Revision 1

JAN 4 '79 '098012

FINAL REPORT
ON
SPOT-WELDED STRUTS
FOR
SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 AND 2

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San Francisco, California

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*The Attachments were previously transmitted via PLA-295 dated October 9, 1978 and are not forwarded with this report.

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1.0 PURPOSE

The purpose of this report is to provide final data and information as required by 10CFR50.55(e)(3) subsequent to the notification of a reportable deficiency. The subject deficiency is associated with spot/resistance welding in strut material.

2.0 SPOT-WELDED STRUTS

2.1 Struts

Basic strut sections are light gage (thickness varying from 0.105 to 0.109 inch) channels manufactured by cold forming mild steel strip. These channel sections are connected to each other in various configurations such as back-to-back, back-to-side, or side-to-side by using a welding process commercially known as spot-welding or resistance welding. The channel sections and built-up sections used on Susquehanna project are either mill-galvanized or hot-dip galvanized after spot-welding and are supplied by Unistrut Corporation, Wayne, Michigan; Power Strut, Division of Van Huffel Tube Corporation, Warren, Ohio; and B-Line Systems Incorporated, Highland, Illinois. These were procured as standard off-the-shelf items with no formal Quality Assurance. Various configurations used on Susquehanna are given in Figure I.

Strut members are used in field fabricated supports for electrical raceways, HVAC ducts and instrumentation lines. The governing documents are drawing 8856-E-53 for electrical raceways, Specification 8856-M-323-C for HVAC ducts and Drawing 8856-JG-16 for instrumentation.

The supports are designed in accordance with 'Specification for the Design of Cold-formed Steel Structural Members' (1968 Edition), published by American Iron and Steel Institute.

2.2 Spot-Welding

The spot/resistance welding process consists of passing high current through the thicknesses of adjoining plates resulting in metal-to-metal fusion. The quality of a spot weld is dependent on many variables such as pressure on the electrode tips, finish of the material, presence of impurities on the material, build-up of zinc and other contaminents on the welding electrodes, contact between joining surfaces, voltage and amperage. Therefore, unless these parameters are closely monitored and controlled, the result may be inadequate fusion.

3.0 BACKGROUND

Since the use of strut material began on the Susquehanna Project, there were three isolated instances when the adjoining channels separated during handling or assembling. These member lengths were rejected.

However, in recent months there have been significant instances on other nuclear projects where inadequate fusion was observed at the weld spots. As a result of this, on March 25 and 26, 1978, Bechtel field engineering personnel performed an inspection on Unistrut member P-1004A, Powerstrut member PS-3022 and B-Line member B22-X. The tested members were part of installed electrical raceway and HVAC duct supports. The method of inspection consisted of 'sounding' the members with a ball peen hammer to detect separated spot welds and verification of the separation by insertion of a card between the members at the spot welds. The inspection indicated a high incidence of spot-welds with inadequate or no fusion. Therefore, Project Quality Assurance (QA) issued Management Corrective Action Report (MCAR) 1-23 on March 28, 1978.

4.0 DEFICIENCY AND ITS SAFETY IMPLICATIONS

Based upon the results of the inspection as described in Section 3.0, it was determined that:

a. The deficiency is related to spot-welding technique and/or procedure.

b. The quality of the spot-welding is indeterminate, without further investigation.

Various combinations and configurations of channel struts have been used in the support systems. Individual members have been designed as composite sections for which the connection (spot-welding used in this instance) between adjoining channels is relied upon to carry the postulated loads within established 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 design loading conditions.

5.0 IMMEDIATE ACTION

A 'Hold' was imposed on further installation of member P-1004A or its equivalent unless the member was stitch-welded to develop equivalent design strength of the spot-welding.

6.0 TEST PROGRAM

6.1 General

Although it was determined that a deficiency existed in some spot-welded members, the extent of the deficiency was unknown. So the first step was to establish the scope of the problem. Since there is no practical nondestructive method for examining the soundness of spot welds in the erected material, it was decided to initiate a destructive test program.

6.2 Basis of Test Program

The underlying approach is described below.

a. Obtain representative samples, selected at random, from the installed and stock material for all shapes and manufacturers.

b. Perform destructive shear test on the samples to obtain failure loads.

c. Analyze the test results statistically for each shape and manufacturer to compute corresponding expected strength per spot-weld at a certain confidence level.

6.3 Samples

Samples were obtained by Bechtel field engineering personnel and sent to a recognized testing laboratory.

Samples were typically 6" long containing two spot-welds. For the stock material, two samples were obtained from each 20'-0" length and only one sample from any given installed member selected at random. For the installed material, generally one sample was obtained for every 100 feet of the installed quantity.

6.4 Testing

Testing was done by Pittsburgh Testing Laboratory (PTL) in Pittsburgh, Pennsylvania. Test method and procedures are fully described in PTL's report. (See Attachment A).

6.5 Statistical Analysis

Based upon the test results, histograms were plotted for each shape and manufacturer. Mean and standard deviation were computed for each case. The test results generally follow the normal distribution.

The expected failure load per spot weld was determined by using the mean of the failure load based upon the test results and subtracting one and a half times the standard deviation. This approach provides more than 90% confidence level for the expected failure load.

Based upon above criteria, the expected failure loads were computed and are given in Table I.

7.0 TECHNICAL EVALUATION OF DEFICIENCY

7.1 General

The technical evaluation in this section is limited to all strut members installed and/or at the jobsite which are not fabricated.

7.2 Design Criteria and Theoretical Considerations

AISI specification 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. This allowable shear is based upon "Recommended Practices for Resistance Welding," AWS C1.1, by American Welding Society. Based on this criteria, the failure load for a spot should be over 4,000 pounds. However, in light of the problem associated with spot-welding, it is necessary to assess bases of code requirements and evaluate structural adequacy of the installed material without compromising the basic design philosophy.

The connection provided by spot welds between adjoining channel 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 many variables such as loading, sectional properties, end conditions and if the member is used as a beam, brace, column or tie.

The allowable shear of 1.65 kips/spot specified by the code is the upper limit for designing purpose. However, from the evaluation point of view, it is more realistic to consider actual maximum design shear calculated individually as required for each shape. Secondly, for the strut material (Fy = 33 k.s.i.) the allowable bending stress (F_b) per code is 20 k.s.i. for 0.105 inch thickness. Therefore, the factor of safety for the bending stress is considered to be 1.65 while for the spot-welds, it is 2.5, which is rather high. Reason for this could be attributed to many variable, affecting the weld strength. For the material in question on Susquehanna, an extensive test program has been carried out and expected failure loads for each shape are well defined. Therefore, it is reasonable to assume that a factor of safety of 2.0 for spot-welds, which is still higher than the factory of safety for bending of the strut material would still be adequate and consistent with the basic design philosophy.

7.3 Design Shear

The design of framing members in the support system is based upon allowable shear of 1650 lbs. per spot weld. Therefore, to maintain a minimum safety factor equal to 2.0, the expected failure load must be 3300 lbs. or greater.

7.3.1 The strut sections with the expected failure load equal to or greater than 3300 lbs/spot weld, are considered to be structurally adequate.

7.3.2 However, for the other sections, further evaluation is necessary.

Design loads on the support systems are governed by many considerations such as type of support, structure, elevation, etc. For individual members in a support, design shear forces additionally depend upon if the members are loaded flexurally or axially. It is noted that for flexural members, shear forces are generally high.

For the earlier investigation, a 5'-0" long member supporting uniformly distributed load was considered to be a representative case for various loading conditions, and member shapes, and comparison was made between computed design shears and expected failure loads.

However, in the final analysis, actual design shears were computed in individual members for all support types in various buildings and at different elevations.

These shear values vary considerably; therefore, the existing members, which may be adequate at a certain location, may need strengthening elsewhere depending on the aforementioned variables. In any case, a factor of safety of 2.0 has been maintained.

7.4 Summary

Based upon a factor of safety, of 2.0, all shapes are grouped in three categories.

Category I

Unistrut: P-5501, P-1001C, P-3301, P-1001A P-1001C3

Powerstrut: PS-151, PS-202

These shapes are structurally adequate and need no repair.

Category II

Unistrut : P-1001, P-5001

Powerstrut: PS-201, PS-101, PS-204

PS-3080

B-Line : B-12A

These sections are considered deficient at certain locations and need to be repaired as required.

Category III

Unistrut : P-1004A

Powerstrut: PS-3022

B-Line : B-22X, B-11A

All members of above shapes are to be repaired/ strengthened to provide shear connection capacity equal to twice the design strength required.

8.0 CORRECTIVE ACTION

8.1 General

Corrective actions are grouped in several categories. Each category and corresponding action is described below.

8.2 Installed and Stock Material

8.2.1 Powerstrut PS-3022,
Unistrut P-1004A
B-Line B-22X.

Based upon the inspection by Bechtel field engineering personnel, all material of this configuration was deemed to be deficient, and will be completely repaired without taking any credit for the existing spot welds.

8.2.2 B-Line B-11A.

Installed and stock quantity for this shape was small; therefore, no samples were obtained. In the absence of any test data on the existing spot welds, this section will be repaired to develop required design capacity to meet the design criteria.

⚠ 8.2.3 Powerstrut: PS-151, PS-202

Unistrut: P-5501, P1001C, P-3301, P-1001A, P-1001C3

Based upon the technical evaluation in Section 7.0, existing spot-welding is adequate and will perform satisfactorily under design loads. Therefore, no further action is deemed necessary.

⚠ 8.2.4 Powerstrut; PS-201, PS-101, PS-204, PS-3080

Unistrut : P-1001, P-5001

B-Line: B12A

These members do not meet the design criteria, therefore, a detailed re-analysis and redesign has been performed to compute required additional strength and design drawings have been prepared to show the necessary repair details. The required repair will be performed on the installed and stock material. On completion of the repair, the strut material will satisfy the design criteria.

8.3 Strut Material to be Received in the Future

Until now, the strut material was procured as a standard 'off the shelf' item. However, in light of the problem experienced with the spot-welding, a new specification 8856-C-92 (see Attachment C) was developed for procurement of all spot-welded struts in the future. The results of the testing by PTL positively indicate that the spot-welds on a plain material have much higher strength than spot-welds on mill-galvanized material. Therefore, the specification stipulates that strut material to be coated after spotwelding. In addition to this, to provide a reasonable assurance of attaining the design strength, the supplier is required to introduce a destructive testing program on the production samples and no material will be shipped to Susquehanna jobsite unless it meets the acceptance criteria. This action should prevent the recurrence of this problem in the future.

9.0 REPAIR METHODS

9.1 General

Construction has been provided the option to select any one of the following methods on a case-by-case basis.

9.2 Replacement

This method is to replace the deficient material with new material to be procured per Specification 8856-C-92 (see Attachment C).

9.3 Mechanical Fasteners

Second method is to provide 1/4" dia. self-drilling and self-tapping metal screws to obtain required shear strength. These screws will be procured per Specification 8856-C-91 (see Attachment C). In order to assure strength requirements for the screws, it is required to perform a destructive shear test on samples and each lot must meet the acceptance criteria.

In addition to self-drilling and self-tapping screws, other mechanical fasteners are being considered such as pop-rivets or clamps. If these are determined to be technically acceptable, they will be used as alternate to the screws.

9.4 Welding

Third approach is to provide intermittent stitch welding at the joint between channels and/or channel and side plate.

10.0 CONCLUSION

On completion of the required repair/replacement of the existing spot-welded struts determined to be deficient, the existing support systems will be structurally adequate to satisfy the design requirements. Secondly, procurement of new spot-welded strut material per new specification (see Attachment C), will provide adequate assurance of preventing the recurrence of this problem in the future.

TABLE I

EXPECTED FAILURE LOADS

Manufacturer	Member	Mean (lbs) (A)	Standard Deviation (lbs) (B)	Expected Failure Load = A - 1.5 B (lbs)	Remarks
Unistrut	P-1001	4140	1213	2321	Cat. II
	P-5501	5499	1229	3656	Cat. I
	P-5001	4357	1072	2749	Cat. II
	P-1001C	5386	1033	3837	Cat. I
	P-3301	5465	1025	3928	Cat. I
	P-1001A	4192	554	3361	Cat. I
	P-1001C3 (Back to back)	5186	629	4243	Cat. I
	P-1001C3 (Back to side)	5126	458	4439	Cat. I
Powerstrut	PS-201	4418	1194	2627	Cat. II
	PS-151	5533	892	4195	Cat. I
	PS-101	3855	782	2682	Cat. II
	PS-204	4150	2233	801	Cat. II
	PS-3080 (Back to back)	4126	1252	2248	Cat. II
	PS-3080 (Back to side)	4666	1511	2400	Cat. II
	PS-202	5783	1222	3950	Cat. I
B-Line	B12A	3565	1317	1590	Cat. II

Note: 1. Above numbers in the table are based upon one spot weld.
2. For explanation of 'Remarks" column, refer to section 7.4.
3. For shapes in Figure 1 and not in table above (i.e. those in Category III), refer to section 7.4.

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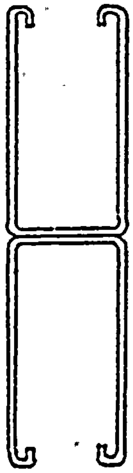
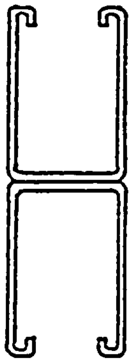
FIGURE 1

STRUT SHAPES AND IDENTIFICATION



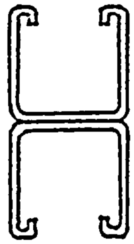
Shape J

Unistrut P-5001
Powerstrut PS-101
B-Line B-11A



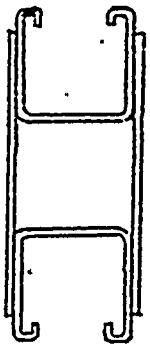
Shape R

Unistrut P-5501
Powerstrut PS-151
B-Line B-12A



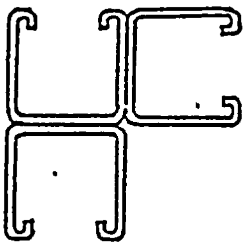
Shape K

Unistrut P-1001
Powerstrut PS-201



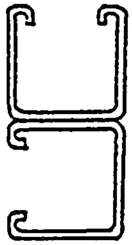
Shape M

Unistrut P-1004A
Powerstrut PS-3022
B-Line B-22X



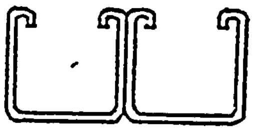
Shape N

Unistrut P-1001C3
Powerstrut PS-3080



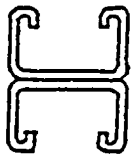
Shape L

Unistrut P-1001C
Powerstrut PS-204



Shape Q

Unistrut P-1001A
Powerstrut PS-202



Shape P

Unistrut P-3301