FINAL REPORT ON
SPOT WELDED STRUTS
FOR SNUPPS PROJECTS

TABLE OF CONTENTS

SECTION	TITLE	PAGE
1.0	Introduction	1
2.0	Material Description	1
3.0	Material Deficiency and its Safety Implication	1
4.0	Technical Evaluation and Criteria	2
5.0	Test Program at Jobsites	3
6.0	Additional Plan of Action	3
7.0	Test Program at Unistrut Corporation	4
8.0	Corrective Measures	5
9.0	Conclusions	5

TABLES:

1.	Test Results of Callaway and Wolf Creek Jobsites	6
2.	Test Specimen Details	7
3.	Shear Load Test Summary	8
4.	Retest of Specimen	9

SKETCH:

1.	Test Set-Up	10

1.0 INTRODUCTION

In accordance with the requirements of 10CFR 50.55e, this report is prepared to provide a final summary of the deficiency in spot resistance welding of electrical raceway support material, purchased under Specification No. 10466-E-037.

In July 1978, SNUPPS Project was advised of a problem related to inadequate spot resistance welding on the strut supplied by Unistrut to several other projects, where the adjoining channels were separating during fabrication of supports. No such failure was reported on either of SNUPPS jobsites. Immediately, tests were initiated at both SNUPPS sites. A total of 76 randomly selected samples from different strut types were subjected to a shear test to verify the weld strength. No failure was reported. The specification was revised to include shear test for any new material purchase as a precaution. Additionally, 380 randomly selected samples from both sites were tested at Unistrut test laboratory to obtain more data. Only one Unistrut Part No. P-5501, Coil No. 7J-4661 from Wolf Creek site, was found unsatisfactory. Immediately, actions were taken to remove this strut from the site.

2.0 MATERIAL DESCRIPTION

Basic strut channels are roll formed from hot dipped galvanized #12 gauge, 0.105 inch thick strip steel. These channels are connected to each other in various configurations, such as back-to-back, back-to-side, or side-to-side, by spot resistance welding. This material is purchased from Unistrut Corporation, Wayne, Michigan, as standard catalog items under the Specification 10466-E-037, used in field fabricated supports for electrical raceways.

3.0 MATERIAL DEFICIENCY AND SAFETY IMPLICATIONS

The strut is used in the electrical raceway support system design. The connection provided by spot welds between the strut sections is relied upon to maintain the integrity of the built-up section to carry the postulated loads, within the design margins. Thus, inadequate

fusion at the spot welding may result in inadequate strength and may adversely affect the safe operation of the plant, under severe loading conditions.

After revieweing the nature of the deficiency experienced on other projects, the following was concluded:

a. The deficiency was related to spot welding technique and/or procedure.
b. The quality of the spot welding can not be evaluated without actual test to verify the strength of the weld.
c. Destructive shear test will provide the failure load data for the weld, and will positively verify the soundness of the spot weld.

4.0 TECHNICAL EVALUATION AND CRITERIA

Based on the "Recommended Practices for Resistance Welding", AWS C1.1, by American Welding Society, AISI Specification for the Design of Cold-Formed Steel Structural Members, Part I, Section 4, specifies allowable shear strength per spot weld to be equal to 1.65 kips, with a factor of safety of 2.5 for 0.109 inch thickness. High factor of safety is specified to account for the dependence of the quality of spot weld on many variables such as tips of electrodes, pressure, voltage, current, presence of impurities, finish of the material, maintenance of the equipment.

The connection provided by spot welds between the strut sections is relied upon to maintain the integrity of the built up sections. The calculated shear in a spot weld in a member depends upon variables such as loading, sectional properties, end conditions, use of strut as beam, brace, column or tie, etc. Factor of safety used for the bending stresses in the struts is 1.65 in the design of the supports. Therefore, it is reasonable to consider a shear value different than that specified by AWS. Conservative weld strength requirement for SNUPPS Project is calculated to be a maximum of 1,200 lbs only. Therefore, for the analysis of the test data, failure load of 1,200 lbs. or below is considered inadequate.

It was also decided that when failure load is below 3,200 lbs. for a test specimen, two adjacent welds shall be tested to provide additional data. A value of 3,200 lbs. failure load is chosen as a conservative design base which includes safety factor of 2.5+.

5.0 TEST PROGRAM AT JOBSITES - (Callaway and Wolf Creek)

5.1 Testing

a. Forney Compressive Testing Machine (which is used for concrete testing) with specially fabricated fixtures was selected to perform this test.

b. Samples were selected at random from every strut lot received for different purchase orders.

c. Destructive shear test was performed and failure loads were recorded.

d. Summary of the test data is tabulated in Table No. 1.

5.2 Review of Test Data

Out of 76 samples tested, only one weld was below 3,200 lbs., failure load being 1,600 lbs., with adjacent weld at 3,400 lbs. Including the above weld, there were 3 welds between 3,400-4,000 lbs., two at 4,000 lbs., and 71 were above 4,000 lbs. Highest value was 9,000 lbs.

5.3 Conclusion of Initial Test

This data did not indicate any problems with struts at SNUPPS sites, and provided reasonable assurance about the adequate quality of spot welds. In addition, the specification was revised to require additional testing for future shipments.

6.0 ADDITIONAL PLAN OF ACTION

The following plan of action was decided in the meeting between Unistrut, SNUPPS and Bechtel on August 17, 1978:

a. Unistrut indicated that starting in 1978, all materials fabricated and delivered to the SNUPPS jobsites had been subjected to pull tests, the results of which were traceable to individual coils of materials delivered. This data was reviewed and considered acceptable, subject to final Bechtel audit. (This data was reviewed at Unistrut by a Bechtel representative on October 17, 1978, and was considered acceptable.)

b. Representative samples from 1976-1977 strut material shall be subjected to shear test, as the pull test data was not available or traceable.

c. Materials to be shipped in the future shall be required to have shear test, per revised specification.

7.0 TEST PROGRAM AT UNISTRUT CORP., WAYNE, MICHIGAN

7.1 Criteria

Basic criteria was set per Paragraph 4.

7.2 Samples

Quantity of samples was based on one weld per 100 feet of strut. An effort was made to select the samples from all different coil numbers previously delivered to Callaway and Wolf Creek jobsites. All samples were taken from stock, fabrication shop or scrap pile. Table No. 2 lists numbers of samples from each site, by strut type and number of coils. 3" long test specimens (380 total) were prepared and identified by Unistrut Q.A. department.

7.3 Testing

Shear tests were performed using compressive shear test set up per Sketch No. 1. The tests were witnessed by a Bechtel representative.

7.4 Review of Test Data

Summary of the test data is tabulated in Table No. 3. 352/380 specimens exceeded 3,200 lbs. shear load. An additional 15 specimens had shear loads between 2,400-3,200 lbs. An additional 10 specimens had shear loads between 1,200-2,400 lbs. Only 3 specimens were below 1,200 lbs., which were considered inadequate. Two of these were from the same Coil No. 7J-4661, Unistrut P-5501. These welds failed at sawcut, but three other samples from the same coil were above 4,000 lbs. One specimen below 1,200 lbs., was from Coil No. 7X-4444, Unistrut P-1001. There was a total of 15 samples from this coil, from which only one was below 1,200 lbs., two were above 2,400 lbs., and twelve were above 3,200 lbs. There were 15 samples from Coil No. 7K-4444 (same coil as 7X-4444, but different operator), 14 were above 3,200 lbs., and only one was at 2,350 lbs.

Additional data for the welds adjacent to the specimen with a failure load of below 3,200 lbs., are tabulated in Table No. 4. Average shear load (average of the original specimen and two adjacent welds), was higher than that of the original specimen. Two exceeded 3,200 lbs., one of which was from Coil No. 7K-4444.

7.5 Statistical Analysis

The test data was grouped according to the welding machine which produces a given shape. Statistical analyses were performed on each sample to include computation of sample statistics (e.g. mean and standard deviation), plotting histograms, and fitting probability density functions to the data. The factor of safety against failure, computed as,

$$\text{Factor of safety} = \frac{\text{Minimum specified weld strength}}{\text{Maximum design load}}$$

was greater than 2 for all samples; which is greater than the factor of safety for the strut material of 1.65. The minimum specified weld strength was determined for a 90% confidence level; i.e. 10% failures (minimum specified weld strength) in the lower tail of the probability density function.

7.6 Conclusion of Shear Tests at Unistrut

Based on the above, one Coil No. 7J-4661, Unistrut P-5501 at Wolf Creek site, was considered inadequate. All other pre-1978 strut material exceeds the design requirement; failure in Coil No. 7X-4444 is considered to be an isolated case.

8.0 CORRECTIVE MEASURES

a. Specification No. 10466-E-037 has been revised to include additional testing of the spot weld at the manufacturing plant. Documentation is required to be shipped with the strut.

b. Unistrut P-5501 Coil No. 7J-4661 is being removed from the Wolf Creek job site and will be replaced with acceptable material.

9.0 CONCLUSIONS:

The problem described in this report was the result of:

a. Inadequate test program prior to 1978 by Unistrut to verify the strength of the spot weld.

b. Inadequate maintenance of welding equipment by Unistrut.

Supplier's actions including the added Quality Assurance and test programs per revised specifications, will provide adequate assurance of effectively precluding reoccurrence of this problem in the future.

Table No. 1 - Shear Load Test Summary for Callaway and Wolf Creek Jobsites

Unistrut Part No.		No. Of Specimen	SHEAR LOADS (lbs.)			
			< 1,200	< 2,400	< 3,200	> 3,200
P-1001	Callaway	60				60
	Wolf Creek	8		1		7
(A)	TOTAL	68		1		67
P-5501	Callaway	0				0
	Wolf Creek	4				4
(B)	TOTAL	4				4
P-5001	Callaway	0				0
	Wolf Creek	4				4
(C)	TOTAL	4				4
TOTAL (A+B+C)		76		1*		75

Note: *1. When adjacent weld was subjected to shear test, it exceeded 3,200 lbs.

2. At Callaway, minimum and maximum shear loads were 4,000 lbs. and 9,000 lbs., respectively.

3. At Wolf Creek, minimum and maximum shear loads were 3,400 lbs. and 7,200 lbs., respectively.

Table No. 2 - Test Specimen Details:

	Unistrut Part No.	Total Quantity	Total No. Of Specimen	UNION - (CALLAWAY)			KANSAS - (WOLF CREEK)		
				Total Quantity	No. Of Specimen	No. Of Coils	Total Quantity	No. Of Specimen	No. Of Coils
	P-1001	20,000	216	10,000	91	7	10,000	125	8
	P-5501	8,000	68	2,000	12	5	6,000	56	6
	P-5001	9,500	96	3,500	23	2	6,000	73	29
TOTAL		37,500	380	15,500	126	14	22,000	254	43

Note: (1) Coil numbers selected for the sample at Callaway were different from those at Wolf Creek.

(2) All the samples were randomly taken from the respective coil number and Unistrut part number.

(3) P-1001, 20 foot long sections were made with five head welding machine. Samples representing each weld head were taken.

Table No. 3 - Shear Load Test Summary

Unistrut Part No.	No. Of Specimen	SHEAR LOADS (lbs.)			
		<1,200	<2,400	<3,200	>3,200
P-1001 Callaway	91	0	5	5	81
Wolf Creek	125	1	1	2	121
(A) TOTAL	216	1	6	7	202
P-5501 Callaway	12	0	1	5	6
Wolf Creek	56	2	1	2	51
(B) TOTAL	68	2	2	7	57
P-5001 Callaway	23	0	0	1	22
Wolf Creek	73	0	2	0	71
(C) TOTAL	96	0	2	1	93
TOTAL (A+B+C)	380	3*	10	15	352

* (1) 2 were from Coil No. 7J-4661, Part No. P-5501. Total of 6 samples from this coil were tested. 3 were above 4,000 lbs., 1 was 1,400 lbs., and 2 failed at sawcut.

* (2) 1 was from Coil No. 7X-4444(P-1001). A total of 15 samples were tested, twelve were above 3,200 [illegible] were above 2,400 lbs, and only one was below [illegible].

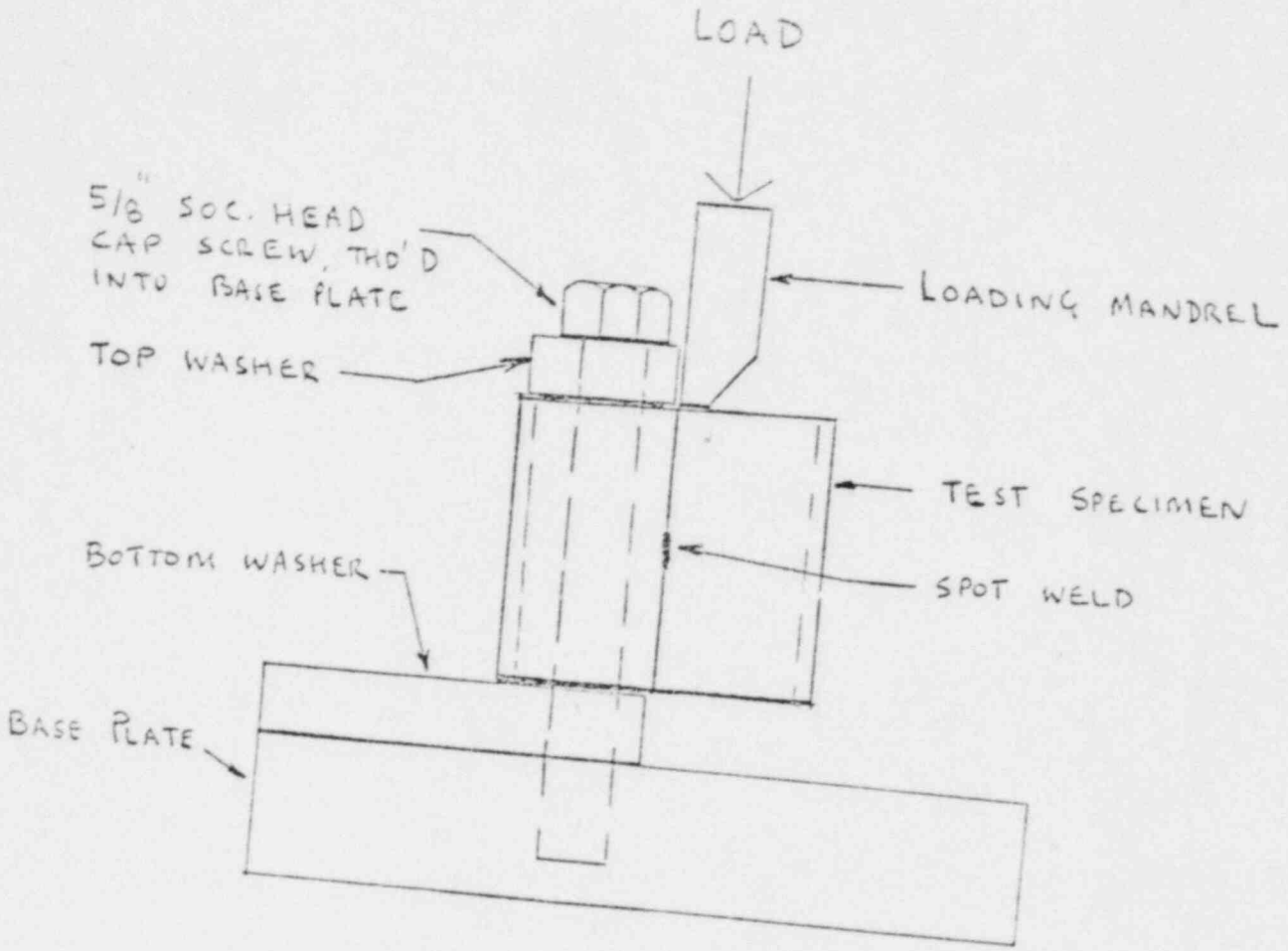
There were 15 samples from Coil No. 7K-4444 (same coil as 7X-4444, but different operator), 14 were above 3,200 lbs., and one was at 2,350 lbs. When adjacent welds were tested, average load exceeded 3,200 lbs.

Table No. 4 - Retest of Specimen, Below 3,200 lbs, Shear Load.

Unistrut Part No.	No. Of Specimen	AVERAGE SHEAR LOAD (lbs.)			
		<1,200	<2,400	<3,200	>3,200
P-1001 Callaway	10	0	5	4	1
Wolf Creek	4	1	1	1	1
(A) TOTAL	14	1	6	5	2
P-5501 Callaway	6	0	0	6	0
Wolf Creek	5	2	1	2	0
(B) TOTAL	11	2	1	8	0
P-5001 Callaway	1	0	0	1	0
Wolf Creek	2	0	2	0	0
(C) TOTAL	3	0	2	1	0
TOTAL (A+B+C)	28	3	9	14	2

Note: 1. Average shear load is the average of two adjacent welds and the original specimen.

2. Three specimens with a shear load below 1,200 lbs., are the same three specimens described in Table No. 3.



TEST SET UP

SKETCH. 1