PART II

Effect of Preheating

Procedure

In view of the results obtained on full scale hatch corner specimen number 15 by preheating, it was evident that more basic information on the effect of preheating would be desirable. The metallurgy of welds has established the presence of a heat affected zone adjacent to the weld metal, which contains large grains and is harder than either the weld or parent metal. In an effort to obtain some details regarding the effects of preheating on the heat affected zone and the weld metal the following tests were conducted.

Two single pass weld beads, one of 3/16" E-6010 electrode at 135 amps and the other of 3/16" E-6020 electrode at 200 amps, were deposited on pieces of ship plate (Steel C) 18 in. x 18 in. x 3/4 in. as shown in Fig. 29. The beads were deposited on one specimen with the plate at a temperature of 70° F and on another after preheating the plate to 400° F. A third plate was prepared upon which beads were deposited using E-6010 and E-6020 electrodes with the plate at a temperature of 70° F. This plate with the deposited beads was then heated for 8 hours at 1000° F similar to the treatment given hatch corner specimen 9. A fourth plate upon which E-6010 and E-6020 beads were deposited was used as a control for specimen number 3. This plate was not subjected to postheat and the beads were deposited with the plate at a temperature of 70° F.

Specimens were taken from the center of each of the six weld beads. These specimens were polished, etched and subjected to microhardness (Knoop, with 500 gm. load) surveys as shown in Fig. 30. In the parent and weld metal the hardness impressions were spaced 0.25 mm.

Essentially in a weld you are searching the heat affected zone and the [illegible] the [illegible] from which the process [illegible] [illegible] will be. Using 200 amps will give higher temp [illegible] apart whereas in the heat affected zone the spacing was reduced to 0.10 mm.

In addition to the previously mentioned tests two multiple pass fillet welds were made as shown in Fig. 31. The first fillet was made using E-6020 electrode and the second using E-6010 with the plate being allowed to cool between each pass so that all beads were deposited with the specimen at a temperature of 70° F. Specimens were then prepared similar to the others and microhardness surveys of each pass as shown in Fig. 30 were conducted.

Results and Discussion

In Fig. 32 there is presented one of the Knoop hardness surveys with hardness plotted as a function of distance from the weld edge for the preheated and non-preheated E-6010 weld beads. The data in Table VI show clearly the increase in width and the decrease in hardness of the heat affected zone by preheating. The reduction in hardness of the weld metal, although significant, is not as much as in the heat affected zone. The maximum hardness of the heat affected zone for the preheated specimens is practically the same for both the electrodes used. In spite of the fact that the maximum hardness of the heat affected zone for the E-6010 electrode is greater than that for the E-6020 electrode as deposited without preheat, the hardness of the weld bead itself is not influenced by the type of electrode. The results of specimens 3 and 4 show that heating of the weld beads for 8 hours at 1000° F reduces maximum hardness of the heat affected zone and the average hardness of the parent and weld metal. The width of the heat affected zone, of course, was not changed as a result of the heating.

An examination of the microstructures reveals the reasons for some of the results presented in Table VI. Referring to Figs. 33 and 34, the effects of the different cooling rates which accompany welding with or without preheating, are apparent. The heat affected zone of the preheated specimen shows evidence of the intermediate transformation products which were able to form during the slower cooling from the Austenitic phase. At a lower magnification (X500) such as in Figs. 35, 36, 37, and 38 the presence of more free ferrite in the preheated welds is apparent. The change in width of the heat affected zones as a result of preheating is shown in Figs. 39, 40, 41, and 42. Figs. 43 to 50, inclusive, show the effect of postheating on the microstructure of the weld metal and the heat affected zones for the E-6010 and E-6020 weld beads. The effect is more pronounced for the E-6010 heat affected zone than for the E-6020.

The effect of multiple passes on the maximum hardness of the heat affected zone and the average hardness of the weld is shown in Table VII. The hardness generally increases with each pass as the heat from each succeeding bead reduces the maximum hardness in the heat affected zone of the proceding bead. The initial hardness of the heat affected zone for the first fillet weld (E-6020) was reduced in the process of welding the second fillet (E-6010) and in the same manner the average weld hardness was probably reduced.

In analyzing the results obtained there seems to be little doubt that changes brought about in the structure and hardness were attributable to the reduction in the severity of the quenching effect normally produced by the metal surrounding the weld. Although no quantitative data were obtained with regards to the cooling rates present in a non-preheated weld, observations of the microstructure in Fig. 33 showed that the quenching effect must have been of the order of magnitude of a water quench.

As stated previously, it was not intended to make a complete investigation of the effects of preheat and postheat, but, to investigate some of the effects. From the tests conducted it is apparent that preheating does produce marked changes in the hardness of the weld material and the heat affected zone and increases the width of the latter. It is also evident that postheating at 1000° F for eight hours is not as effective as preheating at 400° F in reducing the hardness of the weld metal and the heat affected zone and does not widen the heat affected zone. Just how much these changes are responsible for the improved performance of preheated and postheated specimens is not yet known. Undoubtedly other effects, such as change in chemical composition and impact properties, also result. Further study of this entire subject, particularly the effects of preheating, is needed.

PART III

Model Studies

Procedure

A series of asymmetrical and symmetrical models were constructed and tested in an effort to obtain one model of each type which approximated the Bushnell and Schuyler data as closely as possible. Comparison of the two was then made.

In the asymmetrical model, various factors were altered after each successive test to improve the stress distributions. The following factors were investigated.

a. The location of the line of applied load with respect to the corner of the hatch,

b. the extent of attachment of end tab to coaming,

c. effect of transverse restraint and omission of transverse restraining bars,

d. increased end tab width with corresponding fillet between end tab and specimen edge,

e. increased stiffness of end tabs with heavier center plate.

From the results of these changes the model shown in Fig. 51 was constructed and tested.

For the symmetrical design a celluloid model was first built and Stresscoat (brittle coating) was applied to obtain a preliminary indication of the stress distribution. From these results it was apparent that a transverse slot would have to be cut between the end tab and the hatch opening in order to achieve the desired distribution of stress near the corner of the hatch. With this information as a guide several symmetrical specimens were constructed and tested. The factors which were investigated during the tests were

a. length of transverse slot,

b. fillet radius between end tabs and specimen edge,

c. size and stiffness of end tabs.

The specimen design resulting from these preliminary tests is shown in Fig.52, and the resulting model was constructed and tested.

Results

The strain distributions for both tests on the final designs are shown in Fig. 53 along the transverse section AB for the small loading of 6,000 psi nominal stress and for a higher load of 13,750 psi. Figure 54 shows the principal stresses and their directions for the two models under the applied nominal stress of 6,000 psi for both.

An indication of the distortions as the models were loaded to failure is given in Fig. 55. Although the deflections shown are not exactly comparable measurements for the two specimens, they do give an indication that there is less movement in the symmetrical specimen than in the asymmetrical one.

The two specimens after failure are shown in Figs. 56 and 57. For the asymmetrical one the maximum load was 192,800 lbs. which gave a nominal stress computed over the net load carrying section at the hatch corner of 48,500 psi. For the symmetrical specimen the maximum load was 424,000 lbs. which gave a nominal stress of 53,000 psi. However, as can be seen from Figs. 56 and 57, the failure occurred at the slot. It would be necessary to reinforce the ends of the slot for any subsequent tests of this design.

The transverse loading device[1] used on the first quarter scale asymmetrical models did not introduce significant change in the stress ratios near the corner. The subsequent tests were conducted without this bar. An additional reason for leaving off this bar was that the rather heavy bars welded to the sides of the specimen against which the transverse member acted were found to have considerable effect on the stress distribution in the deck.

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[1] See Bibliography

CONCLUSIONS

1. Steel C when used in the hatch corner specimen has a transition from cleavage to shear at slightly below 120° F.

2. Using preheat at 400° F is the most effective procedure yet tried both as to strength and energy absorption, being more effective than stress relief at 1000° F for 8 hours or the use of 25-20 electrode. It results in about 30 per cent increase in maximum strength and superior performance of the welds as compared with specimens welded in the usual manner. Preheating does not appear to influence the type of fracture.

3. Riveting as used in this particular design gave inferior results in so far as strength is concerned.

4. Preheating at 400° F reduces the hardness and increases the width of the heat affected zone and produces a somewhat different microstructure of both the weld and heat affected zones.

5. Post heat treatment at 1000° F for 8 hours results in a decreased hardness in both the heat affected zone and the weld metal and a change in the microstructure. This treatment does not result in any change in the width of the heat affected zone.

6. The greater stress concentration and the somewhat less distortion for the symmetrical quarter scale model as compared with the asymmetrical one is an indication of a more severe stress condition in the former.

7. In view of this conclusion, it follows that the full scale asymmetrical model used for the main tests may not represent a condition as severe as would exist for a full scale symmetrical specimen or for the ship itself.

8. Due to the size of the symmetrical quarter scale model resulting from this investigation it is apparent that the space limitations of the available testing equipment prohibit the testing of a full scale symmetrical specimen. In view of this and the lack of time, it was decided that no further work would be done on models by this project.

Bibliography

1 Progress Report on "Cleavage Fracture of Ship Plate as Influenced by Design and Metallurgical Factors (NS-336): Hatch Corner Specimen Tests", OSRD No. 5352, Serial No. M-512, July 21, 1945.

2 Final Report on "Cleavage Fracture of Ship Plate as Influenced by Design and Metallurgical Factors (NS-336): Hatch Corner Specimen Tests," OSRD No. 6387, Serial No. M-607, December 4, 1945.

3 Report: Structural Tests on the S.S. Philip Schuyler.
U. S. Maritime Commission; June, 1945.

TABLE I

Welding Sequence - Hatch Corner Specimens

Units	Position	Electrode
A. Place, tack and weld 8 to 2; and 7 to 3	Horizontal	E-6020
Jig Horizontal, Bottom Side Up		
B. Place, tack and weld end tabs to deck plate 1	Flat	"
Jig Horizontal, Top Side Up		
C. Place, tack and weld end tabs to deck plate 1	"	"
Jig Horizontal, Bottom Side Up		
D. Place, tack and weld 4A and 4F to 1	Horizontal	"
E. " " " " 6 to 1	"	"
F. Place and tack 5 to 1 and 6	"	"
G. Weld 5 to 1	"	"
H. Weld 4F to 6	Vertical & Horizontal	E-6010
I. Weld 5 to 6	" "	"
J. Place unit 8 and 2 to 1 and 6; tack 2 to 6 (outboard) and 2 to 1 (outboard)	Horizontal & Vertical	"
K. Weld 2 to 6 (outboard)	Vertical	"
L. Weld 2 to 1 (aft & fwd; 2 sides simultaneously)	Horizontal	E-6020
M. Tack and weld 2 to 1 (inboard)	"	"
Jig Vertical		
N. Place and tack unit 7 and 3 to 1 and 2	Horizontal & Vertical	E-6010
O. Weld 6 to 2 and 3 to 2; simultaneously	Horizontal	E-6020
P. Weld 6 to 8 (inboard then outboard)	Horizontal & Overhead	E-6010 E-6020
Q. Complete welding 4F and 5 to 6	Overhead, Horizontal	E-6010 E-6020
R. Tack 9 to 6	Horizontal	"
Jig Horizontal, Bottom Side Up		
S. Weld 9 to 8 (bottom)	"	"
T. Weld 3 to 2 (outboard)	Vertical	E-6010
U. Weld 3 to 1	Horizontal	E-6020
V. Weld 4A to 3	Vertical & Horizontal	E-6010 E-6020
W. Weld 7 to 2	Horizontal &Overhead	E-6010 E-6020
Jig Vertical Position		
X. Tack and weld 3 to 3A (inboard)	Flat	"
Jig Horizontal Position, Bottom Side Up		
Y. Backchip and weld 3 to 3A (deck to bottom)	"	"
Jig Horizontal Position, Top Side Up		
Z. Weld 9 to 8 (top side)	"	"
Remove Specimen From Jig		
AA. Backchip and weld 3 to 3A (deck to top)	Vertical	E-6010
BB. Weld one pass 3 to 2	"	E-6010
CC. Fill deck corner void with weld	Flat	E-6020
DD. Weld 5 passes 3 to 2	Vertical	E-6010
EE. Weld 2 to 1 and 3 to 1; simultaneously	Horizontal	E-6020
FF. Place and tack 10 to 1, 2, 3, and weld 1 pass	"	"
GG Complete weld 10 to 1	"	"
HH. Complete weld 10 to 2, 3	"	"
II. Weld 9 to 6	"	"
JJ. Weld restraining bars to 1	"	"

TABLE II

Analysis of Steels

Steel	% C	% Mn.	% P	% S	% Si.
A*	.23	.47	0.011	0.042	0.02
B*	0.15	0.76	.010	0.030	.04
C*	0.24	0.49	0.015	0.033	
D	0.19	0.52	0.01	0.02	0.24
E*	0.23	0.39	0.019	0.032	0.008

* Supplier's analysis

TABLE III

Tensile and Hardness Properties

Steels for Hatch Corner Specimens

Plate No.	Direc.	Tensile Data (.505 Bars)				Reduction in Area (%)	Hardness (Rockwell "B")
		Yield (PSI)	Ultimate (PSI)	Break (PSI)	Elongation (% in 2")		
A-57*	Long.	35,500	61,200	47,400	39.5	59.6	
	Trans.	38,100	60,400	48,800	36.2	56.3	
B-1 As rolled	Long.	35,050	56,900	38,600	40.9	67.6	62
	Trans.	34,000	57,000	47,500	39.6	58.6	
B-6 Normalized	Long.	36.900	59,500	43,400	39.3	64.0	64
	Trans.	36,500	57,200	43,500	38.5	63.0	
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	
D-2	Long.	37,800	63,700	46,900	37.2	62.8	68
	Trans.	40,600	63,600	48,600	36.6	59.6	
E-2	Long.	35,000	58,900	45,300	37.2	59.6	
	Trans.	35,300	58,200	46,200	35.6	58.0	
		Tensile Data (Full Thickness)					
A-57	Long.	35,100	61,400	47,900	49.2	58.7	
	Trans.	34,800	59,800	49,000	46.1	56.3	
B-1 As rolled	Long.	31,000	56,500	43,700	53.2	66.6	
	Trans.	31,400	56,400	45,600	48.7	58.4	
B-6 Normalized	Long.	32,200	56,900	41,100	52.0	64.0	
	Trans.	32,000	56,500	43,400	51.6	60.5	
C-1	Long.	37,500	66,500	53,600	45.5	56.5	
	Trans.	34,100	66,200	56,600	32.5	50.4	
D-2	Long.	35,900	61,300	45,800	47.1	62.3	
	Trans.	36,100	60,500	47,600	46.4	59.2	
E-2	Long.	31,400	57,200	44,500	49.1	59.1	
	Trans.	31,000	56,600	45,600	45.5	58.0	

* Letter in plate number refers to type of steel.

RESULTS, FULL SCALE HATCH CORNER TESTS

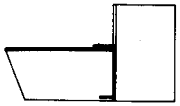
SPECIMEN NO.	KIND OF STEEL AS ROLLED UNLESS NOTED [4]	TEST TEMP. °F.	NOMINAL STRESS AT [1] FAILURE LB IN^2	LONGITUDINAL STRESS CONCENTRATION BASED ON 200,000 LB. LOAD [2]								
				GAGES								
				5	6	7	8	9	10	17	18	H 19 V
14	C	120	(AT MAX. LOAD) 25,600	2.0	2.1	1.5	2.4	2.2		-2.0	2.7	14
												3.6
15	C 400° PREHEAT	70	32,600			1.6	2.5	2.3	1.9	-1.5	2.7	16
												4.0
16	C RIVETED	70	20,900	2.0	1.9	2.4	2.4	2.7			1.2	
17	C	72	24,800	.9	1.2	.9	1.5	1.2	.7	-1.0	1.5	3.0
												2.6
18	C 400° PREHEAT	70	32,800									
19	C RIVETED	70	(AT MAX. LOAD) 20,600									

SPECIMEN NO.	STRAIN CONCENTRATIONS [3] FOR 200,000 LB. LOAD 1,200,000 LB. LOAD													TOTAL ENERGY ABSORBED PIN TO PIN IN.LB.	
	GAGES														
	5L	6L	7L	8L	9L	12T 12B	13	14T 14B	15T 15B	16T 16B	17H 17V	18L	19H 19V	AT MAX LOAD	AT FAIL.
14	2.0	2.1	1.6	2.3	2.2	3.5 3.5		0.5 0.9	4.4 3.8	1.3 1.5	-2.3 1.4	2.9	13.5 -0.5	284,000	484,000 AT FAILURE OF LONGITUDINAL GIRDER
	2.2	2.7	1.3	2.9	1.9	3.5 7.0	15	-1.0 0.2	3.2 6.0	1.5 0.5	-2.5 0	3.3	15.0 1.2		
15			1.6	2.1	2.2	3.2 2.8	1.6	0.7 0.4	3.4 3.4	1.6 1.0	-1.9 1.9	2.9	15 -0.7	1,046,000	
			1.2	2.2	2.1	4.0 4.2	7.8	-0.5 1.2	5.1 6.5	3.7 1.4	-1.9 1.2	3.0	19 -1.6		
16	2.0	2.2	2.3	2.3	2.7							2.0		790,000	
	1.8	.9	.4	5.7	3.9							.4			
17	1.0	1.8	1.1	1.5	1.3	2.7 1.9	2.1	0.3 0.3	2.6 2.0	1.1 0.7	-1.2 0.8	1.7	9.5		
	2.0	2.3	1.5	3.4	3.3	1.6 3.1		-.6 -.7	1.7 4.1	6.9	-1.8 0.7	2.4	0.8		
18														1,358,000	
19														① 412,000	② 588,000 SEE REMARKS

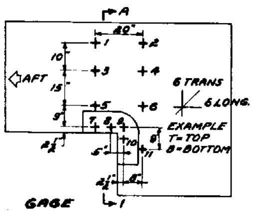
SPECIMEN NO.	STRAIN RATIOS LONG./TRANS. 200,000 LB. LOAD 1,200,000 LB. LOAD									STRAINS AT OR NEAR FAILURE MICRO IN IN				THICKNESS REDUCTION AT FRACTURE %						REMARKS
	GAGES									GAGES				DISTANCE FROM						
														CORNER IN.	FRACTURE EDGE IN.					
	5	6	7	8	9	10	11 [5]	19H/19V	17H/17V	12B	15B	18L	19H		1/16	1/4	1/2	3/4	1	
14	-11.2	-5.5	-3.9	11	-6.8		-8.3	-29	-1.6	8,400	6,600	MAX. STRAIN 1,800	12,000+	SHEAR						SHEAR FAILURE AT CORNER.
	-3.5	-4.5	-3.0	-7.8	-3.7		12	12	89											
15			-3.1	3.0	-6.1	5.4	5.7	-21	-1.0	11,000+	13,000+	13,000+	20,000+	13	0.8	0.3	0	0	0	CLEAVAGE FAILURE AT CORNER. (SHEAR IN WELDS)
			-9.8	2.6	-17	17	-2.8	12	-1.7					34	1.8	0.1	0	0	0	
16	-4.4	-1.7	-13	-13	-3.1		2.5					1,000								CLEAVAGE FAILURE AT CORNER. VALUES SHOWN ARE FOR GAGES 3 OR MORE DIAMETERS FROM RIVET HOLE.
	-2.0	-5.9	-7.1	-9.8	-12.7		.3													
17	-6.9	-3.6	-2.0	2.1	-6.2	5.2	-4.6		-1.6	1,100	800	1,400	1,500	13	2.7	2.3	1.7	1.2	0.5	SUBJECTED TO REPEATED LOADING CLEAVAGE FAILURE AT CORNER. SEE NOTE 6. AT BOTTOM OF TABLE
	-3.9	-9.3	-3.0		-14	-6.1			-2.6					34	1.4	1.4	1.3	1.0	0.5	
18																				CLEAVAGE FAILURE AT CORNER. NO GAGE READINGS TAKEN.
19																				CLEAVAGE FAILURE AT CORNER. NO GAGE READINGS TAKEN. ① FAILURE PROCEEDED HALFWAY THROUGH DOUBLER & LATER CONTINUED TO SECOND RIVET HOLE. ②

NOTES:

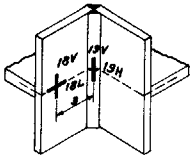
1. BASED ON LOAD CARRYING SECTION OF DECK, DOUBLER, LONGITUDINAL COAMING BELOW DECK.
2. BASED ON AVERAGE OF LONGITUDINAL STRESSES FOR GAGES 1-2-3-4 TOP & BOTTOM.
3. BASED ON AVERAGE OF LONGITUDINAL STRAINS FOR GAGES 1-2-3-4 TOP & BOTTOM.
4. E-6010 & E-6020 ELECTRODE USED UNLESS NOTED
5. READINGS QUESTIONABLE. GAGE #11 VERY CLOSE TO DOUBLER WELD.

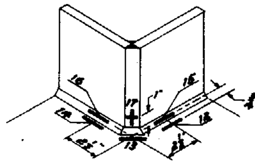


LOAD CARRYING SECTION A-1

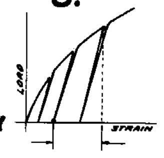


GAGE LOCATION PLAN





6.



STRAIN INCREMENT USED IN COMPUTATIONS

TABLE IV

RESULTS, FULL SCALE HATCH CORNER TESTS

SPECIMEN NO.	KIND OF STEEL 4 AS ROLLED UNLESS NOTED	TEST TEMP °F.	NOMINAL STRESS AT FAILURE 1 LB./IN²	LONGITUDINAL STRESS CONCENTRATION BASED ON 200,000 LB. LOAD 2 GAGES								
				5	6	7	8	9	10	17H	18	19V
1	A	32	24,200	1.5	1.8	1.3	2.0	2.0	1.3	-1.7	1.9	6.2
												2.1
2	C	32	23,200	—	1.6	—	—	—	—	—	—	—
5	C	68	24,000	1.6	2.0	1.2	2.1	2.3	1.5	-1.9	2.6	10.4
												3.4
10	C MUREX H.T.S.	32	23,600	1.5	2.0	1.7	2.5	2.1	1.6	-1.9	2.5	13.8
												4.3
9	C STR. REL. AFT. WELD	72	MAX. STRESS 30,000 29,400	1.5	1.8	1.7	2.4	2.4	1.8	-1.5	2.6	8.4
												2.6
13	C 25-20 ELECTR.	32	27,700	1.7	2.0	1.8	2.7	2.4	1.6	-1.7	2.7	7.1
												0.7
11	B	32	MAX. STRESS 25,700 25,600	1.6	—	1.6	2.2	2.3	1.2	-1.1	2.7	8.9
												2.4
8	B	66	MAX. STRESS 27,000 26,100	2.0	2.3	2.0	2.9	2.9	1.8	-2.7	3.0	18.9
												5.5
3	B NORMALIZED	32	MAX. STRESS 26,900 23,500	1.4	2.1	1.5	2.3	2.1	1.6	-0.8	2.5	5.1
												1.7
4	D NORMALIZED	32	25,900	1.4	1.7	0.9	2.2	2.0	1.5	-0.8	1.9	—
												—
7	D NORMALIZED	72										
12	D NORMALIZED	72	MAX. STRESS 27,800	1.5	1.5	1.7	2.4	—	1.3	-1.4	3.5	14
												3.6
6	E	32	23,100	1.5	1.7	1.4	2.1	2.0	1.4	-1.1	1.8	5.9
												0.7

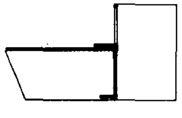
SPECIMEN NO.	STRAIN CONCENTRATIONS 3 FOR 200,000 LB. LOAD / 1,200,000 LB. LOAD GAGES												
	5L	6L	7L	8L	9L	12T 12B	13	14T 14B	15T 15B	16T 16B	17H 17V	18L	19H 19V
1	1.4	1.8	1.4	1.8	2.0	2.5 2.4	2.7	0.9 0.5	3.0 —	1.6 —	-1.6 0.3	2.1	5.6 0.3
	1,000,000 LB. 1.8	2.3	1.3	0.9	1.9	1.7 4.0	14.4	-0.1 -0.1	2.1 —	3.2 —	-1.4 0.1	3.3	6.9 0.2
2	—	1.6	—	—	0.8	— —	—	— —	— —	— —	— —	—	— —
	—	2.0	—	1,250,000 LB. —	—		—	— —	— —	— —	— —	—	— —
5	1.6	2.0	1.3	2.0	2.2	4.5 3.0	3.0	0.9 0.3	4.7 3.9	3.2 1.5	-2.1 0.9	2.8	9.9 0.5
	2.0	2.0	1.1	2.0	2.9	2.0 4.4	11.9	-0.5 -0.3	2.3 6.5	— 2.5	-1.5 0.4	2.1	10.6 -8.2
10	1.5	1.9	1.8	2.2	1.9	3.4 2.6	2.7	0.3 0.5	3.4 3.5	1.3 1.1	-2.3 1.8	2.7	1.3 0.3
	2.2	2.5	1.4	5.2 ←8 ONLY→	4.0	— 11.5	—	— 2.1	— 12.2	— 0.8	-2.9 -0.2	5.8	1.7 1.0
9	1.4	1.8	1.8	2.1	2.3	2.9 2.9	1.2	1.1 0.4	2.9 3.4	1.2 1.1	-1.9 1.7	2.8	7.9 0.2
	1.6	2.0	1.5	3.6	2.0	2.0 6.5	7.1	0 0.1	2.3 5.0	1.9 1.0	-1.6 0.8	2.2	14.3 0.1
13	1.6	2.0	1.7	2.3	2.2	3.5 1.5	—	1.0 1.0	3.5 2.8	1.6 0.5	-2.2 2.3	2.8	6.7 -1.3
	1.9	2.2	1.5	3.3	2.4	6.4 7.2		1.5 4.3	8.7 6.2	3.4 0.7	-3.1 3.7	5.0	5.3 -3.1
11	1.7	1.9	1.7	2.2	2.4	4.2 3.3	1.7	0.6 1.0	5.0 3.8	1.3 1.4	-1.6 1.3	3.1	9.6 -0.2
	2.1	2.0	1.3	5.8	2.2	8.5 12.6	2.9	-0.2 1.0	9.1 9.9	-2.4 0.2	-1.2 1.5	6.6	4.4 -1.9
8	2.0	2.2	2.0	2.6	2.6	4.5 3.8	3.6	0.2 1.0	5.3 4.3	1.3 1.3	-2.6 1.8	3.2	17.3 0
	2.2	2.0	1.4	7.4	4.2	6.7 17.9	19.8	-1.4 1.4	7.6 18.3	-2.0 -0.1	-2.2 1.3	7.5	1.5 -0.8
3	1.4	2.1	1.5	2.1	2.1	2.6 2.5	1.8	0.6 —	— —	— —	-1.1 1.2	2.6	4.8 0.2
	1.7	2.4	1.5	4.0	2.3	3.1 7.4	10.0	0 —	— —	— —	-4.1 2.0	3.3	4.0 -0.7
4	1.4	1.7	1.0	2.0	1.9	2.6 —	1.7	0.4 0.2	3.0 —	1.6 0.7	-1.2 1.3	2.3	— -1.0
	1.8	2.4	1.1	3.4	2.4	4.8 —	6.4	0.2 -0.1	3.6 —	4.2 1.6	-1.4 1.1	3.4	— -1.9
7													
12	1.5	1.6	1.6	2.2	—	3.0 2.8	1.6	0.9 0.5	3.3 3.3	1.5 0.6	-1.8 1.7	3.6	1.3 -0.4
	1.8	2.1	1.7	3.7	—	3.6 5.9	11.7	-0.8 -0.2	4.2 7.0	8.7 0.6	-2.4 0.5	4.7	12.4 -0.5
6	1.4	1.7	1.5	1.9	2.0	2.6 2.4	2.5	0.2 0.3	2.9 2.8	1.6 1.1	-1.3 0.8	2.0	5.9 -1.0
	2.0	2.1	1.5	3.1	2.5	3.9 5.9	12.0	-0.2 0.1	3.9 6.9	2.7 3.5	-1.5 0.7	1.0	6.6 -1.3

SPECIMEN NO.	TOTAL ENERGY ABSORBED PIN TO PIN IN. LB.		STRAIN RATIOS LONG./TRANS. 200,000 LB. LOAD / 1,200,000 LB. LOAD GAGES								
	AT MAX LOAD	AT FAIL.	5	6	7	8	9	10	11 5	19H/19V	17H/17V
1			-6.3	-3.7	-2.6	—	-4.7	6.7	-3.5	20.2	-4.8
			-4.0	-2.5	-3.3	1,000,000 LB. 8.2	-5.5	3.4	-5.7	32.2	-11.9
2			—	-2.8	—	—	0.9	—	-4.2	— —	— —
			—	-4.3	—	1,250,000 LB. —	—	—	13.6	— —	— —
5			-8.1	-4.2	-2.6	12.0	-11.0	4.7	-7.2	21.7	-2.3
			-7.4	-75.4	-4.3	10.8	-17.1	—	79.4	-1.3	-3.5
10			-7.6	-6.4	-4.7	7.4	—	7.2	1.3	4.8	-1.3
	180,000	180,000	-4.0	-5.5	-4.2	10.1 ←8 ONLY→	-7.1	-15.5	—	-1.7	1.3
9			—	-3.7	-4.5	4.8	—	5.7	-3.7	3.6	-1.1
			-7.3	-3.5	-3.6	12	-15	6.3	-18	300	-2.1
13			-5.1	-3.7	-2.9	10.4	-7.2	1.1	-7.7	-5.2	-1.0
	232,000	232,000	-4.1	-4.1	-2.8	6.0	-14.4	-10.6	-24.1	-1.7	-0.8
11			—	—	—	4.2	—	2.0	10.8	-4.8	-1.2
	340,000	522,000	-4.0	—	-6.0	13.0	-7.4	-2.6	11.3	-2.4	-0.8
8			-6.5	-4.3	-3.3	8.5	—	6.0	-6.4	—	-1.5
			-3.0	-7.5	-2.4	6.5	-11.7	-0.6	5.8	-1.9	-1.7
3			-10.2	-6.7	-5.6	4.6	—	3.1	—	2.3	-0.9
			-3.0	-7.4	-3.0	—	-10.8	5.7	—	-5.7	-2.1
4			-7.0	-4.8	-2.6	5.5	—	8.3	—	—	-0.9
			-4.6	-4.2	-2.2	14.0	-32.2	4.4	30.1	—	-1.3
7											
12			-5.7	-3.1	-4.8	7.5	—	0.9	-3.5	-2.9	-1.1
	514,000	1,196,000+	-3.4	-2.9	-4.0	9.4	—	1.8	-1.8	-2.3	-4.6
6			—	-6.9	-5.4	9.0	-12.3	—	—	-5.8	-1.6
			-3.5	-5.6	-3.4	-6.1	—	—	24.0	-5.0	-2.2

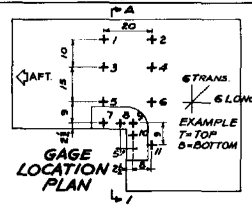
SPECIMEN NO.	STRAINS AT OR NEAR FAILURE MICRO IN/IN GAGES				THICKNESS REDUCTION AT FRACTURE % DISTANCE FROM						REMARKS
	12B	15B	18L	19H	CORNER IN.	FRACTURE EDGE IN. 1/16	1/4	1/2	3/4	1	
1					20	2.4	1.5	0.7	—	—	CLEAVAGE FAILURE. STEEL A USED FOR DECK ONLY.
					32	3.2	2.1	0.8	—	—	
2					16	1.1	0.2	0	—	—	CLEAVAGE FAILURE. GAGE READINGS UNRELIABLE DUE TO DIFFICULTIES IN SWITCHING CIRCUITS.
					32	1.2	0.5	0	—	—	
5	3600	5,000	—	7,000+	19	1.9	1.0	0.3	0	0	CLEAVAGE FAILURE. SLIGHT AM'T OF SHEAR AT TOP & BOTTOM EDGES ALONG FRACTURE.
					34	2.3	0.9	0.1	0	0	
10	9,200	8,800	4,400	13,800	19	1.5	0.9	0.4	0	0	CLEAVAGE FAILURE. SMALL CRACK IN DOUBLER OCCURED AT 400,000 LBS. PASSING DIRECTLY THROUGH GAGE #13.
					34	2.0	1.3	0.5	0.1	0	
9	12,300+	15,200	9,200	14,300+	19	1.9	1.1	0.3	0.2	0.1	CLEAVAGE FAILURE. FILLET WELD BETWEEN TRANSVERSE COAMING AND DOUBLER FAILED PRIOR TO MAIN FAILURE.
					34	1.9	1.2	0.7	0.4	0.2	
13	94,00	8,300	6,200	—	19	0.5	0.3	0.1	0	0	PULLING TAB FAILED AT 1,595,000 LB. TAB REPAIRED AND SPECIMEN RELOADED. CLEAVAGE FAILURE OCCURED AT HATCH CORNER.
					34	1.5	0.8	0.1	0	0	
11	13,500	7,900+	7,300	5,500	19	1.3	1.1	0.7	0.5	0.3	CLEAVAGE FAILURE.
					34	3.3	2.5	1.5	0.7	0.1	
8	14,400+	13,200+	7,800	15,000+	NO MEASUREMENTS POSSIBLE. PART SHEAR, PART CLEAVAGE. SEE PHOTOGRAPHS						DECK FAILURE EXTENDED ABOUT 3" FROM CORNER IN SHEAR, THEN SUDDEN CLEAVAGE FAILURE OCCURED EXTENDING ABT. 18" FROM CORNER, ENDING IN SHEAR
3					16	2.9	1.9	1.3	—	—	SUDDEN NOISE AT 1,600,000 LB. LOAD DROPPED & CLEAVAGE FAILURE OCCURED AT 1,400,000 LB. NO TRANSVERSE BARS USED. DECK LAMINATED.
					34	1.9	0.8	0.4	—	—	
4					19	1.2	0.7	0.5	0.3	0.2	CLEAVAGE FAILURE
					34	2.5	0.7	0.5	0.4	0.3	
7											TEST INVALID DUE TO WELDING DIFFICULTIES.
12	7,300	6,700	4,000	10,700+	SHEAR FAILURE						SHEAR FAILURE AT CORNER.
	(AT	MAX.	LOAD)		SEE PHOTOGRAPHS						
6	4,400	5,000	500	9,400	19	0.3	0	0	0	0	CLEAVAGE FAILURE.
					34	1.6	0.8	0.1	0	0	

NOTES

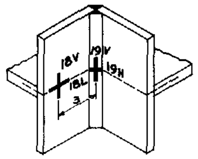
1. BASED ON LOAD CARRYING SECTION OF DECK, DOUBLER, LONGITUDINAL COAMING BELOW DECK.
2. BASED ON AVERAGE OF LONGITUDINAL STRESSES FOR GAGES 1-2-3-4 TOP AND BOTTOM.
3. BASED ON AVERAGE OF LONGITUDINAL STRAINS FOR GAGES 1-2-3-4 TOP AND BOTTOM.
4. E-6010 & E-6020 ELECTRODE USED UNLESS NOTED.
5. READINGS QUESTIONABLE. GAGE #11 VERY CLOSE TO DOUBLER WELD.



LOAD CARRYING SECTION A-1



GAGE LOCATION PLAN



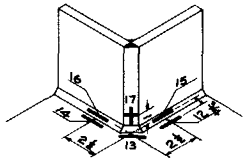


TABLE V

TABLE VI

Single Pass Specimens

Electrode	Spec. No.	Plate Temp. °F	Max.Hardness Heat Affected Zone - Knoop **	Av. Weld Hardness Knoop **	Av. Width of Heat Affected Zone - MM	Av. Parent Metal Hardness - Knoop **
E-6010	1	70	433	239	2.08	178
E-6010	2	400	290	215	3.82	199
E-6020	1	70	368	237	2.97	206
E-6020	2	400	292	206	4.15	175
E-6010*	3	70	284	225	1.80	158
E-6010	4	70	484	256	1.73	184
E-6020*	3	70	232	194	2.92	153
E-6020	4	70	298	213	2.85	185

* Plate specimen with deposited beads annealed at 1000° F for 8 hours.

**Several hardness traverses were made in each case. "Max. Hardness" is the maximum value found. "Av. Hardness" is the average of all the values measured in the area specified (from 20 to 60 readings).

TABLE VII

Multiple Pass Specimen

Electrode	Order of Passes	Max. Hardness Heat Affected Zone - Knoop	Average Weld Hardness Knoop
E-6020	1	258	215
E-6020	2	298	217
E-6020	3	328	214
E-6010	4	271	213
E-6010	5	508	238
E-6010	6	452	235

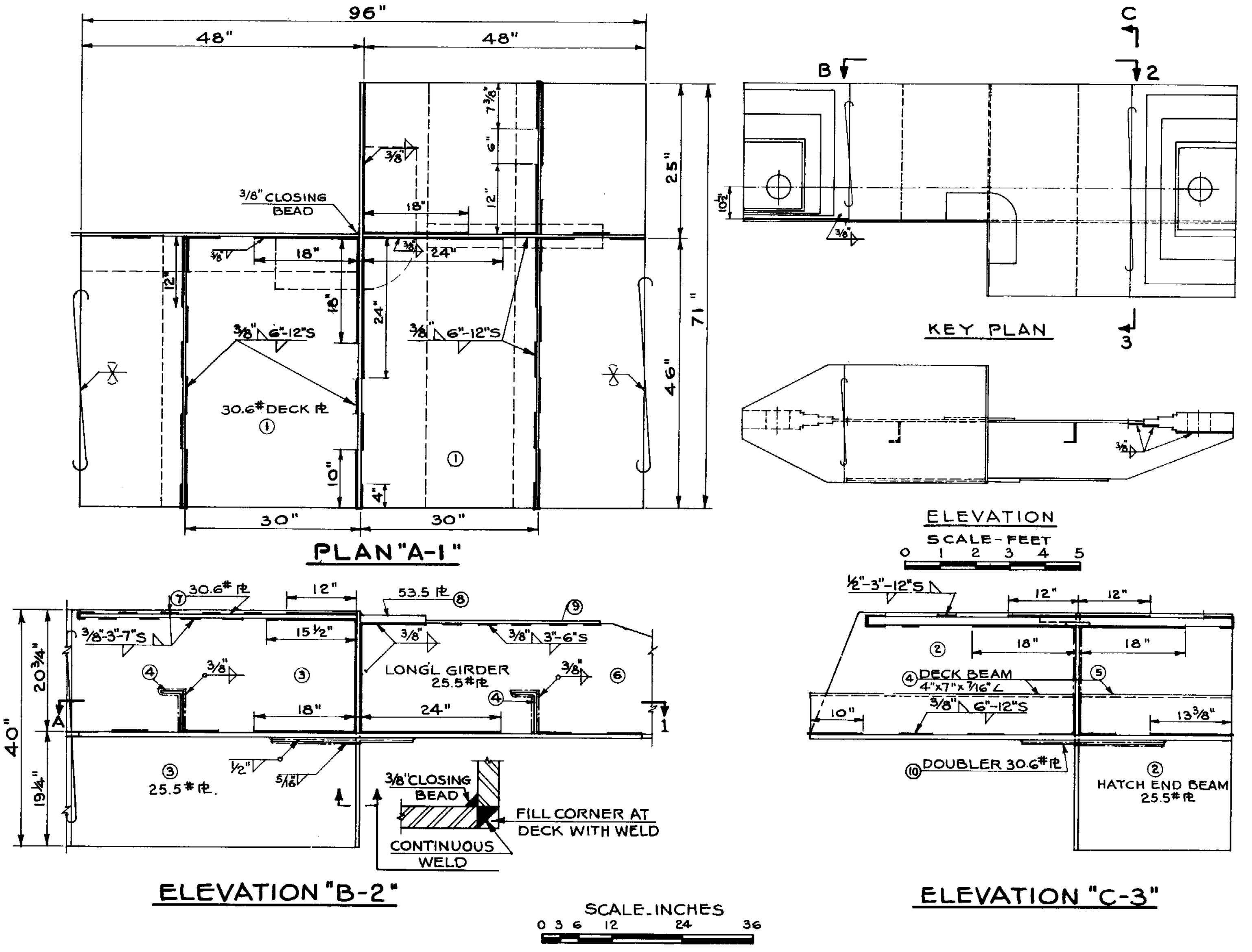
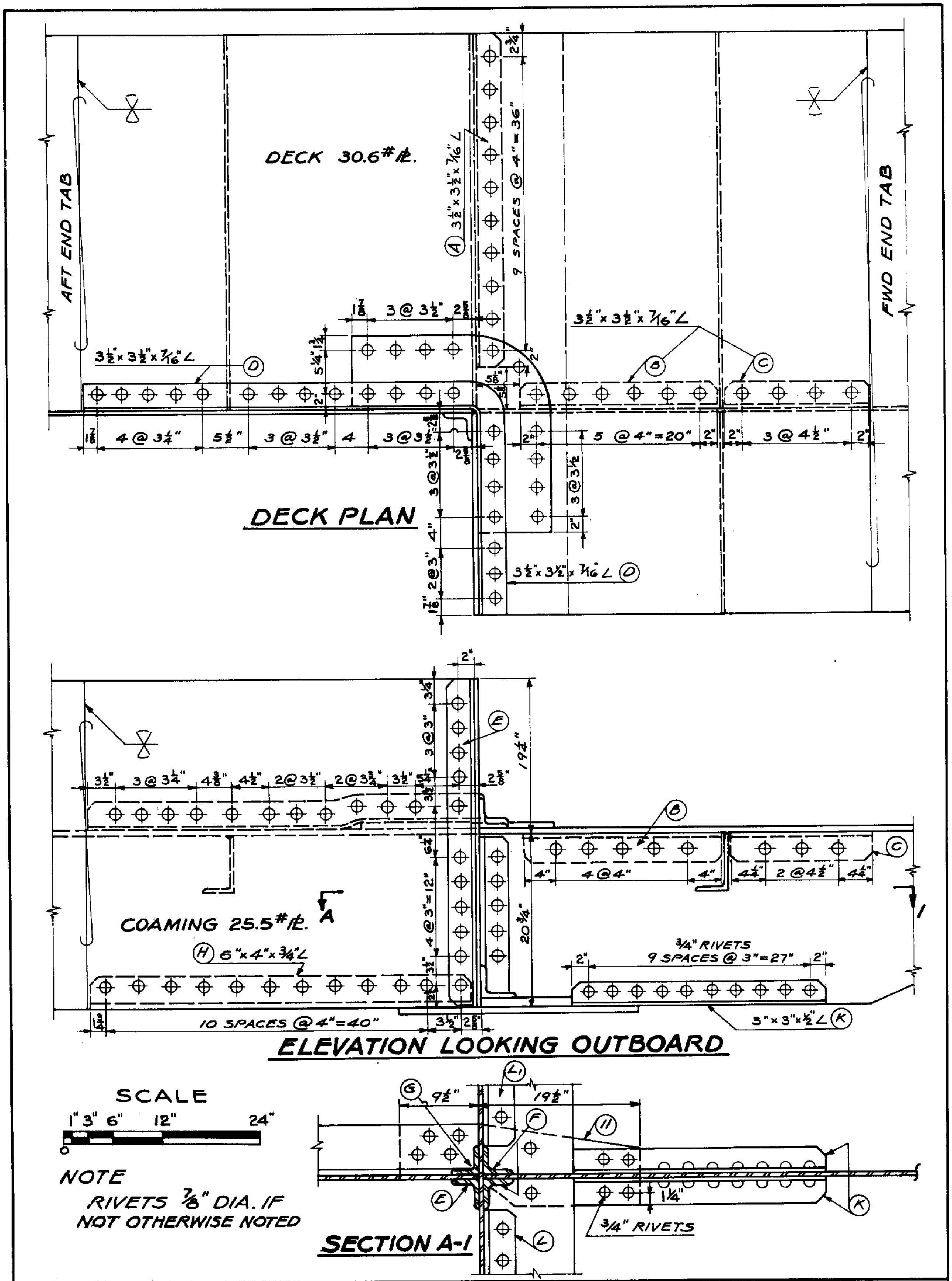


FIG. I

UNIVERSITY OF CALIFORNIA WELDING RESEARCH-NRC- 92 B 310 ENGINEERING BLDG. BERKELEY, CALIF.	REVISED DESIGN OF THE "FULL SCALE HATCH CORNER MODEL	SCALE	AS SHOWN	APPROVED	
		DR. BY	R. SISSON	6/11/45	DWG R-301
		CH. BY		/ /	PANEL



UNIVERSITY OF CALIFORNIA
WELDING RESEARCH
BERKELEY, CALIFORNIA

DESIGN OF RIVETED HATCH CORNER SPECIMEN

DR. BY R.C.S. 3/28/46
CHK. BY MMJ
APPVD. EJL

FIG. 2
DWG. No.
R-302