PP&L

TWO NORTH NINTH STREET, ALLENTOWN, PA. 18101 PHONE: (215) 821-5151

NORMAN W. CURTIS
Vice President-Engineering & Construction
821-5381

April 6, 1979

Mr. Boyce H. Grier
Director, Region I
U. S. Nuclear Regulatory Commission
631 Park Avenue
King of Prussia, Pennsylvania 17406

SUSQUEHANNA STEAM ELECTRIC STATION
FINAL REPORT OF UNDERSIZED WELDS ON
SAFETY RELATED PIPE HANGERS
DOCKET NOS: 50-387/50-388
LICENSE NOS: CPPR-101/CPPR-102
ERs 100450/100508 FILE 840-4
PLA-343

Dear Mr. Grier:

This supplements our letters PLA-202 dated December 1, 1977, PLA-239 dated April 6, 1978, and PLA-316 dated February 2, 1979 and represents the final report relative to the subject deficiency which was reported under the provisions of 10CFR50.55(e).

The deficiency involved dimensionally undersized welds on safety related pipe hangers fabricated for the Susquehanna Steam Electric Station by ITT Grinnell, Warren, Ohio under Bechtel Purchase Order 8856-P-3. The nonconforming conditions represented a deviation from hanger detailed design drawings and required an extensive evaluation of the "as-fabricated" undersized welds.

Investigation of the problem revealed that the problem resulted, in part, from the fact that the specification for shop fabrication of hangers (8856-M-209) lacked specific criteria for the acceptance/rejection of welds. This situation was corrected when, on October 18, 1977, Revision 11 of P.O. 8856-P-3 was transmitted to the supplier and provided a revised Specification 8856-M-209 which included appropriate inspection acceptance criteria.

Having established the necessary inspection criteria for future production of pipe hangers, an extensive reinspection program for all hangers produced by ITT Grinnell prior to October 18, 1977 was instituted by Bechtel QC at the SSES construction site on December 1, 1977 and was devised to prevent the

installation of nonconforming hangers; to verify the supplier's compliance to the new fabrication and inspection requirements; and to provide orderly controls for continuing construction installation activities. Visual inspections by Bechtel QC confirmed the acceptability of all Q-listed hangers shipped by ITT Grinnell after 10/18/77.

On December 12, 1977, the Bechtel inspection effort was directed towards all hangers at SSES which had been fabricated prior to the October 18, 1977 date. All welds on pipe supports and hanger components were examined by Bechtel in accordance with Article 9 of ASME B&PV Code Section V-1971 and the following ANSI Standard B31.1 visual acceptance criteria:

- Unacceptable indications
  - (1) Cracks - external surface.
  - (2) Undercut on surface which is greater than 1/32 inch deep.
  - (3) Weld reinforcement greater than that specified in a table in Para. 127.4.2 of the ANSI B31.1 Standard.
  - (4) Lack of fusion on surface.
  - (5) Incomplete penetration (applies only when inside surface is readily accessible).
- Fillet weld minimum dimensions as specified in ANSI B31.1-1973.

As necessary, during the Bechtel inspection effort, which was undertaken on 12/12/77 and concluded on 3/15/78, welds which did not meet specification requirements were reworked.

On March 15, 1978 Bechtel QC concluded the primary inspection function and ITT-Grinnell quality control personnel assumed the inspection function on-site employing the same (Bechtel) visual inspection acceptance criteria. Prior to initiating the inspections, Grinnell's QC Program was submitted to and approved by Bechtel Engineering.

At the outset of ITT-Grinnell's inspection effort, Bechtel QC held a preparatory meeting with ITT-Grinnell and established Bechtel QC surveillances, reviews and witness and hold points. (Bechtel QC documents its activities on Field Inspection Reports which are prepared weekly.)

There is a computer listing of pipe hangers which has been modified to provide a record of all the safety-related pipe hangers affected. The listing provides columns designating the hangers which, as determined by the Bechtel survey, have been judged acceptable or have been designated as requiring rework. These records have been updated to reflect where rework was accomplished and the status of the acceptability of the welds affected. These records reflect the interim (12/1/77 to 3/15/78) Bechtel inspection and rework effort.

Records of ITT-Grinnell's activities are maintained in accordance with its QC Program. The records of Bechtel and ITT-Grinnell inspections are being kept as separate documents. Both sets of records contain similar pertinent information.

In conjunction with its inspection effort, ITT-Grinnell prepared the attached report of the results and an analysis to verify the adequacy of the Susquehanna Project's hangers which were fabricated by ITT Grinnell in the fulfillment of Bechtel Purchase Order #8856-P-3-AC Rev. 12. This report has been reviewed and accepted by Bechtel Engineering who have stated:

> "In summary the conclusions of the report substantiate the adequacy of the Q-Listed hangers in question because:
>
> (a) All Q-Listed hangers shipped prior to 10/18/77 were inspected for undersized welds as well as for compliance with the revised specification requirements for visual weld acceptance criteria.
>
> (b) All Q-Listed hangers with undersized welds were analyzed in the "as-fabricated" condition to determine stress levels of the undersized welds.
>
> (c) None of the Q-Listed hangers with undersized welds were found to have weld stresses that exceeded the agreed upon allowables.
>
> (d) The ITT-Grinnell analysis of the undersized welds in the Q-Listed hangers has demonstrated that this condition does not present a safety hazard because none of the welds were over-stressed."

Presently, hangers in fabrication at the supplier's plant, being produced in accordance with Bechtel Specification 8856-M-209, Rev. 7, are of acceptable quality. We therefore conclude that additional corrective measures to preclude recurrence are not necessary.

Very truly yours,

N. W. Curtis
Vice President-Engineering & Construction

ARS:mcb

cc: Mr. J. G. Davis (15)
Acting Director-Office of Inspection & Enforcement
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Mr. G. McDonald, Director (1)
Office of Management Information & Program Control
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Mr. Robert M. Gallo
U. S. Nuclear Regulatory Commission
P.O. Box 52 Shickshinny, PA 18655

ITT GRINNELL CORPORATION

FIELD SURVEY INSPECTION OF PIPE SUPPORT SHOP WELDS FOR SUSQUEHANNA NUCLEAR PROJECT Q-LISTED HANGERS

FINAL REPORT

11/13/78

By _____ Date 11/13/78
L. Moreau
Project Engineer

Reviewed _____ Date 11/13/78
P. Stanish
Project Manager

Approved _____ Date 11/13/78
M. Grosso
Manager of Operations

_____ Date 11/13/78
R. Masterson, P.E.
Manager of Research,
Development &
Engineering

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ABSTRACT

This report contains the results of a field survey, through August 15, 1978 of Q-Listed supports with shop welds, made by ITT Grinnell's Warren Ohio fabrication facility, conducted by Bechtel Power Corporation and ITT Grinnell's engineering and Quality Control Departments. The results are analyzed to verify the adequacy of the supports on the Susquehanna Project fabricated by ITT Grinnell in the fulfillment of Purchase Order #8856-P-3-AC Rev. 12, as committed to the NRC by Pennsylvania Power & Light. In total, five hundred sixty (560) Q-Listed supports have been surveyed and one hundred fifty two (152) are found to have portions of shop welds below the size specified on the support detail. These welds are analyzed for the "as-fabricated" stress levels using the smallest weld section found along the particular weld. The results of this analysis show that all surveyed Q-Listed supports meet weld stress requirements of ANSI B31.1 and the stress acceptance criteria for welds.

I. INTRODUCTION

An agreement between Bechtel Power Corporation, Pennsylvania Power & Light and ITT Grinnell was reached to survey all of the shop welds for Q-Listed supports made at ITT Grinnell's Warren facility, and shipped prior to 10/18/77. ITT Grinnell agreed to compile and analyze each shop weld found in the surveyed assemblies with a non-conformance as defined by ITT Grinnell Quality Control Procedure #SQ-006 Rev. 0, which was approved by Bechtel on February 7, 1978, based on the smallest section of weld found.

The basis of this report intended to justify the acceptability of the referenced supports, by showing that none of the shop welds on these supports would be overstressed in the "as-fabricated" condition. Since specific tolerances are not required by ANSI B31.1, or the design specification, it is ITT Grinnell's position that supports fabricated with shop welds slightly below the size specified on the design drawing should be acceptable provided no shop welds are overstressed in the "as-fabricated" condition.

II. METHOD OF SURVEY

Prior to ITT Grinnell's inspection efforts, Bechtel had performed a preliminary survey of one hundred seventy two (172) Q-Listed supports. Of these, sixty-nine (69) were found to have weld sizes different from the design drawings. The results of this survey are given in Section IV of this report.

ITT Grinnell has inspected three hundred eighty eight (388) Q-Listed supports. Of these, eighty three (83) were found to have weld sizes different from the design drawings, as defined by ITT Grinnell Q.A. Procedure SQ-006. All discrepancies were tabulated and forwarded to ITT Grinnell's Hanger Engineering Department for analysis. The results of ITT Grinnell's survey through August 15, 1978 are included in summary in Section IV of this report. For the purpose of this report, a hanger requiring rework is defined as a support that has any shop weld that is overstressed due to undercut or shallow size in the "as-fabricated" configuration.

III. METHOD OF ANALYSIS

Weld stress calculations were performed for each Q-Listed support as required to verify that none of the shop welds were overstressed in the "as-fabricated" configuration. These calculations were performed using the smallest section found, carried the full length of the weld. This represents a conservative approach, since very few of the shop welds questioned were undersize for the full length.

Forces on the welds were determined in accordance with ITT Grinnell's Stress Criteria dated January 17, 1978, see Appendix D, which was approved with comments by Bechtel on March 9, 1978. The load per linear inch was calculated and compared to the maximum allowable load per linear inch as specified in the above listed Stress Criteria.

IV. Analysis of Results

A. Weld size different from design drawing

Listed below are the "as-fabricated" weld stresses for the shop welds in question on the surveyed assemblies, the allowable load per the Stress Criteria for the "as-fabricated" size, and the "α ratio" which is the allowable load divided by the actual calculated stress. All welds analyzed meet the maximum stress requirements of ITT Grinnell's Stress Criteria.

Sketch #	Shop Weld#	Load on Weld Actual (#/in.)	Allow (#/in.)	α
DBB-209-H15(Q)	1	160	1580	10
HBD-62-H10(Q)	1	44	1385	32
DBB-209-H3(Q)	1	122	1190	9.7
DBB-122-H5(Q)	1	750	995	1.33
H10(Q)	1	304	1580	5.2
H8 (Q)	1	73	1385	19
GBB-107-H14 sh.1(Q)	1	89	1190	13.4
sh.2(Q)	2	72	1190	16.5
HBB-101-H2(Q)	1	Pure Compression		
GBB-118-H5(Q)	1	Stiffener Plate Weld		
H8(Q)	1	"		
H10(Q)	1	"		
218-H5(Q)	1	"		
DLA-102-H4(Q)	1	"		
HBB-101-H4(Q)	1	124	1385	11
GBB-118-H11 sh.1(Q)	1	41	1580	38
sh.2(Q)	2	Stiffener Plate Weld		
GBB-107-H11(Q)	1	73	1580	22
"	2	73	1580	22
"	3	780	1190	1.5
HBB-108-H2(Q)	1	16	1190	72
"	2	6	1190	188
"	3	19	1190	63
HBB-220-H1(Q)	1	42	1385	33
"	2	405	1385	3.4
DBB-209-H5(Q)	1	109	1580	14.5
GBB-101-H13 sh.1(Q)	1	1037	1385	1.3
sh.2(Q)	1	680	1190	1.8
GBB-107-H13(Q)	1	85	1190	14.1
"	2	1257	1463	1.2
HRC-22-H6(Q)	1	412	1380	3.3
"	2	Not Loaded		
GBB-101-H30(Q)	1	778	1980	2.5
GBB-102-H15(Q)	1	448	1380	3.1
GBB-107-H17(Q)	1	400	1385	3.5
H18(Q)	1	Pure Compression		
GBB-101-H14(Q)	1	1260	1385	1.1
GBB-118-H7(Q)	1	Pure Compression		
GBB-118-H9(Q)	1	Stiffener Plate Weld		
HBB-220-H3(Q)	1	225	1385	6.2

Sketch #	Shop Weld#	Load on Weld Actual (#/in.)	Load on Weld Allow (#/in.)	
HRC-22-H1(Q)	1	50	1385	27.7
GBB-101-H7(Q)	2	185	1385	7.5
"	6	767	1190	1.6
GBB-218-H3(Q)	1	Stiffener Plate Welds Only		
GBB-218-H8(Q)	1	Stiffener Plate Welds Only		
GBB-218-H9(Q)	1	Stiffener Plate Welds Only		
GBB-218-H10(Q)	1	Stiffener Plate Welds Only		
GBB-118-H3(Q)	1	Stiffener Plate Welds Only		
HRC-22-H5(Q)	1	Not Loaded		
H4(Q)	1	Not Loaded		
DCA-111-H1(Q)	1	Pure Compression		
DLA-104-H1(Q)	1	" "		
DBB-113-H2(Q)	1	195	800	4.1
GBB-218-H6(Q)	1	Compression		
DLA-104-H3(Q)	1	Compression		
"	2	Not Loaded		
GBB-118-H1(Q)	1	Compression		
GBC-101-H63(Q)	1	"		
HBB-220-H5(Q)	1	128	1385	10.8
"	2	511	1385	2.7
H6(Q)	1	132	1385	10.5
DLA-103-H1(Q)	1	1166	1385	1.2
MST-022-H7(Q)	1	870	1980	2.3
H6(Q)	1	1445	1980	1.4
GBC-101-H61(Q)	1	Compression		
MSL-100-H4(Q)	1	"		
MST-022-H1(Q)	1	1055	1980	1.9
MST-022-H3(Q)	1	1055	1980	1.9
DLA-101-H2(Q)	1	Compression		
DBB-122-H4(Q)	1	"		
DCA-111-H2(Q)	1	"		
H4(Q)	1	"		
DBB-107-H2(Q)	1	Not Loaded		
"	2	" "		
GBB-218-H2(Q)	1	" "		
"	2	185	1190	6.4
GBB-118-H9(Q)	1	Not Loaded		
"	2	137	1385	10.1
GBB-107-H12(Q)	1	390	1385	3.6
"	2	276	1385	5
HRC-123-H5(Q)	1	55	1190	21.6
"	2	55	1190	21.6
"	3	55	1190	21.6
"	4	55	1190	21.6
"	5	75	1580	21.1
DBB-120-H7(Q)	1	Compression		
HRC-112-H12(Q)	1	412	1580	3.84
HRC-110-H2(Q)	4	177	1580	8.93
DBA-105-H2(Q)	1	Pure Compression		
DBB-112-H4(Q)	1 thru 4	Pure Compression		
DBB-114-H18(Q)	1	213	1190	5.58
GBB-119-H13(Q)	1	Pure Compression		
GBB-109-H11(Q)	1	Pure Compression		
DBB-115-H18(Q)	1	Pure Compression		

Sketch#	Weld#	Load on Weld Actual (#/in.)	Allow (#/in.)	
GBB-104-H41 (Q)	1	Pure Compression		
HBB-108-H1 (Q)	15 to 12	531	1190	2.24
DBB-114-H7 (Q)	1	Pure Compression		
DBB-120-H1 (Q)	1 & 2	Pure Compression		
HBB-110-H2 (Q)	5	503	1580	3.14
GBB-107-H12 (Q)	4 to 5	64	1385	21.6
GBB-107-H12 (Q)	3 to 5	182	1385	7.6
DBB-121-H2 (Q)	1	286	1190	4.2
DBB-115-H12 (Q)	1	25	1190	47.6
DBB-121-H3 (Q)	1	934	1190	1.27
DBB-109-H18 (Q)	1	Pure Compression		
"	2	205	1190	5.80
"	4-7	277	800	2.89
EBB-102-H3(Q)	1	536	1190	2.22
GBB-101-H11 (Q)	2	530	1190	2.24
"	5	680	1190	1.75
"	6	680	1190	1.75
"	7	364	1190	3.27
DBB-121-H24 (Q)	1	153	1190	7.77
GBB-107-H12 (Q)	1	390	1385	3.55
"	2	275	1385	5.03
GBB-118-H9(Q)	Stiff. Plate Secondary Member			
HBB-220-H3 (Q)	3 to 2	225	1385	6.15
GBB-109-H15 (Q)	3 & 4	Weld in compression		
GBB-115-H8 (Q)	2 & 3	584	1580	2.70
GBB-104-H29 (Q)	1 thru 4	519	1580	3.04
DBA-105-H2 (Q)	1	Weld in compression		
HBB-109-H3 (Q)	1	652	1190	1.82
"	2	639	1190	1.86
GBB-110-H13 (Q)	1	11	1190	108.18
HBB-108-H4 (Q)	3	946	1190	1.25
DBB-117-H6 (Q)	2	755	1190	1.57
" H3 (Q)	1	89	1190	13.37
HRC-131-H2 (Q)	1	745	1190	1.59
HRC-112-H11 (Q)	2	179	1190	6.64
GBB-104-H15 (Q)	2	280	1190	4.25
HBB-120-H5 (Q)	1	74	1190	16.08
HBB-110-H29 (Q)	2 & 3	226	1190	5.26
"	4 & 5	254	1190	4.68

All welds analyzed maintained a certain safety margin (α ratio) which ranged from 1.10 to 188. The reason for the wide variation in safety margin is that many of the shop welds questioned were designed at a minimal fabrication size regardless of the magnitude of the load applied.

NOTES:

1 - All welds included in the listing given in this section which have the comment "compression" in the stress column and do not list a calculated stress, reflect welds which are 1/16" or less undersize.

2 - All welds included in the listing given in this section which have the comment "stiffener plate weld" are shown without a calculated stress since they are secondary members.

IV. Analysis of Results

B. Undercut Welds

1. The following sketches have shop welds in compression with 1/16" undercuts or less, which Grinnell has handled in the same fashion as in Section IV.(A).

	Weld#		Weld#
DBB-107-H5 (Q)	1	DBB-114-H7 (Q)	1
DCA-110-H2 (Q)	1	GBB-109-H13 (Q)	4
GBB-103-H8 (Q)	3	GBC-101-H39 (Q)	1
GBB-214-H1 (Q)	1	GBC-101-H71 (Q)	1
GBC-101-H68 (Q)	1	HBB-110-H13 (Q)	1,2,7
GBC-101-H82 (Q)	1,2	HBB-113-H22 (Q)	1 thru 4
HBB-113-H11 (Q)	1	HRC-112-H4 (Q)	1 & 3
HRC-112-H2 (Q)	2	HBB-110-H17 (Q)	1 & 2
HRC-112-H7 (Q)	1 & 2	DCA-110-H5 (Q)	1
DBB-114-H17 (Q)	1	HBB-113-H3 (Q)	1
HBB-110-H19 (Q)	1	GBB-104-H7 (Q)	1
HRC-112-H14 (Q)	3	HBB-120-H8 (Q)	5

2. The following sketches have shop welds in tension with 1/16" undercuts or less. We have the following comments on those subject sketches.

a. DBB-121-H22 - The undercut is on the knee brace which is not needed. The section modulus of a M4x13 is 5.24 and the design requires 2.18. Therefore, the knee brace is not required.

b. GBB-112-H11 - The undercut is on the M-Beam weld to the plate. The area of this member is 3.81 sq. in. and it has been reduced by .06 sq. in. Therefore, this undercut does not need any rework.

c. GBB-101-H18 - The undercut is on the knee brace which is not required. The section modulus of a 6WF 15.5 is 10 and the design requires 6.26. Therefore, the knee brace is not required.

d. GBB-109-H8 - The undercut is on the knee brace which is not required. The section modulus of a 4 M13 is 5.24 and the design requires 3.86. Therefore, the knee brace is not required.

e. HRC-104-H2 - The undercut is at both ends of item #3 for a length of 1/4 of an inch. The maximum shear force at each end of item #3 is 581#. The surface area required to withstand 581# is less than 1/2 inch., the surface area remaining with the undercut is .95 sq. inches. Therefore, this undercut does not need any rework.

f. The following sketches have actual cross sectional areas or stresses less than required by design for the undercut material. No rework is required:

GBB-101-H8
HRC-123-H3
HBB-110-H26
GBB-112-H11
GBB-107-H3
DBB-115-H2

g. The following support, HBB-110-H3, could not be evaluated due to inadequacy on the original design

3. We have considered undercut welds in bending. The following sketches have the greatest moments that we have found during our survey to date.

Sketch No.	Load	Plate Thickness Required	Plate Thickness Design	Under-Cut	New Plate Thickness
HRC-126-H1	702	.552"	.625"	.031"	.594"
HCB-102-H1	340	.289"	.375"	.031	.344"

From the above finding, Grinnell concluded the undercuts in bending are all acceptable. The remaining supports in this category are:

3. (cont'd.)

HRC-123-H11 (Q)	GBB-101-H1 (Q)
GBB-109-H18 (Q)	GBB-104-H32 (Q)
HRC-126-H1 (Q)	DBB-115-H3 (Q)
HCB-102-H1 (Q)	HRC-131-H2 (Q)
GBB-101-H17 (Q)	HBB-113-H16 (Q)
GBB-110-H13 (Q)	HBB-110-H29 (Q)

4. The following sketches have welds with undercuts of secondary members, such as stiffener plates, which may be disregarded from the report.

(Q) DBB-107-H7 Weld No. 2

(Q) GBB-104-H22 Weld No. 4, 5

V. CONCLUSION

Of the five hundred sixty (560) Q-Listed supports surveyed, one hundred fifty two (152) were found to have shop welds that were shallower than the size specified in the design detail. These shop welds were recorded, subsequently analyzed, and the actual stress in the "as-fabricated" condition compared against mutually agreed upon allowables. The calculated safety margins (α ratio) ranged from 1.1 to 188. Through observation, it was seen that all welds were below allowables; therefore, none of the surveyed and analyzed supports have any shop welds which are overstressed.

As a result of this survey, all Q-Listed support welds on assemblies fabricated by ITT Grinnell and shipped to the Susquehanna jobsite have been visually inspected, calculations performed and all welds have been found to meet all requirements.

ITT Grinnell concludes from this inspection that all Q-Listed supports shipped prior to 10/18/77 to the Susquehanna jobsite are totally suitable for the designed service. All as fabricated welds meet the requirements of ANSI B31.1 or the agreed upon stress criteria.

VI. APPENDICES

APPENDIX A

QUALITY ASSURANCE PROCEDURE SQ-004

TITLE:
QUALITY ASSURANCE REQUIREMENTS - FIELD INSPECTION OF WELDS

Prepared By: R. Pavlik Date: 2/15/78
Approved By: [signature] Date: 2-15-78
Approved By: _____ Date: _____
EFFECTIVITY DATE 2/15/78 SUPERCEDES REV. 0
Q.A./Q.C. Approval: [signature] Date: 2/15/78

FOR: (Check One) ☐ P.H.D. Engineering ☐ Hanger R&D ☐ Manufacturing ☒ Other (Specify) Quality Control

1.0 OBJECTIVE:

This procedure shall document the Quality Assurance Requirements applying to the Field Inspection and/or Re-Inspection of Welds on Pipe Supports produced by ITT Grinnell.

2.0 APPLICATION:

This procedure shall apply to the Field Inspection of Fillet Welds on Customer Designed (Non-Standard) Pipe Supports manufactured by ITT Grinnell for the Susquehanna Steam Electric Station located @ near Berwick, Pennsylvania. All Bechtel Designed Shop Welds to be inspected shall be indicated on the ITT Grinnell Master Checklist as provided by ITT Grinnell PHD-Engineering.

3.0 QUALITY ASSURANCE REQUIREMENTS:

3.1 Organization - ITT Grinnell Personnel involved in the Field Inspection of Welds and their primary responsibilities will be as follows:

A. Inspection Personnel - will be responsible for the Visual and Dimensional Examination of Welds and for the generation and maintenance of documentation as required by this procedure. These persons shall report to the Warren Plant Quality Control Representative.

B. Warren Plant Quality Control Representative - a member of the Warren Plant Quality Control Department and will be responsible for the activities of the Inspection Personnel Will also provide interface at the Project Site between PHD-Engineering and the inspection program, and so forth. Also will be responsible for carrying out the requirements of this procedure at the Project Site. This person shall report to the Warren Plant Quality Control Manager.

C. Project Engineer - a member of PHD-Engineering and will be responsible for Engineering activities required by this procedure. Will also provide interface between Engineering, the customer, and Quality Assurance activities.

TITLE:
QUALITY ASSURANCE REQUIREMENTS - FIELD INSPECTION OF WELDS

Prepared By: R. Pavlik Date: 2/15/78
Approved By: _____ Date: _____
Approved By: _____ Date: _____
O.A./O.C. Approval: _____ Date: _____

EFFECTIVITY DATE 2/15/78 SUPERCEDES REV. 0

FOR: (Check One) ☐ P.H.D. Engineering ☐ Hanger R&D ☐ Manufacturing ☒ Other (Specify) Quality Control

D. Warren Plant Quality Control Manager - will have the overall administrative and Quality Assurance Requirements specified by this procedure.

3.2 Inspection - General

A. ITT Grinnell shall perform the Field Inspections and/or Re-inspections.

B. All inspection personnel performing Field Inspections of Fillet Welds shall be properly trained and qualified in accordance with Quality Control Procedure SQ-005, Rev. 0, Personnel Qualifications.

3.3 Weld Inspection

A. Welds to be inspected shall be those welds as shown on the latest revisions of the sketches to which the Pipe Supports were manufactured. The sketches shall be provided by ITT Grinnell PHD-Engineering.

B. Welds shall be inspected to the requirements specified in Quality Control Procedure SQ-006, Rev. 0, Visual and Dimensional Criteria for Welds.

C. All inspections performed shall be documented on a daily basis on the Daily Inspection Worksheet, Attachment 1.

D. The Master Checklist shall be noted each day showing which hanger assemblies have been inspected and whether or not the welds were in conformance to specifications.

E. Welds that have been inspected shall be identified in the following manner:

1) Each hanger assembly in which all the welds have been found to be in conformance to specifications shall be tagged with a Green Quality Approved Tag, Attachment 2.
2) Each hanger assembly in which one or more welds have been found in non-conformance to specifications shall be tagged with a Red Reject Tag, Attachment 3. The red tag may be removed and discarded upon disposition of the non-conformance and then green tagged, Attachment 2.

TITLE:
QUALITY ASSURANCE REQUIREMENTS - FIELD INSPECTION OF WELDS

Prepared By: R. Pavlik Date: 2/15/78
Approved By: _____ Date: _____
Approved By: _____ Date: _____
Q.A./Q.C. Approval: _____ Date: _____

EFFECTIVITY DATE 2/15/78 SUPERCEDES REV. 0

FOR: (Check One) ☐ P.H.D. Engineering ☐ Hanger R&D ☐ Manufacturing ☒ Other (Specify) Quality Control

F. Welds found to be in non-conformance to the requirements of Procedure SQ-006, Rev. 0, shall be dispositioned per the requirements specified in Section 3.4 below.

3.4 Non-Conformances

A. Non-conforming Materials shall be identified per the requirements of 3.3E-2 and logged per 3.3D.

B. The non-conformance shall be noted on the Daily Inspection Worksheet. The extent of the non-conformances shall be indicated in the applicable sections of the worksheet.

C. The disposition of Non-conformances shall be as follows:

1) The inspector shall forward to ITT Grinnell PHD-Engineering the original copy of the Daily Inspection Worksheet and the sketch for each non-conformance. One copy of the Worksheet and sketch shall be retained at the Site for reference. The worksheet shall identify the non-conforming welds and the extent of the non-conformance and the sketch shall show the type of support, location, etc. (NOTE: The welds may not be numbered on the sketch. It may, therefore, be necessary for the inspector to number the welds in order to provide a tie-in between the worksheet and the sketch. In that event, the welds can be numbered in any manner the inspector wants so long as the welds can be tied back to its applicable worksheet.

2) ITT Grinnell PHD-Engineering shall determine the disposition of the non-conformances through calculations and analysis based on the data contained in the worksheet. The acceptance or rejection of non-conformances shall be per the requirements of Quality Control Procedure SQ-007, Rev. 0, Acceptance Criteria for Welds.

3) PHD-Engineering, after determining the disposition of the non-conformances, shall return the Worksheet to the inspector. The worksheet shall have the disposition to be taken noted on the worksheet. The sketch shall be retained by PHD-Engineering for their records.

TITLE:
QUALITY ASSURANCE REQUIREMENTS - FIELD INSPECTION OF WELDS

Prepared By: R. Pavlik Date: 2/15/78
Approved By: _____ Date: _____
Approved By: _____ Date: _____
O.A./O.C. Approval: _____ Date: _____

EFFECTIVITY DATE 2/15/78 SUPERCEDES REV. 0

FOR: (Check One) ☐ P.H.D. Engineering ☐ Hanger R&D ☐ Manufacturing ☒ Other (Specify) Quality Control

4) In addition to returning the Worksheet, PHD-Engineering shall also at that time, generate a Rejected Material Report (RMR), Attachment 4, for rejected non-conformances (ie., Welds requiring rework). The RMR shall be completely filled in and dispositions noted and the MRB Authorization signed by the Project Engineer or his representative. The RMR No.'s shall be noted on the worksheet.

5) The RMR shall be distributed as follows:

a) PHD-Engineering shall retain the yellow copy (Supervisor Charged) for their records and forwarded to the inspector, the remaining copies, who will in turn distribute those copies.
b) The white copy (Quality Control) shall be retained by the inspector until the disposition has been carried out. The inspector shall verify that the disposition has been satisfactorily completed (the rework shall be in accordance with Bechtel Approved Procedures), and at that time, he shall note on the copy that the rework is O.K. and initial and date the copy. The copy shall then be forwarded to the Warren Plant Quality Control Manager.
c) The green copy (Dept. Supervisor) shall be forwarded to the Bechtel Representative. This copy shall be the means by which the customer is notified that a non-conformance is unacceptable and requires rework.
d) The gold copy (Production Control) shall be placed in Project Site files.
e) The hard-back copy shall be affixed to the affected hanger assembly and removed and discarded after satisfactory completion of the disposition.

3.5 Documentation - Maintenance and Distribution

A. The Documentation required for the verification of compliance to this procedure shall consist of the following:

1) Certificate of Qualification for Inspection Personnel
2) Project Sketches
3) Daily Inspection Worksheets
4) Rejected Material Reports
5) ITT Grinnell Master Checklist

TITLE:
QUALITY ASSURANCE REQUIREMENTS - FIELD INSPECTION OF WELDS

Prepared By: R. Paylik Date: 2/15/78
Approved By: _____ Date: _____
Approved By: _____ Date: _____
Q.A./Q.C. Approval: _____ Date: _____

EFFECTIVITY DATE 2/15/78 SUPERCEDES REV. 0

FOR: (Check One) ☐ P.H.D. Engineering ☐ Hanger R&D ☐ Manufacturing ☒ Other (Specify) Quality Control

B. The maintenance of the above listed documentation shall be as follows:

1) Certificate of Qualification - This document shall be kept on file with the Warren Plant Quality Control Manager and be available for review. A copy of the document shall also be kept on file by the Warren Plant Quality Control representative at the Project Site and be available for review.

2) Project Sketches shall be maintained as follows:

a) Sketches involving welds in conformance with specifications may be discarded after the inspection of those welds.
b) Sketches involving welds that are in non-conformance to specifications shall be kept on file with PHD-Engineering and be available for review.

3) Daily Inspection Worksheets shall be maintained as follows:

a) One copy of all worksheets shall be kept on file at the Project Site.
b) A copy of the worksheets involving non-conformances shall be kept on file by PHD-Engineering.
c) The original copies of all worksheets shall be kept on file by the Warren Plant Quality Control Manager.

4) Rejected Material Reports shall be kept on file by those groups receiving copies as outlined in 3.4C.

5) ITT Grinnell Master Checklist - one copy shall be retained by the inspection group at the Project Site and one copy maintained by PHD-Engineering.

C. Distribution of the above documents during the implementation of this procedure shall be in accordance with the specific sections of this procedure which address those documents. Any other distribution of the documents shall be at the discretion of the Warren Plant Quality Control Manager.

NOV 20 '78 : 036127

REVISION: A

Page 6 of 6

TITLE:
QUALITY ASSURANCE REQUIREMENTS - FIELD INSPECTION OF WELDS

Prepared By: R. Pavlik Date: 2/15/78
Approved By: _____ Date: _____
Approved By: _____ Date: _____
O.A./O.C. Approval: _____ Date: _____

EFFECTIVITY DATE 2/15/78 SUPERCEDES REV. 0

FOR: (Check One) ☐ P.H.D. Engineering ☐ Hanger R&D ☐ Manufacturing ☒ Other (Specify) Quality Control

D. Upon completion of the Field Inspection of Welds, the Project Site shall forward all their records to the Warren Plant Quality Control Manager. ITT Grinnell shall at that time, in accordance with contract requirements, notify the customer that the inspection program has been completed and obtain from the customer, directions as to what they want done with the records, ie; destroy, store, or send to customer.

ATTACHMENT 1

NOV 23 78 0361127

ITT GRINNELL - WARREN, OHIO

DAILY INSPECTION WORKSHEET

NO. _____

HANGER MARK NO.	WELD NO.	SPECIFIED WELD SIZE		ACTUAL FILLET WELD SIZE INDICATE ACTUAL SIZE(S) IF UNDERSIZE AND THE LENGTH OF THE SIZE(S).							OVER-SIZE	WELD CONFORMANCE TO SKETCH		CONTENTS	DO NOT WRITE IN THESE SPACES - FOR P.I.D. ENGINEERING USE.			
				EXACT	UNDERSIZE										DISPOSITION		DISPOSITION BY AND DATE OF DISPOSITION	
		SIZE	LGTH.	LGTH.	SIZE	LGTH.	SIZE	LGTH.	SIZE	LGTH.	LGTH.	YES	NO		ACCEPT AS - IS	REWORK (REJECT		

INSPECTOR _____ DATE _____

ATTACHMENT 2
SQ-004

NOV 20 '78 096127

ITT GRINNELL
WARREN, OHIO

QUALITY APPROVED

Order No. _____ Reg. No. _____

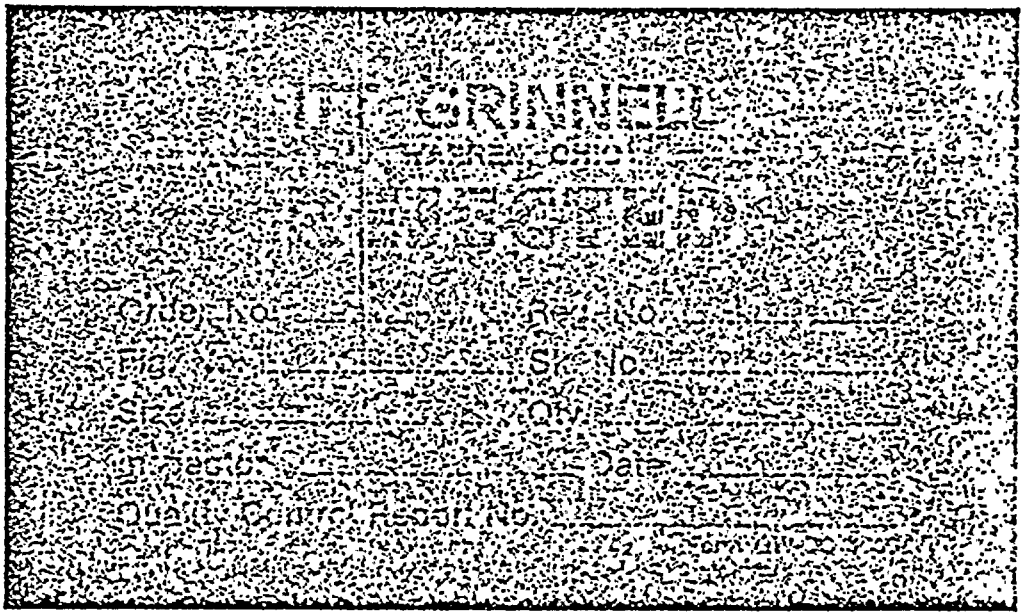
Fig. No. _____ Sk. No. _____

Size _____ Qty. _____

Inspector _____ Date _____

Form GW-QC 1007

ATTACHMENT 3
SQ-004



ATTACHMENT 4
SQ-004
NOV 20 '78 096127

UARCO BUSINESS FORMS
CHICAGO, ILLINOIS

Grinnell Corporation
Hanger Division
n, Ohio 44481

Rejected Material Report

No. 02363

re No./Description		Order No.	Date
		Source	Lot Size
/Sketch No.	Rev.	Log No.	Sample Size
nded for		Inspector	Total No. Reject

INSPECTOR'S REPORT

n	

MRB DISPOSITION

	Accept as is (See comments)			Q.C.		
	Rework			ENG.		
	Repair					
	Scrap					
	Other (Specify in Comments block)					

mments:

QUALITY CONTROL

M GW-QC-1028

APPENDIX B

QUALITY ASSURANCE PROCEDURE SQ-005

ITT GRINNELL CORP. GRAPH.

PIPE HANGER DIVISION
PROVIDENCE, R.I./WARREN, OHIO NOV 20 '78 096127

REVISION: 0

QUALITY ASSURANCE/QUALITY CONTROL PROCEDURE

Page 1 of 2

TITLE:

PERSONNEL QUALIFICATIONS

Prepared By: R. Pavlik Date: 1/31/78

Approved By: [signature] Date: 2-1-78

Approved By: Date:

EFFECTIVITY DATE 1/31/78 SUPERCEDES REV. N/A

O.A./O.C. Approval: [signature] Date: 2/1/78

FOR: (Check One) ☐ P.H.D. Engineering ☐ Hanger R&D ☐ Manufacturing ☒ Other (Specify) Quality Control

1.0 OBJECTIVE:

This procedure shall document the training and qualification requirements for Inspection Personnel conducting Field Inspections of Welds.

2.0 APPLICATION:

This procedure shall apply to all Inspection Personnel performing Field Inspections of Fillet Welds on Pipe Supports manufactured by ITT Grinnell for the Susquehanna Steam Electric Station.

3.0 TRAINING AND QUALIFICATION REQUIREMENTS:

3.1 All Inspection Personnel shall have a Visual Examination to assure natural or corrected near distance acuity such that they are capable of reading standard J-1 Letters on Standard Jager Test type charts for near vision. The examination must be taken at least once annually to maintain qualification for Field Inspection of Welds.

3.2 All Inspection Personnel shall attend a training session of at least 2 1/2 hours (or combination thereof). The training session shall be conducted by the Warren Plant Quality Control Department. The course contents shall consist of the following:

A. Quality Assurance Requirements (Procedure SQ-004, Rev. 0)
B. Inspection Criteria (Procedure SQ-006, Rev. 0)
C. Inspection Methods, Techniques.
D. Use, Handling of Inspection Gages and Tools

3.3 Upon completion of the training session, each candidate shall be tested as follows:

A. Written test covering topics listed above.
B. Practical Test to demonstrate proficiency in inspection. The test shall consist of having each candidate visually and dimensionally inspecting selected welded items and evaluating the persons use of gages and techniques. Also general questions shall be asked regarding the procedure to be followed for non-conforming welds and the like.

TITLE: PERSONNEL QUALIFICATIONS

Prepared By R. Pavlik Date 1/31/78
Approved By: _____ Date: _____
Approved By: _____ Date: _____
Q.A./Q.C. Approval: _____ Date: _____

EFFECTIVITY DATE 1/31/78 SUPERCEDES REV. N/A

FOR: (Check One) ☐ P.H.D. Engineering ☐ Hanger R&D ☐ Manufacturing ☒ Other (Specify) Quality Control

3.4 To be qualified to Field Inspect Welds, in addition to the requirements specified in 3.1, 3.2, and 3.3 above, each person must achieve a passing grade on the tests specified in 3.3 above. A passing grade is combined average of 80% for both tests, with a score of not less than 70% for any individual test.

3.5 A Certificate of Qualification shall be made out for each person who successfully meets the requirements of this procedure. (Attachment 1)

ITT Grinnell Corporation

621 Dana Avenue, N. E.
Warren, Ohio 44481
Telephone (216) 399-7566

CERTIFICATE OF QUALIFICATION

This is to certify that _____ has met the applicable requirements for formal training and testing in accordance with Quality Control Procedure SQ-005, Rev. 0, Personnel Qualifications in order to qualify for:

FIELD INSPECTION OF FILLET WELDS

APPROVED BY: _____ TITLE: _____ DATE: _____	APPROVED BY: _____ QC MGR.: _____ DATE: _____

TEST SCORES:

Written: _____

PRACTICAL: _____

AVERAGE: _____

APPENDIX C

QUALITY ASSURANCE PROCEDURE SQ-006

PIPE HANGER DIVISION
PROVIDENCE, R.I./WARREN, OHIO

NOV 20 78 030127

REVISION: 0

QUALITY ASSURANCE/QUALITY CONTROL PROCEDURE

Page 1 of 2

TITLE:

VISUAL AND DIMENSIONAL CRITERIA FOR WELDS

Prepared By: R. Pavlik Date: 2/1/78

Approved By: J.B. Date: 2-1-78

Approved By: Date:

EFFECTIVITY DATE 2/1/78 SUPERCEDES REV. N/A

Q.A./Q.C. Approval Date: 2/1/78

FOR: (Check One) ☐ P.H.D. Engineering ☐ Hanger R&D ☐ Manufacturing ☒ Other (Specify) Quality Control

1.0 OBJECTIVE:

This procedure shall document the Visual and Dimensional Criteria applying to Field Inspection of Welds.

2.0 APPLICATION:

This procedure shall apply to Field Visual and Dimensional Inspection of Fillet Welds on Pipe Supports manufactured by ITT Grinnell for Susquehanna Steam Electric Station.

3.0 TYPES OF EXAMINATIONS:

3.1 Visual Examination: Visual Examination shall consist of inspecting welds using unaided eyesight, except for the use of articicial lighting and mirrors for hard to get welds and welds located in areas with insufficient lighting.

3.2 Dimensional Examination: Dimensional Examination shall consist of comparing welds with sketch requirements using weld fillet gages, scales, and steel tapes not requiring calibration.

4.0 LEVELS OF EXAMINATION:

Both Visual and Dimensional inspections shall be made for the total length of all welds requiring inspection.

5.0 VISUAL ACCEPTANCE CRITERIA OF WELDS:

5.1 The following indications shall be considered to be in nonconformance:

a) Cracks - external surfaces.

b) Undercut on surface which is greater than 1/32 inch deep as determined by comparison with ITT Grinnell Calibrated Comparator.

c) Lack of fusion on surface.

d) Incomplete penetration (Applies only when inside surface is readily accessible).

5.2 Weld Profiles shall be as illustrated in Figure 1.

TITLE:
VISUAL AND DIMENSIONAL CRITERIA FOR WELDS

Prepared By: R. Pavlik Date: 2/1/78
Approved By: _____ Date: _____
Approved By: _____ Date: _____
O.A./O.C. Approval: _____ Date: _____

EFFECTIVITY DATE 2/1/78 SUPERCEDES REV. N/A

FOR: (Check One) ☐ P.H.D. Engineering ☐ Hanger R&D ☐ Manufacturing ☒ Other (Specify) Quality Control

6.0 DIMENSIONAL ACCEPTANCE CRITERIA OF WELDS:

6.1 Welds shall be inspected for size as illustrated in Figure 1. (NOTE: For angles greater than 120° or less than 60°, the size of the weld shall be determined by measuring to the lines of fusion as illustrated in Figure 1.

6.2 All welds in which any part of the length weld is below the size indicated on the sketch, shall be considered in non-conformance to the sketch requirements.

7.0 NON-CONFORMANCES:

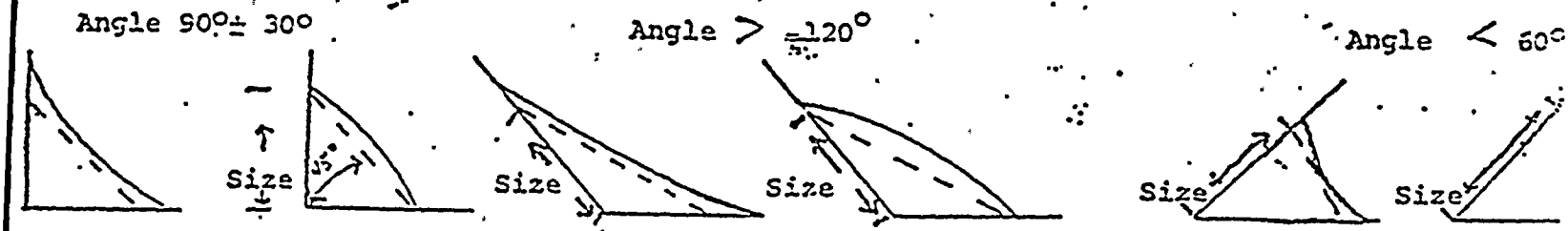
Non-conformances shall be documentated and dispositioned per the requirements specified in Procedure SQ-004, Quality Assurance Requirements.

8.0 SURFACE CONDITIONS:

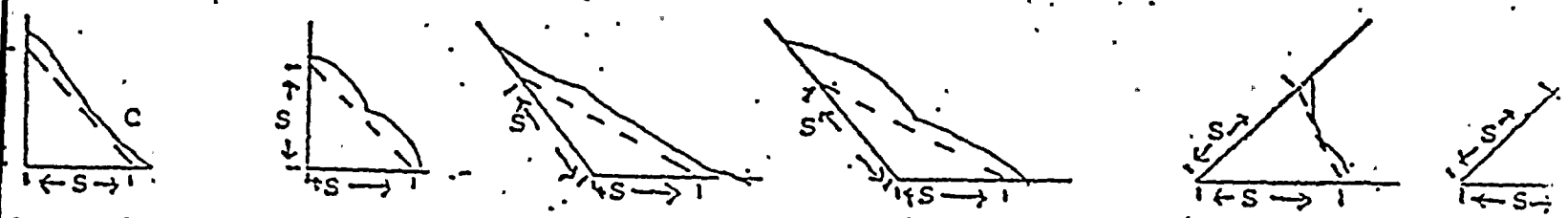
Welds will be inspected in the as coated condition, free from surface conditions that will interfere with obtaining meaningful results.

SQ-006 REV 0

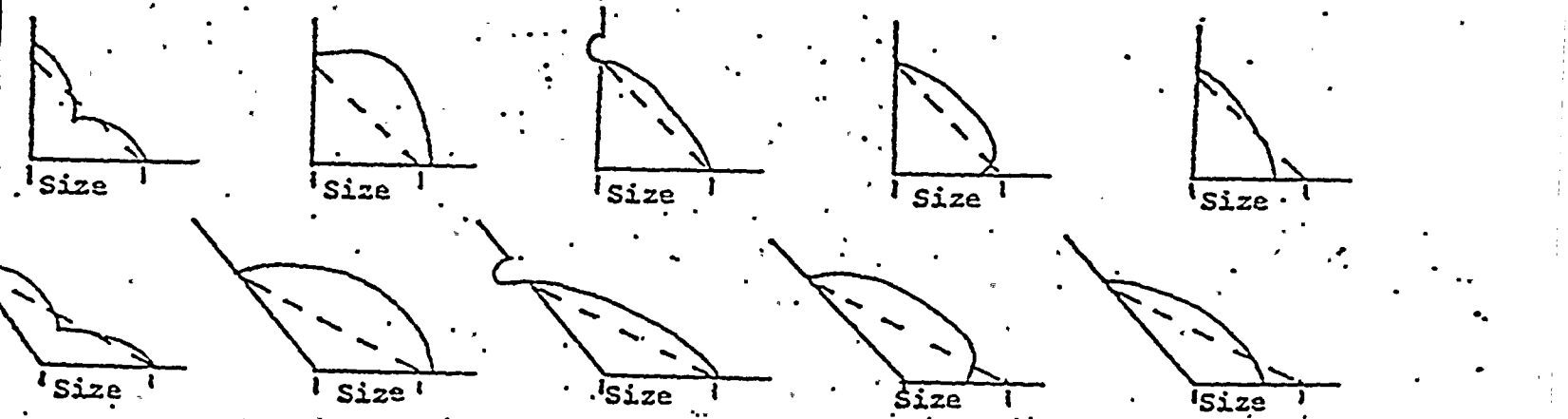
FIGURE 1



Desirable Fillet Weld Profiles



Acceptable Fillet Weld Profiles



Defective Fillet Weld Profiles

APPENDIX D

STRESS ACCEPTANCE CRITERIA FOR WELDS

January 27, 1978 096127

ITT GRINNELL CORPORATION
PIPING DIVISION
SUSQUEHANNA UNIT #1 & 2 JAN 31 78 081848
FILLET WELD ACCEPTANCE CRITERIA

GUIDELINES TO DETERMINE
ACCEPTABILITY OF UNDERSIZED WELDS

1.) Allowable load/inch for one side fillet weld

3/16 = ~~1360#/in.~~ 1190 #/in
1/4 = ~~1810#/in.~~ 1580 #/in
5/16 = ~~2270#/in.~~ 1980 #/in
3/8 = ~~2720#/in.~~ 2380 #/in
1/2 = ~~3620#/in.~~ 3170 #/in

BECHTEL COMMENT

2.) PURE TENSION HANGERS

a) Measure effective length of the fillet weld.

b) Measure the size of fillet weld with the appropriate gage. See note 6.

c) Assume total effective length to be undersized ~~Record the length of weld that is undersized.~~

d) ~~Use an interaction between the undersized and the design weld to come up to the allowable calculated load (see example).~~ Multiply total effective length to allowable load/inch outlined above to come up with allowable calculated load.

BECHTEL COMMENT

e) Compare calculated allowable load with the design load.

BECHTEL COMMENT

f) If the allowable calculated load is greater than the design load, weld is approved. If it is less than the design load, weld is disapproved.

3.) PURE COMPRESSION HANGERS & SHEAR HANGERS

a) If weld is only 1/16" undersized, the weld is approved. If the undersize is greater than 1/16", repeat steps C through F above.

BECHTEL COMMENT

4.) For supports with bending loads on the weld, the allowable loads should be calculated according to Attachment 1 (See Example II) AND SENT TO BECHTEL SFHO FOR FINAL ACCEPTANCE.

5.) The support type should be as per SFHO fig. 1x-2.6.

6.) For welds in tension and bending, fit-up gaps in excess of 1/32" shall be deducted from the size of the fillet weld in b) and d) above.

7.) When design or fabrication creates the situation where design fillet conditions are physically impossible to achieve, this condition shall be sent to Bechtel SFHO FOR DISPOSITION.

8856-P3-91-#2

EXHIBIT X

JAN 31 78 NOV [illegible] 818 656127

PURE TENSION MATTER

The total effective weld length was measured as 10 inches with 8 inches of 1/4 inch and 2 inches of 3/16 in. weld. The total tensile load applied at the joint is 15000 #.

Using the chart and interacting the loads

8 inches of 1/4" or greater
8 x 18~~2~~ = 14~~4~~#
2 inches of 3/16
2 x 1360 = 2720#

Total = 1448~~0~~ + 272~~0~~ = 1720~~0~~# > 15000#

∴ Weld is approved.

use worked up allowables for fillet welds

BECHTEL COMMENT

January 17, 197[illegible]

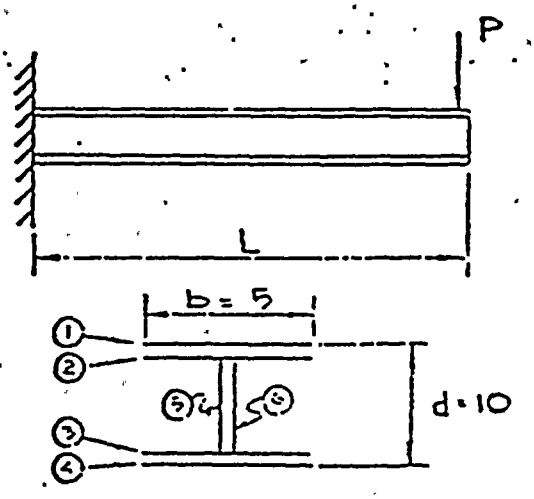
NOV 20 '78 096127

ATTACHMENT 1 MAR 31 '78 081848

EXAMPLE II

BENDING

Beam loaded as shown below has a 1/4" weld all around. The welds are measured and are shown in weld diagram.



L = 20"
P = 7000#
M = 140000 in #

Weld 1 & 4 are 1/16 undersized.

From Table 4 (See Attachment 2)

$$f = \frac{M}{Sw}$$

but, f for the cross section above is not constant. We can still relate the moment capacity of the weld to the applied bending moment and if the moment capacity of the weld group is greater than the applied moment, then the weld is acceptable.

Therefore, from table 4 & 5, (See Attachment 3).

$f\ (Sw) = Mw$

f 1/4 = 1820 #/in 1580
f 3/16 = 1360 #/in 1190

$(f1/4)\ (Sw1/4) + (f3/16)\ (Sw\ 3/16) = Mw$

BECHTEL COMMENT

BECHTEL COMMENT

1580
[illegible] (83.3) + [illegible] (50) = Mw

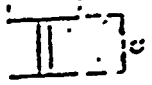
150773 + 68000 in-# = Mw

218773 in-# = Mw

BECHTEL COMMENT

218773 > 140000

Weld is acceptable



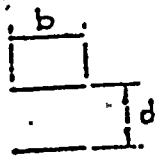
Sw1/4 = bd + $\frac{d^2}{3}$

= (10)(5) + $\frac{25}{3}$

= 50 + 33.3

= 83.3 in^2

JLK 31 78 081848.



Sw3/16 = bd

= (10)(5)

= 50 in^2

Normally the use of these standard design formulas results in a unit stress, psi, however, when the weld is treated as a line, these formulas result in a force on the weld, lbs per linear inch.

For secondary welds, the weld is not treated as a line, but standard design formulas are used to find the force on the weld, lbs per linear inch.

In problems involving bending or twisting loads Table 5 is used to determine properties of the weld treated as a line. It contains the section modulus (S_w), for bending, and polar moment of inertia (J_w), for twisting, of some 13 typical welded connections with the weld treated as a line.

For any given connection, two dimensions are needed, width (b) and depth (d).

Section modulus (S_w) is used for welds subject to bending loads, and polar moment of inertia (J_w) for twisting loads.

Section moduli (S_w) from these formulas are for maximum force at the top as well as the bottom portions of the welded connections. For the unsymmetrical connections shown in this table, maximum bending force is at the bottom.

If there is more than one force applied to the weld, these are found and combined. All forces which are combined (vectorially added) must occur at the same position in the welded joint.

Determining Weld Size by Using Allowables

Weld size is obtained by dividing the resulting force on the weld found above, by the allowable strength of the particular type of weld used (fillet or groove), obtained from Tables 6 and 7 (steady loads) or Tables 8 and 9 (fatigue loads).

If there are two forces at right angles to each other, the resultant is equal to the square root of the sum of the squares of these two forces.

$$f_r = \sqrt{f_1^2 + f_2^2} \qquad \text{.....(3)}$$

If there are three forces, each at right angles to each other, the resultant is equal to the square root of the sum of the squares of the three forces.

$$f_r = \sqrt{f_1^2 + f_2^2 + f_3^2} \qquad \text{.....(4)}$$

One important advantage to this method, in addition to its simplicity, is that no new formulas must be used, nothing new must be learned. Assume an engineer has just designed a beam. For strength he has used the standard formula $\sigma = M/S$. Substituting the load on the beam (M) and the property of the beam (S) into this formula, he has found the bending stress (σ). Now, he substitutes the property of the weld, treating it as a line (S_w), obtained from Table 5, into the same formula. Using the same load (M), $f = M/S_w$, he thus finds the force on the weld (f) per linear inch. The weld size is then found by dividing the force on the weld by the allowable force.

TABLE 5—Properties of Weld Treated as Line

Outline of Welded Joint (bold)	Bending (about horizontal axis x-x)	Twisting
	$S_w = \frac{d^2}{6}$	$J_w = \frac{d^3}{12}$
	$S_w = \frac{d^2}{3}$	$J_w = \frac{d(4b^2+d^2)}{6}$
	$S_w = bd$	$J_w = \frac{b^3}{6} + \frac{bd^2}{2}$
	$S_w = \frac{(b+2c)d^2}{6}$ top; $\frac{d^2(b+c)}{2b+4c}$ bottom	$J_w = \frac{(b+2c)d^3}{12} - \frac{c^2d^2}{b+2c}$
	$S_w = bd + \frac{d^2}{3}$	$J_w = \frac{bd(b+d)^2}{6}$
	$S_w = \frac{(b+2c)d^2}{3}$ top; $\frac{d^2(b+c)}{2b+4c}$ bottom	$J_w = \frac{(b+2c)d^3}{12} - \frac{c^2d^2}{b+2c}$
	$S_w = \frac{(b+2c)d^2}{3}$ top; $\frac{(2c+d)^2}{4c+2d}$ bottom	$J_w = \frac{d^2(3c+d)}{6(c+d)} - \frac{b^2}{6}$
	$S_w = bd + \frac{d^2}{3}$	$J_w = \frac{b^3+3bd^2+d^3}{6}$
	$S_w = 2bd + \frac{d^2}{3}$	$J_w = \frac{2b^3+6bd^2+d^3}{6}$
	$S_w = \frac{\pi d^2}{4}$	$J_w = \frac{\pi d^3}{4}$
	$S_w = \frac{\pi d}{2}\left(b' + \frac{d'}{2}\right)$ $S_w = \frac{J_w}{c}$ where $c = \frac{\sqrt{b'^2+d'^2}}{2}$	

Applying System to Any Welded Connection

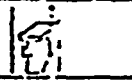
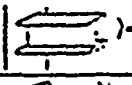
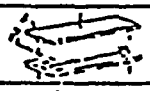
1. Find the position on the welded connection where the combination of forces will be maximum. There may be more than one which should be considered.

2. Find the value of each of the forces on the welded connection at this point. (a) Use Table 4 for the standard design formula to find the force on the weld. (b) Use Table 5 to find the property of the weld treated as a line.

3. Combine (vectorially) all of the forces on the weld at this point.

4. Determine the required weld size by dividing this resultant value by the allowable force in Tables 6, 7, 8, or 9.

TABLE 4—Determining Force on Weld

Type of Loading		standard design formula stress lbs/in²	treating the weld as a line force lbs/in.
	PRIMARY WELDS transmit entire load at this point		
	tension or compression	$\sigma = \frac{P}{A}$	$f = \frac{P}{A_w}$
	vertical shear	$\sigma = \frac{V}{A}$	$f = \frac{V}{A_w}$
	bending	$\sigma = \frac{M}{S}$	$f = \frac{M}{S_w}$
	twisting	$\sigma = \frac{TC}{J}$	$f = \frac{TC}{J_w}$
	SECONDARY WELDS hold section together - low stress		
	horizontal shear	$\tau = \frac{VAy}{It}$	$f = \frac{VAy}{In}$
	torsional horizontal shear*	$\tau = \frac{T}{2At}$	$f = \frac{T}{2A}$

* A = area contained within center line.
(*) applies to thin tubular sections only.

6. SIMPLE TENSILE, COMPRESSIVE OR SHEAR LOADS ON WELDS

For a simple tensile, compressive or shear load, the given load is divided by the length of the weld to arrive at the applied unit force, lbs per linear inch of weld. From this force, the proper leg size of fillet weld or throat of groove weld may be found.

7. BENDING OR TWISTING LOADS ON WELDS

The problem here is to determine the properties of the welded connection in order to check the stress in the weld without first knowing its leg size. Some design texts suggest assuming a certain weld-leg size and then calculating the stress in the weld to see if it is overstressed or understressed. If the result is too far off, then the weld-leg size is readjusted.

This has the following disadvantages:

1. Some decision must be made as to what throat section is going to be used to determine the property of the weld. Usually some objection can be raised to any throat section chosen.

2. The resulting stresses must be combined and, for several types of loading, this can be rather complicated.

In contrast, the following is a simple method to determine the correct amount of welding required for adequate strength. This is a method in which the weld is treated as a line, having no area, but a definite length and outline. This method has the following advantages:

1. It is not necessary to consider throat areas because only a line is considered.

2. Properties of the welded connection are easily found from a table without knowing weld-leg size.

3. Forces are considered on a unit length of weld instead of stresses, thus eliminating the knotty problem of combining stresses.

4. It is true that the stress distribution within a fillet weld is complex, due to eccentricity of the applied force, shape of the fillet, notch effect of the root, etc.; however, these same conditions exist in the actual fillet welds tested and have been recorded as a unit force per unit length of weld.

8. DETERMINING FORCE ON WELD

Visualize the welded connection as a single line, having the same outline as the connection, but no cross-sectional area. Notice, Figure 14, that the area (A_w) of the welded connection now becomes just the length of the weld.

Instead of trying to determine the stress on the weld (this cannot be done unless the weld size is known), the problem becomes a much simpler one of determining the force on the weld.

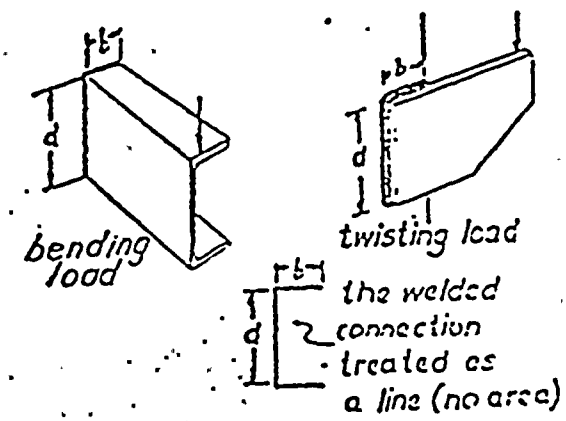


FIG. 14 Treating weld as a line.

By inserting the property of the welded connection treated as a line into the standard design formula used for that particular type of load (see Table 4), the force on the weld may be found in terms of lbs per linear inch of weld.

Example: Bending

Standard design formula (bending stress)	Same formula used for weld (treating weld as a line)
$\sigma = \frac{M}{S} = \frac{\text{lbs}}{\text{in.}^2}$ stress	$f = \frac{M}{S_w} = \frac{\text{lbs}}{\text{in.}}$ force