the lug near to the longitudinal.



The maximum stresses decrease considerably with increasing height of the lug.

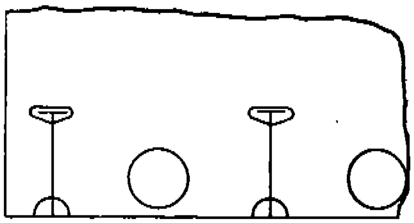


In two-sided lug connections the overall shear force in the girder will cause the highest stresses below the lug fixation point.

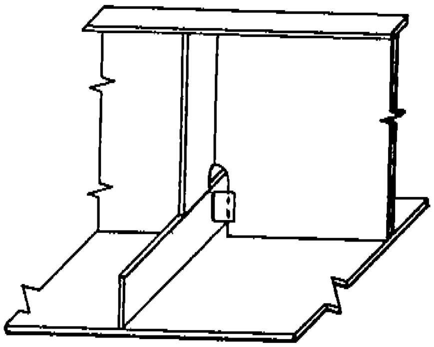


In a one-sided lug connection the maximum stresses will always appear above the lug.

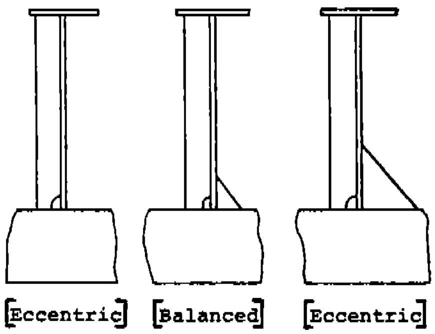
FIGURE 2-9 (Cont'd.)



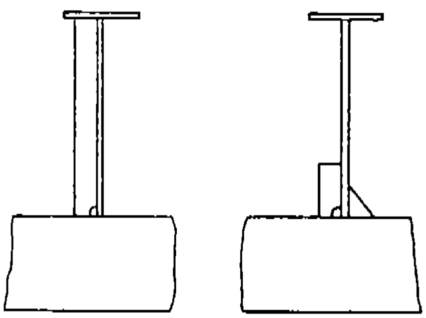
Cutouts in web plating in order to get sufficient throughflow area should preferably be located as separate cutouts between cutouts for longitudinals, and if possible at the middle of the girder span.



When the force to be transferred from the longitudinal to the girder exceeds the force-carrying capacity of the two lugs alone a common solution has been to locate a vertical stiffener at the web plate and connect this stiffener to the longitudinal. This connection must, however, be very well designed in order to avoid cracks at the weld between the longitudinal and the vertical stiffener.



It is important that the vertical force is evenly distributed to the longitudinal i.e. minimum [eccentricity] relative to the plate.



If the vertical stiffener is placed there in order to contribute to force transmission only, it may be of moderate length (e.g. 3 times its own [width]).

FIGURE 2-10

LOCAL FATIGUE DETAILS FOR SHIP STRUCTURAL DETAIL 1-B-4

REF. 66 | PROPOSED ADDITIONS

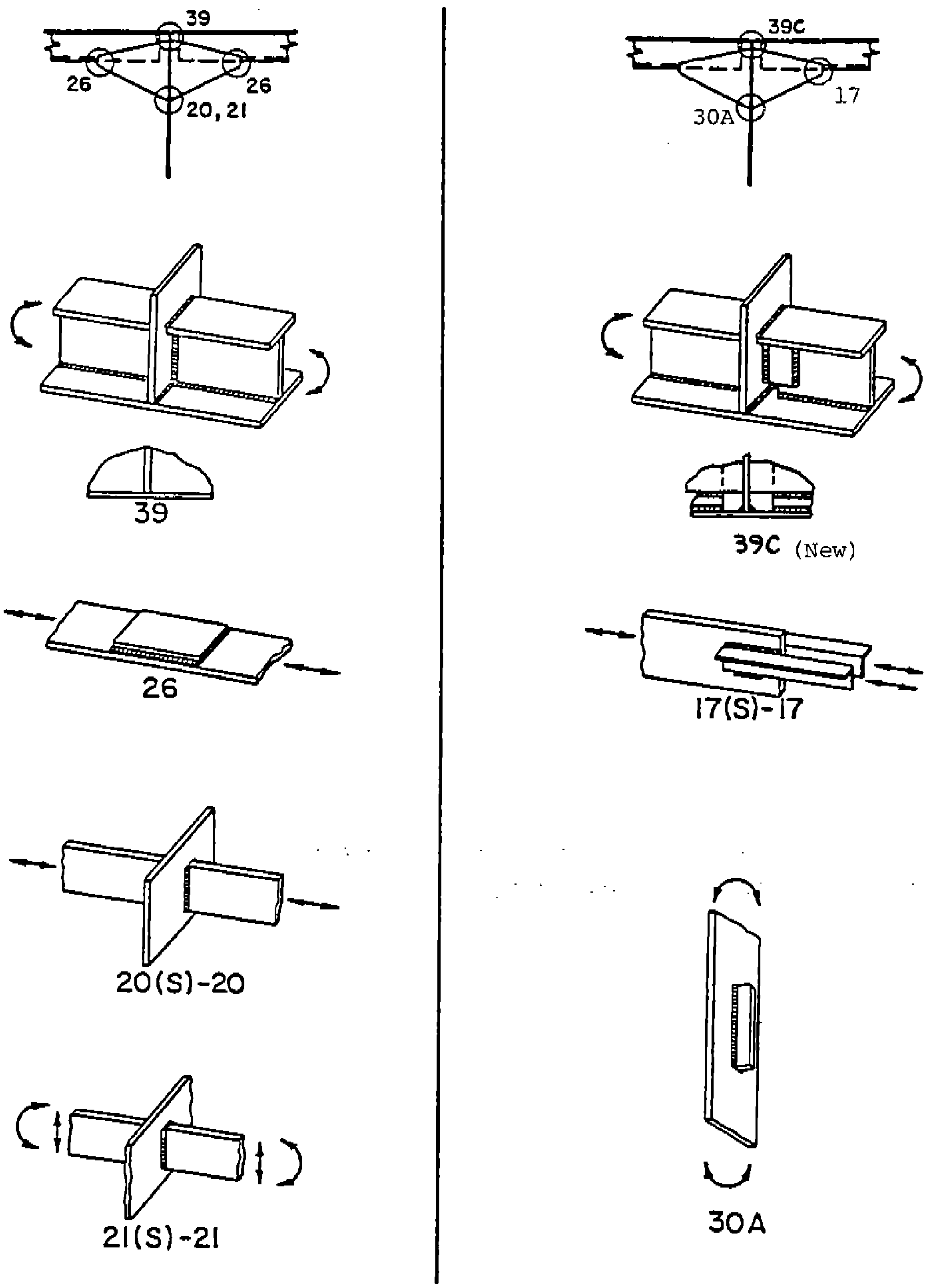
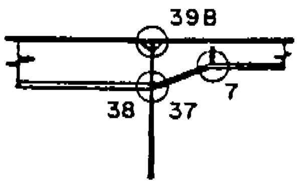
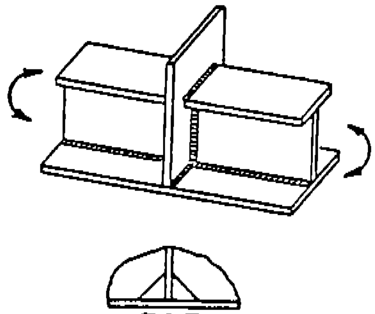


FIGURE 2-11

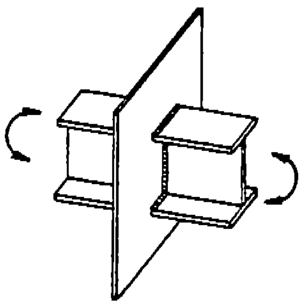
LOCAL FATIGUE DETAILS FOR SHIP STRUCTURAL DETAIL 1-A-1

REF. 66

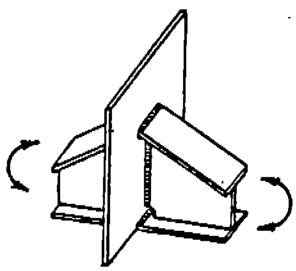




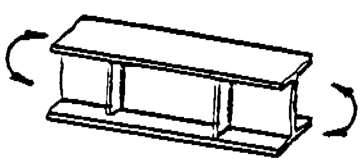
39B



38(S)-38

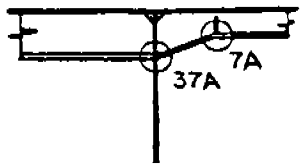


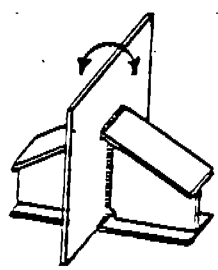
37(S)-37



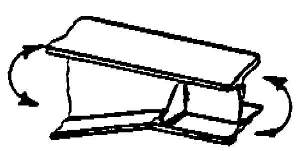
7

PROPOSED ADDITIONS





37A (New)



7A (New)

or misalignments, or internal weld discontinuities. The magnitude of the discontinuity has a direct effect on the stress and strain concentrations which adversely affect the fatigue strength. The detrimental influence of sea water on fatigue strength is sometimes considered to be a geometrical effect. Some of the primary stress factors which affect the fatigue behavior are constant versus random amplitude loading, stress range, type of stress (compressive is less damaging than tensile stress), residual stresses built-in during construction, frequency of loading, and the sequence in which variable loadings are applied. The type of welded steel normally used in shipbuilding has a smaller effect on fatigue strength than other factors and in some cases the differences among the various steels are small enough to be neglected (Ref. 66), particularly for higher cycle fatigue problems.

Suggestions for modeling typical ship structural details using a series of simpler local fatigue details are given in Appendix A of Ref. 66. As an example, the left-hand side of Fig. 2-10 shows the local fatigue details recommended for analyzing ship structural detail 1-B-4 (this designation refers to family number 1, family group B, and detail number 4 as described in Section 3 and shown in Fig. 3-1). It is suggested that several additional local fatigue details be included as shown on the right-hand side of Fig. 2-10. Local fatigue detail 39C is a square cornered, lapped connection which can have a quite high stress concentration factor and consequently a low fatigue life. Local fatigue detail 17(S)-17 is suggested because the entire load in the stiffener must be transmitted to the bracket plate. Local fatigue detail 30A is probably the most significant potential failure mode. This represents bending of the relatively flexible bulkhead plating over the "hard spot" of the relatively stiff bracket which has been the cause of many cracks as shown in Figs. 2-1, 2-2, and 2-3. The basic loading may be due to either vibration or hydrostatic pressure on the bulkhead and the ship loading history (stress range versus cycles) is not well defined for either load. As Ref. 66 indicates, most of the available ship loading histories are for longitudinal hull girder bending stresses. Very little information on ship loading history is available for secondary structures such as transverse bulkheads or web frames. Fig. 2-11 presents similar data for ship structural detail 1-A-1. Local fatigue detail 37A represents flexing of the bulkhead plate similar to (but less severe than) local fatigue detail 30A of Fig. 2-10. Local fatigue detail 7-A shows a flange knuckle with tangency chocks, flange butt weld, and fillet welds to the flange all of which contribute to the fatigue problem. Local fatigue details 39C, 37A, and 7A are new configurations which are not currently covered by Ref. 66. However, neither of these details (1-B-4 or 1-A-1) is recommended for normal ship use (see further discussion in Section 3).

2.3 STRUCTURAL TOLERANCES

Ref. 56 discusses the influence of structural deviations on strength. It states that "very few ships that were reportedly inspected in accordance with previous or current structural and weld tolerance standards have failed in service." Three of the four examples cited involved various types of misalignment which is a detail beyond the scope of the current study. What is of concern here is the effect normal construction tolerances have on the selection of structural details and how well the different resulting details perform. As an example, the right hand side of the fourth line of Fig. 2-3 shows a detail in which it is hard to fit the beam to the frame (i.e., the tolerances on beam length and location must be tightly controlled). However, this detail performed much better than the detail on the left hand side which had more liberal tolerances but, consequently, required the bracket to carry the entire beam load to the shell frame. A similar situation occurs in the third line of Fig. 2-3. The arrangement on the right is harder to fit and consequently costs more but it has performed better than the one on the left with the more liberal fitting tolerances.

In general, lap welded structural details used with angle type framing members are easier to fit and thus cost less than butt and tee welded structural details used with tee type framing members. However, the former details introduce eccentricities into the structural arrangement and it is harder to maintain structural continuity. Consequently, lap welded details generally do not perform as well as butt and tee welded details as will be discussed in Section 3 of this report.

2.4 SERVICE EXPERIENCE

For the project reported here, Refs. 55 and 59 have provided the most useful data on successful service experience. Consequently, a brief summary of those reports is included here. As shown in Table 2-1, 86 ships were surveyed and grouped in 7 categories. For the bulk carriers, containerships, and general cargo ships, 12 vessels in each category were surveyed in the midships area only.

TABLE 2-1

SUMMARY OF SHIPS SURVEYED

No. of Ships	Classification	Code	Number Built USA	Number Built Foreign
16	Bulk Carriers	B	3	13
5	Combination Carriers	CC	5	0
24	Containerships	C	20	4
17	General cargo	G	15	2
2	Miscellaneous	M	1	1
9	Naval	N	9	0
13	Tanker	T	13	0
86			66	20

Fig. 2-12 summarizes the resulting data: 607,584 details were observed in 634 different configurations which were assigned to 56 family groups and 12 families. Fig. 2-13 gives a description of the primary function of each family along with a sketch of a typical configuration. Note that the family numbers are not in order. Family No. 8 (Stiffener Clearance Cutouts) is inserted before Family Nos. 3 and 4 (Non-tight and Tight Collars) because these details are so closely related. Also, Family No. 9 (Structural Deck Cuts) is inserted before Family No. 7 (Miscellaneous Cutouts) because the former is more important and should be discussed first. This order is maintained throughout the present report. Because of survey limitations, no Knife Edge Crossings (Family No. 6) were observed.

A total of 6,856 failures were observed for an average failure rate of 1.13%. Fig. 2-14 summarizes the observations and failure rates for each family. Almost half of the details observed were Miscellaneous Cutouts (Family No. 7) followed by Beam Brackets (Family No. 1), Stiffener Clearance Cutouts (Family No. 8), and Panel Stiffeners (Family No. 12). The highest failure rates observed were in Tripping Brackets (Family No. 2), Beam Brackets (Family No. 1), and Gunwale Connections (Family No. 5).

Fig. 2-15 shows the average number of details observed and failure rate versus ship type. The most interesting result is that miscellaneous and naval ships had very small failure rates of 0.08 and 0.14 percent, respectively. Since only two miscellaneous ships were observed versus nine naval ships, the results from the latter type should be given a much higher confidence level. Since naval ships had almost an order of magnitude smaller failure rate than the average ship, the differences in naval and commercial ship details are discussed in Chapter 3 and Appendix C of this report. Ref. 72 gives the exact geometry of many naval ship details.

Fig. 2-16 shows the number of details observed, the number of failures, and the failure rate by ship type and location (aft, midships, and forward). The data has been normalized or ratioed to represent seven ships of each type to permit more accurate comparison between ship types. From the combined results (Ref. 55 plus 59), the highest failure rate occurs amidships with the forward portion of the ships a close second. The highest failure rates were observed in the following order: amidships on general cargo ships, containerships, and combination carriers followed by forward on bulk carriers, containerships, and combination carriers. Similar plots for each detail family are included in Appendix A.

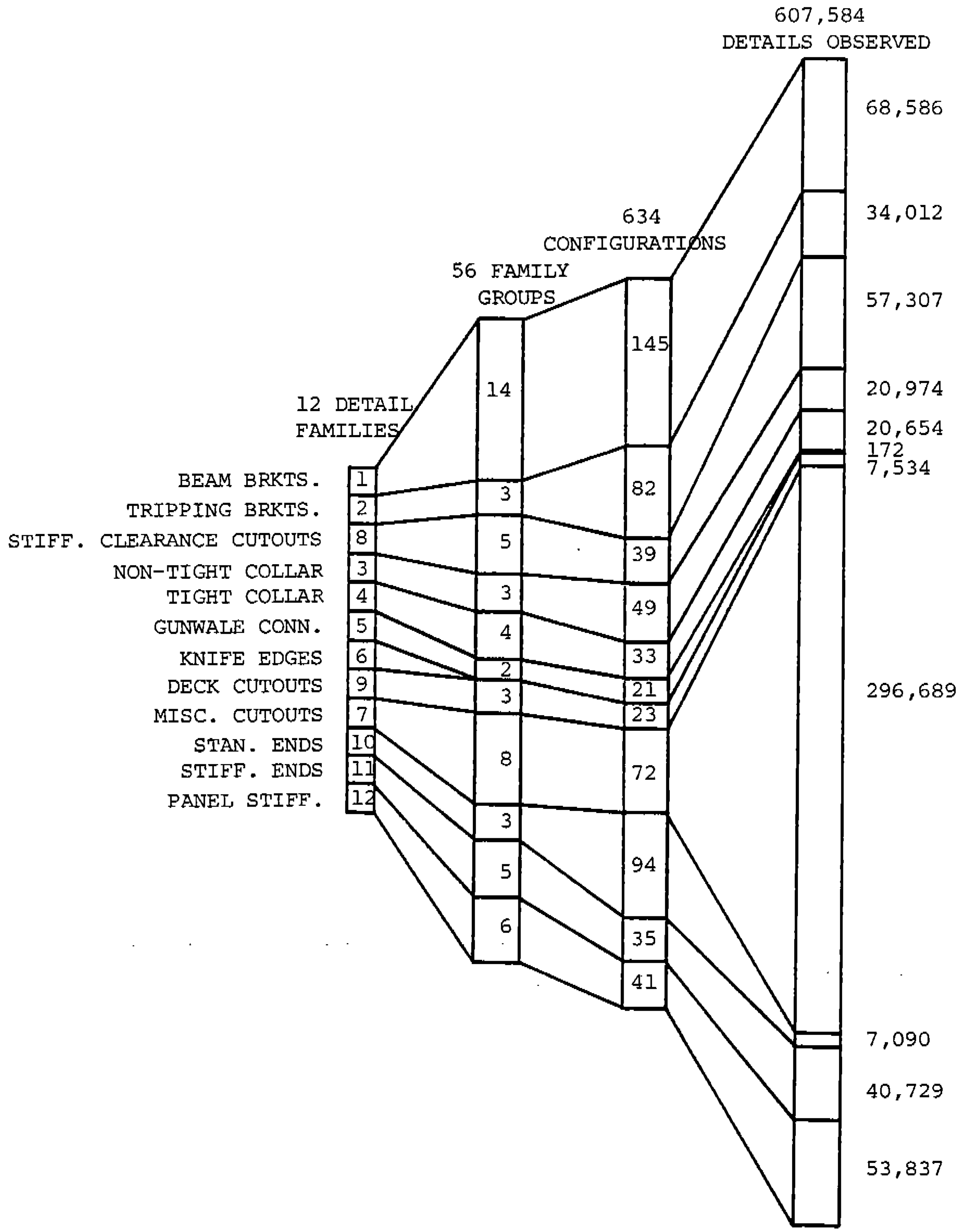
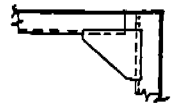
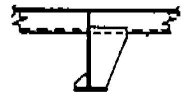
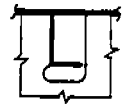
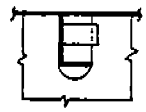
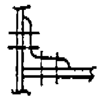
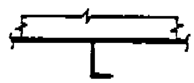
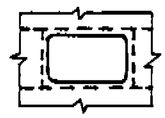
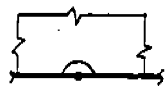
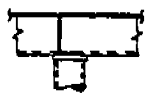
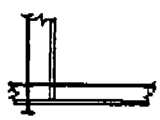
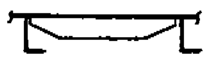


FIGURE 2-12

SUMMARY OF STRUCTURAL DETAILS SURVEYS

FIGURE 2-13

TYPICAL DETAILS SURVEYED

DETAIL FAMILY NO.	FAMILY NAME	FUNCTION - PROVIDES:	TYPICAL CONFIGURATION
1	BEAM BRACKETS	END CONSTRAINT FOR FRAMING	
2	TRIPPING BRACKETS	LATERAL SUPPORT	
8	STIFFENER CLEARANCE CUTOUTS	FOR PASSING ONE MEMBER THROUGH ANOTHER AND A SHEAR CONNECTION	
3	NON-TIGHT COLLARS	SHEAR CONNECTION FOR CONTINUOUS FRAMING	
4	TIGHT COLLARS	SAME AS #3 AND A TIGHT PENETRATED PLATE	
5	GUNWALE CONNECTIONS	CONNECTION OF STRENGTH DECK TO SIDE SHELL	
6	KNIFE EDGE CROSSING	NO USEFUL FUNCTION (A PROBLEM TO AVOID)	
9	STRUCTURAL DECK CUTS	PASSAGE THROUGH DECKS FOR ACCESS, TANK CLEANING, PIPING, CABLES, ETC.	
7	MISCELLANEOUS CUTOUTS	HOLES FOR ACCESS, DRAINAGE, EASE OF FABRICATION, CABLEWAYS, PIPES, AIR HOLES, ETC.	
10	STANCHION ENDS	LOAD PATH BETWEEN STANCHION AND DECK	
11	STIFFENER ENDS	DESIGNED END RESTRAINT FOR LOAD CARRYING MEMBERS	
12	PANEL STIFFENERS	STABILITY TO PLATING	

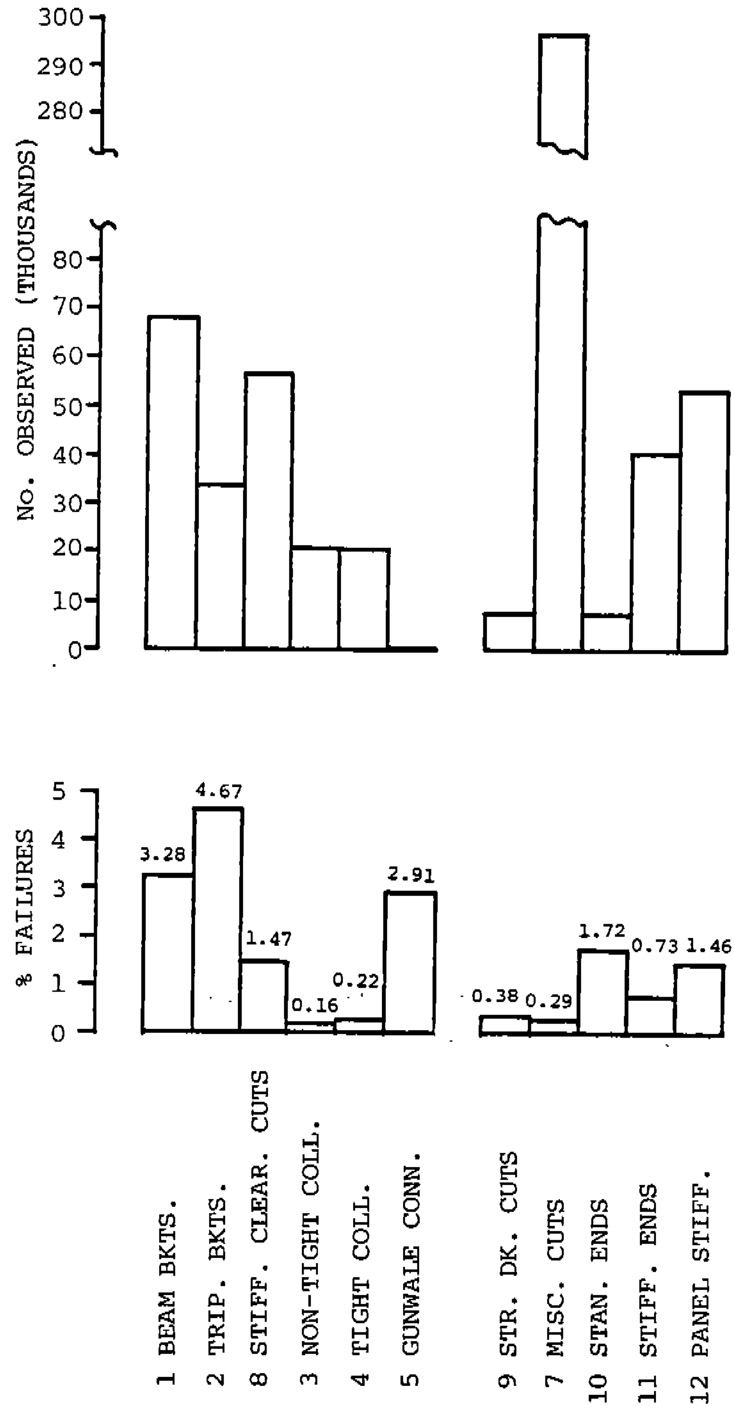


FIGURE 2-14

DATA SYNTHESIS BY DETAIL FAMILIES

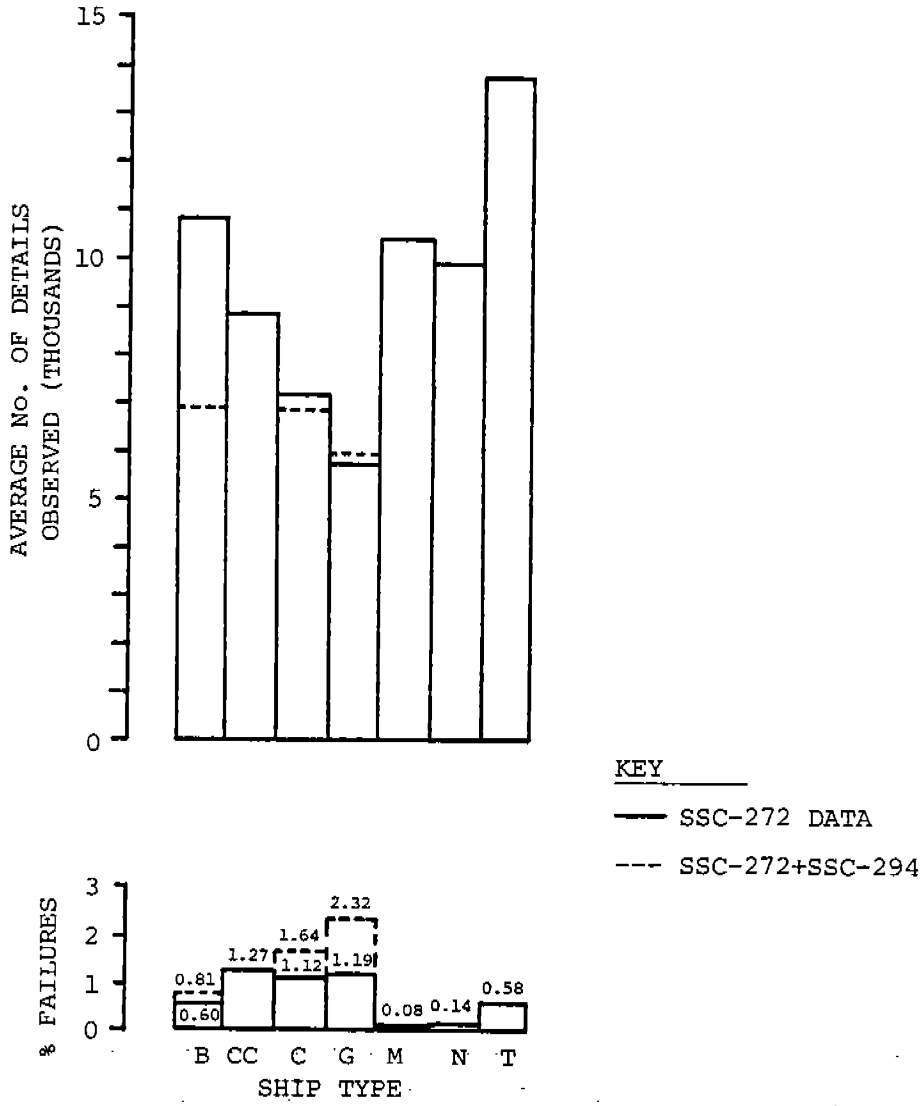


FIGURE 2-15

DATA SYNTHESIS BY SHIP TYPE

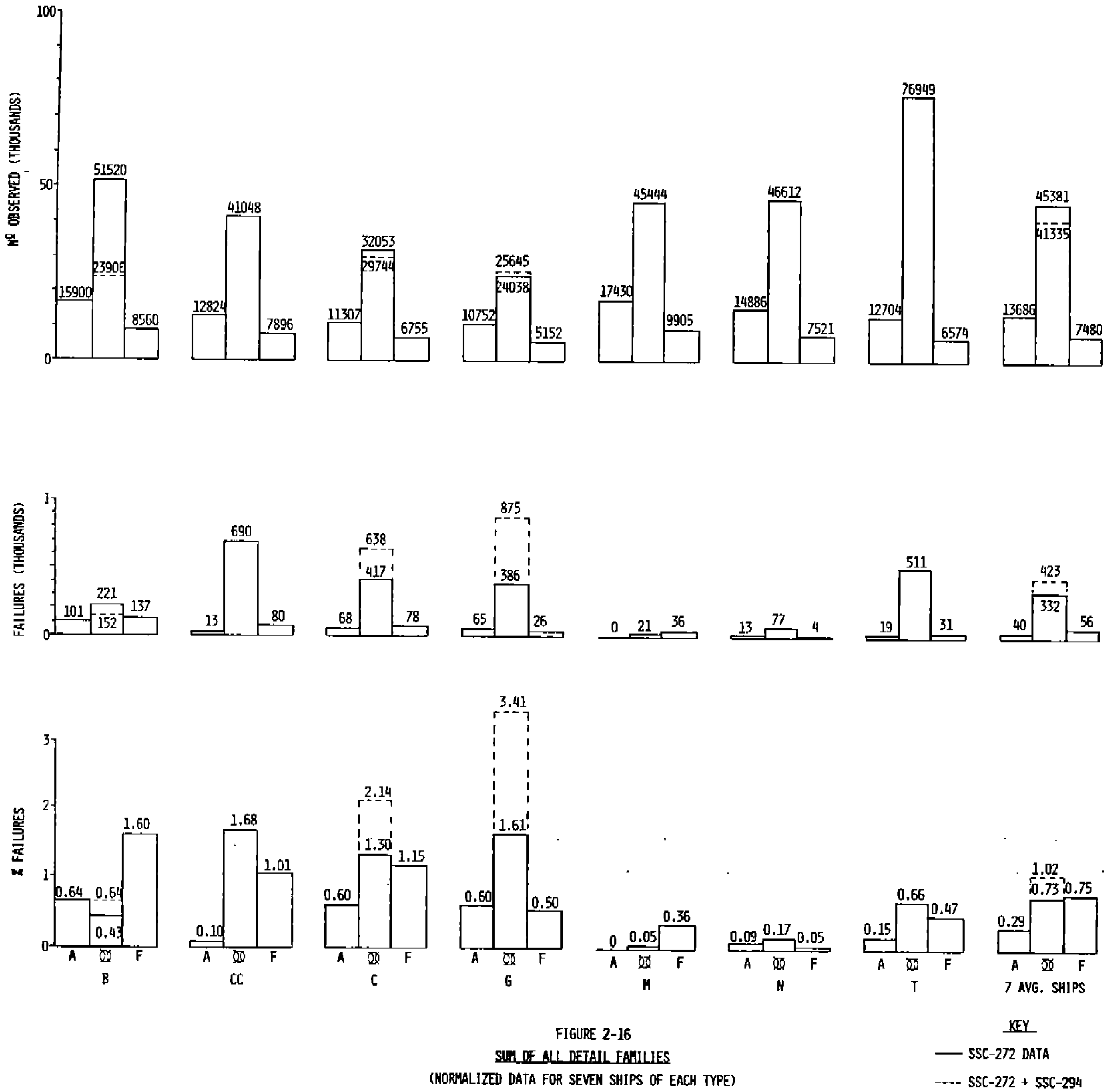


FIGURE 2-16

SUM OF ALL DETAIL FAMILIES

(NORMALIZED DATA FOR SEVEN SHIPS OF EACH TYPE)

2.5 GENERAL DESIGN PHILOSOPHY

In general, the design philosophy for any given structure must be keyed to the magnitude of the loads and the consequences of a potential failure. On moderately loaded secondary structures the appropriate structural details can be much simpler and less costly than those required for highly stressed main hull grider structure. Some design philosophy has been discussed in the preceding sections. The paragraphs that follow briefly review and the twelve families of details as presented in Refs. 50, 51, 55, 59 and 73, and give the authors' opinions for the failures observed and the design philosophy to use to avoid the observed problems.

In the beam bracket configurations of Family No. 1, twenty percent of the surveyed failures attributed to design were caused by instability of the plate bracket edge or by instability of the plate bracket panel. While the stress levels in the buckled brackets were in all probability well below the allowable stress levels for normal loading, the details failed. This elastic instability, which resulted from loads that produce critical compressive and/or shear stresses in unsupported panels of plating, can be eliminated by proper consideration in the design process. Plating stability is normally determined by panel size, plate thickness, type of load and the edge restraint of the plating. Any change in these factors could have a significant influence on the ability of the plate bracket to perform its intended function.

The failures of beam brackets by cracking occurred predominantly where face plates had been sniped, at the welded connections, at the ends of the bracket, at cutouts in the brackets, and where the brackets were not properly backed up at hatch ends. The sniping of face plates on brackets prevents good transition of stress flow, creates hard spots and produces fatigue cracks due to the normally cyclic stresses of these members. Care must be taken to ensure proper transition with the addition of chocks, back-up structure, reinforcement of hole cuts, and the elimination of notches.

To reduce the potential for familiar tearings and fatigue cracks in decks, bulkheads and beams, transition brackets should be made continuous through the plating or be supported by stiffeners rigid enough to transmit the loads.

The greater number of failures in the tripping bracket configurations of Family No. 2 occurred at hatch side girders, particularly in containerships. This will be a continuing problem unless the brackets are designed to carry the large lateral loads due to rolling when containers are stacked two to four high on the hatches. The brackets must, in turn, be supported by properly designed backing structure to transmit the loads to the basic ship structure.

Tripping brackets supported by panels of plating can be potential problems, depending on the plate thickness. Brackets landing on plate that is thick in relationship to their own thickness may buckle in the panel of the bracket, produce fatigue cracks along the weld toe, or cause lamellar tearing in the supporting plate. Brackets landing on plate with a thickness equal to or less than their own thickness may result in either fatigue cracks or buckling of an unsupported plate panel.

The stiffener clearance cutouts of Family No. 8 are basically non-tight collars without the addition of the collar plate. Suggestions made for non-tight collars and miscellaneous cutouts are applicable to this family.

The non-tight collar configurations of Family No. 3 experienced only a few failures. There are considerations, however, that must be used by the designer to ensure the continuation of this trend. The cutouts should be provided with smooth, well-rounded radii to reduce stress risers. Where collars are cut in high stress areas, suitable replacement material should be provided to eliminate the over-stressing of the adjacent web plates. These steps should reduce the incidence of plate buckling, fatigue cracking and stress corrosion observed in this family.

There were few failures for Detail Family No. 4, tight collars. Most of the failures for Detail Family No. 5, gunwale connections, were collision and/or abuse where the sheer strake extended above the deck.

There were a small number of failures in structural deck cuts, Family No. 9, but the critical nature of any failure in a structural deck makes it a very important area. Structural deck cuts, because of their location, influence the longitudinal strength of the ship. Therefore, care must be taken to eliminate both notches in the corners and rough spots to reduce the potential for fatigue cracks. Well-rounded corners with radii equivalent to 25% of the width perpendicular to the primary stress flows should be used. Special reinforcements in the form of tougher or higher strength steel, inserts, coamings and combinations of the above should be used where fatigue and high stresses are a problem. Extreme care should be use in locating and sizing all structural deck cuts to reduce the amount of material that is removed from the hull girder and to limit the perforated effect when a number of cuts are located in line athwartship.

For Detail Family No. 7, miscellaneous cutouts, the reasons for failure were as varied as the types of cutouts. Potential problems can be eliminated by the designer if, during detail design, proper consideration is given to the following:

- Use generous radii on all cuts.
- Use cuts of sufficient size to provide proper welding clearances.
- Avoid locating holes in high tensile stress areas.
- Avoid square corners and sharp notches.
- Use adequate spacing between cuts.
- Properly reinforce cuts in highly stressed areas.
- Locate cuts on or as near the neutral axis as possible in beam structures.
- Avoid cuts at the head or heel of a stanchion.
- Plug or reinforce structural erection cuts located in highly stressed areas.

The most damaging crack observed during the surveys was in the upper box girder of a containership. This structure is part of the longitudinal strength structure of the ship, in addition to being subjected to high local stresses due to container loadings on the upper deck. Openings in this structure must be located, reinforced and analyzed for secondary bending streses caused by high shear loads.

In general, failures in stanchion ends, Family No. 10, were cracks which developed in or at the connection to the attachment structure. The addition of tension brackets or shear chocks and the elimination of snipes would reduce the incidence of structural failure. All stanchion end connections should be capable of carrying the full load of the stanchion in tension or compression. Stanchions used for container stands or to support such structures as deckhouses on the upper deck should be attached to the deck with long, tapered chocks to improve stress flows from hull-induced loads, and in no case should "V" notches be designed into such connections.

The stiffener ends in Family No. 11 with sniped webs and/or flanges or square cut ends sustained failures. In nearly all cases, the failures occurred in the attached bulkhead plate, the web connection when the flange was sniped, or the shear clip used for square cut stiffener ends.

Stiffeners that support bulkheads subject to wave slap, such as exposed bulkheads on the upper deck or tank bulkheads, should not be sniped, and suitable backing structure should be provided to transmit the end reaction of the stiffeners.

While sniping stiffeners ensures easier fabrication, any sitffeners subject to tank pressures or impact-type loading should be restrained at the ends and checked for flange stability to prevent lateral instability under load.

Panel stiffeners, Family No. 12, while classified as not being direct load-carrying members, should be designed for the anticipated service load. For instance, panel stiffeners on tank bulkheads, as any other stiffener designed for pressure loads, should be designed to carry their portion of the local load on the panel of plate material. In those instances where panel sitffeners are subject to pressure head loads, the stiffeners should be treated in the same manner as other local stiffening.

Panel stiffeners used as web stiffeners on deep girders should not be expected to restrain the free flange from buckling in the lateral direction unless they are designed as lateral supports.

The design of panel stiffeners should be the same as other local stiffeners with respect to cutouts, notches and other structural irregularities.

3. PERFORMANCE OF STRUCTURAL DETAILS

For the project reported here, most of the details shown in Ref. 59 have been assigned to family groups as shown in Table 3-1 which are more in line with a designer's needs. For example, the previous family groups used for tripping brackets were "one side", "two sides", and "flanged". The comparisons between the first two groups were very useful but the present classification gives a designer the observed alternatives for stabilizing stiffeners, shallow girders, deep girders, hatch girders, and bulwarks.

Within each group, the details are arranged in order of observed performance similar to Ref. 73. For example, in Fig. 3-1, detail 1-B-7 (the first detail in the group) had the best observed performance (204 observations with no failures) while detail 1-B-8 (the last detail in the group) had the worst observed performance (603 observed with 45 failures for a 7.5% failure rate). In these figures a minus (-) indicates a crack of weld or base material while a plus (+) indicates failure by buckling. Since the major difference in performance has been in naval versus commercial ship details, the observations on naval ships are shown in parentheses followed by an "N". Where the detail has been used on both naval and commercial ships, the first figures shown are the total observations (naval plus commercial).

Since Stiffener Clearance Cutout Details (Family No. 8) are closely related to Non-tight or Tight Collar Details (Family Nos. 3 and 4), they will be discussed first. Similarily, Deck Cutout Details (Family No. 9) are more important and will be discussed before Miscellaneous Cutout Details (Family No. 7).

In Figs. 3-1 through 3-16, a total of 220 details are either combined with similar geometries or eliminated to help focus on the most significant good and bad design features. A total of 38 details are combined with similar details when the slight differences in detail geometry had no apparent impact on service performance. For example, details 1-C-20 and 1-C-21 have a slight difference in the shape of the bracket yet both performed without failure so their survey results are combined in Fig. 3-2. In another example, many of the miscellaneous cutouts of Family No. 7 have been regrouped by location rather than by function. This reduces the number of details considered because the same geometry can serve many functions such as an air escape, drain hole, pipeway, wireway or weld clearance hole. Within each family group, a further 182 details were eliminated because of relatively infrequent observed use. This leaves 414 details in Figs. 3-1 through 3-16. The full list of 634 details ranked as described above can be found in Ref. 73.

TABLE 3-1

REVISED CLASSIFICATION OF DETAILS

Beam Bracket Details - Family No. 1

Structurally Continuous - Physically Intercostal Beams
- Plate Bracket Without Bulkhead Stiffener
- Built-Up Bracket Without Bulkhead Stiffener
- Plate Bracket In Way of Bulkhead Stiffener
- Built-Up Bracket In Way of Bulkhead Stiffener
- Built-Up Bracket In Way of Girder

Straight Corner Brackets
- Plate
- Flanged
- Built-Up

Curved Corner Brackets
- Plate
- Built-Up

Hatch Girder End Brackets

Beam End Brackets
- At "Soft" Plating
- At Structural Sections
- Plates at Rigid Structure
- Flanged at Rigid Structure
- Built-Up at Rigid Structure

Tripping Bracket Details - Family No. 2

For Stiffeners
For Shallow Girders
For Deep Girders
For Hatch Girders
For Bulwarks

Stiffener Clearance Cutout Details - Family No. 8

Bars
Bulb Flats
Angles
Tees

Non-Tight Collar Details - Family No. 3

Bars
Bulb Flats
Angles
Tees

Tight Collar Details - Family No. 4

Bars
Bulb Flats
Angles
Tees

Gunwale Connection Details - Family No. 5

Riveted
Welded

Deck Cutout Details - Family No. 9

Not Reinforced
Reinforced
Hatch Corners

Miscellaneous Cutout Details - Family No. 7

Access Openings
Lapped Web Openings
In Way of Corners
In Way of Plate Edge
Miscellaneous

Stanchion End Details - Family No. 10

Top of Circular Stanchions
Bottom of Circular Stanchions
Top of "H" Stanchions
Bottom "H" Stanchions

Load Carrying Stiffener End Details - Family No. 11

Full Connection
Padded
Lapped
With End Chocks
With Clips
Sniped

Panel Stiffener Details - Family No. 12

Flat Bars
Shapes
Flat Bars on Girder Webs In Way of Longitudinals
Flat Bars on Girder Webs
Flanged

3.1 BEAM BRACKET DETAILS - FAMILY NO. 1

3.1.1 Brackets for Structurally Continuous - Physically Intercostal Beams

3.1.1.1 Plate Brackets Without Bulkhead Stiffeners

The primary problem area with these details is the hard spot the bracket gives to the bulkhead plating (see Fig. 3-1). Most of the failures observed were cracks in the bulkhead. Detail 1-B-9 is close to the original T2 tanker design. This and similar designs have been extensively analyzed and tested (Refs. 2, 6, 8, 10, 17, 18, 34, 40 & 67). In addition to the bulkhead, cracks have been observed in the plate bracket and in the attached shell plating. The service experience of this and similar details has led to improved details being fitted in subsequent ships. Generally, the stiffening is now continued through the bulkhead plating with some bulkhead stiffening fitted to reduce the hard spot caused by the stiffener flange.

3.1.1.2 Built-Up Brackets Without Bulkhead Stiffeners

The two details of this group were only observed on naval ships. The hard spot on the bulkhead plating is distributed over the width of the stiffener flange so it is less severe than that of the previous group. Detail 1-A-11 should have tangency chocks at the flange knuckle. No failures were observed but these details should not be used whenever there is a significant load on the bulkhead plating.

3.1.1.3 Plate Bracket In Way of Bulkhead Stiffener

Only one detail was observed in this group and no failures were observed.

3.1.1.4 Built-Up Bracket In Way of Bulkhead Stiffener

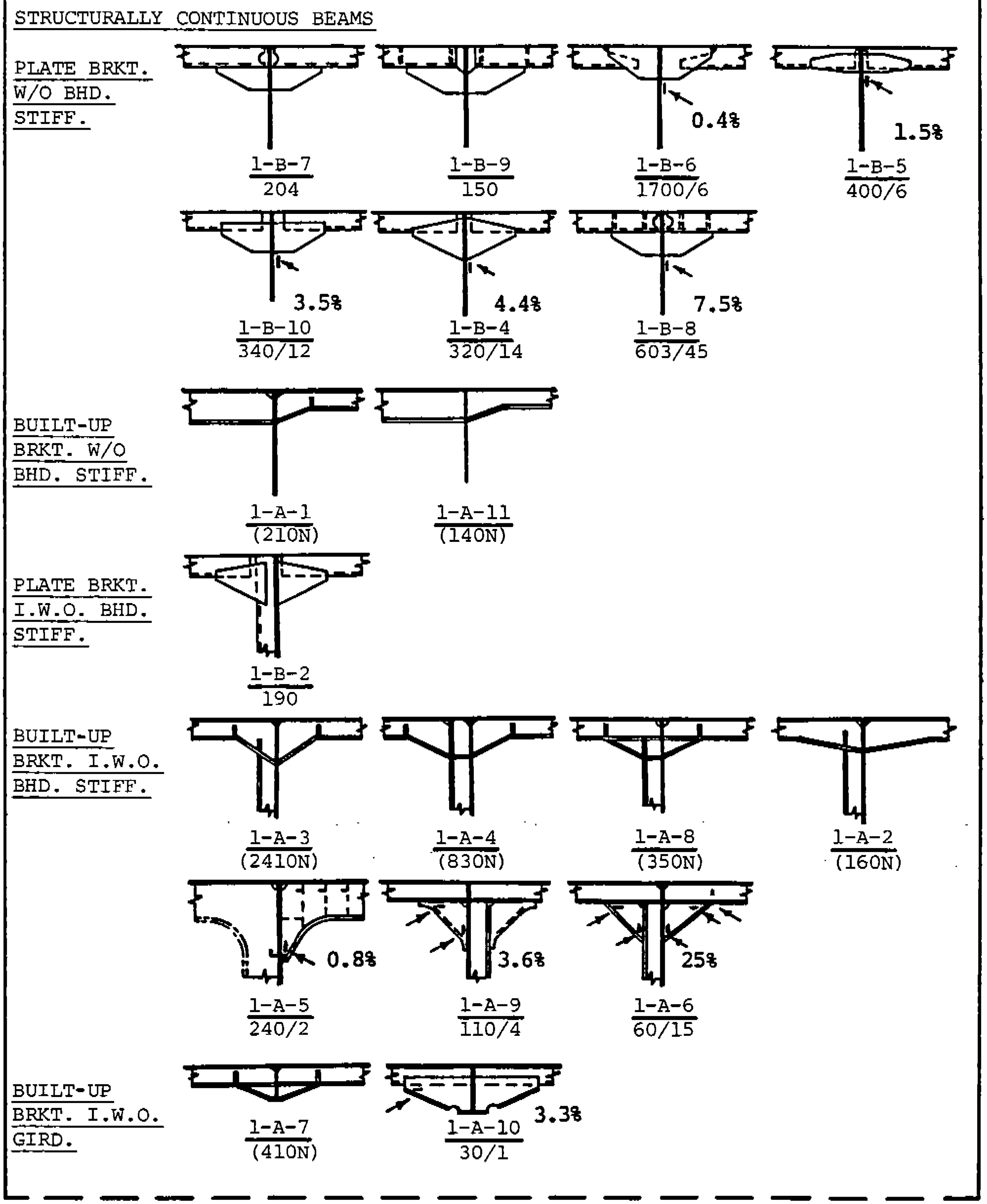
The first four details in this group were used on naval ships and no failures were observed. The last three details were used on commercial ships and failures were observed on all three. The failures were due to a combination of factors including sniping of flanges or welding in the flanges but then omitting the chocks backing up the bracket flanges. In detail 1-A-2 the flange knuckle was sufficiently small that tangency chocks could be eliminated. The stress concentrations which can occur when backup chocks are omitted are well illustrated in Ref. 52.

3.1.1.5 Built-Up Bracket In Way of Girder

This group performed similar to the previous one: the naval detail (which had symmetric sections and adequate chocking) showed no failures while the commercial detail (which had asymmetric sections and lapped joints) had a failure.

FIGURE 3-1

PERFORMANCE OF BEAM BRACKET DETAILS-FAMILY NO. 1



3.1.2 Straight Corner Brackets

3.1.2.1 Plate

A wide variety of flat plate corner brackets have been used on commercial ships (Fig. 3-2) with only a few observed on naval ships. In some cases both stiffeners are cut clear at their ends (e.g., details 1-C-4 and 1-C-9) while in others at least one stiffener end is welded in (e.g., details 1-C-20 & 21 and 1-C-3) and in one case a chock was added to increase the lateral stiffness of the joint (detail 1-C-5). Failures have been observed in more than half of the configurations with buckling as the predominant failure mode. Providing adequate bracket thickness to prevent buckling is the primary design problem. Most of these details provide very little lateral restraint to the attached stiffening so other details are preferred where the stiffening is heavily loaded.

3.1.2.2 Flanged

Adding a flange to the flat plate corner brackets eliminates most of the buckling failures. A few still occur probably because these commercial ship sections are asymmetric. The weak link in this group is the bracket welding which must transfer the entire load between the stiffeners in most cases.

3.1.2.3 Built-Up

The built-up straight corner brackets performed without failure and are characteristic naval ship details (i.e., symmetric sections, flange ends welded in and backed up, etc.). Detail 1-G-4 would only be adequate for moderately loaded structures because of the missing tangency chocks.

3.1.3 Curved Corner Brackets

3.1.3.1 Plate

Using a radiused cut on the inside of a flat plate bracket improves the stress flow and stiffness distribution of these details. Consequently, these details performed better than their straight counterparts. A few cracks and buckles were observed, however. In fatigue tests curved corner brackets have performed much better than straight corner brackets (Ref. 35).

3.1.3.2 Built-Up

Adding a curved flange to a flat plate bracket requires careful design. Additional out-of-plane bending stresses are introduced into the flange if the radius is too small. This causes a loss in flange efficiency as discussed in Refs. 25, 46, and 49 (pg. 7-5). Chocks and additional panel stiffening such as that shown in detail 1-F-3 are often required for this group.

FIGURE 3-2

PERFORMANCE OF BEAM BRACKET DETAILS-FAMILY NO. 1-Cont'd

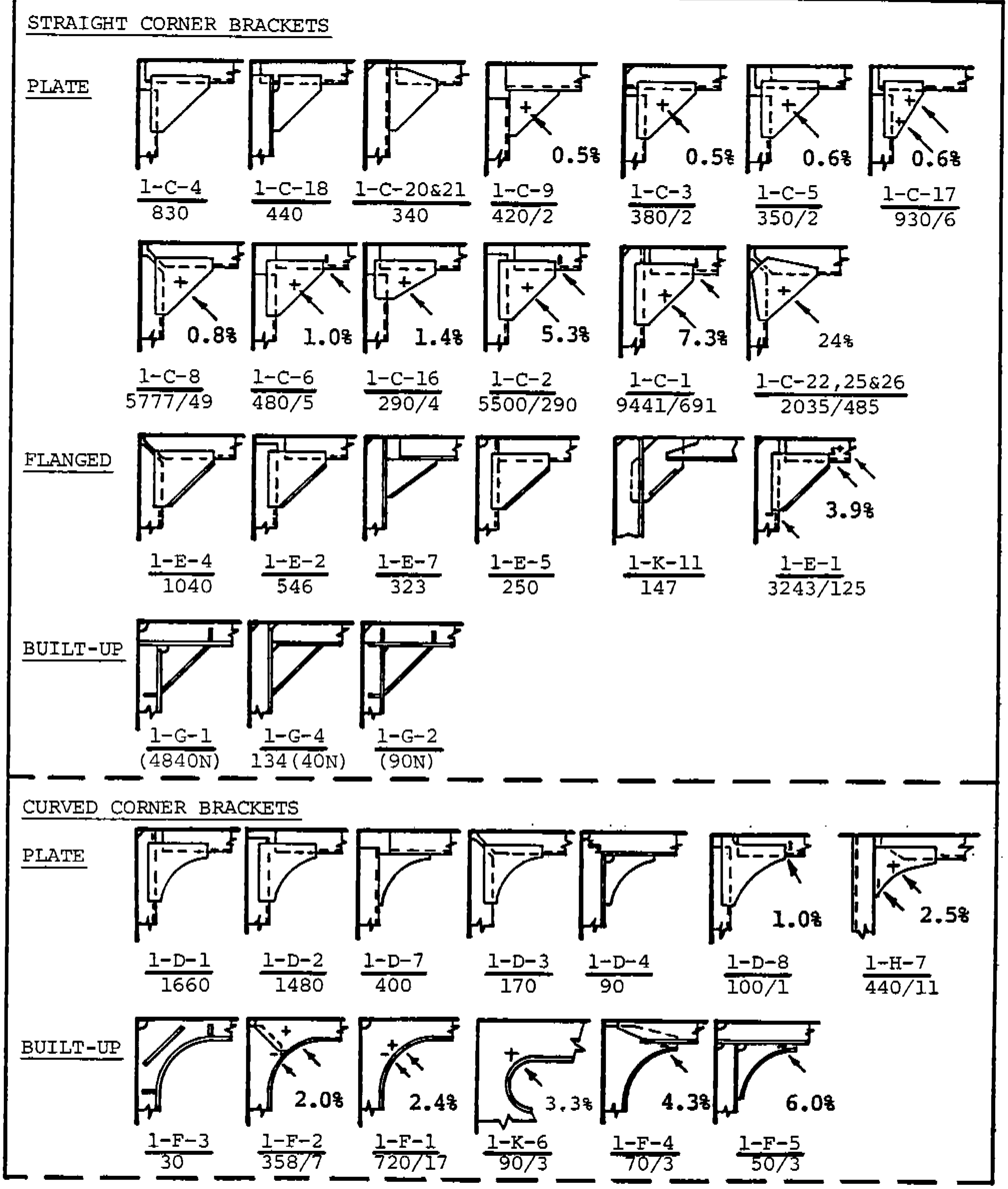
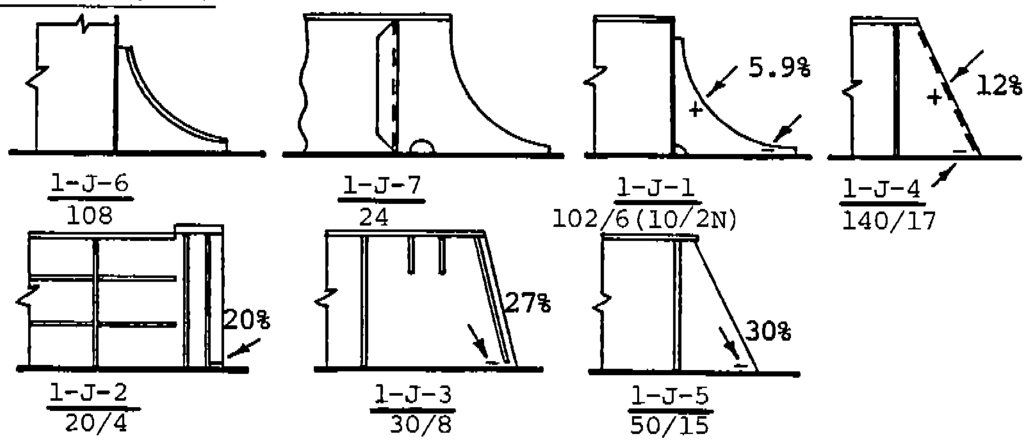


FIGURE 3-3

PERFORMANCE OF BEAM BRACKET DETAILS-FAMILY NO. 1-Cont'd

HATCH GIRDER END BRACKETS



3.1.4 Hatch Girder End Brackets

End brackets with large radii and adequate plate thickness performed well. Cracks can be expected with near right angle ends because of the hard spot.

3.1.5 Beam End Brackets

3.1.5.1 At "Soft" Plating

Whenever structural beams terminate on plating which is subject to hydrostatic loading, the connection needs to be reinforced. The most desirable connection both for the stiffener and the plating is a bracket extending to another stiffener on the plating such as in details 1-H-6 and 1-K-1. Other alternatives are discussed under Stiffener End Details - Family No. 11.

3.1.5.2 At Structural Sections

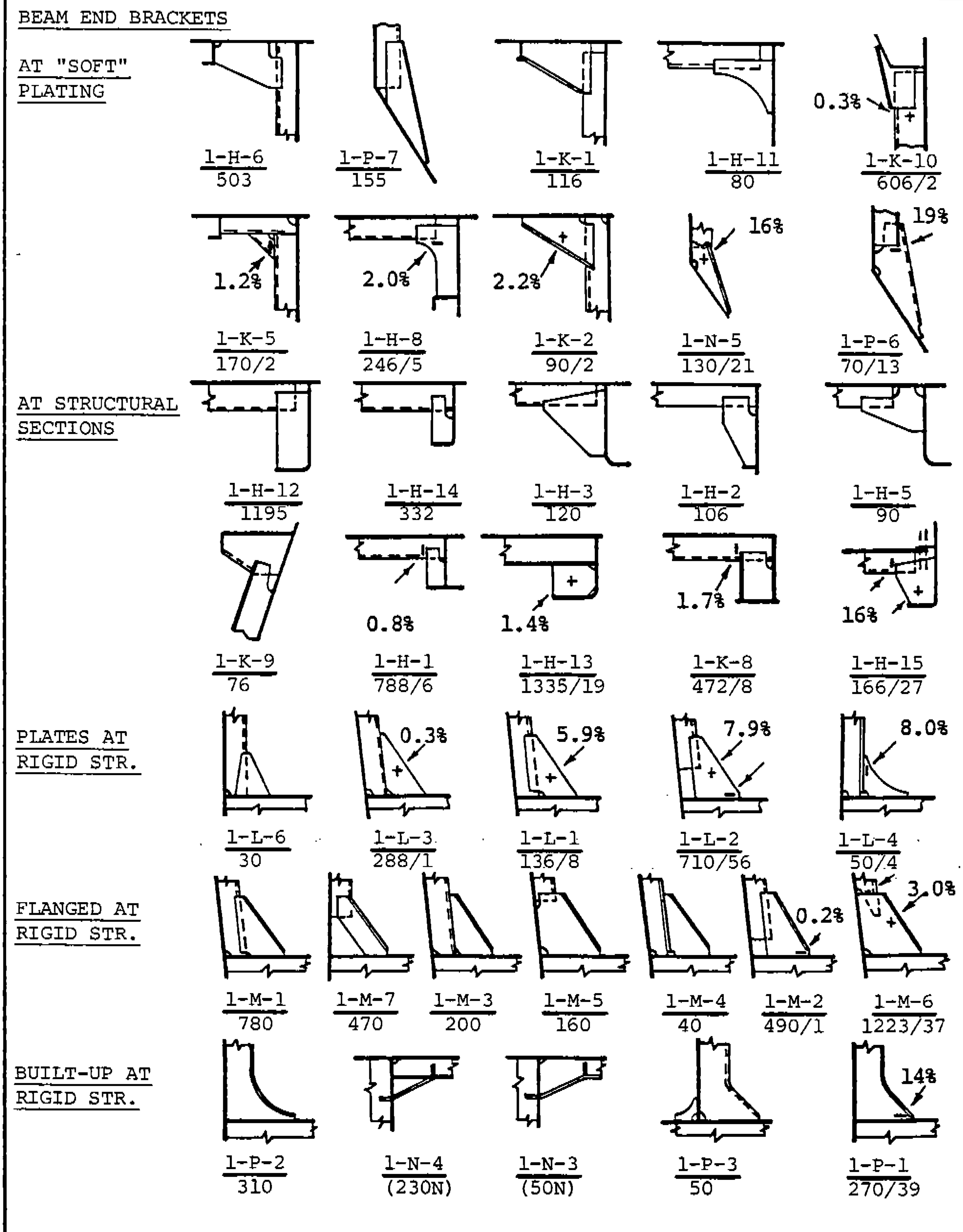
Beams ending on structural sections are not as severe a problem as the previous group. A bracket at this location generally serves two functions: providing the desired beam end support and also providing lateral support to the deeper structural section (girder, stringer, hatch girder, etc.). With only a few exceptions, the observed variations in this group are well designed.

3.1.5.3 Plates at Rigid Structure

End brackets made from flat plates suffer the same problems as the corresponding corner brackets: buckling due to insufficient bracket thickness and eccentric connections.

FIGURE 3-4

PERFORMANCE OF BEAM BRACKET DETAILS-FAMILY NO. 1-Cont'd



3.1.5.4 Flanged at Rigid Structure

These details performed reasonably well as would be expected from a comparison to corner brackets. A few cracks and buckles were observed, however.

3.1.5.5 Built-Up at Rigid Structure

A generous radius such as in detail 1-P-2 or typical naval ship geometries such in details 1-N-4 and 1-N-3 provide satisfactory service in this group.

3.2 TRIPPING BRACKET DETAILS - FAMILY NO. 2

3.2.1 For Stiffeners

This group (see Fig. 3-5) was relatively trouble free: only a few cracks and buckles were observed. Some of the details only provide limited lateral support (for the web only in details 2-B-18, 2-A-21, and 2-A-30). Others would only provide lateral support for relatively light stiffening on thick plating (details 2-A-19 and 2-A-17). unless the bracket is backed up by structure on the opposite side of the plating. Lateral support on one side of the stiffener appears to be sufficient.

3.2.2 For Shallow Girders

The relatively few observed failures in this group were cracks at sharp corners or lapped welds. However, sharp corners and lapped welds performed well on details very similar to those with failures. Hence the failures must be on heavily loaded structures or those poorly fabricated or maintained. Brackets on one side of the member seem to perform as well as those on both sides except in special cases. One special case would be at knuckles in the flange of the girder.

3.2.3 For Deep Girders

More failures were observed in this group than in the previous two groups combined. This shows a trend for larger structures to have more problems than smaller ones. One sided brackets seem to perform as well as two sided brackets except in special cases. Buckling seems to be a more severe problem (75% of the failures) than cracking. Even reasonably stable details such as 2-C-25 had a significant number of buckling failures which would indicate quite high lateral loads.

3.2.4 For Hatch Girders

Tripping brackets on hatch girders (Fig. 3-6) have a long history of problems. The failures were attributed to poor welding, poor maintenance, abuse, and inadequate design. Many of the latter were found on containerships whose hatch girders receive large lateral loads from rolling when containers are stacked up to four tiers high on the hatches. Loads from heavy seas on

FIGURE 3-5
PERFORMANCE OF TRIPPING BRACKET DETAILS-FAMILY NO. 2

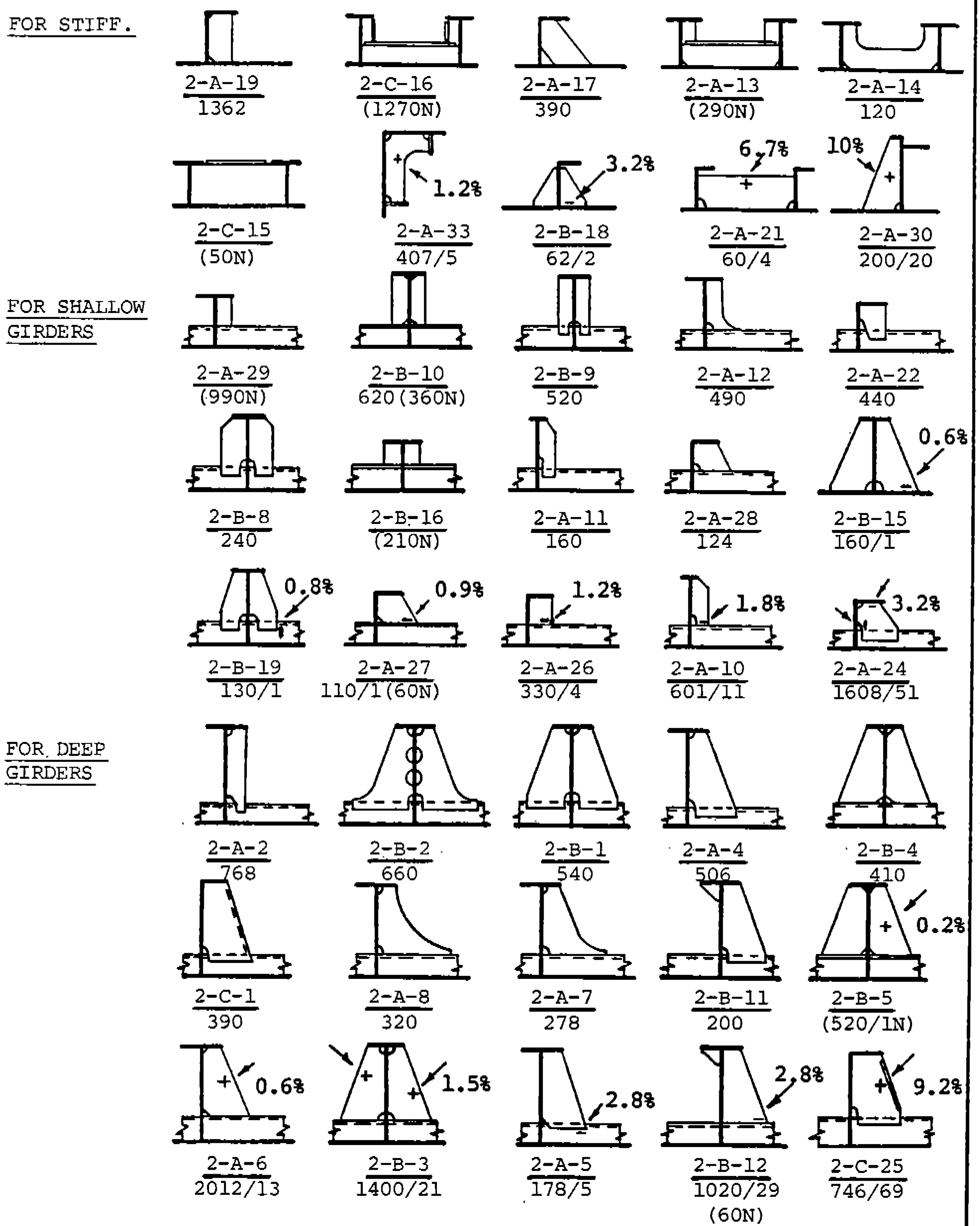
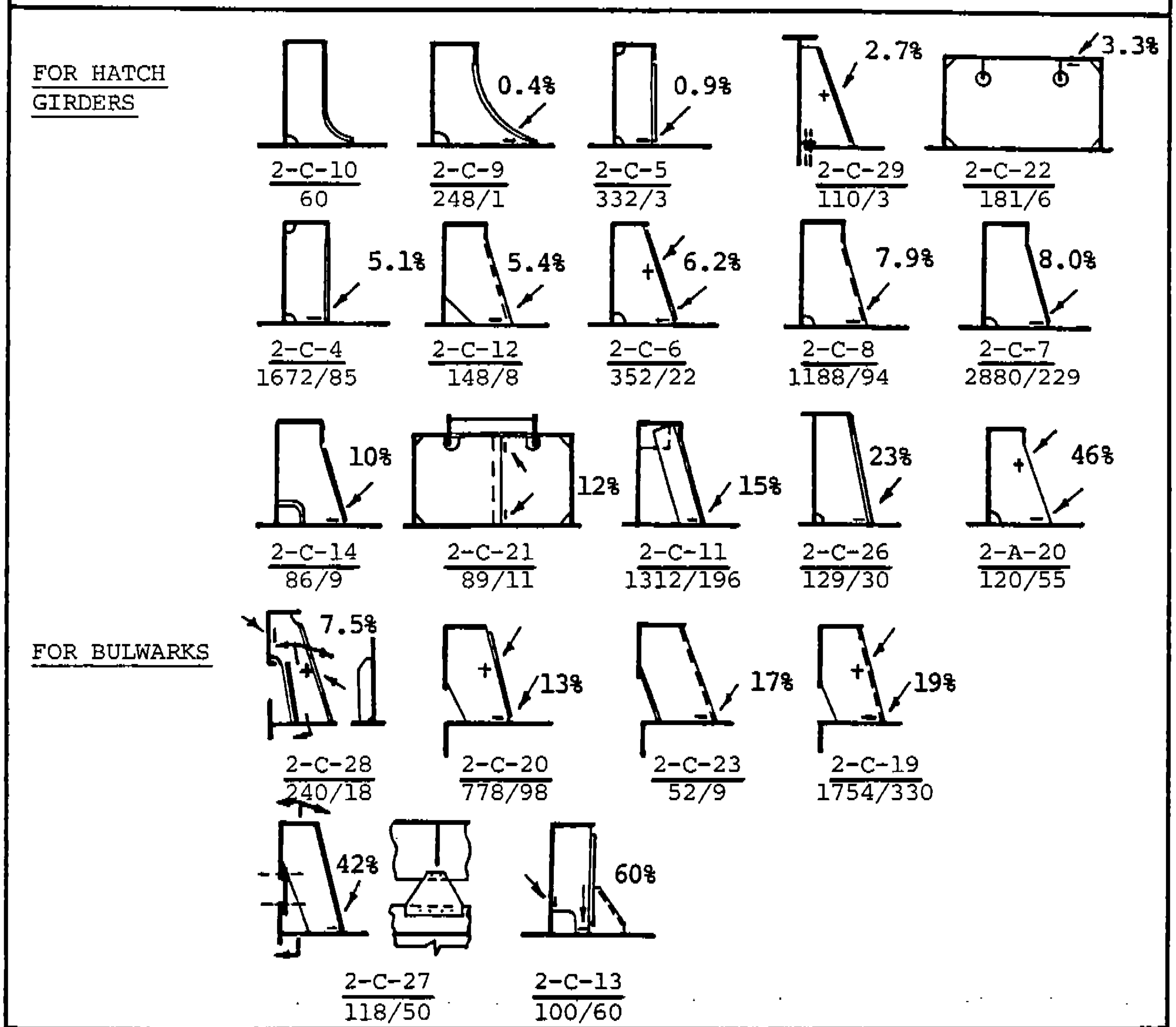


FIGURE 3-6

PERFORMANCE OF TRIPPING BRACKET DETAILS-FAMILY NO. 2-Cont'd



bulk carriers were also a problem. Under such loadings these brackets become load carrying structural members which require careful design in contrast to normal tripping brackets whose primary function is to merely provide lateral support to load carrying members.

3.2.5 For Bulwarks

Failures were observed in all details assigned to this group for many of the same reasons as hatch girder tripping brackets. In addition, many bulwark brackets received much abuse from cargo handling. Failures were also observed where bulwarks were used as tie down points to secure the booms of general cargo ships. Careful design and adequate backup structure below the deck is needed for bulwark brackets. Other bulwark failures are discussed in Ref. 24.

3.3 STIFFENER CLEARANCE CUTOUT DETAILS - FAMILY NO. 8

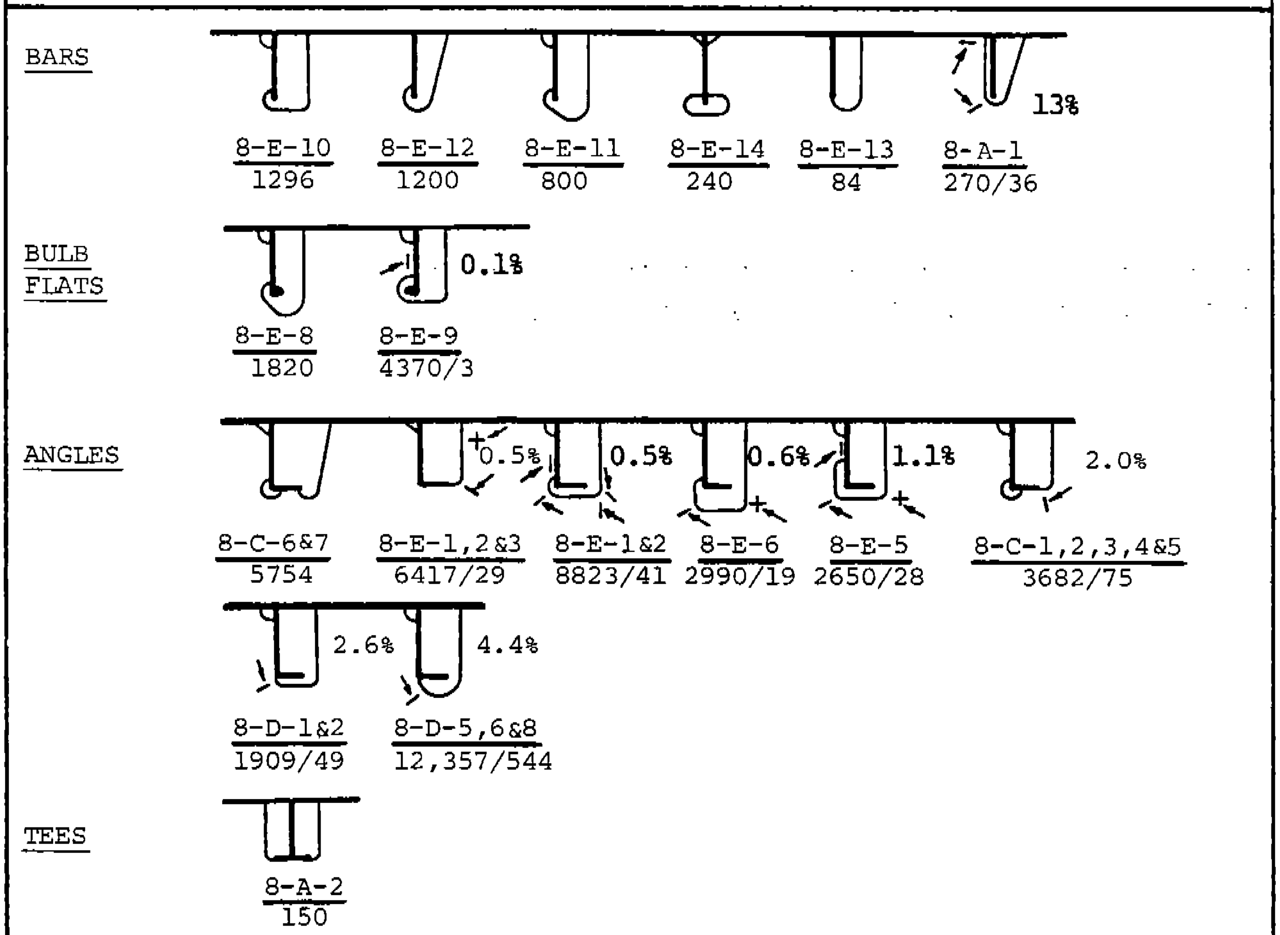
The function of this family (Fig. 3-7) is to provide for passing a stiffening member through other structure such as a girder or a non-tight bulkhead. In addition, the details generally provide a shear attachment for moderately loaded stiffeners. When the lateral load on the stiffener becomes large, additional connection is provided by non-tight collars (see Family No. 3) and/or other stiffening (see Family No. 12-C). The general features which provide successful service are well rounded cutouts free from designed in or fabricated notches and an adequate shear connection for the stiffener.

3.3.1 Bars

In addition to four successful details in this group, one potential problem detail and one problem detail was observed. The latter (detail 8-A-1) had no shear connection to the flat bar and was generally observed on brackets supporting bulwarks of general cargo ships. The reduction in shear area of the bracket was the apparent cause of the failures. The potential problem detail (8-E-13) requres careful fitting and welding to avoid problems. Any trimming of this cutout to correct fittup errors can introduce notches at the lower end of the flat bar and it is difficult to properly wrap the ends of the fillet welds at this point.

FIGURE 3-7

PERFORMANCE OF STIFFENER CLEARANCE CUTOUT DETAILS-FAMILY NO. 8



3.3.2 Bulb Flats

The two details in this group performed well although there were a few failures in detail 8-E-9 attributed to an inadequate shear attachment for the stiffener and poor welding.

3.3.3 Angles

A large variety of geometries has been observed for this group with failures in many of them. The causes of failures were equally varied: poor design, fabrication or welding along with neglect, heavy seas, and minor collisions. Apparently these details provide an inadequate shear attachment for the angles in many cases along with notches which should be avoided. In addition, cracks were observed at well rounded cutouts along with some buckling. This would indicate that collar plates and/or additional stiffening should have been fitted in many cases. Providing a flange connection in addition to the normal web connection for these details seems to reduce the overall failure rate by two-thirds (15,853 observations with 104 failures = 0.7% versus 28,729 observations with 681 failures = 2.4%).

3.3.4 Tees

Detail 8-A-2 provides only a flange attachment which makes it suitable only for very lightly loaded structures. Similar flange only connections for lightly loaded angle shapes have also been observed (Ref. 39).

3.4 NON-TIGHT COLLAR DETAILS - FAMILY NO. 3

Non-tight collars (Fig. 3-8) provide two basic functions: increased shear attachment for the stiffening member and reinforcement of the opening in the penetrated plate. As a group, these details performed much better than the simple clearance cutouts of Family No. 8 with almost an order of magnitude difference in the failure rates (0.16% versus 1.47%, Fig. 2-14).

3.4.1 Bars

Only two configurations are shown for this group. The cutout for the first seems unusually complicated while the second appears to be an attempt to utilize the greater ductility of longitudinally loaded versus transversely loaded fillet welds.

3.4.2 Bulb Flats

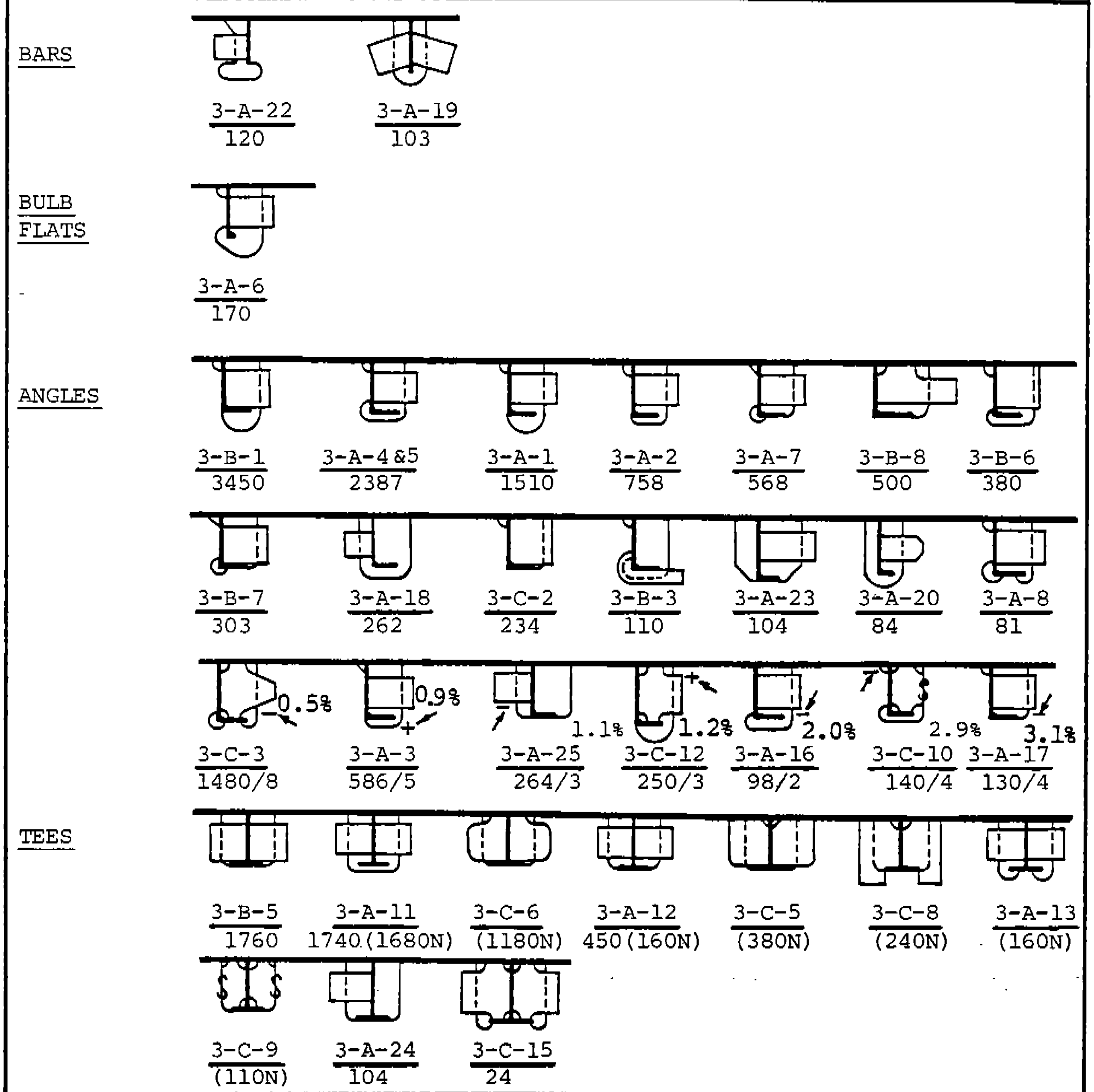
The one detail observed for bulb flats shows the characteristics of most successful collar details: well rounded cutouts, adequate margins for trimming, and adequate access for welding and painting.

3.4.3 Angles

As with stiffener clearance cutouts, a wide variety of non-tight

FIGURE 3-8

PERFORMANCE OF NON-TIGHT COLLAR DETAILS-FAMILY NO. 3



collar details for angles was observed. The failure rate for these details is very small and does not seem to be related to whether or not a stiffener flange attachment is provded.

3.4.4 Tees

There were no observed failures in this group of predominantly naval ship details. Providing only a web attachment for the stiffeners as in detail 3-A-11 seems adequate for most applications. Flush collars such as detail 3-C-9 should only be required for relatively thick penetrated plates and high stress locations.

3.5 TIGHT COLLAR DETAILS - FAMILY NO. 4

In addition to providing a shear attachment for the stiffener, tight collars (Fig. 3-9) must also ensure the watertight or oiltight integrity of the penetrated bulkhead. If the bulkhead must withstand a significant hydrostatic load, additional stiffening is generally required to avoid a hard spot where the stiffener penetrates the bulkhead as discussed for the first two groups of details for Family No. 1. The observed failure rate for tight collars is low and approximately the same as for non-tight colars.

3.5.1 Bars

The detail most often observed for this group is merely a slot in the bulkhead which, of course, requires careful fitting. The three piece lapped collar of detail 4-C-7 would appear to offer little advantage over the single piece lapped collar of detail 4-C-1 to offset the additional welding required. Flush collars such as detail 4-C-2 should only be necessary on relatively thick bulkheads at high stress locations.

3.5.2 Bulb Flats

Again the most observed detail for this group is a simple slot in the bulkhead. A two piece lapped collar would be a suitable alternative for many applications although none were observed.

3.5.3 Angles

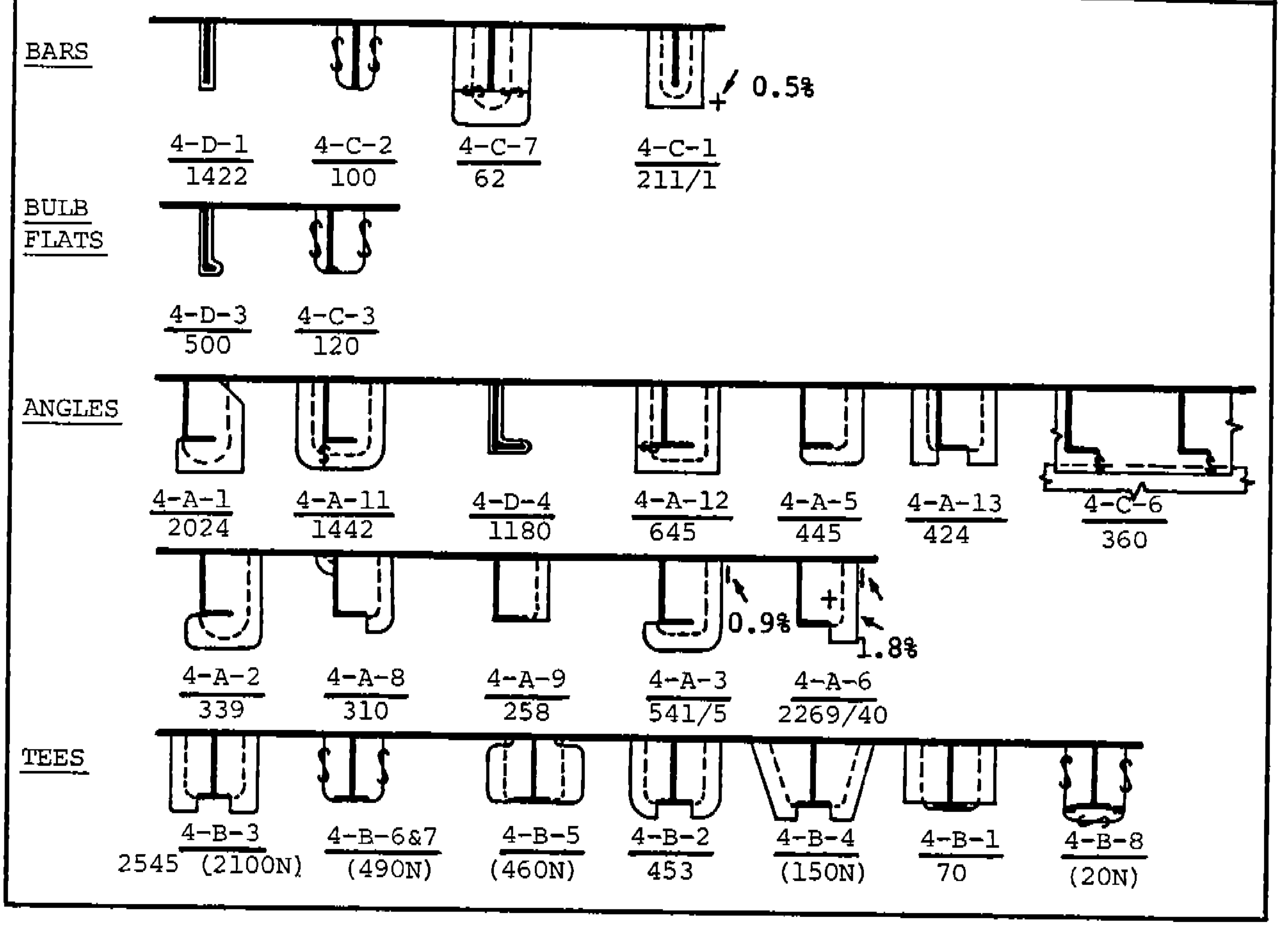
Most of the details observed in this group are lapped collars although a reeving slot was observed a significant number of times. The few failures observed were attributed to neglect and minor collisions. A flush collar plate might be desirable for thick bulkheads although none were observed.

3.5.4 Tees

The majority of details observed were lapped collars on naval ships. A number of flush collars were also observed on naval ships. No reeving slots and no failures were observed.

FIGURE 3-9

PERFORMANCE OF TIGHT COLLAR DETAILS-FAMILY NO. 4



3.6 GUNWALE CONNECTION DETAILS - FAMILY NO. 5

3.6.1 Riveted

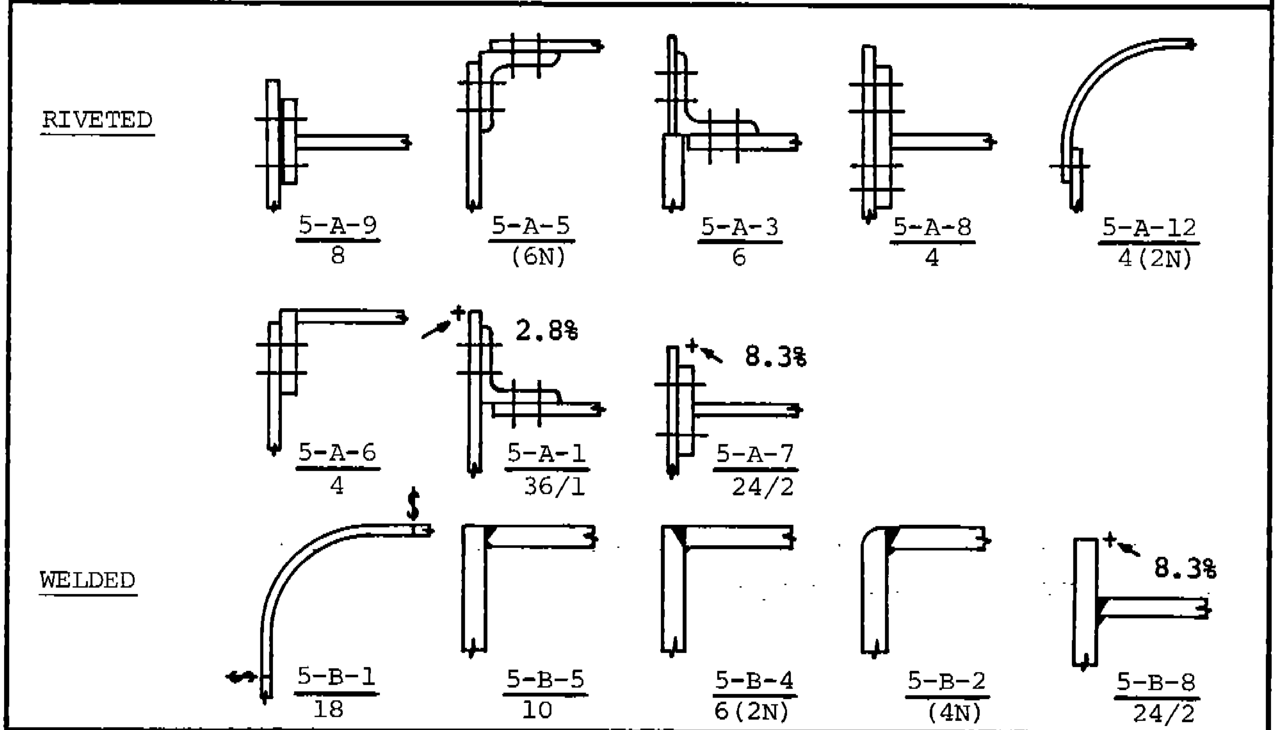
There were only two detail types in this group (Fig. 3-10) to experience failures and both cases were attributed to collision and/or abuse in details where the sheer strake extended above the deck. Since the performance of all the details is satisfactory the simplest design is the obvious choice.

3.6.2 Welded

Only one of the five types of welded gunwale connections shown failed. As was the case with riveted connections, the cause of failure was collision and/or abuse on the vulnerable portion of the sheer strake which extended above the deck.

FIGURE 3-10

PERFORMANCE OF GUNWALE CONNECTION DETAILS-FAMILY NO. 5



3.7 DECK CUTOUT DETAILS - FAMILY NO. 9

3.7.1 Not Reinforced

The unreinforced deck cutouts observed (Fig. 3-11) are small openings normally used for access. Generally stiffening members are fitted a few inches from the opening. This group performed surprisingly well with only one failure observed which was at a fairly small radius corner. The features which promote good service are large corner radii, smooth cuts, and a location in low stress areas of the deck (see examples in App. A and B of Ref. 49 and Fig. 2-6 of Ref. 10).

3.7.2 Reinforced

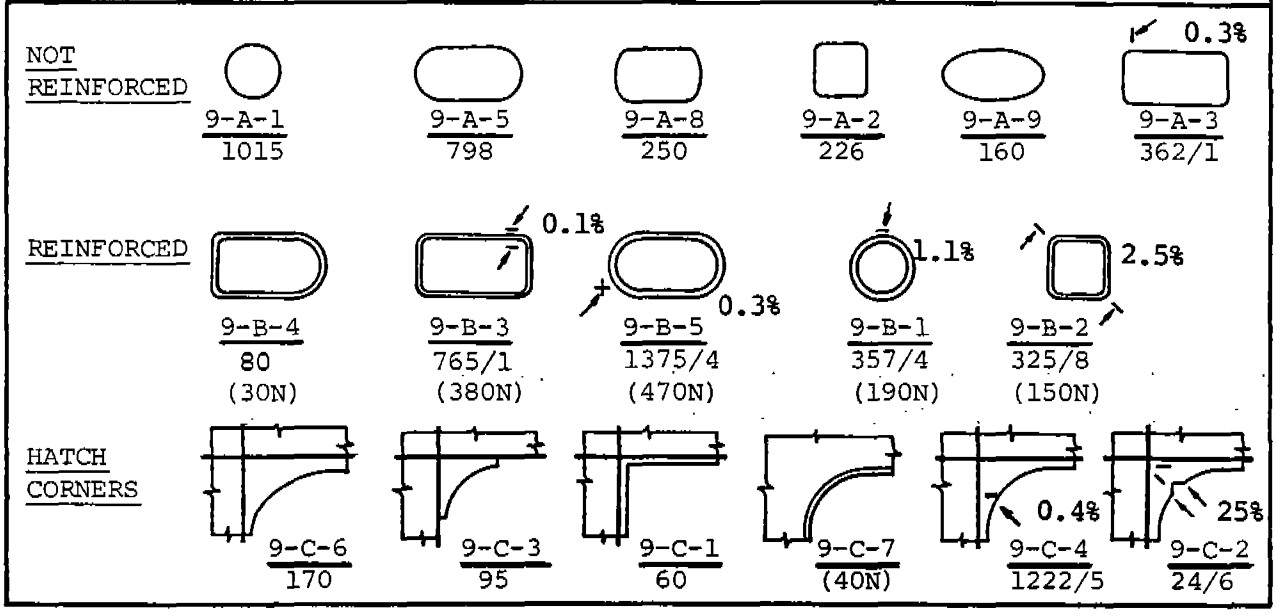
This group also consists of relatively small openings normally used for access. The reinforcement consists of a flat bar either centered on, or to one side of, the deck plating. Seventeen failures were observed which were attributed to poor fabrication, poor welding, neglect, abuse, heavy seas, and minor collisions. Again, large corner radii and low stress locations are desirable.

3.7.3 Hatch Corners

The relative size of hatches on many ships requires careful design of the corners of the deck cut. This is particularly true on large containerships which are inherently torsionally flexible (Refs. 21, 31, and 60). A total of eleven failures were observed. The five in detail 9-C-4 were due to a combination of poor welding, neglect, and minor collisions. The six failures in detail 9-C-2 were due to poor design. A notch was cut into the smooth corner radius to accommodate a container guide rail. A surprising number (60) of functionally sound square corner cuts (detail 9-C-1) were observed on bulk and combination carriers. Such details are not recommended even in low stress areas.

FIGURE 3-11

PERFORMANCE OF DECK CUTOUT DETAILS-FAMILY NO. 9



3.8 MISCELLANEOUS CUTOUT DETAILS - FAMILY NO. 7

3.8.1 Access Openings

The most successful access openings observed (Fig. 3-12) were small, flat oval, unreinforced cuts (detail 7-A-3). Large, square cornered cuts sustained failures even when reinforced by a coaming. In general, the large openings are reinforced while the small ones need not be if located in low stress areas of the ship.

3.8.2 Lapped Web Opening

Lapped web openings performed fairly well with most of the failures being attributed to poor fabrication and welding. The three failures of detail 7-D-1 were attributed to heavy seas.

3.8.3 In Way of Corners

Cuts in corners are used primarily for drainage (group 7-C details) or to provide clearance for welding (group 7-H details). Generally they perform well. The straight corner snipes of details 7-C-16 and 7-H-9 were observed to perform slightly better (0.10% failure rate) than the radiused cuts of details 7-C-15 and 7-H-10 (0.15% failure rate). This is somewhat surprising because it is easier to wrap the ends of the welds with the latter details. The difference in observations (77,130 for the former details versus 32,533) may account for the slight different in failure rates.

3.8.4 In Way of Plate Edges

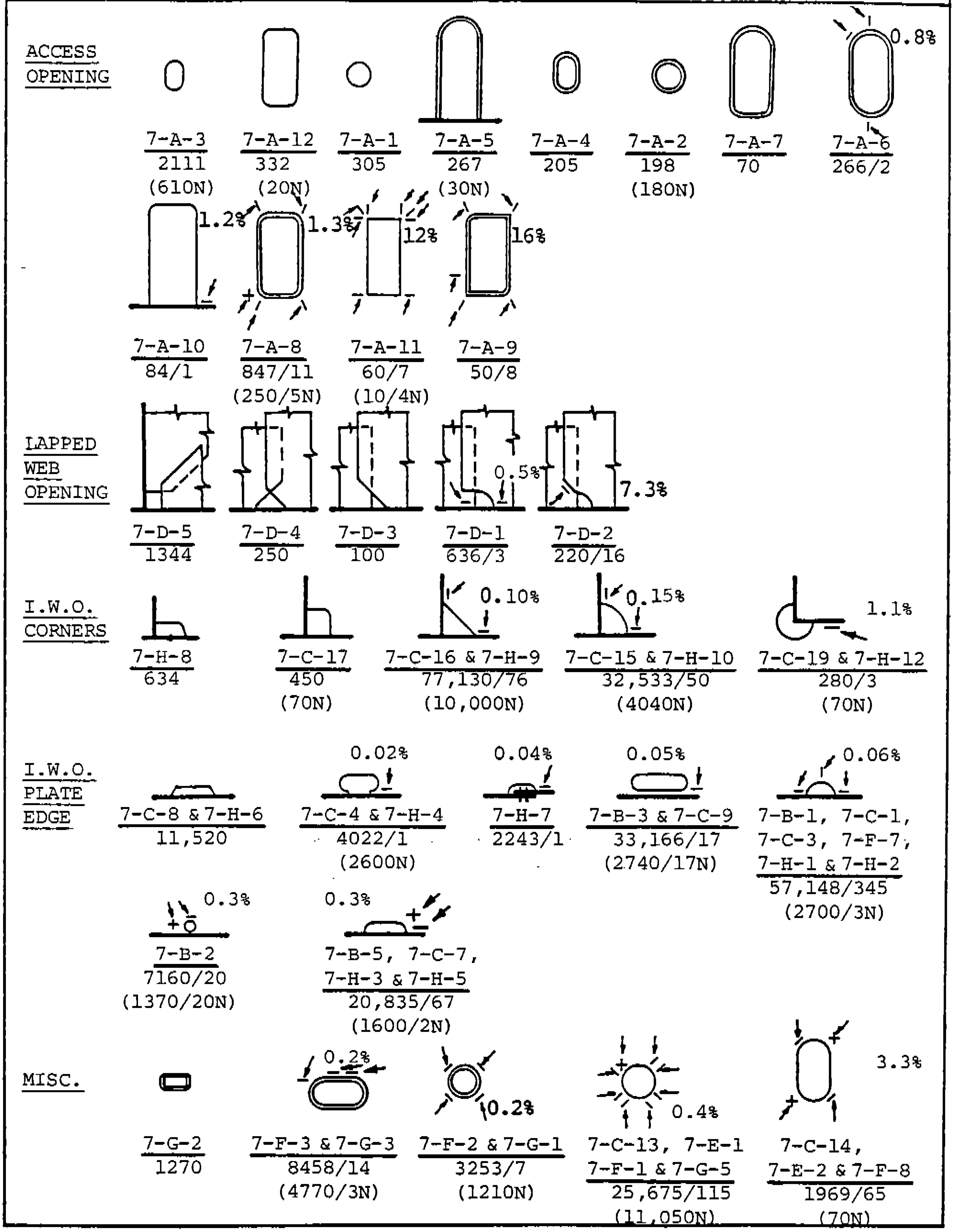
At the edges of plates, cuts are used primarily for air escapes (group 7-B details), drainage (group 7-C details), pipeways (group 7-F details), or weld clearance (group 7-H details). Again the failure rate is relatively small with a large number of observations. Most of the failures observed were in detail 7-H-1 which were attributed to poor design, fabrication, and welding along with heavy seas and minor collisions.

3.8.5 Miscellaneous

The cuts assigned to this group are used primarily for drainage (group 7-C details), lightening the structural member (group 7-E details), pipeways (group 7-F details), and wireways (group 7-G details). Most of the failures were observed in lightening holes (details 7-E-1 and 7-E-2). Lightening Holes were oberved on all seven ship types although failures were observed mostly on tankers and combination carriers. Some of the openings were in regions of high shear and secondary bending stresses and some failures were attributed to loadings from heavy seas. Ship personnel have indicated that the metal at the edges is susceptible to rapid corrosion and the holes in horizontal structure are dangerous. Consequently, it would appear most desirable to eliminate lightening holes except for very weight critical structures or where the holes are also needed for other functions such as drainage, emergency access, etc.

FIGURE 3-12

PERFORMANCE OF MISCELLANEOUS CUTOUT DETAILS-FAMILY NO.7



3.9 STANCHION END DETAILS - FAMILY NO. 10

3.9.1 Top of Circular Stanchions

The majority of designs examined (Fig. 3-13) seemed to perform satisfactorily. Since the satisfactory designs included both relatively simple and complex configurations, the obvious choice in any given situation would be the simplest (cheapest) detail meeting the requirements.

3.9.2 Bottom of Circular Stanchions

Only one detail out of this group of 10 had any serious problems. Detail 10-B-9 performed exceptionally poorly with a 100% failure rate. Two closely spaced stanchions resulted in their stiffening chocks running into each other and being butt welded along this vertical intersection. Where the vertical butt weld met the sloping upper edge of the chocks a sharp "V" was formed resulting in a point of stress concentration and eventual failure.

3.9.3 Top of "H" Stanchions

Most of these details performed well (Fig. 3-14). The failures in details 10-C-6 and 10-C-35 were attributed to abuse and/or minor collisions so their geometry is not necessarily suspect. Details 10-C-1 and 10-C-5 should be avoided whenever possible. The former supports a stiff stanchion by a relatively flexible beam with built in notches at the intersections. The latter also has built in notches along with an inadequate end connection.

3.9.4 Bottom of "H" Stanchions

Failures in two details (10-B-15 and 10-B-25) were attributed to abuse and/or minor collisions. Four of the remaining unsatisfactory details (10-B-21, 10-B-28, 10-B-22, and 10-B-26) had a common characteristic which was not found in any of the successful details of this group. These four stanchion bottoms are elevated somewhat on pedestal like structures formed by fitting a chock between the supporting deck and a large horizontal stiffener (similar to a built up angle). Cracks were observed between the chocks and stiffener and/or the chocks and deck. All of these stanchion bases are asymmetric in at least one plane and the cracks were found in locations where they might be expected to develop while resisting eccentric loads.

FIGURE 3-13

PERFORMANCE OF STANCHION END DETAILS-FAMILY NO. 10

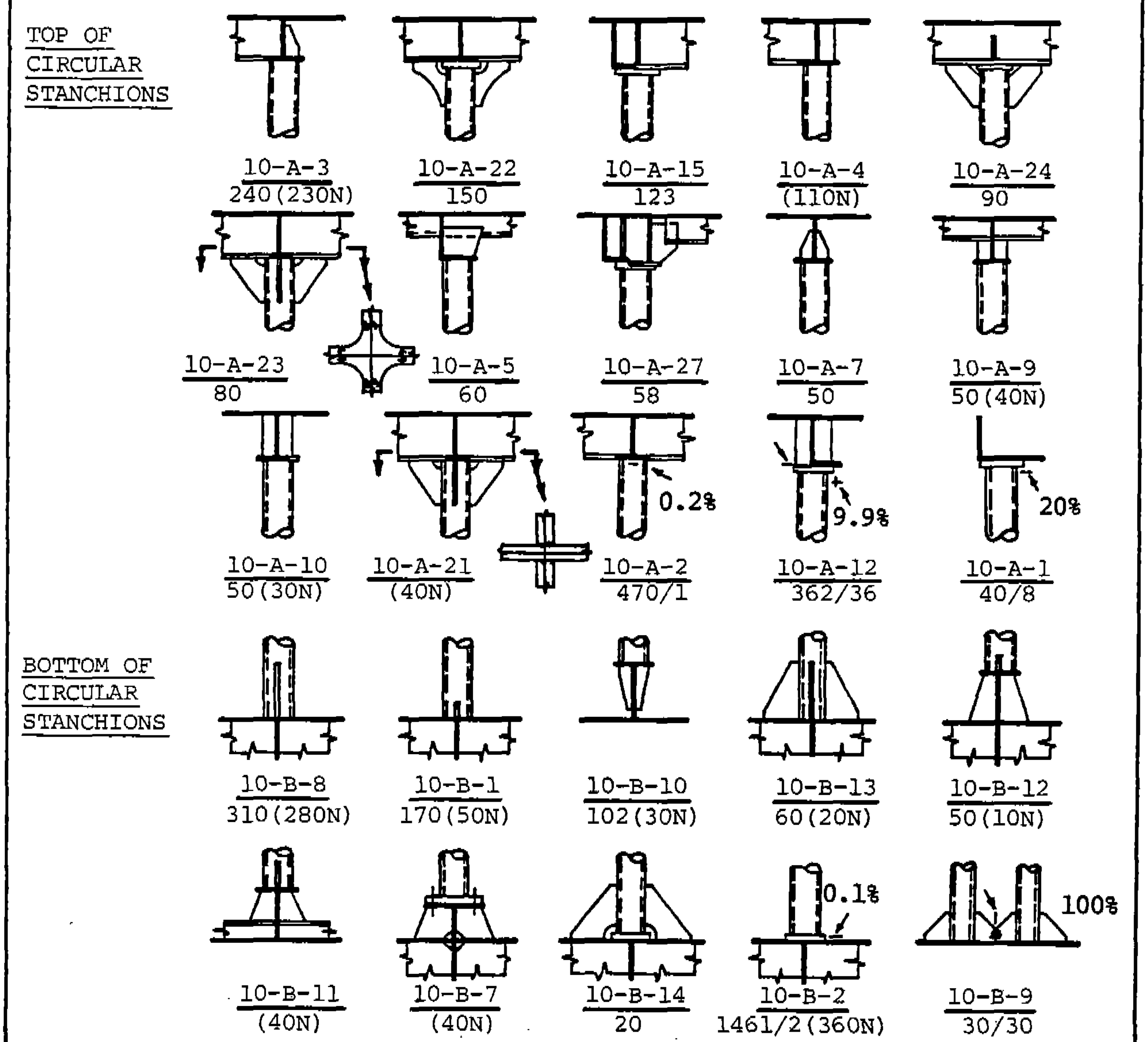
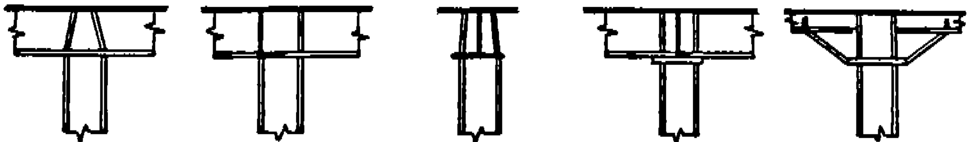


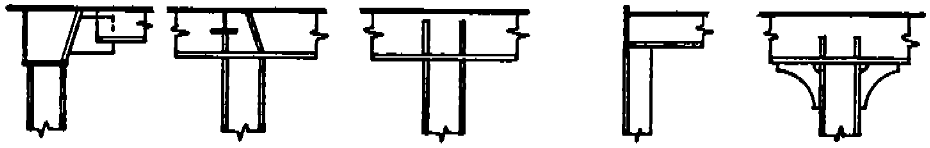
FIGURE 3-14

PERFORMANCE OF STANCHION END DETAILS-FAMILY NO.10-Cont'd

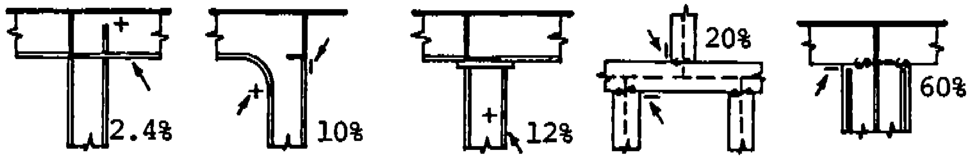
TOP OF "H" STANCHIONS



10-C-13	10-C-31	10-C-14	10-C-21	10-C-20
160(120N)	108	(100N)	100	(80N)

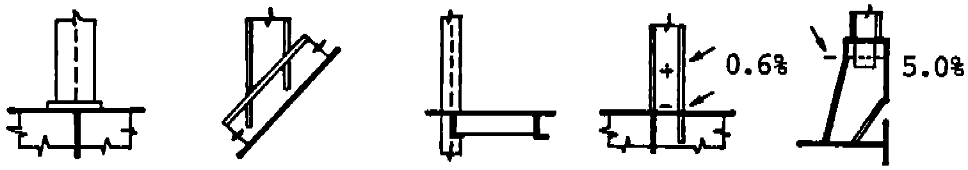


10-C-32	10-C-12	10-C-9	10-C-2	10-C-25
70	60(40N)	56	50	50(30N)



10-C-7	10-C-6	10-C-35	10-C-1	10-C-5
84/2	20/2	8/1	10/2	10/6

BOTTOM OF "H" STANCHIONS



10-B-16	10-B-18	10-B-17	10-B-15	10-B-21
490(160N)	60	40	350/2(150N)	40/2

10-B-25	10-B-28	10-B-22	10-B-26	10-B-24
10/1	10/2	10/2	14/6	10/6

3.10 LOAD CARRYING STIFFENER END DETAILS - FAMILY NO. 11

The details assigned to this family (Fig. 3-15) are for load carrying members in contrast to those of the next family (panel stiffeners) which are used principally to stabilize plating.

3.10.1 Full Connections

The only detail of this category with failures was 11-A-9. This detail was found on six of the ship types that were surveyed, but all of the cracks occurred on only two of the ship types (general cargo ships and tankers). Neglect was cited in both cases as a failure cause while the one ship type with the majority of cracks (general cargo ships) also suffered from faulty design. The large number (4,333) of successful details of this type found on the other four ship types seems to indicate that the basic design is not at fault but that poor construction and maintenance led to problems.

3.10.2 Padded

No failures were seen in any of the four details of this group (745 observations).

3.10.3 Lapped

The two lapped stiffener end details of this group which lapped the two members to be joined directly to one another (details 11-D-2 & 11-D-1) had no failures. Both of these details are relatively simple and apparently work well. Detail 11-D-5 uses a gusset plate to aid in making the connection. One of the angles being joined has the end of a leg butt welded to the edge of the gusset plate with the lapping occuring only between the plate and the other structural member. Cracking was noted in some of these details near the butt weld, probably due to high localized stress caused by a relatively sharp transition in both geometry and stiffness. Detail 11-D-4, which failed in tension and shear, appears to have a designed-in weakness where the un-sniped leg of the smaller angle passes over the sharp corner of the larger angle.

3.10.4 With End Chocks

The three details of this group had no failures.

3.10.5 With Clips

The success/failure rate of clips seems to be influenced by the ship type on which they are used. It was noted during the surveys that some clip failures were contributed to by heavy corrosion; details 11-B-4 & 11-B-1 fall into this category. These two detail types were found to have failed on tankers where corrosion is high. General cargo ships also were hard on clip connections with failures in four types (details 11-B-4, 11-B-1, 11-B-9, &

11-B-6) out of the five observed. Cargo falling or shifting against bulkheads (detail 11-B-4) was mentioned as a likely cause. Bulk carriers, on the other hand, successfully used clip connections (details 11-B-7, 11-B-8, & 11-B-4) with no observed failures.

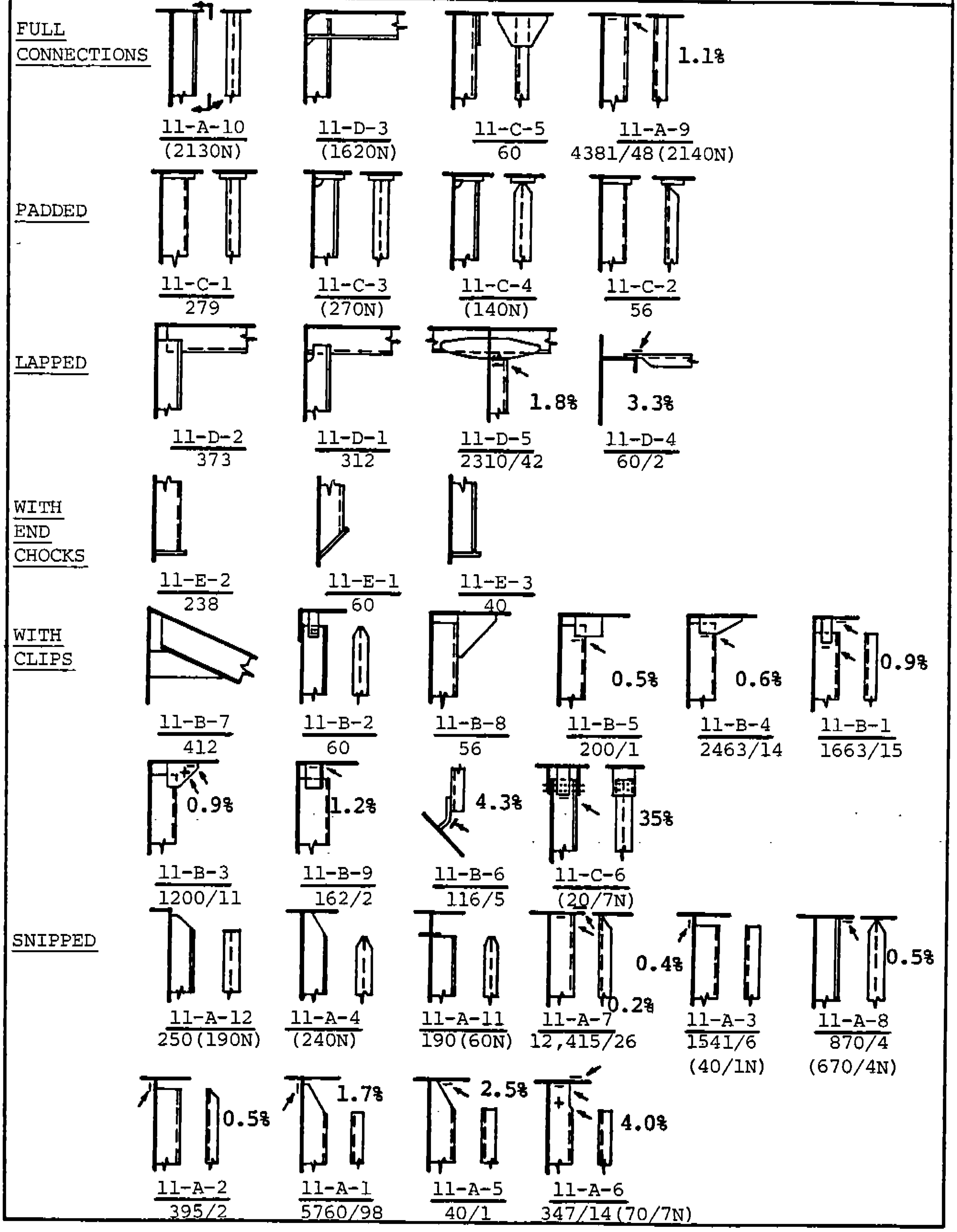
3.10.6 Sniped

Seven out of 10 details in this group were subject to cracking failures in the area of the stiffener ends. The design of the stiffener end influenced the failure mode. Those details with partially built in ends (11-A-7, 11-A-8, 11-A-5, & 11-A-6) led to failures related to the plating to which the stiffener was being attached. In some cases cracks developed between the stiffener ends and the above mentioned plate while in other instances the stiffener ends caused this plating to fail because of hard spots. The other situation, where the stiffener ends were fully sniped (details 11-A-3, 11-A-2, & 11-A-1), caused failures in the plating being stiffened.

A point worth noting is the difference in success rate between structural tees and angles in this application. The three details with no failures were all tees while six out of the seven details with cracking problems were angles.

FIGURE 3-15

PERFORMANCE OF STIFFENER END DETAILS-FAMILY NO. 11



3.11 PANEL STIFFENER DETAILS - FAMILY NO. 12

3.11.1 Flat Bars

The majority of failures of these details (Fig. 3-16) occurred in areas where there was a sudden change in the relative stiffness. For example, many of the cracks observed were on the panel being stiffened between its periphery and the ends of the sniped stiffeners. In the case of the un-sniped stiffeners, failures were noted in the sharp corners formed where the stiffener met the plating to which the stiffened panel was being attached. Buckling was also observed on some of the flat bars included in details which had cracking failures.

3.11.2 Shapes

The angle stiffening details shown vary according to their end treatment (web sniped, flange sniped, one end cut off, and fully built-in). Every type suffered failures, many similar to those mentioned above for flat bars. In addition, those angles with fully built-in ends caused hard spot failures where their leg ends contacted bulkheads. A particularly bad detail (22% failure rate) was one in which both legs were sniped at both ends (detail 12-B-2).

Structural tee stiffeners were also grouped according to their end treatment. Tees were found to be a much more reliable method of stiffening then angles. Only one category of end restraint had any failures. Tees with one end built-in and the other end with sniped flange (detail 12-B-7) had a flange buckling failure rate of 0.4%.

3.11.3 Flat Bars on Webs In Way of Longitudinals

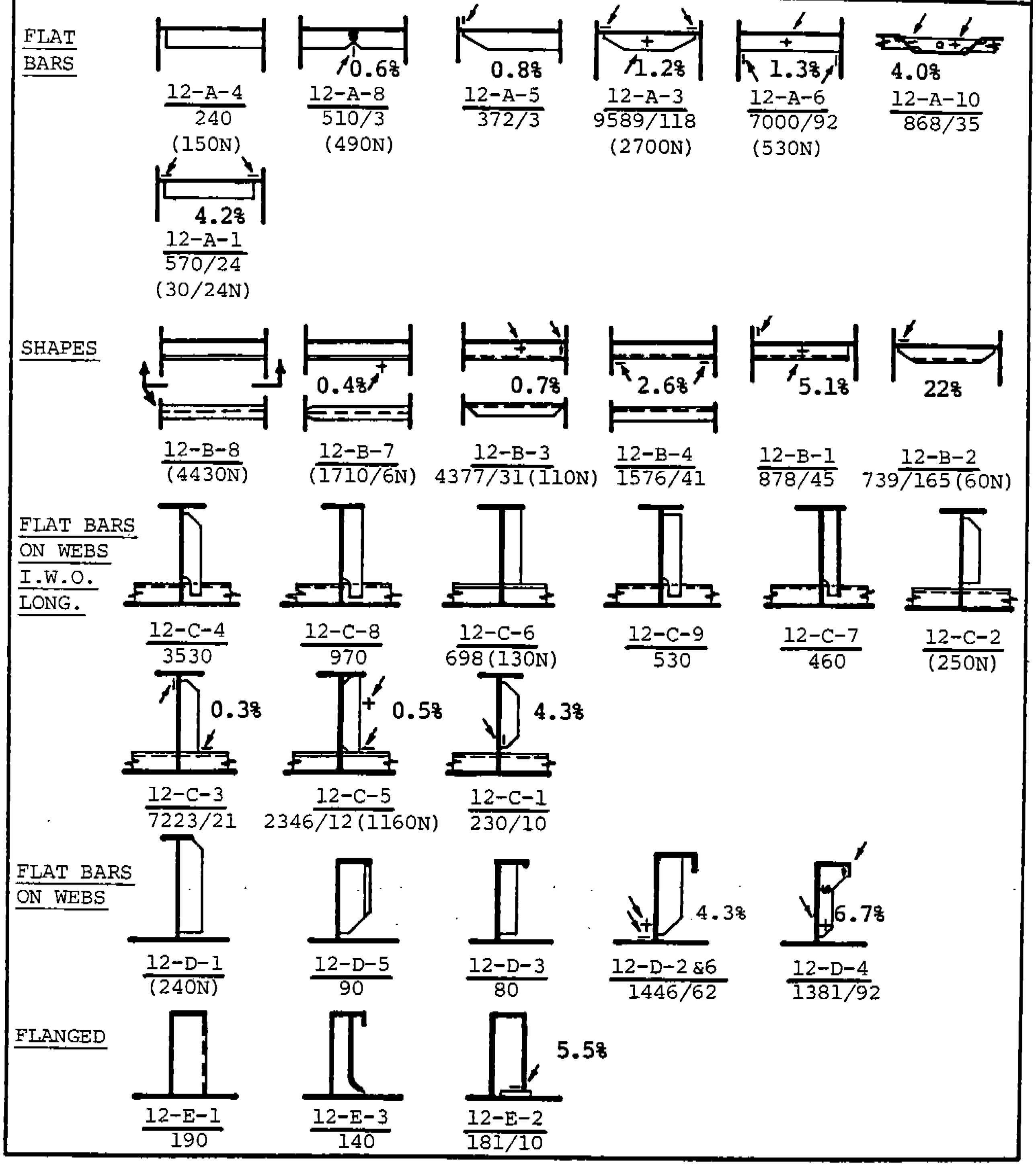
No failures were observed in details where the flat bar formed a lap type joint with the longitudinal. By using a lap type joint rather than butting the flat bar against the top of the longitudinal, the situation where an inadequate weld would be placed at a point of stress concentration was reduced. Two of the three details (details 12-C-3 & 12-C-5) where the flat bar was welded to the top of the longitudinal failed by cracking along the weld line. Detail 12-C-1 experienced the highest failure rate of this group (4.3%). The flat bar, which was sniped at both its upper and lower end, would in some cases form cracks at its lower end where it was welded to the web. Apparently flexing of the web, perhaps from some sort of lateral loading, was causing failure at this point of transition in stiffness.

3.11.4 Flat Bars on Webs

Most of the failures in this group were associated with the sniped end of the flat bar (the end nearest the plating to which the web being stiffened was attached). It appears that lateral loads on the web or twisting forces between the web and the attached plating were focused on this narrow

FIGURE 3-16

PERFORMANCE OF PANEL STIFFENER DETAILS-FAMILY NO. 12



unstiffened region causing premature failure. Both buckling and cracking were observed. Detail 12-D-4 was also observed to have cracking problems between the flat bar and the down turned lip at the outer edge of the web flange. These failures might have resulted from less than ideal welds due to the awkward positioning and sharp internal corner of this area of the detail.

3.11.5 Flanged

The only failures of this group occurred to detail 12-E-2 and were the result of abuse, not a design defect.

4. FABRICATION MAN-HOUR ESTIMATING

Very little published data is available on the cost of structural details. Reference 3 gives laboratory construction hours for various types of corner bracket details. Reference 49 shows typical man-hours for many details of specific sizes. Reference 61 presents a general method for making cost trade-offs and gives several examples which are more applicable to building construction than ship fabrication. In this section a simple method for determining preliminary construction man-hours for a wide variety of details and sizes is presented and discussed.

4.1 PROCEDURE

As a first step in establishing an estimating procedure, the ship structural details shown in Section 3 were subdivided into elementary pieces or operations. Typical sizes and thicknesses for each piece or operation were then determined followed by typical fillet weld sizes. Next the fabrication and construction operations for each piece or operation were identified. In this context fabrication steps are preliminary operations generally performed in a shop while construction steps are those operations involving subassembly or final assembly which can be either in a shop or in the field. The individual steps are identified:

FABRICATION:

- Layoff - measuring, marking, scribing, identifying, and inspecting material.
- Cutting - grinding, planing, shearing, sawing, drilling, burning, and inspecting material.
- Forming - pressing, bending, rolling, furnacing, and inspecting material.

CONSTRUCTION:

- Layout - receiving instructions, locating, and moving material to work area.
- Cutting - grinding, drilling, and burning.
- Fitting - erecting, tacking, and securing assembly.
- Welding - preparation and welding.
- Inspection - locating and inspecting job by structural inspection department.

Man-hours were then determined for each piece and operation using industrial standards. These values are tabulated in Appendix B and an index to the pieces and operations can be found on page B-1. Hours for the details selected for the design guide (Appendix C) were then determined by simple addition of the hours for the individual pieces and operations as will be illustrated in Section 4.3. The man-hours represent what is perceived to be the current practice in the U.S. shipbuilding industry and not necessarily the practice of any individual shipyard.

4.2 LIMITATIONS

The man-hours shown in Appendix B are typical values applicable to either naval or commercial ships built with either mild or high strength steel (51 KSI or 36 Kg/mm^2 maximum yield strength). To make the man-hours applicable to both naval and commercial ships, average weld sizes have been used. It should be noted that there are differences in naval and commercial ship welding requirements.

All welding values were developed from existing standards using shielded metal arc welding (SMAW) stick electrode in the flat position. However, the more expensive vertical and overhead welding would inevitably be required for some details. For larger details this cost increase could be reduced by the use of semi-automatic welding processes such as gas metal arc welding (GMAW). For some details it will be noted that increasing plate thicknesses require less time (see Table B-13 as an example). This result is due to thicker plates requiring larger weld sizes which allows the use of larger diameter electrodes with resulting higher deposition rates.

Generally, the man-hour norms are applicable to new construction where relatively large numbers of pieces and operations are involved and optimum processes can be used. For example, numerically controlled burning is used whenever possible (note cutting times in Tables B-6 and B-9). In Table B-9 the cuts were priced for over 5 pieces using one torch or over 10 pieces using two torches. Very small radius cuts (1/2 inch) were priced using a T1 travograph machine. Flat bar ends were priced using a Radiograph machine. Angle and tee shape ends were priced using hand torching. For flat bars, the hand torch times per inch decrease as the length of cut increases due to the warm-up time involved.

An approximate breakdown of the time for chocks (Table B-5) is:

Layoff	6.0%
Cutting	35.6%
Fitting	28.8%
Welding	23.1%
Inspection	6.5%
	100.0%

From the above discussion, it should be evident that the man-hour norms of Appendix B are approximate values suitable for preliminary trade-off studies. There is no substitute for detailed industrial engineering studies of specific alternatives for a given structural detail using the specific facilities that will be used for construction. However, these man-hour norms have been compared to those of Ref. 49 with reasonably consistent results. The major differences are in cuts where numerically controlled burning has been utilized for the hours in Appendix B wherever possible.

4.3 EXAMPLES

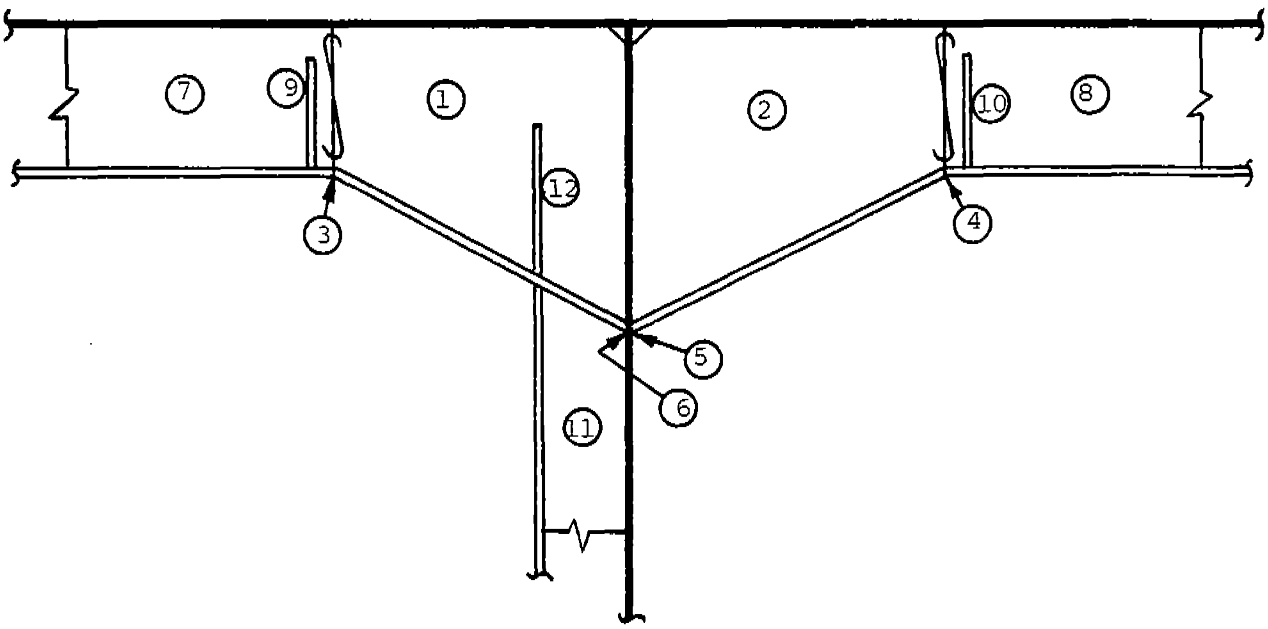
Table 4-1 gives a typical calculation for one of the more complicated beam brackets. Interpolation is required in some of the tables in Appendix B. Otherwise the procedure is fairly simple.

Table 4-2 summarizes calculations for three different beam brackets for a variety of stiffener sizes. For the smallest stiffener size shown, all three bracket details require essentially the same construction time. For the two larger stiffeners, the third detail (1-A-8) requires significantly less time. This illustrates the point that the optimum detail can be a function of the size of members being joined. It is also interesting to note that the least expensive detail (1-A-8) was also the least observed detail of the three shown.

Calculations for a commercial ship flat plate corner bracket are given in Table 4-3 and a non-tight collar in Table 4-4. For simple details such as these, the calculations are fairly easy.

TABLE 4-1

SAMPLE CALCULATION: BUILT-UP BEAM BRACKET IN WAY OF BULKHEAD STIFFENER



Calculations for 8"x6½"x24#I-T stiffeners for detail 1-A-3:

MEMBERS	DESCRIPTION	TABLE & ITEM NO.	MANHOURS
① & ②	0.25" Brackets(includes welds on all sides)	B-3-1	2x1.41 =2.82
③ & ④	6.5"x0.4375" Flat Bar Ends (with butt welds)	B-16-7	2x1.16* =2.32
⑤ & ⑥	6.5"x0.4375" Flat Bar Ends (full penetration tee welds)	B-16-7	2x1.16**=2.32
⑦ & ⑧	Tee Stiffener Ends (no welds)	B-18-1	2x0.11 =0.22
⑨ & ⑩	2.75" x7" x 0.25" Chocks	B-5-1	4x0.26* =1.04
⑪	Bhd. Stiffener End (with fillet welds)	B-18-7	0.76
⑫	3" x 10" x 0.4375" chocks	B-5-1	2x0.51* =1.02

Total Fabrication Time 10.50 mhrs.

* These values determined by interpolation in the designated tables.

** Use same hours as butt welds.

TABLE 4-2

FABRICATION TIME VERSUS SIZE OF MEMBERS

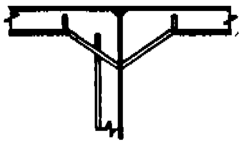
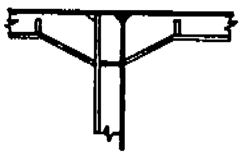
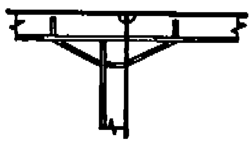
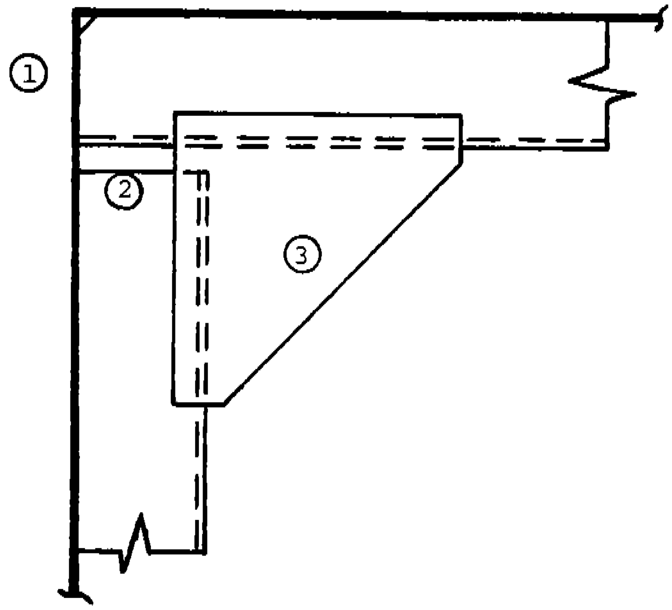
DETAIL NO.	SKETCH	NO. OBSERVED	MAN-HOURS FOR STIFFENER SIZES: 6x4x9#I-T	8x6-1/2x24#I-T	12x6-1/2x35#I-T
1-A-3		(241ON)	4.80	10.50	15.94
1-A-4		(83ON)	5.04	10.80	17.00
1-A-8		(35ON)	4.90	8.42	13.70

TABLE 4-3

SAMPLE CALCULATION: PLATE CORNER BRACKET



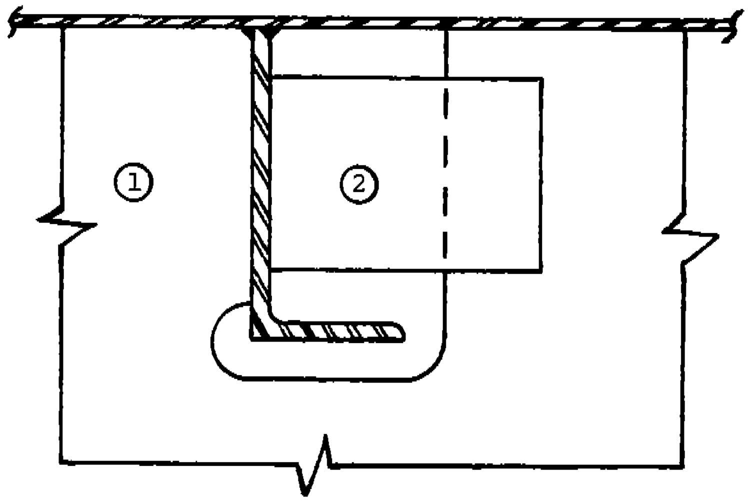
Calculations for 8"x4"x1/2"L for detail 1-C-3:

MEMBERS	DESCRIPTION	TABLE & ITEM NO.	MANHOURS
1	Cut & weld stiffener web & flange at end	B-17-5	0.72
2	Square cut stiffener end (no weld)	B-17-1	0.11
3	18" x 18" x 0.5" bracket	B-1-1	1.66

Total Fabrication Time 2.49 mhrs.

TABLE 4-4

SAMPLE CALCULATION: NON-TIGHT COLLAR



Calculations for 8"x4"x1/2"L for detail 3-A-4:

MEMBERS	DESCRIPTION	TABLE & ITEM NO.	MANHOURS
1	Cut & weld web plate	B-6-6	0.33
2	7" x 5" x 0.5" lapped collar	B-7-1	0.76
Total Fabrication Time			1.09 mhrs.

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5. CONCLUSIONS & RECOMMENDATIONS

5.1

Appendix B of this report provides matrices of construction hours for a wide range of part sizes which can be used for trade-off studies of different structural details for specific applications.

5.2

Appendix C of this report provides a guide to the selection of structural details for both naval and commercial ships which combine good service experience with reasonable construction costs.

5.3

Additional work is needed on fatigue, particularily the identification of appropriate local fatigue models for ship structural details, assembling fatigue data for these models, and identifying stress histories for transversely oriented ship structure.

5.4

Systematic collection of data on the service performance and cost of ship structural details should be continued.

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APPENDIX A

SERVICE EXPERIENCE BY DETAIL FAMILIES, SHIP TYPE, & LOCATION

Contents

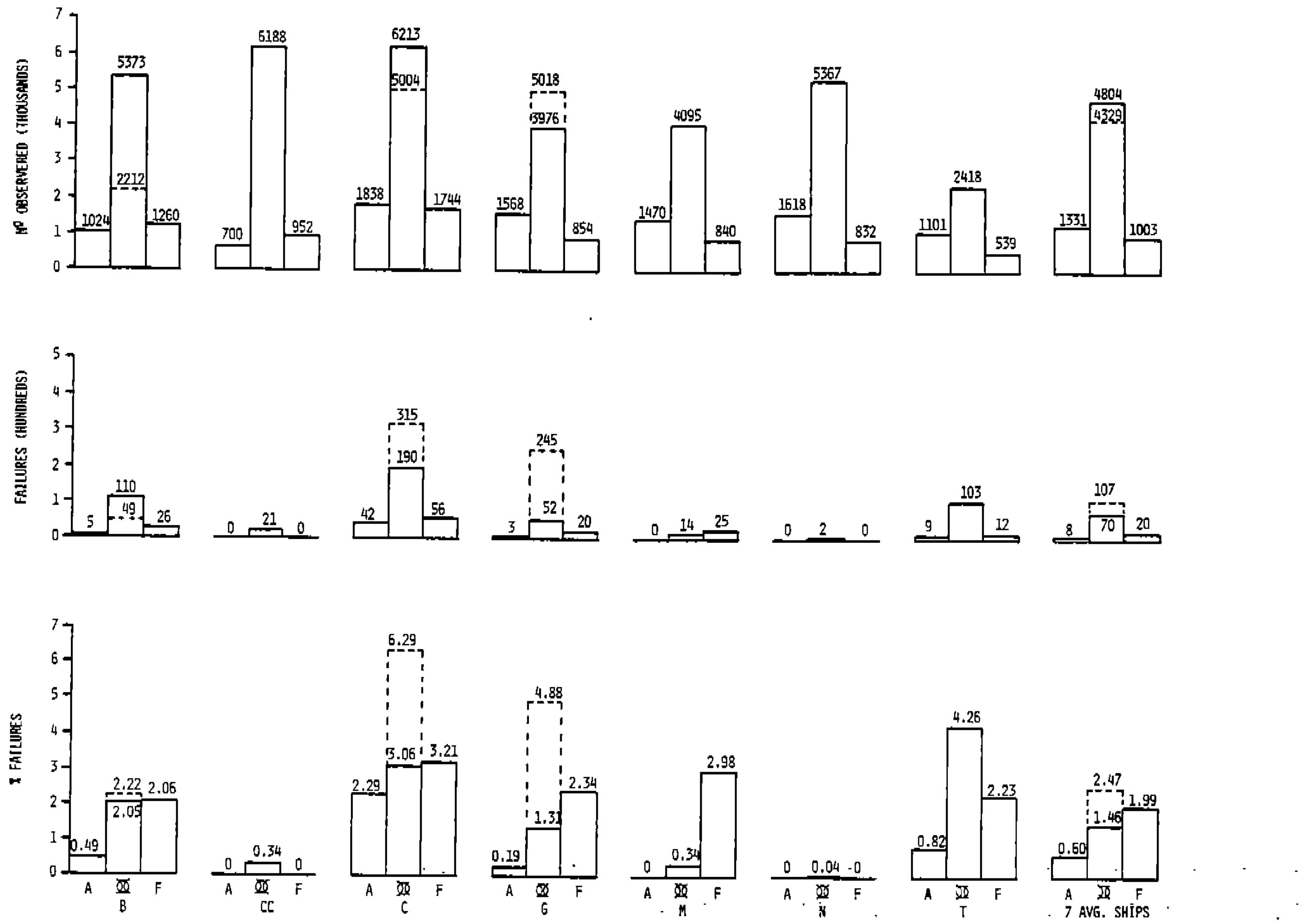

FIGURE A-1
BEAM BRACKET DETAILS-FAMILY Nº 1
(NORMALIZED DATA FOR SEVEN SHIPS OF EACH TYPE)

KEY
—— SSC-272 DATA
---- SSC-272+SSC-294

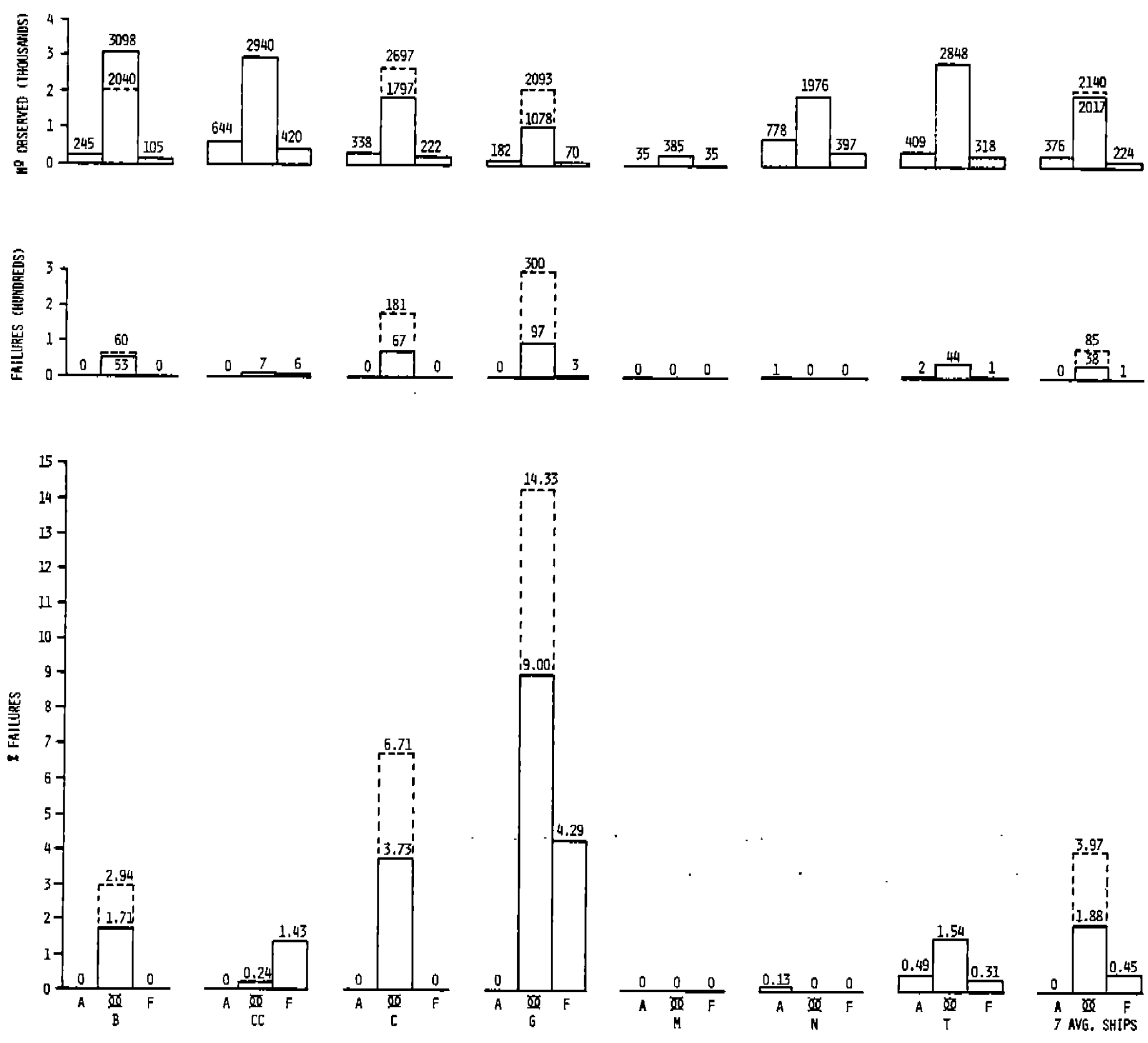

FIGURE A-2
TRIPPING BRACKET DETAILS-FAMILY Nº 2
(NORMALIZED DATA FOR SEVEN SHIPS OF EACH TYPE)

KEY
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--- SSC-272+SSC-294

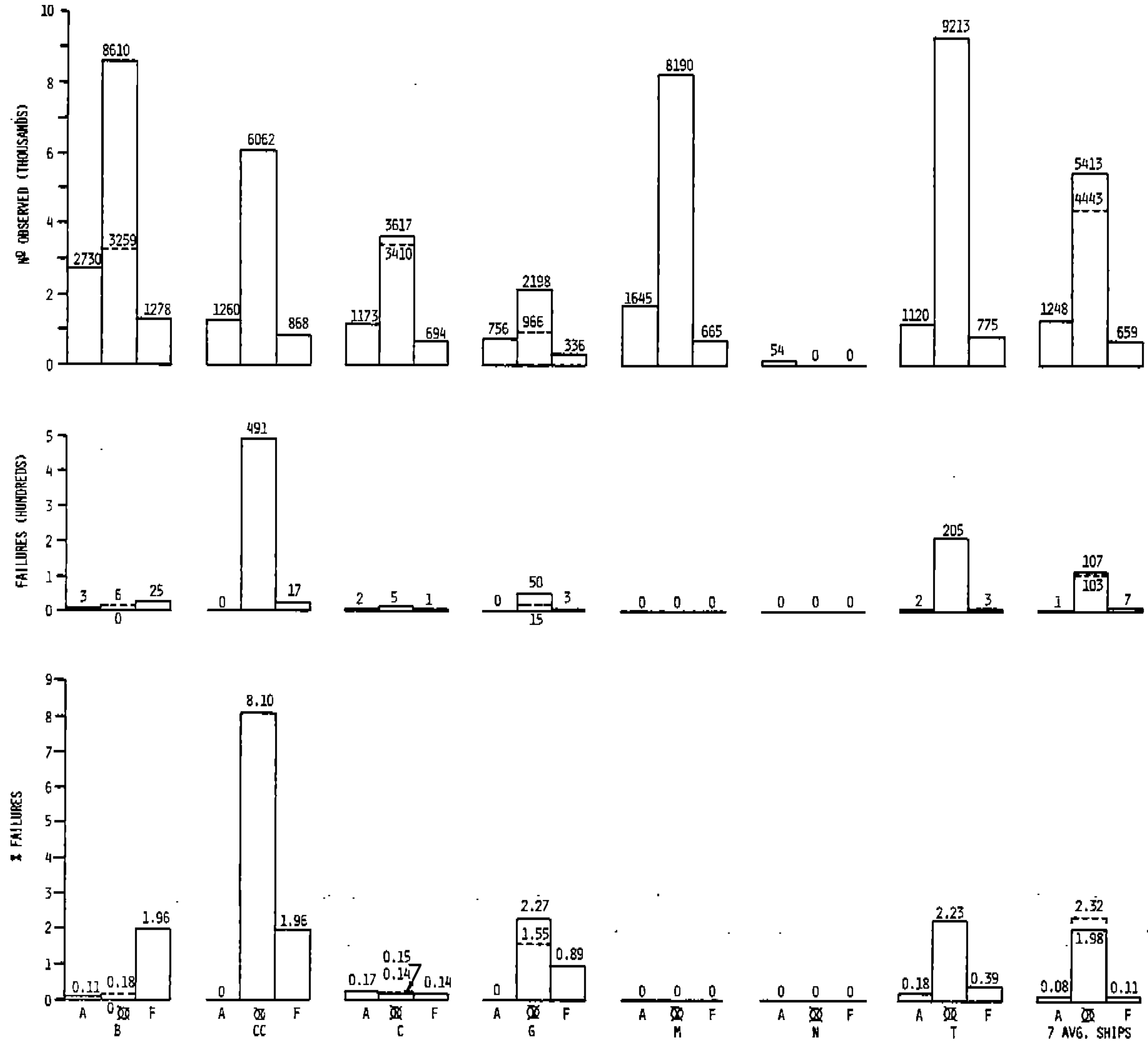

FIGURE A-3

STIFFENER CLEARANCE CUTOUT DETAILS-FAMILY Nº 8

(NORMALIZED DATA FOR SEVEN SHIPS OF EACH TYPE)

FIGURE A-4
NON-TIGHT COLLAR DETAILS-FAMILY Nº 3
(NORMALIZED DATA FOR SEVEN SHIPS OF EACH TYPE)

KEY
— SSC-272 DATA
---- SSC-272+SSC-294

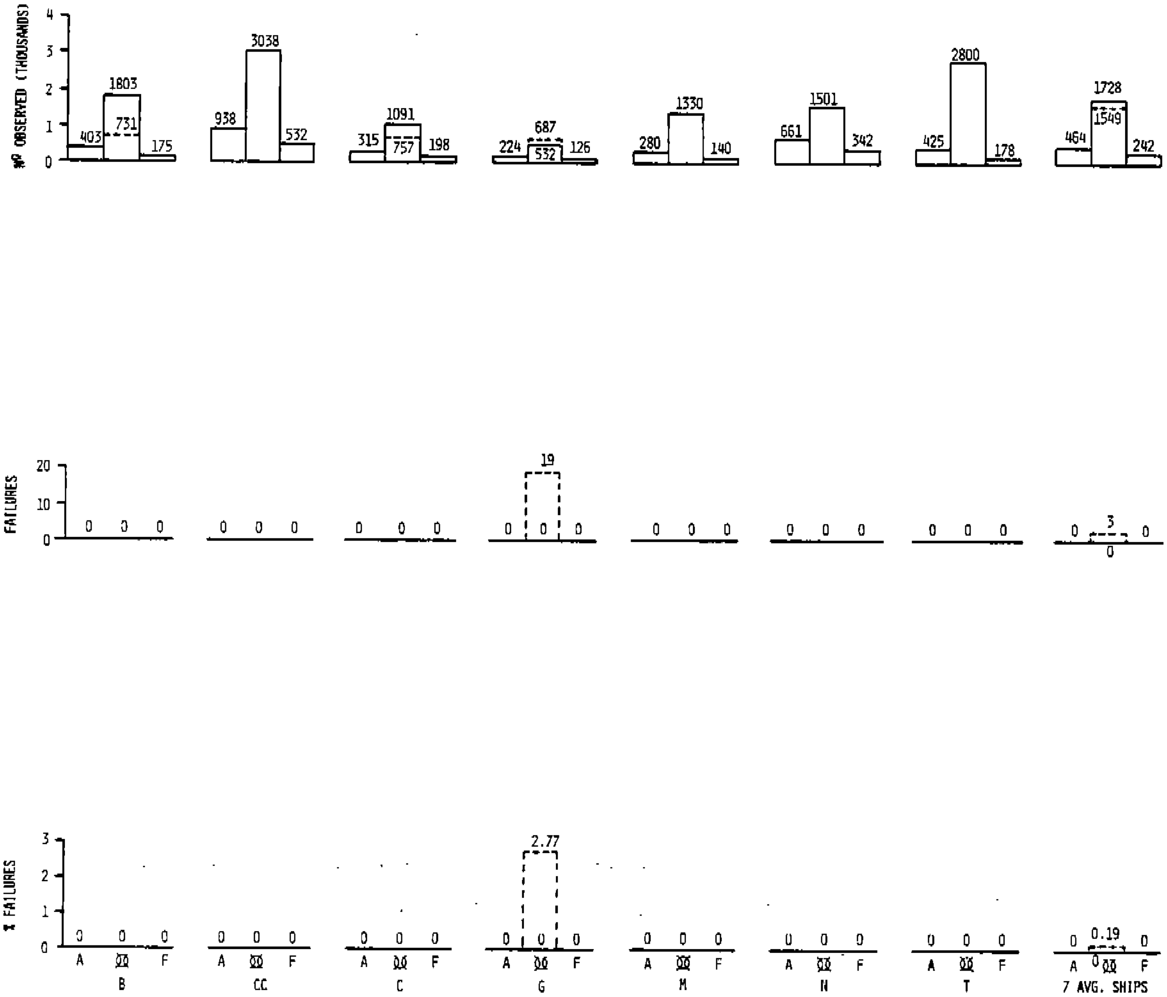

FIGURE A-5
TIGHT COLLAR DETAILS-FAMILY Nº 4
(NORMALIZED DATA FOR SEVEN SHIPS OF EACH TYPE)

KEY
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---- SSC-272+SSC-294

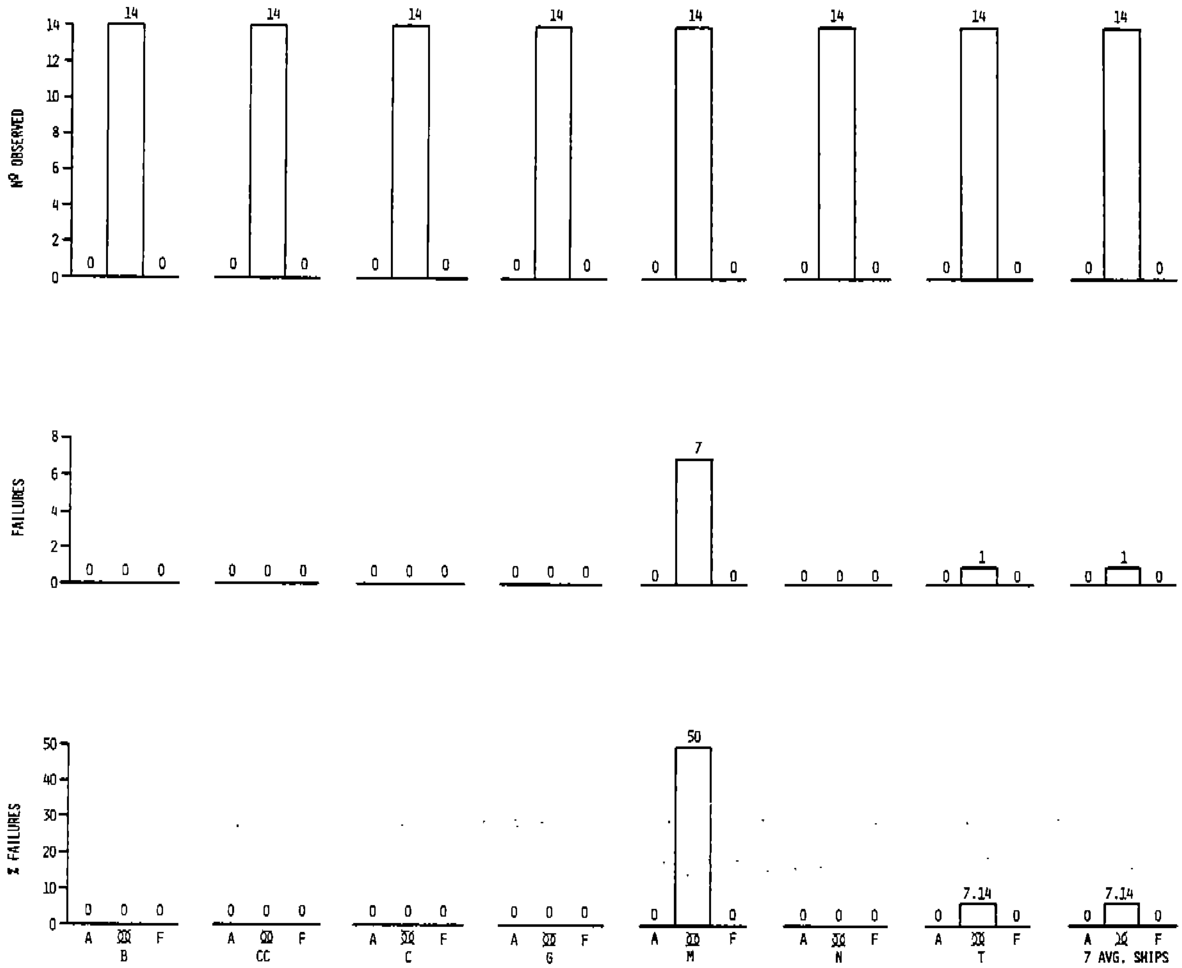

FIGURE A-6
GUNWALE CONNECTION DETAILS-FAMILY Nº 5
(NORMALIZED DATA FOR SEVEN SHIPS OF EACH TYPE)

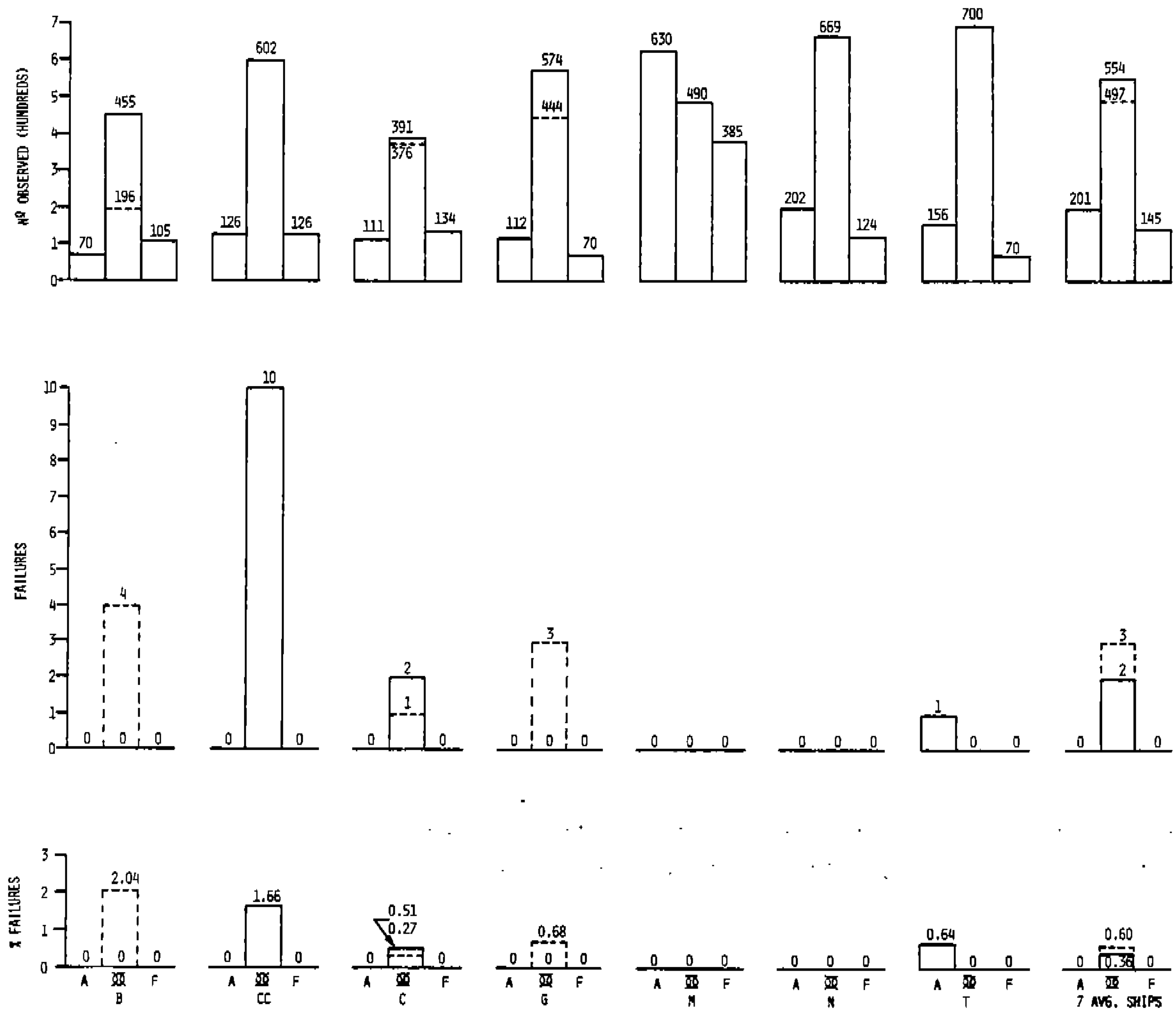

FIGURE. A-7
STRUCT. DECK CUTS-FAMILY Nº 9
(NORMALIZED DATA FOR SEVEN SHIPS OF EACH TYPE)

KEY
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---- SSC-272+SSC-294

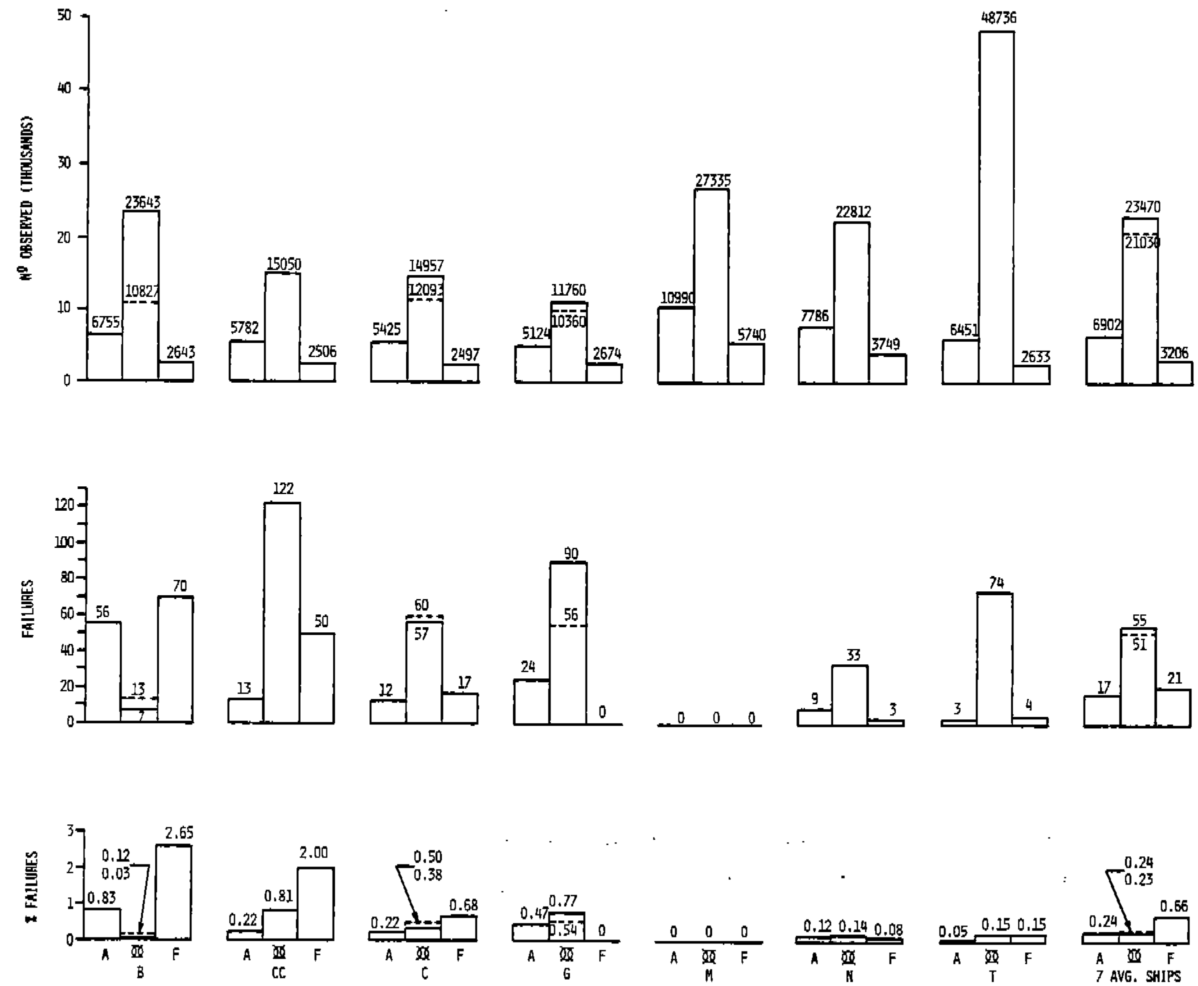

FIGURE A-8
MISCELLANEOUS CUTOUT DETAILS-FAMILY Nº 7
(NORMALIZED DATA FOR SEVEN SHIPS OF EACH TYPE)

KEY
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---- SSC-272+SSC-294

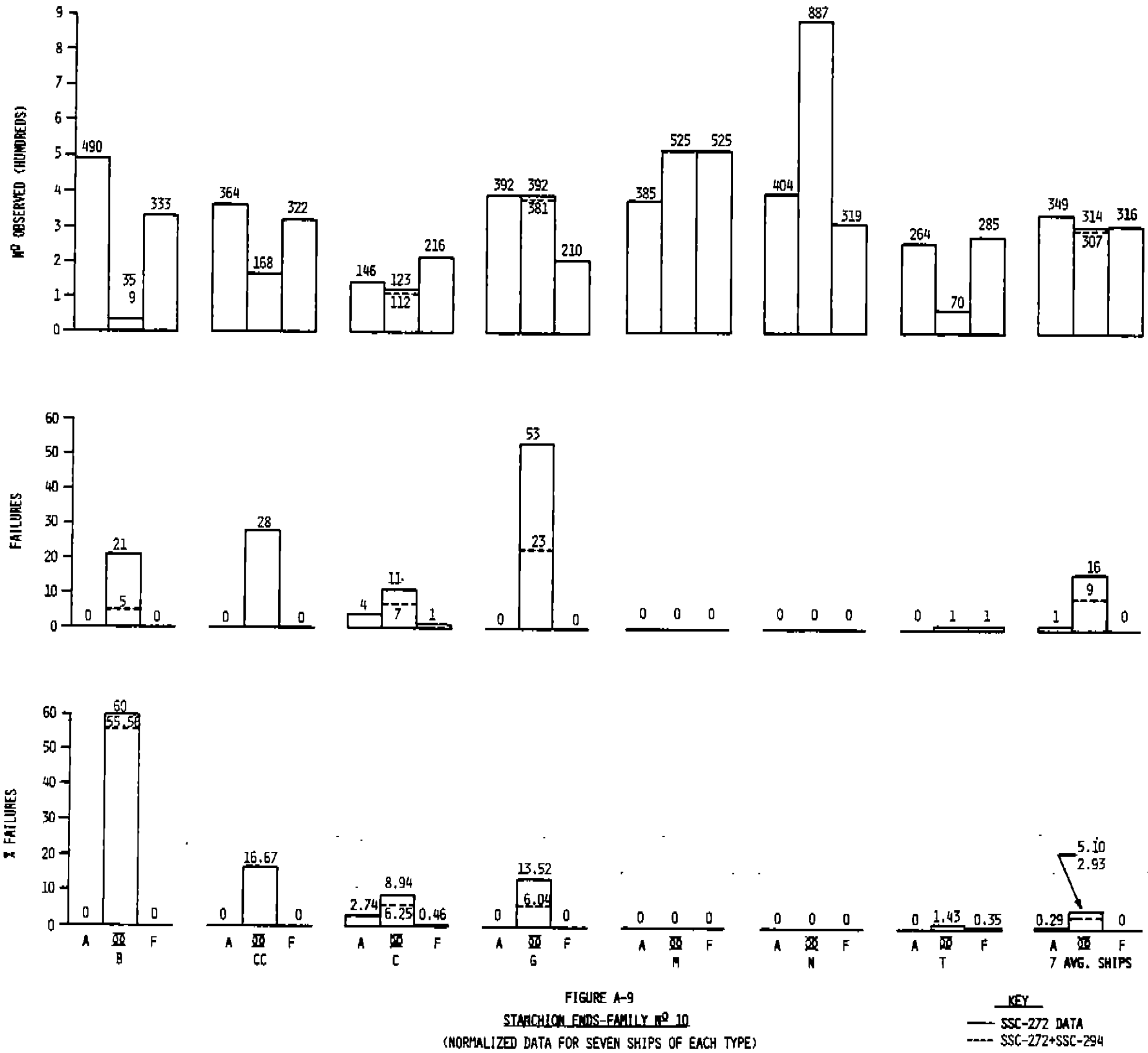


FIGURE A-9
STANCHION ENDS-FAMILY Nº 10
(NORMALIZED DATA FOR SEVEN SHIPS OF EACH TYPE)

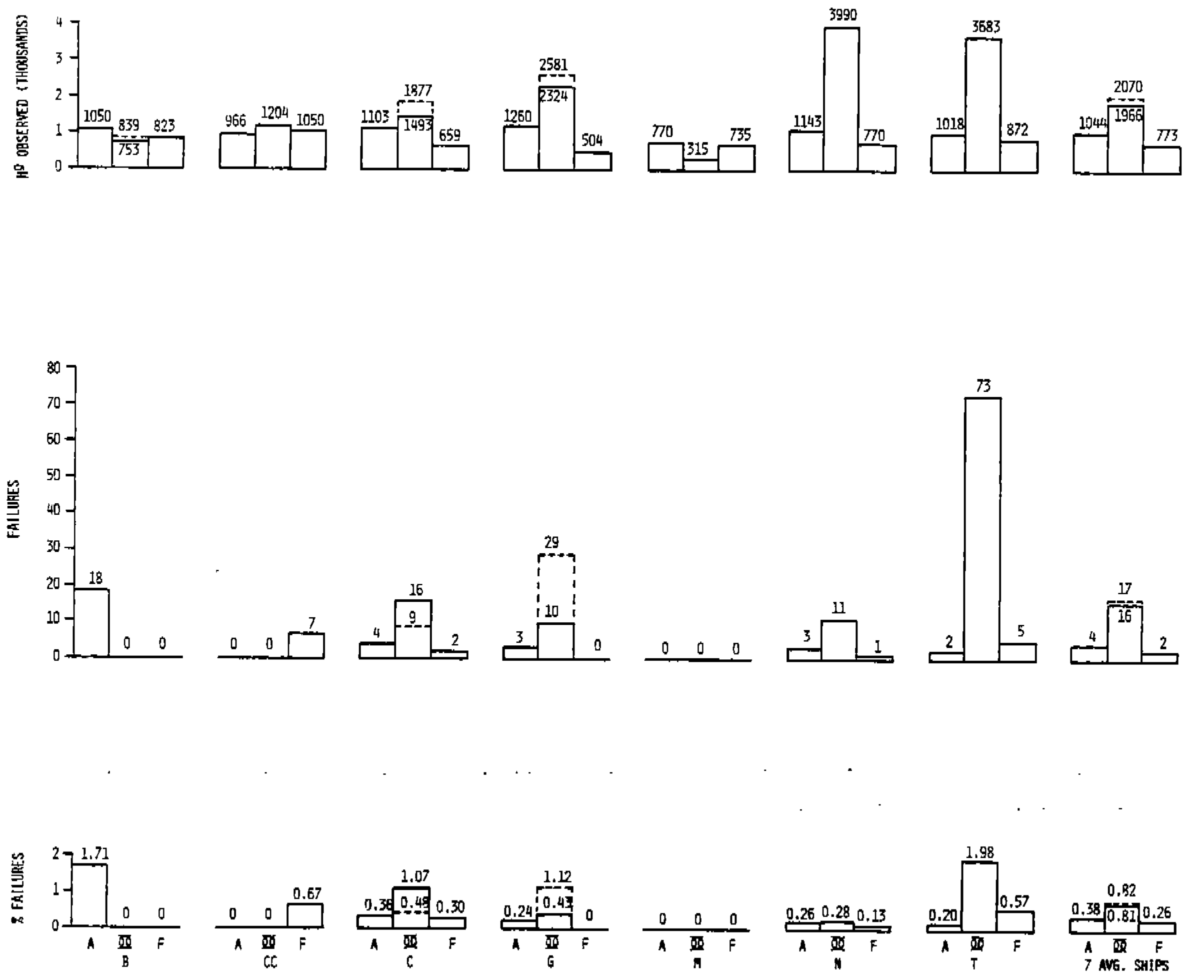


FIGURE A-10

STIFFENER ENDS-FAMILY Nº 11

(NORMALIZED DATA FOR SEVEN SHIPS OF EACH TYPE)

KEY

—— SSC-272 DATA

---- SSC-272+SSC-294

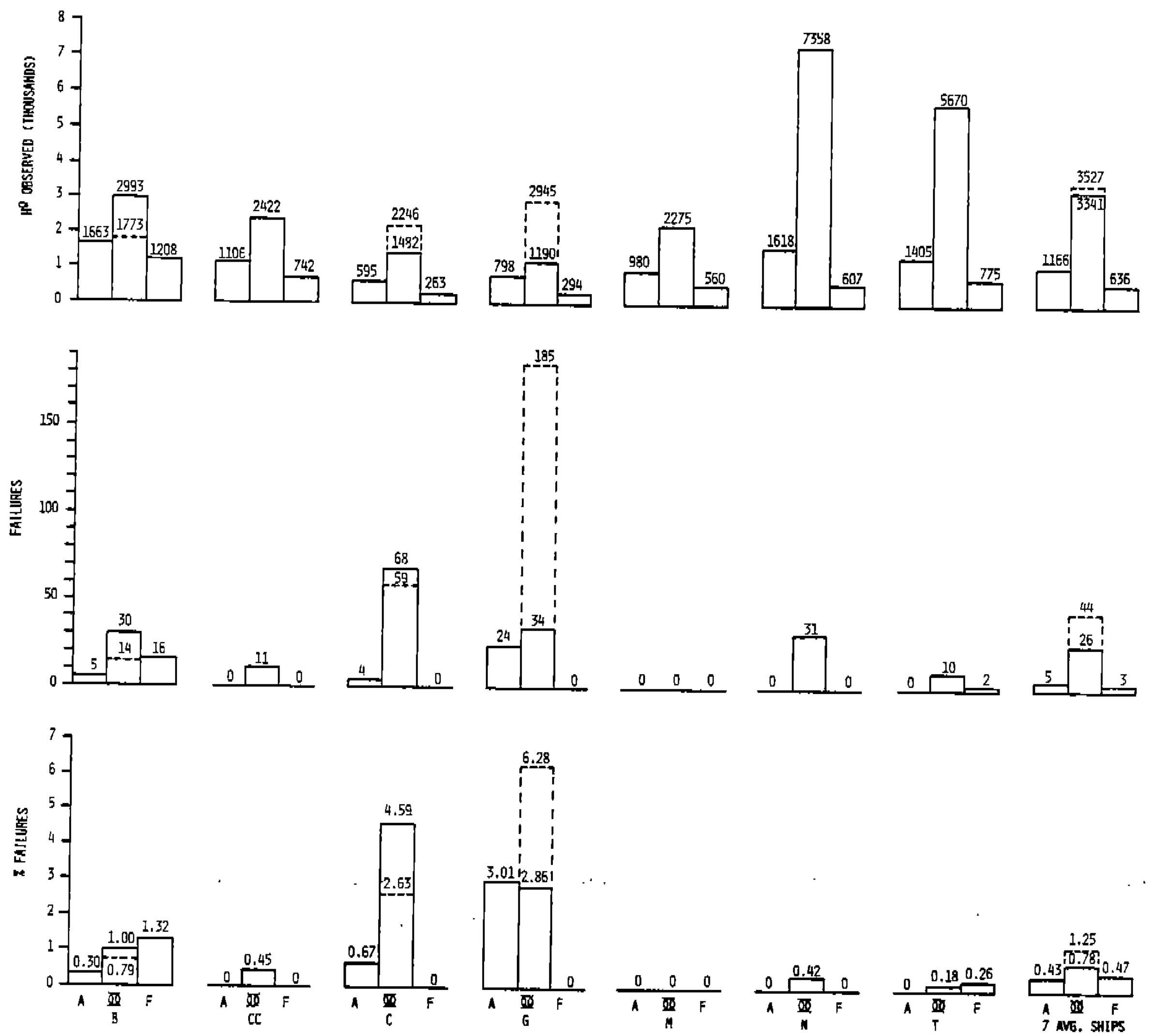


FIGURE A-11
PANEL STIFFENERS-FAMILY Nº 12
(NORMALIZED DATA FOR SEVEN SHIPS OF EACH TYPE)

KEY
—— SSC-272 DATA
---- SSC-272+SSC-294

APPENDIX B

FABRICATION MAN-HOUR NORMS

Man-hour norms for fabrication are arranged as follows:

TABLE B-1

FABRICATION MAN-HOUR NORMS FOR PLATE CORNER BRACKETS

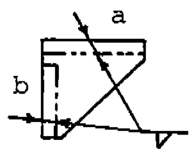
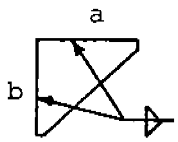
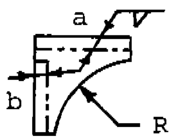
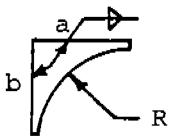
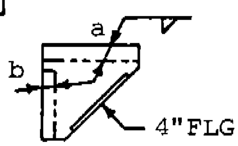
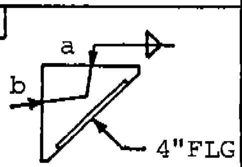
ITEM	FABRIC. STEPS			CONSTRUCTION STEPS					SIZE	TOTAL MANHOURS FOR:				
	Layoff	Cutting	Forming	Layout	Cutting	Fitting	Welding	Inspect.	(a x b)	1/4"PL	3/8"PL	1/2"PL	3/4"PL	1" PL
1 	x	x		x		x	x	x	6" x 6"	0.16	0.31	0.50	-	-
									10" x 10"	0.27	0.52	0.85	1.10	-
									14" x 14"	-	0.77	1.25	1.61	2.48
									18" x 18"	-	-	1.66	2.13	3.28
2 	x	x		x		x	x	x	6" x 6"	0.19	0.37	0.60	-	-
									10" x 10"	0.32	0.62	1.00	1.29	-
									14" x 14"	-	0.87	1.41	1.81	2.78
									18" x 18"	-	-	1.81	2.32	3.57
3 	x	x		x		x	x	x	6" x 6"	0.16	0.31	0.50	-	-
									10" x 10"	0.27	0.53	0.85	1.10	-
									14" x 14"	-	0.77	1.26	1.62	2.48
									18" x 18"	-	-	1.66	2.13	3.28
4 	x	x		x		x	x	x	6" x 6"	0.19	0.37	0.60	-	-
									10" x 10"	0.32	0.62	1.01	1.29	-
									14" x 14"	-	0.87	1.41	1.81	2.78
									18" x 18"	-	-	1.81	2.33	3.58
5 	x	x	x	x		x	x	x	6" x 6"	0.16	0.40	0.51	-	-
									10" x 10"	0.28	0.53	0.86	1.10	-
									14" x 14"	0.41	0.78	1.26	1.62	2.49
									18" x 18"	0.53	1.02	1.66	2.13	3.28
6 	x	x	x	x		x	x	x	6" x 6"	0.20	0.37	0.61	-	-
									10" x 10"	0.33	0.62	1.01	1.30	-
									14" x 14"	0.46	0.87	1.41	1.81	2.79
									18" x 18"	0.58	1.11	1.81	2.33	3.58

TABLE B-2

FABRICATION MAN-HOUR NORMS FOR TEE CORNER BRACKETS

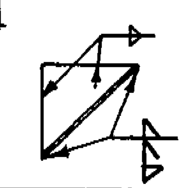
ITEM	FABRIC. STEPS			CONSTRUCTION STEPS					SIZE (Cut from I-T)	TOTAL MANHOURS FOR BEAM WEIGHT/FT. OF:				
	Layoff	Cutting	Forming	Layout	Cutting	Fitting	Welding	Inspect.		9-10#	12-13#	16-18#	24-26#	33-35#
1 	x	x		x		x	x	x	6" I-T	1.22	1.22	1.22	-	-
									8" I-T	1.31	1.31	1.31	1.78	-
									10" I-T	1.40	1.40	1.40	1.88	2.77
									12" I-T	-	1.49	1.49	1.97	2.94

TABLE B-3

FABRICATION MAN-HOUR NORMS FOR CONTINUOUS PLATE BRACKETS

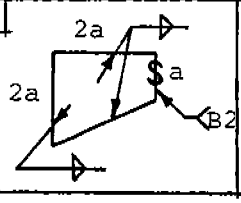
ITEM	FABRIC. STEPS			CONSTRUCTION STEPS					SIZE (Stiffener Depth-a)	TOTAL MANHOURS FOR:				
	Layoff	Cutting	Forming	Layout	Cutting	Fitting	Welding	Inspect.		1/4"PL	3/8"PL	1/2"PL	3/4"PL	1" PL
1 	x	x		x		x	x	x	6"	1.06	2.14	-	-	-
									8"	1.41	2.86	2.79	-	-
									10"	1.76	3.57	3.49	-	-
									12"	2.11	4.29	4.18	6.81	-

TABLE B-4

FABRICATION MAN-HOUR NORMS FOR TRIPPING BRACKETS

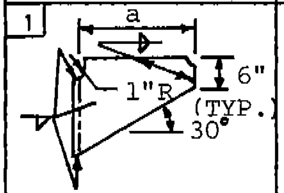
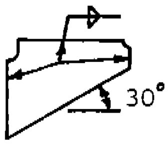
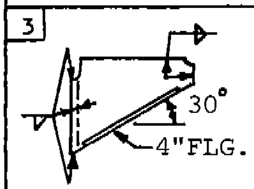
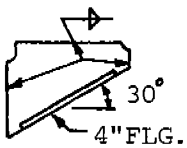
ITEM	FABRIC. STEPS			CONSTRUCTION STEPS					SIZE (Bracket Length a)	TOTAL MANHOURS FOR:				
	Layoff	Cutting	Forming	Layout	Cutting	Fitting	Welding	Inspect.		1/4" PL	3/8" PL	1/2" PL	3/4" PL	1" PL
1 	x	x		x		x	x	x	12"	-	0.51	0.99	1.61	-
									24"	-	-	1.72	2.81	2.51
									36"	-	-	-	4.01	3.59
									48"	-	-	-	-	4.67
2 	x	x		x		x	x	x	12"	-	0.48	0.92	1.51	-
									24"	-	-	1.66	2.71	2.42
									36"	-	-	-	3.91	3.50
									48"	-	-	-	-	4.58
3 	x	x	x	x		x	x	x	12"	0.52	0.52	0.99	1.61	-
									24"	-	0.90	1.73	2.82	2.52
									36"	-	-	2.47	4.02	3.60
									48"	-	-	3.21	5.22	4.67
4 	x	x	x	x		x	x	x	12"	0.48	0.48	0.93	1.51	-
									24"	-	0.87	1.67	2.71	2.43
									36"	-	-	2.41	3.92	3.50
									48"	-	-	3.15	5.12	4.58

TABLE B-5

FABRICATION MAN-HOUR NORMS FOR CHOCKS

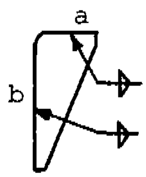
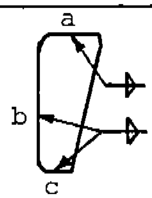
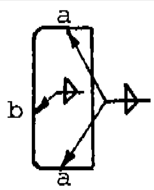
ITEM	FABRIC. STEPS			CONSTRUCTION STEPS					SIZE (a x b x c)	TOTAL MANHOURS FOR:				
	Layoff	Cutting	Forming	Layout	Cutting	Fitting	Welding	Inspect.		1/4"PL	3/8"PL	1/2"PL	3/4"PL	1" PL
1 	x	x				x	x	x	1.5" x 4.5"	0.16	0.19	0.28	-	-
									2" x 6"	0.21	0.26	0.37	0.67	-
									4" x 12"	0.42	0.52	0.73	1.33	1.48
									6" x 18"	-	0.79	1.10	2.00	2.22
2 	x	x				x	x	x	1.5"x3"x1"	0.15	0.19	0.25	-	-
									2"x4"x1"	0.19	0.24	0.32	0.60	-
									4"x8"x2"	0.38	0.48	0.65	1.20	1.36
									6"x12"x4"	-	0.74	1.02	1.86	2.10
3 	x	x				x	x	x	1.5" x 4"	0.21	0.29	0.35	-	-
									2" x 6"	0.29	0.40	0.48	0.93	-
									4" x 10"	0.54	0.75	0.89	1.73	2.12
									6" x 14"	-	1.10	1.29	2.52	3.12

TABLE B-6

FABRICATION MAN-HOUR NORMS FOR STIFFENER CLEARANCE CUTOUTS

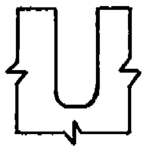
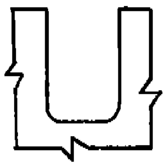
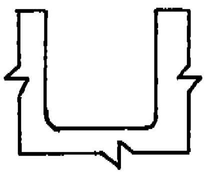
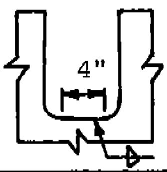
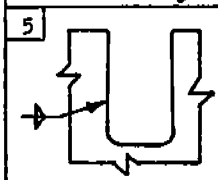
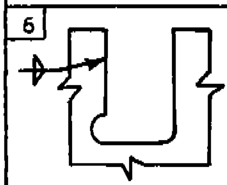
ITEM	FABRIC. STEPS: Layoff	FABRIC. STEPS: Cutting	FABRIC. STEPS: Forming	CONSTRUCTION STEPS: Layout	CONSTRUCTION STEPS: Cutting	CONSTRUCTION STEPS: Fitting	CONSTRUCTION STEPS: Welding	CONSTRUCTION STEPS: Inspect.	SIZE (Stiffener Depth)	TOTAL MANHOURS FOR: 1/4"PL	3/8"PL	1/2"PL	3/4"PL	1" PL
1 	x	x							6"	0.01	0.01	0.01	0.02	0.02
									8"	0.01	0.01	0.02	0.02	0.02
									10"	0.02	0.02	0.02	0.02	0.03
									12"	0.02	0.02	0.02	0.03	0.03
2 	x	x							6"	0.01	0.01	0.02	0.02	0.02
									8"	0.02	0.02	0.02	0.02	0.03
									10"	0.02	0.02	0.02	0.03	0.03
									12"	0.02	0.02	0.03	0.03	0.04
3 	x	x							6"	0.01	0.02	0.02	0.02	0.02
									8"	0.02	0.02	0.02	0.02	0.03
									10"	0.02	0.02	0.02	0.03	0.04
									12"	0.02	0.02	0.03	0.03	0.04
4 	x	x				x	x	x	6"	0.06	0.12	0.20	0.26	0.40
									8"	0.07	0.13	0.20	0.26	0.40
									10"	0.07	0.13	0.21	0.27	0.40
									12"	0.07	0.13	0.21	0.27	0.41
5 	x	x				x	x	x	6"	0.10	0.18	0.30	0.39	0.60
									8"	0.13	0.25	0.40	0.52	0.79
									10"	0.16	0.31	0.50	0.64	0.99
									12"	0.19	0.37	0.60	0.77	1.19
6 	x	x				x	x	x	6"	0.07	0.14	0.23	0.29	0.45
									8"	0.10	0.20	0.33	0.42	0.64
									10"	0.14	0.26	0.43	0.55	0.84
									12"	0.17	0.32	0.53	0.68	1.04

TABLE B-6 - Fabrication Man-hour Norms for Stiffener Clearance Cutouts (Cont'd)

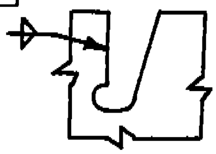
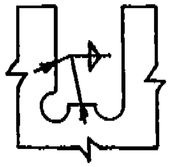
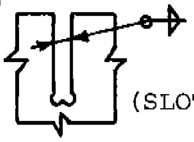
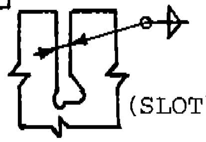
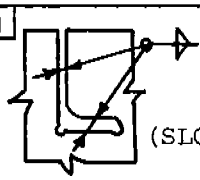
ITEM	FABRIC. STEPS			CONSTRUCTION STEPS					SIZE (Stiffener Depth)	TOTAL MANHOURS FOR:				
	Layoff	Cutting	Forming	Layout	Cutting	Fitting	Welding	Inspect.		1/4" PL	3/8" PL	1/2" PL	3/4" PL	1" PL
7 	x	x				x	x	x	6"	0.07	0.14	0.22	0.28	0.44
									8"	0.10	0.20	0.32	0.41	0.64
									10"	0.13	0.26	0.42	0.54	0.84
									12"	0.16	0.32	0.52	0.67	1.04
8 	x	x				x	x	x	6"	0.09	0.17	0.28	0.35	0.54
									8"	0.12	0.23	0.38	0.48	0.75
									10"	0.15	0.30	0.48	0.61	0.94
									12"	0.18	0.35	0.58	0.74	1.14
9  (SLOT)	x	x				x	x	x	6"	0.20	0.39	0.64	0.82	1.27
									8"	0.27	0.52	0.84	1.08	1.66
									10"	0.33	0.64	1.04	1.34	2.06
									12"	0.40	0.76	1.24	1.60	2.46
10  (SLOT)	x	x				x	x	x	6"	0.23	0.44	0.72	0.92	1.42
									8"	0.29	0.56	0.92	1.18	1.81
									10"	0.36	0.69	1.12	1.44	2.21
									12"	0.42	0.81	1.32	1.70	2.61
11  (SLOT)	x	x				x	x	x	6"	0.32	0.62	1.00	1.29	1.99
									8"	0.39	0.74	1.20	1.55	2.38
									10"	0.45	0.86	1.41	1.80	2.78
									12"	0.51	0.99	1.61	2.06	3.18

TABLE B-7

FABRICATION MAN-HOUR NORMS FOR LAPPED COLLARS

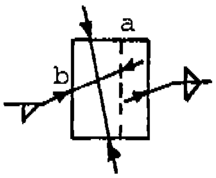
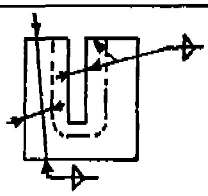
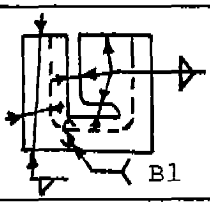
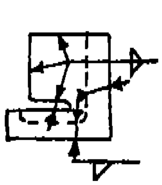
ITEM	FABRIC. STEPS			CONSTRUCTION STEPS					SIZE (a x b or Stiffener Size)	TOTAL MANHOURS FOR:				
	Layoff	Cutting	Forming	Layout	Cutting	Fitting	Welding	Inspect.		1/4"PL	3/8"PL	1/2"PL	3/4"PL	1" PL
1 	x	x		x			x	x	4" x 3"	0.31	0.50	0.45	0.99	1.43
									4" x 5"	0.43	0.70	0.63	1.39	2.00
									4" x 7"	0.56	0.90	0.81	1.78	2.57
									4" x 9"	0.68	1.10	0.99	2.18	3.14
									7" x 3"	0.40	0.65	0.58	1.29	1.86
									7" x 5"	0.52	0.85	0.76	1.69	2.43
									7" x 7"	0.65	1.05	0.94	2.08	3.00
									7" x 9"	0.77	1.25	1.12	2.48	3.57
									7" x 11"	0.89	1.46	1.30	2.88	4.14
2 	x	x		x			x	x	6" F.B.	1.24	2.01	1.80	3.97	5.71
									8" F.B.	1.48	2.41	2.15	4.76	6.85
									10" F.B.	1.73	2.81	2.51	5.56	8.00
									12" F.B.	2.01	3.26	2.92	6.45	9.28
3 	x	x		x		x	x	x	4" x 3" L	1.65	2.49	2.33	4.85	6.63
									6" x 4" L	2.03	3.12	2.89	6.08	8.42
									8" x 4" L	2.29	3.54	3.27	6.93	9.63
									10" x 6" L	2.79	4.34	3.99	8.52	11.92
4 	x	x		x		x	x	x	4" x 3" L	0.97	1.58	1.41	3.13	4.50
									6" x 4" L	1.22	1.98	1.77	3.92	5.64
									8" x 4" L	1.50	2.18	1.95	4.32	6.22
									10" x 6" L	1.65	2.68	2.40	5.31	7.64

TABLE B-7 - Fabrication Man-hour Norms for Lapped Collars (Cont'd)

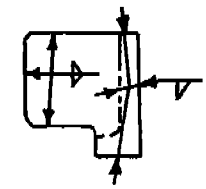
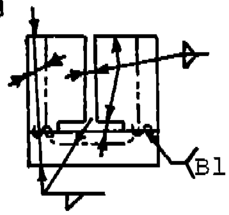
ITEM	FABRIC. STEPS			CONSTRUCTION STEPS					SIZE of Stiffener	TOTAL MANHOURS FOR:				
	Layoff	Cutting	Forming	Layout	Cutting	Fitting	Welding	Inspect.		1/4"PL	3/8"PL	1/2"PL	3/4"PL	1" PL
5 	x	x		x		x	x	x	6" x 4"I-T	0.78	1.28	1.14	2.53	3.64
									8" x 4"I-T	0.91	1.48	1.32	2.93	4.21
									10" x 4"I-T	1.03	1.68	1.50	3.32	4.78
									12" x 4"I-T	1.16	1.88	1.68	3.72	5.36
									4" x 3" L	0.66	1.08	0.96	2.13	3.07
									6" x 6"I-T	0.91	1.48	1.32	2.92	4.21
									8" x 6"I-T	1.03	1.68	1.50	3.32	4.78
									10" x 6"I-T	1.16	1.88	1.68	3.72	5.36
									12" x 6"I-T	1.28	2.08	1.86	4.12	5.93
									6" x 4" L	0.85	1.38	1.24	2.73	3.93
									8" x 4" L	0.97	1.58	1.41	3.13	4.50
									10" x 6" L	1.22	1.98	1.77	3.92	5.64
6 	x	x		x		x	x	x	6" x 4"I-T	2.44	3.59	3.43	6.96	9.33
									8" x 4"I-T	2.69	4.00	3.79	7.76	10.48
									10" x 4"I-T	2.94	4.40	4.15	8.55	11.62
									12" x 4"I-T	3.18	4.80	4.51	9.34	12.76
									8" x 6"I-T	3.12	4.69	4.42	9.15	12.48
									10" x 6"I-T	3.37	5.10	4.78	9.94	13.62
									12" x 6"I-T	3.62	5.50	5.13	10.73	14.76

TABLE B-8

FABRICATION MAN-HOUR NORMS FOR FLUSH COLLARS

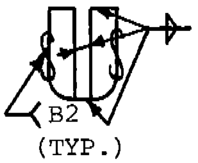
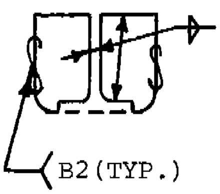
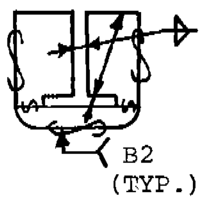
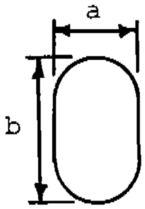
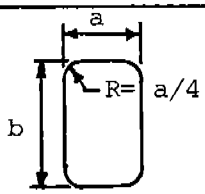
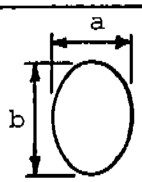
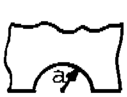
ITEM	FABRIC. STEPS			CONSTRUCTION STEPS					SIZE of Stiffener	TOTAL MANHOURS FOR:				
	Layoff	Cutting	Forming	Layout	Cutting	Fitting	Welding	Inspect.		1/4" PL	3/8" PL	1/2" PL	3/4" PL	1" PL
1 	x	x		x		x	x	x	6" F.B.	1.13	2.51	2.46	4.02	4.93
									8" F.B.	1.46	3.24	3.18	5.17	6.34
									10" F.B.	1.78	3.98	3.90	6.34	7.75
									12" F.B.	2.10	4.71	4.62	7.49	9.15
2 	x	x		x		x	x	x	6" x 4"I-T	1.36	2.88	2.80	4.76	6.00
									8" x 4"I-T	1.69	3.62	3.52	5.92	7.41
									10" x 4"I-T	2.01	4.35	4.24	7.08	8.82
									12" x 4"I-T	2.33	5.08	4.96	8.24	10.22
									8" x 6"I-T	1.81	3.82	3.69	6.31	7.98
									10" x 6"I-T	2.14	4.55	4.42	7.48	9.39
									12" x 6"I-T	2.46	5.28	5.14	8.63	10.79
3 	x	x		x		x	x	x	6" x 4"I-T	2.01	4.48	4.40	7.16	8.76
									8" x 4"I-T	2.34	5.22	5.12	8.32	10.17
									10" x 4"I-T	2.66	5.95	5.84	9.48	11.58
									12" x 4"I-T	2.98	6.68	6.56	10.63	12.98
									8" x 6"I-T	2.62	5.78	5.66	9.29	11.45
									10" x 6"I-T	2.94	6.52	6.38	10.46	12.86
									12" x 6"I-T	3.27	7.25	7.10	11.61	14.26

TABLE B-9

FABRICATION MAN-HOUR NORMS FOR CUTS

ITEM	FABRIC. STEPS: Layoff	FABRIC. STEPS: Cutting	FABRIC. STEPS: Forming	CONSTRUCTION STEPS: Layout	CONSTRUCTION STEPS: Cutting	CONSTRUCTION STEPS: Fitting	CONSTRUCTION STEPS: Welding	CONSTRUCTION STEPS: Inspect.	SIZE (a x b)	TOTAL MANHOURS FOR: 1/4"PL	3/8"PL	1/2"PL	3/4"PL	1" PL
1 	x	x							1" Dia.	0.02	0.02	0.02	0.02	0.02
									2" Dia.	0.01	0.01	0.01	0.01	0.01
									4" Dia.	0.01	0.01	0.01	0.01	0.02
									12" Dia.	0.02	0.03	0.03	0.04	0.04
									18" Dia.	0.04	0.04	0.05	0.06	0.07
2 	x	x							1" x 2"F.O.	0.01	0.01	0.01	0.01	0.01
									2" x 4"F.O.	0.01	0.01	0.01	0.01	0.01
									4" x 8"F.O.	0.01	0.02	0.02	0.02	0.02
									15"x18"F.O.	0.04	0.04	0.05	0.06	0.07
									18"x36"F.O.	0.06	0.07	0.08	0.10	0.12
									26"x66"F.O.	0.11	0.12	0.14	0.16	0.20
3 	x	x							4" x 8"	0.02	0.02	0.02	0.02	0.03
									18" x 36"	0.07	0.07	0.08	0.10	0.12
									26" x 66"	0.11	0.12	0.14	0.17	0.20
									31" x 72"	0.13	0.13	0.16	0.18	0.22
4 	x	x							2"x4" Elps.	0.01	0.01	0.01	0.01	0.01
									4"x8" Elps.	0.01	0.01	0.02	0.02	0.02
									15"x18"Elps	0.04	0.04	0.05	0.05	0.06
									18"x36"Elps	0.06	0.06	0.08	0.09	0.11
5 	x	x							1" R	0.01	0.01	0.01	0.01	0.01
									2" R	0.01	0.01	0.01	0.01	0.01
									4" R	0.01	0.01	0.01	0.01	0.01

NOTE: Hours are based on numerically controlled (NC) burning equipment.

TABLE B-10

FABRICATION MAN-HOUR NORMS FOR REINFORCING RINGS

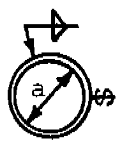
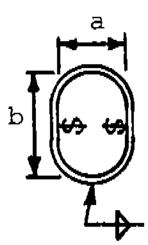
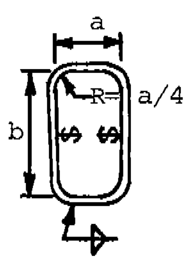
ITEM	FABRIC. STEPS			CONSTRUCTION STEPS					SIZE	TOTAL MANHOURS FOR:				
	Layoff	Cutting	Forming	Layout	Cutting	Fitting	Welding	Inspect.		1/4"PL	3/8"PL	1/2"PL	3/4"PL	1" PL
1 	x	x	x			x	x	x	4"Dia 4"xt	0.84	1.26	1.49	-	-
									12"Dia 4"xt	1.17	1.78	2.32	2.81	3.64
									18"Dia 4"xt	1.42	2.17	2.89	3.52	4.68
									18"Dia 6"xt	1.66	2.58	3.23	3.97	5.16
2 	x	x	x			x	x	x	4"x8"F.O. 4"xt	1.10	1.92	2.24	-	-
									15"x18"F.O. 4"xt	1.56	2.66	3.43	4.31	5.60
									18"x36"F.O. 6"xt	2.29	4.01	5.09	6.45	8.47
									26"x66"F.O. 6"xt	2.95	5.19	6.94	8.80	12.04
3 	x	x	x			x	x	x	4" x8" 4"xt	1.11	1.94	2.68	-	-
									18" x 36" 6"xt	2.30	4.03	5.11	6.48	8.52
									26" x 66" 6"xt	2.96	5.21	6.97	8.84	12.09
									31" x 72" 6"xt	3.12	5.51	7.46	9.48	13.08

TABLE B-11

FABRICATION MAN-HOUR NORMS FOR ENDS OF CIRCULAR STANCHIONS

ITEM	FABRIC. STEPS			CONSTRUCTION STEPS					SIZE (Outside Diameter)	TOTAL MANHOURS FOR WALL THICKNESS OF:				
	Layoff	Cutting	Forming	Layout	Cutting	Fitting	Welding	Inspect.		1/4"	3/8"	1/2"	3/4"	1"
1 				x	x	x	x	x	2"	0.10	0.16	-	-	-
									3"	0.15	0.24	0.21	-	-
									6"	0.29	0.47	0.42	0.94	-
									10"	-	0.79	0.71	1.56	2.25

TABLE B-12

FABRICATION MAN-HOUR NORMS FOR ENDS OF "H" STANCHIONS

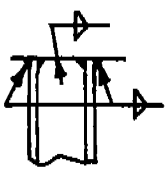
ITEM	FABRIC. STEPS			CONSTRUCTION STEPS					SIZE	TOTAL MANHOURS FOR STANCHION WEIGHT OF:				
	Layoff	Cutting	Forming	Layout	Cutting	Fitting	Welding	Inspect.		15-16#	25-31#	48-49#	65-67#	89-92#
1 				x	x	x	x	x	6 x 6 WF	0.55	0.84	-	-	-
									8 x 8 WF	-	0.97	1.69	2.80	-
									10 x 10 WF	-	-	1.79	2.43	3.50
									12 x 12 WF	-	-	-	2.15	3.70

TABLE B-13

FABRICATION MAN-HOUR NORMS FOR PADS

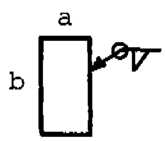
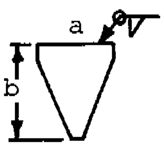
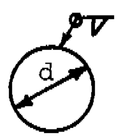
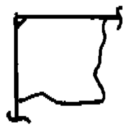
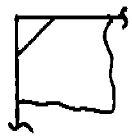
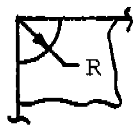
ITEM	FABRIC. STEPS			CONSTRUCTION STEPS					SIZE (a x b)	TOTAL MANHOURS FOR:				
	Layoff	Cutting	Forming	Layout	Cutting	Fitting	Welding	Inspect.		1/4"PL	3/8"PL	1/2"PL	3/4"PL	1" PL
1 	x	x				x	x	x	2" x 5"	0.35	0.35	0.32	0.69	-
									2" x 7"	0.45	0.45	0.41	0.89	1.29
									2" x 9"	0.55	0.55	0.49	1.09	1.57
									2" x 11"	-	0.65	0.58	1.29	2.48
									7" x 7"	0.70	0.70	0.63	1.39	-
									9" x 9"	0.91	0.91	0.81	1.79	2.57
									11" x 11"	1.11	1.11	0.99	2.18	3.14
									13" x 13"	-	1.31	1.50	2.58	3.71
2 	x	x				x	x	x	6" x 7"	0.58	0.58	0.52	1.14	-
									6" x 9"	0.68	0.68	0.61	1.50	1.93
									6" x 11"	0.78	0.78	0.70	1.54	2.21
									8" x 13"	-	0.89	0.79	1.74	2.50
3 	x	x				x	x	x	3" Dia.	0.24	0.24	0.21	0.47	-
									6" Dia.	0.47	0.47	0.43	0.94	1.35
									9" Dia.	0.71	0.71	0.64	1.40	2.02
									12" Dia.	-	0.95	0.85	1.87	2.69

TABLE B-14

FABRICATION MAN-HOUR NORMS FOR SNIPES

ITEM	FABRIC. STEPS			CONSTRUCTION STEPS					SIZE	TOTAL MANHOURS FOR:				
	Layoff	Cutting	Forming	Layout	Cutting	Fitting	Welding	Inspect.		1/4"PL	3/8"PL	1/2"PL	3/4"PL	1" PL
1 	x	x							1/8"x1/8"	0.06	0.06	0.06	0.07	0.07
									1/4"x1/4"	0.08	0.08	0.08	0.08	0.08
									1/2"x1/2"	0.09	0.09	0.09	0.09	0.10
									5/8"x5/8"	0.10	0.10	0.10	0.10	0.10
2 	x	x							1" x 1"	0.10	0.10	0.10	0.10	0.11
									2" x 2"	0.09	0.09	0.09	0.09	0.10
									3" x 3"	0.08	0.08	0.08	0.08	0.08
									4" x 4"	0.08	0.08	0.08	0.08	0.08
3 	x	x							1" R	0.11	0.11	0.11	0.11	0.11
									2" R	0.09	0.09	0.09	0.09	0.10
									3" R	0.08	0.09	0.09	0.09	0.09
									4" R	0.08	0.08	0.08	0.08	0.09

NOTE: Manual burning assumed.

TABLE B-15

FABRICATION MAN-HOUR NORMS FOR FLAT BARS

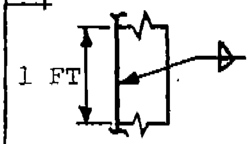
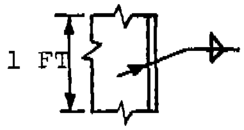
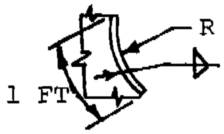
ITEM	FABRIC. STEPS			CONSTRUCTION STEPS					SIZE (F.B. Width)	TOTAL MANHOURS FOR:				
	Layoff	Cutting	Forming	Layout	Cutting	Fitting	Welding	Inspect.		1/4"PL	3/8"PL	1/2"PL	3/4"PL	1" PL
1 						x	x	x	4"	0.14	0.26	0.26	-	-
									6"	-	0.26	0.26	0.38	-
									8"	-	-	0.26	0.38	0.55
									10"	-	-	-	0.38	0.55
2 						x	x	x	4"	0.14	0.28	0.28	-	-
									6"	0.14	0.28	0.28	0.40	-
									8"	0.14	0.28	0.28	0.40	0.58
									10"	-	0.28	0.28	0.40	0.58
3 	x		x			x	x	x	6"R 4"FB	0.31	0.44	0.48	-	-
									6"R 6"FB	0.35	0.48	0.50	0.62	-
									6"R 8"FB	0.36	0.50	0.52	0.64	0.85
									6"R 10"FB	-	0.51	0.53	0.66	0.87
									12"R 4"FB	0.34	0.47	0.51	-	-
									12"R 6"FB	0.37	0.50	0.52	0.65	-
									12"R 8"FB	0.39	0.52	0.54	0.67	0.88
									12"R 10"FB	-	0.53	0.57	0.69	0.92
									18"R 4"FB	0.36	0.49	0.53	-	-
									18"R 6"FB	0.39	0.52	0.55	0.68	-
									18"R 8"FB	0.41	0.54	0.57	0.69	0.91
									18"R 10"FB	-	0.56	0.61	0.73	0.96

TABLE B-16

FABRICATION MAN-HOUR NORMS FOR FLAT BAR ENDS

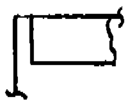
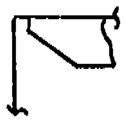
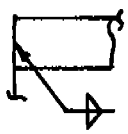
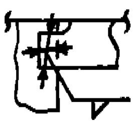
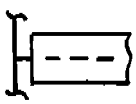
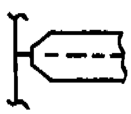
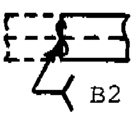
ITEM	FABRIC. STEPS		CONSTRUCTION STEPS						SIZE (F.B. Depth)	TOTAL MANHOURS FOR:				
	Layoff	Cutting	Forming	Layout	Cutting	Fitting	Welding	Inspect.		1/4"℞	3/8"℞	1/2"℞	3/4"℞	1" ℞
1 	x	x							4"	0.12	0.12	0.13	-	-
									6"	-	0.12	0.12	0.12	-
									8"	-	-	0.12	0.12	0.12
									10"	-	-	-	0.12	0.12
2 	x	x							4"	0.16	0.16	0.16	-	-
									6"	-	0.15	0.15	0.15	-
									8"	-	-	0.15	0.15	0.15
									10"	-	-	-	0.15	0.15
3 	x	x				x	x	x	4"	0.16	0.27	0.24	-	-
									6"	-	0.40	0.36	0.79	-
									8"	-	-	0.48	1.06	1.52
									10"	-	-	-	1.32	1.90
4 	x	x				x	x	x	4"	0.16	0.27	0.24	-	-
									6"	-	0.40	0.36	0.64	-
									8"	-	-	0.48	0.86	1.28
									10"	-	-	-	1.08	1.60
5 	x	x							4"	0.11	0.11	0.11	-	-
									6"	0.11	0.11	0.12	0.12	-
									8"	0.12	0.12	0.12	0.12	0.13
									10"	-	0.12	0.12	0.13	0.14
6 	x	x							4"	0.17	0.17	0.17	-	-
									6"	0.17	0.17	0.18	0.18	-
									8"	0.18	0.18	0.18	0.18	0.19
									10"	-	0.18	0.18	0.19	0.20
7 	x	x				x	x	x	4"	0.27	0.71	0.72	-	-
									6"	0.40	1.07	1.08	1.52	-
									8"	0.54	1.42	1.45	2.03	2.23
									10"	-	1.78	1.81	2.54	2.79

TABLE B-17

FABRICATION MAN-HOUR NORMS FOR ANGLE STIFFENER ENDS

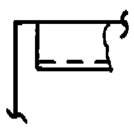
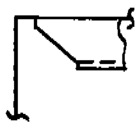
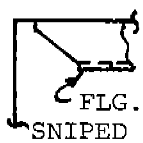
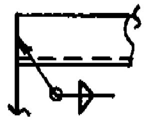
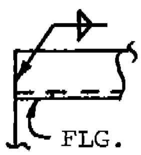
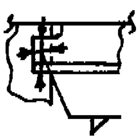
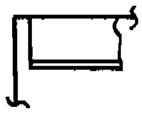
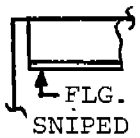
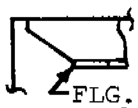
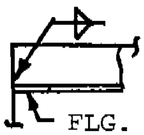
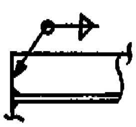
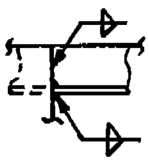
ITEM	FABRIC. STEPS			CONSTRUCTION STEPS					SIZE	TOTAL MANHOURS FOR:				
	Layoff	Cutting	Forming	Layout	Cutting	Fitting	Welding	Inspect.	(Depth x Flange Width)	1/4" PL	3/8" PL	1/2" PL	3/4" PL	1" PL
1 	x	x							4" x 3"	0.10	0.10	0.10	-	-
									6" x 4"	-	0.10	0.10	0.11	-
									8" x 4"	-	-	0.11	0.11	0.12
									10" x 6"	-	-	0.12	0.12	0.13
2  FLG. SNIPED 45°	x	x							4" x 3"	0.15	0.15	0.15	-	-
									6" x 4"	-	0.15	0.15	0.15	-
									8" x 4"	-	-	0.16	0.16	0.17
									10" x 6"	-	-	0.16	0.17	0.18
3 	x	x							4" x 3"	0.20	0.20	0.20	-	-
									6" x 4"	-	0.19	0.19	0.20	-
									8" x 4"	-	-	0.19	0.19	0.20
									10" x 6"	-	-	0.18	0.18	0.19
4  FLG. SNIPED 45°	x	x							4" x 3"	0.26	0.26	0.26	-	-
									6" x 4"	-	0.24	0.25	0.25	-
									8" x 4"	-	-	0.24	0.25	0.26
									10" x 6"	-	-	0.23	0.24	0.24
5 	x	x				x	x	x	4" x 3"	0.29	0.47	0.42	-	-
									6" x 4"	-	0.67	0.60	1.32	-
									8" x 4"	-	-	0.72	1.59	2.29
									10" x 6"	-	-	0.95	2.12	3.05
6  FLG. SNIPED 45°	x	x				x	x	x	4" x 3"	0.18	0.28	0.25	-	-
									6" x 4"	-	0.41	0.37	0.81	-
									8" x 4"	-	-	0.49	1.07	1.54
									10" x 6"	-	-	0.61	1.33	1.92
7 	x	x				x	x	x	4" x 3"	0.14	0.25	0.22	-	-
									6" x 4"	-	0.38	0.34	0.62	-
									8" x 4"	-	-	0.47	0.86	1.28
									10" x 6"	-	-	0.60	1.08	1.61

TABLE B-18

FABRICATION MAN-HOUR NORMS FOR TEE STIFFENER ENDS

ITEM	FABRIC. STEPS			CONSTRUCTION STEPS					SIZE	TOTAL MANHOURS FOR BEAM WEIGHT/FT. OF:				
	Layoff	Cutting	Forming	Layout	Cutting	Fitting	Welding	Inspect.	(Depth)	9-10#	12-13#	16-18#	24-26#	33-35#
1 	x	x							6" I-T	0.10	0.10	0.10	-	-
									8" I-T	0.10	0.11	0.11	0.11	-
									10" I-T	0.11	0.11	0.11	0.11	0.11
									12" I-T	-	0.12	0.12	0.12	0.12
2  FLG. SNIPED 45° N/F	x	x							6" I-T	0.18	0.18	0.18	-	-
									8" I-T	0.18	0.18	0.18	0.18	-
									10" I-T	0.17	0.18	0.18	0.18	0.18
									12" I-T	-	0.18	0.18	0.18	0.19
3 	x	x							6" I-T	0.22	0.23	0.23	-	-
									8" I-T	0.22	0.22	0.22	0.22	-
									10" I-T	0.22	0.22	0.22	0.22	0.23
									12" I-T	-	0.22	0.22	0.22	0.23
4  FLG. SNIPED 45° N/F	x	x							6" I-T	0.27	0.28	0.28	-	-
									8" I-T	0.27	0.28	0.28	0.28	-
									10" I-T	0.26	0.27	0.27	0.27	0.28
									12" I-T	-	0.27	0.27	0.27	0.28
5  FLG. SNIPED 45° N/F	x	x				x	x	x	6" I-T	0.21	0.26	0.27	-	-
									8" I-T	0.22	0.35	0.35	0.35	-
									10" I-T	0.23	0.23	0.44	0.44	0.45
									12" I-T	-	0.28	0.52	0.53	0.54
6 	x	x				x	x	x	6" I-T	0.22	0.43	0.43	-	-
									8" I-T	0.27	0.51	0.51	0.60	-
									10" I-T	0.31	0.31	0.60	0.68	0.76
									12" I-T	-	0.35	0.68	0.76	0.80
7 	x	x				x	x	x	6" I-T	0.32	0.43	0.55	-	-
									8" I-T	0.27	0.51	0.63	0.76	-
									10" I-T	0.40	0.40	0.71	0.80	0.92
									12" I-T	-	0.44	0.68	0.93	1.22

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APPENDIX C

DESIGN GUIDE FOR SHIP STRUCTURAL DETAILS

Contents | Page

C.1 INTRODUCTION

This design guide is a compilation of 160 details which have a history of successful service balanced against reasonable fabrication costs for both naval and commercial ships. The original list of 634 details from Refs. 59 and 73 was reduced by the selection process shown in Table C-1. It should be noted that the 414 details presented and discussed in Section 3 of this report include details with relatively high failure rates to allow discussion of poor design practices along with good design practices.

TABLE C-1 NUMBER OF DETAILS CONSIDERED

Original detail list	634
Combined with similar details	38
subtotal	596
Infrequently used details	182
subtotal (in Sec. 3)	414
High failure rates	125
subtotal	289
Non-optimum geometries	129
total (in Appendix C)	160

The details in this design guide are arranged in eleven families and 55 family groups. In the figures each detail is labeled with the number assigned in SSC Report No. SSC-294 (Ref. 59) to permit ready reference to that background data. Below the detail label is the observed number of details followed by the number of failures, if any. Numbers followed by an N and enclosed in parentheses are observations on naval ships. Failures are indicated on the detail sketches with a plus (+) denoting buckling and a minus (-) indicating cracking. The failures are also highlighted with arrows and a failure percentage. Below the observation numbers is listed an estimated fabrication time for a typical size of the detail which permits ready comparison between family groups as well as between individual details. Fabrication time for other sizes of details can be readily determined from the values listed in Appendix B.

C.2 BEAM BRACKET DETAILS - FAMILY NO. 1

C.2.1 Brackets for Structurally Continuous - Physically Intercostal Beams

C.2.1.1 Plate Bracket In Way of Bulkhead Stiffener

Only one detail was observed in this group as shown in Fig. C-1. This is a typical commercial ship detail with lapped brackets which can be fabricated in significantly fewer hours than the typical naval ship details in the next family group.

C.2.1.2 Built-Up Bracket In Way of Bulkhead Stiffener

All three details shown in this group are naval ship details. The first two details are built-up from plate to slightly different configurations while the third detail is built-up primarily from rolled shapes. For the 8" deep stiffener used, the third detail (1-A-8) shows a significant cost savings over the first two details. Table 4-2 shows the same trend for a 12" deep stiffener while calculations for a 6" deep stiffener show essentially the same construction hours for all three details.

Since the detail's size can have an impact on fabrication cost, it is recommended that a designer perform calculations for his specific detail using the values in Appendix B. An example calculation is given in Table 4-1. In addition to generally being the least expensive arrangement, detail 1-A-8 should also be the strongest because the deck beam flanges help stiffen this connection.

The normal procedure in sizing the bracket plate in details 1-A-3 and 4 is to use the same thickness as the web of the deck stiffener. Since the bracket depth is generally twice the beam depth, there is a potential buckling problem in the bracket if these details are heavily loaded although no buckling was observed in these details. Formulas for checking buckling are available in Refs. 4, 9, 12, 15, and 28.

C.2.1.3 Built-Up Bracket In Way of Girder

The construction of the one detail shown in this group is similar to detail 1-A-8 of the previous group. Alternatives similar to details 1-A-3 and 4 were not observed.

C.2.2 Straight Corner Brackets

C.2.2.1 Plate

The details shown in this group follow a distinct trend for the strongest details to require the most fabrication time. The few failures observed have been buckling which is attributed to insufficient bracket thickness rather than the basic geometry. Detail 1-C-4 is the least expensive although there is potential for failure in the unsupported plating in the corner similar to that shown in Fig. C-2. Detail 1-C-8 eliminates this potential failure mode for a small increase in both fabrication time and material required (i.e., longer stiffeners must be ordered if the webs of both stiffeners are to be sniped). The remaining details (1-C-3, 1-C-20, & 1-C-21) are the strongest and most expensive details. The increased cost is due to the fitting and welding of the flange and web at the end of one of the stiffeners in each detail. This connection helps to reduce the load which must be transferred through the bracket plate, increases the lateral stiffness of the detail, and could provide backup for a stiffener on the opposite side of the connection if needed. If none of these features is required at a given location, the flange of the attached beam could be sniped for a savings of about 1/4 hr. per detail.

C.2.2.2 Flanged

Flanging small plate brackets can be accomplished for almost negligible cost. The hours shown in Fig. C-1 are for brackets of the same thickness as the previous group. In many cases a flanged bracket of lesser thickness than a plate bracket could be used because of the increased panel stability the flange provides. In these cases the flanged brackets would be less expensive than the flat plate brackets. The stiffener endings are very similar to those described in Section C.2.2.1.

The failures in detail 1-E-1 were observed amidships on containerships and general cargo ships. They were attributed to heavy seas and minor collisions so these asymmetric details are not desirable on heavily loaded members.

C.2.2.3 Built-Up

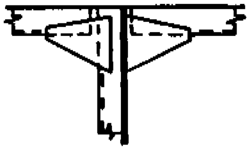
The one detail shown in Fig. C-1 for this group performed very well. Detail 1-G-1 is a typical naval ship detail with symmetric sections and adequate chocks at critical areas which requires more time to fabricate than the typical commercial ship details of the previous two groups.

FIGURE C-1

COST VERSUS PERFORMANCE - BEAM BRACKET DETAILS-FAMILY NO. 1

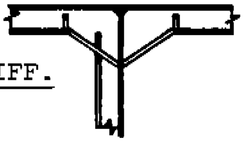
STRUCTURALLY CONTINUOUS BEAMS

PLATE BRKT.
I.W.O. BHD.
STIFF.

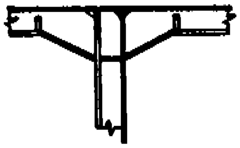


1-B-2
190
4.33 hrs.

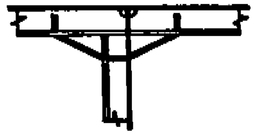
BUILT-UP BRKT.
I.W.O. BHD. STIFF.



1-A-3
(2410N)
10.50 hrs.



1-A-4
(830N)
10.80 hrs.



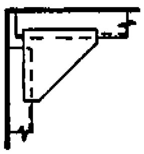
1-A-8
(350N)
8.42 hrs.

BUILT-UP BRKT.
I.W.O. GIRD.

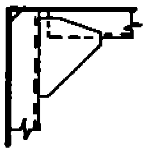
1-A-7
(410N)
6.28 hrs.

STRAIGHT CORNER BRACKETS

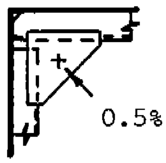
PLATE



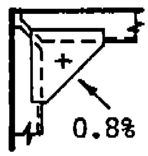
1-C-4
830
1.88 hrs.



1-C-20 & 21
340
2.56 hrs.

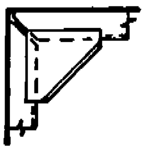


1-C-3
380/2
2.49 hrs.

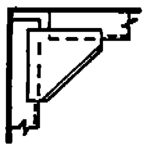


1-C-8
5777/49
2.03 hrs.

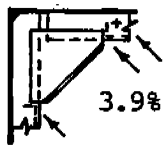
FLANGED



1-E-4
1040
2.04 hrs.

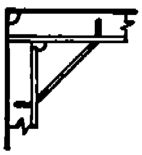


1-E-2
546
1.88 hrs.



1-E-1
3243/125
2.49 hrs.

BUILT-UP



1-G-1
(4840N)
4.24 hrs.

Note: Hours shown are for 8"x4"x½"L or 8"x6½"x24# I -⊥.

C.2.3 Curved Corner Brackets

C.2.3.1 Plate

Fabrication costs for flat plate curved corner brackets (Fig. C-3) are essentially the same as the similar straight corner brackets. Appropriate application areas are also similar. The curved brackets generally have a much smaller failure rate although the numbers observed are also much smaller than the straight corner brackets.

C.2.3.2 Built-Up

Only one detail is shown in this group in Fig. C-3 because all others observed had a significant incidence of failure. The hours for this detail are relatively high because of the face plate, chocks, and panel stiffening required to stabilize the thin plating used in the corner. The butt welds required at the bracket-stiffener intersections also increase the fabrication time over the lap welded connections of the previous group.

C.2.4 Hatch Girder End Brackets

The least expensive hatch girder end bracket shown is a simple extension of the hatch girder plating with a generous radius (detail 1-J-7). However, this detail should be more susceptible to buckling than detail 1-J-1 because it extends further beyond the end of the hatch opening. Detail 1-J-1 has an observed history of buckling failures, primarily on containerships. Adding a flange to these details as in detail 1-J-6 should eliminate most buckling problems but the expense is relatively high.

C.2.5 Beam End Brackets

C.2.5.1 At "Soft" Plating

Only two details are shown in this group (Fig. C-4) and again the strongest detail (1-H-6) is the most expensive. The fabrication time shown for this detail includes about 1/4 hour for welding the stiffener flange to the deck which could be eliminated in some cases as discussed in the section on straight flat plate corner brackets. If no bending restraint at the end of the stiffener is required, the padded end connections of Family No. 11 could be used with significant cost savings.

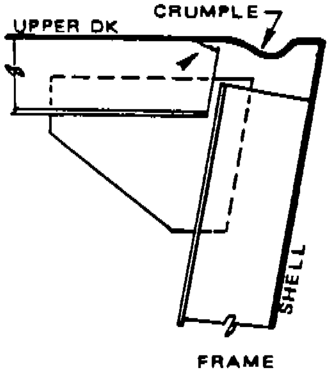


FIGURE C-2

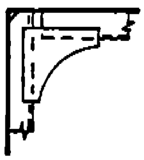
POTENTIAL FAILURES IN WAY OF CORNER BRACKET

FIGURE C-3

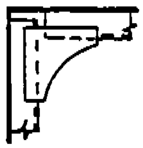
COST VERSUS PERFORMANCE - BEAM BRACKET DETAILS-FAMILY NO. 1 - Cont'd.

CURVED CORNER BRACKETS

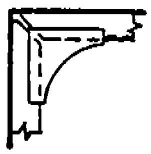
PLATE



1-D-1
1660
2.49 hrs.

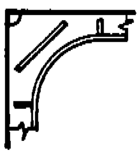


1-D-2
1480
1.88 hrs.



1-D-3
170
2.04 hrs.

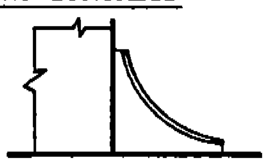
BUILT-UP



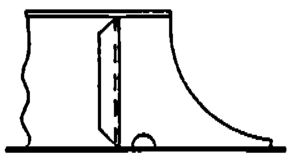
1-F-3
30
6.38 hrs.

Note: Hours shown are for 8"x4"x½" L or 8"x6½"x24# I-⊥.

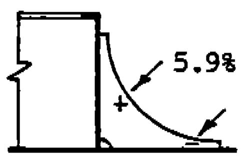
HATCH GIRDER END BRACKETS



1-J-6
108
6.59 hrs.



1-J-7
24
0.87 hrs.



1-J-1
102/6
(10/2N)
3.68 hrs.

C.2.5.2 At Structural Sections

Beam end brackets at structural sections perform two basic functions: an ending for the beam and lateral support for the structural section (girder or stringer). The detail ranking by fabrication time is similar to the previous group and to plate corner brackets: the detail with the beam end fully welded (detail 1-H-14) is significantly stronger and more expensive than the detail where the beam terminates clear of the joint (detail 1-H-12).

C.2.5.3 Plates at Rigid Structure

Of the three details shown, the primary cost differences are due to the size of the bracket (detail 1-L-6 is smaller than detail 1-L-1) and the fitting requirements (detail 1-L-3 must be fitted to two surfaces rather than one as on details 1-L-6 and 1-L-1). The failures observed in details 1-L-3 and 1-L-1 were attributed to insufficient bracket thickness rather than the basic detail geometry.

C.2.5.4 Flanged at Rigid Structure

The fabrication times shown for these details are for brackets with the same thickness as plate brackets. In many cases, thinner plates could be used for flanged brackets with significant savings in fabrication time. The least expensive detail (1-M-2) terminates the beam clear of the joint by a small amount. The next detail in order of expense (1-M-5) terminates the beam well clear of the joint with the bracket replacing the stiffener at the end which helps reduce the length of welding involved. In details 1-M-1 and 1-M-3, the stiffeners are fully welded to the deck with the bracket added on. For these two details, about 1/4 hour could be saved by sniping the beam flange if this loss in strength is acceptable at a given location. Detail 1-M-3 is more expensive than detail 1-M-1 because its bracket must be fitted to two surfaces (the deck and the beam flange).

C.2.5.5 Built-Up at Rigid Structure

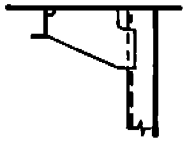
The three details shown follow trends similar to corner and continuous beam brackets. The radiused connection (1-P-2) is the least expensive but its cost could increase significantly for heavily loaded beams if additional chocks and stiffening similar to the curved built up corner bracket 1-F-3 are required. Details 1-N-4 and 1-N-3 follow the same trend as continuous built-up bracket details 1-A-8 and 1-A-4, respectively. The details built-up from rolled sections (1-N-4 and 1-A-8) are less expensive than those built-up from plate (1-N-3 and 1-A-4) for the stiffener size indicated.

FIGURE C-4

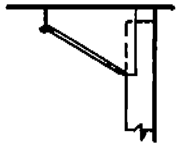
COST VERSUS PERFORMANCE - BEAM BRACKET DETAILS-FAMILY NO. 1 -Cont'd.

BEAM END BRACKETS

AT "SOFT" PLATING

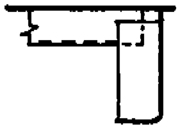


1-H-6
503
2.44 hrs.

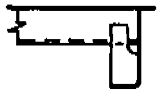


1-K-1
116
1.85 hrs.

AT STRUCTURAL SECTIONS

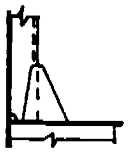


1-H-12
1195
0.59 hrs.

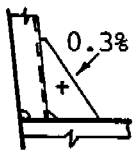


1-H-14
332
1.20 hrs.

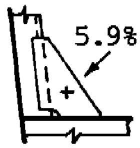
PLATES AT RIGID STR.



1-L-6
30
1.94 hrs.

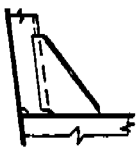


1-L-3
288/1
2.32 hrs.

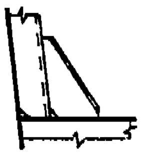


1-L-1
136/8
2.20 hrs.

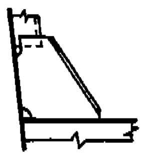
FLANGED AT RIGID STR.



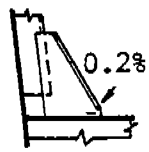
1-M-1
780
2.20 hrs.



1-M-3
200
2.32 hrs.

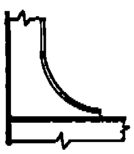


1-M-5
160
2.12 hrs.

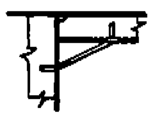


1-M-2
490/1
1.33 hrs.

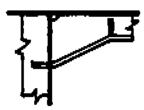
BUILT-UP AT RIGID STR.



1-P-2
310
3.05 hrs.



1-N-4
(230N)
3.32 hrs.



1-N-3
(50N)
4.59 hrs.

Note: Hours shown are for 8"x4"x½" L or 8"x6½"x24# I-⊥.

C.3 TRIPPING BRACKET DETAILS - FAMILY NO. 2

C.3.1 For Stiffeners

The four stiffener tripping brackets shown in Fig. C-5 represent different design conditions so a cost/performance trade-off between them is not appropriate. The least expensive detail (2-A-19) is only suitable for relatively light stiffening on thick plating unless the chock is "backed-up" by structure on the opposite side of the plating. The next detail in order of fabrication cost is 2-A-14. This detail ties two stiffeners together which considerably increases the lateral support provided. The detail shown is one piece but it can easily be built-up from flat bars. If the plating is subject to a lateral load, this bracket detail must be designed to carry a portion of the load to the stiffeners. As the stiffener sizes increase and/or the lateral load on the plating increases, additional stiffness and strength, respectively, are required for the portion of the detail between the stiffeners and detail 2-A-13 results. When the depth of the stiffeners increases and the length of the flat bars becomes over six inches, tee shapes are specified for the vertical members as in detail 2-C-16 to provide sufficient lateral stiffness.

C.3.2 For Shallow Girders

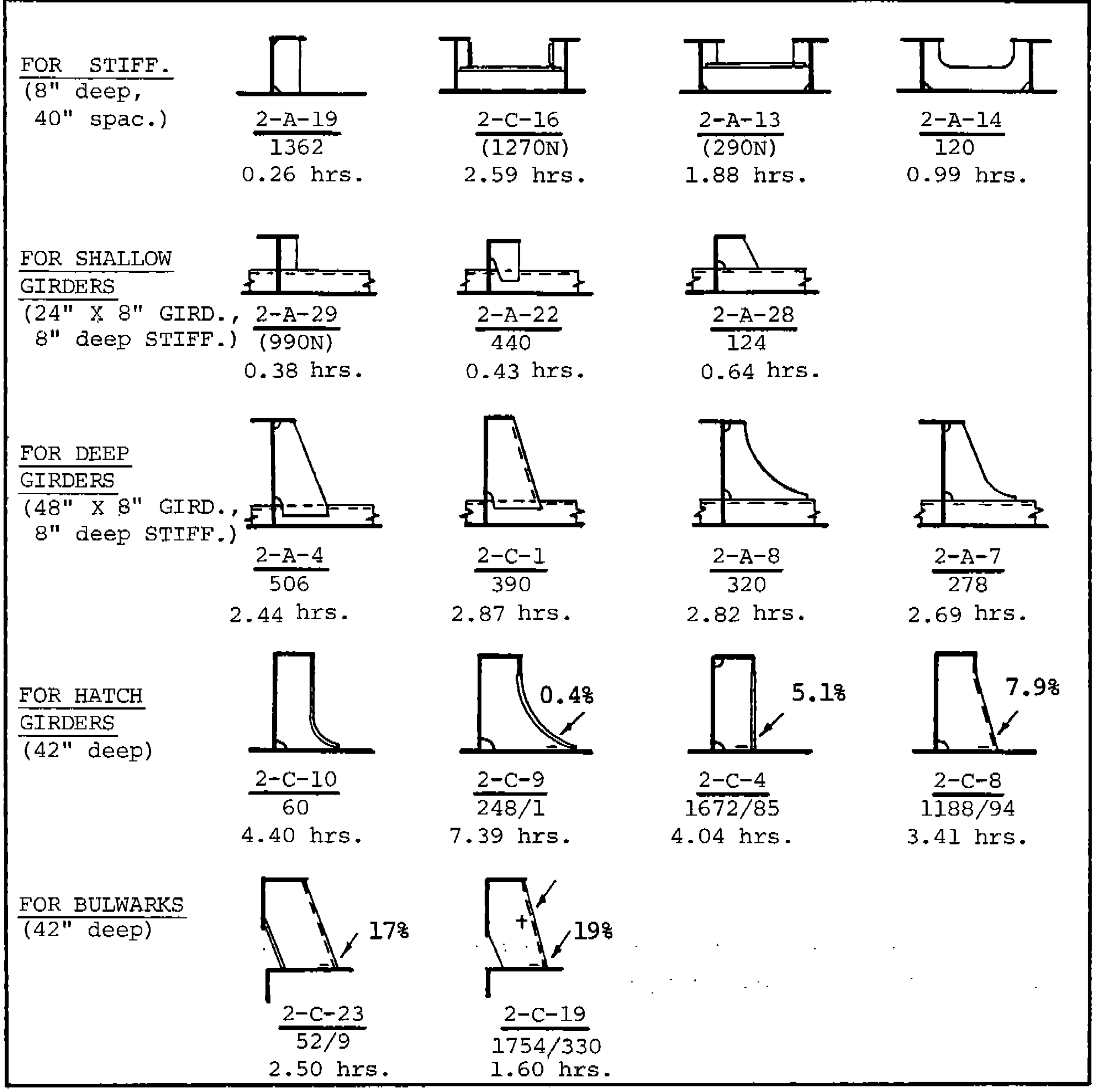
Tripping brackets for shallow girders are generally large chocks tied into stiffening as shown in Fig. C-5. Detail 2-A-29 is the least expensive because a standard girder size was used and the girder flange of this detail is centered on the web. Consequently, its tripping bracket requires less weld and less time than the other two details shown. In general, there seems to be little difference in fabrication time for lapped brackets such as detail 2-A-22 and fitted brackets such as detail 2-A-28. The major reason for the difference in the hours shown is the wider base of the latter detail which requires more weld. The wider base of detail 2-A-28 also provides greater stiffness so the strongest detail is again the most expensive.

C.3.3 For Deep Girders

Three of the deep girders shown in Fig. C-5 have centered flanges and, consequently, smaller tripping brackets than the fourth detail (2-C-1). The bracket size rather than the bracket flange is the primary reason why detail 2-C-1 has the highest fabrication time. Of the other three details, the lapped bracket of detail 2-A-4 is the least expensive primarily because the portion attached to the stiffener is smaller and consequently requires less welding than the radiused brackets 2-A-8 and 2-A-7.

FIGURE C-5

COST VERSUS PERFORMANCE - TRIPPING BRACKET DETAILS-FAMILY NO. 2



C.3.4 For Hatch Girders

The lower end of the flanges of the first two brackets shown in Fig. C-5 are sniped while the hours for the last two brackets are with the flanges welded to the deck. Most of the failures observed in the latter two brackets occurred where the flanges had been sniped where they meet the deck. Detail 2-C-8 is the least expensive and generally provides adequate service when the flange is welded to the deck and the detail is adequately "backed-up" by structure below the deck. Detail 2-C-4 requires more time because of the welding associated with its centered face plate. The primary reason for the difference in cost for the first two brackets is the larger size of bracket detail 2-C-9.

C.3.5 For Bulwarks

Many failures have been observed in bulwark brackets and a primary problem area has been in way of sniped flanges at the deck. The hours shown are for details with flanges welded to the deck. Detail 2-C-23 is significantly stronger than detail 2-C-19 because it has flanges on both sides of the section at the deck.

C.4 STIFFENER CLEARANCE CUTOUT DETAILS - FAMILY NO. 8

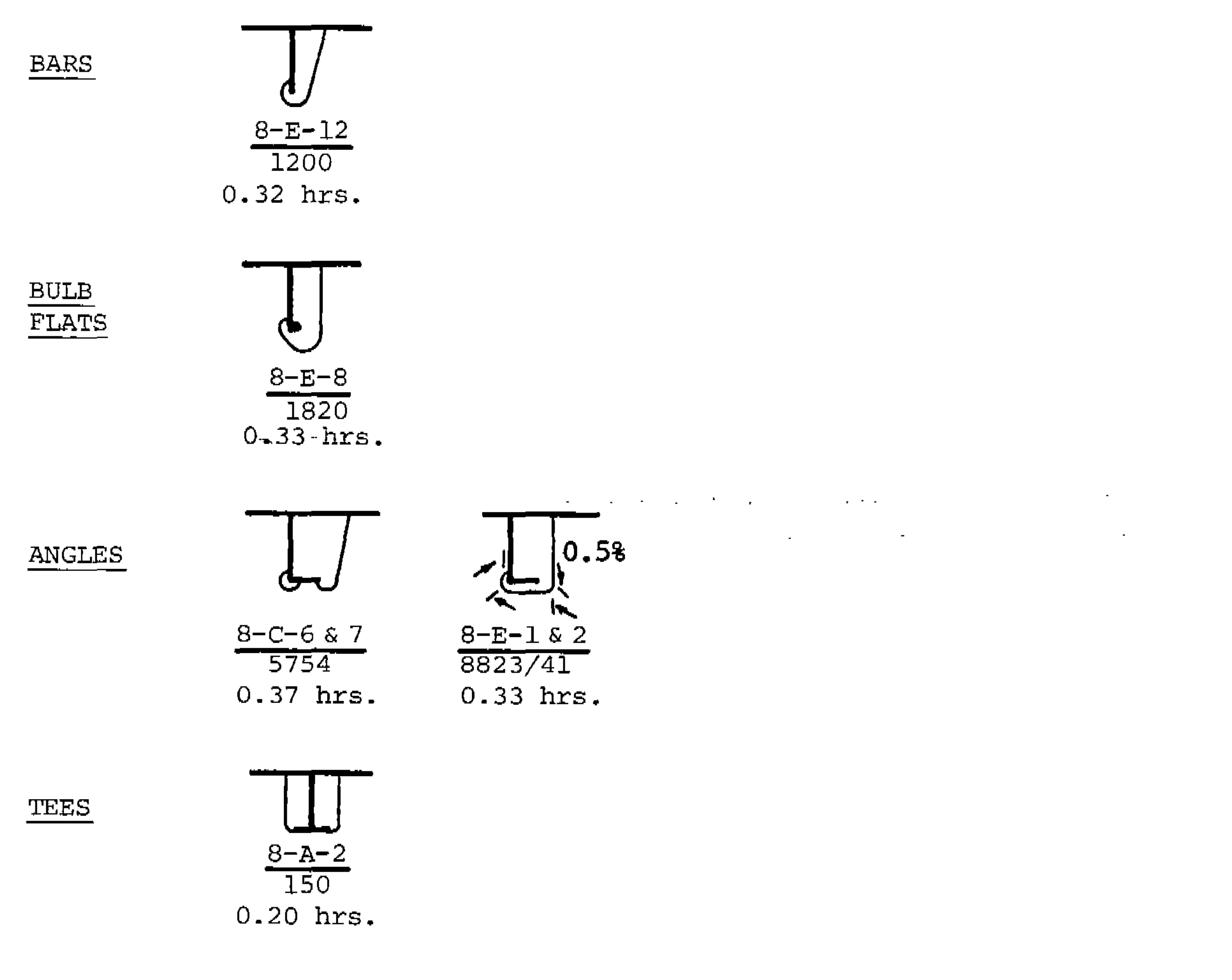
The major portion of the fabrication hours shown in Fig. C-6 is due to the welding required. All of the details shown provide some shear attachment for the stiffening member to the penetrated plate for a relatively modest cost. Details 8-C-6&7 provide both a web and flange attachment for the angle which gives more lateral support to both the angle and the penetrated member. The cost increase for the increased strength is fairly small. Detail 8-A-2 is suitable only for stiffening members with relatively smaller lateral loads than those of the other details shown.

As the lateral load on the stiffening member increases, additional connection to the supporting structure should be provided by collars (see Section C.5) and/or panel stiffeners (see Section C.12, Family Group 12-C). These additions also strengthen the supporting structure which may be critical in some cases.

If simple clearance cutouts are satisfactory in a girder, there is a preferred arrangement for the shear connection to the stiffeners as shown in Fig. C-7: the connection should be on the side toward the girder supports. This corresponds to the condition termed "counter clockwise shear" in Ref. 60 (pgs. 64 & 65) where stress concentrations are expected to be half of what they would be in the opposite case [comparing Fig. 29(b) with Fig. 29(a) in Ref. 60]. For cases where this arrangement is not feasible, as in Fig. C-8 where all the stiffener flanges are located to improve drainage, collar plates should be fitted as shown. The real issue is not clockwise versus counter clockwise shear but whether the local load Q tends to add to or subtract from the initial load in the flat bar stiffener caused by the basic girder shear force. The second paragraph on page 60 of Ref. 60 states that "for Configuration (b), where a counter clockwise shear is applied..., the distance d across the cutout is increased, resulting in tension in the flat bar stiffener... This tension will now be reduced when the local load Q from the shell longitudinal is applied." However, when the loading is reversed, the local force Q relieves the "compressive stresses in the clockwise case." When the loading is reversed, the direction of the girder shear is also reversed. Thus for both loading directions, the location with minimum stresses referred to is the upper one in Fig. 27 of Ref. 60 where the shear connection to the longitudinal is on the side closest to the girder support. Consequently, there is a preferred orientation for the shear connections to the longitudinals as shown in Fig. C-7.

FIGURE C-6

COST VERSUS PERFORMANCE - STIFFENER CLEARANCE CUTOUT DETAILS-FAMILY NO. 8



Note: Hours shown are for 8" deep stiffeners penetrating ½" plate.

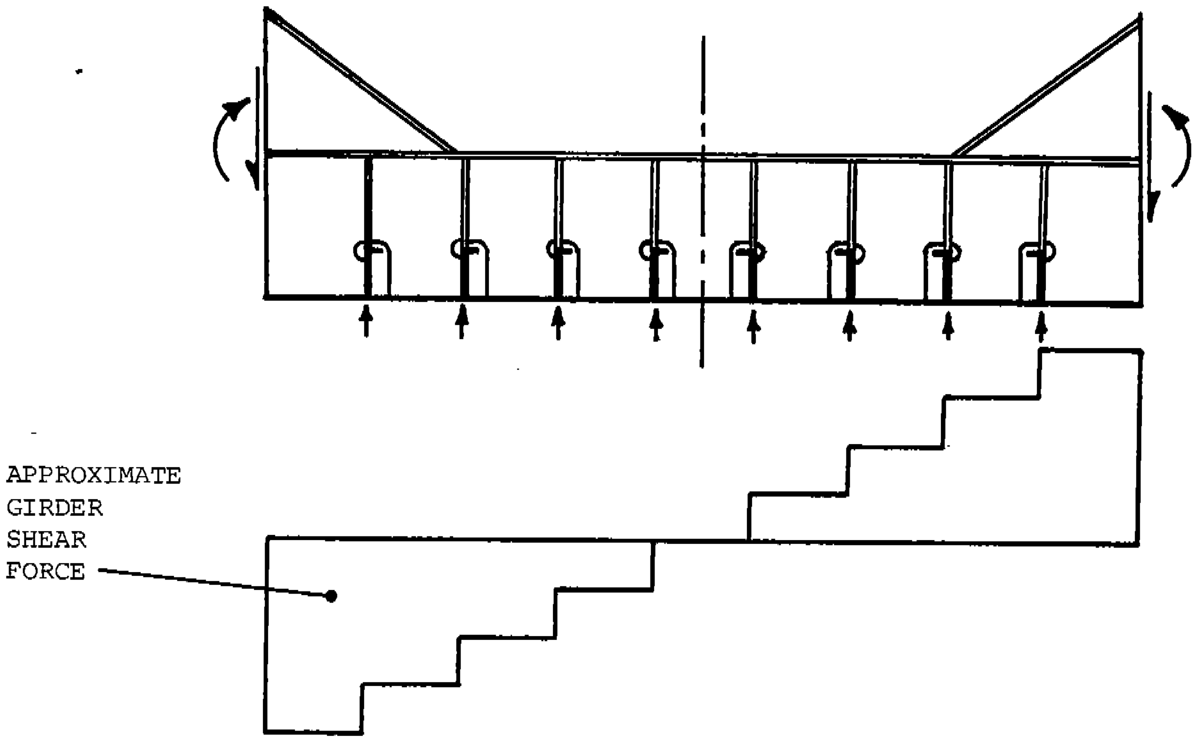


FIGURE C- 7

PREFERRED ARRANGEMENT OF STIFFENER CLEARANCE CUTOUTS

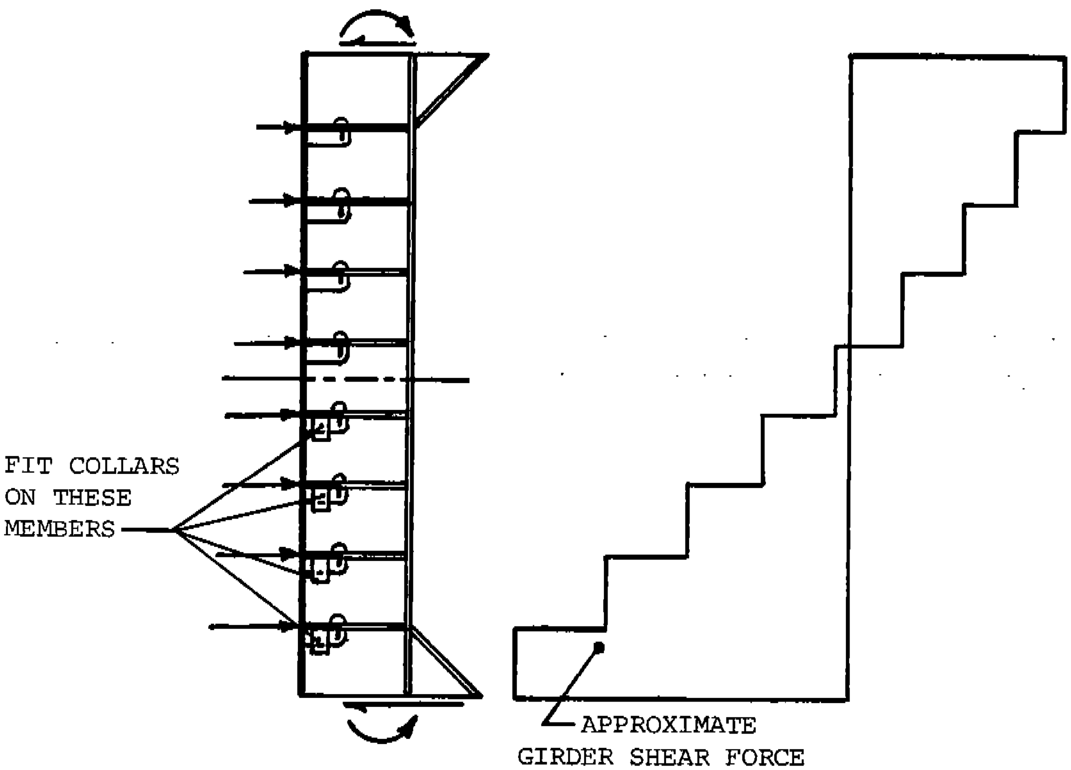


FIGURE C- 8

STIFFENER CLEARANCE CUTOUTS IN A VERTICAL GIRDER

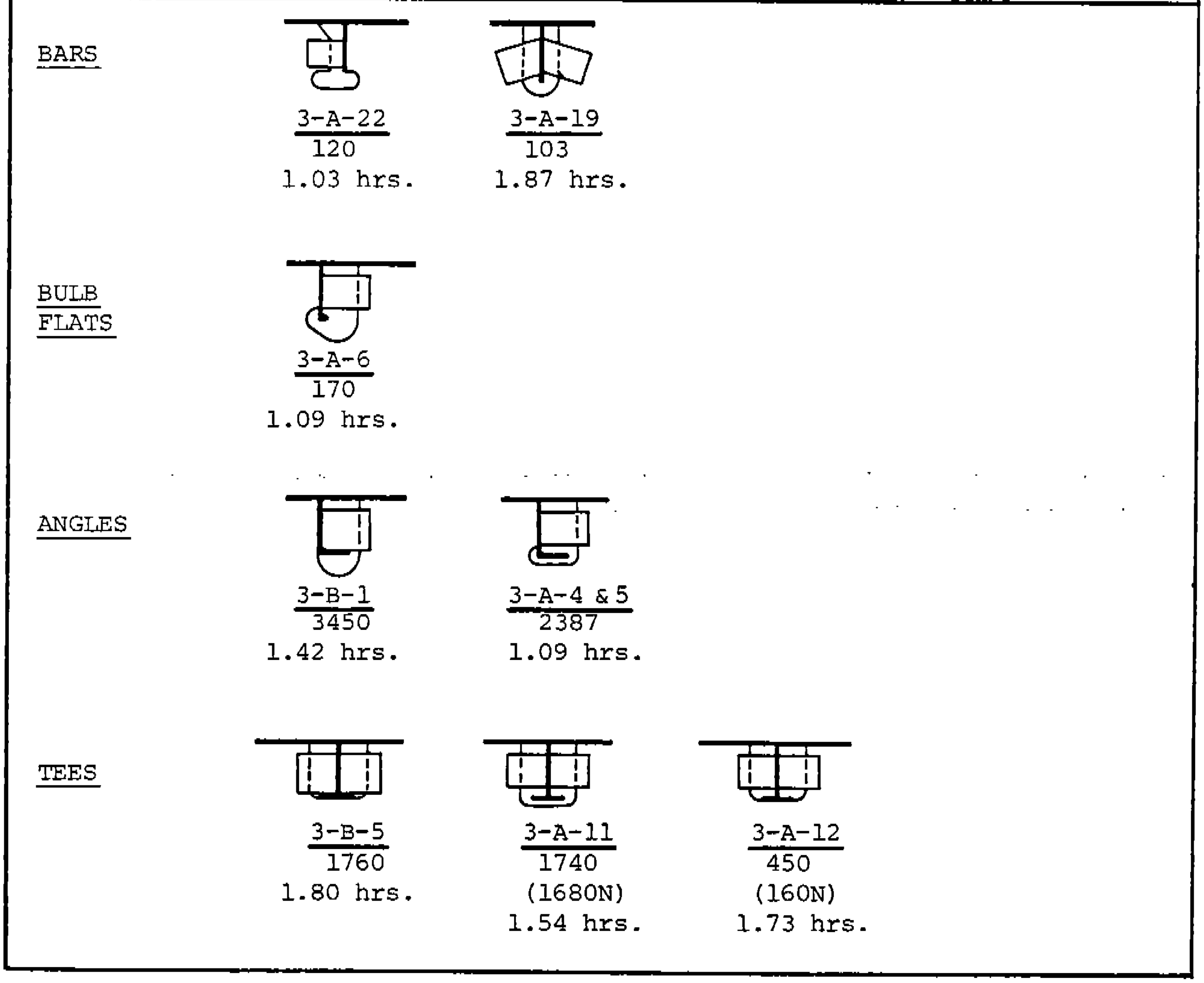
C.5 NON-TIGHT COLLAR DETAILS - FAMILY NO. 3

Non-tight collars provide additional connection of the stiffening members to the supporting structure and strengthen the latter when compared to the corresponding clearance cutouts discussed in Section C.4. The cost of such reinforcement is relatively high, about 1.4 hours (Fig. C-9) versus 0.3 hours (Fig. C-6) per detail.

C.5.1 Bars and Bulb Flats

Detail 3-A-19 is considerably more expensive than details 3-A-22 and 3-A-6 although the latter have higher potentials for requiring rework during construction (i.e., the frame spacings and locations on the attached plating for detail 3-A-19 do not have to be controlled as

FIGURE C-9
COST VERSUS PERFORMANCE - NON-TIGHT COLLAR DETAILS-FAMILY NO. 3



Note: Hours shown are for 8" deep stiffeners penetrating ½" plate.

accurately during construction as they do on details 3-A-22 and 3-A-6). Typical commercial shipbuilding tolerances are discussed in Ref. 56. In general, it appears that fabrication costs can be minimized by using clearance cutouts which provide one of the required shear attachments thereby eliminating as many collar plates as possible.

C.5.2 Angles

The two details shown differ mainly in that one detail (3-B-1) provides a larger collar with a flange attachment in addition to the standard web attachments to the supporting structure. Again the stronger connection is the more expensive one.

C.5.3 Tees

The three details shown follow the same trend as those for angles: the strongest detail is the most expensive.

C.6 TIGHT COLLAR DETAILS - FAMILY NO. 4

C.6.1 Bars

Three different designs are shown in Fig. C-10 for flat bar framing. The least expensive (the simple slot of detail 4-D-1) also requires the most accurate fitting so it has the highest potential for requiring rework during construction which is not reflected in the fabrication hours shown. The clearance cutout with lapped collar (detail 4-C-1) simplifies the fitting but requires more welding and hence considerably more fabrication time. The hours for the flush collar (detail 4-C-2) show that butt welds are significantly more expensive than fillet welds.

C.6.2 Bulb Flats

The cost and performance of the two details shown in this group follow the same trends as for bars.

C.6.3 Angles

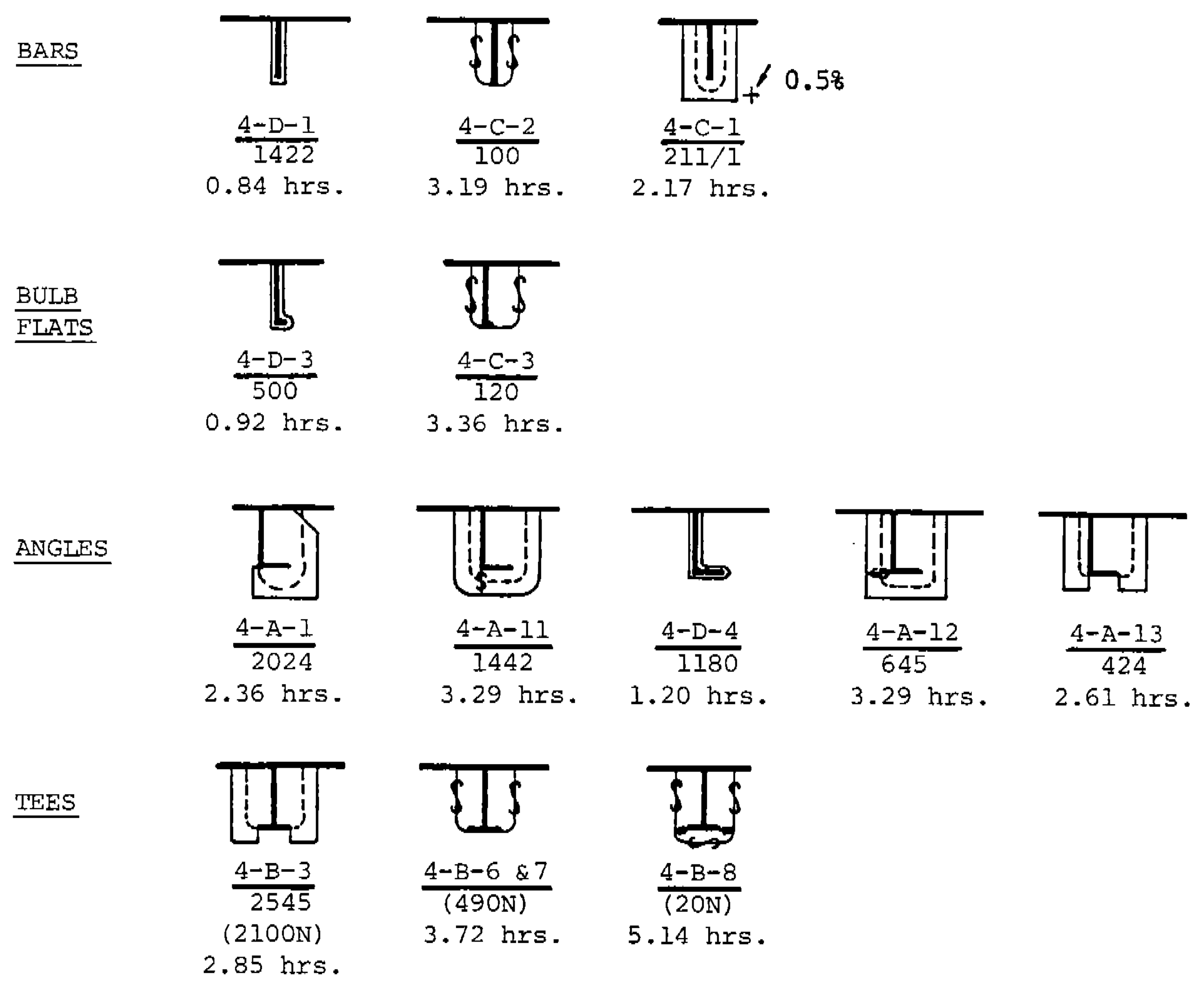
In contrast to the previous two groups, the least expensive detail observed for angles (the reeving slot of detail 4-D-4) is not the detail observed most. Apparently the tight fitting requirements of this detail have resulted in lapped collars being used more extensively. For the lapped collars, it appears that use of a clearance cutout which has some connection to the stiffening member as in details 4-A-1 and 4-A-13 minimizes the expense of these details.

C.6.4 Tees

The lapped collar (detail 4-B-3) is both the least expensive and most observed detail. If flush collars are required, their expense can be minimized by using a clearance cutout with some attachment to the stiffening member (detail 4-B-6&7 versus 4-B-8).

FIGURE C-10

COST VERSUS PERFORMANCE - TIGHT COLLAR DETAILS-FAMILY NO. 4



Note: Hours shown are for 8" deep stiffeners penetrating ½" plate.

C.7 GUNWALE CONNECTION DETAILS - FAMILY NO. 5

C.7.1 Riveted

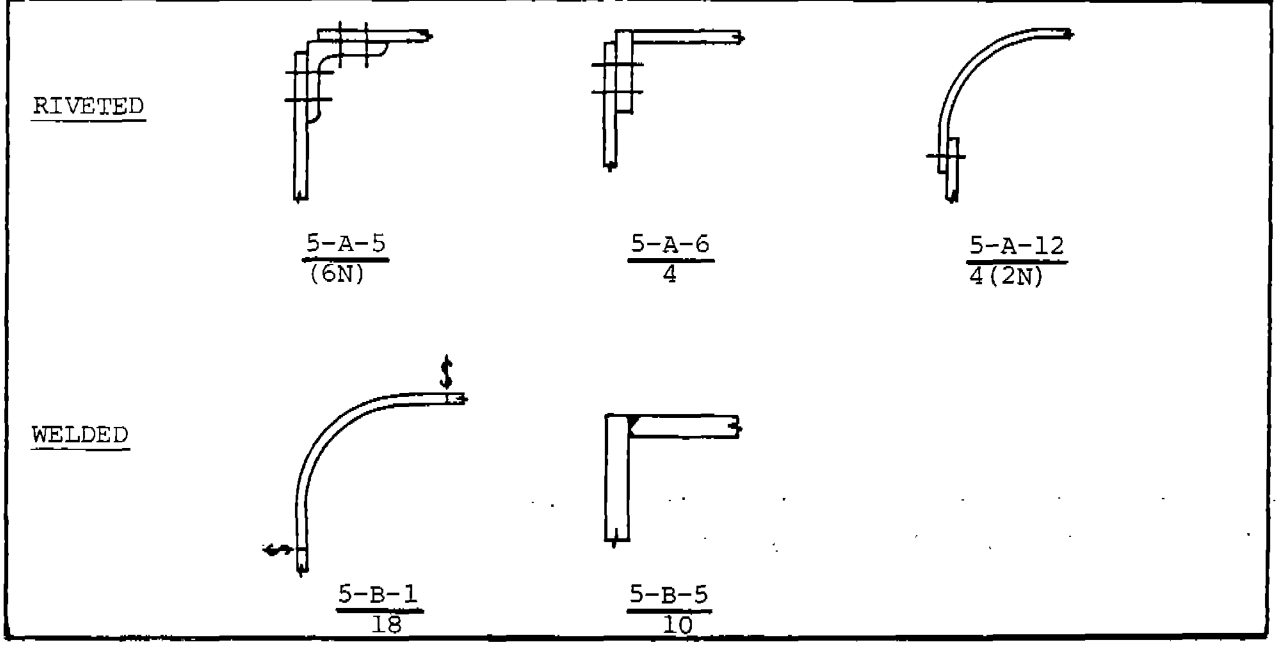
The riveted gunwale connections observed were used primarily as crack arresters. Current practice is to use special notch tough materials in the shear and/or stringer strakes. Consequently, riveting costs were not determined.

C.7.2 Welded

Two alternate welded designs are shown in Fig. C-11. The rolled plate of detail 5-B-1 eliminates the raw plate edge of detail 5-B-5 but it has the disadvantage of requiring transitions to square corners near the ends of the ship and loss of deck area. The latter may be a significant consideration on containerships and roll-on/roll-off vessels. This type of trade-off is beyond the scope of the project reported here.

FIGURE C-11

COST VERSUS PERFORMANCE - GUNWALE CONNECTION DETAILS-FAMILY NO. 5



C.8 DECK CUTOUT DETAILS - FAMILY NO. 9

The expense of fitting reinforcement for openings in structural decks is well illustrated by Fig. C-12. With modern burning equipment, holes can be cut for a negligible cost compared to the expense of fitting and welding reinforcement. Construction costs can be minimized if necessary openings can be located in low stress areas and left unreinforced. An attractive alternative might be to group openings in a thicker plate inserted in the deck utilizing existing butts and seams. The cost of cutting the thicker plate would be negligible compared to the cost of fitting reinforcement.

C.8.1 Not Reinforced

The fabrication times shown are essentially a function of the opening perimeter. Consequently, the feature which promotes minimum fabrication time is the same feature which promotes minimum stresses: openings with as large corner radii as possible. If area governs the opening required, a circular cut is preferred. If linear dimensions are controlling, then a flat oval is preferred.

C.8.2 Reinforced

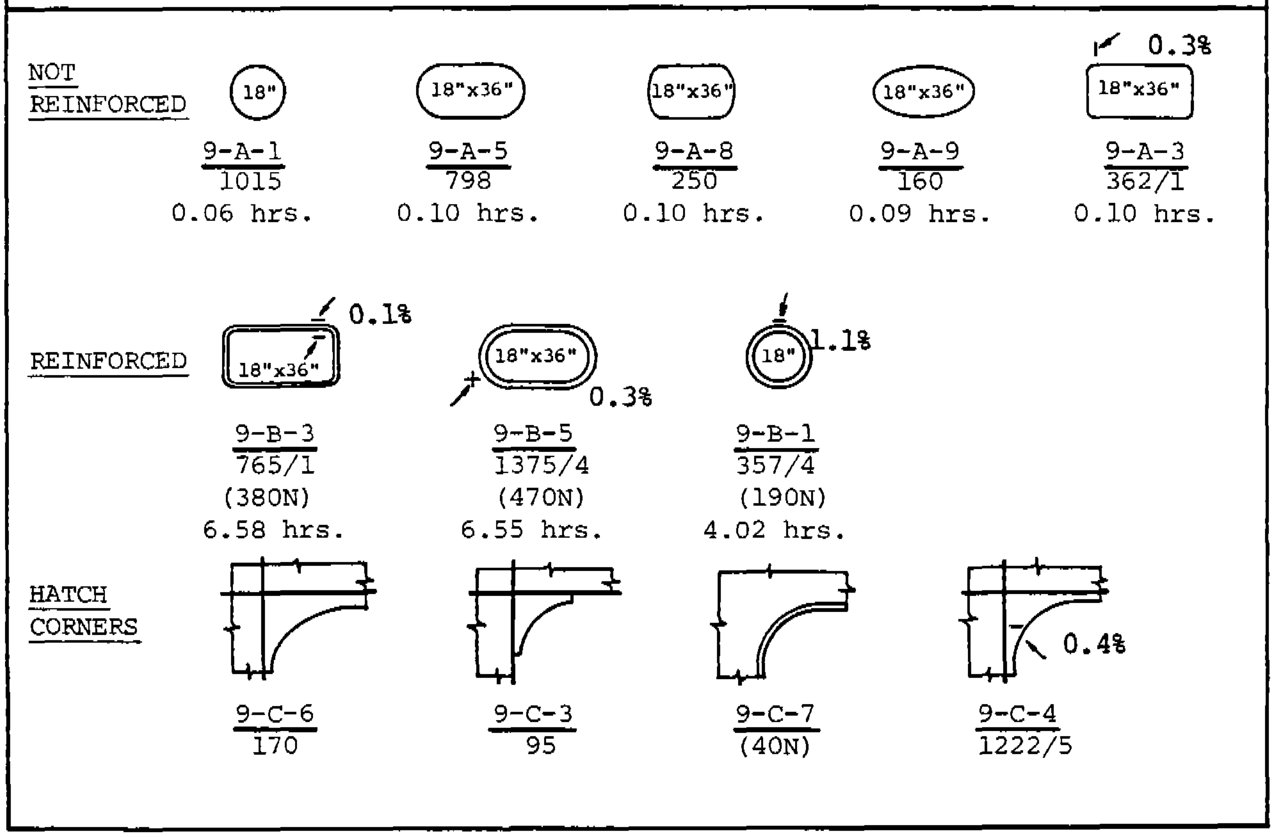
The primary elements in the cost of reinforcing rings are due to forming the ring, butt welding the ring, and then fillet welding the ring to the deck structure. Circular rings are easier to form and fit than flat ovals. There appears to be little difference in cost between flat oval and "rectangular" reinforcements. Consequently, the preferred openings are first circular, then flat oval, and finally rectangular (with as large corner radii as possible). The four failures observed in detail 9-B-1 were attributed to poor welding.

C.8.3 Hatch Corners

Fabrication hours have not been determined for hatch corners because of insufficient data on scantlings involved. Recent papers which describe analyses of hatch corners include Refs. 21, 31, 60, and 71.

FIGURE C-12

COST VERSUS PERFORMANCE - DECK CUTOUT DETAILS-FAMILY NO. 9



Note: Hours shown are for 3/4" plate and automatic burning equipment.

C.9 MISCELLANEOUS CUTOUT DETAILS - FAMILY NO. 7

C.9.1 Access Openings

The preferred access openings are similar to deck cuts: small, unreinforced openings located in low stress areas. Costs of fabrication and potential for failures increase significantly as openings become larger with smaller corner radii.

C.9.2 Lapped Web Openings

The least expensive openings are those where only one of the plates is sniped (details 7-D-3 and 7-D-1). The three observed failures in detail 7-D-1 were attributed to heavy seas rather than basic detail geometry. It is easier to wrap the ends of the welds and paint plate edges on detail 7-D-1 than on details 7-D-4 and 7-D-3. Consequently, detail 7-D-1 is the recommended geometry.

C.9.3 In Way of Corners

Both performance and cost seem to favor the straight snipe over the radiused corner. These openings are used for drainage and to provide welding access. For a given leg dimension, the latter detail (7-C-15) performs both functions better and allows more space to wrap the weld ends and paint the plate edge. Since the failure rates are so small and the fabrication hours are so close, a choice between the two details is difficult, but detail 7-C-15 is recommended.

C.9.4 In Way of Plate Edge

Since numerically controlled burning equipment was used in determining the fabrication time for these openings, all of the hours are small. Welding time has not been included in these hours and the first, second, fourth, and sixth details shown would have less weld. However, modern automatic welding processes (particularly on a panel line) would favor the continuous welds. Consequently, details 7-B-3 and 7-B-2 would be the first choices for drainage openings or air escapes. Where complete drainage or access to butt welds in the attached plating is required, detail 7-B-1 is suitable.

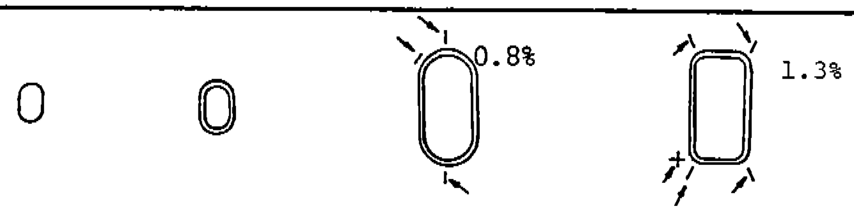
C.9.5 Miscellaneous

The expensive, reinforced miscellaneous openings performed significantly better than the less expensive, unreinforced cuts. However, most of the latter were lightening holes which should be eliminated except for very weight critical structures. The first choice detail should be an unreinforced circular opening if it can be located in a low stress area followed by a reinforced circular opening or a reinforced flat oval.

FIGURE C-13

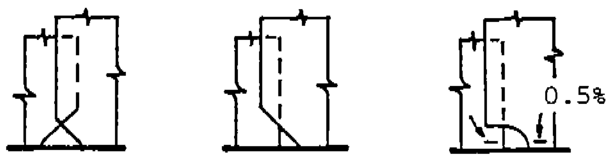
COST VERSUS PERFORMANCE - MISCELLANEOUS CUTOUT DETAILS-FAMILY NO. 7

ACCESS OPENINGS



7-A-3	7-A-4	7-A-6	7-A-8
2111(610N)	205	266/2	847/11
18"x36":	18"x36":	26"x66":	(250/5N)
0.08 hrs.	5.17 hrs.	7.08 hrs.	26"x66":
			7.14 hrs.

LAPPED WEB OPENINGS



7-D-4	7-D-3	7-D-1
250	100	636/3
3"x1½":	3"x3":	3"R:
0.16 hrs.	0.08 hrs.	0.10 hrs.

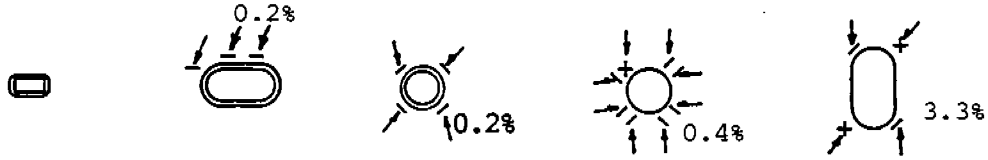
I.W.O. CORNERS

7-C-16 & 7-H-9	7-C-15 & 7-H-10
77,130/76	32,533/50
(10,000N)	(4040N)
3"x3":	3"R:
0.08 hrs.	0.09 hrs.

I.W.O. PLATE EDGE

7-C-8 & 7-H-6	7-C-4 & 7-H-4	7-B-3 & 7-C-9	7-B-1, 7-C-1, 7-C-3, 7-F-7, 7-H-1 & 7-H-2	7-B-2	7-B-5, 7-C-7, 7-H-3 & 7-H-5
11,520	4022/1	33,166/17	57,148/345	7160/20	20,835/67
2"x8":	(2600N)	(2740/17N)	(2700/3N)	(1370/20N)	(1600/2N)
0.01 hrs.	3"x6":	3"x6":	1½"R:	1½"Dia:	2"x8":
	0.01 hrs.	0.01 hrs.	0.01 hrs.	0.01 hrs.	0.01 hrs.

MISC.



7-G-2	7-F-3 & 7-G-3	7-F-2 & 7-G-1	7-C-13, 7-E-1, 7-F-1 & 7-G-5	7-C-14, 7-E-2 & 7-F-8
1270	8458/14	3253/7	25,675/115	1969/65(70N)
4"x8":	(4770/3N)	(1210N)	(11,050N)	15"x23":
2.70 hrs.	15"x23":	18"Dia.:	18"Dia.:	0.06 hrs.
	3.91 hrs.	2.94 hrs.	0.05 hrs.	

Note: Hours are for ½" plate and automatic burning equipment for the first, fourth, and fifth groups.

C.10 STANCHION END DETAILS - FAMILY NO. 10

For many stanchion end connections, fabrication costs can be minimized by locating the stanchion at the intersection of structural members.

C.10.1 Top of Circular Stanchions

The least expensive detail shown in Fig. C-14 (detail 10-A-2) utilizes existing structure entirely. The only cost involved is cutting and welding the stanchion end. The next detail in order of cost is detail 10-A-3 which requires one added chock followed by detail 10-A-7 which requires two added chocks. However, none of these details would be suitable for heavily loaded stanchions because the deck structure only backs up the stanchion at four local points in each case. The deck beam flanges help distribute the loads at the interfaces, but these details cannot be expected to develop the full strength of the stanchion unless the stanchion has a high slenderness ratio (and consequently a low design strength) or the deck beams are relatively heavy. The other three details (10-A-22, 10-A-24, and 10-A-21) reduce this problem by adding pads and/or chocks to help distribute the load. Comparing detail 10-A-22 with detail 10-A-21, it could be concluded that pads are the least expensive reinforcement.

C.10.2 Bottom of Circular Stanchions

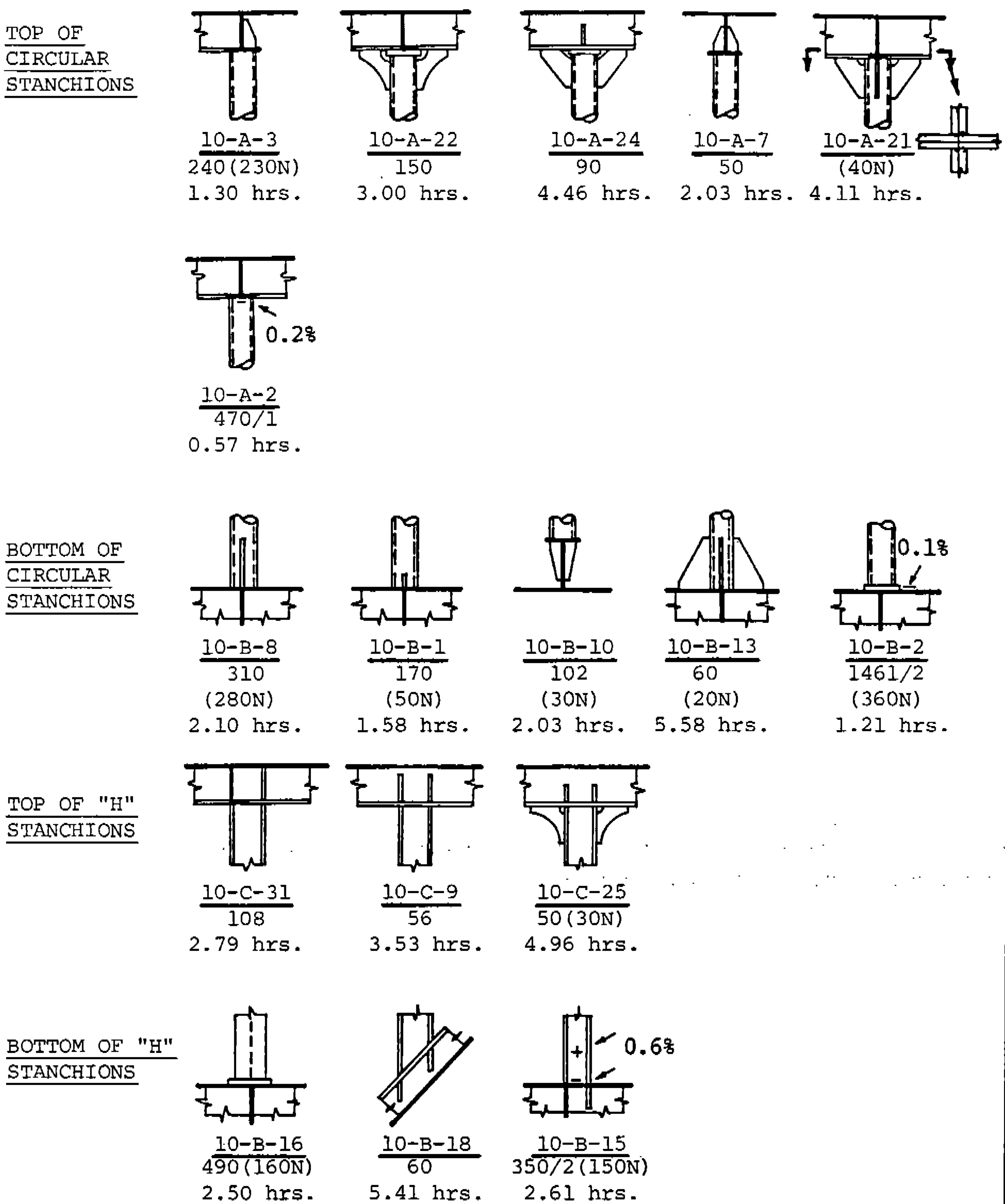
The least expensive detail shown in Fig. C-14 for this group is a simple pad (detail 10-B-2). However, two failures were observed for this detail. The two chock detail 10-B-10 and the four large chock detail 10-B-13 show a normal increase of cost with increasing numbers of added pieces. The remaining two details shown (10-B-8 and 10-B-1) are sometimes called tension chocks and are used where space is not available to fit chocks as in detail 10-B-13. These details are fabricated by slotting the end of the stanchion and fitting it over a rectangular plate previously welded to the deck. The only difference between the two details shown is the length of the plate. The resulting details are relatively inexpensive although the potential for rework is higher than that of the other details shown.

C.10.3 Top of "H" Stanchions

The details shown in Fig. C-14 show a direct relationship between the number of added pieces and the fabrication cost. The numbers observed followed the opposite trend so this is one group where the least expensive detail was also the most often observed.

FIGURE C-14

COST VERSUS PERFORMANCE - STANCHION END DETAILS-FAMILY NO. 10



Note: Hours shown are for 8" dia. x½" thick pipe or 8"x8"x48# WF.

C.10.4 Bottom of "H" Stanchions

Of the three details shown in Fig. C-14, the least expensive is the simple pad (detail 10-B-16). Using existing structure to back up one flange (detail 10-B-15) gives a relatively economical design which is very similar to the top connection detail 10-C-31. The remaining design (detail 10-B-18) costs considerably more because of the difficulty in fitting and welding the stanchion to a sloping girder and the additional chocks required.

C.11 LOAD CARRYING STIFFENER END DETAILS - FAMILY NO. 11

The fabrication hours shown in Fig. C-15 are for two approximately equal strength members based on section modulus. In general, the hours for the I-T section details are less than those of the angle section. This result comes primarily from the I-T section having a thinner web and flange than the angle section and, consequently, requiring smaller fillet welds.

C.11.1 Full Connections

The term full connection is used here to indicate that the entire web and flange of a stiffener is connected to supporting structure. The best detail structurally is 11-D-3 where the stiffener lands on another member which enables both shear and bending moments to be transmitted through the connection. However, this detail is also the most expensive. For the other two details, very little bending moment can be transmitted by the connection so the primary justification for welding in the flange is to provide lateral support for the stiffener. These two connections should not be used where the plating at the end of the stiffener is subject to hydrostatic loading unless such plating is relatively thick. For example, navy requirements limit these two details to stiffeners 6" or smaller on 0.75" or thicker plate. Otherwise, backup structure or pads should be fitted. Most of the failures in detail 11-A-9 were attributed to poor maintenance.

C.11.2 Padded

Adding pads to an end connection is relatively expensive. Sniping the flange first reduces the cost for those stiffeners which do not require lateral support at the ends.

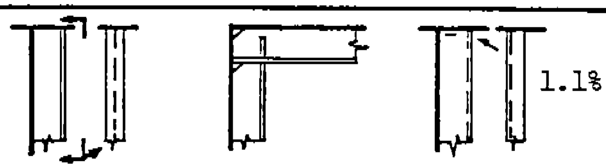
C.11.3 Lapped

Lapping two structural members provides a relatively low cost joint which will transmit some bending moment in addition to shear forces. Detail 11-D-2 provides limited lateral support, however. Again, the strongest detail (11-D-1) is the most expensive because of the additional fitting and welding required when the horizontal stiffener shown is welded to the vertical plating.

FIGURE C-15

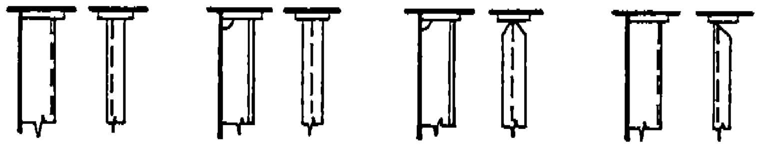
COST VERSUS PERFORMANCE-STIFFENER END DETAILS-FAMILY NO. 11

FULL CONNECTIONS



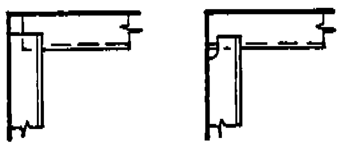
11-A-10	11-D-3	11-A-9
(2130N)	(1620N)	4381/48(2140N)
0.60 hrs.	1.62 hrs.	0.72 hrs.

PADDED



11-C-1	11-C-3	11-C-4	11-C-2
279	(270N)	(140N)	56
1.39 hrs.	1.36 hrs.	0.84 hrs.	0.98 hrs.

LAPPED

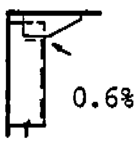


11-D-2	11-D-1
373	312
0.59 hrs.	0.97 hrs.

WITH END CHOCKS

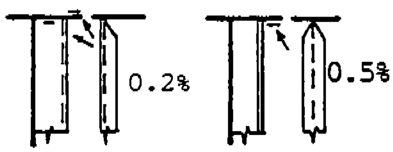
11-E-2	11-E-3
238	40
1.20 hrs.	1.20 hrs.

WITH CLIPS



11-B-4
2463/14
0.84 hrs.

SNIPPED



11-A-7	11-A-8
12,415/26	870/4(670/4N)
0.49 hrs.	0.35 hrs.

NOTE: hrs. shown are for 8"x4"x½"L or 8"x6½"x24#I-T.

C.11.4 With End Chocks

End chocks are relatively expensive and only transmit the beam's shear load to the backing structure which presumably exists on the opposite side of the plating.

C.11.5 With Clips

Clips are a fairly inexpensive means of ending stiffeners where only a shear connection is required. The hours shown are more than either the sniped connections (details 11-A-7 and 11-A-8) or two of the three full connections (details 11-A-10 and 11-A-9). However, it should be noted that the latter connections have a much higher potential for rework. Also, clips provide little lateral support for the stiffener.

C.11.6 Sniped

Sniping the flanges of full end connections reduces their cost because of the reduced weld. However, the stiffener looses lateral support and the hard spot on the attached plating becomes more severe than that of the full end connections.

C.12 PANEL STIFFENER DETAILS - FAMILY NO. 12

Panel stiffeners are not direct load carrying members. However, they will pick up load from the plating to which they are attached. Stiffness is the primary design criteria for panel stiffeners. For any given weight, tees and angles are stiffer and consequently make better panel stiffeners than flat bars. However, when both ends of the panel stiffener are sniped, then flat bars are preferred. The hours shown in Fig. C-16 are all for typical 6" deep stiffening although the angle and the tee sections are much stiffer than the flat bar.

C.12.1 Flat Bars

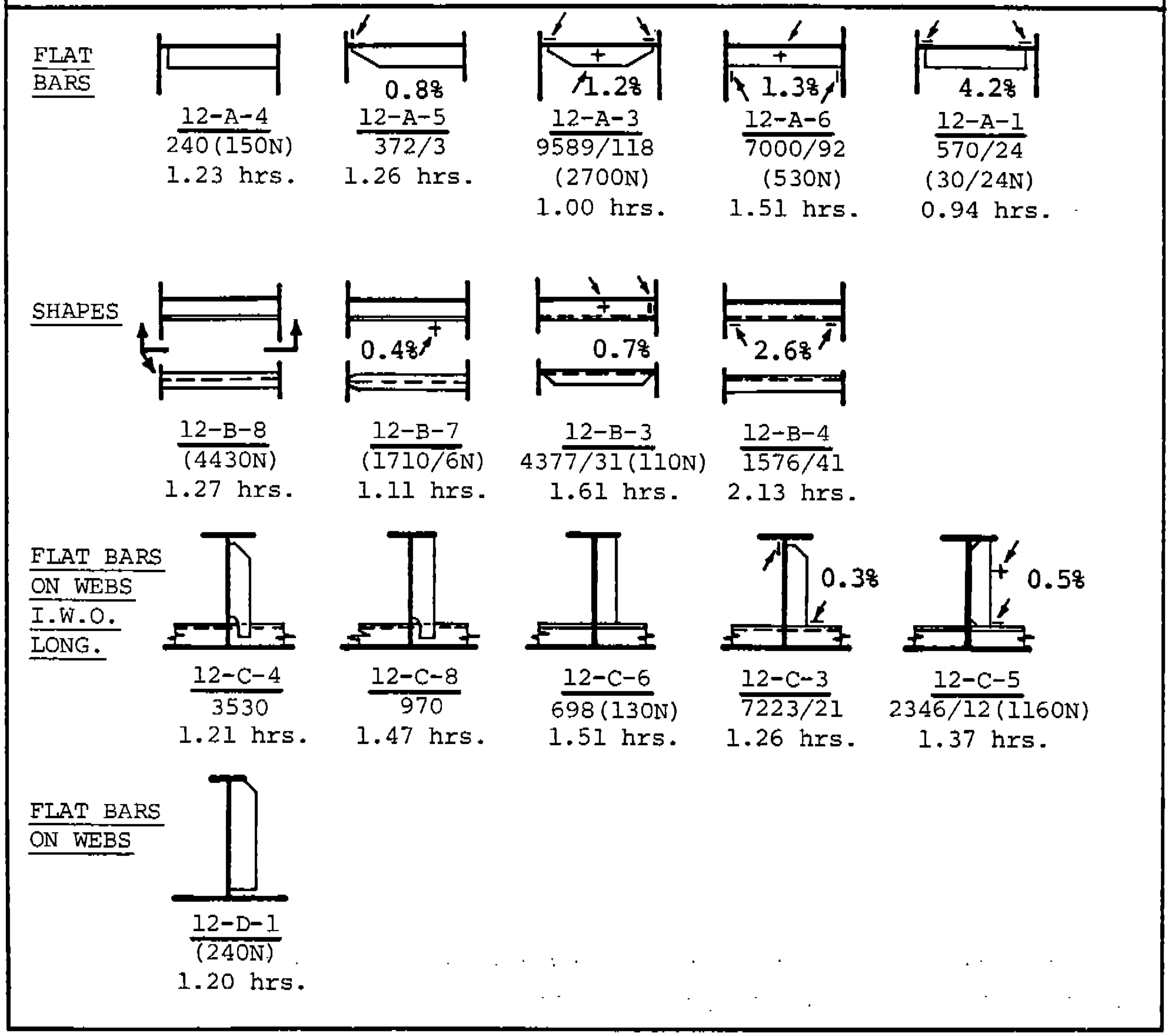
The fabrication times for the flat bars shown in Fig. C-16 vary almost directly with the amount of welding on the ends. The shape of an unwelded end is relatively insignificant (compare the hours for 12-A-4 with 12-A-5 and 12-A-3 with 12-A-1) and sniped ends seem to perform better than straight end cuts (comparing 12-A-3 and 12-A-1). Welding in the straight end cuts as in detail 12-A-6 increases the lateral stiffness of the flat bar but leaves hard spots on the attached plating which can lead to cracking.

C.12.2 Shapes

Shapes performed better than flat bars as panel stiffeners and tees performed better than angles. Angles are slightly more expensive than tees for the sizes and arrangements shown in Fig. C-16 because the angle has a thicker web and consequently requires heavier welds than the tee.

FIGURE C-16

COST VERSUS PERFORMANCE - PANEL STIFFENER DETAILS-FAMILY NO. 12



Note: Hours shown are for 6"x½" F.B., 6"x4"x3/8" L, or 6"x4"x16# I-⊥, all 36" long.

C.12.3 Flat Bars on Webs In Way of Longitudinals

These panel stiffeners perform two functions: stabilizing the web of a girder and helping to transmit the longitudinal's lateral load into the girder. Sniping the stiffener clear of the girder flange seems to perform well and help reduce the cost of these details.

C.12.4 Flat Bars on Webs

Only one detail is shown in this group because most of the others observed were very similar. Ending or sniping the stiffener clear of the attached plating both reduces the cost of the detail and eliminates a hard spot on the plating.

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