FINAL REPORT

on

CAUSES OF CLEAVAGE FRACTURE IN SHIP PLATE: HATCH CORNER DESIGN TESTS

by

E. PAUL DeGARMO AND A. BOODBERG
UNIVERSITY OF CALIFORNIA
Under Navy Contract NObs-31222

COMMITTEE ON SHIP CONSTRUCTION
DIVISION OF ENGINEERING AND INDUSTRIAL RESEARCH
NATIONAL RESEARCH COUNCIL

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2101 Constitution Avenue
Washington, D. C.

December 4, 1947

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Navy Department
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Dear Sir:

Attached is Report Serial No. SSC-16 entitled "Causes of Cleavage Fracture in Ship Plate: Hatch Corner Design Tests". This report has been submitted by the contractor as the final report on one phase of the work done on Research Project SR-92, under Contract NObs-31222 between the Bureau of Ships, Navy Department and the University of California.

The report has been reviewed and acceptance recommended by representatives of the Committee on Ship Construction, Division of Engineering and Industrial Research, NRC, in accordance with the terms of the contract between the Bureau of Ships, Navy Department and the National Academy of Sciences.

Very truly yours,

Frederick M. Feiker, Chairman
Division of Engineering and
Industrial Research

Enclosure

Preface

The Navy Department through the Bureau of Ships is distributing this report to those agencies and individuals that were actively associated with this research program. This report represents a part of the research work contracted for under the section of the Navy's directive "to investigate the design and construction of welded steel merchant vessels."

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FINAL REPORT

U. S. NAVY RESEARCH PROJECT NObs-31222

CAUSES OF CLEAVAGE FRACTURE IN SHIP PLATE

Hatch Corner Design Tests

September 1, 1946 to August 15, 1947

From: University of California
Department of Engineering

Report prepared by:
E. Paul DeGarmo
A. Boodberg

CONTENTS

LIST OF TABLES AND ILLUSTRATIONS

LIST OF TABLES AND ILLUSTRATIONS - Cont'd.

LIST OF TABLES AND ILLUSTRATIONS - Cont'd.

LIST OF TABLES AND ILLUSTRATIONS - Cont'd.

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ABSTRACT

This report deals with the testing of 12 full scale hatch corner specimens. One of these was essentially the same as the hatch corner used in the earliest "Liberty" type ships, and the same as has been used in the earlier tests. Two of the specimens tested were invalid due to laminated plates. The others included the modifications of: continuous longitudinal girder; full penetration welds; U.S.C.G. Code 5 and Code 1 modifications, and the effectiveness of the doubler plate in the Code 5 modification; the British Code 1A modification; extended coaming; diagonal braces at the bottom of the girder joint; a new design similar in configuration to the hatches used on Victory type ships; a new design involving a hot-formed double radius corner plate. The strength and energy absorbing abilities of each were determined. The use of an extended coaming was found to be a very effective and simple modification. The design utilizing the formed corner was far superior to all other and produced definitely ductile behavior, a quality which has not before been found in welded hatch corners.

This report deals with the construction and test of these twelve specimens. Throughout this report specimen No. 5, from previous tests, is used as a basis of comparison.

PROCEDURE.

The specimens which were tested are listed in Table I.

Except for one piece in one specimen, all were constructed from one lot of low carbon semi-killed steel of ABS ship quality, which had been used for some of the previous tests. This steel had previously been designated as Steel "C". The analysis and strength properties of this material are shown in Tables II and III. All of the specimens were constructed at Shipyard No. 3 at Richmond, California, by project welders, and then brought to the University where strain gages were applied and the tests conducted. The tests were conducted at approximately 70°F., the variation from this temperature being less than ± 4 degrees.

Energy absorption measurements were made on all specimens by measuring the strain which took place between the pins in the two pulling tabs. The same method was used as has been described in previous reports.[4]

The basic design, Specimen 5, is shown in Fig. 1. It will be noted that it consists of three principal strength members. These are: deck, longitudinal girder, and hatch end beam. The longitudinal girder is actually in two pieces. Each of these members contains a right angle interior corner. They are mutually perpendicular to each other when assembled and form an extremely rigid structure. A doubler plate is fillet welded to the deck and coaming. A heavy hatch end beam flange, longitudinal girder flanges and deck beams complete the specimen.

All welding was done with AWS type E6010 and E6020 electrodes. The welds were given a very careful visual inspection both prior to and after testing and in no case were any significant defects found.

In order to apply the load and obtain proper stress distribution, heavy pulling tabs were attached to each end of the specimen. These are shown in Fig. 58. To supply some transverse restraint, such as would be supplied by the remaining structure in an actual ship, three transverse restraining beams were attached to all specimens above deck. These are shown in Figs. 37 and 41 and several other of the photographs. These beams were given a small initial compressive load, prior to testing, by means of adjustable wedges. This was the same procedure which had been used on previous hatch corner specimens.

The first modification which was made to the basic specimen was to make the longitudinal girder continuous instead of the hatch end beam. Since the failures in ships were transverse and tests of previous specimens had shown that the longitudinal to hatch end beam joint was a weak point, it was felt that this change would give a considerable increase in strength. Specimen 27 contained this single design variation.

A considerable number of early "Liberty" type ships were constructed with square corners in the deck plate at the hatch openings. In order to strengthen these hatch corners a gusset type of reinforcement was added, as shown in Fig. 2. Diagonal angle brackets were also added at the bottom of the longitudinal girder and hatch end beam intersection, (U.S.C.G. Code 5). Specimen 28 involved this modification.

The hatch corners of a large number of later "Liberty" ships were constructed in accordance with U.S.C.G. Code 1, shown in Fig. 3. This type corner was incorporated in Specimen 30. In order to determine the effectiveness of the large doubler which is included in the Code 1 modification, Specimen 29 was constructed as shown in Fig. 4 without the doubler. Otherwise these two specimens were identical.

In testing Specimen 30 a failure occurred in the upper end tab at a load of 2,180,000 pounds. The load was removed and a new end tab was attached.

The specimen was then reloaded to failure.

On a number of "Liberty" ships operated or repaired by the British, the hatch corner reinforcement shown in Fig. 5 was used. This has been designated as British Code 1A. It involves three significant features. First, full penetration welds are used between the deck and doubler plates and the coaming. Second, an unusual shape doubler is used. Third, diagonal strapping is added at the bottom of the girder system. Specimen 31 incorporated these British modifications.

Since the British Code 1A modification contained three significant changes from the basic design, it was desirable to know the effect of each of the changes. It appeared that the use of full penetration welds might be the most significant of the three changes. Therefore, Specimen 32, as shown in Fig. 6, was built using full penetration welds between the deck and doubler plates and the hatch coaming. Otherwise it was the same as Specimen 5.

Previous tests had shown that in the basic design the longitudinal coaming above deck carries about 75 per cent as much load as the longitudinal girder below deck. The abrupt termination of this longitudinal coaming at the corner of the hatch opening results in a severe stress concentration. Specimens 33 and 37 had the longitudinal coaming extended above deck for 30 inches beyond the hatch end beam as shown in Fig. 7. Unfortunately the hatch end beam of Specimen 37 was made from a piece of steel which was badly laminated. This was discovered just prior to the test and close observation during the test showed that the results were greatly affected by this condition and cannot be considered valid.

Specimen 34 was an entirely new design. This design was suggested by the American Bureau of Shipping and has been designated as the A.B.S. design.

The details are shown in Fig. 8. The general configuration is similar to the hatch corner used on the "Victory"type ships but the plates are not as heavy. The distinctive features are: (a) an 18" radius in the deck plate, (b) a coaming separate from the longitudinal girder and hatch end beam, (c) continuous longitudinal girder, (d) extended longitudinal coaming, (e) a substantial one piece flange, containing generous radii, at the bottom of the main girder intersection, and (f) the use of "snipes" to avoid concentrations of welding at the intersections of three plates. The previous tests had indicated that all of these features would contribute to better performance.

Specimen 35 was also of entirely different design. This design was based upon some preliminary small scale tests which were conceived and carried out at the University of California by Mr. H. E. Kennedy. The details of this specimen are shown in Figs. 9, 10, 11 and 12. The main feature of this specimen is the use of a hot-formed section at the corner. A piece of 3/4 inch "C" steel was forged to form the corner, resulting in a 5/8 inch thickness at the top of the formed section where it was attached to the coaming. The coaming and the longitudinal transition piece between the deck and coaming were formed cold. This design resulted in the coaming being 6 inches out of line with the longitudinal and transverse girder system. A continuous longitudinal girder was used on this specimen.

Since the coaming of this specimen was not in the same location as those of the others, it was necessary to use a special transition section in connecting the coaming to the upper pulling tab. This is shown in Fig. 11.

In testing this specimen no failure occurred at a load of 3,000,000 pounds, the rated capacity of the testing machine. The load was removed. After an interval of about 66 hours the specimen was broken by overloading the testing machine.

Specimen 36 was the same as specimen 5 except for the addition of diagonal brackets at the bottom of the longitudinal girder-hatch end beam joint, like those shown in Fig. 2. This test was designed to isolate one of the factors which was present in the British modification. Unfortunately, upon testing, this specimen was found to have a very badly laminated hatch end beam plate so the results were not valid. Specimen 38 was a repeat of this test. However, nearly all of the 5/8 inch thick "C" steel had been used and it was necessary to make the hatch end beam of this specimen out of another piece of steel. This steel was obtained on the local market and had tensile properties as shown in Table IV. These properties are very nearly the same as those for "C" steel and it is not felt that its use for the hatch end beam of this specimen in any way affected the results obtained.

RESULTS

The principal results of the tests are shown in Tables V and VI. In all cases except a portion of the doubler in specimen 30, cleavage type fractures were obtained. In several instances a crack would originate and progress for a few inches, accompanied by a slight decrease in maximum load. This would be followed in an instant by major failure of the specimen, in all cases complete, or nearly complete failure of the deck. It is felt that the stress value which is most important is the one corresponding to maximum load. On the other hand, the important energy value is the one which indicates all of the energy absorbed up to the point of major failure. These are the two values which are shown in Table VI.

The nominal stress values shown in Tables V and VI were computed by dividing the load by the area which supported this load. In all specimens except 33, 34, 35 and 37, this area included the deck outboard of the coaming, the longitudinal girder up to the top of the doubler, the longitudinal girder flange, and the doubler, if any. Where radii existed, as in the deck plate in Specimen 29, one third of the radius was included in the width of the plate. In specimens 33, 34 and 37, having extended coamings, the transverse area of the entire longitudinal coaming was included in the load carrying area. For specimen 35 (Kennedy design) the formed section up to two-thirds the height of the radius was included. Some of these areas were somewhat arbitrary but there did not appear to be any exact simple method which could be used.

Photographs of the various specimens are shown in Figs. 13 to 65. In order to serve as a basis of comparison, photographs of the failure in a previous specimen, No. 4, are shown in Figs. 13 to 18 inclusive. The failure in this particular specimen was typical of all cleavage fractures which occurred in specimens of the basic design.

It will be noted in Tables VI and V that the addition of diagonal brackets at the bottom of the girder joint (Specimen 38) increased the maximum nominal stress only 5 per cent.* However, the increase in energy absorption at failure was 38 per cent.

The use of a continuous longitudinal (Specimen 27) gave a 19.4 per cent increase in maximum stress and increased the energy absorption by 140 per cent.

The gusset reinforcement (Specimen 28, U.S.C.G. Code 5) gave a maximum stress increase of 30.5 per cent and increased the energy absorption at failure by 324 per cent.

The use of a radius in the deck plate at the hatch corner (Specimen 30, U.S.C.G. Code 1) produced a 52 per cent increase in maximum stress and a 1610 per cent increase in total energy absorption. The effectiveness of the doubler in this design is seen by comparing the results obtained with specimen 29 which was the same except that the doubler was omitted. It will be noted that the absence of the doubler reduced the maximum stress by 6.5 per cent and the energy absorption by over 71 per cent. It should be remembered that about one-third of the fracture in the doubler of specimen 30 was shear. This undoubtedly accounts for some of the increase in energy. While these are single tests, it appears that the doubler is very desirable in this particular design.

The British modification (Specimen 31) produced results which are rather difficult to account for. The increase in maximum stress was slightly over 25 per cent and the total energy absorption increased 765 per cent. This specimen contained full penetration welds, diagonal reinforcing brackets and a

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* All increases in strength and energy absorption are based upon the values for Specimen 5.

doubler of unique shape. Specimen 32 which also contained full penetration welds with the regular small doubler showed an increase in maximum stress of 24 per cent but an increase in total energy absorption of only 280 per cent. Even if the increase of 38 per cent in energy absorption found due to diagonal reinforcing brackets in Specimen 38 is added, the total is still far short of the increase in energy absorption shown by the British modification, although the results of Specimens 29 and 30 do indicate that a doubler can have considerable effect on energy absorption.

The results of Specimen 33 are most interesting in that a simple modification produced outstanding results. By the simple expedient of extending the coaming above deck for 30 inches, the maximum stress was increased by almost 45 per cent and the total energy absorption by 1645 per cent. It should be remembered that the longitudinal of this specimen was not continuous but intercostal. As shown in Table V, this specimen actually carried greater load than Specimen 30. Thus this simple modification gave increased strength better than the U. S. C. G. 1 modification and energy absorption considerably superior. It is unfortunate that the repeat test of this modification (Specimen 37) was invalid due to a laminated plate. However, the results, even with this badly laminated plate, indicate that this modification is very effective. Careful observations were made during the testing of Specimen 37 and there was no question but that the laminated plate was the cause of the early failure. In both Specimens 33 and 37 the absence of distortion at the hatch corner which resulted from the use of the extended coaming was remarkable. In other specimens the corner of the coaming started to distort below a load of 1,000,000 pounds. In these specimens almost no distortion occurred until just before failure.

It would be interesting to extend the coaming of a specimen of the basic design by adding a triangular plate to a completed specimen. This would correspond to adding this reinforcement to an existing hatch corner on a ship. If the results were nearly as effective as found in Specimen 33, this simple procedure would be an easy and effective way of strengthening hatch corners of existing ships.

The performance of Specimen 34, (ABS design) was excellent, as was expected from the features which were incorporated in it. The computed increase in maximum stress was only 36.8 per cent which is somewhat less than for some of the other modifications. However, the computed stress for this specimen is probably not a fair method of comparison since it contained more metal which had to be included in the load carrying area than was the case for the other specimens, yet it seems certain that a lot of this area was actually carrying very little load. This is borne out by the load values which show that this specimen carried a load of 2,880,000 pounds which is greater than for any except Specimen 35. The energy absorption of this specimen was an increase of 1990 per cent over that of the basic specimen. The fracture of this specimen originated at the intersection of the longitudinal and transverse coamings and the deck and travelled in four directions as shown by Figs. 49, 50, 51, 52, 53 and 54.

Specimen 35 represented a departure from conventional hatch design. The results indicate that this departure was well justified. The maximum load sustained by this specimen was much greater than for any other and the maximum nominal stress was more than proportionally higher due to the fact that a minimum of material was used. The maximum nominal stress of 54,100 psi is an increase of 124 per cent over that of the basic design and is the only case where the maximum nominal stress clearly exceeded the yield strength of the material. That this specimen did behave in a truly ductile manner is shown clearly in Figs. 56 and 57 which were taken after the specimen had been subjected to the first 3,000,000 pound loading. Fig. 56 is particularly significant in that this evidence of necking in the deck plate did not occur in any other specimen.

The total energy absorption of 6,786,000 inch pounds was considerably better than any other specimen and represented an increase of 2840 per cent over that of the basic specimen.

Perhaps the most significant fact about the test of Specimen 35 is that the fracture did not occur in the corner, as shown in Fig. 58. This is the only specimen for which this is true. The fracture originated in the cold-formed section at about the mid-point of the radius where an arc had been struck in welding on a flanging clip. At the conclusion of the tests there was no sign of any cracks of any kind in the vicinity of the corner.

While it could not be measured, observation indicated that the reduction in thickness in the deck plate on a section near the corner was probably greater than that which occurred near the fracture. There was considerably more necking near the corner than at the fracture. Since over 60 hours elapsed between the initial and second loading of this specimen, it is possible that some strain-age hardening may have occurred.

The design of Specimen 35 represents a distinctly different approach than that of Specimen 34 (ABS design). Specimen 34 is extremely rigid as the result of the use of the extended coaming and the heavy cross-over flange at the bottom of the girder intersection. On the other hand, Specimen 35 was designed to avoid rigidity and allow plastic flow to occur easily. However, strength was not sacrificed by this procedure.

While Specimen 35 represents a departure from conventional hatch design, it appears to be entirely practicable. Only slight structural changes would have to be made to incorporate it into new ships. In view of the results obtained in these tests, it appears that these changes could well be made in order to utilize this type of hatch corner.

From the production viewpoint the design of Specimen 35 offers no difficulties. In fact it is very well suited to either small or large scale production.

While, in view of the results, one hesitates to make any suggestions for changes in the design, Mr. Kennedy and the investigators believe it would be desirable to "snipe" the hatch end beam at the top and bottom where it intersects the longitudinal girder.

The load-strain curves from which the energy determinations were made are shown in Fig. 66.

The gage layouts used on the various specimens are shown in Figs. 67 to 70 inclusive. Since a very complete stress investigation had been made on Specimen 1, tested previously, it is included to serve as a basis for comparison. This specimen was of the standard design except that it had a longitudinal and hatch end beam 3/4 inch thick instead of 5/8 inch. Figs. 71 to 74 inclusive, show the principal stresses determined at the various gage locations at a load of 200,000 pounds on some of the specimens. Although the stress values determined at this low load are quite small it was necessary to use this load since at higher loads some of the gages in each specimen indicated plastic flow so the strain readings could not be converted to stress values. Fig. 75 shows the stress distribution in Specimen 34 (ABS design).

For those who are interested in the strain values at higher loads, the load-strain data for the individual gages are included as Figs. 76 to 80, inclusive, in Appendix A.

In a previous report[4] a temperature-transition curve for hatch corner type specimens constructed from "C" steel was included. Data have recently been obtained at the University of California, but not directly as a part of this work, for hatch corners constructed of "B" steel. Fig. 81 in Appendix B shows the temperature-transition curves for hatch corner type specimens of both "B" and "C" steels.

CONCLUSIONS

From the results of the tests described in this report the following conclusions are drawn:

1. There are two basically different approaches to improved welded hatch corner design. One results in a very rigid structure wherein improved performance is obtained by the addition of structural members and the reduction of points of high multi-axial stress concentration insofar as possible (a problem which is difficult with increased rigidity). The second approach is to design for a minimum of rigidity so that plastic flow may occur naturally and easily, with the result that high stress concentrations do not occur. This second type of design appears to be the superior.

2. Since the principal stresses in the ship girder system adjacent to the hatches are longitudinal rather than transverse, the longitudinal girders near hatch corners should be made continuous with the transverse girders intercostal. Such construction adds about 19 per cent in strength and 140 per cent in ability to absorb energy.

3. The use of a hot-formed corner, having a radius in both vertical and horizontal planes, in the corner of a welded hatch, as exemplified by Specimen 35,

produced far better results, both in strength and energy absorption, than any other design tested. This was the only design in which the plates showed any appreciable plastic flow.

4. If the rigid type of welded hatch design is to be used, the most beneficial single feature which can be incorporated is an extension of the longitudinal coaming for at least 30 inches beyond the transverse coaming. This single feature produced an increase of nearly 45 per cent in maximum nominal stress and 1645 per cent in energy absorption, as compared to the basic design. This simple change resulted in as much of an improvement as that obtained by the use of the more complicated U.S.C.G. Code 1 modification.

5. The use of a hatch corner gusset plate and diagonal bars at the bottom of the girder system as a method of strengthening "Liberty" type ships (U.S.C.G. Code 5) was fairly effective. Its use in these tests produced a strength increase of 30 per cent and a 324 per cent increase in energy absorption. Of these increases, about one-sixth of the strength and one-fourth of the energy absorption was due to the diagonal brackets and the remainder to the gusset plate reinforcement.

6. The method of reinforcement used on "Liberty" type ships by the British, commonly designated as British Code 1A, was about equal to the U.S.C.G. Code 5 modification in strength but was about twice as good in energy absorbing ability.

7. Hatch corners of U.S.C.G. Code 1 design are very much superior to those having the basic design. They are about 52 per cent stronger and will absorb about 1600 per cent more energy. The doubler plate used in this design adds only moderately to the strength but appears to be responsible for nearly 76 per cent of the increased energy absorbing ability.

8. The use of full penetration welds between the deck and doubler plates

and the coaming in a specimen of the basic design, in which the transverse hatch end beam was continuous and the longitudinal girder was intercostal, increased the strength by 24 per cent and the energy absorbing ability by 280 per cent.

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3. DeGarmo, E. Paul, J. L. Meriam, R. C. Grassi and J. W. Harmon; "Progress Report on Cleavage Fracture of Ship Plate: Hatch Corner Tests": Committee on Ship Construction, Division of Engineering and Industrial Research, National Research Council; Serial No. SSC-1. July 24, 1946.

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TABLE I.

Specimens Tested

Specimen No.	Distinguishing Features
5	Standard design "C" steel.
27	Continuous longitudinal girder.
28	Gusset plate reinforcement - U.S.C.G. Code 5.
29	Slotted coaming (no doubler) - U.S.C.G. Code 1.
30	Slotted coaming (with doubler) - U.S.C.G. Code 1.
31	British modification - British Code 1A.
32	Full penetration welds.
33	Extended coaming.
34	ABS design.
35	Kennedy design.
36	Diagonal brackets - invalid, laminated plate.
37	Extended coaming, repeat of No. 33 - laminated plate.
38	Brackets on lower part, repeat of No. 36. Commercial type steel, similar to "C" steel.

TABLE II.

Analysis of Steel "C"

% C.	% Mn.	% P.	% S.
0.24	0.49	0.015	0.033

(Supplier's analysis)

TABLE III.

Tensile and Hardness Properties Steel "C"

Plate No.	Direc.	Yield (PSI)	Tensile Data (.505 Bars) Ultimate (PSI)	Break (PSI)	Elongation (% in 2")	Reduction in Area %	Hardness (Rockwell "B")
C-1	Long.	35,230	68,700	55,300	36.0	59.6	71
	Trans.	35,750	68,000	57,050	33.6	52.5	
			Tensile Data (Full Thickness)				
C-1	Long.	37,500	66,500	53,600	45.5	56.5	
	Trans.	34,100	66,200	56,600	32.5	50.4	

TABLE IV

Tensile and Hardness Properties Commercial Steel (Used in Specimen 38)

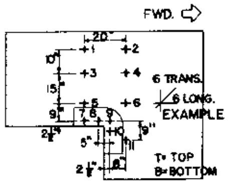
Direc.	Yield (PSI)	Tensile Data (.505 Bars) Ultimate (PSI)	Elongation (% in 2")	Reduction in Area %	Hardness (Rockwell "B")
Long.	35,720	64,480	37.0	53.9	67.3
Trans.	36,003	64.403	39.5	59.8	
		Tensile Data (Full Thickness)	(in 8"%)		
Flat.	35,737	64,800	30.8	59.7	

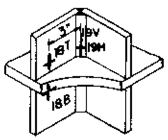
RESULTS, FULL SCALE HATCH CORNER TESTS

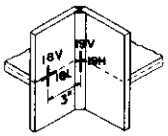
SPECIMEN NO.	NOMINAL LOAD AT FAILURE LBS. MAXIMUM FAILURE	NOMINAL STRESS AT (1) FAILURE LB/IN^2 MAXIMUM FAILURE	LONGITUDINAL STRESS CONCENTRATION BASED ON 200,000 LB. LOAD (2) GAGES									STRAIN CONCENTRATIONS (3) FOR 200,000 LB. LOAD 1,200,000 LB. LOAD GAGES													TOTAL ENERGY ABSORBED PIN TO PIN IN. LB. MAXIMUM FAILURE	STRAIN RATIOS 200,000 LB. LOAD 1,200,000 LB. LOAD GAGES									MAXIMUM STRAIN AT OR NEAR FAILURE MICRO IN/IN GAGES				THICKNESS REDUCTION AT FRACTURE % DISTANCE FROM FRACTURE EDGE IN.						REMARKS
			5	6	7	8	9	10	17	T 18L B	H 19 V	L 5	L 6	L 7	L 8	L 9	T 12 B	13	T 14 B	T 15 B	T 16 B	H 17 V	T 18L B	H 19 V		5	6	7	8	9	10	(4) 11	19H/19V	17H/17V	B 12	B 15	T 18L B	H 19	CORNER IN	1/16	1/4	1/2	3/4	1	
5	1,450,000	24,000	1.6	2.0	1.2	2.1	2.3	1.5	-1.9	2.6	10.4	1.6	2.0	1.3	2.0	2.2	4.5 3.0	3.0	.9 .3	4.7 3.9	3.2 1.5	-2.1 .9	2.8	9.9 .5	230,000	-8.1	-42	-2.6	12	-11	4.7	-7.2	21.7	-2.3	3,600	5,000	—	7,000	19	1.9	1.0	.3	0	0	BASIC DESIGN. ENERGY VALUE OBTAINED FROM TEMPERATURE_ ENERGY CURVE FOR C STEEL.
											3.4	2.0	2.0	1.1	2.0	2.9	2.0 4.4	11.9	-.5 -.3	2.3 6.5	— 2.5	-1.5 .4	2.1	10.6 -8.2		-7.4	-75	-4.3	10.8	-17.1	—	79	-1.3	-3.5					34	2.3	.9	.1	0	0	
27	1,745,000	28,900	1.7	1.9	1.3	1.6	2.1	1.0	-1.3	2.0	11.7	1.7	1.9	1.4	1.2	2.1	3.9 3.2	3.4	1.4 .7	5.1 4.0	1.7 1.0	-1.6 1.3	2.3	11.4 -.8	552,000	-6.0	-3.8	-4.0	1.1	-7.2	—	-7.7	-14	-1.3	14,100	11,600	8,200	11,100	19	1.9	1.2	.8	.5	.3	CONTINUOUS LONGITUDINAL GIRDER, (HATCH END BEAM INTERCOSTAL). CLEAVAGE FAILURE AT CORNER.
											2.6	2.1	2.5	1.3	1.6	2.4	6.1 11.8	9.4	.7 1.6	7.3 12.8	3.5 1.0	-1.3 .5	5.1	10.8 -1.1		-2.8	-3.3	-3.0	.7	-4.2	-1.3	30	-10	-2.8					34	2.1	1.9	1.5	.6	.3	
28	2,125,000	31,500	1.3	1.5	1.3	1.5	1.6	1.2	-.3	1.2	2.1	1.3	1.6	1.3	1.5	1.7	1.8 1.9	1.6	-.3 -.3	2.2 1.8	.2 -.2	-.7 1.6	1.4 1.5	2.4 -1.4	868,000	—	-3.1	-6.5	-7.3	-4.7	—	-4.8	-1.7	-.5	5,600	3,600	1,700	2,500	19	1.8	1.4	1.0	.7	.5	GUSSET PLATE REINFORCEMENT. (U.S.C.G. CODE 5)
	2,120,000	31,400								1.5	-.7	1.5	2.0	1.4	1.6	1.5	2.1 2.2	3.0	0 -.3	2.5 2.4	.4 .1	-.6 1.7	1.9 1.9	2.6 -1.5	974,000	-6.8	-5.8	-4.8	-13	-3.9	-2.4	-12	-1.8	-.4					34	.7	.6	.5	.4	.3	
29	1,950,000	34,400	2.0	2.1	2.9	3.0	2.8	3.1	2.4	2.6	2.9	2.0	2.2	2.8	2.7	2.8	3.8 32	1.8	.3 -.6	4.0 3.2	1.1 .2	2.5 -.6	2.7 N.G.	2.2 1.8	1,042,000	-6.8	-3.7	-12	5.8	-4.8	-5.8	-7.0	1.3	-3.8	9,900 at 1,350,000 lb load	11,200 at 1,500,000 lb load	9,300	N.G.	19	1.1	.8	.5	.4	.3	SAME AS 30 EXCEPT NO DOUBLER.
	1,920,000	33,800								N.G.	2.6	2.6	2.4	5.8	4.0	4.8	5.6 109	3.6	-1.3 -3.7	4.9 8.1	.3 -1.6	2.1 -.1	5.9 N.G.	.8 —	1,132,000	-17.5	-4.5	-4.9	5.4	-5.5	-2.6	—	N.G.	-22					34	1.6	1.1	.7	.4	.3	
30	2,550,000	36,800	1.3	1.4	2.2	2.2	2.2	1.8	-.3	2.4	2.0	1.3	1.5	2.1	2.0	2.3	2.0 2.2	2.0	-.2 -.5	1.1 2.0	0 -2.5	-.1 -.8	2.2 2.4	1.8 .5	3,316,000	—	-4.0	—	8.0	-6.0	-3.8	-3.5	3.5	-.1	5,600	3,000	4,800	N.G.	20	1.5	1.2	.9	.7	.5	U.S.C.G. CODE 1. END TAB FAILURE AT 2,180,000 LBS. ON FIRST LOADING. SPECIMEN RELOADED TO FAILURE. NO GAGE READINGS TAKEN ON SECOND LOADING.
	2,370,000	34,200								2.6	1.1	1.2	1.3	2.6	2.3	1.8	2.2 2.3	3.3	.5 -.3	2.2 2.2	.4 0	0 -.9	1.8 2.4	1.5 .4	3,938,000	-11	-3.1	-20	3.5	-8.0	-15	-3.2	4.3	0			6,100		34	3.1	1.8	.9	.4	.1	
31	1,920,000	30,400	1.8	1.0	1.7	2.7	2.3	1.5	.1	3.2	6.9	1.7	1.0	1.7	2.4	2.1	4.2 3.2	2.7	1.7 1.1	4.9 3.9	1.8 2.0	-.7 2.8	3.3	6.6 -1.2	1,990,000	-4.7	-3.2	-3.5	9.7	-17	3.4	-5.2	-5.4	-.2	16,000	17,300	13,100	14,600	19	2.3	1.6	.8	.2	0	BRITISH MODIFICATION.
											.8	3.7	.9	1.8	9.6	2.2	13 9.3	0	3.1 4.0	15 11	3.6 .5	.3 .6	6.1	4.7 3.4		-2.7	-1.9	-4.2	30	4.9	.6	-4.6	1.4	-.4					34	.7	.5	.3	.2	.1	
32	1,815,000	30,000	1.4	1.8	1.5	1.8	1.7	1.2	-1.0	2.8	6.6	1.4	1.8	1.5	1.7	1.7	2.4 3.0	1.1	.5 .7	2.7 3.0	1.4 .9	-1.1 .8	3.0	6.9 -2.4	793,000	-6.7	-4.5	-3.2	9.3	-4.7	6.0	-8.3	-2.9	-1.4	16,000	16,000	11,500	9,900	19	.9	.7	.5	.4	.3	BASIC DESIGN WITH FULL PENETRATION WELDS.
	1,755,000	29,000									-.4	2.2	2.4	1.5	3.9	2.2	6.5 9.5	3.4	.8 3.2	6.6 9.5	5.3 3.7	-1.9 .3	4.6	8.0 -5.0	882,000	-3.7	-7.7	-2.9	40	—	-5.1	23	-1.6	-6.8					34	2.8	2.5	2.0	1.6	1.2	
33	2,610,000	34,900	.8	1.1	.9	1.1	1.0	.4	—	1.0	2.8	.9	1.3	1.0	1.1	1.0	1.7 2.4	—	.7 .7	2.1 2.4	.7 .9	— -.3	1.8	4.5 -1.2	3,772,000	-5.3	-3.3	-4.5	3.9	5.1	-1.4	-8.0	-2.7	—	16,800	16,000	11,000	16,000	19	.9	.7	.8	.5	.3	EXTENDED COAMING.
	2,250,000	30,100									-.2	1.4	1.6	1.0	1.3	1.0	3.2 3.1	—	1.3 .9	4.4 3.5	1.4 1.3	— -.4	1.8	2.5 -1.7	4,024,000	-4.3	-3.7	-3.2	15	4.9	-.8	-6.0	-15	—					34	2.8	1.9	1.0	.5	.2	
34	2,880,000	33,200	1.1	1.4	1.5	1.3	1.4	1.2	—	—	.2	1.0	1.4	1.4	1.2	1.4	.9 1.7	—	-.2 -.2	1.1 1.3	0 -.1	— -.3	1.4 1.3	.3 -.4	5,800,000	—	-2.9	—	—	-4.3	-4.4	-3.4	-.8	—	11,000	11,000	11,000	5,000	19	.7	.5	.3	.2	.1	A.B.S. DESIGN.
											-.4	1.3	1.5	1.6	1.3	1.4	.9 1.6	—	-.2 -.1	.7 1.5	-.1 -.1	— -.3	1.7 1.4	.4 -.5		-24	-3.1	-36	-14	-4.5	-3.5	-3.1	-.8	—			11,000		34	2.0	1.1	.6	.3	.1	
35	3,265,000	54,100	1.4	1.2	1.5	1.4	1.4	1.4	—	—		1.4	1.2	1.5	1.4	1.5	—	—	—	—	—	—	—	—	6,786,000	-7.3	-2.7	-6.5	-3.1	-2.9	-2.3	-2.9	—	—	—	—	—	—	19	1.9	1.1	.5	.3	.2	KENNEDY DESIGN. SPECIMEN LOADED TO 3,000,000 LBS. SPECIMEN RELOADED TO FAILURE. NO GAGE READINGS TAKEN ON SECOND LOADING.
												2.1	1.6	3.2	1.4	4.5	—	—	—	—	—	—	—	—		-6.1	-3.9	-5.7	-16	-11	3.9	3.3	—	—					34	1.7	1.1	.7	.4	.3	
36	1,460,000	23,700																							146,000																				BASIC DESIGN WITH ANGLE BRACES. INVALID, LAMINATED PLATE. NO GAGE READINGS TAKEN.
	1,380,000	22,400																							221,800																				
37	2,470,000	33,600																							2,017,000																				REPEAT OF 33 — INVALID, LAMINATED PLATE. NO GAGE READINGS TAKEN.
38	1,550,000	25,500	1.9	2.1	1.8	3.2	2.6	1.4	-1.5	4.2	5.7	1.9	2.3	2.0	3.1	2.6	6.0 5.0	1.7	.8 .7	7.8 5.4	2.2 .5	-2.0 2.0	3.6	6.0 -1.7	277,000	-6.4	-3.2	-2.5	—	-8.5	4.3	-3.7	-3.6	-1.0	10,000	11,200	5,300	12,900							REPEAT OF 36. HATCH END BEAM OF COMMERCIAL STEEL.
	1,400,000	23,000									0.1	2.4	2.3	1.6	4.3	2.8	8.2 11	5.7	-.3 .3	9.5 13	6.2 1.0	-2.4 2.3	6.2	7.1 -2.3	417,600	-3.0	-7.0	-2.6	—	-7.0	-2.4	—	-3.1	-1.0											

NOTES

1. BASED ON LOAD CARRYING SECTION OF DECK, DOUBLER, LONGITUDINAL COAMING BELOW DECK. (ACTUAL PLATE THICKNESS)
2. BASED ON AVERAGE OF LONGITUDINAL STRESSES FOR GAGES 1-2-3-4 TOP AND BOTTOM.
3. BASED ON AVERAGE OF LONGITUDINAL STRAINS FOR GAGES 1-2-3-4 TOP AND BOTTOM.
4. READINGS QUESTIONABLE. GAGE 11 VERY CLOSE TO DOUBLER WELD.
5. TEST TEMPERATURE 70° ± 4°F.







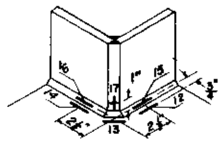
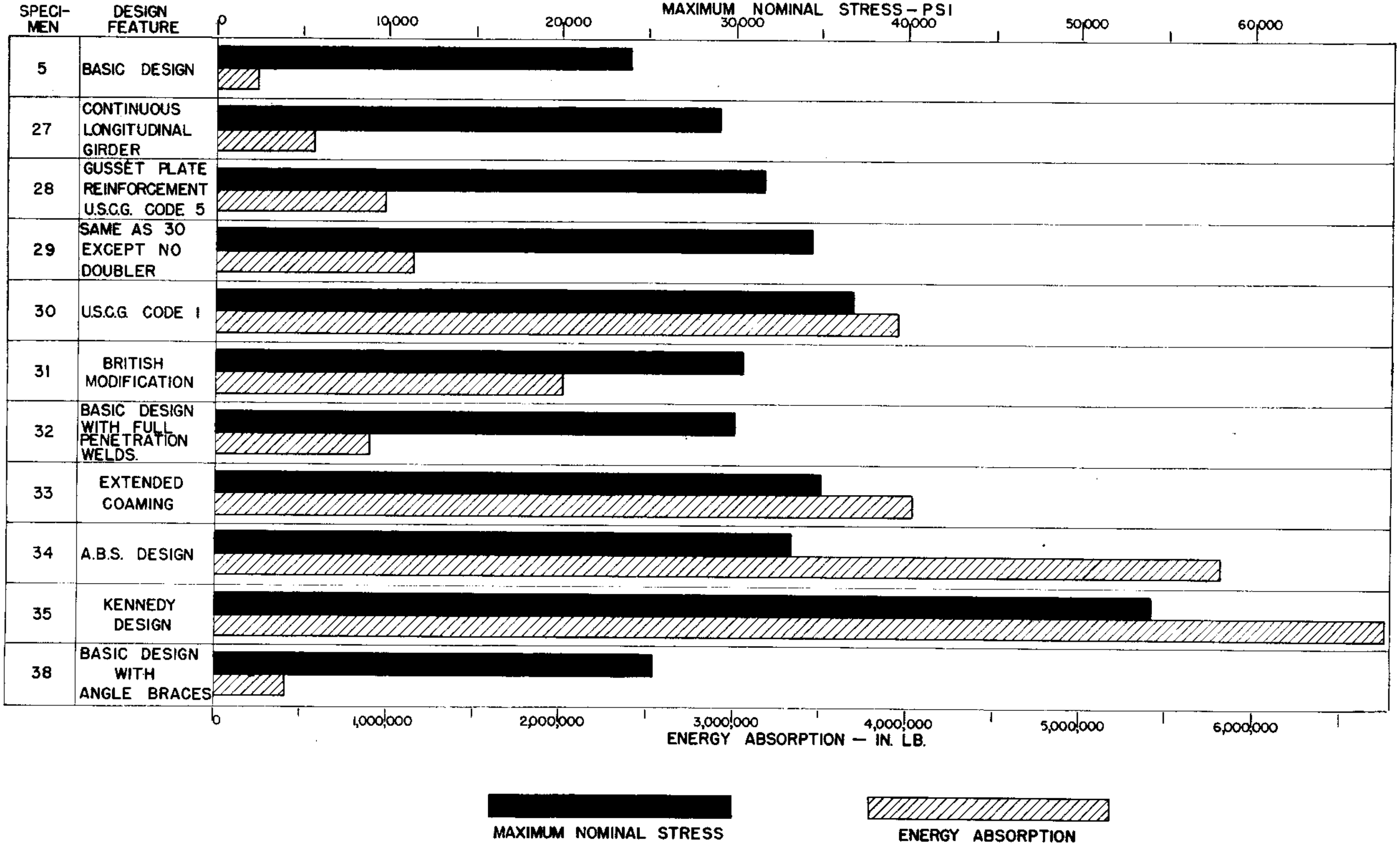


TABLE V

TABLE VI

HATCH CORNER TESTS

MAXIMUM NOMINAL STRESS AND ENERGY ABSORPTION



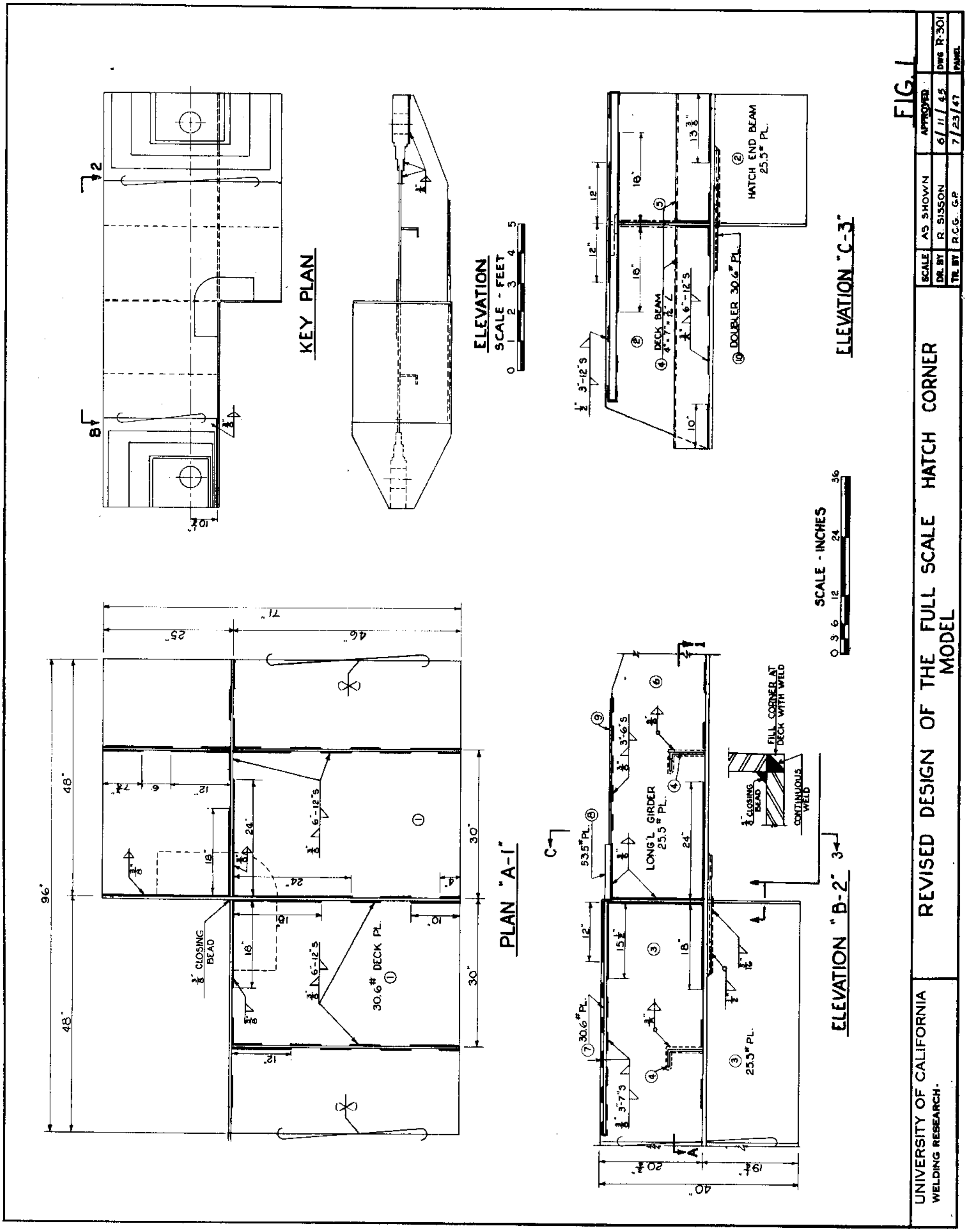
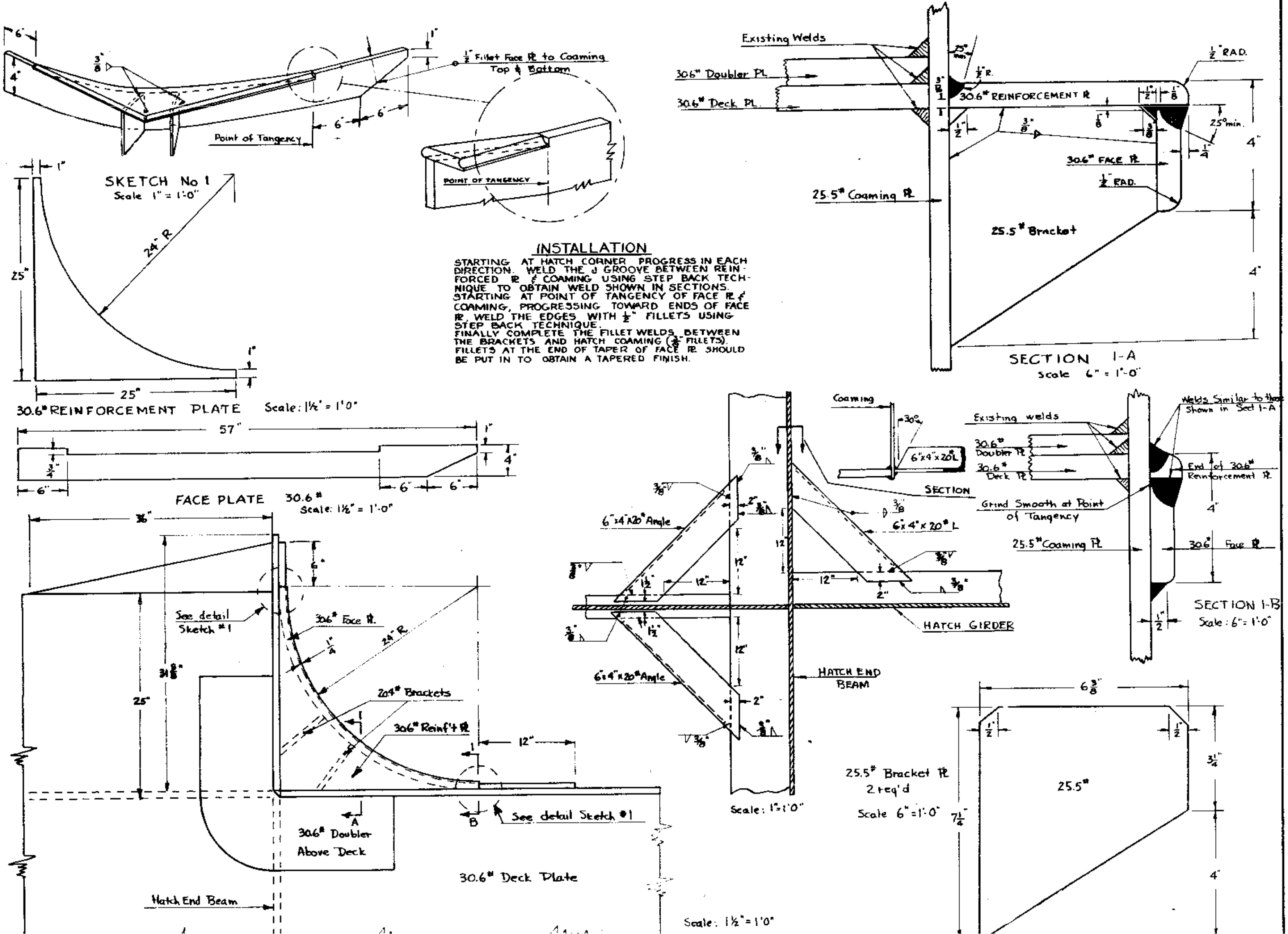


FIG. 1

REVISED DESIGN OF THE FULL SCALE HATCH CORNER MODEL



INSTALLATION

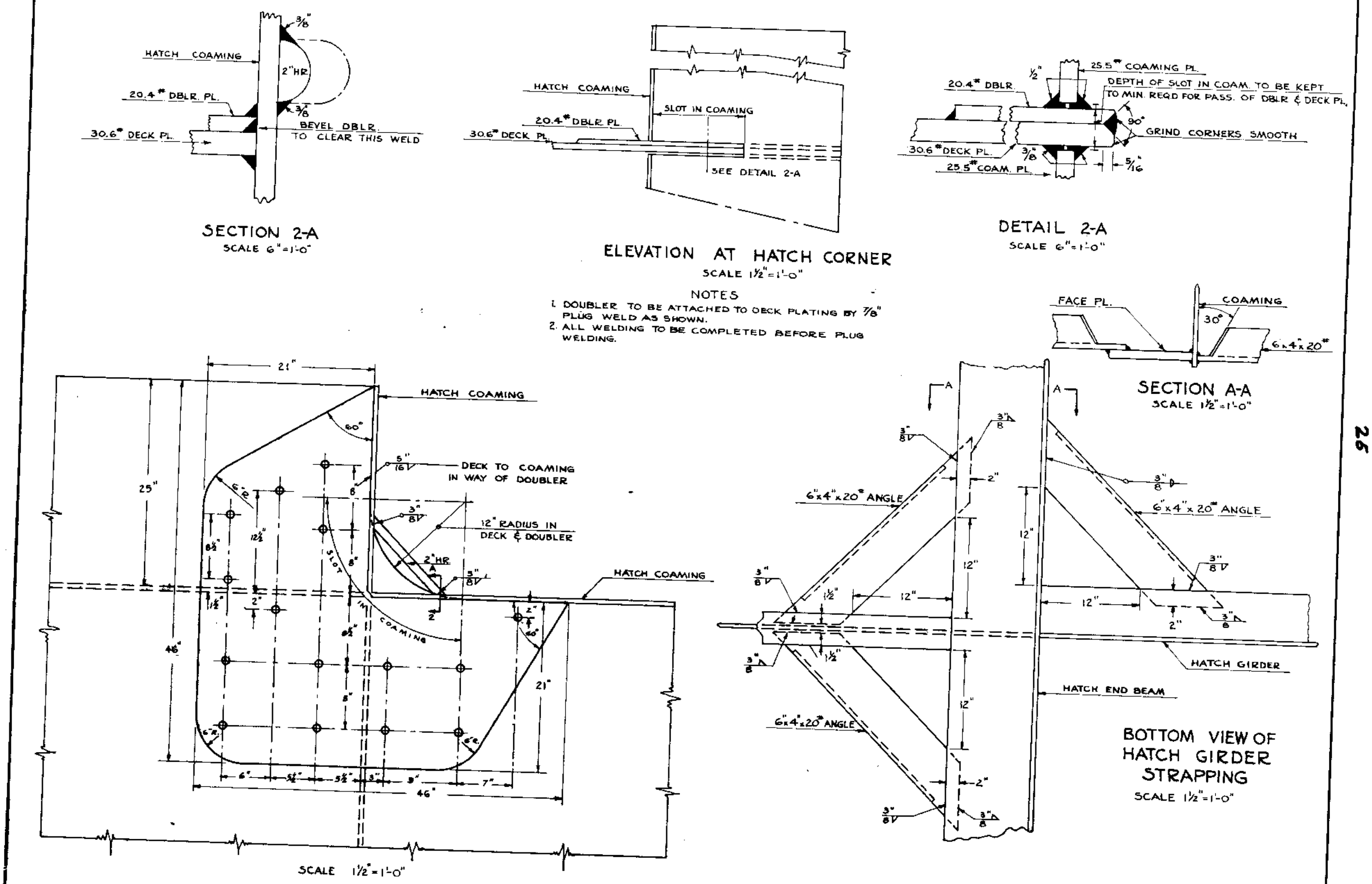
STARTING AT HATCH CORNER PROGRESS IN EACH DIRECTION. WELD THE J GROOVE BETWEEN REINFORCED PL & COAMING USING STEP BACK TECHNIQUE TO OBTAIN WELD SHOWN IN SECTIONS.
STARTING AT POINT OF TANGENCY OF FACE PL & COAMING, PROGRESSING TOWARD ENDS OF FACE PL, WELD THE EDGES WITH 1/2" FILLETS USING STEP BACK TECHNIQUE.
FINALLY COMPLETE THE FILLET WELDS BETWEEN THE BRACKETS AND HATCH COAMING (3/8" FILLETS). FILLETS AT THE END OF TAPER OF FACE PL SHOULD BE PUT IN TO OBTAIN A TAPERED FINISH.

FIG. 2

UNIVERSITY OF CALIFORNIA
WELDING RESEARCH-HATCH DESIGN
112 ENG MAT. LAB. BERKELEY, CALIF.

DETAIL OF GUSSET PLATE REINFORCEMENT (U.S.C.G. CODE 5) FOR HATCH CORNER SPECIMEN #28

SCALE	AS SHOWN	APPROVED	aB
DR. BY	aB	10/ 23/ 46	DWG L57
TR. BY	RNB.	/ /	PANEL —

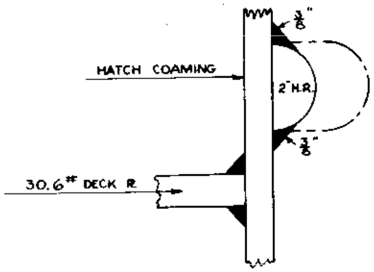


NOTES

1. DOUBLER TO BE ATTACHED TO DECK PLATING BY 7/8" PLUG WELD AS SHOWN.
2. ALL WELDING TO BE COMPLETED BEFORE PLUG WELDING.

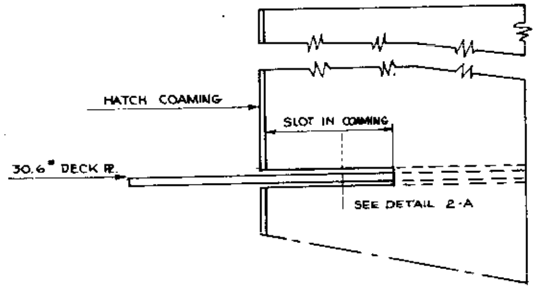
FIG. 3

UNIVERSITY OF CALIFORNIA WELDING RESEARCH - U.S.N. HATCH DESIGN 112 ENG. MAT. LAB. BERKELEY, CALIF.	HATCH CORNER REINFORCEMENTS (U.S.C.G. CODE 1) FOR SPECIMEN 30	SCALE AS SHOWN	APPROVED	aB
		DR. BY J. J. B.	11/27/46	DWG L-59
		TR. BY	/ /	PANEL



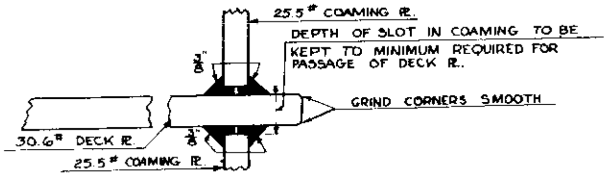
SECTION 2-A

SCALE 6" = 1'-0"



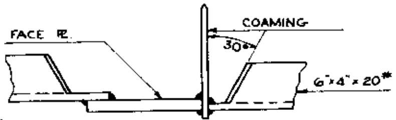
ELEVATION AT HATCH CORNER

SCALE 1½" = 1'-0"



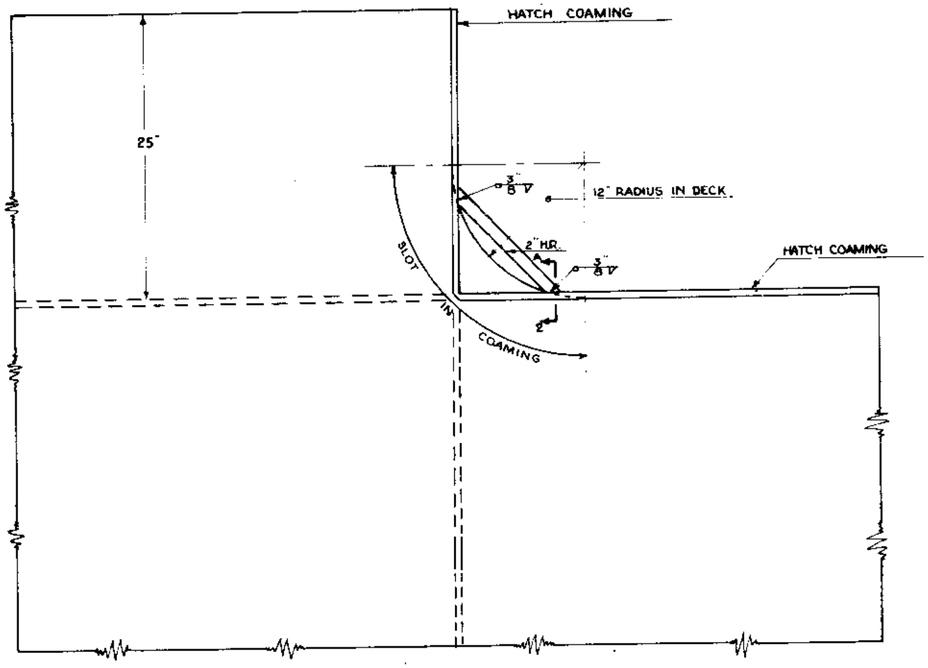
DETAIL 2-A

SCALE 6" = 1'-0"

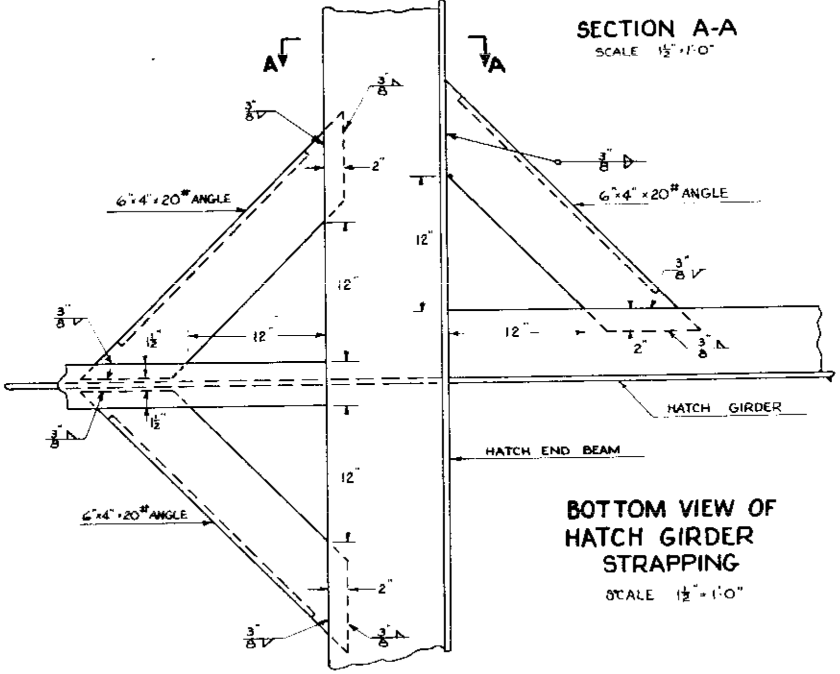


SECTION A-A

SCALE 1½" = 1'-0"



SCALE 1½" = 1'-0"



BOTTOM VIEW OF HATCH GIRDER STRAPPING

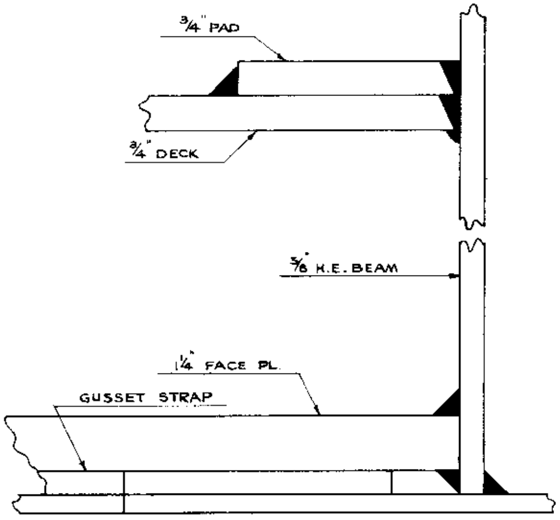
SCALE 1½" = 1'-0"

FIG 4

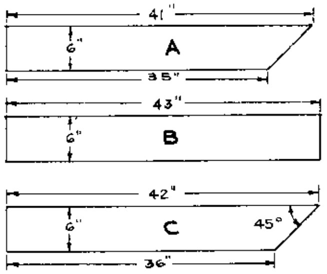
UNIVERSITY OF CALIFORNIA WELDING RESEARCH	HATCH CORNER REINFORCEMENTS FOR SPECIMEN 29	SCALE	AS SHOWN	APPROVED	
		DR. BY	G.P.	7 / 17 / 47	DWG
		TR. BY		/ /	PANEL

INSTALLATION OF DOUBLERS & STRAPS

1. DECK PLATE TO BE VEE-ED AT COAMING TO GIVE FULL PENETRATION WELD.
2. WELD DECK PLATE TO COAMING.
3. FIT DOUBLER PAD ON TOP VEE-ED AT COAMING TO GIVE FULL PENETRATION WELD.
4. WELD PAD ALL AROUND WITH 5/8" FILLET
5. STRAPS A, B & C TO BE WELDED TOGETHER AS SHOP ASSEMBLY BEFORE ATTACHMENT TO HATCH CORNER.
6. FIT & WELD GUSSET STRAP ASSEMBLY TO HATCH END BEAM & LONGITUDINAL GIRDER.

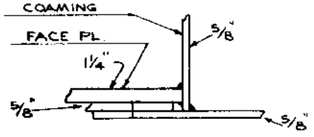


WELDING DETAIL FOR SECTION A-A
SCALE 6"=1'-0"

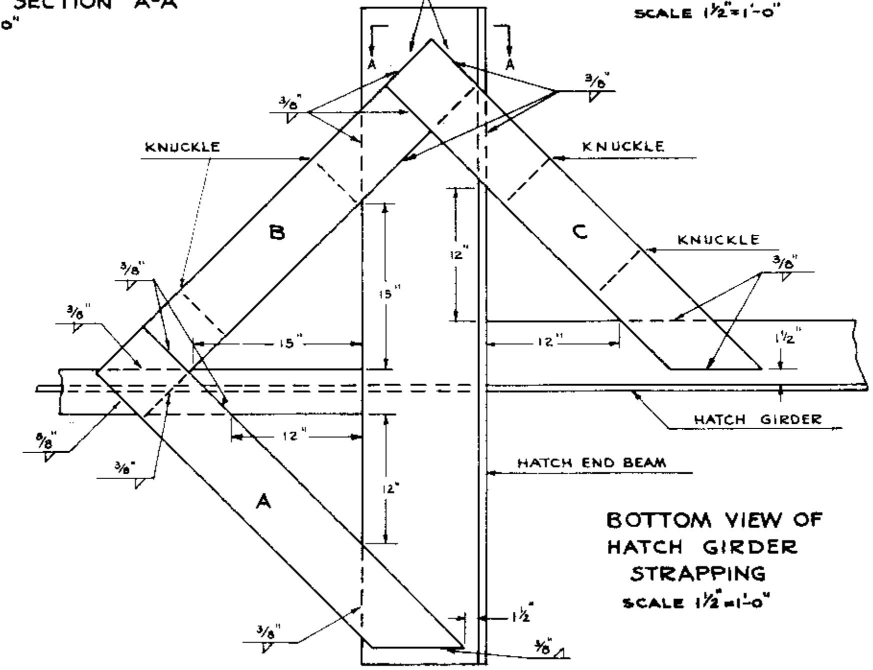


DETAILS OF GUSSET STRAPS (5/8" PL.)
SCALE 1"=1'-0"

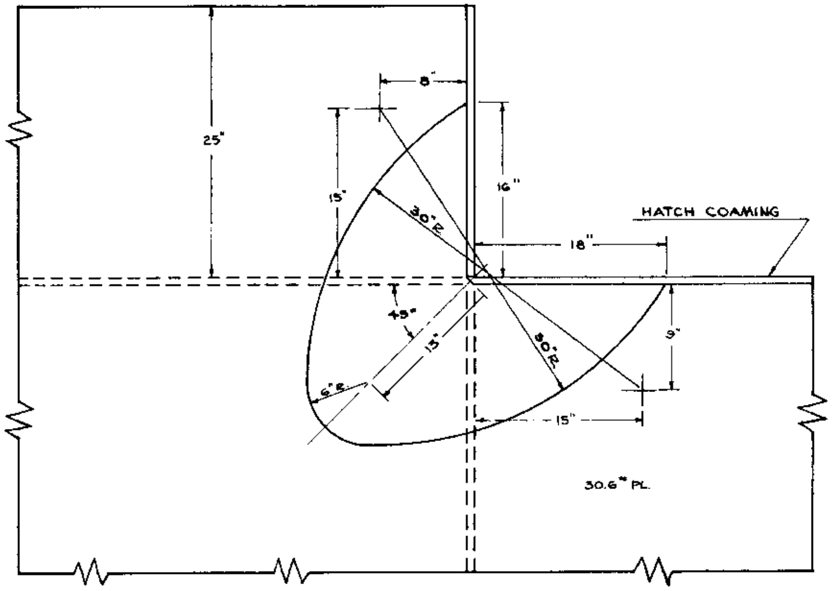
WELDING DETAIL



SECTION A-A
SCALE 1 1/2"=1'-0"



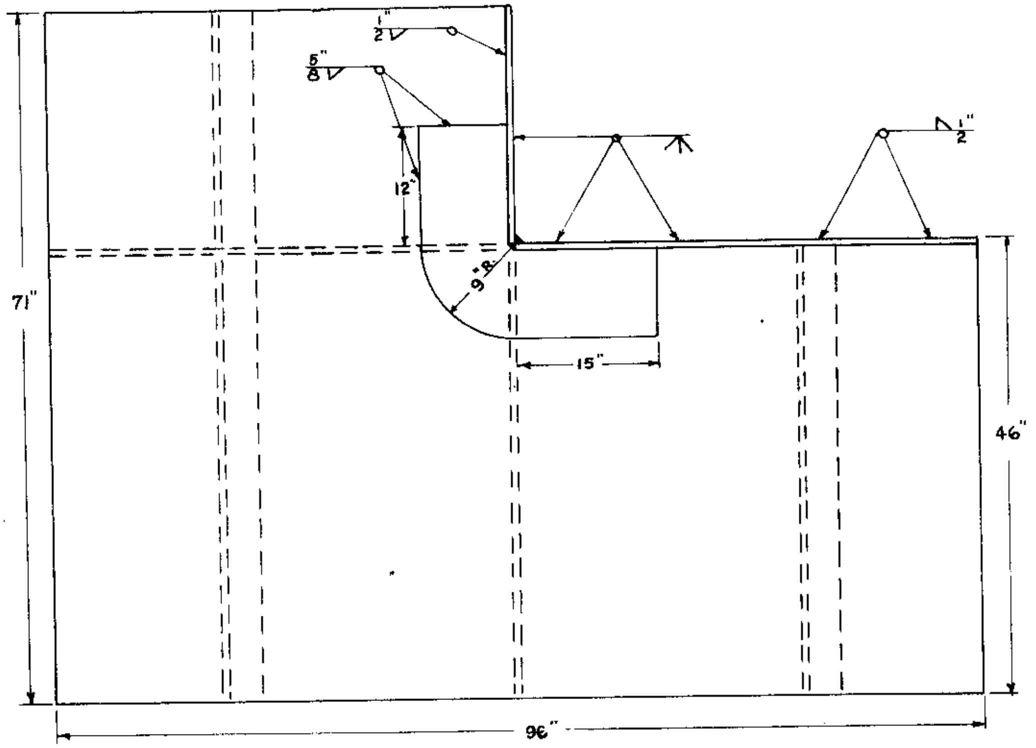
BOTTOM VIEW OF HATCH GIRDER STRAPPING
SCALE 1 1/2"=1'-0"



SCALE 1 1/2"=1'-0"

FIG. 5

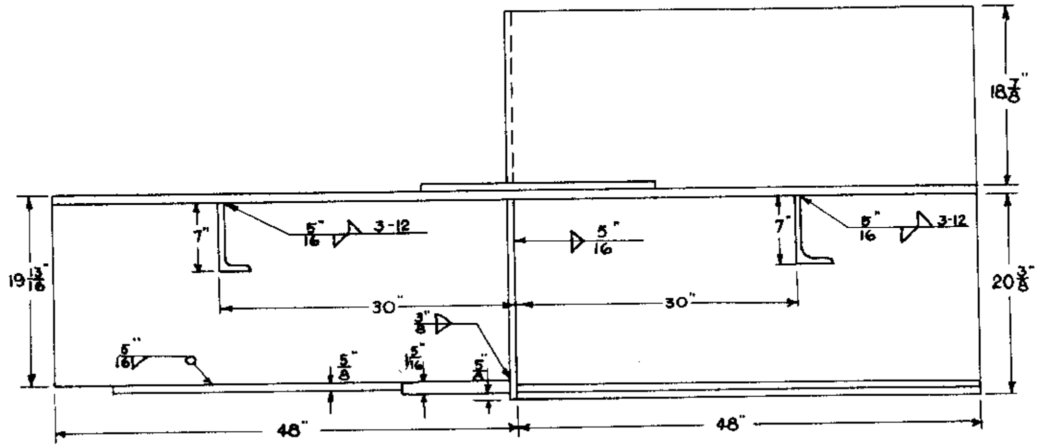
UNIVERSITY OF CALIFORNIA WELDING RESEARCH - USN HATCH DESIGN 112 ENG. MAT. LAB. BERKELEY, CALIF.	HATCH CORNER REINFORCEMENT (BRITISH CODE IA) FOR SPECIMEN NO. 31	SCALE	AS SHOWN	APPROVED	AR
		DR. BY	J. J. B.	12/18/46	DWG L-60
		TR. BY		/ /	PANEL



PLAN VIEW

NOTES

SPECIMEN 32 MADE WITH FULL PENETRATION WELDS BETWEEN THE DECK AND DOUBLER PLATES AND THE HATCH COAMING.
JOINT OF TRANSVERSE AND LONGITUDINAL GIRDERS TO BE FILLET WELDED AS IN PREVIOUS SPECIMENS.



ELEVATION

FIG. 6

DETAILS OF HATCH CORNER SPECIMEN 32	SCALE	1"=1'-0"	APPROVED	
	DR. BY	G. P.	7 / 17 / 47	DWG L-68
	TR. BY		/ /	PANEL

EXTENDED COAMING SPECIMEN #33

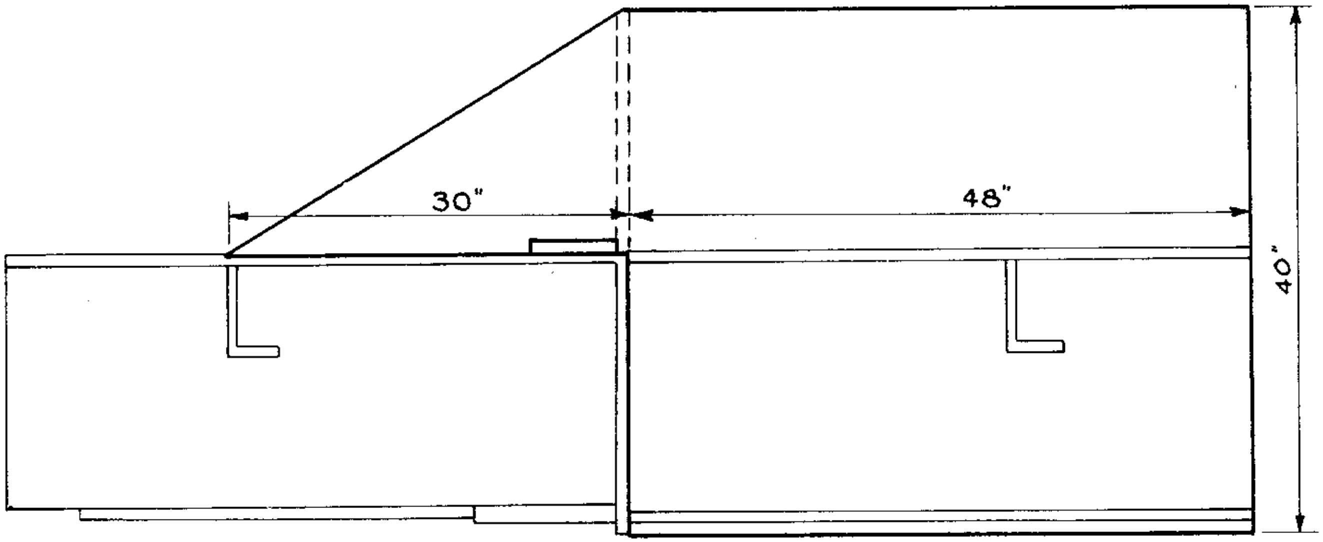


PLATE LAYOUT FOR PART OF LONGITUDINAL GIRDER AND COAMING SHOWING EXTENSION

FIG. 7

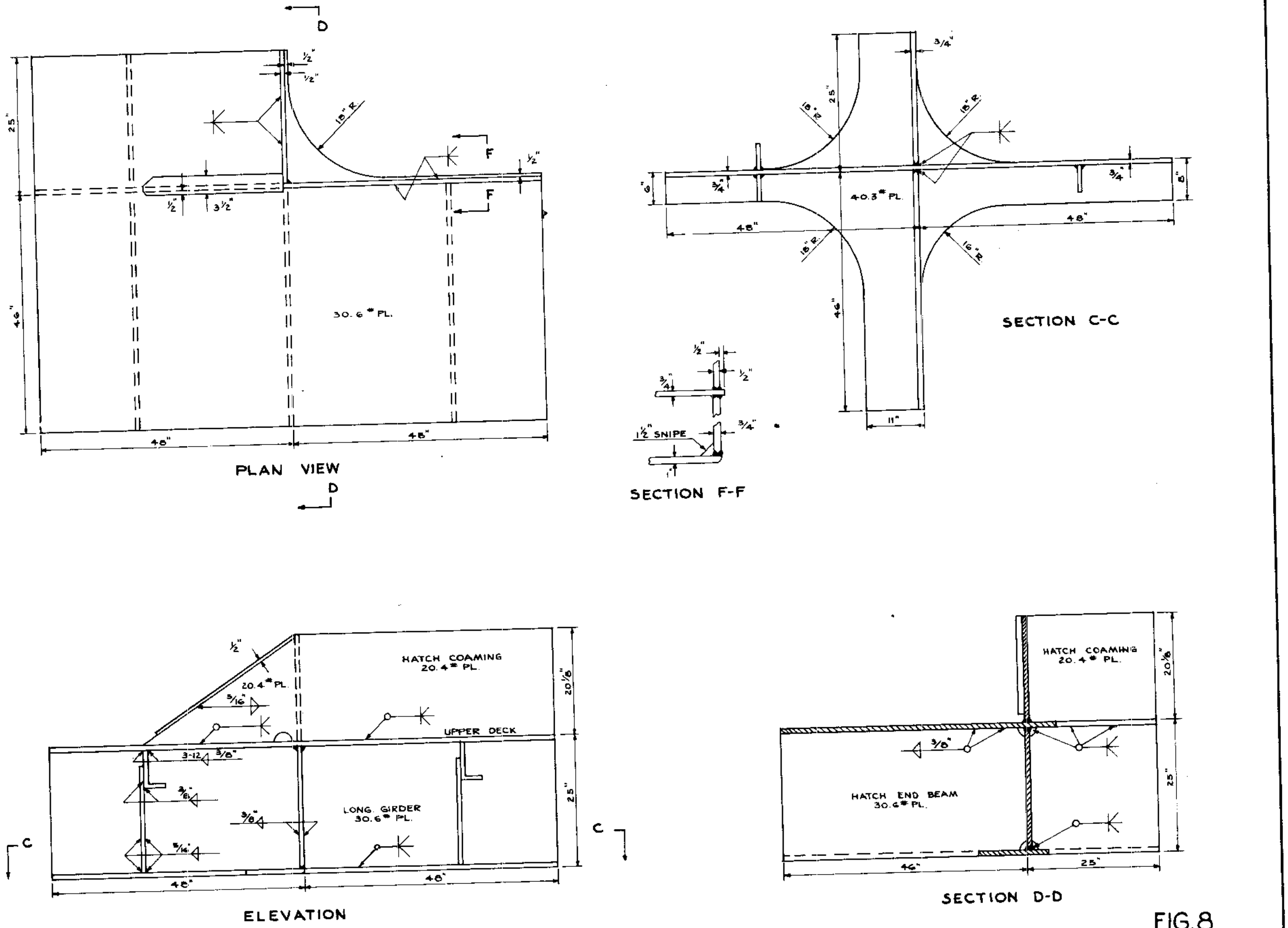


FIG. 8

UNIVERSITY OF CALIFORNIA
WELDING RESEARCH-[redacted] HATCH DESIGN
[redacted] BERKELEY, CALIF.

FULL SCALE ASYMMETRIC HATCH CORNER
SPECIMEN 34 (MODIFIED A.B.S. DESIGN)

SCALE	1" = 1'-0"	APPROVED	
DR. BY	J. J. B.	2 / 21 / 47	DWG L-64
TR. BY		/ /	3RD REV.

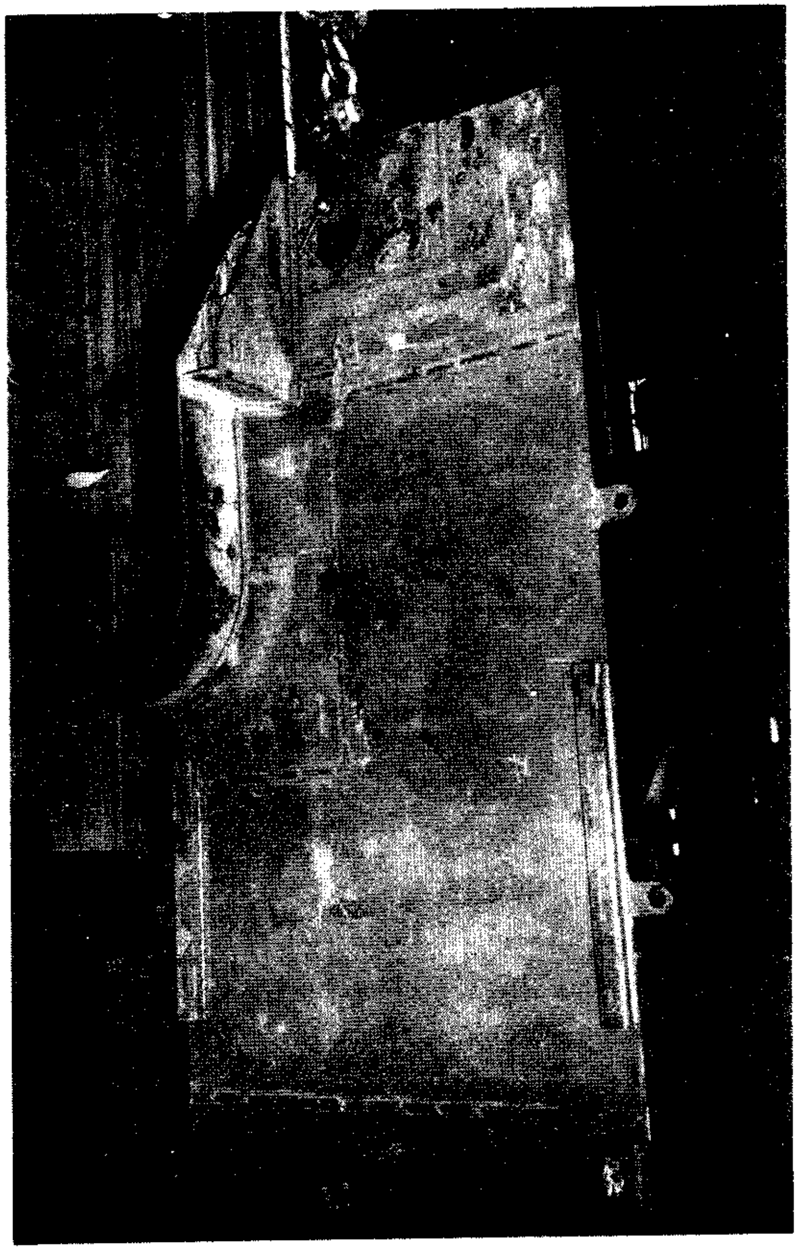


Fig. 11 Specimen 35: Above deck view before test

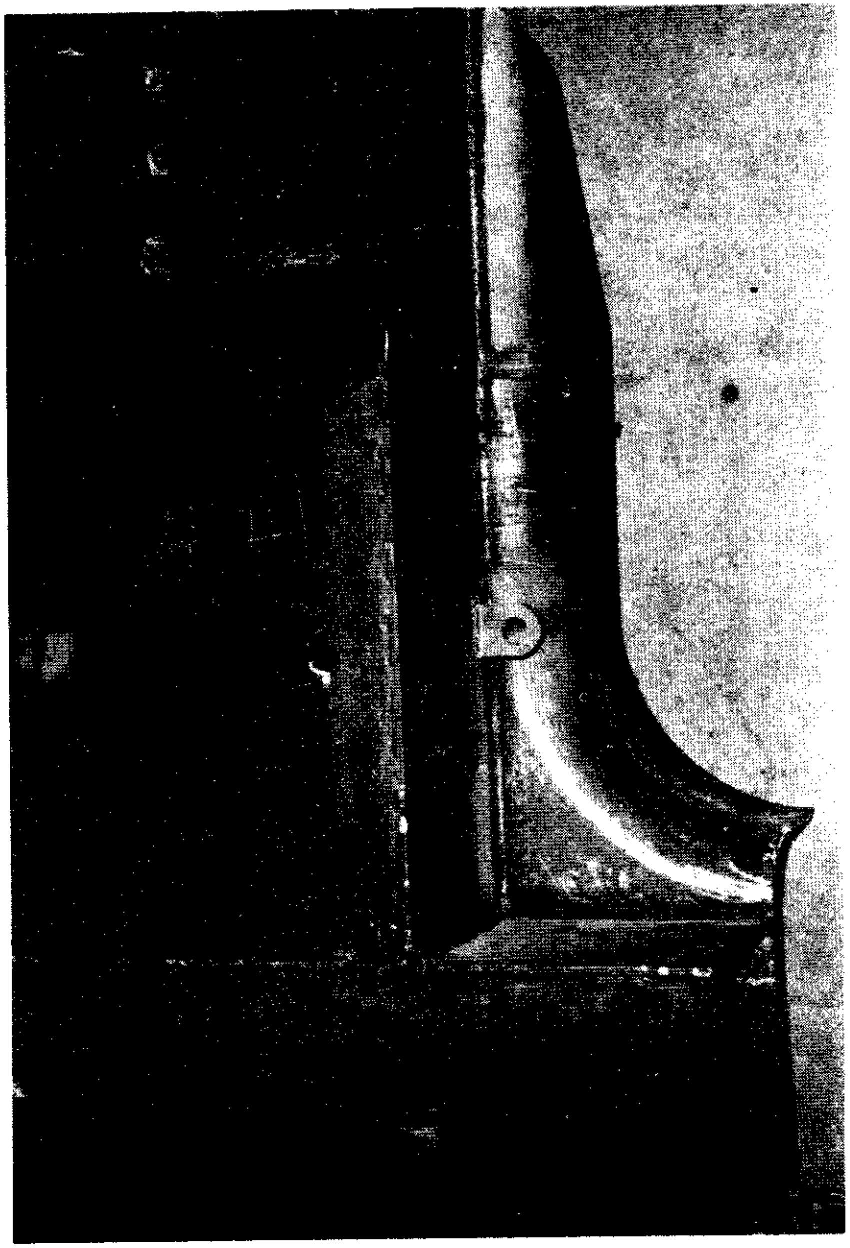


Fig. 12 Specimen 35: Below deck view before test

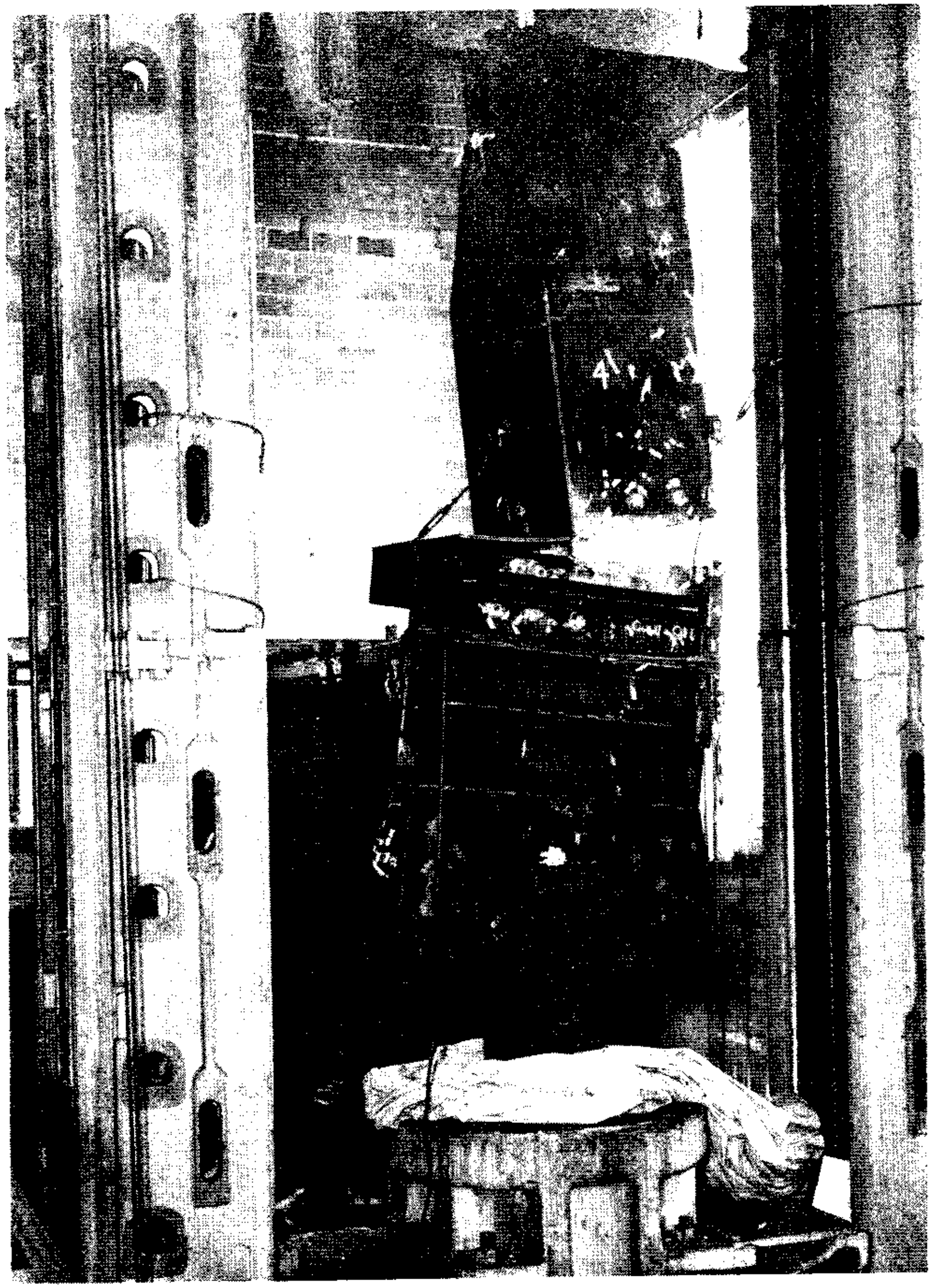


Fig. 13 Specimen 4: Overall view from above

Fig. 14 Specimen 4: Overall view from below

Fig. 15 Specimen 4: View of fractures from above

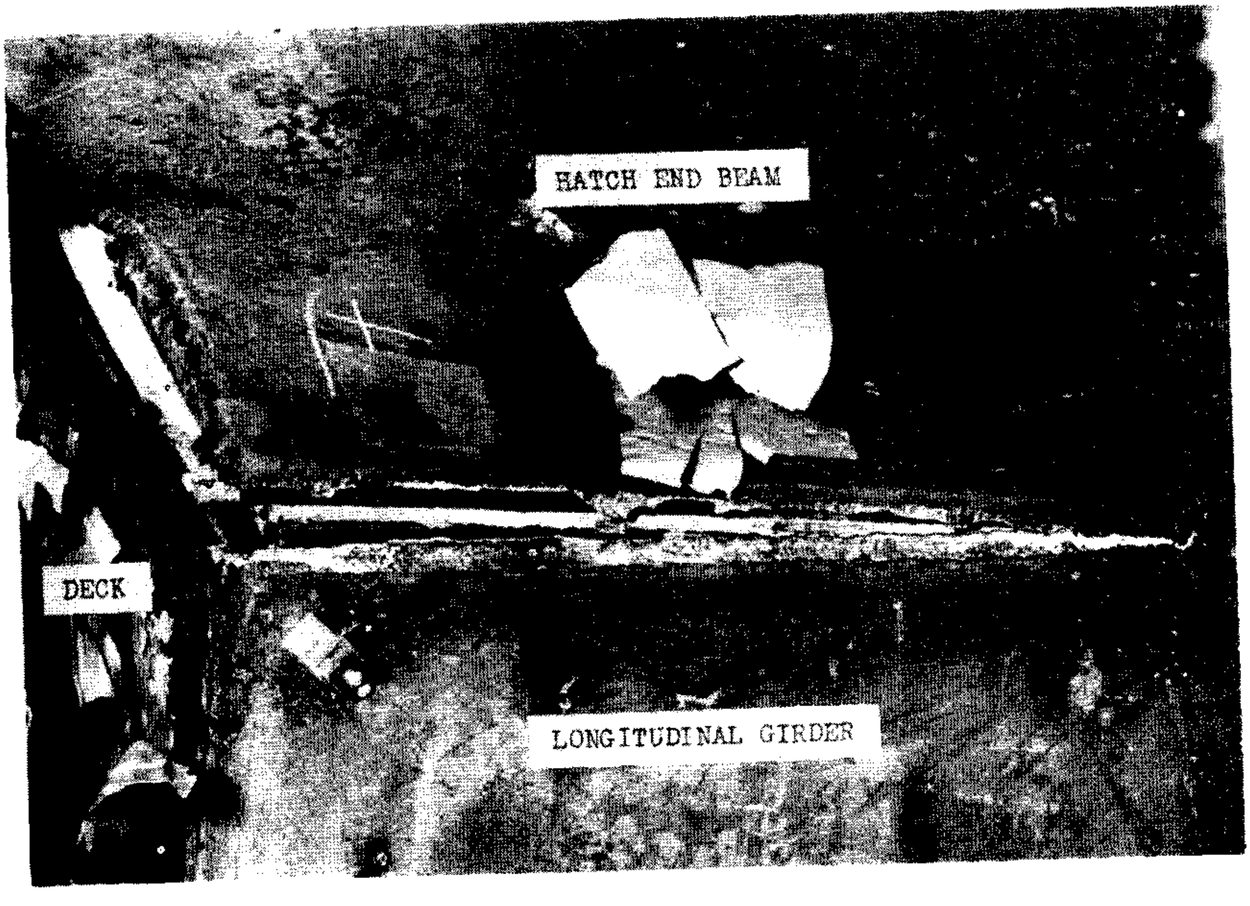


Fig. 16 Specimen 4: View of fractures from below, outboard and forward of hatch end beam

Fig. 17 Specimen 4: View of fracture in weld between longitudinal flange and hatch end beam flange

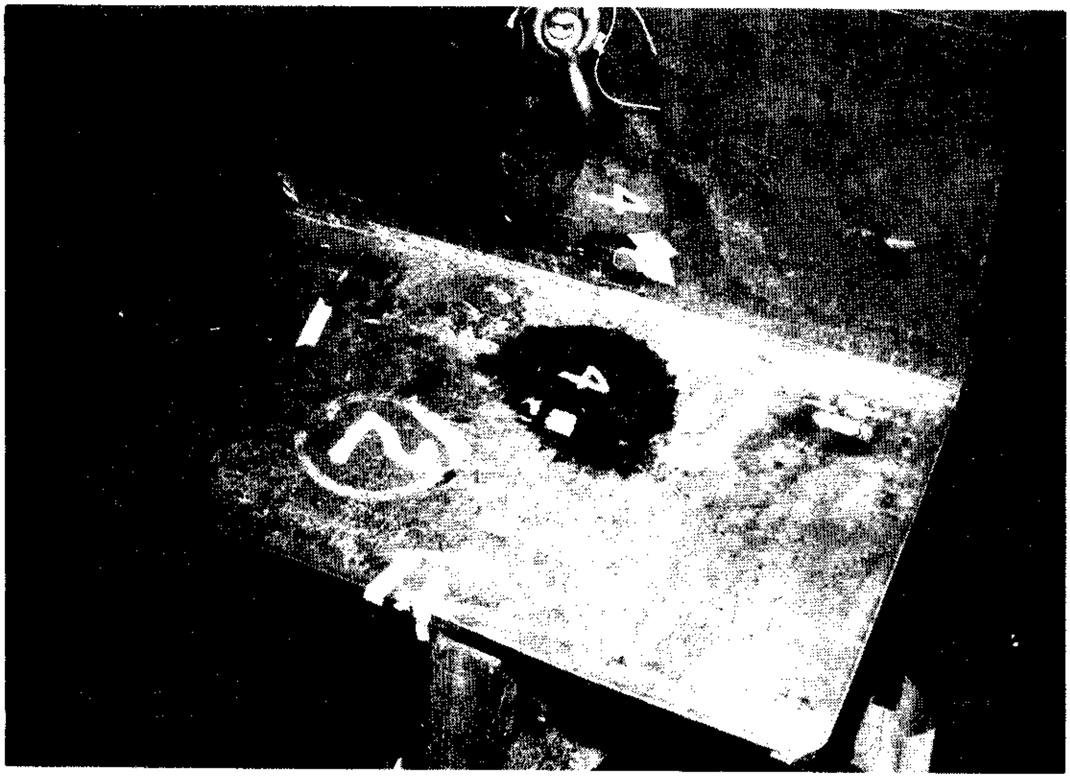


Fig. 18 Specimen 4: View of corner from inside of hatch

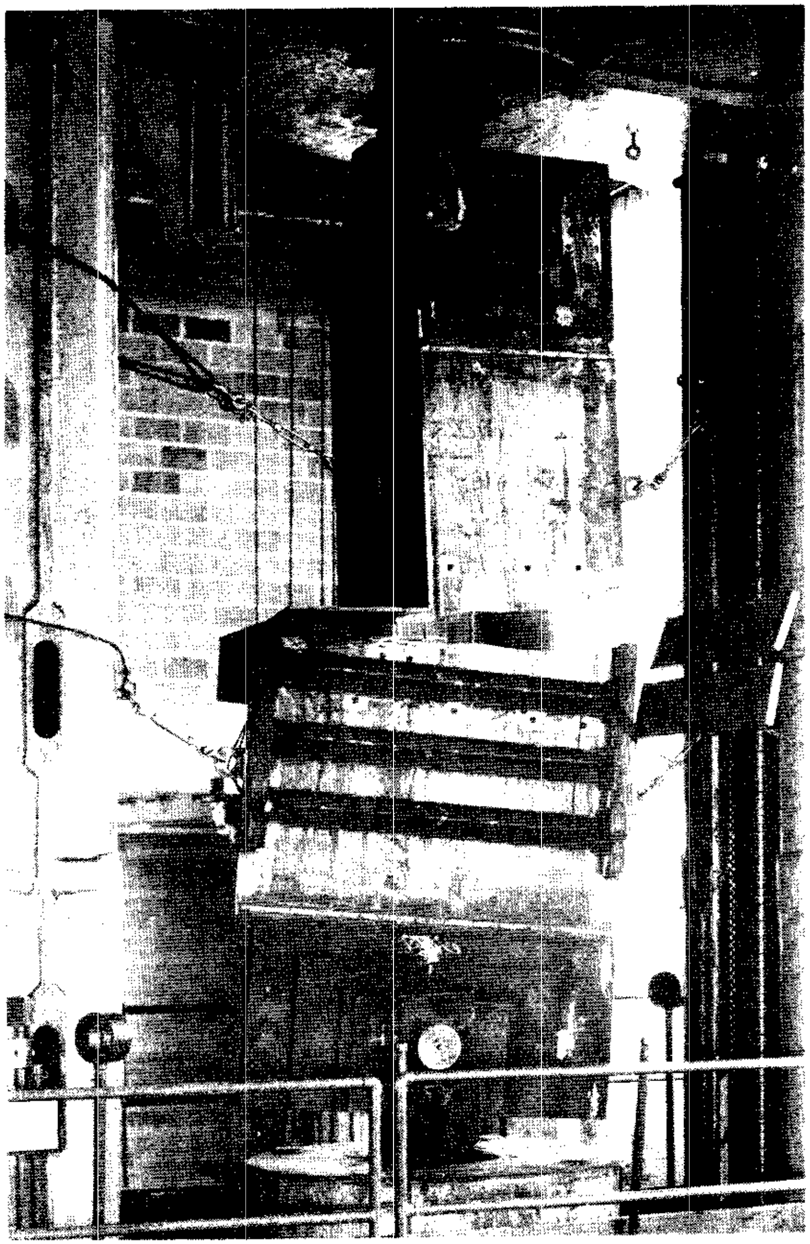


Fig. 19 Specimen 27: Overall view from above.

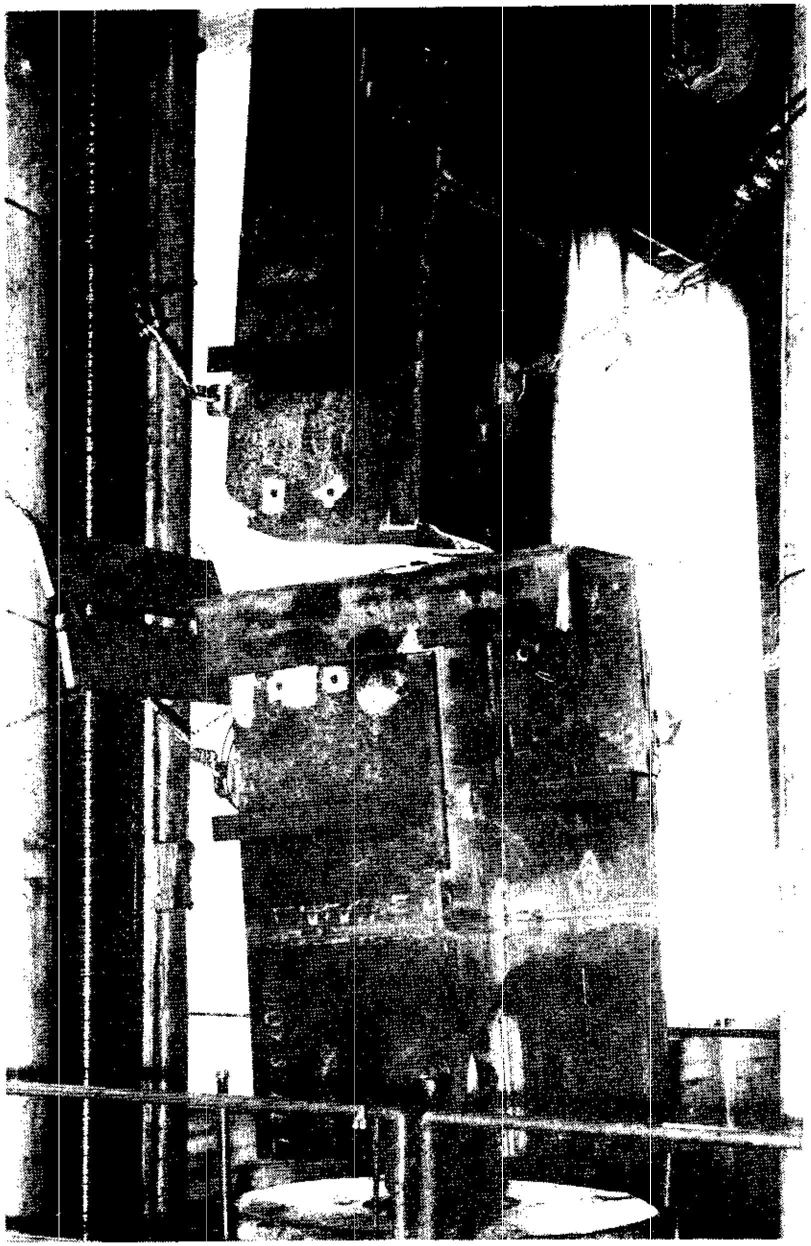


Fig.20 Specimen 27: Overall view from below

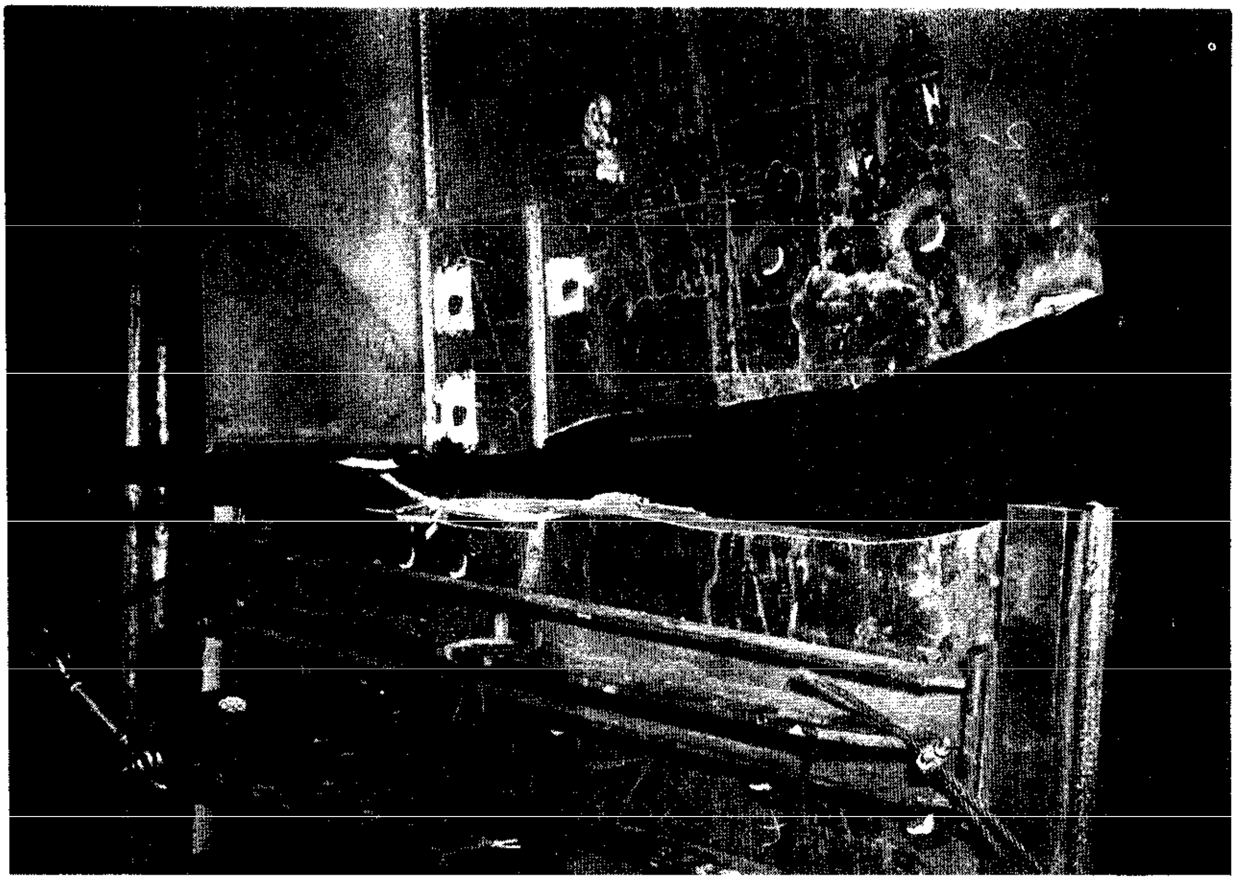


Fig. 21 Specimen 27: View of fractures from above

Fig. 22 Specimen [illegible] View of fractures [illegible] hatch

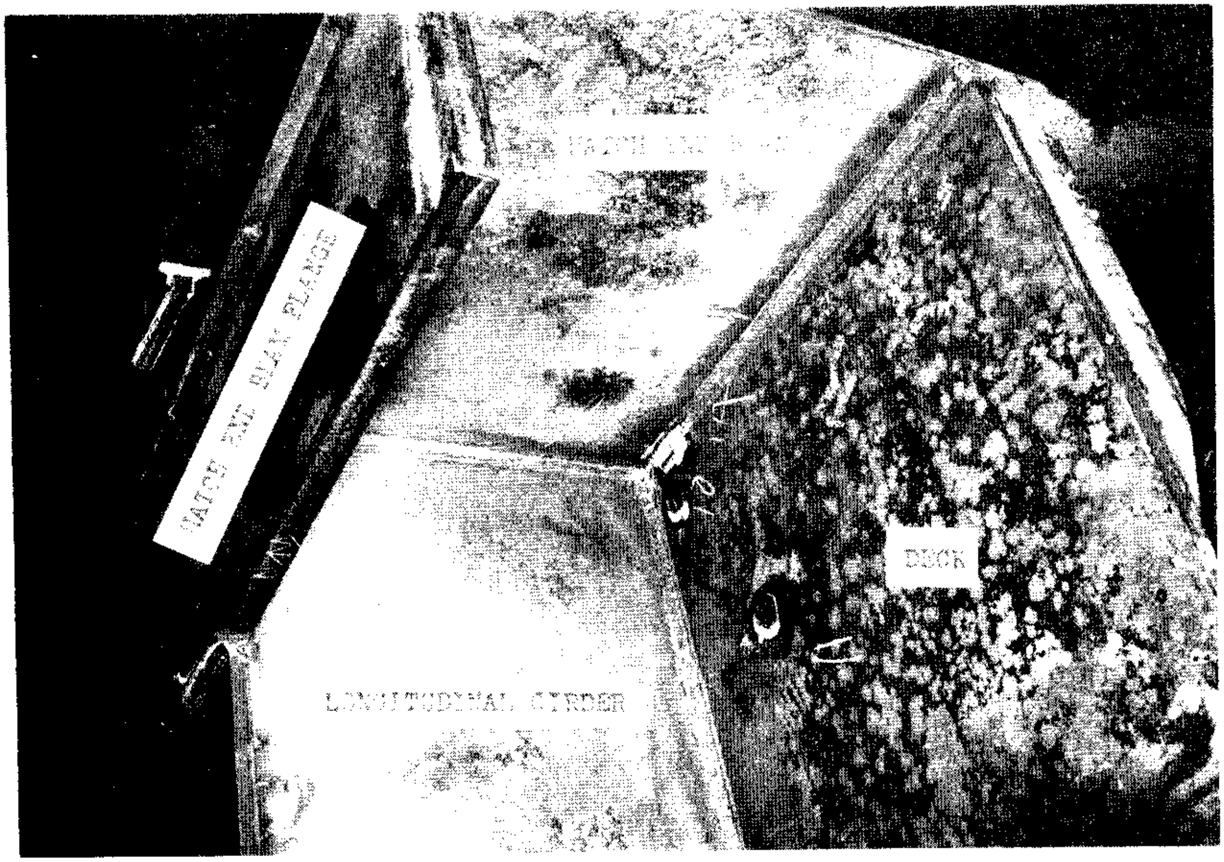


Fig. 23 Specimen 27: View from below deck, inboard, showing absence of fractures

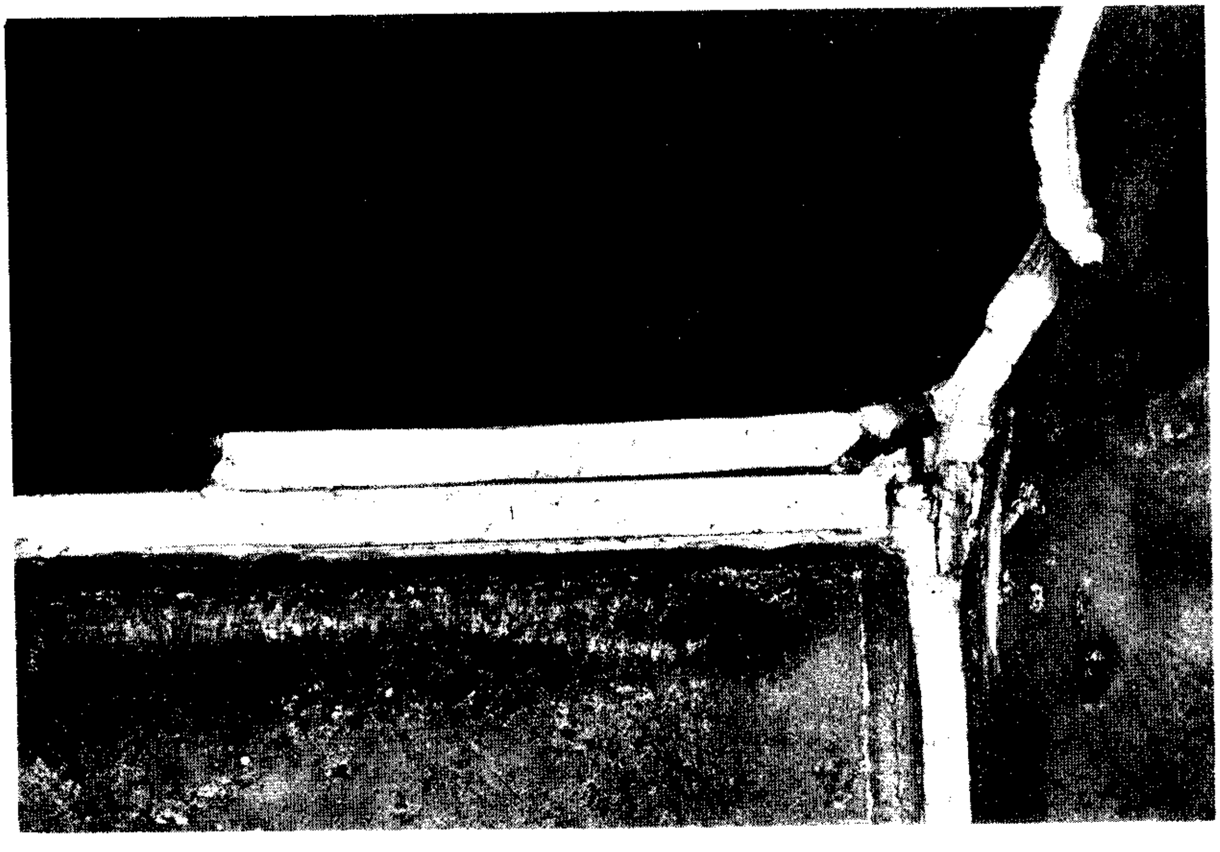


Fig. 24 Specimen 27: Close-up of fracture patterns in deck and doubler

Fig. 25 Specimen 28: Overall view from below

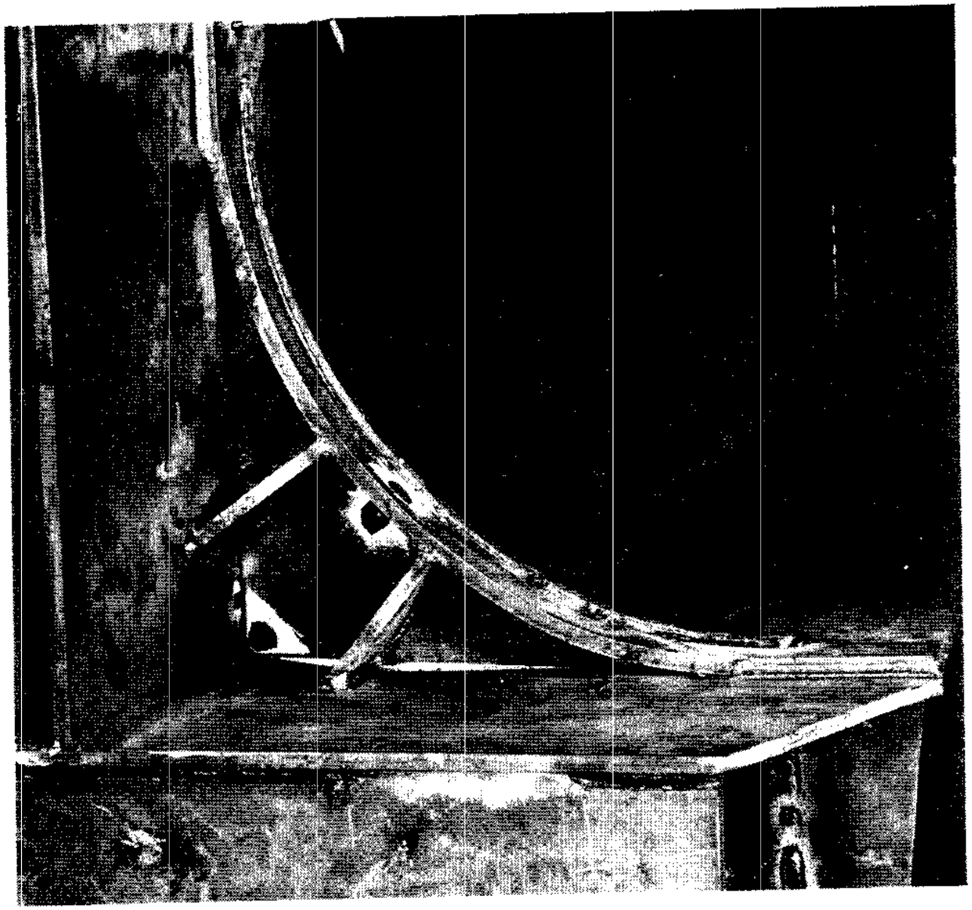


Fig. 26 Specimen 28: View of gusset plate reinforcement from below

Fig. 27 Specimen 28: View of fractures from above

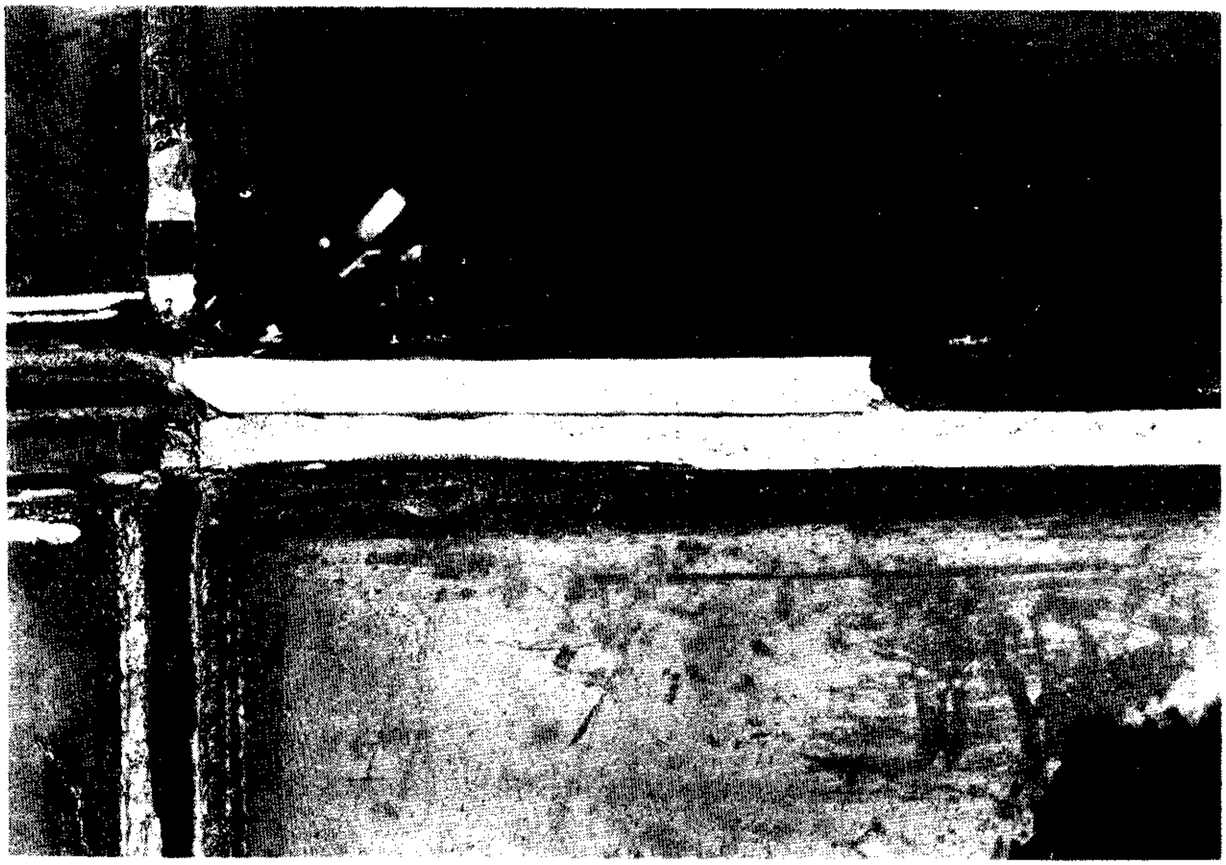


Fig. 28 Specimen 28: Fracture patterns in deck and doubler

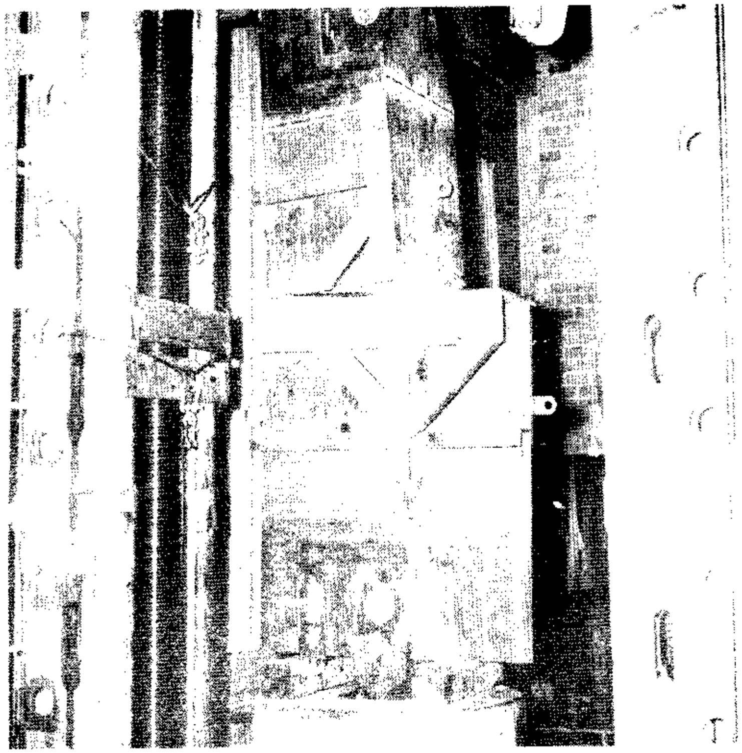


Fig. 29 Specimen 29: Overall view from below

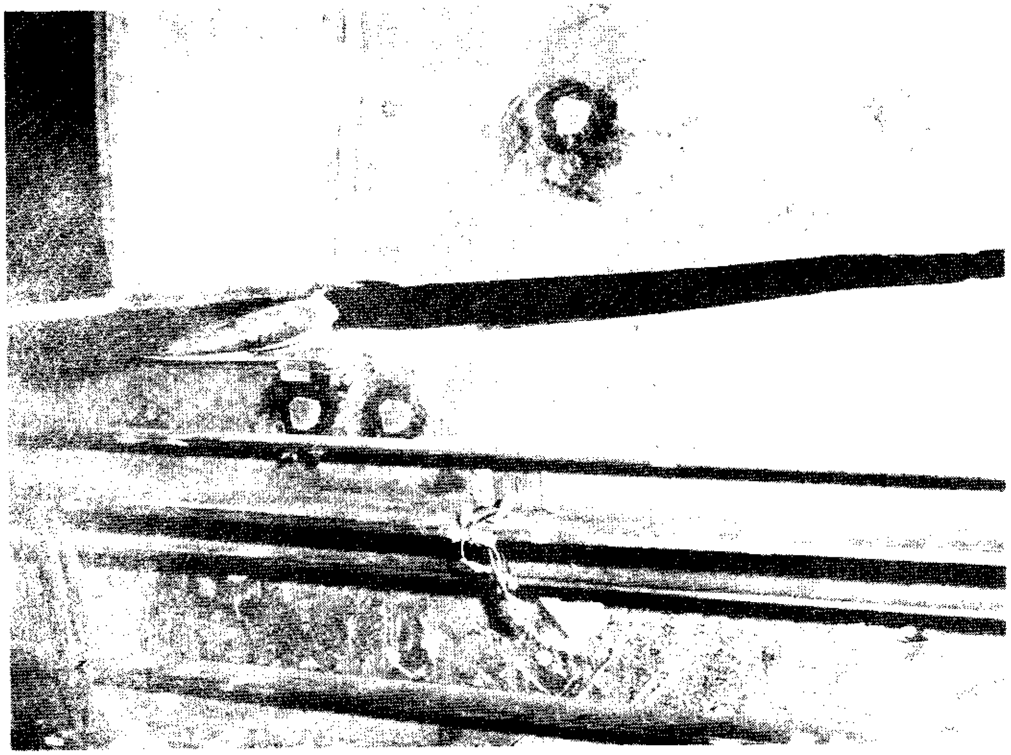


Fig. 30 Specimen 29: View of fractures from above

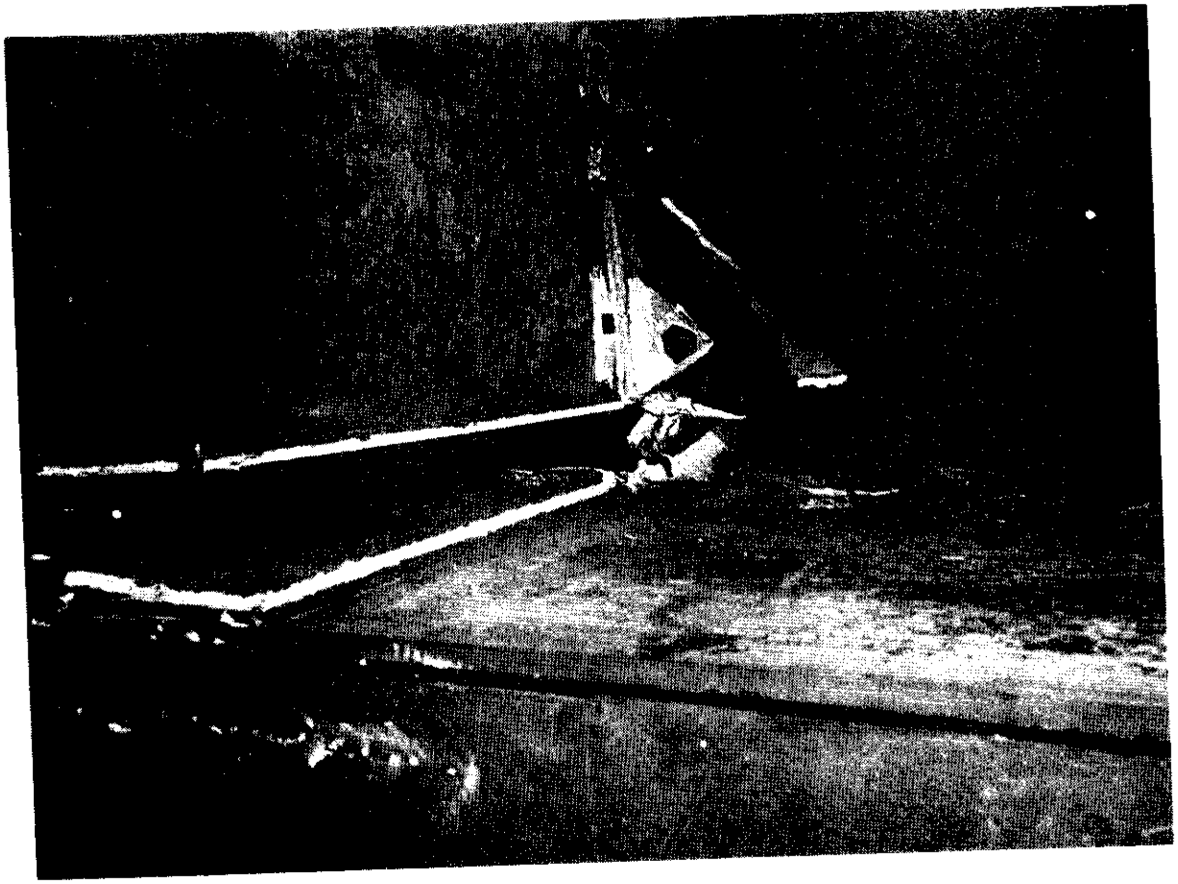


Fig. 31 Specimen 29: View of fractures from inside of hatch

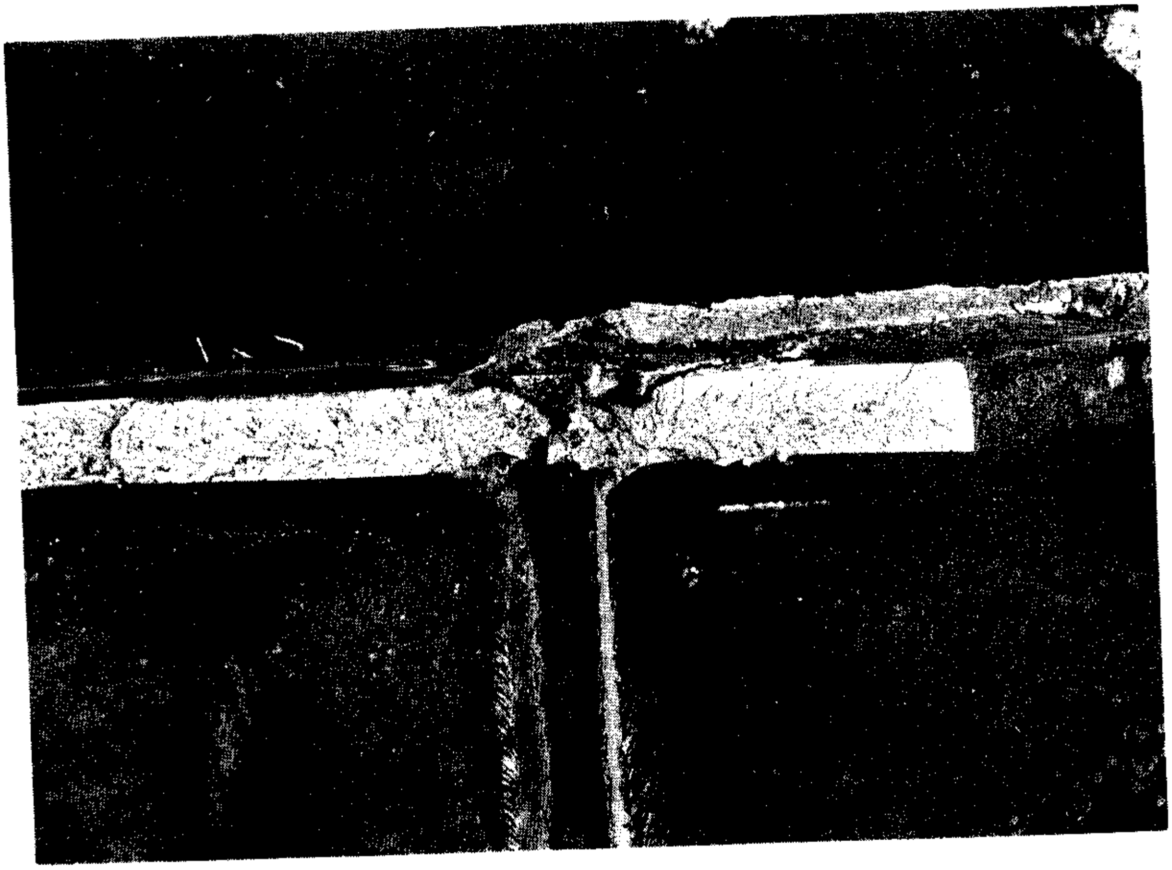


Fig. 32 Specimen 29: View of fracture patterns [illegible] deck at corner

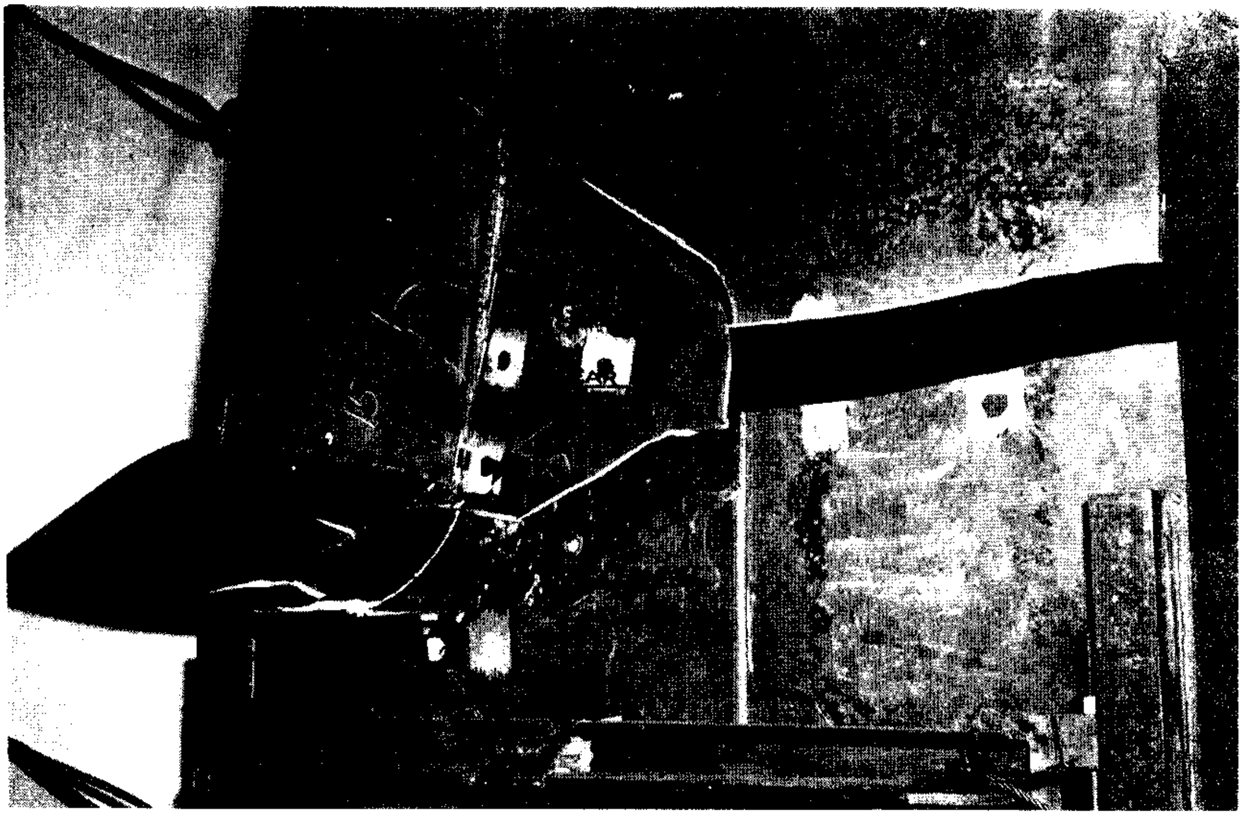


Fig. 33 Specimen 30: View of fractures from above

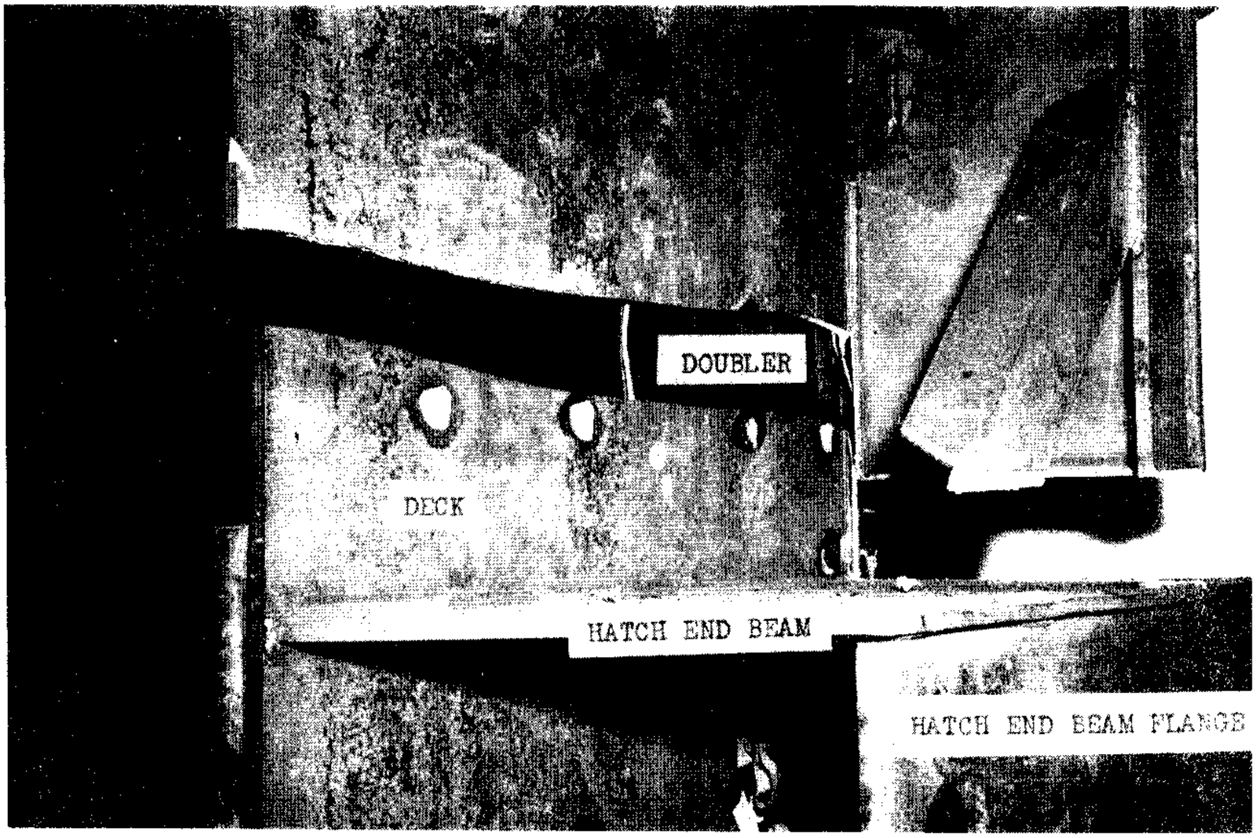


Fig. 34 Specimen 30: View of fractures from below deck and outboard

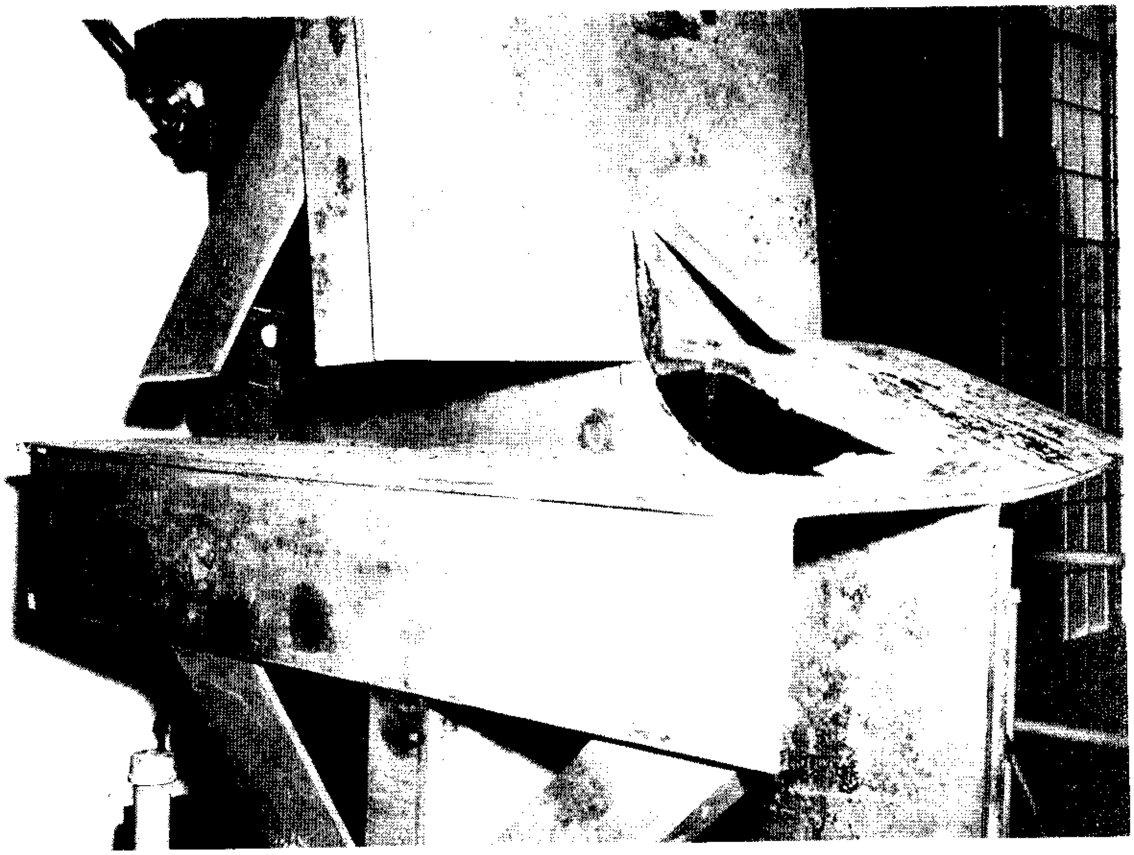


Fig. 35 Specimen 30: View of fractures from inside of hatch

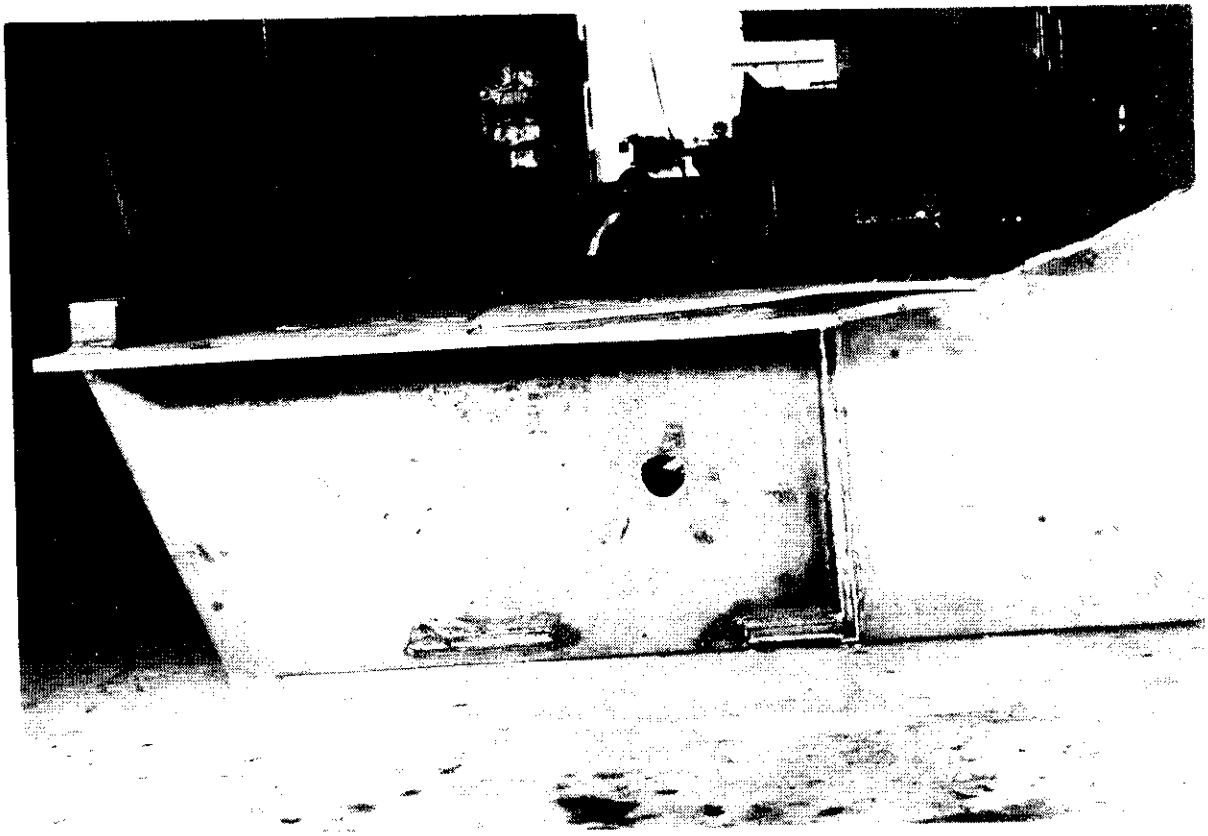


Fig. 36 Specimen 30: View of fractures in deck and doubler

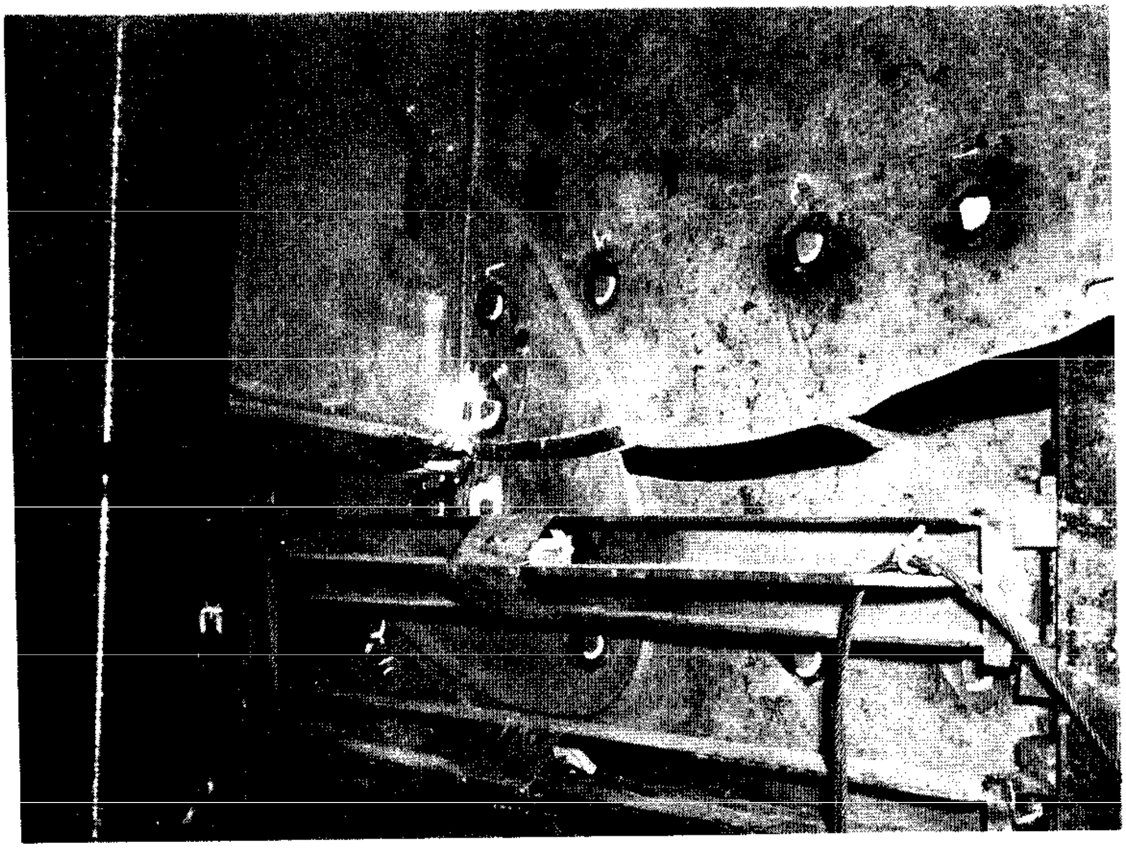


Fig. 37 Specimen 31: View of fractures from above

Fig. 38 Specimen 31: View from below deck, outboard and aft of hatch end beam

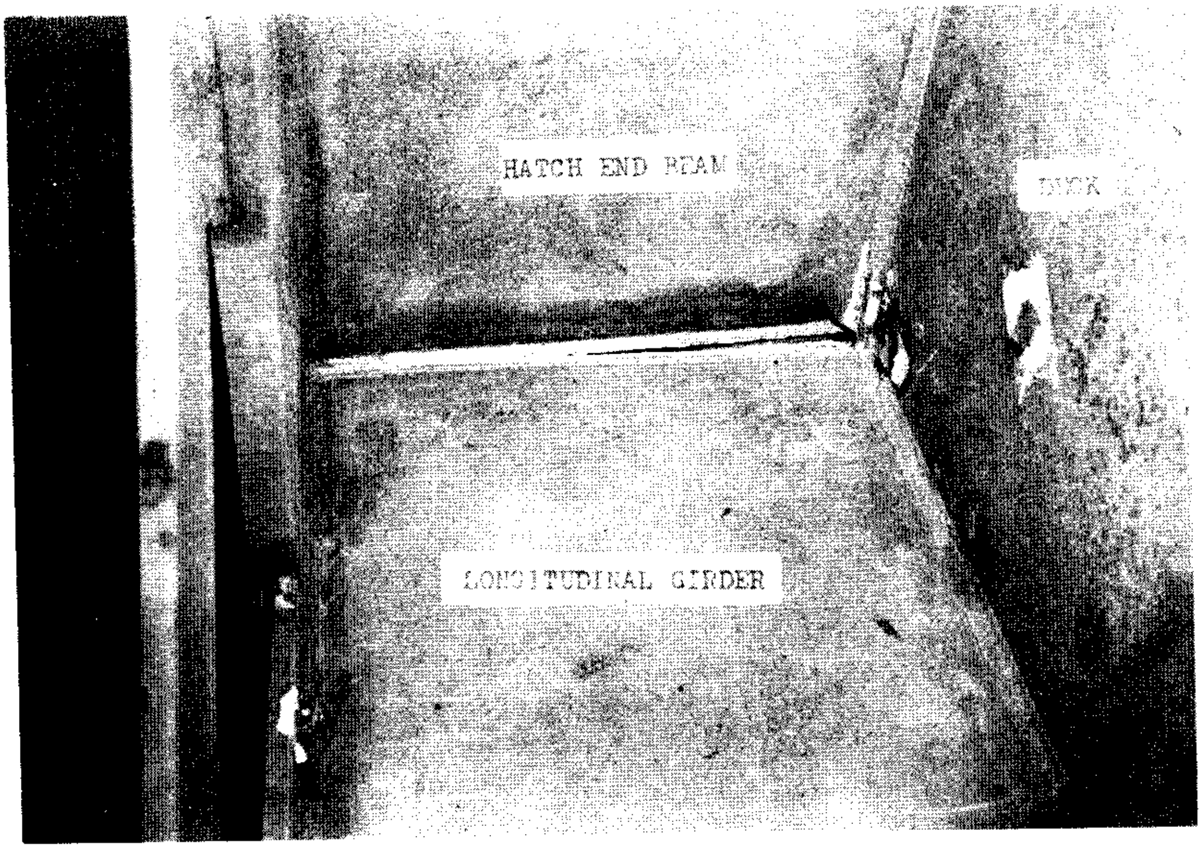


Fig. 39 Specimen 31: View from below deck, outboard and forward of hatch end beam

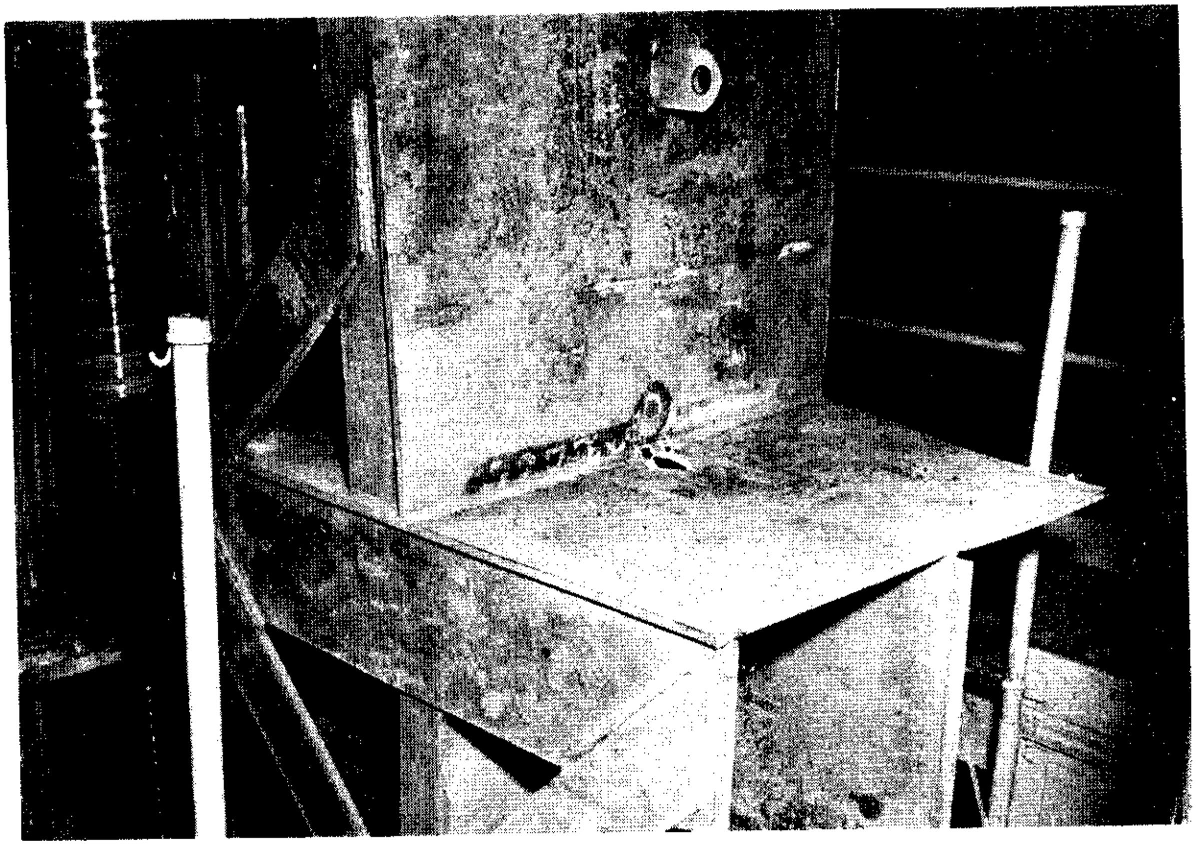


Fig. 40 Specimen 31: View from inside of hatch

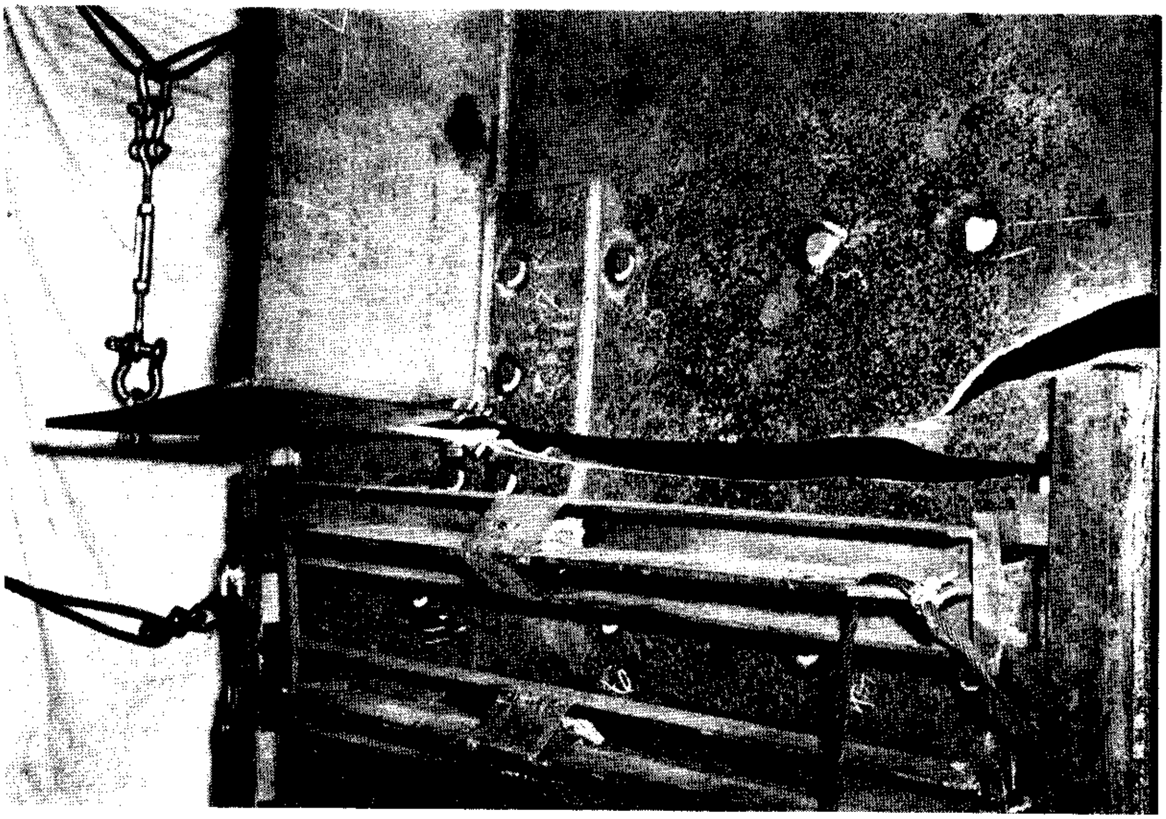


Fig. 41 Specimen 32: View of fracture from above

Fig. 42 Specimen 32: View from below deck, inboard and forward of hatch end beam

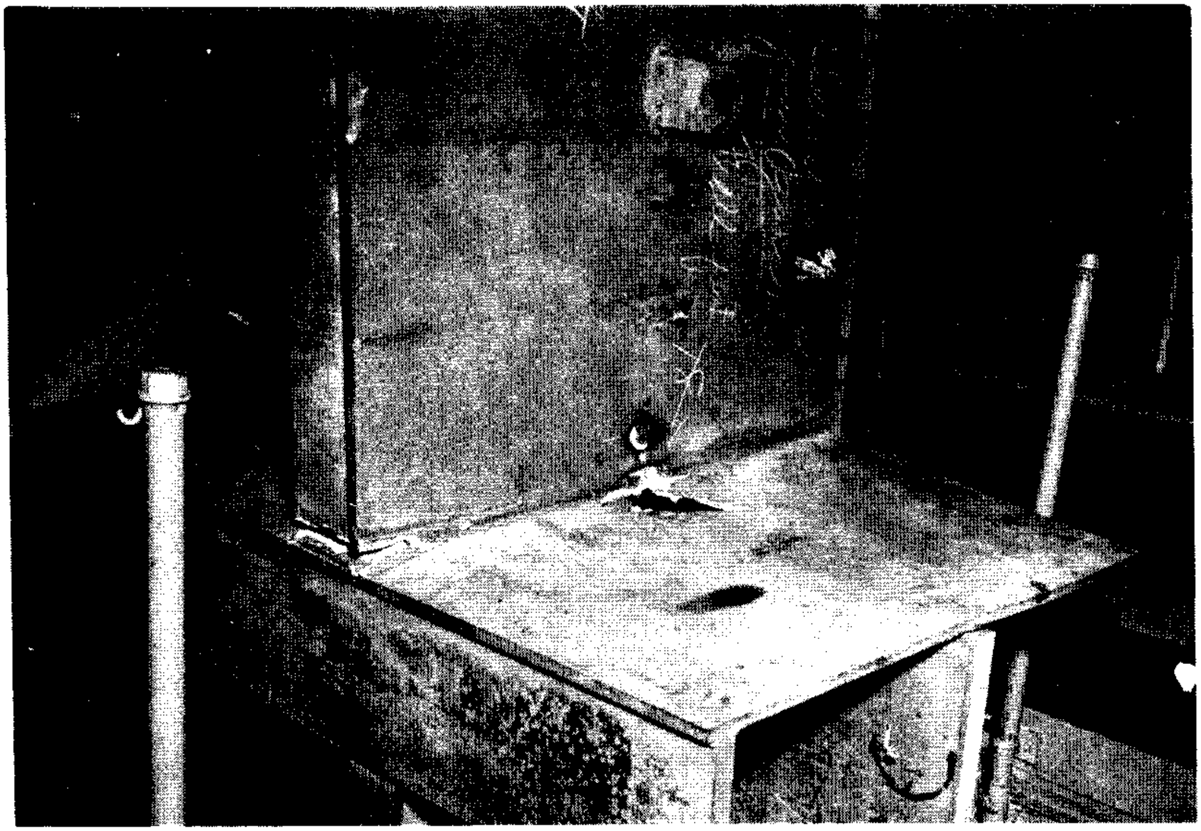


Fig. 43 Specimen 32: View from inside of hatch

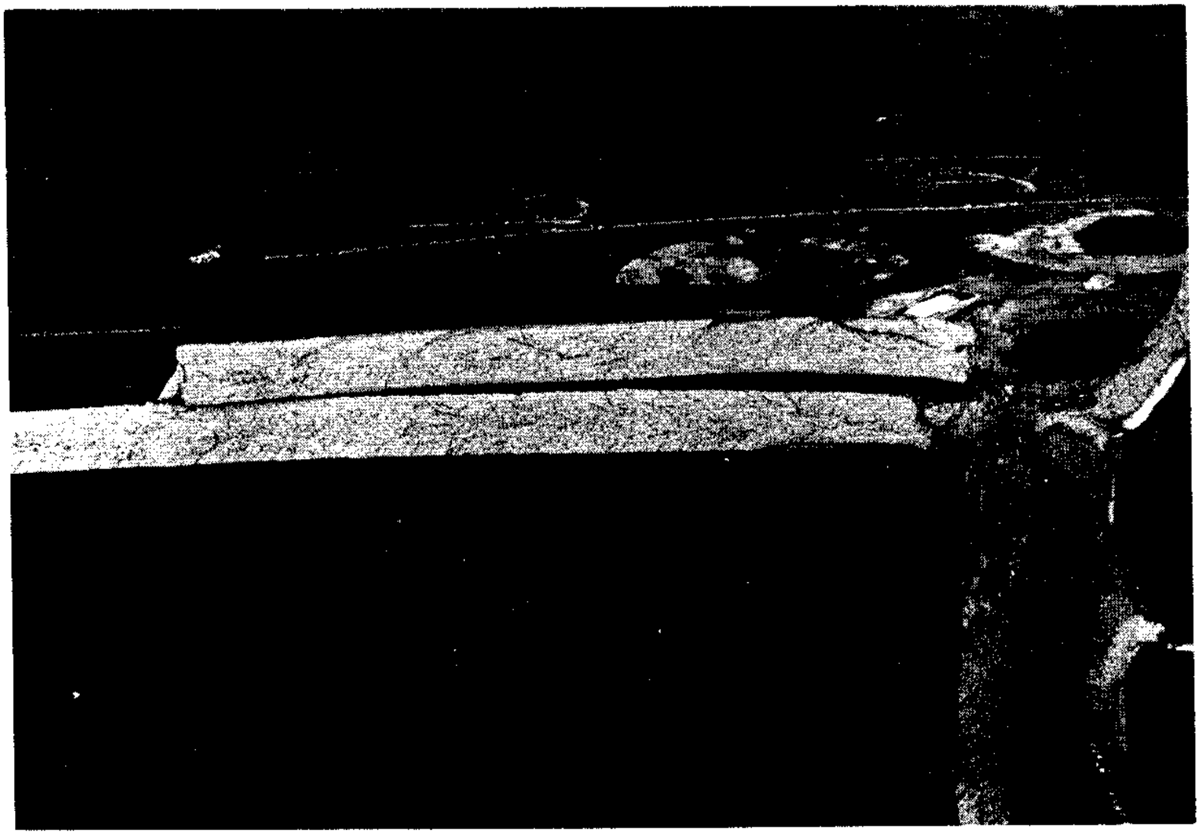


Fig. 44 Specimen 32: Fracture pattern in deck and doubler

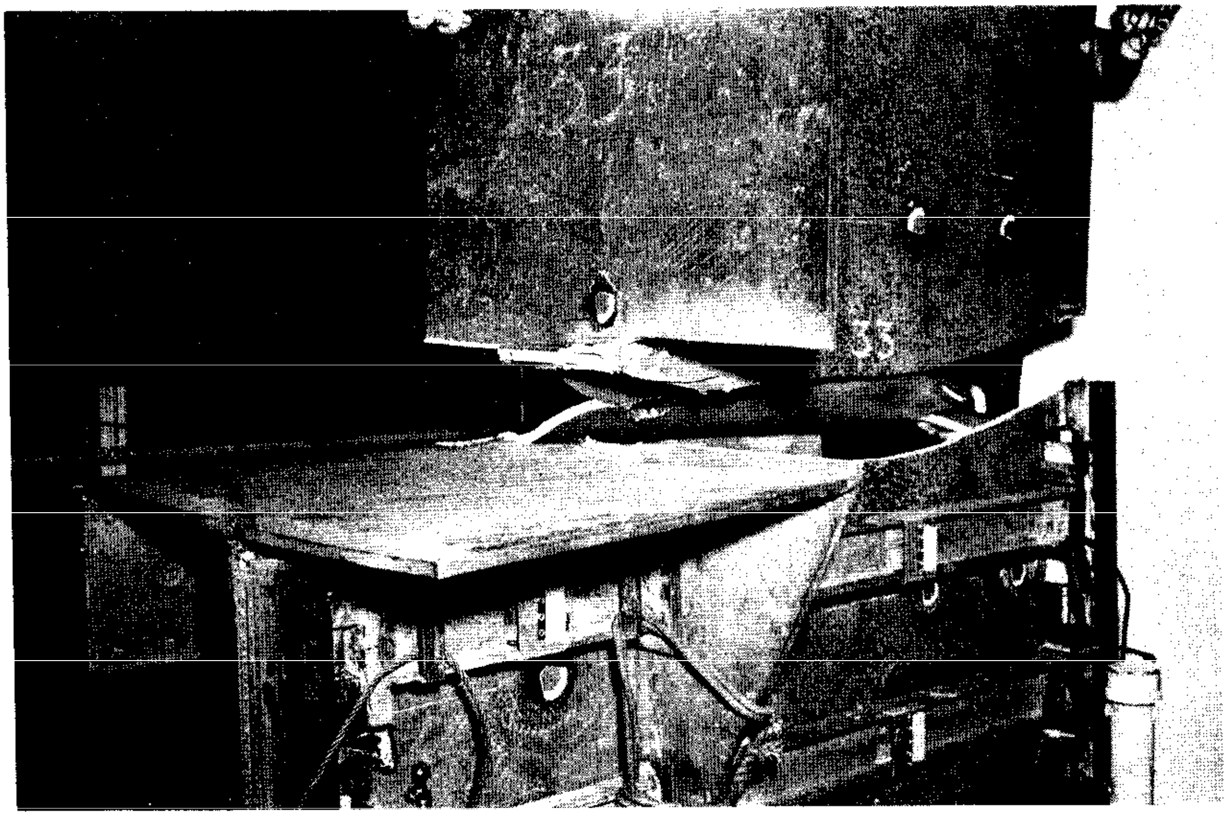


Fig. 45 Specimen 33: View of fractures from above deck and inboard

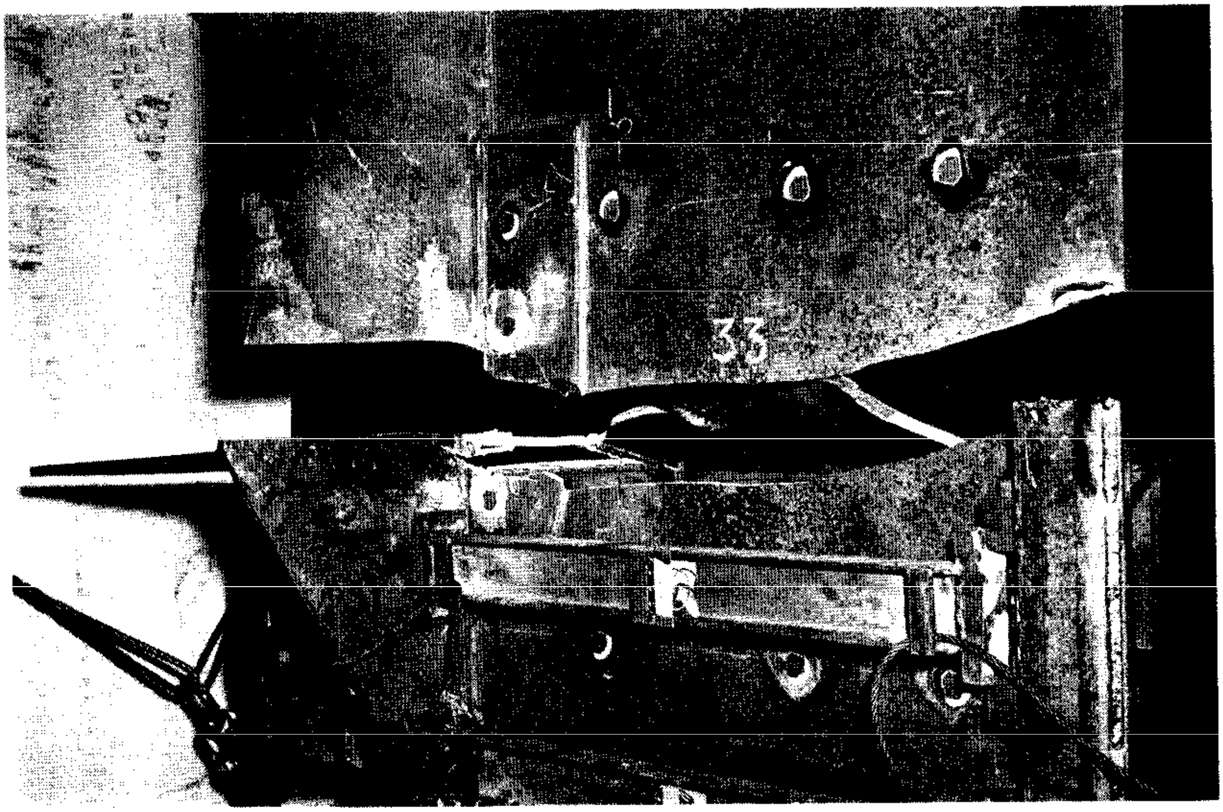


Fig. 46 Specimen 33: View of fractures from above deck and outboard

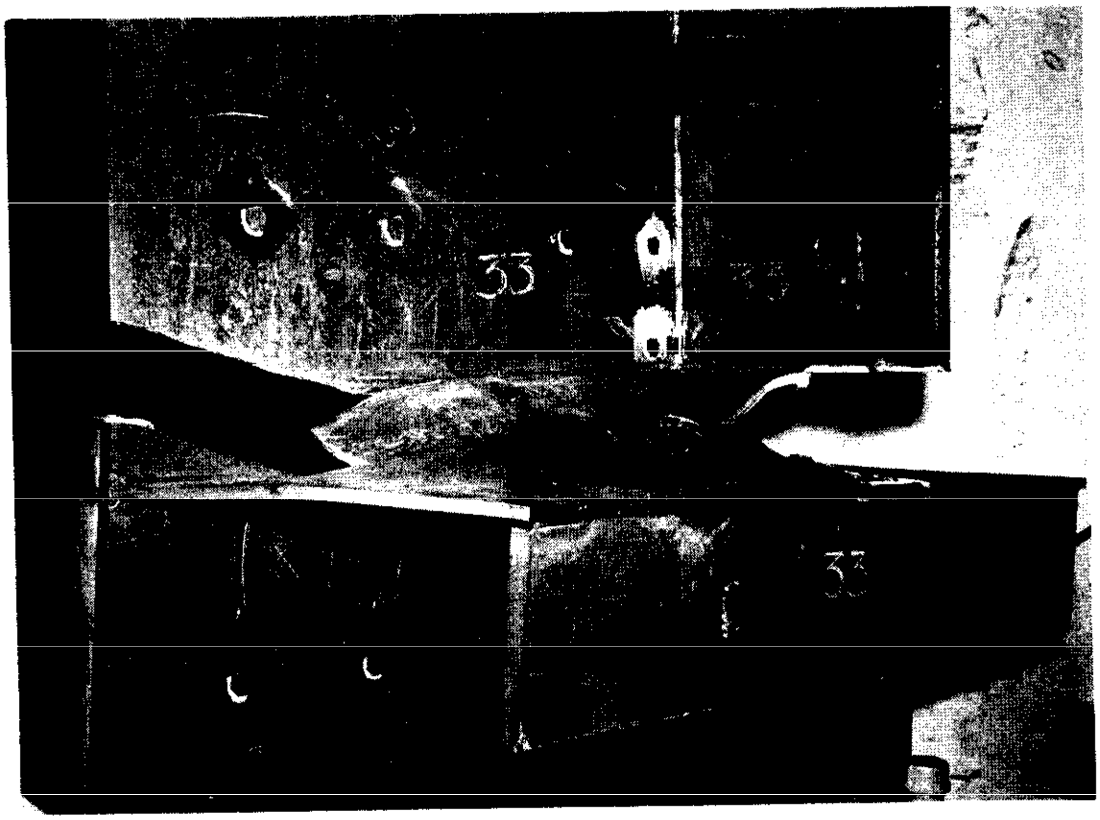


Fig. 47 Specimen 33: View of fractures from below deck and outboard

Fig. 48 Specimen 33: Fracture patterns in deck and doubler

Fig. 49 Specimen 34: Overall view from above deck

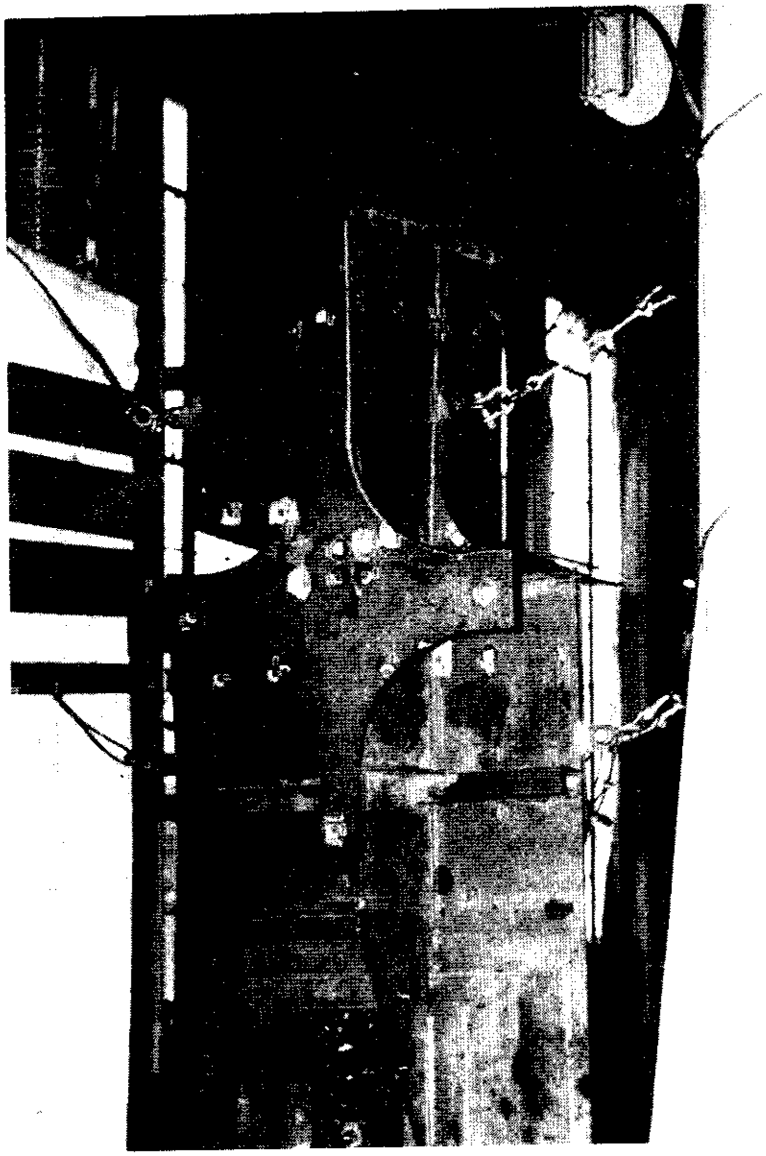


Fig. 50 Specimen 34: Overall view from below deck

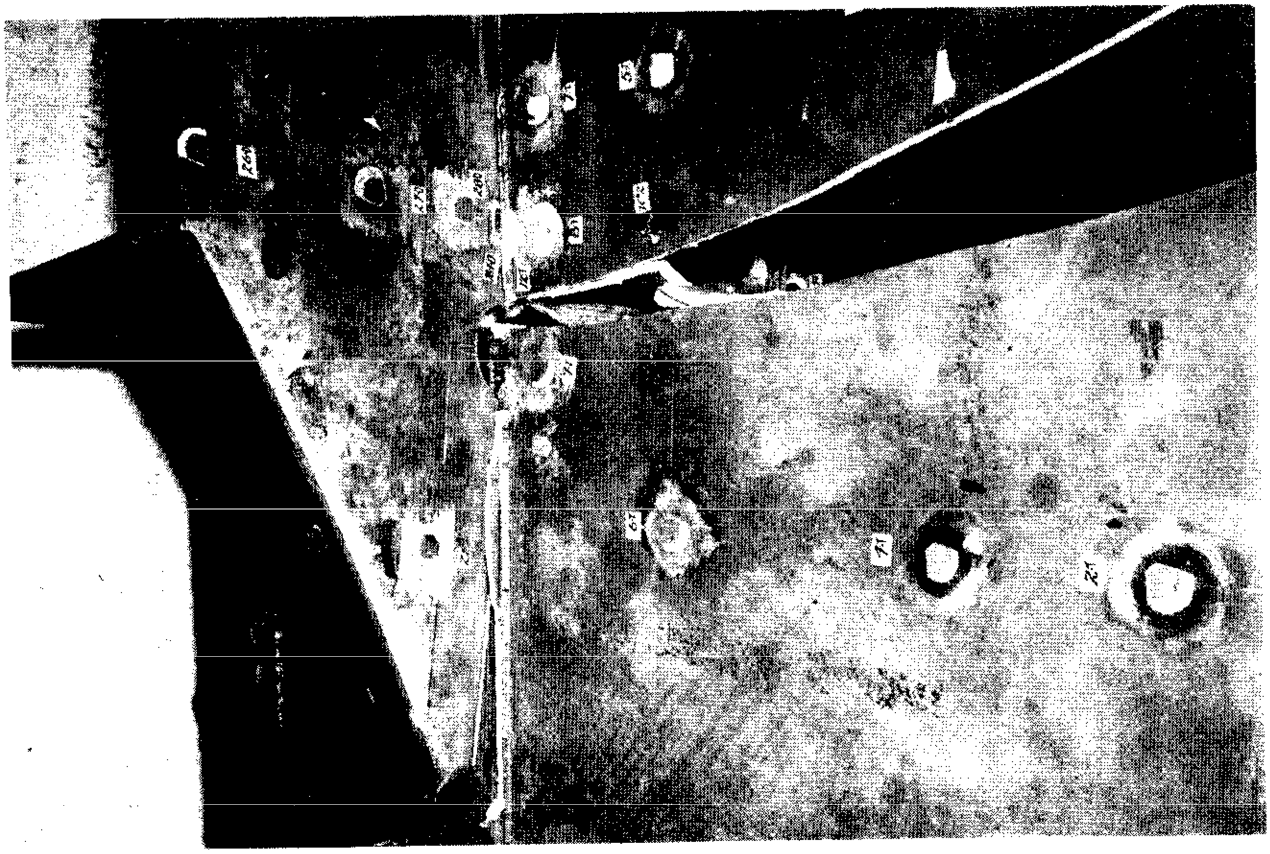


Fig. 51 Specimen 34: View of fractures from above deck

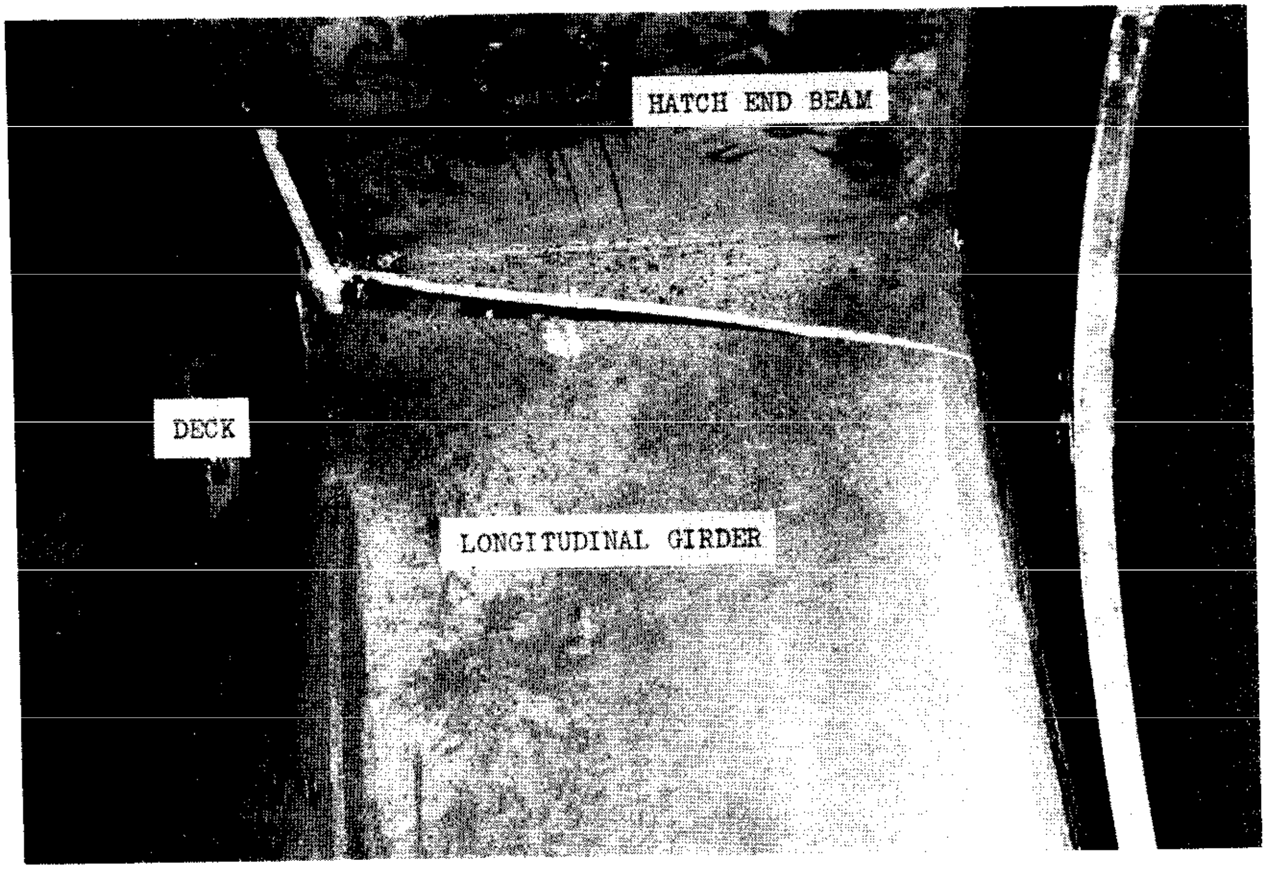


Fig. 52 Specimen 34: View from below deck, outboard and forward of hatch end beam

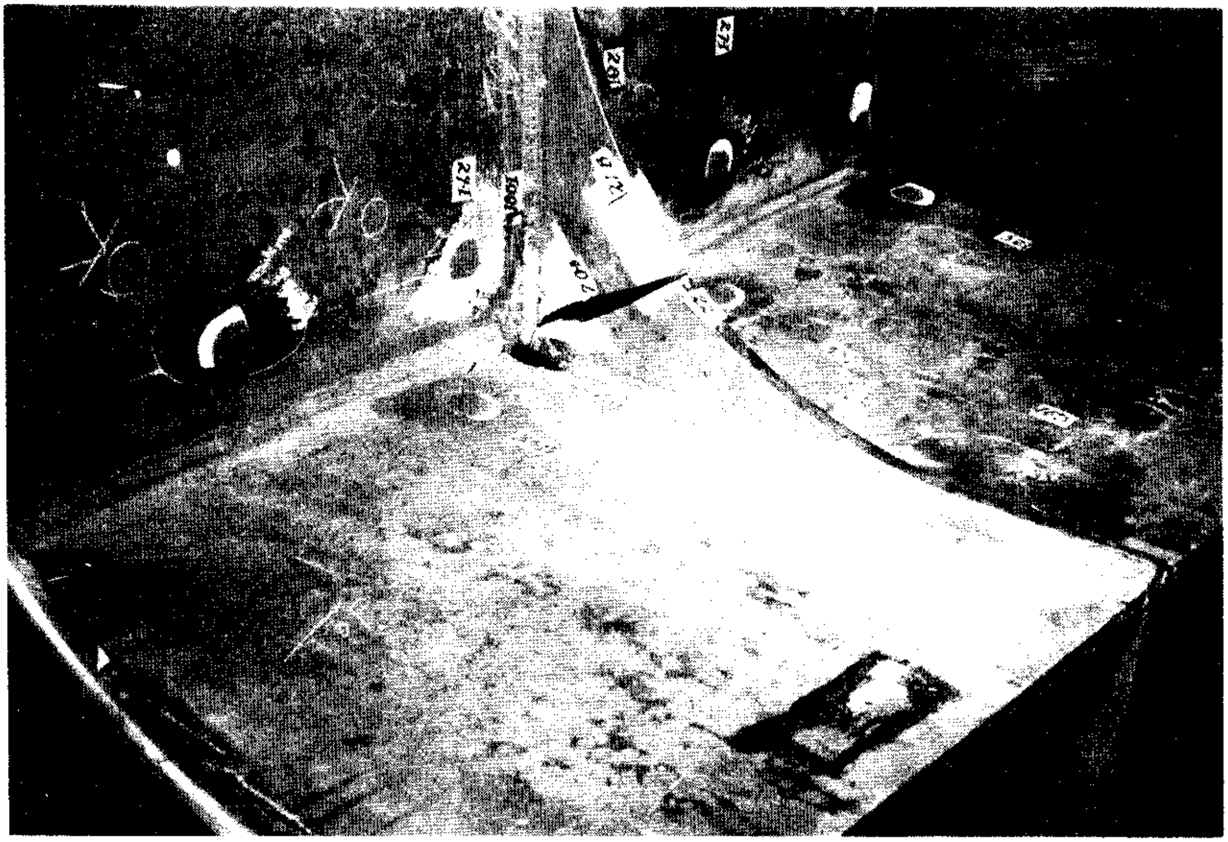


Fig. 53 Specimen 34: View from inside of hatch

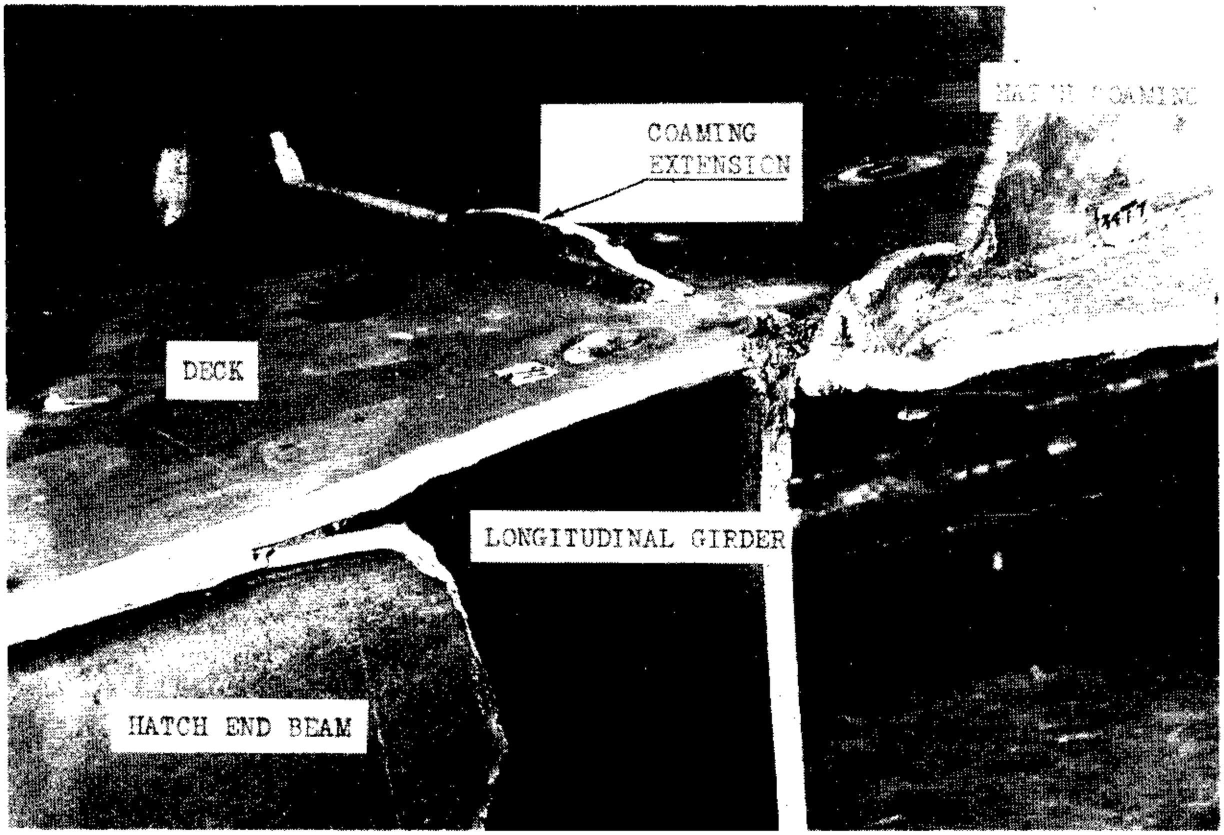


Fig. 54 Specimen 34: Fracture patterns, looking forward

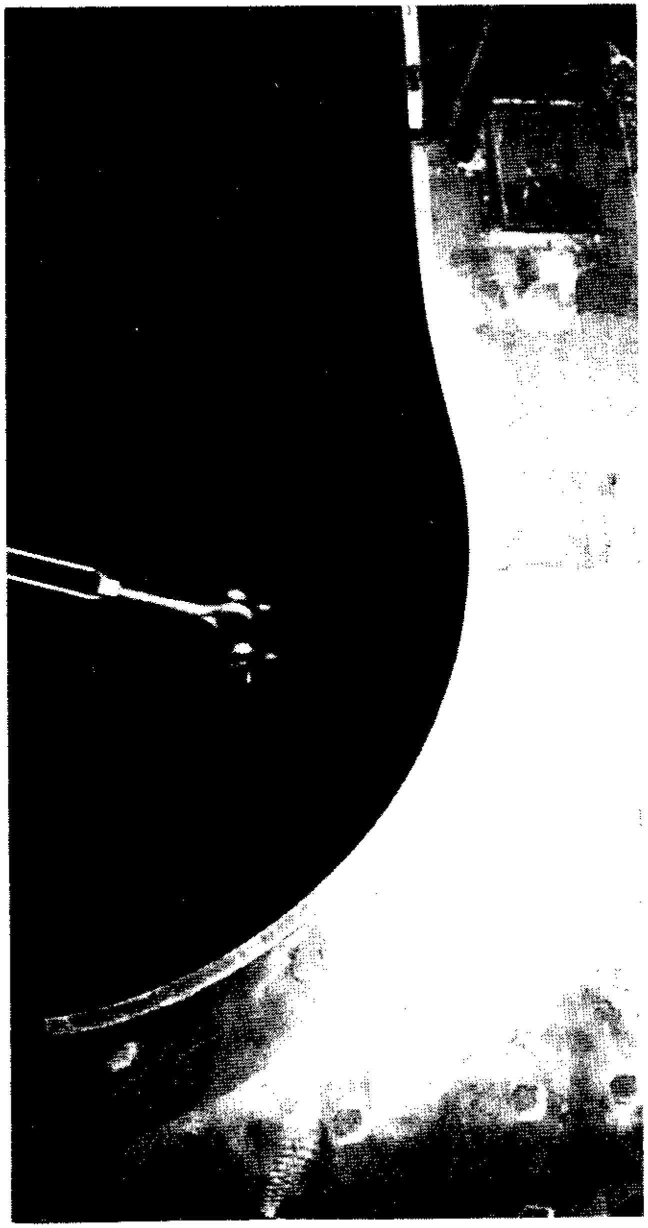


Fig. 55 Specimen 35: View showing distortion in coaming at end of first test

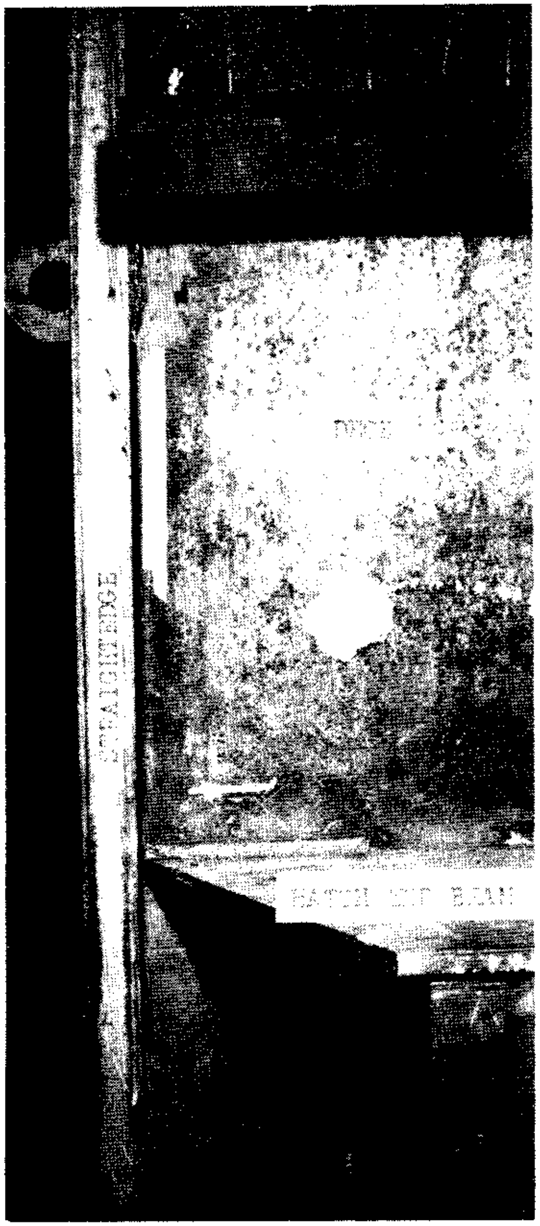


Fig. 56 Specimen 35: View showing necking in deck plate at end of first test (3,000,000 lb. load)

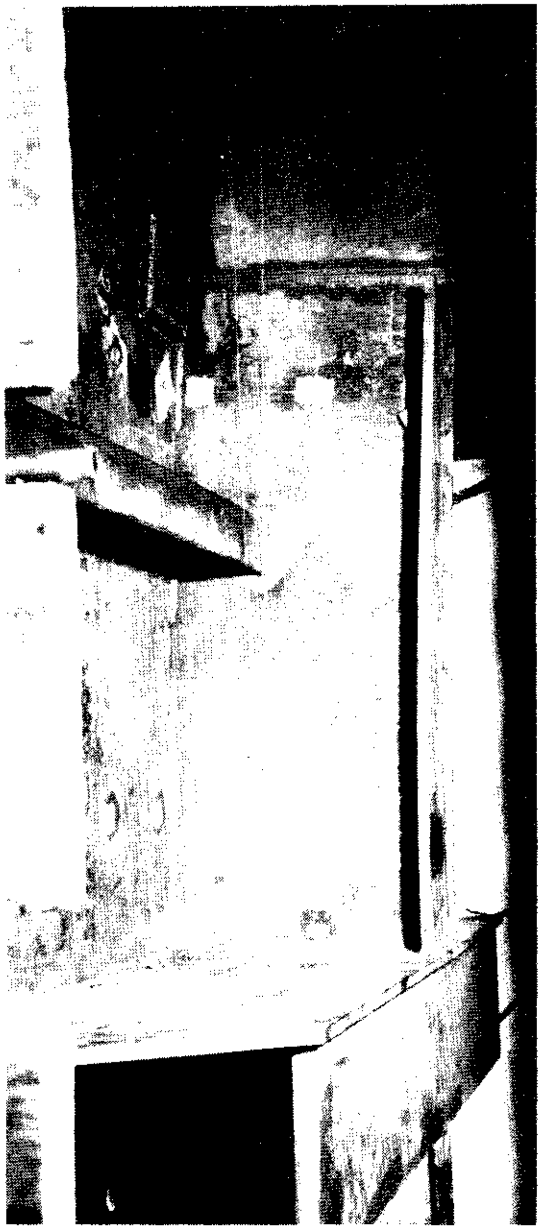


Fig. 57 Specimen 35: View showing distortion in longitudinal at end of first test

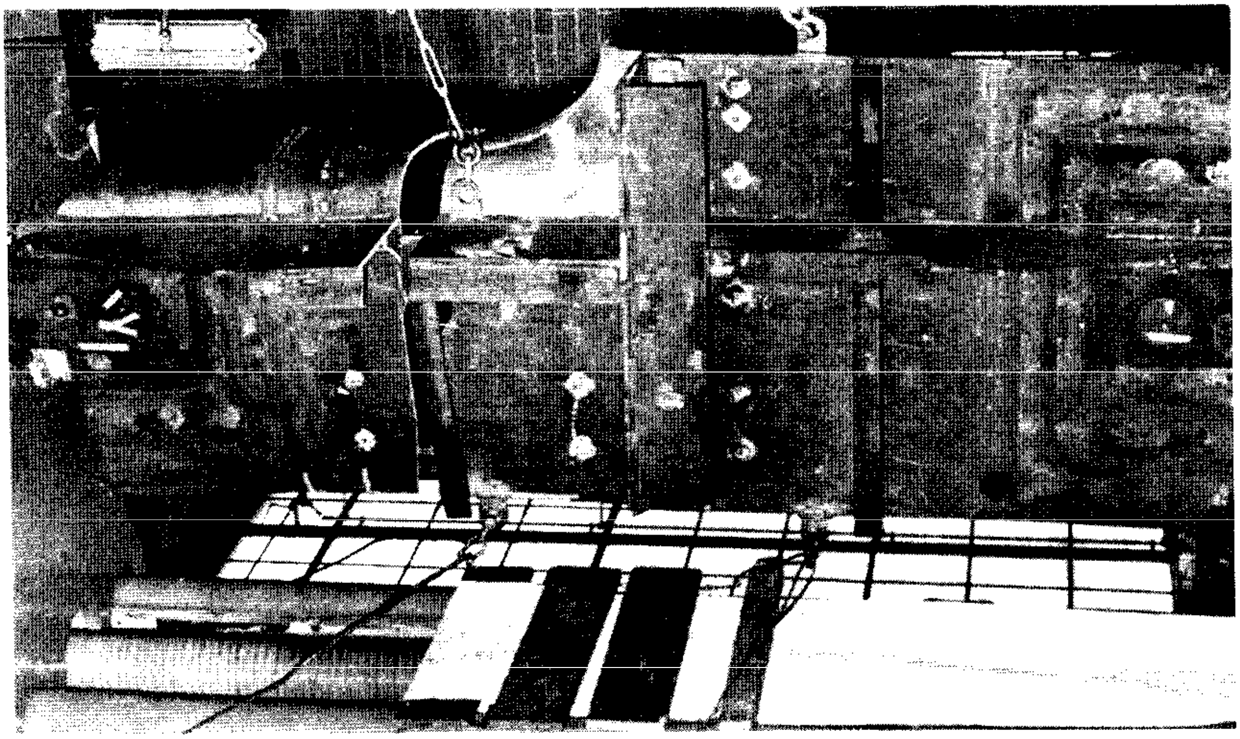


Fig. 59 Specimen 35: Overall view from below deck after failure

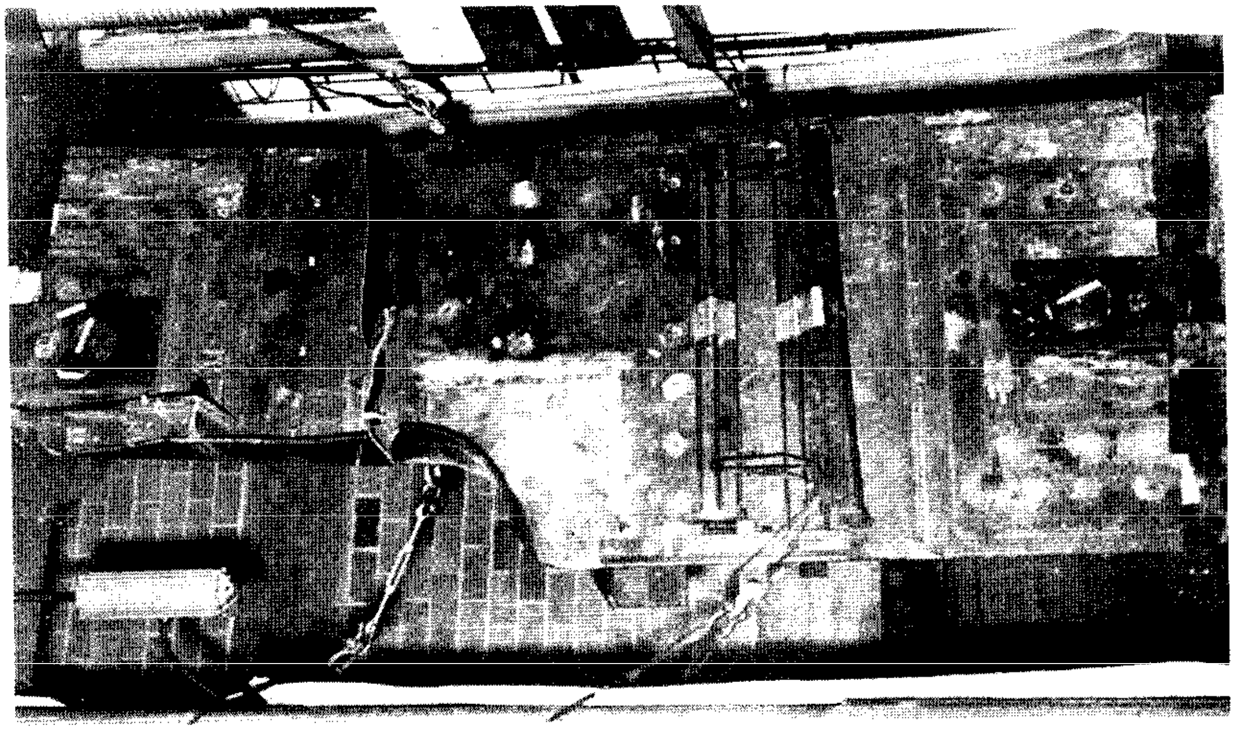


Fig. 58 Specimen 35: Overall view from above deck after failure

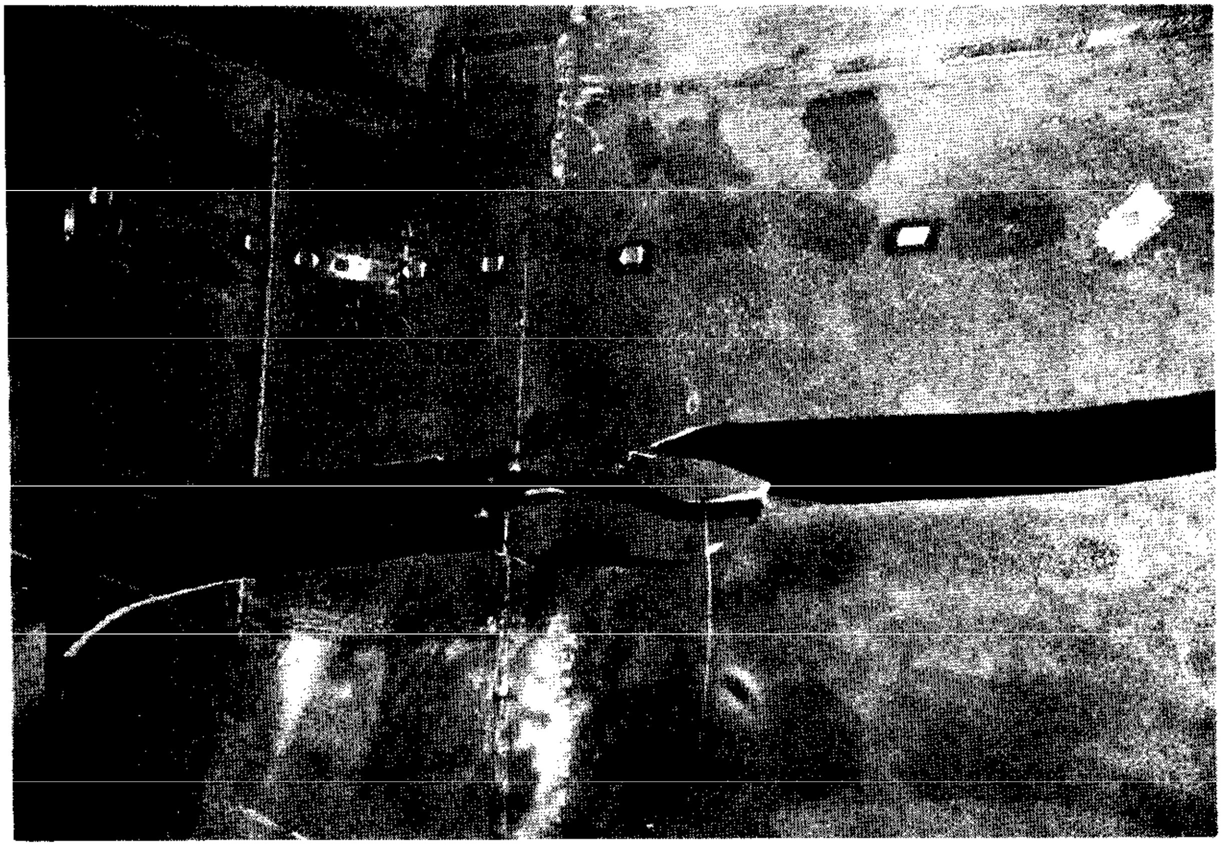


Fig. 60 Specimen 35: View of fractures from above deck

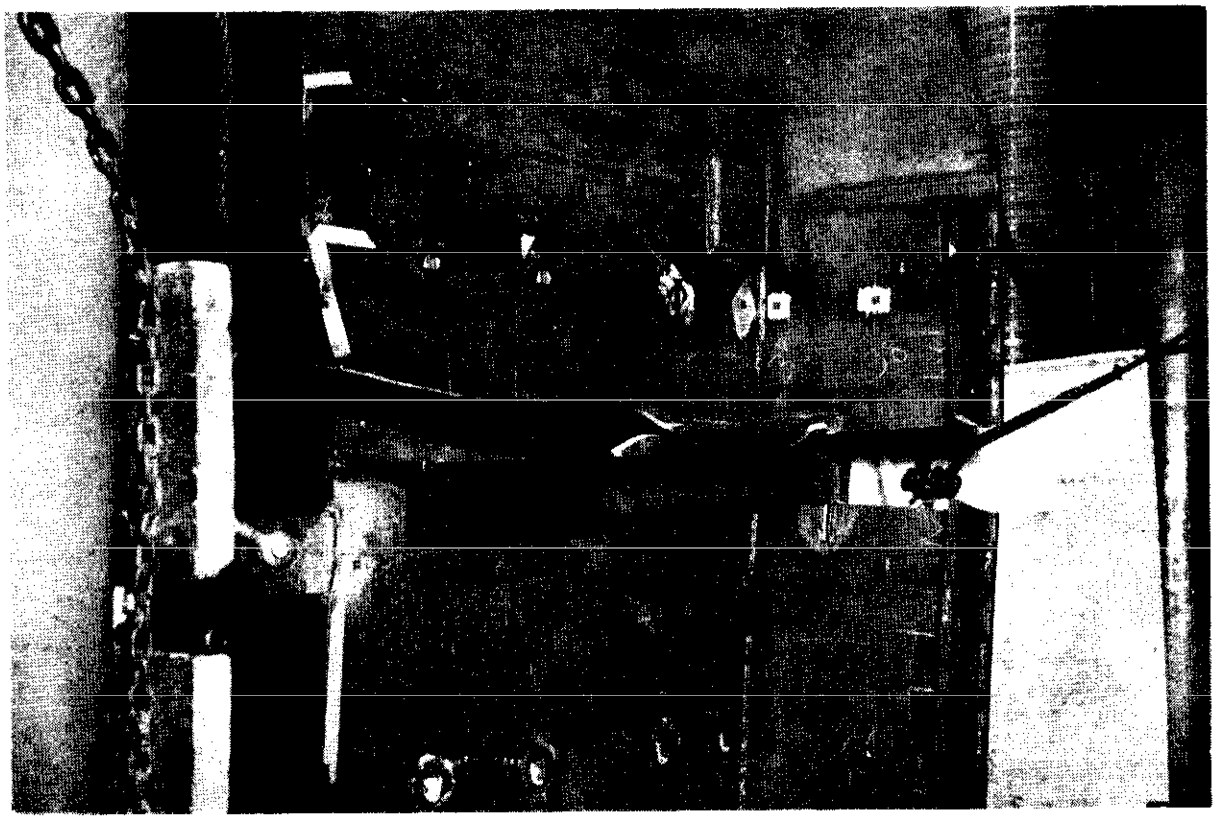


Fig. 61 Specimen 35: View of fractures from below deck

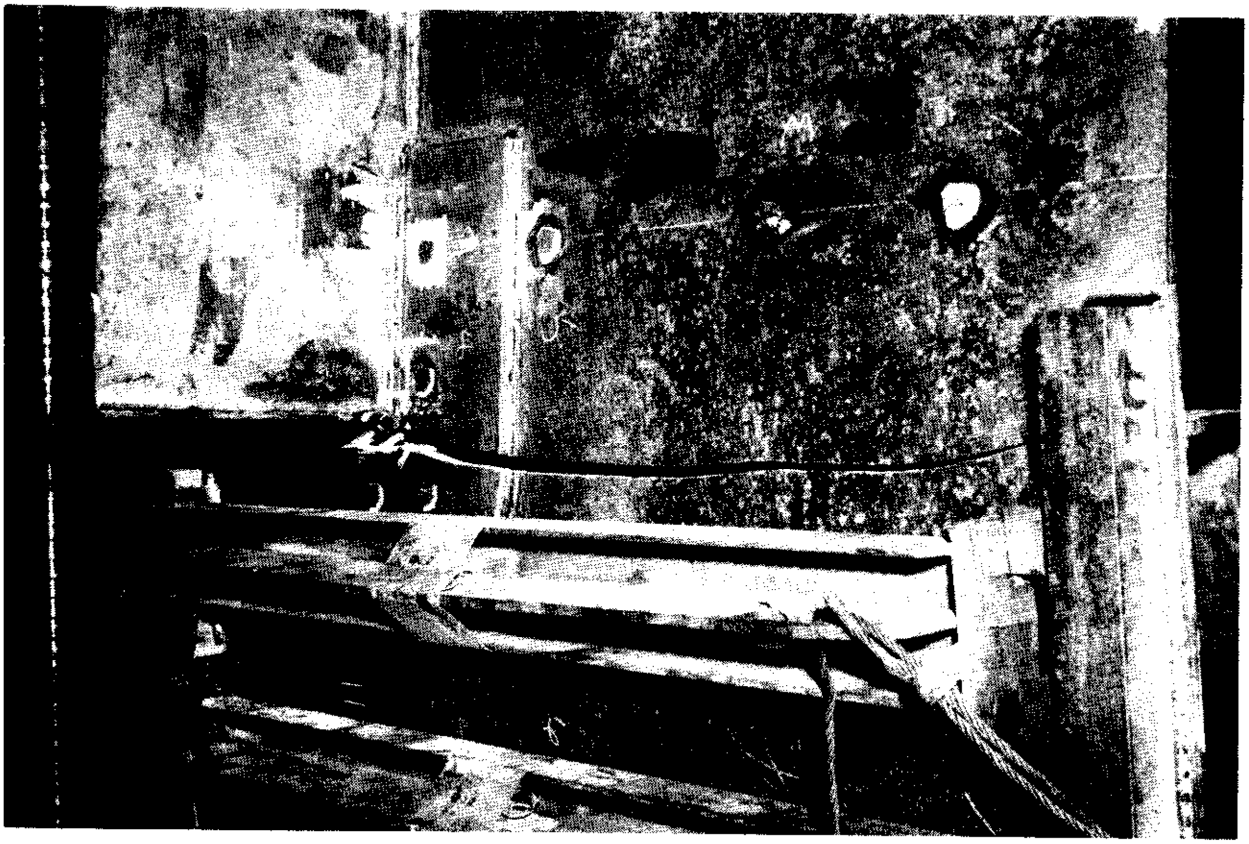


Fig. 62 Specimen 38: View of fractures from above deck

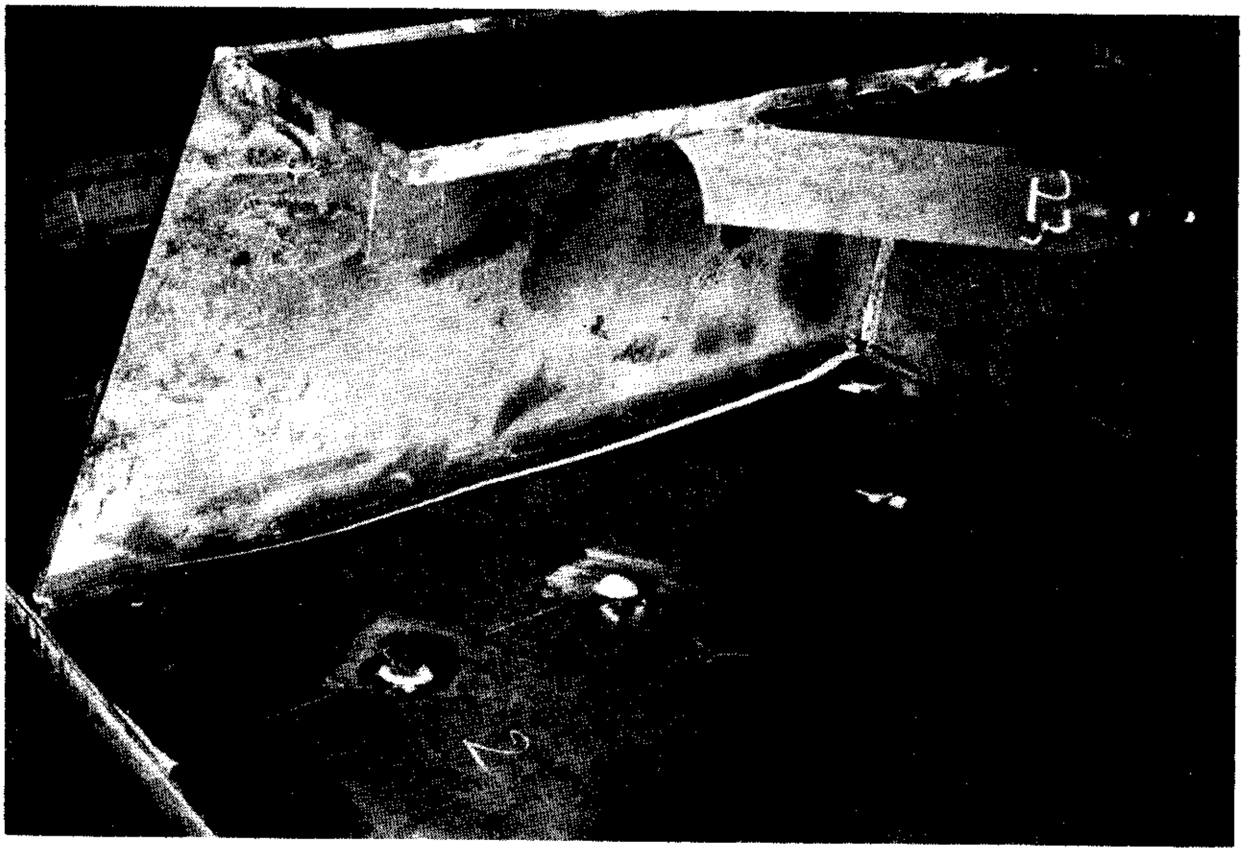


Fig. 63 Specimen 38: View of fracture from below deck, outboard and forward of hatch end beam

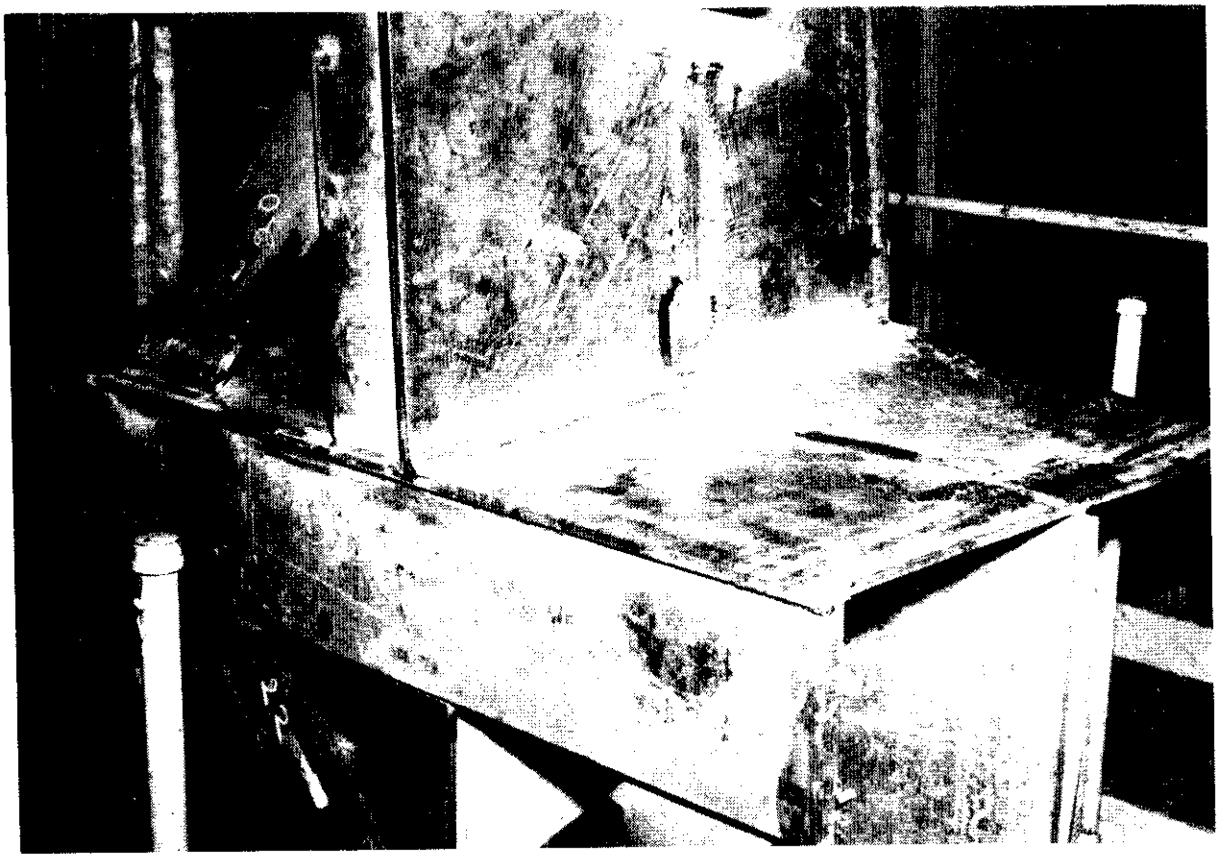


Fig. 64 Specimen 38: View from inside of hatch

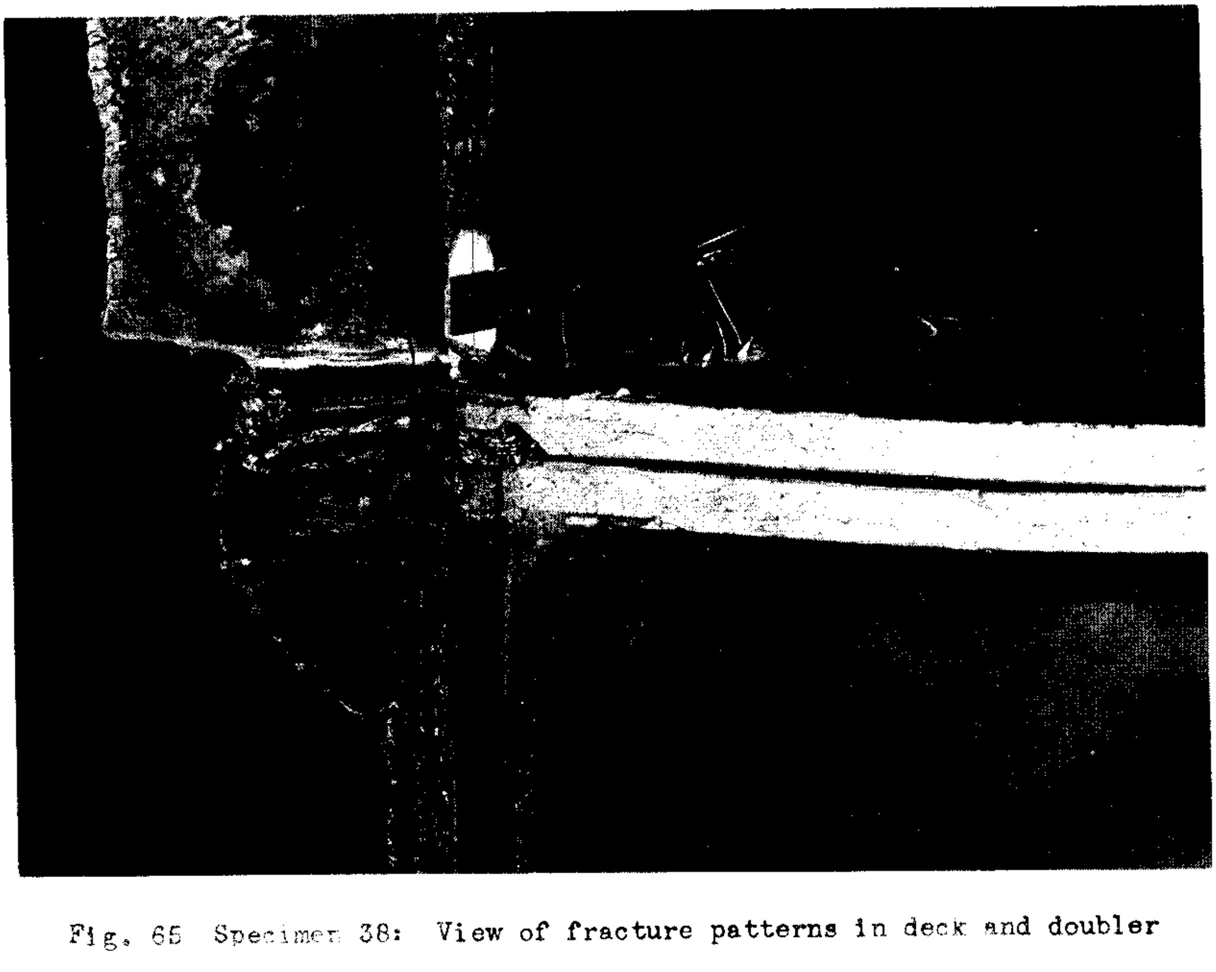


Fig. 65 Specimen 38: View of fracture patterns in deck and doubler

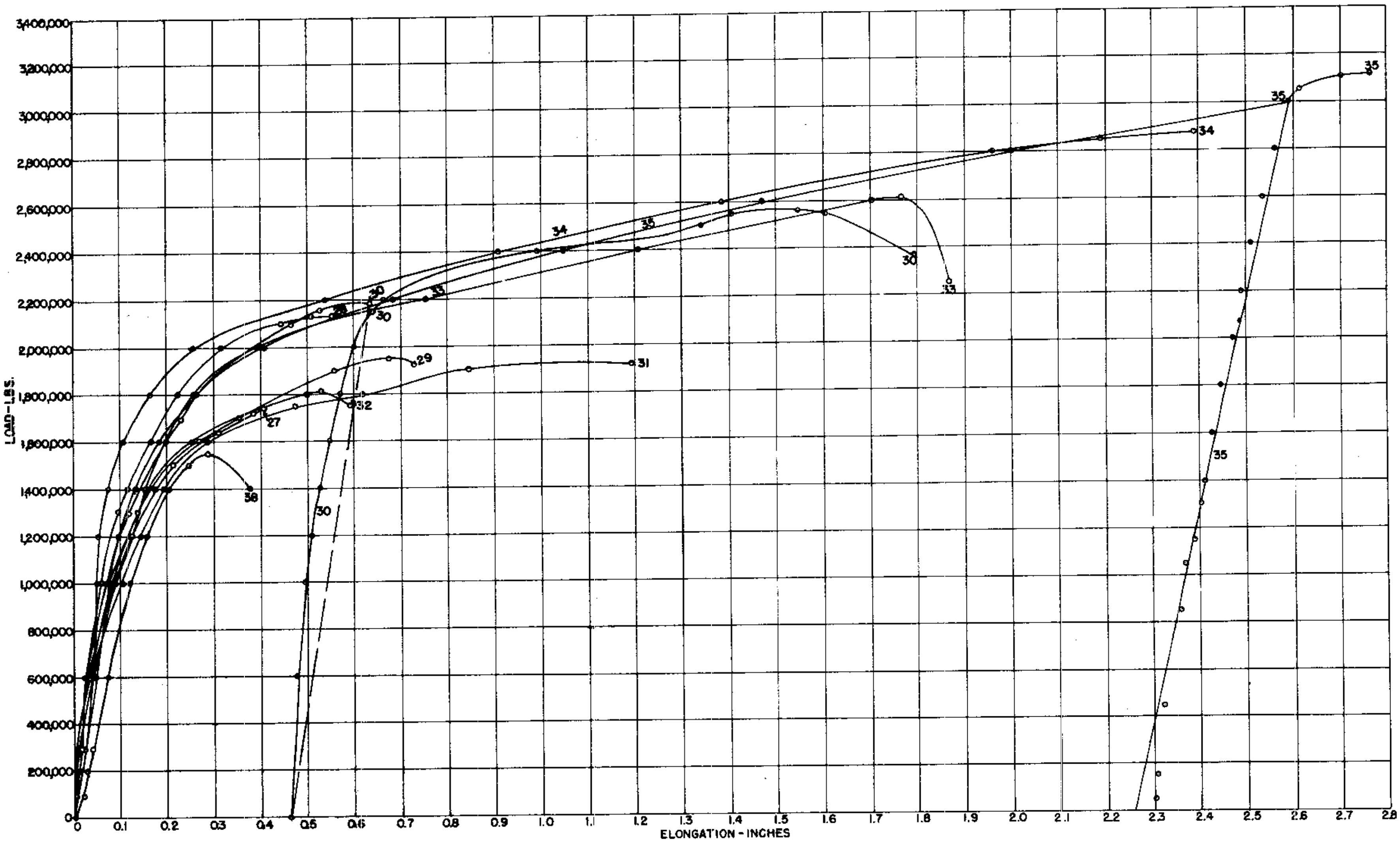
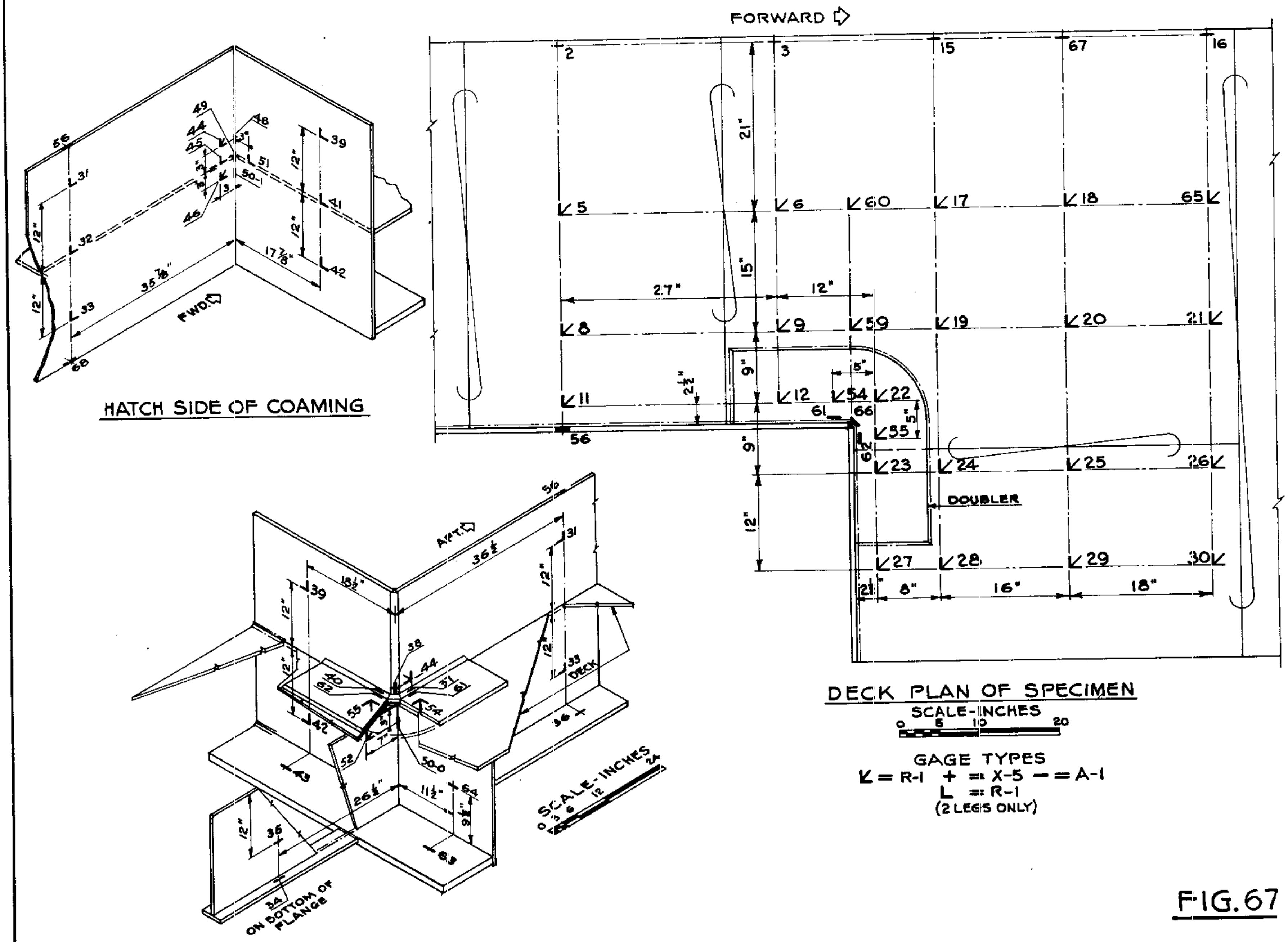


FIG 66

UNIVERSITY OF CALIFORNIA WELDING RESEARCH	LOAD-STRAIN CURVES FOR ENERGY DETERMINATION	SCALE		APPROVED
		DR. BY	/ /	DWG
		TR. BY	/ /	PANEL



HATCH SIDE OF COAMING

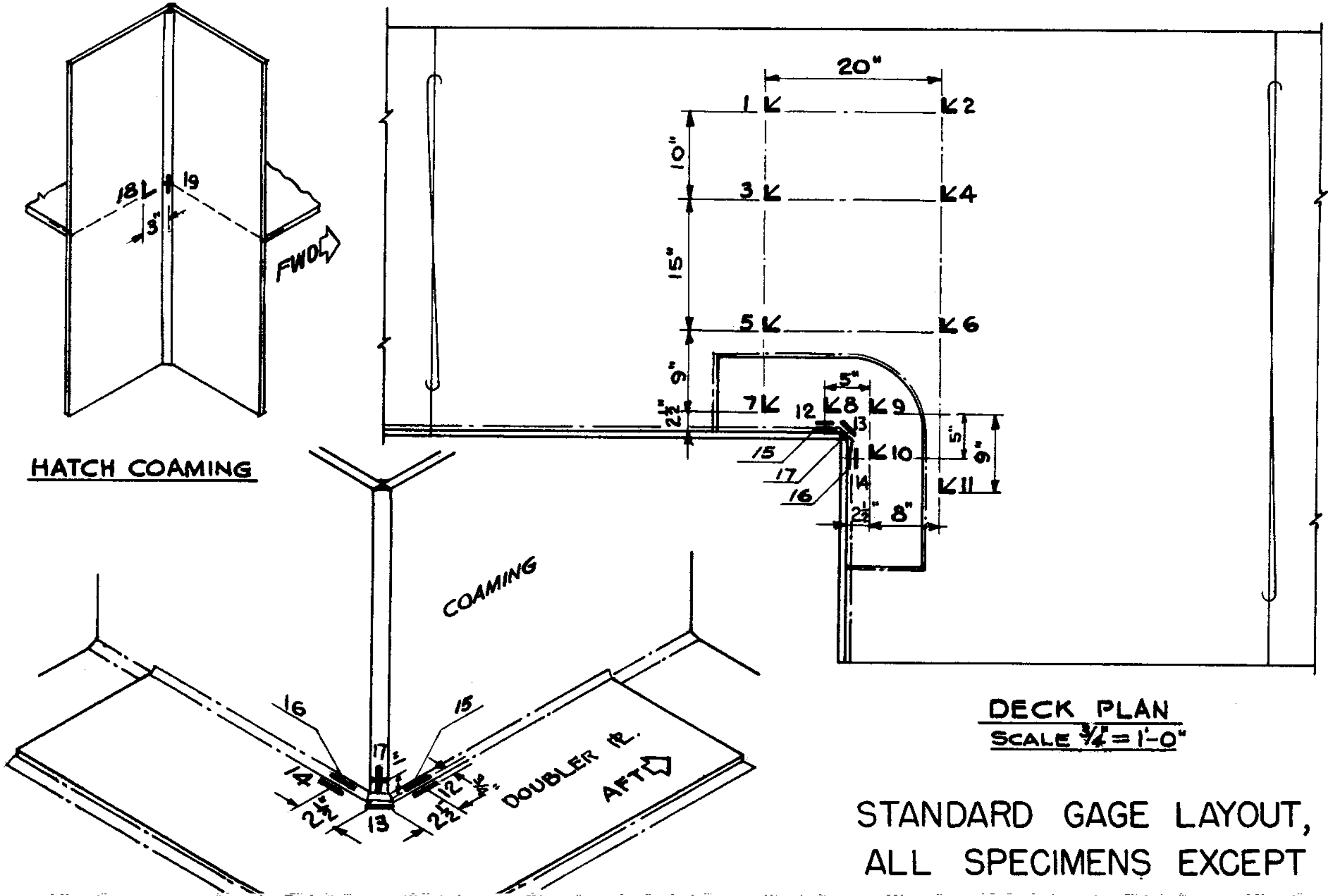
DECK PLAN OF SPECIMEN

SCALE-INCHES
0 5 10 20

GAGE TYPES
Ⲕ = R-1 + = X-5 — = A-1
L = R-1
(2 LEGS ONLY)

FIG. 67

UNIVERSITY OF CALIFORNIA WELDING RESEARCH	GAGE LAYOUT FOR FULL SCALE HATCH CORNER SPECIMEN	SCALE	AS SHOWN	APPROVED	R.C.G.
		DR. BY	R. SISSON	2/15/45	DWG R119
		TR. BY	R.C.S	3/25/45	PANEL L20



HATCH COAMING

DECK PLAN
SCALE 3/4" = 1'-0"

STANDARD GAGE LAYOUT,
ALL SPECIMENS EXCEPT

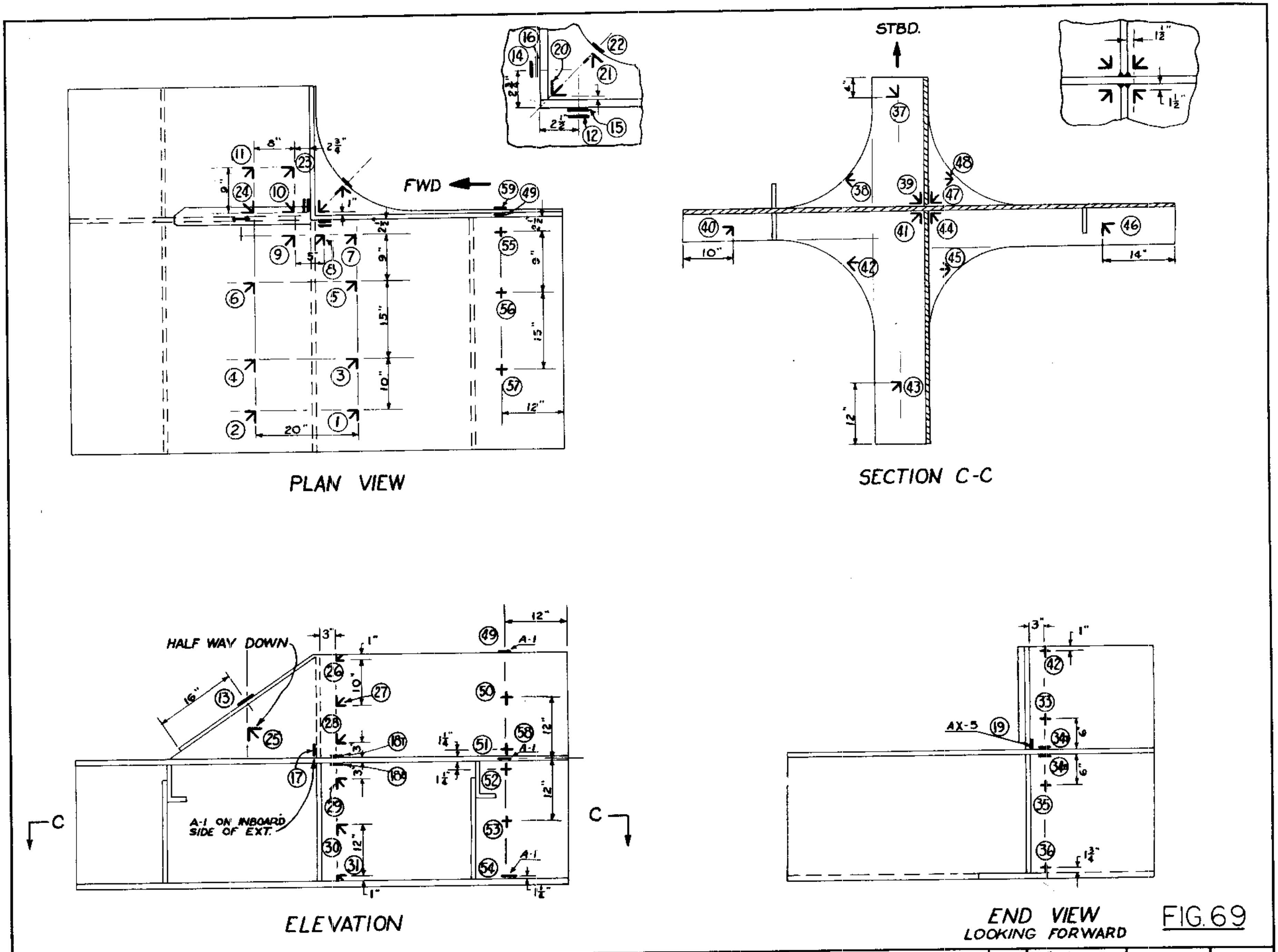
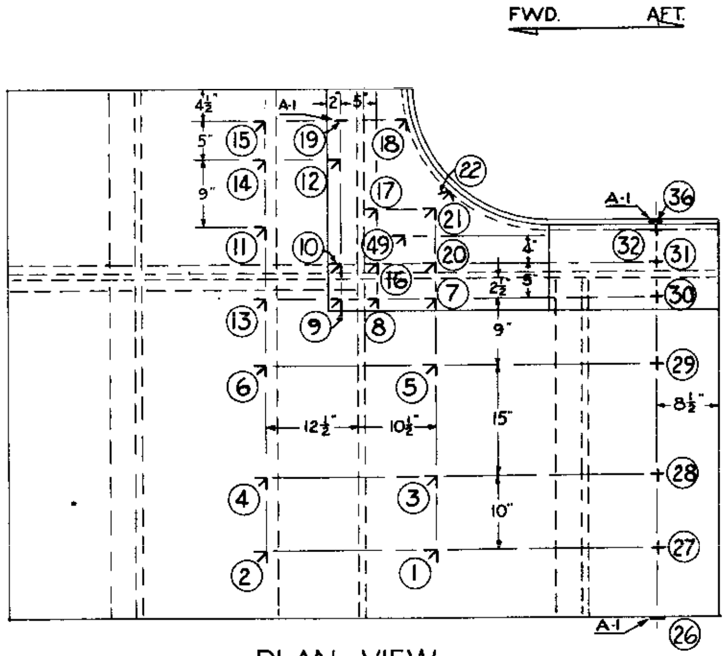
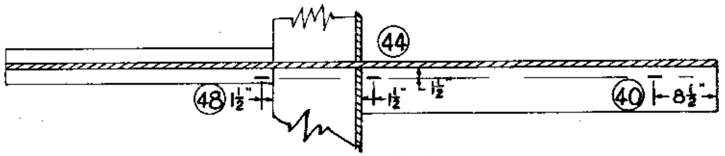


FIG. 69

UNIVERSITY OF CALIFORNIA WELDING RESEARCH-	GAGE LAYOUT FOR HATCH CORNER SPECIMEN 34 (MODIFIED ABS DESIGN)	SCALE	1"=1'-0"	APPROVED	
		DR. BY	J.J.B. + M.J.G.	5/20/47	DWG L-72
		TR. BY	REVISED	6/6/47	

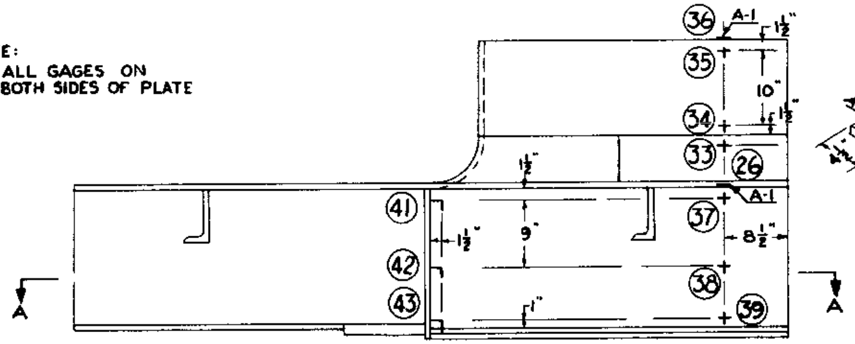


PLAN VIEW

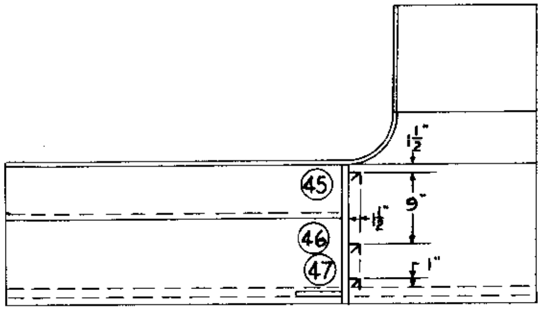


SECTION "A"-"A"

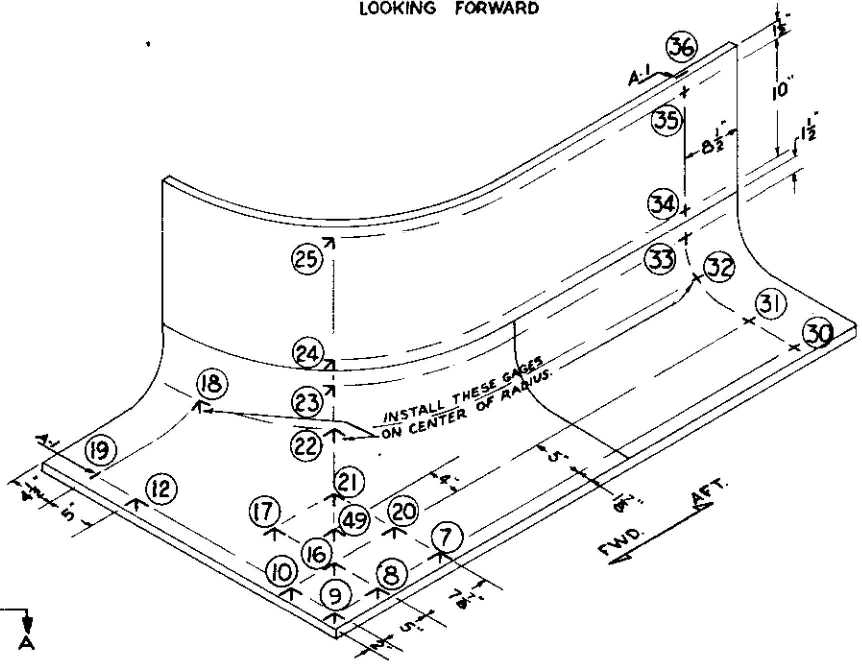
NOTE:
ALL GAGES ON
BOTH SIDES OF PLATE



ELEVATION



END VIEW
LOOKING FORWARD



SECTION VIEW OF CORNER

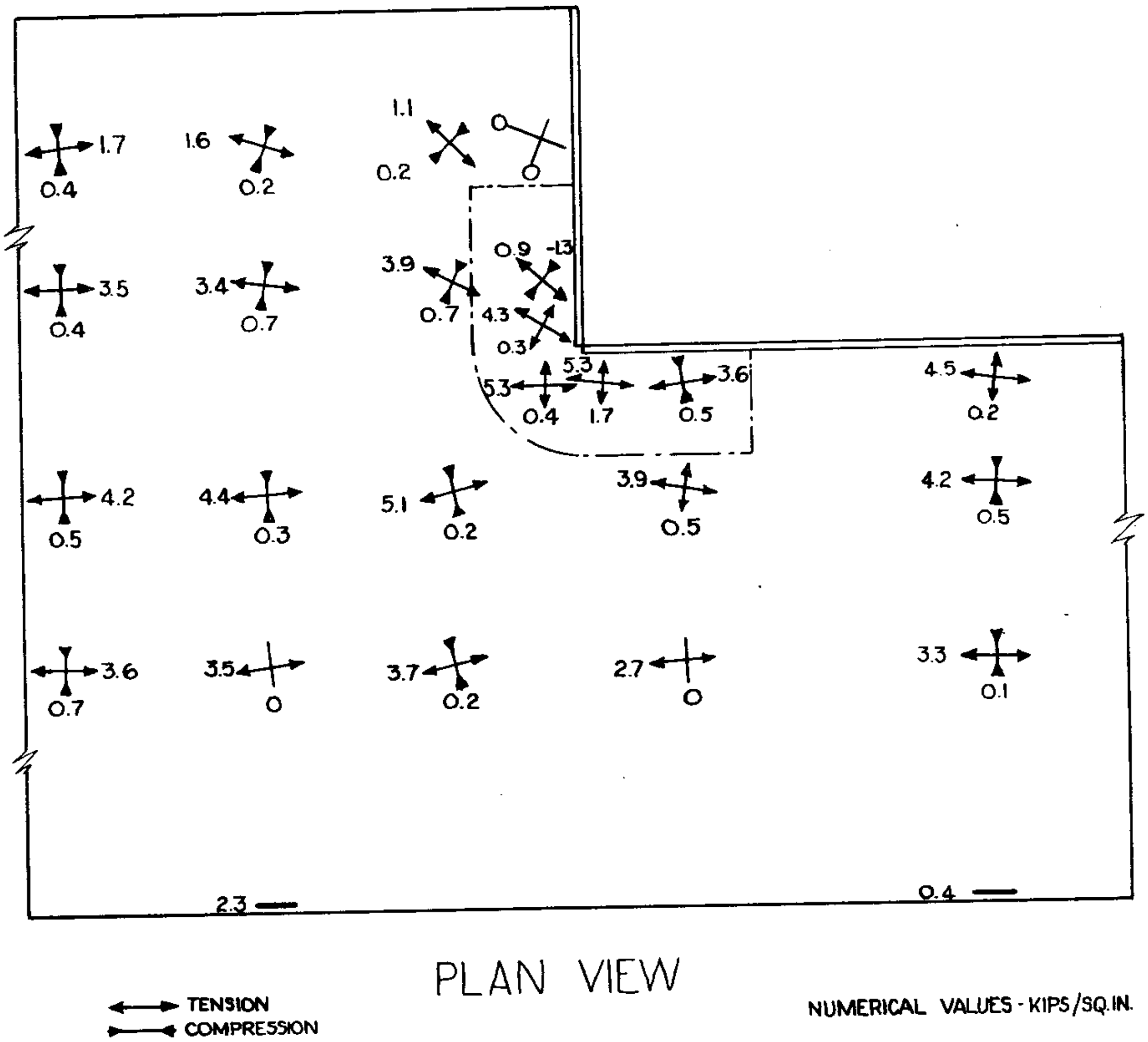
GAGE TYPES
↗=AR-1 +=AX-5 —=A-1

FIG 70

UNIVERSITY OF CALIFORNIA
WELDING RESEARCH

GAGE LAYOUT FOR HATCH CORNER SPEC 35

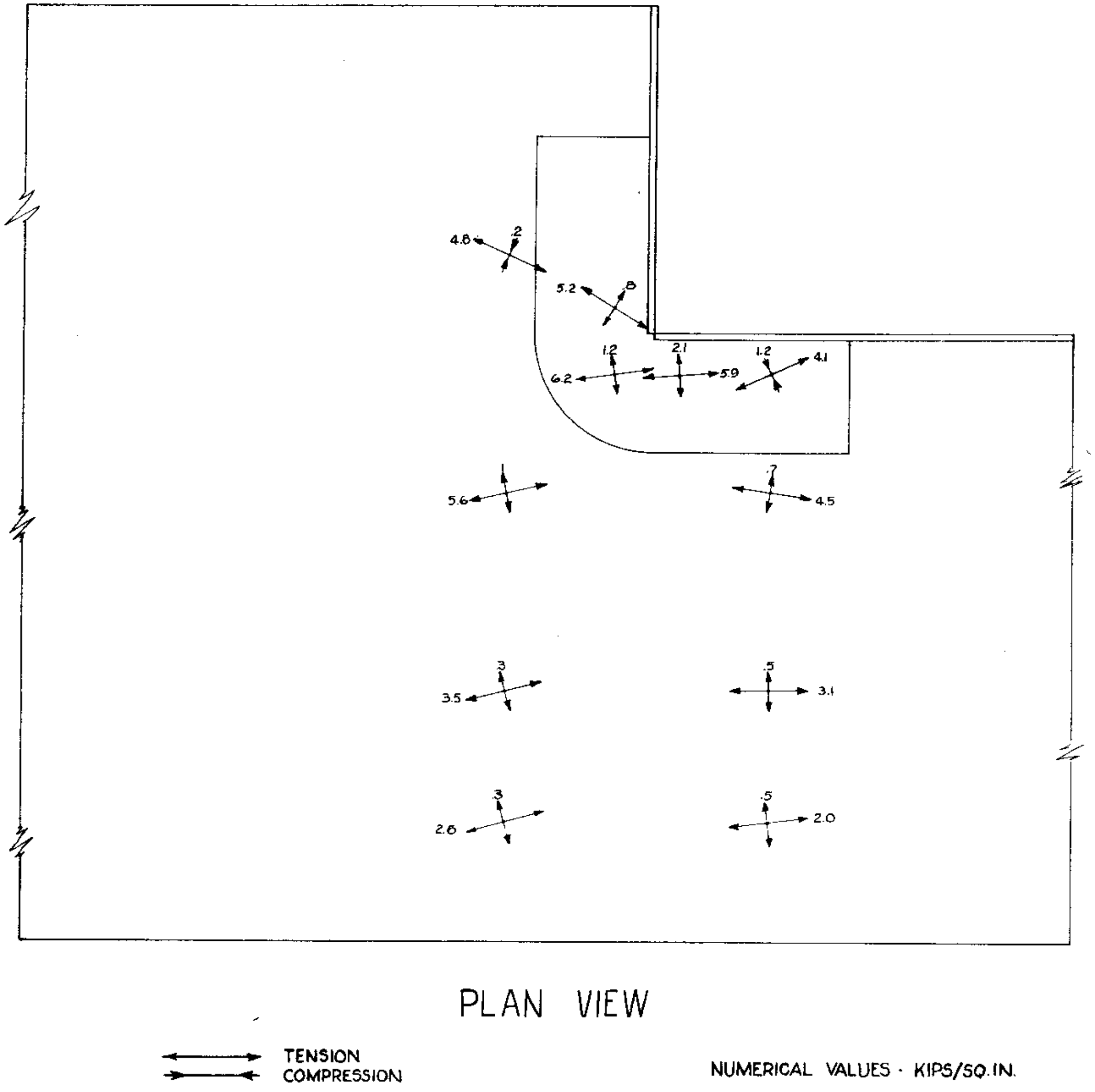
SCALE	1"=1'-0" 1½"=1'-0"	APPROVED	GB
DR. BY	J.J.B.	6 / 12 / 47	DWG L-75
TR. BY	G.P.	9 / 4 / 47	PANEL



PLAN VIEW

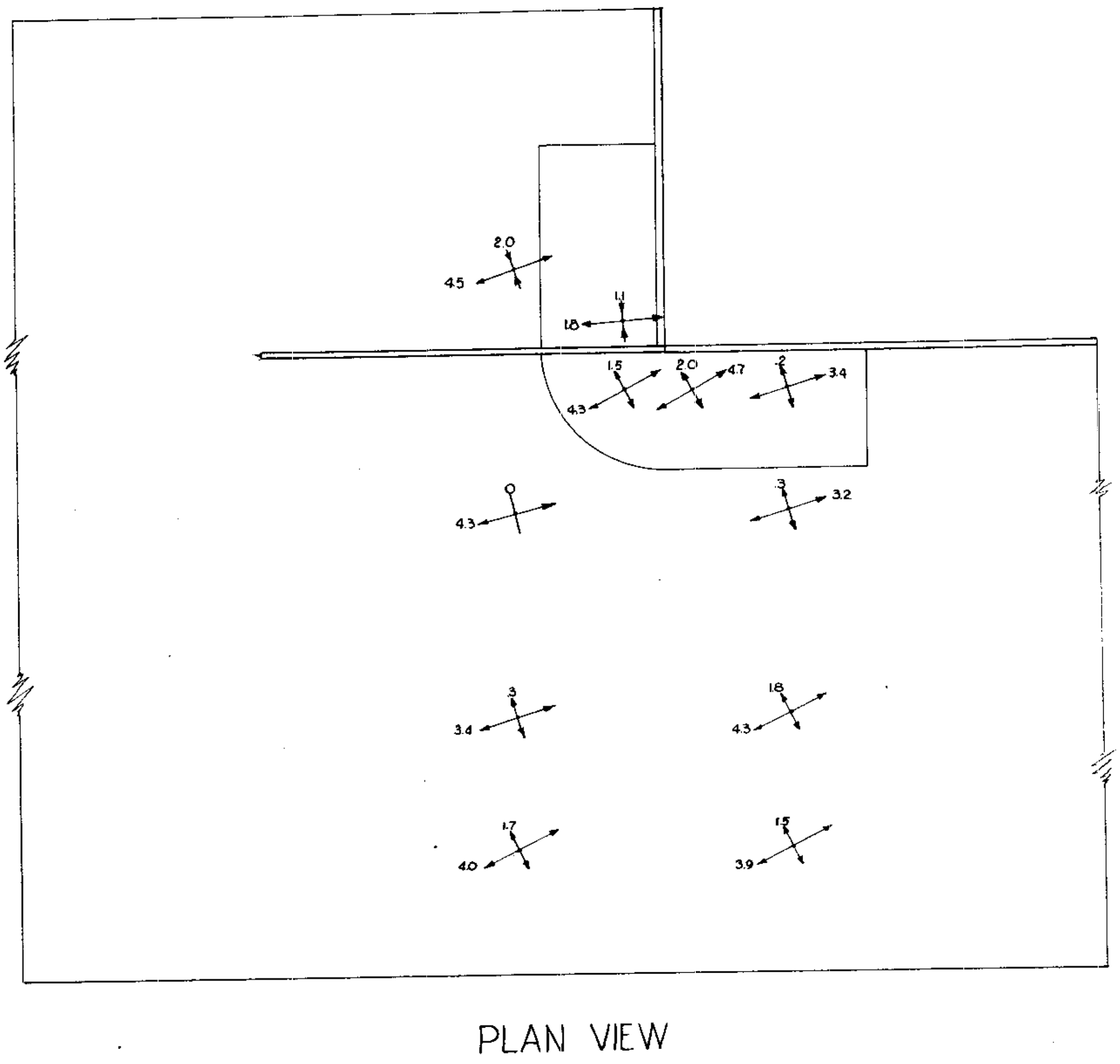
NUMERICAL VALUES - KIPS/SQ.IN.

USN HATCH DESIGN R.112 ENG. MAT. LAB. BERKELEY, CALIF.	FIG. 71A: PRINCIPAL STRESSES AT 200,000# LOAD SPEC. I	SCALE	0 3 6	APPROVED	
		DR. BY	G.P.		DWG
		TR. BY			PANEL



NUMERICAL VALUES · KIPS/SQ.IN.

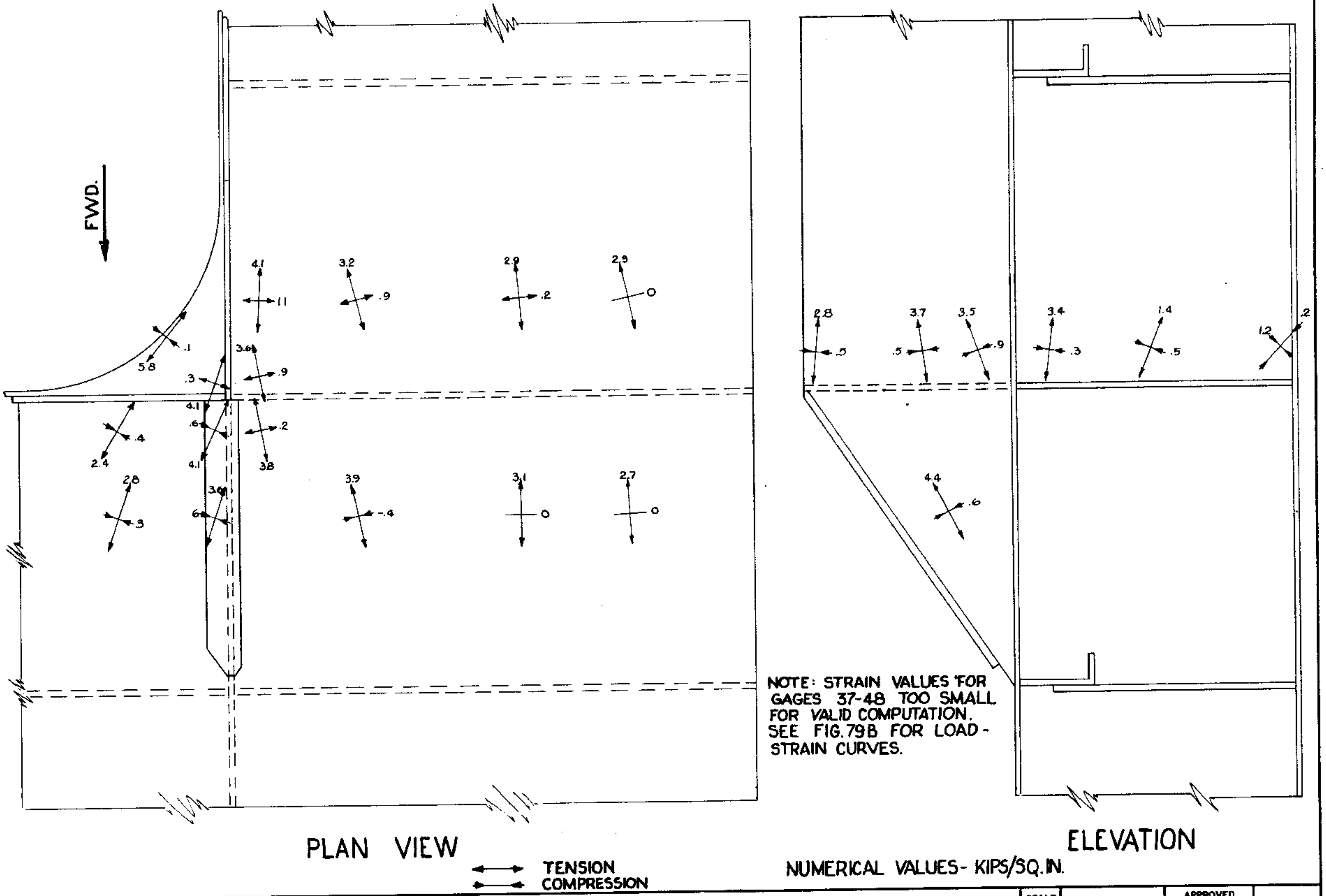
UNIVERSITY OF CALIFORNIA WELDING RESEARCH-	FIG. 71B: PRINCIPAL STRESSES AT 200,000# LOAD SPEC. 5	SCALE	2" = 1'-0"	APPROVED	
		DR. BY	G. P.	8 / 15 / 47	DWG
		TR. BY		/ /	PANEL



⟷ TENSION
→← COMPRESSION

NUMERICAL VALUES - KIPS/SQ. IN.

UNIVERSITY OF CALIFORNIA WELDING RESEARCH	FIG. 72: PRINCIPAL STRESSES AT 200,000# LOAD SPECIMEN 33	SCALE	2" = 1'-0"	APPROVED	
		DR. BY	G P	6 /15 /47	DWG
		TR. BY		/ /	PANEL

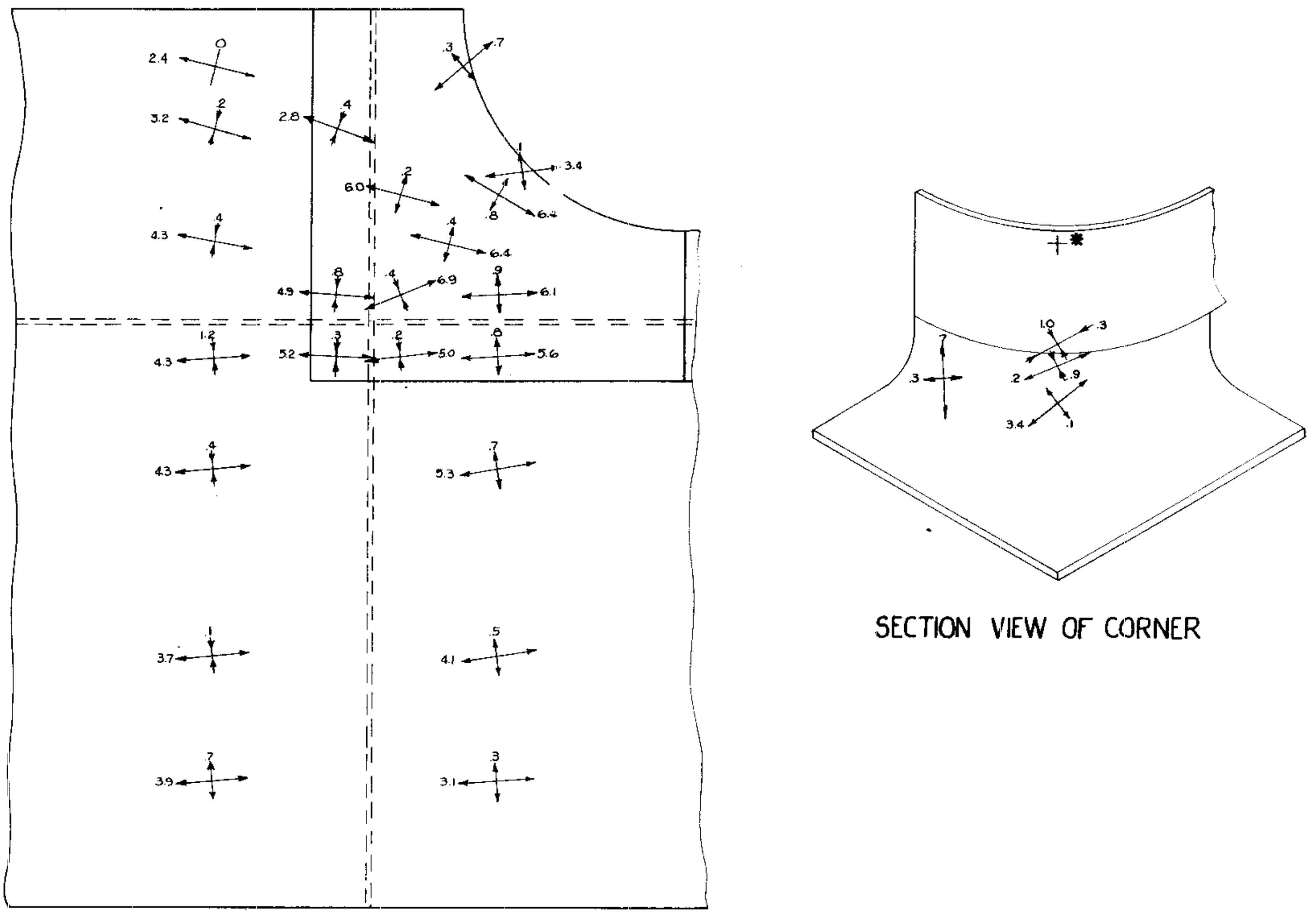


NOTE: STRAIN VALUES FOR GAGES 37-48 TOO SMALL FOR VALID COMPUTATION. SEE FIG. 79B FOR LOAD-STRAIN CURVES.

UNIVERSITY OF CALIFORNIA
WELDING RESEARCH:

FIG. 73: PRINCIPAL STRESSES AT 200,000# LOAD SPECIMEN 34

SCALE
DR. BY
TR. BY
APPROVED
/ /
/ /
DWG
PANEL



PLAN VIEW

SECTION VIEW OF CORNER

⟷ TENSION
→← COMPRESSION

NUMERICAL VALUES - KIPS/SQ.IN.

✱STRAIN VALUES TOO SMALL FOR VALID COMPUTATION. SEE FIG.80A FOR LOAD-STRAIN CURVES.

UNIVERSITY OF CALIFORNIA WELDING RESEARCH -	FIG. 74: PRINCIPAL STRESSES AT 200,000# LOAD SPECIMEN 35	SCALE		- APPROVED
		DR. BY	/ /	DWG
		TR. BY	/ /	PANEL

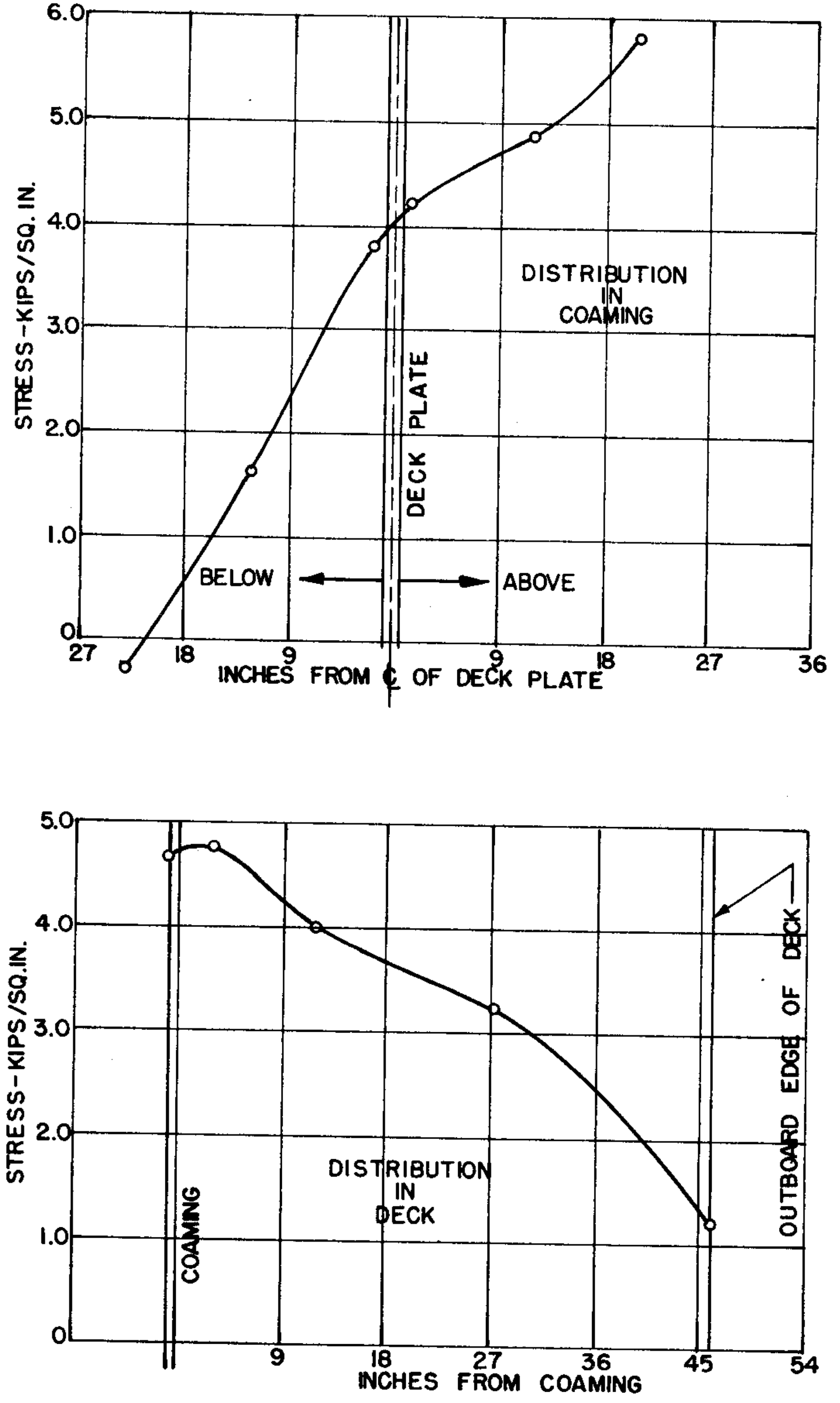
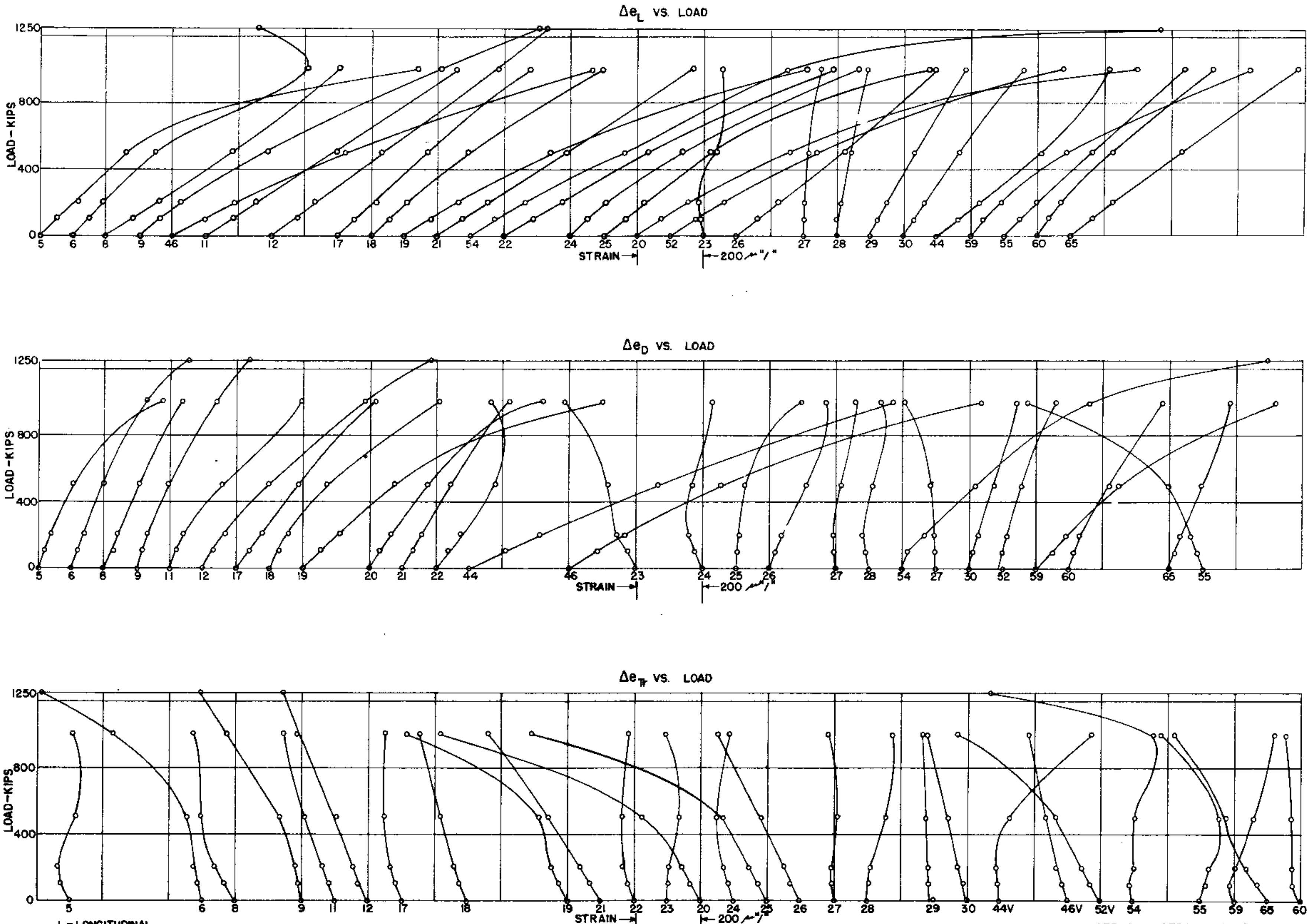


FIG. 75 LONGITUDINAL STRESS DISTRIBUTION IN DECK PLATE AND COAMING 36" AFT OF CORNER AT 200,000# LOAD, SPEC.34

APPENDIX A

Load Strain Data for Individual Gages.



L = LONGITUDINAL
D = DIAGONAL
Tr = TRANSVERSE

(SPECIMEN I INCLUDED FOR COMPARISON.
FOR DETAILS SEE REF. 5)

NOTE: ALL STRAIN VALUES ARE BASED ON AVERAGE OF TOP AND BOTTOM OF PLATE UNLESS INDICATED BY ✱

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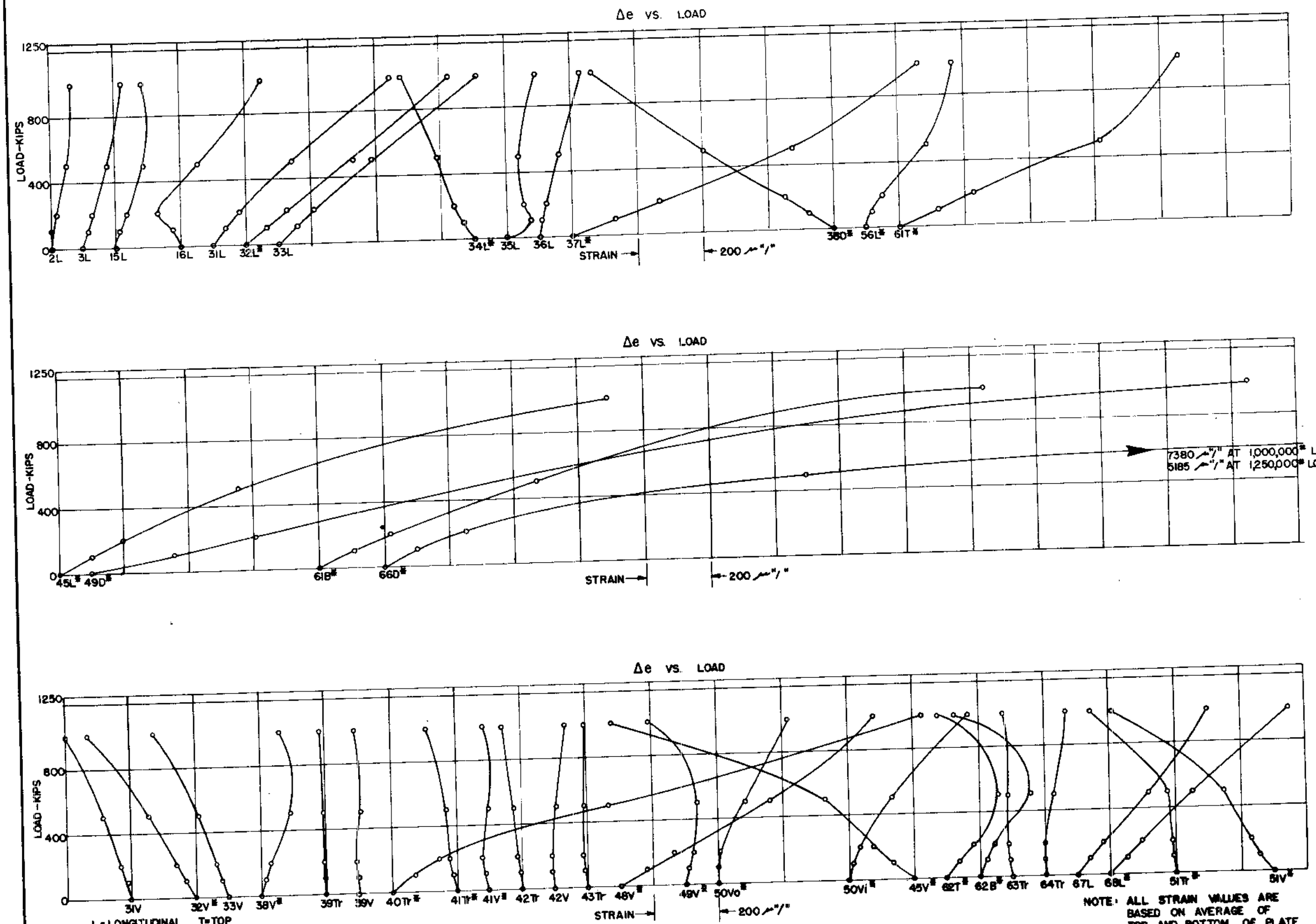
FIG. 76A LOAD - STRAIN CURVES FOR INDIVIDUAL GAGES, SPECIMEN I

SCALE		APPROVED	
DR. BY		/ /	DWG
TR. BY		/ /	PANEL

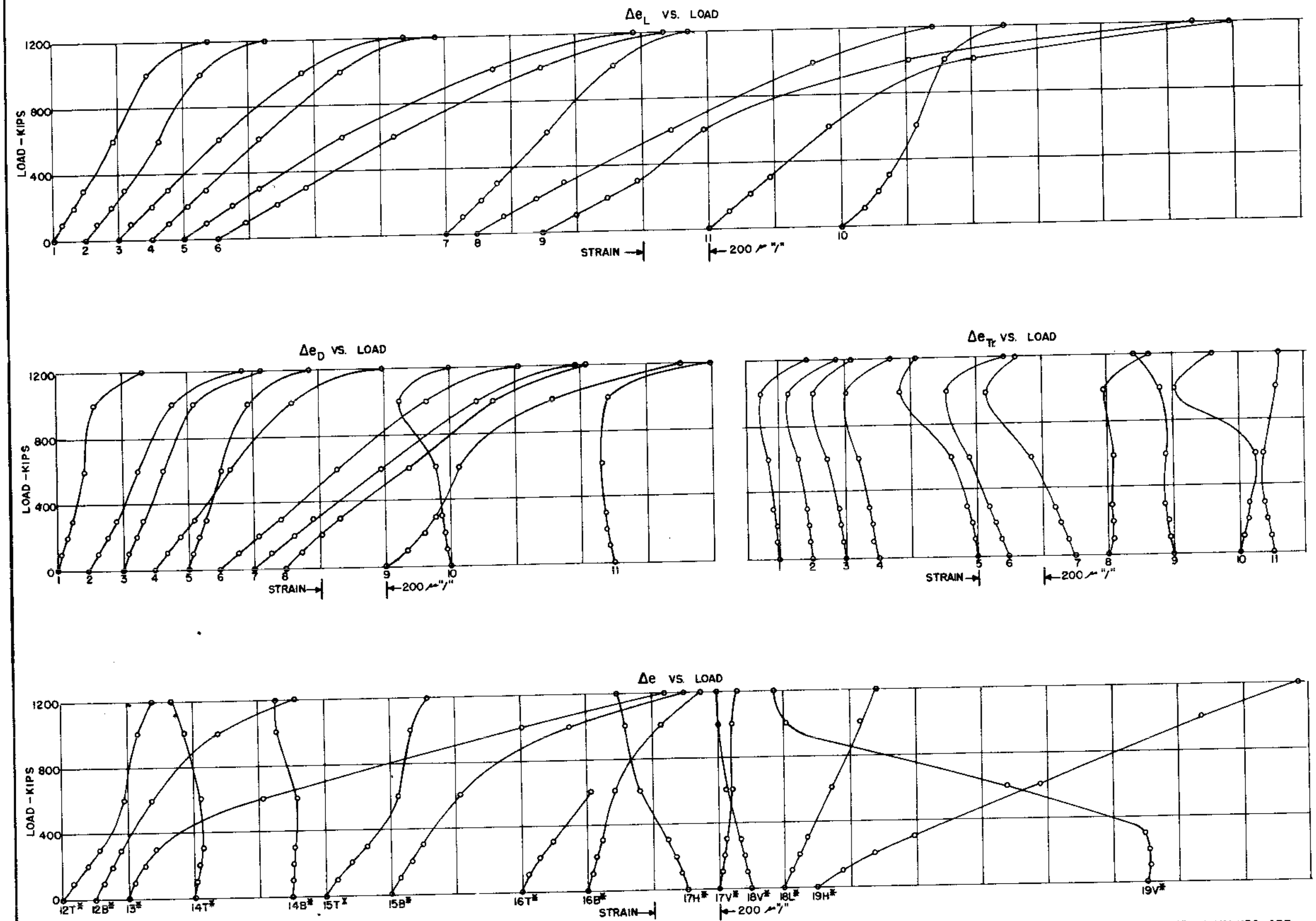


L = LONGITUDINAL
D = DIAGONAL
Tr = TRANSVERSE
V = VERTICAL

T = TOP
B = BOTTOM
i = INBOARD
o = OUTBOARD

NOTE: ALL STRAIN VALUES ARE BASED ON AVERAGE OF TOP AND BOTTOM OF PLATE UNLESS INDICATED BY #

UNIVERSITY OF CALIFORNIA WELDING RESEARCH.	FIG. 76B LOAD-STRAIN CURVES FOR INDIVIDUAL GAGES, SPECIMEN I.	SCALE		APPROVED	
		DR. BY		/ /	DWG
		TR. BY		/ /	PANEL



NOTE: ALL STRAIN VALUES ARE BASED ON AVERAGE OF TOP AND BOTTOM OF PLATE UNLESS INDICATED BY AN ASTERISK.

T = TOP
B = BOTTOM
V = VERTICAL
H = HORIZONTAL

L = LONGITUDINAL
D = DIAGONAL
Tr = TRANSVERSE

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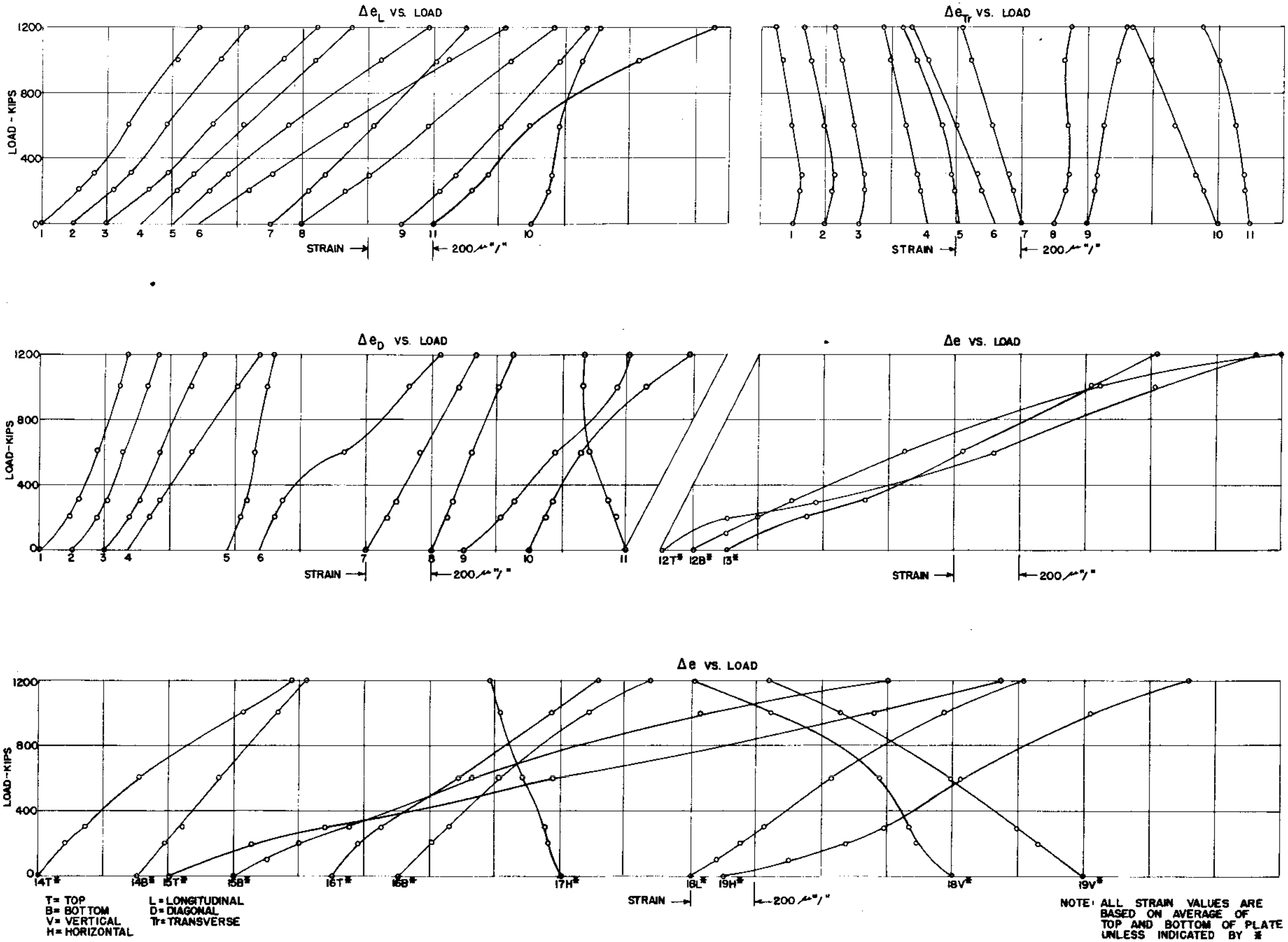
WELDING RESEARCH

FIG.77 LOAD-STRAIN CURVES FOR INDIVIDUAL GAGES, SPECIMEN 5

SCALE		APPROVED	
DR. BY		/ /	DWG
TR. BY		/ /	PANEL



NOTE: ALL STRAIN VALUES ARE BASED ON AVERAGE OF TOP AND BOTTOM OF PLATE UNLESS INDICATED BY *

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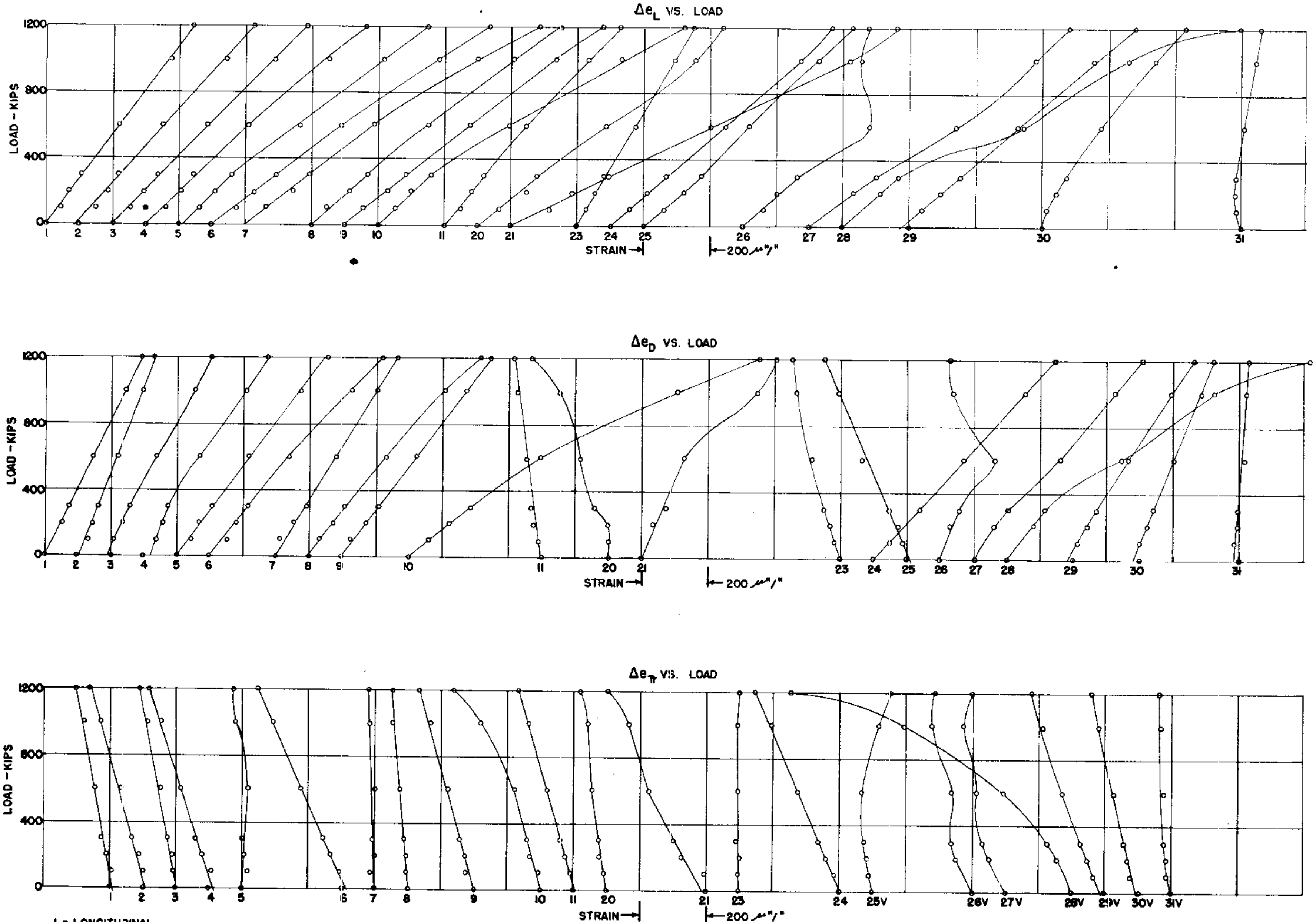
FIG. 78 LOAD-STRAIN CURVES FOR INDIVIDUAL GAGES, SPECIMEN 33

SCALE		APPROVED	
DR. BY		/ /	DWG
TR. BY		/ /	PANEL



L = LONGITUDINAL
D = DIAGONAL
Tr = TRANSVERSE

NOTE: ALL STRAIN VALUES ARE BASED ON AVERAGE OF TOP AND BOTTOM OF PLATE UNLESS INDICATED BY *

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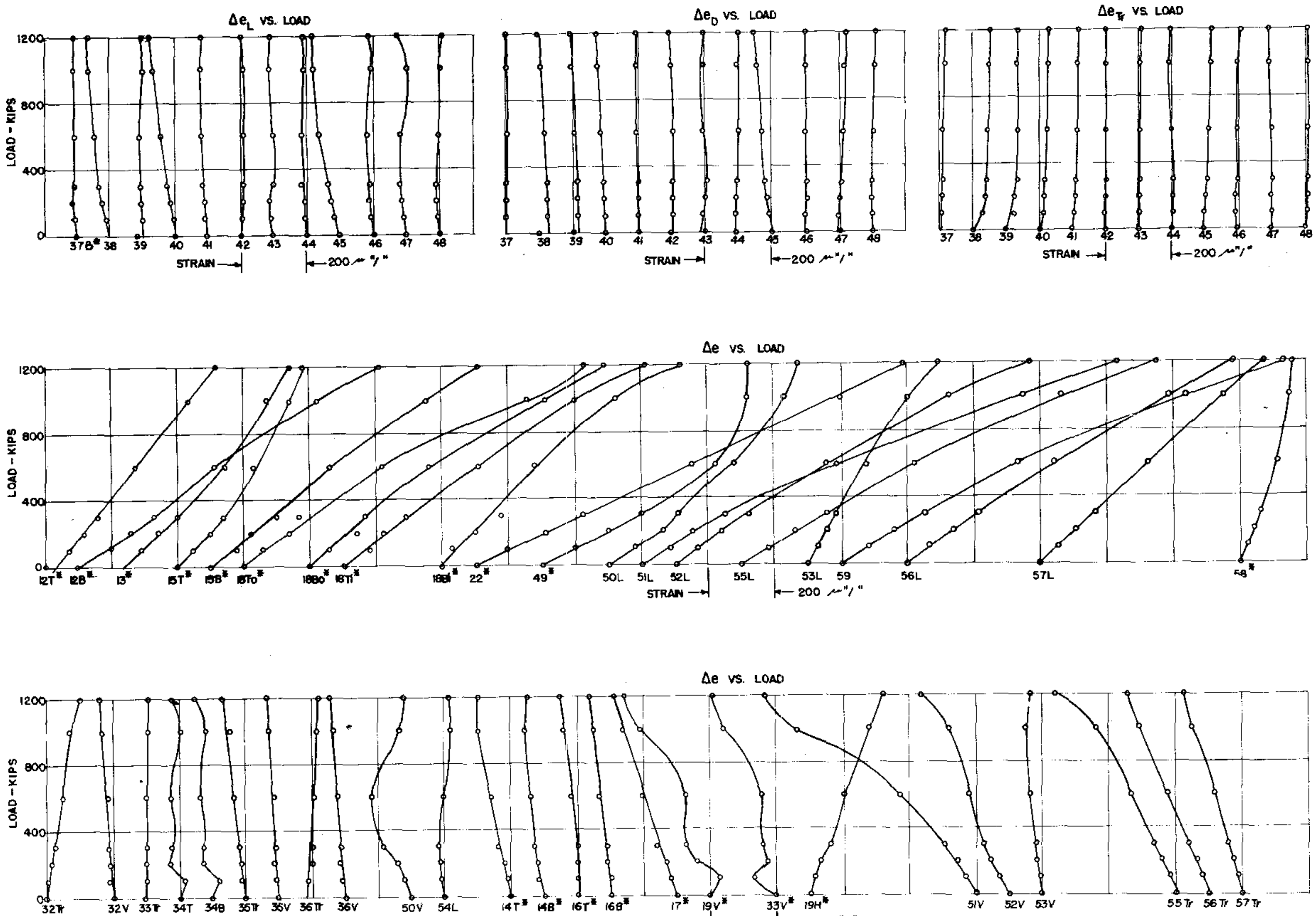
FIG. 79A LOAD-STRAIN CURVES FOR INDIVIDUAL GAGES, SPECIMEN 34

SCALE
DR. BY
TR. BY
APPROVED
/ /
/ /
DWG
PANEL



T= TOP
B= BOTTOM
V= VERTICAL
H= HORIZONTAL
o= OUTBOARD

L= LONGITUDINAL
D= DIAGONAL
Tr= TRANSVERSE
i = INBOARD

NOTE: ALL STRAIN VALUES ARE BASED ON AVERAGE OF TOP AND BOTTOM OF PLATE UNLESS INDICATED BY *

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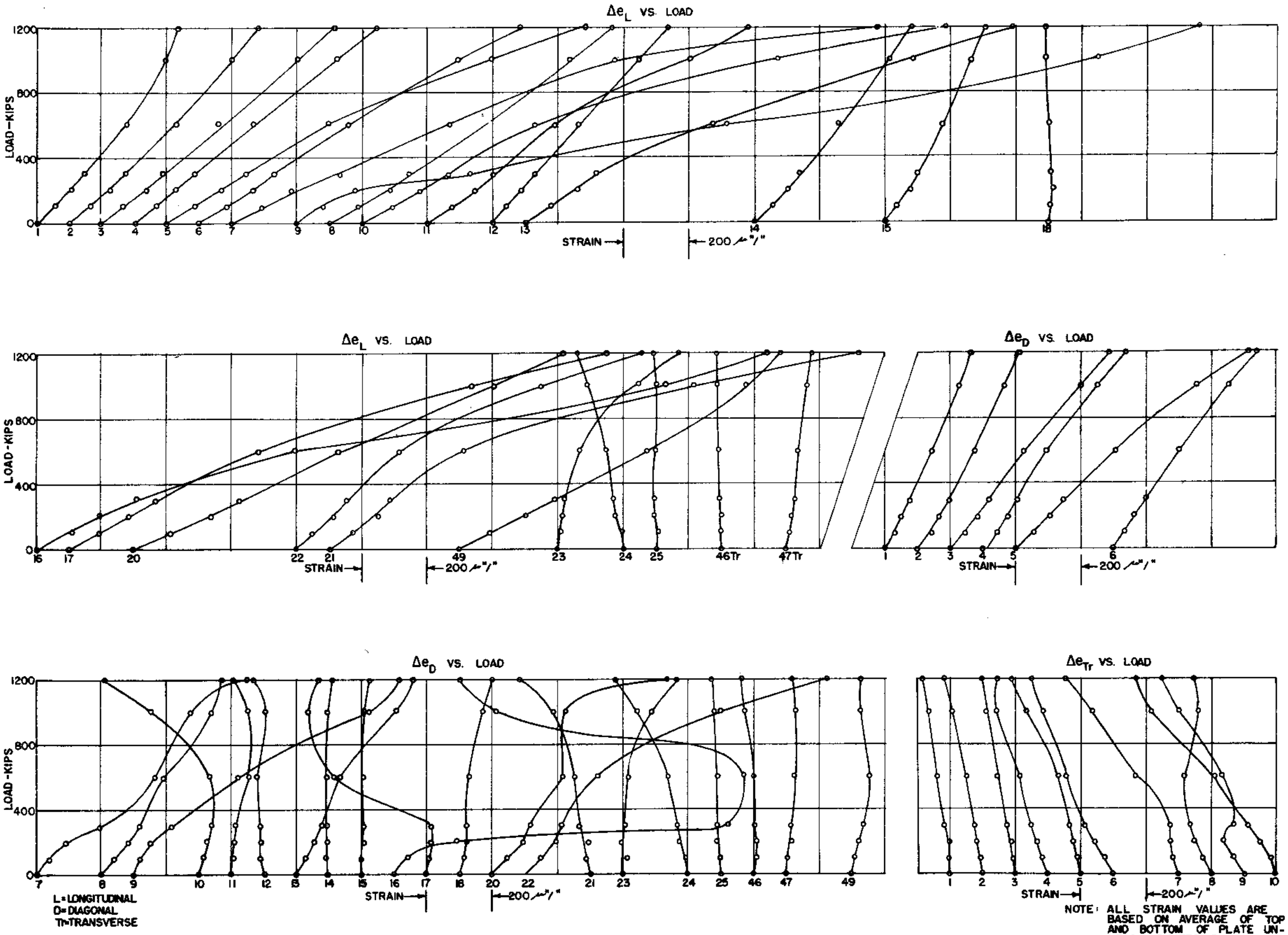
FIG. 79B LOAD-STRAIN CURVES FOR INDIVIDUAL GAGES, SPECIMEN 34

SCALE		APPROVED	
DR. BY		/ /	DWG
TR. BY		/ /	PANEL



NOTE: ALL STRAIN VALUES ARE BASED ON AVERAGE OF TOP AND BOTTOM OF PLATE UNLESS INDICATED BY *

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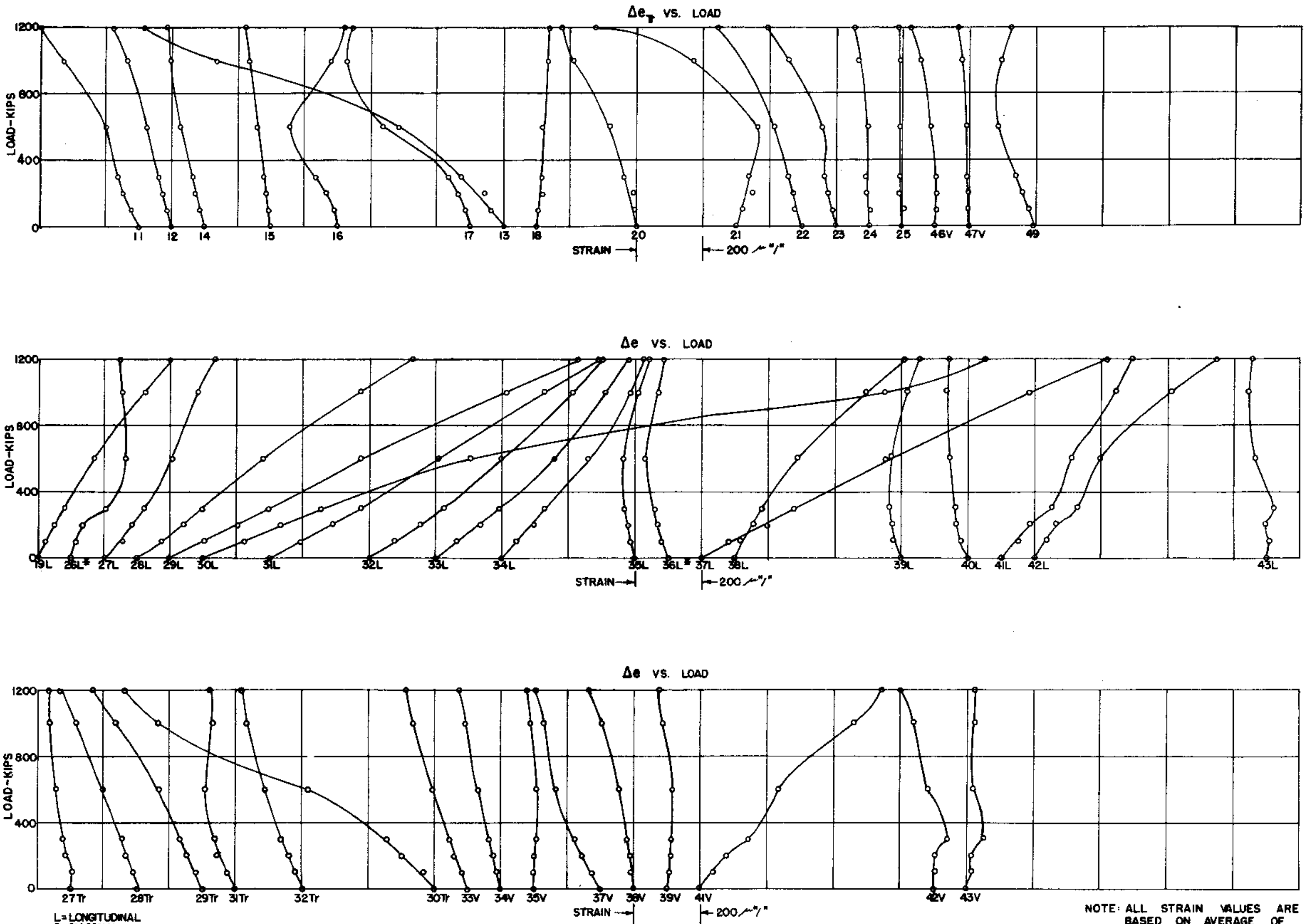
FIG. 80A LOAD-STRAIN CURVES FOR INDIVIDUAL GAGES, SPECIMEN 35

SCALE
DR. BY / /
TR. BY / /
APPROVED
DWG
PANEL



L=LONGITUDINAL
D=DIAGONAL
Tr=TRANSVERSE
V=VERTICAL

NOTE: ALL STRAIN VALUES ARE BASED ON AVERAGE OF TOP AND BOTTOM OF PLATE UNLESS INDICATED BY *

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FIG. 80B LOAD-STRAIN CURVES FOR INDIVIDUAL GAGES, SPECIMEN 35

SCALE
DR. BY / /
TR. BY / /
APPROVED
DWG
PANEL

APPENDIX B

Temperature Transition Curves for Hatch Corner Specimens, "B" and "C" Steels

TEMPERATURE TRANSITION CURVES FOR HATCH CORNER SPECIMENS, "B" AND "C" STEELS

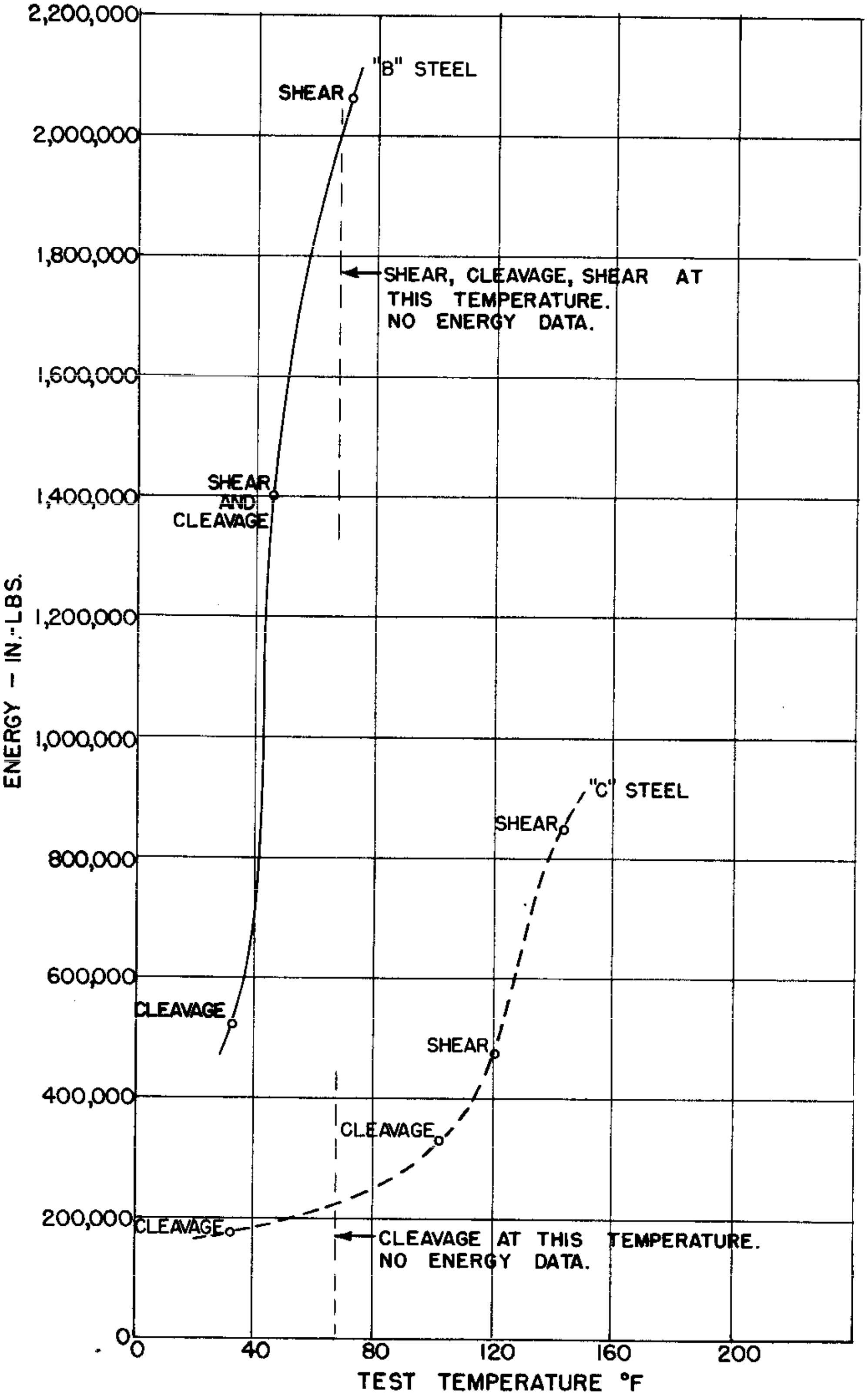

FIG. 81