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July 21, 2014

PG&E Letter DCL-14-060

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

10 CFR 50.55a

Docket No. 50-275, OL-DPR-80
Docket No. 50-323, OL-DPR-82
Diablo Canyon Power Plant Unit 1 and Unit 2
ASME Section XI Inservice Inspection Program Request for Alternative REP-SI: Proposed Alternative to Requirements for Repair/Replacement Activities for Certain Safety Injection Pump Welded Attachments

Dear Commissioners and Staff:

Pursuant to 10 CFR 50.55a(a)(3)(i), Pacific Gas and Electric Company (PG&E) hereby requests NRC approval of Inservice Inspection Request for Alternative REP-SI for Diablo Canyon Power Plant, Units 1 and 2.

An alternative is requested from the requirements of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section XI, for Repair/Replacement rules governing certain socket welded attachments to safety injection pumps. The details of the proposed request are enclosed.

This communication does not contain regulatory commitments (as defined by NEI 99-04).

PG&E requests authorization of this relief request no later than July 21, 2015. If you have any questions, or require additional information, please contact Mr. Tom Baldwin at (805) 545-4720.

Sincerely,

Barry S. Allen

Barry S. Allen

rntt/4231/50500119
Enclosure
cc: Diablo Distribution
cc/enc: Peter J. Bamford, NRC Project Manager
Marc L. Dapas, NRC Region IV Administrator
Thomas R. Hipschman, NRC Senior Resident Inspector
Gonzalo L. Perez, Branch Chief, California Department of Public Health
State of California, Pressure Vessel Unit

10 CFR 50.55a Request Number REP-SI

Proposed Alternative
In Accordance with 10 CFR 50.55a(a)(3)(i)

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In Accordance with 10 CFR 50.55a(a)(3)(i)

Proposed alternative would provide an acceptable level of quality and safety.

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10 CFR 50.55a Request Number REP-SI

Proposed Alternative
In Accordance with 10 CFR 50.55a(a)(3)(i)

-Proposed alternative would provide an acceptable level of quality and safety-

1. ASME Code Components Affected

   Diablo Canyon Power Plant (DCPP), Unit 1, ASME Code Class 2, Safety Injection (SI) Pumps 1-1 and 1-2 nominal pipe size (NPS) ¾ inch vent and drain connection socket weld attachments (four attachment welds per pump); and DCPP, Unit 2, ASME Code Class 2, SI Pump 2-1 NPS ¾ inch vent and drain connection socket weld attachments (four attachment welds). (Note: DCPP, Unit 2, SI Pump 2-2 vent and drain connections were manufactured differently and are not affected).

2. Applicable Code Edition and Addenda

   ASME Section XI, 2001 Edition through 2003 Addenda.

3. Applicable Code Requirement

   IWA-4000, "Repair/Replacement Activities," including IWA-4130, "Alternative Requirements," and IWA-4131, "Small Items," as corrective action for the four affected Code Class 2, NPS ¾ inch socket welds on each pump.

4. Reason for Request

   Relief is requested from implementing the Section XI repair/replacement rules for nonconforming ¾ inch nominal diameter vent valve and drain pipe fitting attachment socket welds. These welds connect to four integrally attached stub piping nipples on each of the three subject SI Pumps. (Note: larger diameter pipe connections to these pumps were supplied with integral flanged connections and are not affected).

   The Unit 1 SI Pumps 1-1 and 1-2 and Unit 2 SI Pump 2-1 are size 2 ½, Model Number JTCH, manufactured by Pacific Pumps. The pump casings are fabricated from martensitic stainless steel and were each supplied with four integrally attached ¾ inch nominal diameter Type 410 martensitic stainless steel (ASME material Type P-6) pipe nipple stubs. One integral vent stub nipple and three integral drain stub nipples were

supplied with each pump. The pump casings including the pipe nipples and their attachment welds to the pump casings were heat treated during pump manufacture and supplied as an integral pump assembly.
The Unit 1 SI pumps and connected piping were installed in 1974 and the Unit 2 SI pump 2-1 and connected piping was installed in 1975 by the original plant construction piping and equipment installation contractor.

During original installation of the pump assemblies in the plant, Type 316 austenitic stainless steel (ASME material Type P-8) isolation valves were welded to the integral vent stub nipple connections, and Type 304 austenitic stainless steel (ASME material Type P-8) pipe fittings (elbows or tees) were welded to each of the integral drain stub nipple connections supplied with each pump. The valve or fitting-to-stub nipple attachment welds were made using the pipe and equipment installation contractor's welding procedure Specification Number 149 (see Attachment 1) using Type 309 stainless steel filler metal. Procedure 149 was qualified for welding carbon steel (ASME material Type P-1) to austenitic stainless steel (ASME material Type P-8). Procedure 149 was not qualified for welding martensitic stainless steel (ASME material Type P-6) to austenitic stainless steel (ASME material Type P-8); and therefore, does not contain provision for post-weld heat treatment that would potentially be required by a P-6 to P-8 Procedure. The discrepancy in welding procedure qualification was discovered in December 2013 during material verification as part of the planning process for anticipated replacement of the Pump 1-1 vent valve due to boric acid leakage from the valve packing.

ASME Section XI would require use of IWA-4000 repair/replacement rules for correction of the four nonconforming ¾ inch nominal diameter socket welds on each subject pump.

5. <u>Proposed Alternative and Basis for Use</u>

PG&E proposes to accept the existing SI Pumps 1-1, 1-2, and 2-1 vent and drain attachment socket welds as-is.

To confirm acceptability of the existing SI pumps vent and drain socket welds, PG&E has:

- conducted welding procedure qualification tests with representative 410 stainless steel and 304 stainless steel base materials using Type 309 filler metal as per the original Welding Procedure Specification 149 parameters without post-weld heat treatment (see Attachment 2);

- performed a Stress and Fracture Mechanics Evaluation of Type 410 Stainless Steel Weldments in SI Pumps at DCPP (see Attachment 3);
- performed nondestructive examinations (NDEs) of the subject welds to determine and verify current conditions; and
- performed a review of the SI pumps operating histories including pressure test records.

Each of these actions are discussed below and detailed in the attachments.

5.1 Welding Procedure Qualification Tests

Welding Procedure Qualification Test Report is presented in Attachment 2. For the weld qualification tests, Arc-Met testing to determine carbon content of the existing SI pumps, 410 stainless steel pipe nipples were attempted but proved unsuccessful due to the small pipe size, short lengths of the drain nipples and adverse component configurations. As a result, Type 410 stainless steel material with the highest carbon content readily available (0.13 percent) was used for the qualification testing. To qualify the procedure, 3/8 inch thick Type 410 stainless steel plate was welded to 3/8 inch thick Type 304 stainless steel plate using a combination of gas tungsten arc welding (GTAW) at the root with shielded metal arc welding (SMAW) for the cover passes. Ambient condition preheat of 66.5°F was used with maximum interpass temperature of 297°F recorded. No post weld heat treatment was used.

The final weld was sectioned to provide two tensile and four bend test specimens which were tested by an independent laboratory. Two of the bend specimens were subjected to root bending, 180 degrees, and two were subjected to face bending, 180 degrees, over rollers with diameter of 4 times the bend specimen thickness, with the weld and heat-affected zones centered within the convex length of bent samples per ASME Section IX, Table QW-451.1 and QW-160, 2013 Edition. The samples were subsequently examined for cracks and other defects and all were found acceptable.

The two tensile test specimens were tested in accordance with ASME Section IX, Table QW-451.1 and QW-150, 2013 Edition, with required ultimate tensile strength of 65 Kips (1000 pounds) per square inch (ksi). Actual ultimate tensile strengths of 75.5 ksi and 76.0 ksi respectively were recorded, with the breaks occurring in the 410 stainless steel parent metal in both instances.

5.2 Stress and Fracture Mechanics Evaluation

Stress and Fracture Mechanics Evaluation Report prepared by Structural Integrity Associates (SIA) is presented in Attachment 3. SIA's evaluation of the ¾ inch Type 410 stainless steel nipples welded to Type 316 valves or Type 304 fittings without post weld heat treatment on the DCPP SI Pump vent and drain lines consisted of stress analysis, evaluation of allowable flaw size under maximum loading, and evaluation of crack propagation of postulated flaws under cyclic fatigue loading. A fracture mechanics approach analogous to the methods of ASME Code Section XI, supplemented with procedures from American Petroleum Institute Standard API-579, was used because the ASME Section XI methods do not address Type 410 martensitic stainless steels, evaluation of (postulated) flaws on piping outside diameter (OD) surfaces, or evaluation of flaws in piping of diameter 4 inches or less.

The postulated flaw extends from the socket weld toe on the Type 410 stainless steel nipple, which is the region where cyclic stresses are the largest, and grows from the OD toward the inside diameter (ID). Additionally, a postulated flaw originating at the ID was evaluated due to the presence of residual tensile stresses as a result of welding.

The depths of OD and ID flaws located along the largest cyclic stress path that would cause crack instability under maximum operating loads and pressure, including seismic/abnormal loads and applicable structural factors, were evaluated. The allowable flaw depth for an OD flaw was determined to be 0.110 inch, approximately 71.6 percent of the wall thickness of 0.154 inch. The allowable flaw depth for an ID flaw was found to exceed 80 percent of the wall thickness.

For cyclic loading, postulated ID flaws are not predicted to grow as all cyclic stress intensity factors are below the fatigue threshold.

For postulated OD crack analysis, 7000 thermal transient cycles, 400 design earthquake cycles, and 20 Hosgri earthquake cycles were assumed. For the postulated OD crack to grow by fatigue under cyclic operating loads, and pressure to the allowable flaw size in the evaluated number of cycles, an initial crack of at least 0.104 inch depth is required. This depth corresponds to a surface length of 0.832 inch for a crack aspect ratio of 4.

For nondestructive test minimum length detection limits of 1/16 inch (such as for liquid penetrant examinations), fatigue crack growth will not occur for a postulated OD flaw where surface length is equal to the detection limit, even for load cycles associated with the Hosgri earthquake.

For a postulated 10 percent through-wall OD flaw, no growth is predicted except for the 20 cycles assumed for the Hosgri event. For that case, the associated crack extension is 8.3×10^{-6} inch.

For a postulated OD crack 0.026 inch deep (just exceeding the fatigue crack growth threshold), the amount of crack extension under the evaluated cyclic loading is 0.0015 inch.

The evaluations of the postulated OD and ID flaws show that crack growth under anticipated cyclic loading is minimal.

5.3 Nondestructive Examinations

During the operating history of the plant, the subject welds have been examined by qualified VT-2 visual examiners every 40 months during scheduled ASME Section XI system pressure tests. No leakage from any of the welds has ever been identified.

Liquid penetrant examinations of all subject welds were performed between December 18 and 20, 2013, with specific attention focused for crack-like indications. No linear or crack-like indications were detected.

5.4 Review of Safety Injection Pumps Operating History

The cumulative number of starts is a measure of the cyclic loading experienced by the pumps, as analyzed in the stress and fracture mechanics evaluation. The SI pumps were each started several times during testing prior to plant operation. During plant operation, the pumps normally function in a stand-by capacity and are periodically started for pump readiness testing and system pressurizations for leak testing, as well as a small number of starts in support of the SI function.

Preoperational starts are an estimate of the number of SI pump starts during preoperational startup testing activities and during three Plant Hot Functional Testing programs. Each pump is estimated to have had 25 preoperational starts.

The total number of operational starts for SI Pumps 1-1, 1-2, and 2-1 through the end of 2013 was estimated using the operating data of each of these pumps to establish an annual average. This average, 11 starts per year for each pump, was extrapolated back to the commencement of plant operation.

Total preoperational and operational start estimates were then added together. The resulting estimated number of starts for each SI pump during the life of the plant was multiplied by 2 as a conservative measure allowing for a higher number of starts per year at beginning of plant life plus any pressurizations of the SI piping by means other than a pump start, such as hydro testing.

The calculation of total starts for each pump is as follows: [Number of preoperational starts plus (Average number of starts per year multiplied by number of years of plant operation)] multiplied by 2.

Total starts for SI Pumps 1-1 and 1-2: [25 starts + (11 starts/year X 29 years)] X 2 = 688 starts

Total starts for SI Pump 2-1: [25 starts + (11 starts/year X 28 years)] X 2 = 666 starts.

The total number of starts to date (approximately half of plant life assuming a 20 year license renewal extension) for each of the subject SI pumps is conservatively estimated to be less than 700 starts. Conservatively assuming an additional 700 starts during the second half of plant life (including the assumed 20 year license extension period), the total number of SI pump starts during all of plant lifetime is estimated to be less than 1400 starts. This is well under the 7000 thermal transient cycles assumed in the fatigue crack growth analysis.

5.5 Conclusion

As discussed above and demonstrated and documented in Attachments 2 and 3, the existing SI pumps vent and drain socket welds provide an equivalent level of quality and safety in accordance with 10 CFR 50.55a(a)(3)(i), thus the existing weldments may be determined acceptable as-is for continued service.

6. Duration of Proposed Alternative

The proposed alternative will apply for the remaining service life of SI Pumps 1-1, 1-2, and 2-1, including the duration of the current operating licenses plus a contemplated license extension period of 20 years.

Weld Procedure Specification No. 149

[NOTE: Best available copy is attached.]

THE M. W. KELLOGG COMPANY
A Division of Pullman Incorporated
Piping Fabrication
Williamsport, PA 17701
P.G. & E. Diablo Canyon Project

Weld Procedure Code No. 149
Spec. No. P8/P1-K1-F5-SMAW-6G
Date 1/4/72
Revision Dates Retyped 7/31/73
Retyped 12/3/73

PROCEDURE SPECIFICATION FOR: Austenitic stainless steel to carbon steel piping, insert welding, GTAW (root) and SMAW (welding).

BASE METAL: The base metal shall conform to the specifications for ASME, Section IX, P8 and P1 materials.

FILLER METAL: The filler metal shall conform to ASME Filler Metal Specifications Number SFA-5.9 and SFA-5.4 for Ferrous Filler metal in Group Number F-5 and 7.

The chemical composition of the weld deposit shall fall within the limits of weld metal Analysis Number A-7.

GAS FOR TORCH SHIELD: Nominal composition of Argon, 99.995% minimum purity (for GTAW process).

GAS FOR BACK-UP PURGE: Argon per Page 4 (for GTAW process).

TACK WELDS FOR SET-UP: The GTAW process using filler metal type listed on Page 2 may be used without back-up purge in 1/16, 3/32, or 1/8 inch diameter.

POSITION: The welding may be done in all positions.

PREHEAT: None Required.

POST HEAT TREATMENT: None.

BACKING STRIP: None.

INTERPASS: 350° F maximum. (May be maintained by application of demineralized water between passes as a coolant.)

TRAVEL SPEED: GTAW--2" - 6" per minute
SMAW
3/32" =1½"-6½" per min
1/8" =1½"-6½" per min
5/32" = 2"- 7" per min
3/16" = 3"- 8" per min

WEAVING: Shall not exceed two electrode diameters or the inside diameter of the gas cup.

WELDING PROCESS: The welding shall be done by the GTAW insert root and SMAW weld out processes using manual equipment. GTAW welding shall be done using a non-consumable electrode of EWTH-2 2% Thoriated Tungsten.

BASE METAL THICKNESS: This procedure is qualified to allow welding of material thickness between 3/16 inch and 1.436 inches, over 3" O.D. only.

PREPARATION OF BASE MATERIAL: The edges or surfaces of the parts to be joined by welding may be prepared by plasma arc, grinding, machining, (flame cutting for P1 materials) or any combination of methods to essentially form the geometry of the weld shown of Page 2 as detailed on the attached sketches and shall be cleaned of all oil or grease and excessive amounts of scale or rust.

ELECTRICAL CHARACTERISTICS: The current used shall be D.C. GTAW-Straight Polarity
SMAW-Reverse Polarity

JOINT WELDING PROCEDURE: The welding technique, such as electrode sizes, and voltage and currents for each electrode, size of the welding tip and filler rods, shall be substantially as shown on Page 2.

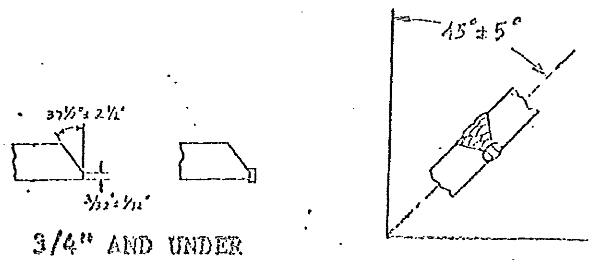
APPEARANCE OF WELDING LAYERS: The welding current and manner of depositing the weld metal shall be such that there shall be practically no undercutting on the side walls of the welding groove or the adjoining base material. See job specifications for specific undercutting limitations.

CLEANING: All slag or flux remaining on any bead of welding shall be removed before laying down the next successive bead of welding.

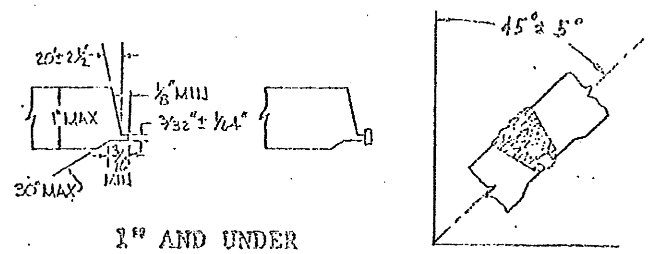
DEFECTS: Any cracks or blow holes that appear on the surface of any bead of welding shall be removed by chipping or grinding before depositing the next successive bead of welding.

THIS PROCEDURE IS A RE-WRITE OF:
Code No. 149, P8/P1-K1-SMAW-F5-6G

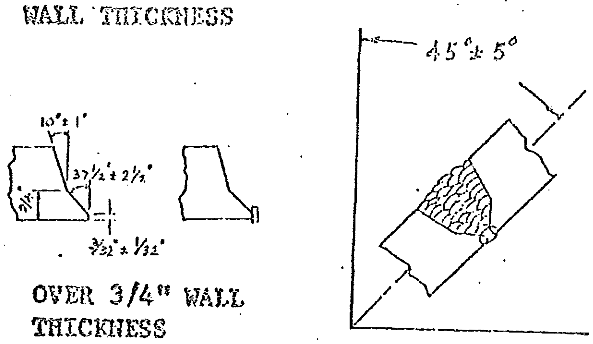
JOINT DETAILS AND WELDING TECHNIQUES



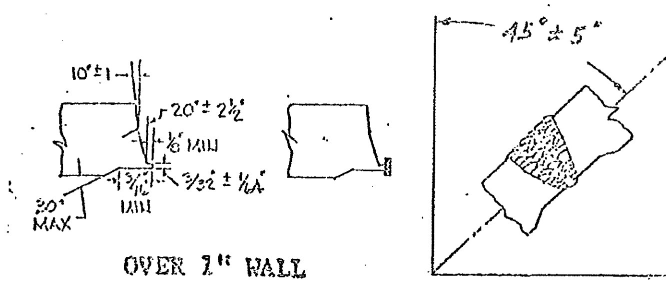
3/4" AND UNDER
WALL THICKNESS



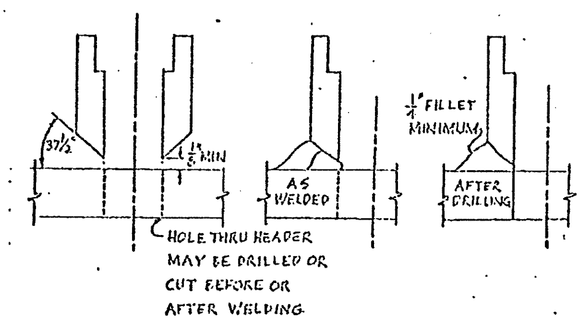
1" AND UNDER
WALL THICKNESS

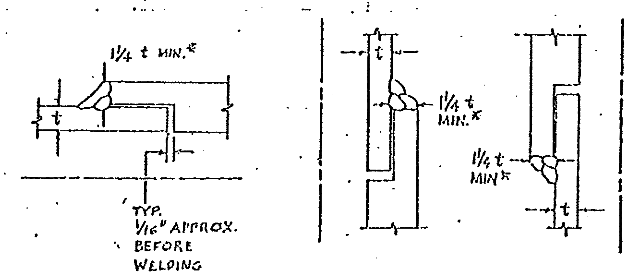


OVER 3/4" WALL
THICKNESS



OVER 1" WALL
THICKNESS





*BUT NOT LESS THAN 1/8"

PASS NO. AND PROCESS	FILLER METAL TYPE OPTIONAL	FILLER Metal Size optional	AMPS	MAX. VOLTS	POLARITY	TORCH SHIELD & FLO RATE (MIN.)	TUNGSTEN SIZE AND POLARITY
ROOT GTAW *	ER-309	Insert 1/8 x 5/32 1/8 x 3/32	55-175	20	Straight	Argon 20 CFH	1/8 or 3/32 Diameter Straight
Balance SMAW	E309	3/32 1/8 5/32 3/16	45-80 70-110 90-140 130-180	24 25 26 27	Reverse	-----	----

FOR FILLETS AND SOCKETS ONLY (DELETE INSERT)

1, 1-2, or 1-3 GTAW	ER-309	1/16 3/32 1/8	60-120 70-150 100-190	14 17 20	Straight	Argon 20 CFH	1/8, or 3/32 Dia. Straight
Balance SMAW	E 309	3/32 1/8 5/32 3/16	45-80 70-110 90-140 130-180	24 25 26 27	Reverse	-----	-----

* NOTE: 1/16, 3/32, or 1/8 ER-309 bare filler metal may be used as applicable for intermittent voids or mismatch in root set-up. If necessary, one complete pass may be made while holding the purge.

THE M.W. KELLOGG COMPANY
A DIVISION OF PULLMAN INCORPORATED
PIPING FABRICATION

RECOMMENDED FORM Q-1 MANUFACTURER'S RECORD OF WELDING PROCEDURE QUALIFICATION TESTS

Specification No. P8/P1-KI-F5-SMAW-6G Date 1/4/72
Welding Process GTAW and SMAW Manual or Machine Manual
Material Specification A312 T304 to A-106-B of P-No. 8 to P-No. 1
Thickness (if pipe, diameter and wall thickness) 6" O.D. x .718" Thk.
Thickness Range this test qualifies 3/16" thru 1.436" / 3 O.D. and over
Filler Metal Group No. F- 7 and F-5
Weld Metal Analysis No. A- 7
Describe Filler Metal if not included in Table Q-11.2 or QN-11.2
For oxyacetylene welding—State if Filler Metal is silicon or aluminum Filled.

FLUX OR ATMOSPHERE
Flux Trade Name or Composition None
Inert Gas Composition Argon
Trade Name --- Flow Rate 20 CFH
Is Backing Strip used? No
Preheat Temperature Range 50° F. Min.
Interpass Temperature Range 350° Max.
Postheat Treatment

WELDING PROCEDURE
Single or Multiple Pass Multiple
Single or Multiple Arc Single
Position of Groove 45 Angular (6G) (See Pars. & Figs. Q-2 & Q-3, or QN-2 & QN-3)
(Flat, horizontal, vertical, or overhead; if vertical, state whether upward or downward)

FOR INFORMATION ONLY
Filler Wire—Diameter 1/16", 3/32" 1/8", 5/32"
Trade Name Chromenar - Chromend
Type of Backing None
Forehand or Backhand ---

WELDING TECHNIQUES
Joint Dimensions Accord with Sheet 2 of 3
amps -- volts -- inches per min. Sheet 1 of 3
Current D.C. Polarity Straight for GTAW, Reverse for SMAW

REDUCED SECTION TENSILE TEST (Figs. Q-6 and QN-6)

Specimen No.	Dimensions Width	Dimensions Thickness	Area	Ultimate Total Load, lb.	Ultimate Unit Stress, psi	Character of Failure and Location
ML-72-17-1	.753	.623	.469	36,000	76,800	Broke in C/S base metal
ML-72-17-2	.739	.623	.460	35,400	77,000	Broke in C/S base metal

GUIDED BEND TESTS (Figs. Q-7.1, Q-7.2, QN-7.1, QN-7.2, QN-7.3)

Type and Figure No.	Result	Type and Figure No.	Result
ML-72-17-1 SB-1	Bent 180° O.K.	ML-72-17-2 SB-3	Bent 180° OK
SB-2	Bent 180° O.K.	SB-4	Bent 180° O.K.

Results of Filletweld Tests, Fig. Q-9(c)
Welder's Name O'Dell, W/Lyautey Clock No. 132/120 Stamp No. DE-AR
Who by virtue of these tests meets welder performance requirements.
Test Conducted by Bob Boyer Laboratory—Test No. Ml-72-17
per

We certify that the statements in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code.

Signed THE M.W. KELLOGG COMPANY
(Manufacturer)

Date 1/4/72 By F. J. Richards

(Detail of record of tests are illustrative only and may be modified to conform to the type and number of tests required by the Code. Recommended Form Q-1 is available for purchase at ASME Headquarters.)
NOTE: Any essential variables in addition to those above shall be recorded.

The M. W. Kellogg Company
A Division of Pullman Incorporated
Piping Fabrication
Williamsport, Pennsylvania 17701

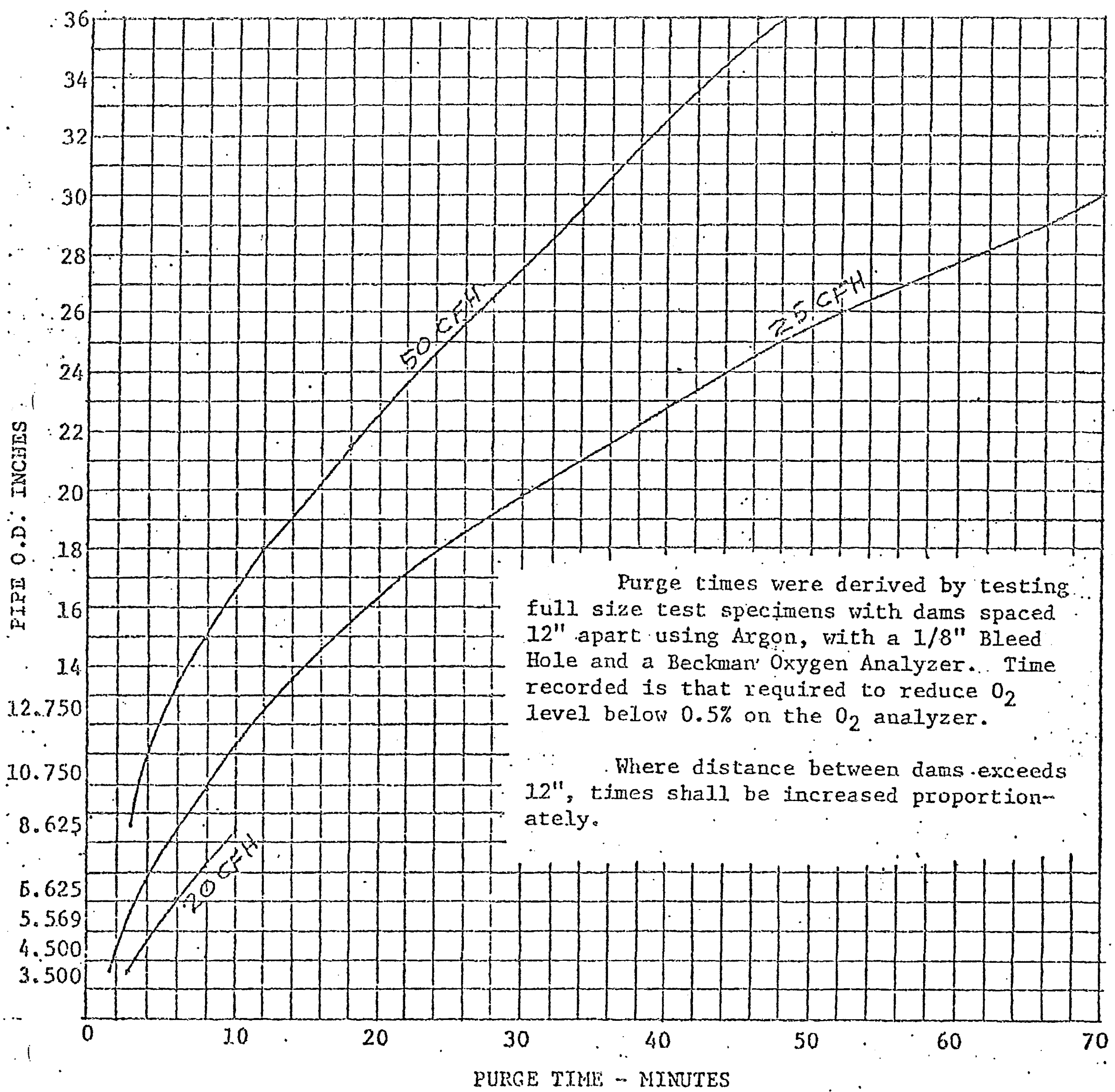
Weld Procedure Code No. 149
Spec. No. B8/P1-K1-F5-SMAG-66
Date See Page 1

BACKING GAS PURGE

This procedure is to be followed to assure that the oxygen content has been reduced to a desired degree of inertness (1% oxygen or less).

(1) Oxygen content of backing gas purge may be checked by any acceptable type of oxygen analyzer.

(2) In lieu of an oxygen analyzer the following chart may be used:



By: E. F. GERWIN
Title: CHIEF ENGINEER

PG&E ATS Report 420DC-14.20: Welding Procedure Qualification Record (PQR) 771 and Associated Documents

Applied Technology Services

PG&E ATS Report 420DC-14.20: Welding Procedure Qualification Record (PQR) 771 and Associated Documents

Prepared by: Bronson R. Shelly

Bronson R. Shelly Digitally signed by Bronson R. Shelly DN: cn=Bronson R. Shelly, o, ou=ATS, Weld Engineering, email=b3s9@pge.com, c=US Date: 2014.07.16 13:07:03 -07'00'

Reviewed By: Daniel J. Tilly

Daniel Tilly Digitally signed by Daniel Tilly DN: cn=Daniel Tilly, o=PG&E, ou=ATS, email=djt9@pge.com, c=US Date: 2014.07.16 14:16:41 -07'00'

Approved By: Daniel J. Tilly

Daniel Tilly Digitally signed by Daniel Tilly DN: cn=Daniel Tilly, o=PG&E, ou=ATS, email=djt9@pge.com, c=US Date: 2014.07.16 14:17:10 -07'00'

(July 2014)

Report No.: 420DC-14.20

Pacific Gas and Electric Company
Applied Technology Services
3400 Crow Canyon Road, San Ramon, California 94583

CONTENTS

Welding Procedure Qualification Record (PQR) 771 and Associated Documents

1 Abstract

Per SAPN 50600119 Task 16 (Attachment 1), ATS Weld Engineering was requested to evaluate and qualify a Procedure Qualification Record (PQR) to support the applicability of the contractor's WPS 149 that had been used for making socket weld connections on 12 identified locations connecting the SI-Pump Nipples to an ASME III, NC piping system. As part of the evaluation, ATS was tasked with determining if the parameters of contractor WPS 149, which was qualified for joining a P8 material to a P1 material, could acceptably join the type 304, (P8) components to the type 410, (P6) pipe nipples. Because obtaining the carbon content of the type 410, (P6) material was deemed impractical ATS Weld Engineering was also tasked with qualifying the PQR with the highest carbon content associated with type 410 material that could be readily procured to support contractor WPS 149.

2. Evaluation

Contractor WPS 149 was evaluated by the ATS Weld Engineering Group and a PQR plan was created with the following conditions (Reference previous ATS report 420DC-13.44).

- The construction and welding codes assigned for this PQR shall be:
  - ASME Section III-NC, 2001 Edition with 2003 Addenda
  - ASME IX 2013 Edition.
- The base materials for the PQR shall be a worst case representation of the SI-Pump pipe nipples and associated piping system:.
  - Type 304/304L (P8)
  - Type 410 (P6)
    - Note: Type 410 base material shall have the highest carbon content that the ATS Weld Engineering Group could readily procure.
- The filler materials for the PQR shall be the same as specified in WPS 149.
  - ER309/309L
  - E309/309L
- This PQR shall be qualified without elevated preheat or post weld heat treatment (PWHT)

3. Procedure Qualification Record (PQR) and Supporting Documentation

The PQR plan described in section 1.1 was executed and documented in PG&E PQR 771. PQR 771 and the following supporting documents are attached to this report.

- PQR Review Check List (Reference Attachment 2)
  - The checklist is used to verify that all the documentation required to support a PQR is acceptable prior to finalizing the PQR package.
    - Note: some of the documentation shown on the checklist is not included in this report because it is not required to assess the worst case PQR comparison to contractor WPS 149. This additional documentation is available upon request.
- Procedure Qualification Record (PQR) 771 (Reference Attachment 3)
  - This is the ATS official PQR that contains all the required essential and nonessential variables as required in ASME IX 2013, Edition. This document could be used to support a Welding Procedure Specification (WPS).
    - Note: in this case the PQR is intended to support the variable requirements of contractor WPS 149 for joining P6 to P8. Reference previous ATS formal report 420DC-13.44.
  - PQR 771 Could Support a WPS with the following ranges. Reference (ASME IX 2013, Edition)
    - Base metals qualified (P-Numbers)
      - Any metal assigned to P6 to any metal assigned to P8 (Reference QW-424).
    - Base metal thickness (T), (Reference QW-451.1) range = 1/16" to 3/4".
      - Process GTAW deposited Weld metal (t) Groove Weld = 3/8" maximum
        - Weld filler metal F-Number 6 / A-Number 8
      - Process SMAW deposited Weld metal (t) Groove Weld = 3/8" maximum
        - Weld filler metal F-Number 5 / A-Number 8
      - Fillet Welds both GTAW and SMAW (Reference QW-451.4) range = All fillet weld sizes on all base metal thickness and all diameters.

        - Note that the 12 SI-Pump socket weld locations would be qualified under this section.
    - Preheat and Post Weld Heat Treatment
        - Preheat none required, 50°F minimum
        - Qualified Without PWHT – PWHT is not permitted

- Record of Welding Data (Reference Attachment 4)
    - This is a record of data recorded during the welding process for the PQR.
        - Note: The essential variables of contactor WPS 149 was matched in PQR 771. Some notable variables are listed below.
            - PQR 771 - Preheat (none) measured at 67°F, Without PWHT
                - Contractor WPS 149 – Preheat none recorded 50°F Minimum, Without PWHT.
            - PQR 771 - GTAW 30-43.26 (KJ/in), SMAW 20-34.57 (KJ/in)
                - Contractor WPS 149 - GTAW 12-72 (KJ/in), SMAW 16-110 (KJ/in).
            - PQR – 771 Filler materials GTAW ER309/309L, SMAW ER309/309L
                - Contractor WPS 149 - Filler materials GTAW ER309, SMAW ER309

- Base Material Certified Material Test Reports (Reference Attachment 5)
    - This is a test report from the material vender with the certifying information for the base materials to be joined for the PQR.
    - SA-240, Type 304/304L, 3/8" Plate Heat Number: (H2J8), a material chemical over check is also included in the Element Lab Report: PAC003-03-24-71934-1.
    - SA-240, Type 410, 3/8" Plate Heat Number: (950163), a material chemical over check is also included in the Element Lab Report: PAC003-03-24-71934-1.

        - Note: The SA-240, Type 410 plate has a carbon content of 0.13% where the maximum allowable is 0.15%. This was the highest carbon content type 410 that ATS Welding Engineering could acquire.

- Filler Metal Certified Material Test Report (Reference Attachment 6)
    - GTAW – ER309/309L, 1/8" diameter rod, was used for PQR 771 Heat Number/Trace Number - 735032 / DT8703. Note: DCPP Supplied
    - SMAW – E309/309L-16, 1/8" diameter electrode, was used for PQR 771, Heat Number/Lot Number - DF8184 / 4D14E-14A. Note: DCPP Supplied
- Element Laboratory Report PAC003-03-24-71934-1 (Reference Attachment 7)
    - This is the third party laboratory report that supports PQR 771. This laboratory report includes the certified test results taken from the welded PQR test plate.
        - Tensile, bend, and chemical over check tests are included in this report.
- ATS Work Traveler for PQR 771 (Reference Attachment 8)
    - This was the work traveler issued at ATS to conduct PQR 771.
        - Various quality checks, Certified Welding Inspector (CWI) inspections, Weld Engineering verifications, and Welding Technician cross checks were logged and signed off on this traveler during the process of welding PQR 771.

4. Conclusion

The socket welds joining the piping system to the SI-Pumps pipe nipples were welded with a WPS qualified for P1 to P8 applications. The systems actual materials were determined to be P6 and P8. This report confirms that, the welding parameters from the contractor WPS 149 (1973 Edition) (a P1 to P8 WPS) can be used to qualify a P6 to P8 WPS.
A PQR for the socket welds was conducted in accordance with ASME Section III-NC, 2001 Edition with 2003 Addenda and ASME IX, 2013 Edition. PQR 771 conforms to the welding parameters of contractor WPS 149 and shows that these parameters can be used to meet the ASME IX, 2013 Edition qualification requirements for a P6 material joined to a P8 material, with an ambient temperature preheat.

Since, the P6 pipe nipple material carbon content could not be verified, the ATS Weld Engineering group used a higher than expected carbon content for the type 410 mockup materials as an added level of conservatism to PQR 771. PQR 771 demonstrates that with a higher carbon content of up to 0.13%, the weld met all the ASME IX, 2013 Edition qualification requirements. It is also noted, that the nominal thickness of PQR 771 (3/8"), represents a larger amount of induced residual stress in the HAZ of the PQR test plate than in the installed socket welds; the nominal thickness of the installed pipe nipples is 0.154". For the actual installed weld connections the thinner thickness if bent (similarly to the qualification requirements) would exhibit less elastic strain on the face of the weld.

It is ATS Weld Engineering's opinion that the combination of the high carbon content and 3/8" base metal thickness makes PQR 771 is a valid worst case PQR. With the additional qualification of PQR 771 it is the opinion of ATS Weld Engineering that the parameters of WPS 149 would be technically acceptable for welding the P6 pipe nipples to the P8 piping system components.

Attachment 1: SAPN 50600119 Task 16

U-1	Notification: **50600119** Type: **DN** Work Type: **EQPR AANS**
	Description: **LTCA Orig. Const Weld made w/incor WPS**
	Order:

Task # 16 Welding Procedure Development

Status: **TSCO**	Task Completed	
Code Group: **DE-ENG-T**	Diablo Engineering Tasks	
Task Code: **0065**	Engineering Evaluation	
Responsible: **User Responsible**	**AEGB**	Alexander Gutierrez **925/866-5340**
Work Ctr: **TES-TEWL**	ATS Welding Services - Dan Tilly	
Created On: **23 Dec 13**	By: **CMN1** Christopher Neary	
Planned Start: **23 Dec 13**	Planned Finish: **31 Mar 14**	
Completed On: **31 Mar 14 22:13**	By: **B3S9** Bronson Shelly	**925/866-5481**

12/23/2013 10:03:13 Christopher Neary (CMN1) Phone 805/545-4018
Additional design code review has been performed in support of this issue.

If the pipe nipples identified by by the Niton analysis have a carbon content of 0.08% or less, they can likely be classified as an ASME Section IX P-7 material instead of P-6. Example material specs which would meet the P-7 classification include type 405 or 410S stainless steels.

The PG&E Nuclear Welding Control Manual permits welding of P-7 to P-8 without elevated preheat or PWHT. Therefore, the existing welds can possibly be qualified to the NWCM and no rework would be required. Doing so would also simplify maintenance work such as the valve replacement requested via 50041641.

The NWCM currently does not contain a WPS applicable to this application.

ATS is requested to perform the following:

1) Perform a review of existing PQRs. A valid PQR will permit welding of P-7 to P-8 material with no changes in essential variable from those in contractor WPS 149.

2) If a valid PQR is found, generate a WPS and issue to the NWCM.

3) If no valid PQR is found, proceed with performing a test weld to support creation of this PQR. NOTE: Although RegGuide 1.44 is not applicable to the SIP welds, the PQR should permit application for RegGuide 1.44 scope if possible without undue burden.

01/09/2014 14:18:19 Christopher Neary (CMN1) Phone 805/545-4018

Carbon analysis of the existing nipples has been determined to be impractical for at least some of the locations. Therefore rework of the existing welds is not being pursued at this time and the PQR described above is not needed.

However, qualification of a PQR to demonstrate ASME Section IX acceptability of the existing welds is desired. ATS is requested to perform a PQR to ASME IX requirements which will support the parameters of contractor WPS 149 for welding P-6 materials to P-8.

The PQR should use material with the highest carbon content which can be readily obtained in order to envelope the possible maximum carbon content in the existing nipples.

03/31/2014 21:17:50 Bronson Shelly (B3S9) Phone 925/866-5481
PQR 771 for the joining of SA-240 Type 410 (P6) to SA-240 Type (P8) has been completed by ATS and has satisfactory passed testing requirements of ASME Section IX. The carbon content of the 410 coupon was verified to be 0.13%. The welding parameters and essential variables used during welding of the test coupon were within the same range of contractor WPS 149. Attached to this SAPN/Task is the PQR 771 Package. This PQR package will be revised per SAPN 50600119 Task 28 to include a signed copy of the PO for the mechanical testing/chemical testing and copies of the filler wire CMTR's. Note, the filler wire used by ATS for PQR 771 was supplied and issued by DCPP. Adding the additional data to the PQR package will not affect the PQR.

Attachment 2: Procedure Qualification Review Checklist

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PROCEDURE QUALIFICATION REVIEW CHECKLIST

PQR Number 771

Complete	Incomplete	N/A	Documentation	Comments
X			Request for WPS Form (Optional)	SAPN 50600119 Task 16
X			Qualification Instructions	Instruction In SAPN/Test Plan Doc.
X			Record of Welding Data	
X			Completed PQR	PO 30501000749 Commercial
X			Base Metal CMTR	PO 30501000749 QSL Vender
X			Base Metal Check	
X			Base Metal Upgrade	
X			Filler Metal CMTR	DCPP Supplied
		X	Filler Metal Check	
		X	Filler Metal Upgrade	
		X	PWHT Record	
X			Tensile Tests	Element # PAC003-03-2471934-1
X			Guided Bend Tests	Element # PAC003-03-2471934-1
		X	Charpy Test	
		X	Dropweight Tests	
		X	Deposit Analysis	
		X	Hardness Tests	
		X	Macroetch Examination	
		X	Corrosion Tests	
		X	Delta Ferrite	
		X	NDE Reports	

☒ PQR package is acceptable to support a quality related WPS at DCPP.

☐ PQR package is acceptable to support a non-quality related WPS at DCPP.

Prepared by [signature] Date 5/19/2014
Responsible Welding Engineer

Approved by [signature] Date 5/21/2014
Supervisor, Welding & NDE Service Unit

Attachment 3: Welding Procedure Qualification Record (PQR 771)

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WELDING PROCEDURE QUALIFICATION RECORD

No. 771 Date 3/31/2014 WPS No.(s) N/A Page 1 of 2

Base Metal Specs SA-240 Type 410 Plate and SA-240 Type 304/304L Plate

P-No/Group No 6/1 To P-No./Group No. 8/1

Thickness Tested 3/8"

Backing Yes Insert None

Position 1G Progression N/A

Backgouging N/A

Minimum Preheat 67°F

Peening None

Maximum Interpass Temperature 297°F

Initial Cleaning Grinding to clean metal and acetone wipe

Postweld Heat Treatment None

Interpass Cleaning Grinding and wire brushing

Weld Metal Thickness Deposited by: Process 1 0.1875" Process 2 0.1875" Process 3 N/A

Shielding Gas Argon (99.9%) CFH 15 Cup Size #7 Backing Gas None CFH N/A

AWS Classification	Diameter(s)	SFA-No.	F-No.	A-No	Polarity
ER309/309L	1/8"	5.9	6	8	DCEN
E309/309L	1/8"	5.4	5	8	DCEP

Coupon I.D. Pass No.	Process	Electrode Filler	Filler Size	Amperage Range	Voltage Range	Travel Speed (ipm)	Min Length Deposit	Max Weave Width	Energy (KJ)	Heat Input (KJ/in)
Passes 1-4	GTAW	ER309/309L	1/8"	127 – 128	12	2.13 – 3.05	12"	0.562"	N/A	30 – 43.26
Passes 5-13	SMAW	E309/309L	1/8"	125 – 131	25 – 26	5.91 – 9.52	12"	0.375"	N/A	20 – 34.57

Notes:

Reference: SAPN 50600119 Task 16.

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WELDING PROCEDURE QUALIFICATION RECORD

No. 771 Date 3/31/2014 WPS No.(s) N/A

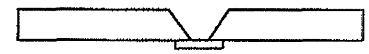
TENSILE TESTS

Sample	UTS (Ksi)	Fracture Type/Location
Weld Specimen 1	75.5	PM(410)
Weld Specimen 2	76.0	PM(410)

GUIDED BEND TESTS

Sample / Type	Results
Sample 1 – Root Bend	Pass
Sample 2 – Root Bend	Pass
Sample 3 – Face Bend	Pass
Sample 4 – Face Bend	Pass

JOINT DESIGN



Groove Weld Flat Positon With Backing

OTHER TESTS PERFORMED

OTHER TESTS PERFORMED	TEST REPORT REFERENCE
Tensile and Bend Test per ASME Sec IX, P6 to P8	Element Report PAC003-03-24-71934-1
Base Metal Chemistry Analysis HT#950163	Element Report PAC003-03-24-71934-1
Base Metal Chemistry Analysis HT#H2J8	Element Report PAC003-03-24-71934-1

We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of ASME Section IX, 2013 Edition

Welder Daniel Sanchez Prepared by Bronson Shelly Date 3/31/2014 Approved by Alex Gutierrez Date 3/31/2014

Attachment 4: Record of Welding Data

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RECORD OF WELDING DATA

PQR Number 771 Test Weld Number 1 Page 1 of 3

Joint Design (Sketch joint to be welded. Include all dimensions, angles, and layering details.)

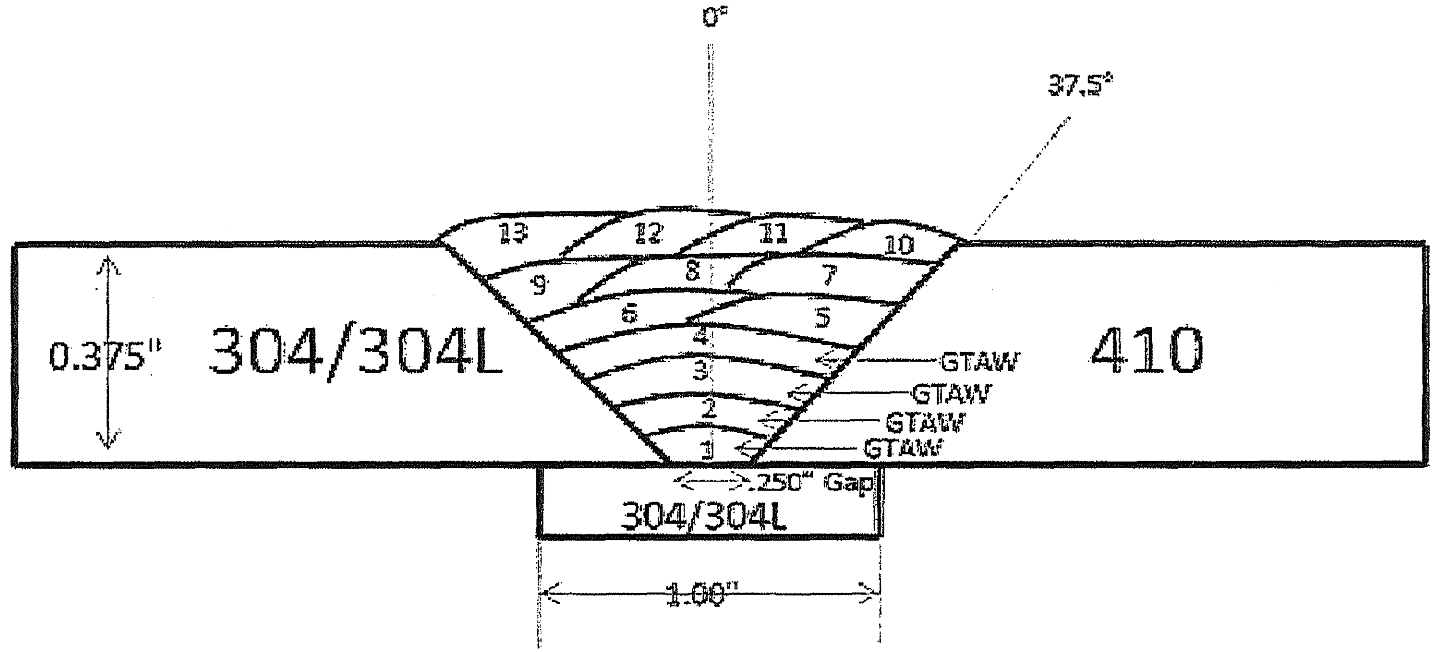

Plate Thickness 0.375 Pipe Diameter N/A Schedule N/A Thickness N/A

Backing Composition 304L Root Opening 0.250" Position 1G Progression FLAT

Thickness of Metal Deposited by First Process 0.1875" Second Process 0.1875" Third Process N/A

NOTES Pre-placed Backing Bar (SA240 304/304L HT#122911) 1/4" Thick

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RECORD OF WELDING DATA

PQR Number 771 Test Weld Number 1 Page 2 of 3

Material Specification SA240 Type 410 Class ____ Grade ____ Heat Number 950163 \

Material Specification SA240 Type 304/304L Class ____ Grade ____ Heat Number H2J8

Insert AWS Class N/A Polarity N/A Size/Style N/A Heat Number ____

Filler 1 AWS Class ER309/309L Polarity DCEN Diameter 0.125" Heat/Lot Number TRACE# DT8703

Filler 2 AWS Class E309L Polarity DCEP Diameter 0.125" Heat/Lot Number 4D14E-14A (WQ)

Filler 3 AWS Class N/A Polarity N/A Diameter N/A Heat/Lot Number ____

Filler 4 AWS Class N/A Polarity N/A Diameter N/A Heat/Lot Number ____

Filler 5 AWS Class N/A Polarity N/A Diameter N/A Heat/Lot Number ____

Filler 6 AWS Class N/A Polarity N/A Diameter N/A Heat/Lot Number ____

Shielding Gas ARGON %99.9 Flow Rate 15CFH Cup Size #7

Backing Gas N/A Flow Rate N/A O_2 Content N/A

Initial Cleaning WIRE BRUSH Interpass Cleaning WIRE BRUSH Contact Tube To Work Distance N/A

AWS Class Nonconsumable Electrode EWTH-2 Diameter 0.093 PWHT Temperture N/A Holding Time N/A

CALIBRATED INSTRUMENTS USED

Description	ID Number	Cal Due Date	Description	ID Number	Cal Due date
FLUKE 381	TEST 15581 ATSICR-32379	03/12/2015	N/A	N/A	N/A
FLUKE 51II	TEST 11569 ATSICR-26288	11/20/2014	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A

Welder DANIEL SANCHEZ Date 03/13/2014 Reviewer Bronson R Shelly Date 3/13/2014

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RECORD OF WELDING DATA

PQR Number 771 Test Weld Number 1 Page 3 of 3

Pass No	Weld Process	Filler No (Page 2)	Current	Voltage	Travel Speed Deposit Length / Seconds	Length SMAW Electrode Burned	Bead Width	Preheat/ Interpass	Wire Speed (GMAW/FCAW)
1	GTAW	1	128	12	12 / 296	N/A	0.250"	66.5 °F	37,888
2	GTAW	1	127.4	12	12 / 236	N/A	0.375"	141 °F	30,066
3	GTAW	1	128	12	12 / 240	N/A	0.500"	240 °F	30,720
4	GTAW	1	128	12	12 / 338	N/A	0.562"	207 °F	43,264
5	SMAW	2	125	26	12 / 122	24.5"	0.375"	245 °F	33,041
6	SMAW	2	125	26	12 / 110	21.5"	0.375"	240 °F	29,791
7	SMAW	2	131	25	12 / 103	23"	0.375"	195 °F	28,110
8	SMAW	2	131	25	12 / 105	22.5"	0.375"	274 °F	28,656
9	SMAW	2	131	25	12 / 76	16.5"	0.375"	257 °F	20,741
10	SMAW	2	131	25	12 / 78	17"	0.375"	279 °F	21,287
11	SMAW	2	131	25	12 / 78	17.5"	0.375"	285 °F	21,287
12	SMAW	2	131	25	12 / 76	16"	0.375"	297 °F	20,741
13	SMAW	2	131	25	12 / 76	15.5"	0.375"	237 °F	20,741
					/				
					/				
					/				

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REQUEST FOR JOINING PROCEDURE

Requestor's Name Chris Neary Date 1/20/2014

Organization PG&E DCPP Location DCPP

Telephone # 805-545-4018 Date Required 3/31/2014

Responsible Weld Engineer Bronson R. Shelly

Base Material SA-240 type 410 to SA-240 type 304 Thickness 0.375"

Construction Code ASME III, NC, 2001-2003 Filler Material ER-309/309L, E309/309L

Sketches and Notes:

See SAPN 50600119 Task 16

Attachment 5: Base Metal Certified Material Test Reports (CMTR's)

TP 410 Plates HT# 950163

ATI Allegheny Ludlum — Certificate of Test

Stephen Wolff - Director, Corporate Quality Assurance

500 Green Street
Washington, PA 15301

Mill Information		Customer Information	
Cert Number	0101672-00	Name	ROLLED ALLOYS INC
Sales Order	50-012-238	PO	T82465
Cert Date	Mar-02-2012	PO Date	Jan-13-2012

Sold to: ROLLED ALLOYS INC
PO BOX 310
TEMPERANCE, MI 48182

Ship to: ROLLED ALLOYS INC.
125 WEST STERNS ROAD
TEMPERANCE, MI 48182

Material Information

"ATI 410" STAINLESS STEEL
PMP HOT ROLLED PLATE ANNEALED* PICKLED COMMERCIAL CUT EDGE **TRACER #** Below

ASTM-A-240-11A ASME-SA-240 ED 2010
AMS 5504M UNS S41000

Piece Information

Pcs	Gauge (In)	Width (In)	Length (In)	Heat #	Piece ID	Section Id	Lot #	Total Wt (lbs)
Item: 001	Cust-Id: 189032999001 Cust-Job:			Govt-Contract-#: SchedulaB:		Govt-DO-Rating:		
1	.3750	75.0000	232.0000	950163	AA35292	TR 258793	408386	1916
1	.3750	75.0000	232.0000	950163	AA35297	TR 258794	408326	1916
1	.3750	75.0000	232.0000	950163	AA35298	TR 258795	408326	1916
1	.3750	75.0000	232.0000	950163	AA35299	TR 258796	408326	1916
1	.3750	75.0000	232.0000	950163	AA35300	TR 258797	408326	1916
1	.3750	75.0000	232.0000	950163	AA35301	TR 258798	408326	1916
1	.3750	75.0000	232.0000	950163	AA35302	TR 258799	408326	1916
1	.3750	75.0000	232.0000	950163	AA35304	TR 258800	408326	1916
1	.3750	75.0000	232.0000	950163	AA35305	TR 258801	408326	1916
1	.3750	75.0000	232.0000	950163	AA35306	TR 258802	408326	1916
1	.3750	75.0000	232.0000	950163	AA35307	TR 258803	408326	1916
1	.3750	75.0000	232.0000	950163	AA35308	TR 258804	408326	1916
1	.3750	75.0000	232.0000	950163	AA35309	TR 258805	408326	1916
1	.3750	75.0000	232.0000	950163	AA35310	TR 258806	408386	1916
1	.3750	75.0000	232.0000	950163	AA35311	TR 258807	408386	1916

Chemistry Testing

Element	Requirements Min	Requirements Max	Final Heat Analysis 950163	Loc
C	.08	.15	.13	MI

TRIANGLE ENGINEERING, INC.
Q.A. APPROVED
BY: JRC
DATE: 11-20-12

ALC620 03/13/2012 11:03:37

Chemistry Testing

Element	Requirements Min	Requirements Max	Final Heat Analysis 950163	Loc
MN	---	1.00	.55 ✓	MI
P	---	.040	.024 ✓	MI
S	---	.030	< .001 ✓	MI
SI	---	1.00	.31 ✓	MI
CR	11.50	13.50	12.04 ✓	MI
NI	---	.75	.38 ✓	MI
AL	---	.05	< .01 ✓	MI
MO	---	.50	.05 ✓	MI
CU	---	.50	.15 ✓	MI
N	---	.08	.02 ✓	MI
SN	---	.05	.01 ✓	MI

THE REPORT TO WHICH THIS STAMP IS AFFIXED IS A COPY OF THE ORIGINAL MILL TEST REPORTS WHICH IS KEPT ON FILE IF SEVERAL ITEMS ARE SHOWN IN THIS REPORT, ITEMS (X) ARE PERTINENT TO ITEMS SHIPPED TO YOU
CUSTOMER PO NO. 3501000749
TEI WORK ORDER NO. T27696
DATE 3-5-14 SIGNED [signature]
TRIANGLE ENGINEERING, INC.

Allegheny Ludlum performs chemical analysis by the following techniques:
C, S by combustion/infrared; N, O, H by inert fusion/thermal conductivity;
Mn, P, Si, Cr, Ni, Mo, Cu, Cb, Co, V, by WDXRF; Pb, Bi, Ag by GFAA;
B by OES; Al and Ti (>=0.10%) by WDXRF, otherwise by OES.

950163 - Material was produced by EF melting with AOD refining.

Mechanical Testing

		LOT 408326		LOT 408326		LOT 408386		LOT 408386	
Condition:		ANNEALED		AMS 5504 HT		ANNEALED		AMS 5504 HT	
Direction:		TRANSVERSE		TRANSVERSE		TRANSVERSE		TRANSVERSE	
Temperature:		ROOM TEMP		ROOM TEMP		ROOM TEMP		ROOM TEMP	
Spec:									
Test Limit	Units	Result	Loc	Result	Loc	Result	Loc	Result	Loc
YIELD 0.2%	psi	43900. ✓	TC	---	--	47100. ✓	TC	---	--
TENSILE	psi	74500. ✓	TC	---	--	78000. ✓	TC	---	--
ELONGATION	%	34. ✓	TC	---	--	33. ✓	TC	---	--

Mechanical Testing

		LOT 408326		LOT 408326		LOT 408386		LOT 408386	
Condition:		ANNEALED		AMS 5504 HT		ANNEALED		AMS 5504 HT	
Direction:		TRANSVERSE		TRANSVERSE		TRANSVERSE		TRANSVERSE	
Temperature:		ROOM TEMP		ROOM TEMP		ROOM TEMP		ROOM TEMP	
Spec:									
Test Limit	Units	Result	Loc	Result	Loc	Result	Loc	Result	Loc
RED OF AREA	%	72.	TC	---	--	73.	TC	---	--
HARDNESS	—	164. ✓ HBW	TC	41.0 ✓ HRC	TC	167. ✓ HBW	TC	40.0 ✓ HRC	TC
BEND	P/F	PASS	TC	---	--	PASS	TC	---	--

Lab heat treatment on test samples - 1750F (954C), holding at heat 15 - 30 minutes.

Mechanical Property Requirements

		ANNEALED		AMS 5504 HT	
Condition:		ANNEALED		AMS 5504 HT	
Direction:		TRANSVERSE		TRANSVERSE	
Temperature:		ROOM TEMP		ROOM TEMP	
Spec:					
Test Limit	Units	Min	Max	Min	Max
YIELD 0.2%	psi	30000.	---	---	---
TENSILE	psi	65000.	95000.	---	---
ELONGATION	%	20.	---	---	---
RED OF AREA	%	---	---	---	---
HARDNESS	—	---	217. HBW	35. HRC	45. HRC
BEND	P/F	---	---	---	---

Metallography - General

Test ID	Result Name	Condition	Test Result	Loc	Requirements
LOT 408326	GRAIN SIZE	ANNEALED	8.5	TC	---
LOT 408386	GRAIN SIZE	ANNEALED	9.	TC	---

Metallographic magnification: 100X; Etchant used HCL/PICRIC ACID

304L 1H200 HT# H2JH

NAS

6870 HIGHWAY 42 EAST

METALLURGICAL TEST REPORT

NORTH AMERICAN STAINLESS
6870 HIGHWAY 42 EAST
GHENT, KY 41045

Certificate: 851788 1

Customer: 002830 996

Mail To:
ROLLED ALLOYS - TEMPERANCE
CUSTOMER PICKUP
801 TWIN RAIL DRIVE
MINOOKA, IL 60447

Ship To:
ROLLED ALLOYS - TEMPERANCE
CUSTOMER PICKUP
801 TWIN RAIL DRIVE
MINOOKA, IL 60447

Date: 7/11/2013 Page: 1

Steel: 304/304L

Finish: 1

Your Order: T89054

NAS Order: IN 0171582 01

Corrosion: ASTM A262/02aE;180Bend-OK

PRODUCT DESCRIPTION:

STAINLESS STEEL COIL, HRAP; UNS 30400/30403
ASTM A240/11b,A480/11b,A666/10;ASME SA240/11a,SA480/11a,SA666/11a
CHEM ONLY ON FOLLOWING ASTM: A276/10,A479/11,A484/11,A312/11
CHEM ONLY ON FOLLOWING ASME: SA312/11,SA479/11
AMS 5511H/5513J XMRK; MIL-5059D AMD3(X CRN MEAS); MIL-4043B
NACE MR0175/ISO 15156-3:2003 A, MR0103/07;QQS766D-A X MAG PERM
MIN. SOLUTION ANNEAL TEMP 1900F, WATER QUENCHED
ASME Sect. II, 1995 Edition, 1996 & 1997 Addenda

REMARKS:

Mat'l is Free of Mercury Contamination. No weld repairs.
EN 10204:2004 3.1; RoHS 1 & 2 Compliant
Material is Free of Radioactive Contamination
NAS Steel Making Process: EAF, AOD, & Cont. Casting
Product Mfg.by a Quality Mgt.Sys. in Conf. w/ISO 9001
*Melted & Manufactured in the USA; Mat'l is DFARs Compliant

Product Id	Coil #	Skid #	Thickness	Width	Weight	-------Length------	Mark	Pieces	Commodity Code
01H2J8 E	01H2J8 E		.3750	60.0000	16,250	COIL	1	1	

CHEMICAL ANALYSIS CM(Country of Melt) ES(Spain) US(United States) ZA(South Africa) JP(Japan)

Chemical Analysis per ASTM A751/08

HEAT	CM	C %	CR %	CU %	MN %	MO %	N %	NI %	P %	S %
H2J8	US	.0215	18.0570	.4100	1.8105	.2720	.0705	8.0255	.0310	.0010

SI %
.2040

TRIANGLE ENGINEERING, INC.
Q.A. APPROVED
BY: JRC
DATE: 9-20-13

THE REPORT TO WHICH THIS STAMP IS AFFIXED IS A COPY OF THE ORIGINAL MILL TEST REPORTS WHICH IS KEPT ON FILE IF SEVERAL ITEMS ARE SHOWN IN THIS REPORT, ITEMS (X) ARE PERTINENT TO ITEMS SHIPPED TO YOU
CUSTOMER PO NO. 3501000749
TEI WORK ORDER NO. T27696
DATE 3-5-14 SIGNED
TRIANGLE ENGINEERING, INC.

MECHANICAL PROPERTIES

Product Id#	Coil #	loc	dir	UTS KSI	.2% YS KSI	ELONG %-2"	Hard RB	Tail Hard
01H2J8 E	01H2J8 E	F	T	92.76	56.44	51.94	87.00	91.00

HEAT# H2J8

TRACER# 293216

ROLLED ALLOYS QUALITY ASSURANCE
APPROVED
DATE 7-12-13

NAS hereby certifies that the analysis on this certification is correct. Based upon the results and the accuracy of the test methods used, the material meets the specifications stated. These results relate only to the items tested and this report cannot be reproduced, except in its entirety, without the written approval of NAS.

Technical Dept. Mgr.

ERIC HESS 7/11/2013

Attachment 6: Filler Metal Certified Material Test Reports (CMTR's)

ARCOS INDUSTRIES, LLC
ONE ARCOS DRIVE
Mt. Carmel, PA 17851

This CMTR covers PG&E PO # 118390; Weldstar Nuclear Shipping Ticket # N639470-00

Arcos

DATE 04/29/04

ASME CERTIFICATE NO. QSC-448
EXPIRATION DATE 10/23/05

CERTIFICATION OF TESTS

SOLD TO:
WELDSTAR CO.
P.O. BOX 1150
AURORA, IL 60507

SHIP TO:
WELDSTAR CO.
1750 MITCHELL ROAD
AURORA, IL 60504

ARCOS S.O.	CUSTOMER ORDER NO.		CONSIGNEE ORDER NO.	DATE SHIPPED
80202	903566		N/A	4/29/04
ITEM	SIZE	GRADE	LOT NO./ALLOY NO.	QUANTITY
	1/8 X 14"	ARCOS 309-16	4D14E-14A-HEAT #DF8184	510#

SPECIFICATION: ASME SFA 5.4 CLASS E 309 ASME SECTION II, PART C,
ASME B&PVC SECTION III, SUBSECTION NB2400, 1989 EDITION,
NO ADDENDA. 10CFR21, 10CFR50 APP. B APPLY.
FMC-5.4, REV. 2

CHEMICAL ANALYSIS: WELD

C	Mn	Si	S	P	Cr	Ni	Mo	Cb	Cb + Ta
0.04	1.3	0.60	0.00	0.03	23.7	13.5	0.12		0.039
Ta	Ti	Al	Co	Cu	Fe	V	N		
	0.028		0.096	0.07		0.092	0.08		

ADDITIONAL TEST RESULTS		TENSILE	As Welded	Heat Treated
Ferrite - NB2433.1-1:	9FN	Yield	68,000	
Magna Gage:	9FN	Tensile	93,000	
X-Ray:		Elongation	41%	
Bends:		Red.of Area	72%	
Hardness:				

OTHER INFORMATION: Lot Classification - C1 Intensity of Testing - Schedule K
CONTROL NO. UQ
PREHEAT 60°F, INTERPASS 300°F

THIS MATERIAL IS FREE FROM MERCURY, RADIUM OR ALPHA PARTICLE CONTAMINATION.

We hereby affirm that the reported results on this certification are correct and accurate. All test and results and operations performed by Arcos or its subcontractors are in compliance with the applicable material/customer specification.

ARCOS

WELDSTAR COMPANY'S
QUALITY SYSTEM CERTIFICATE
[illegible] QSC [illegible]
EXPIRATION DATE [illegible]

G. GRATTI
QA MANAGER

QUALITY ASSURANCE DEPARTMENT

ARCOS INDUSTRIES, LLC
ONE ARCOS DRIVE
Mt. Carmel, PA 17851

This CMTR covers Pacific Gas & Electric PO# 135436; Weldstar Nuclear Shipping Ticket #N787221

Arcos

DATE 06/29/07

ASME CERTIFICATE NO. QSC-448
EXPIRATION DATE 10/23/08

CERTIFICATION OF TESTS

SOLD TO:
WELDSTAR CO.
P.O. BOX 1150
AURORA, IL 60507

SHIP TO:
WELDSTAR CO.
1750 MITCHELL ROAD
AURORA, IL 60504

ARCOS S.O.	CUSTOMER ORDER NO.	CONSIGNEE ORDER NO.	DATE SHIPPED
92467A	904402 C/O 1	N/A	06/29/07

ITEM	SIZE	GRADE	LOT NO. - HEAT NO.	QUANTITY
	1/8" X 36"	ARCOS 309/309L	DT8703 - 735032	1200#

SPECIFICATION: ASME SFA 5.9 CLASS ER 309/309L ASME SECTION II, PART C,
ASME B&PVC SECTION III, SUBSECTION NB2400, 2004 EDITION,
AND ALL PARAS AND ADDENDA THRU 2006
10CFR21 AND 10CFR50 APPX. B APPLIES ASME NCA 3800

CHEMICAL ANALYSIS:

C	Mn	Si	S	P	Cr	Ni	Mo		Cb+Ta	
0.017	2.06	0.47	<0.001	0.02	23.3	13.6	0.07		0.006	WIRE
0.019	1.98	0.48	0.003	0.02	23.4	13.8	0.07		0.006	WELD
	Ti	Co		Cu	Fe	V	N			
	0.004	0.031		0.04	BAL	0.063	0.068			WIRE
	0.003	0.032		0.04	BAL	0.064	0.074			WELD

ADDITIONAL TEST RESULTS

Ferrite - NB2433.1-1: 9FN WIRE, 9FN WELD
Magna Gage: 10 FN
X-Ray:
Bends:
Hardness:

TENSILE	As Welded	Heat Treated
Yield	54,000 psi	
Tensile	81,000 psi	
Elongation	53%	
Red.of Area	77%	

OTHER INFORMATION: Lot Classification - S3 Intensity of Testing - Schedule K

GTAW 100% ARGON Control No.8703
60F Preheat, 300F Interpass

THIS MATERIAL IS FREE FROM MERCURY, RADIUM OR ALPHA PARTICLE CONTAMINATION.

We hereby affirm that the reported results on this certification are correct and accurate. All test and results and operations performed by Arcos or its subcontractors are in compliance with the applicable material/customer specification.

WELDSTAR COMPANYS
QUALITY SYSTEM CERTIFICATE
(MATERIALS) QSC 229
EXPIRATION DATE JAN. 5, 2009

QUALITY ASSURANCE DEPARTMENT
Gib Gratti QA Manager

Attachment 7: Element Laboratory Report PAC003-03-24-71934-1

element™

Date: 3/26/2014
P.O. No.: 3501003648***
W/O No.: PAC003-03-24-71934-1

*****CORRECTED TEST CERTIFICATE - EAR-CONTROLLED DATA – 3/31/2014*****

Weld Tensile Test

Test Method	ASME SEC IX (2013 ed) QW-152

Specimen	Initial Width (in)	Initial Thickness (in)	Initial Area (sq. in)	Ultimate Tensile Strength (ksi)	Fracture Location
	Min	Min	Min	Min	
Requirements	N/S	N/S	N/S	65	
WELD #1	0.754	0.3010	0.2270	75.5	P.M (410)
WELD #2	0.753	0.3150	0.2372	76.0	P.M (410)

ROOT BEND

Test Method: ASME SEC. IX (2013 ED.) QW-160
ACC. PER: QW-163
Material Thickness: .300"
Mandrel Diameter: 1.2"

Two samples were Root bent 180 degrees over a roller with a diameter of 4 times the bend specimen thickness with the weld and heat-affected zones centered within the convex length of the bent samples.
The samples were examined for cracks and other defects and were found to meet specification.
Results: 1) ACCEPTABLE 2) ACCEPTABLE

FACE BEND

Test Method: ASME SEC. IX (2013 ED.) QW-160
ACC. PER: QW-163
Material Thickness: .300"
Mandrel Diameter: 1.2"

Two samples were Face bent 180 degrees over a roller with a diameter of 4 times the bend specimen thickness with the weld and heat-affected zones centered within the convex length of the bent samples.
The samples were examined for cracks and other defects and were found to meet specification.
Results: 1) ACCEPTABLE 2) ACCEPTABLE

Test Witnessed By:	Bronson R. Shelly
Date:	3/26/2014

All work was performed in accordance with Element Materials Technology QA Management System Manual Edition 2, Rev. 1, dated 04/02/2012.
Quality Program meets the requirements of 10CFR50 App. B and 10CFR part 21, including Right of Access, Reporting of Non Conformances, Documentation and Requirements.

MATERIAL CONFORMS TO SPECIFICATION

Respectfully submitted

15062 Bolsa Chica, Huntington Beach, CA 92649
(714) 892-1961 ph • (714) 892-8159 fax www.element.com

Justin Bouavanh
Quality Administrator

element

Element Materials Technology
15062 Bolsa Chica
Huntington Beach, CA
92649-1023 USA

P 714 892 1961
F 714 892 8159
T 888 786 7555
info.hb@element.com
element.com

Contact: Andrew Carr
PACIFIC GAS AND ELECTRIC COMPANY
PO BOX 56
AVILA BEACH, CA 93424

*****CORRECTED TEST CERTIFICATE — EAR-CONTROLLED DATA – 4/1/2014*****

Date:	3/26/2014
Purchase Order Number:	3501003648
Work Order Number	PAC003-03-24-71934-1

Description:	WELDED PLATE
Specification:	ASME SEC IX (2013 ED.), ASME SEC III, SUBSECTION NC, 2001 ED. WITH 2003 ADDENDA, PROCEDURE QUALIFICATIONS, SA-240, TYPE 410 TO SA-240, TYPE 304 NUCLEAR QUALITY RELATED WORK
Mat'l. Reqn. No.:	12572411
PQR:	771

CHEMICAL ANALYSIS HT# 950163***
ASME SA 240-2013 410

Element		Result %	Min %	Max %
C	=	0.13	0.08	0.15
Mn	=	0.57	0.00	1.00
P	=	0.024	0.000	0.040
S	=	0.002	0.000	0.030
Si	=	0.31	0.00	1.00
Cr	=	12.1	11.5	13.5
Ni	=	0.4	0.00	0.75
Fe	=	Balance	Balance	Balance

Chemical Analysis performed by Optical Emission per SOP 2.02, Revision 15
Carbon and Sulfur by Combustion per SOP 7.00, Revision 10

CHEMICAL ANALYSIS HT# H2J8***
ASME SA 240-2013 304

Element		Result %	Min %	Max %
C	=	0.015	0.000	0.08
Mn	=	1.81	0.00	2.00
P	=	0.029	0.000	0.045
S	=	0.002	0.000	0.030
Si	=	0.21	0.00	0.75
Cr	=	18.1	18.0	20.0
Ni	=	8.0	8.0	10.5
N	=	0.07	0.00	0.10
Fe	=	Balance	Balance	Balance

Chemical Analysis performed by Optical Emission per SOP 2.02, Revision 15
Carbon and Sulfur by Combustion per SOP 7.00, Revision 10
Nitrogen by Fusion per SOP 13.00, Revision 9

Respectfully submitted

Justin Bouavanh
Quality Administrator

15062 Bolsa Chica, Huntington Beach, CA 92649
(714) 892-1961 ph • (714) 892-8159 fax www.element.com

Attachment 8: ATS Work Traveler for PQR 771

PQR 410 (P6) to 304 (P8) Traveler (SAPN 50600119)

Number	Step	Verification	Recorded Value	Welder Signoff	CWI Signoff	Engineer's Signoff
1	Base Metal	Heat #'s and condition	410 - HT# 95C163 Plate 304/304L HT# H238 Plate 304/304L HT# 122911 Backing	[signature] 3-13-14	Louis Eliseo 3-13-14	[signature] 3/13/14
2	Filler Metal	Heat #'s and condition [initials] 3/13/14	Fluke Test# 15581 Fluke 115C Test#	[signature] 3-13-14	Louis Eliseo	[signature] 3/13/14
3	Equipment Meters	Cal dates and documentation	ER309/309L 1/8" - 5763 E309/309L 3/32" - D42337C E309 1/8" - 0423347	[signature] 3-13-14	Louis Eliseo 3-13-14	[signature] 3/13/14
4	PQR package	Documentation completeness	N/A	[signature] 3-13-14	Louis Eliseo 3-13-14	[signature] 3/13/14
5	Welding Equipment	Set-up and condition	N/A	[signature] 3-13-14	Louis Eliseo 3-13-14	[signature] 3/13/14
6	Fit-up	PQR plate fit-up and dimensions		[signature] 3-13-14	Louis Eliseo 3-13-14	[signature] 3/13/14
7	In Process	Welding variables during welding		[signature] 3-13-14	Louis Eliseo 3-13-14	[signature] 3/13/14
8	Final Inspection	Final weld inspection		[signature] 3-13-14	Louis Eliseo 3-13-14	[signature] 3/13/14
9	Final Package	Documentation reviewed for completeness		—	—	[signature] 3/21/14

SIA Report No. 1301620.402

Stress and Fracture Mechanics Evaluation of Type 410 Stainless Steel Weldments in Safety Injection Pumps at Diablo Canyon Power Plant (Revision 2)

Report No. 1301620.402
Revision 2
Project No. 1301620
May 2014

Stress and Fracture Mechanics Evaluation of Type 410 Stainless Steel Weldments in Safety Injection Pumps at Diablo Canyon Power Plant

Prepared for:

Pacific Gas & Electric Company
San Francisco, California
Contract No. 3500993337

Prepared by:

Structural Integrity Associates, Inc.
San Jose, California

Prepared by:	Heather F. Jackson, PhD, PE	Date:	5/9/2014
Reviewed by:	Clifford Lange, PhD, PE	Date:	5/9/2014
Approved by:	Heather F. Jackson, PhD, PE	Date:	5/9/2014

Structural Integrity Associates, Inc.®

REVISION CONTROL SHEET

Document Number: **1301620.402**

Title: Stress and Fracture Mechanics Evaluation of Type 410 Stainless Steel Weldments in Safety Injection Pumps at Diablo Canyon Power Plant

Client: Pacific Gas & Electric Company

SI Project Number: **1301620** Quality Program: ☒ Nuclear ☐ Commercial

Section	Pages	Revision	Date	Comments
All	All	0	01/17/2014	Initial Issue
1.0 2.0 3.0 4.0 5.0 6.0	1-1 – 1-8 2-1 – 2-8 3-1 – 3-18 4-1 – 4-12 5-1 – 5-2 6-1 – 6-2	1	4/22/2014	Revised to incorporate client comments and format
1.0 4.0	1-6 4-4, 4-10	2	5/9/2014	Revised to incorporate client comments

REGISTERED PROFESSIONAL ENGINEER
HEATHER F. JACKSON
MT 1975
METALLURGICAL
STATE OF CALIFORNIA

Approved by:

Heather F. Jackson, PE

Registration No.: MT 1975

State: California

Date: 5/9/2014

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1.0 INTRODUCTION

This report summarizes the findings of stress and fracture mechanics analyses in support of the Diablo Canyon Power Plant's (DCPP) evaluation of the Safety Injection (SI) pump vent and drain line Type 410 stainless steel welds.

The purpose of the present analyses is to assist DCPP in determining operability based on the current condition of the Type 410 stainless steel pipe nipples. The analysis consists of stress and fracture mechanics analyses to determine allowable flaw sizes and predict fatigue crack growth of hypothetical flaws.

1.1 Background

DCPP is in the process of replacing a Type 316 stainless steel valve on one of the four Safety Injection pumps. These pumps were supplied by the manufacturer with ¾" Type 410 (martensitic) stainless steel pipe nipples welded to the pump casing at the pump vent and drain lines. The Type 410 nipples are joined to ¾" austenitic stainless steel valves and fittings via socket welds fabricated in the field. Figure 1-1 illustrates schematically the four field weld locations of interest on each pump. Checks of various components on that pump verified that a ¾" Type 410 stainless steel nipple is welded to ¾" Type 316 piping. Information received subsequently indicated that one location per pump, the vent valve, is Type 316, while the other three joints on each pump use Type 304 fittings. Reviews of fabrication records verified that a Type 309 stainless steel filler metal was used for the Type 410/Type 316 and 410/304 joints.

Further reviews of the fabrication records indicate that the 410/316 and 410/304 weld joints were made using a P1/P8 (carbon steel/austenitic stainless steel) welding procedure as opposed to the P6/P8 (martensitic/austenitic stainless steel) procedure that was specified. The P1/P8 weld procedure lacks the post-weld heat treatment potentially required by the P6/P8 procedure. Consequently, the condition of the as-welded Type 410 base metal is likely to be affected.

The pump and valve in question appear to be from original construction. Searches of documentation by DCPP personnel suggest that of the three Safety Injection pumps of this design that are still in service at DCPP (the fourth, a Unit 2 pump, was replaced), all three appear to be identical configurations (or have this same basic design), and all appear to have been welded in the same way.

Because the socket weld joining the Type 410 pipe nipple to the Type 316 valve was welded with a P1/P8 procedure, while the systems materials were found to be P6 and P8, this has been identified as a potential operability condition, requiring a prompt assessment of the potential impact of this fabrication issue on plant safety. Structural Integrity Associates, Inc. (SIA in the present report) was contacted to assist DCPP in providing a determination of plant operability based upon this issue.

A previous letter report [1] addressed the first phase of this activity: determination of the probable metallurgical condition of the 410/316 welds and a determination of the suitability of those welds to permit safe operation of the plant. That report concluded that these welds are considered to be conditionally acceptable, pending the results of stress and fracture mechanics analyses, the second phase of this activity and the objective of this report.

1.2 Objective

The primary objectives of the stress and fracture mechanics analyses are: (1) to employ normal and abnormal loading determined from DCPP piping stress reports in order to calculate stresses via finite element modeling, (2) to apply these stresses to hypothetical flaws, assuming lower-bound toughness properties, in order to (3) evaluate the stability and growth of such hypothetical cracks under continued operation.

1.3 Analytical Methodology

A fracture mechanics approach analogous to the methods of ASME Code, Section XI [2] is used to evaluate postulated flaws in the DCPP SI pump Type 410 stainless steel welds. The present case involves a material and flaw geometry not explicitly treated by these ASME Code methods. Specifically, ASME Section XI methods do not address Type 410 martensitic stainless steels, evaluation of (postulated) flaws on piping OD surfaces, or evaluation of flaws in piping of diameter 4 inches or less.

The overall approach, detailed in the sections that follow, consists of:

(1) Identifying applicable flaw configuration and failure criterion

(2) Determining stresses at the flaw location under operating loads

(3) Determining stress intensity factors at the flaw location

(4) Obtaining material fracture toughness and fatigue crack growth properties

(5) Determining allowable flaw size under maximum loading

(6) Analyzing flaw growth under cyclic fatigue loading

Material properties for Type 410 martensitic stainless steel, particularly in the un-tempered condition assumed for the as-fabricated welds, are not provided in ASME Section XI. For such materials, ASME Section XI Articles C-8330 and C-8430 permit properties to be obtained from other sources [2]. Material properties are discussed in Sections 3.2.5 and 4.2.2 of this report.

Regarding flaw geometry, a semi-elliptical circumferential flaw is postulated on the outer surface of the pipe, extending from the root of the weld toe. This location forms a geometric stress concentration and is the region where the cyclic stresses are largest. The flaw is therefore considered to extend from the OD of the pipe toward the ID. Residual stresses are found to be small or strongly compressive near the OD but strongly tensile at the pipe ID, suggesting that an ID-surface flaw should also be considered. Residual stresses would not contribute to fatigue crack growth. However, for the evaluation of allowable flaw size, a flaw at the ID surface is also evaluated. Flaw geometry is discussed further in Section 3.2.2.

The stress intensity factor solutions for circumferential flaws provided in ASME Section XI, Article C-7300 [2], do not address a flaw located at the OD nor for the stress concentration factor associated with the weld toe. Article C-7300 provides no stress intensity factor solution for residual stresses, which must be obtained from other sources, for instance, finite element stress analysis. The use of an influence function can accurately treat a general through-thickness stress gradient and is useful for estimating stress intensity factors for cracks that emanate from stress concentrations, such as a surface crack at a weld toe. An influence function for a semi-elliptical circumferential OD flaw in a pipe with finite R_i/t is therefore desired and is available from API-579 [3]. The stress intensity factors for the postulated flaw are therefore calculated by the influence function procedures described in API-579 [3].

A comparison between the present methodology and the procedures defined in ASME Section XI is summarized below.

ASME Code, Sec. XI [2]	Present Methodology
Stress Intensity Factor Solution	
C-7300 $K_I = K_{Im} + K_{Ib} + K_{Ir}$ $K_{Im} = (SF_m)F_m\sigma_m(\pi a)^{0.5}$ $K_{Ib} = [(SF_b)\sigma_b + \sigma_e]F_b(\pi a)^{0.5}$ $K_{Ir} = Not\ provided$ Comments 1. Applicable to surface flaws on ID 2. No K-solution provided for residual stresses	API-579 Influence Function [3] $\sigma = f(x)$ $K = \int_0^a f(x)\sigma(x)dx$ Comments 1. Specific influence function for OD crack with actual R/t available 2. More realistic, less conservative 3. Accurately treats arbitrary through-thickness stress gradients and surface stress concentrations
Fracture Toughness	
K_{Ic}, tearing, or limit load considered. Toughness properties available for: - Austenitic steel (C-8310) - Ferritic, carbon steel, low alloy steel (C-8320) - C-8330 states "For other piping materials…similar procedures may be used to establish J_{IC}, K_{IC}, or K_C."	Martensitic stainless steel, high strength, low toughness, therefore K_{Ic} used. K_{Ic} obtained from literature.
Fatigue Crack Growth Rate	
Information provided for: - Low alloy, ferritic and carbon steels in water and air (C-8420) - Austenitic in air (C-8410-1) - Alloy 600 in air and water (C-8410-2) - C-8430 states "The fatigue crack growth rates for materials not covered in C-8410 or C-8420 may be obtained from other sources".	Fatigue crack growth rate obtained from literature, water environment used for conservatism.

Details of the stress analysis are provided in Section 2.0. The evaluation of crack stability and allowable crack size is discussed in Section 3.0. Section 4.0 presents the evaluation of fatigue crack growth. A summary of the findings and recommendations are provided in Section 5.0.

1.4 Nomenclature

A	=	Pipe cross-sectional area, inch^2
a	=	Depth of semi-elliptical surface flaw, inch
a_{allow}	=	Maximum allowable flaw depth for stability of postulated cracks, inch
a_f	=	Maximum depth to which a flaw is calculated to grow by the end of the evaluation period, inch
a_i	=	Initial flaw depth at the beginning of the evaluation period, inch
Δa	=	Flaw growth during the evaluation period = $a_f - a_i$, inch
c	=	Half-length of semi-elliptical surface flaw, inch
$2c$	=	Full surface length of semi-elliptical flaw, inch
c_f	=	Maximum half-length to which a flaw is calculated to grow by the end of the evaluation period, inch
c_i	=	Initial flaw half-length at the beginning of the evaluation period, inch
C_o	=	Material constant in flaw growth equation, inch/cycle·(ksi√in)
CVN	=	Charpy V-notch absorbed energy, ft-lb
da/dN	=	Cyclic flaw growth rate, inch/cycle
DE	=	Design earthquake loads
DL	=	Deadweight or dead load
DW	=	Deadweight or dead load
F_i	=	Applied force on the pipe where i refers to x, y, and z components, lbs
F_{eff}	=	Effective force on the pipe, evaluated as the *SRSS* of x, y, and z components, lbs
F_{eq}	=	Equivalent axial tensile force that produces the same stress as the applied forces and moments, lbs
F_m	=	Parameter for circumferential flaw membrane stress intensity factor
F_b	=	Parameter for circumferential flaw bending stress intensity factor
I	=	Moment of inertia, inch^4
ID	=	Inside diameter of pipe, inch
K	=	Stress intensity factor, ksi√in
K_{IC}	=	Material fracture toughness; reflects crack initiation under static, plane strain conditions, ksi√in
K_{max}	=	Maximum stress intensity factor associated with transient stress range ΔK, ksi√in
K_{min}	=	Minimum stress intensity factor associated with transient stress range ΔK, ksi√in
ΔK	=	Cyclic stress intensity factor; maximum range of K fluctuation during a transient, equal to K_{max} minus K_{min}, ksi√in
ΔK_{th}	=	Threshold stress intensity factor for fatigue flaw growth, ksi√in

K_{JC}	=	Fracture toughness parameter calculated at the initiation of crack growth under elastic-plastic conditions, ksi√in
K_Q	=	Fracture toughness parameter calculated at the point of maximum load under elastic-plastic conditions, ksi√in
M_i	=	Applied moment on the pipe where *i* refers to *x, y,* and *z* components, inch-lbs
M_{eff}	=	Effective moment on the pipe, evaluated as the *SRSS* of *x, y,* and *z* components
n	=	Material constant in flaw growth equation
N	=	Number of load cycles in flaw growth evaluation, cycles
OD	=	Outer diameter of pipe, inch
R	=	Load ratio or stress ratio = K_{min}/K_{max}
R_i	=	Inside radius of a pipe, inch
R_o	=	Outside radius of a pipe, inch
S(R)	=	Scaling parameter to account for effect of *R* ratio on fatigue crack growth rate
SF	=	Structural factor for stress, based on service level
SI	=	Safety injection
SIA	=	Structural Integrity Associates
SRSS	=	Square root of the sum of squares
t	=	Thickness of pipe wall, inch
σ	=	Applied tensile stress, ksi

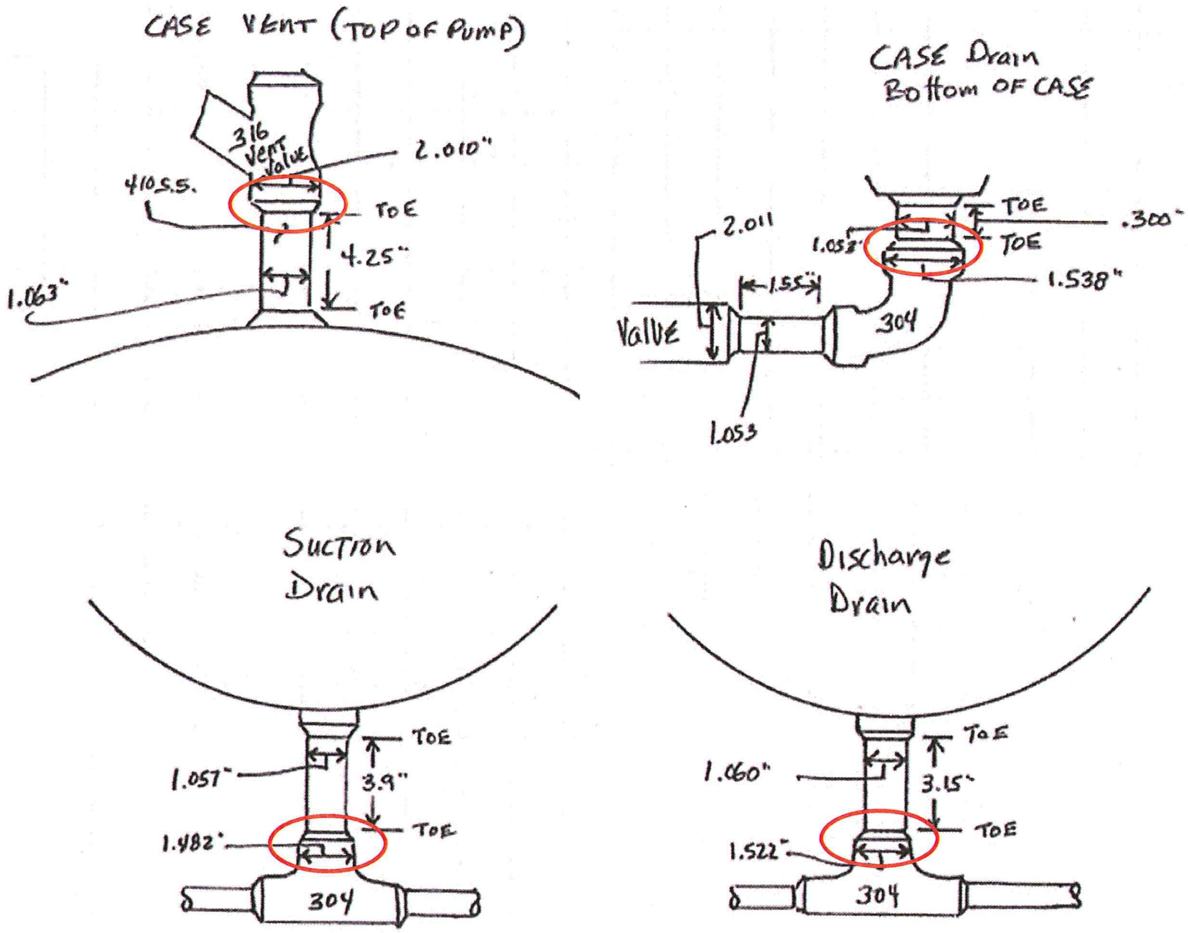


Figure 1-1. Sketches of SI pump Type 410 stainless steel vent and drain line socket weld locations of interest in the present evaluation (red circles), provided by DCPP [4].

2.0 STRESS ANALYSIS

2.1 Objective

A residual stress analysis, unit axial load analysis, and internal pressure analysis are performed. The objective of these analyses is to extract the stress distributions along a specified flaw path for use in subsequent fracture mechanics and fatigue crack growth analyses.

2.2 Analytical Methodology

The analytical approach uses finite element analysis using the ANSYS software package [5] to simulate the multi-pass welding processes. Details of the evaluation process and its comparison to actual test data are provided in [6]. The residual stresses due to welding are controlled by various welding parameters, thermal transients due to application of the welding process, temperature dependent material properties, and elastic-plastic stress reversals.

2.3 Design Inputs

A 2-dimensional axisymmetric finite element model is constructed, including:

- ¾" pipe nipple
- Socket fitting
- Socket weld

The key dimensions used in the finite element model are shown in Figure 2-1, and they are summarized as follows:

- ¾" Type 410 pipe is identified as Schedule 80 [4]
  OD = 1.050" [7]
  ID = 0.742" [7]

- Socket weld (see Assumption #2 below)
  Weld Length = 0.236" with 1:1 taper
- Socket fitting dimensions
  OD = 1.522" (see Assumption #2 below)
  Socket external ID = 1.065" [8]
  Socket internal ID = 0.794" [8]
  Socket Bore Depth = 9/16", typical [9]
  Pipe End Gap = 1/16" [10]

The following materials were used for the modeled components:

- Socket Fitting — Type 316 Stainless Steel (See Assumption #1 below)
- Socket Weld — Type 309 Stainless Steel filler material
- Pipe Nipple — Type 410 (martensitic) Stainless Steel

Structural material properties are developed based on data in the 2001 Edition of the ASME Code with Addenda through 2003 [11,12] and, when available, material property specification publications, such as [13] for Type 410.

2.4 Assumptions

Assumptions used in the finite element stress analysis are summarized as follows:

1. Per Reference [4] and as illustrated in Figure 1-1, the as-built walkdown information shows that the Type 410 pipe nipple is connected to a Type 304 tee for the discharge drain and the suction drain, and to the Type 316 valve bodies. The analyses in this calculation use the material properties of Type 316 stainless steel to represent both Type 304 and 316 socket fittings and valve bodies. Type 316 and Type 304 do not have significantly different mechanical properties, and are not expected to give significantly different stress results for the analyses.

2. With reference to the as-built walkdown information and the pictures taken of the different Type 410 pipe nipples [4], the socket weld covers from the OD of the pipe

nipple to the tee socket OD. Although the valve body OD is 2.010", the walkdown pictures show that the socket weld does not completely cover the valve body welding face. Therefore, the socket weld length is computed as the distance between the socket OD and the pipe nipple OD, which is equal to 0.236" (see Figure 2-1).

3. Three weld nuggets are used to complete the socket weld (see Figure 2-2). The weld nuggets will be applied in the suggested sequence as shown in the figure.

4. Air backed environment on the pipe/socket fitting ID is assumed.

5. No preheat and no post weld heat treatment are assumed. This is consistent with the welding procedure used in applying the socket welds [10].

6. A maximum interpass temperature of 350°F between the deposition of weld nuggets is assumed for all welding processes, per the applicable welding procedure described in [10].

Three load cases are analyzed:

1. Weld residual load
2. Internal pressure of 2,250 psi
3. Unit axial load of 1,000 lbs

2.5 Results

As discussed in the following sections, the postulated flaw extends from the root of the weld toe, which is the region where cyclic stresses are the largest, and grows from the OD toward the ID. Consequently, Stress Path 1 across the pipe is defined at the weld toe OD toward the ID (see Figure 2-1), with axial stresses mapped along the path for residual stress, internal pressure, and unit axial load. The axial stress contour plot for residual stress is shown in Figure 2-3, while the stress contour plot for unit axial load of 1,000 lb is in Figure 2-4 and for internal pressure of 2,250 psi is in Figure 2-5. All axial stresses along Stress Path 1 are plotted in Figure 2-6a, while

Figure 2-6b focuses on the axial stresses produced by unit axial load and internal pressure, which are the cyclic stresses that will tend to grow a fatigue crack.

Stresses along Stress Path 1 are used in subsequent calculations of stress intensity factors for postulated flaws. Inspection of Figure 2-3 shows that the location of maximum axial weld residual stress appears to be displaced from Stress Path 1 shown in Figure 2-1. However, Stress Path 1 is located at the location of maximum stress produced by unit axial load (Figure 2-4) and internal pressure (Figure 2-5), the cyclic stresses that would drive fatigue crack growth. The geometric discontinuity at the weld toe produces a stress concentration on the OD at Stress Path 1, and Figure 2-6b shows that stresses due to axial load and internal pressure are amplified close to the OD at the weld toe. While the weld residual stresses are strongly compressive at the OD and tensile at the ID, Figure 2-6a shows that the peak weld residual tensile stress on the crack path is 60 ksi, which is less than 50% of typical yield strengths of un-tempered Type 410 [14].

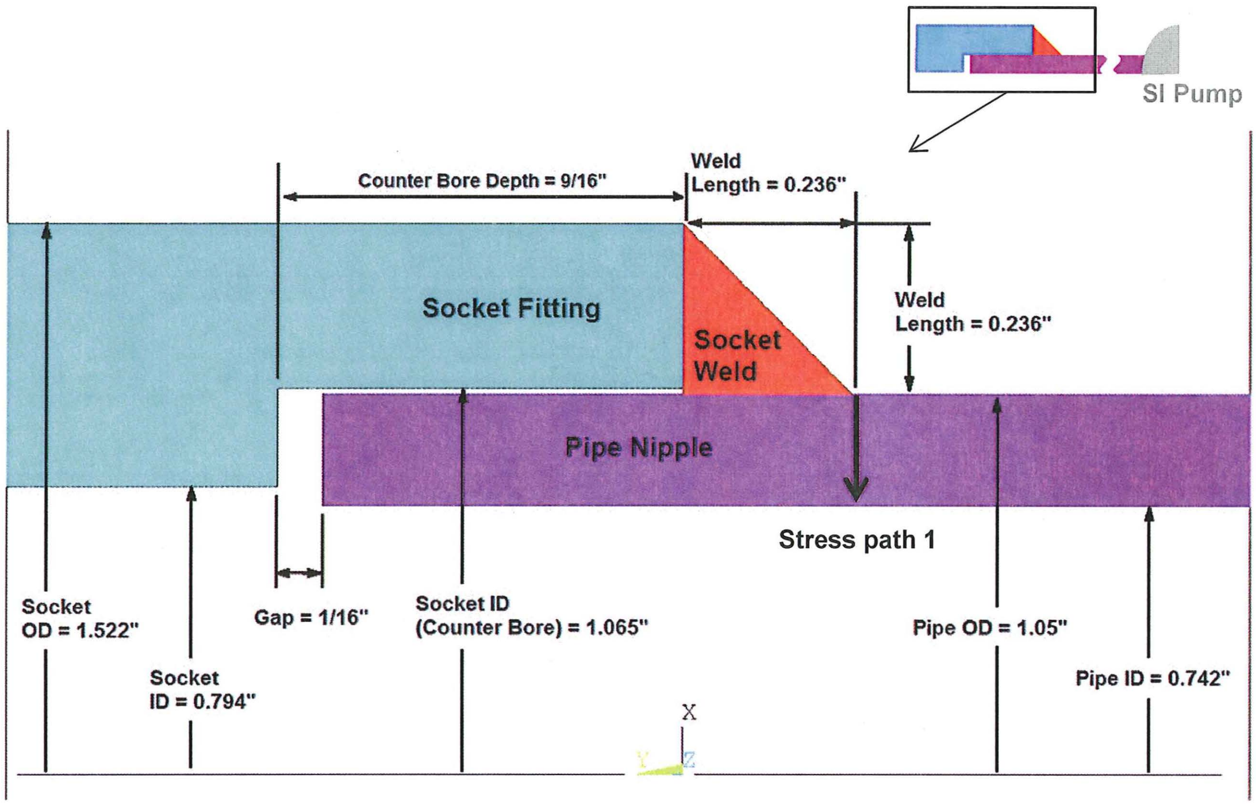


Figure 2-1. Finite element model showing key dimensions of socket welds. Stress Path 1 originates at the OD weld toe going toward the ID. Inset illustrates location of SI pump (not included in model).

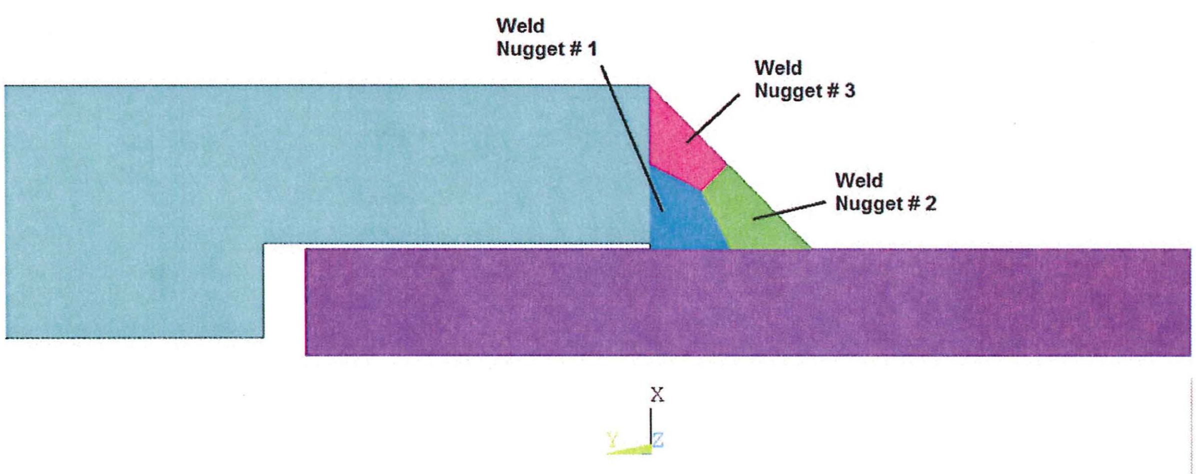


Figure 2-2. Finite element model showing the weld nuggets.

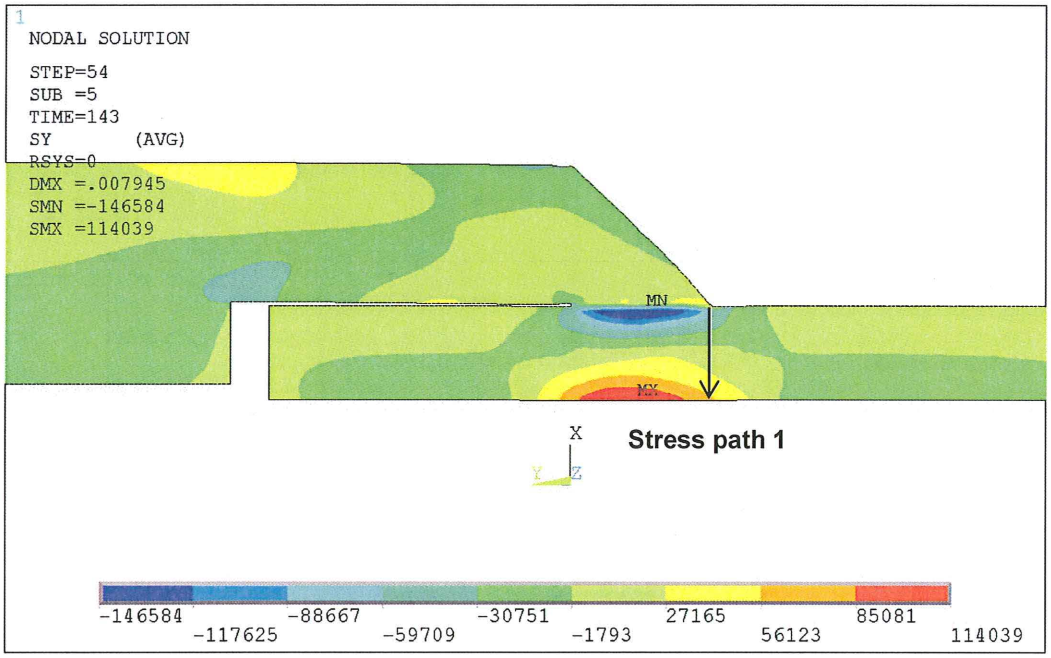


Figure 2-3. Contour plot of axial weld residual stress.

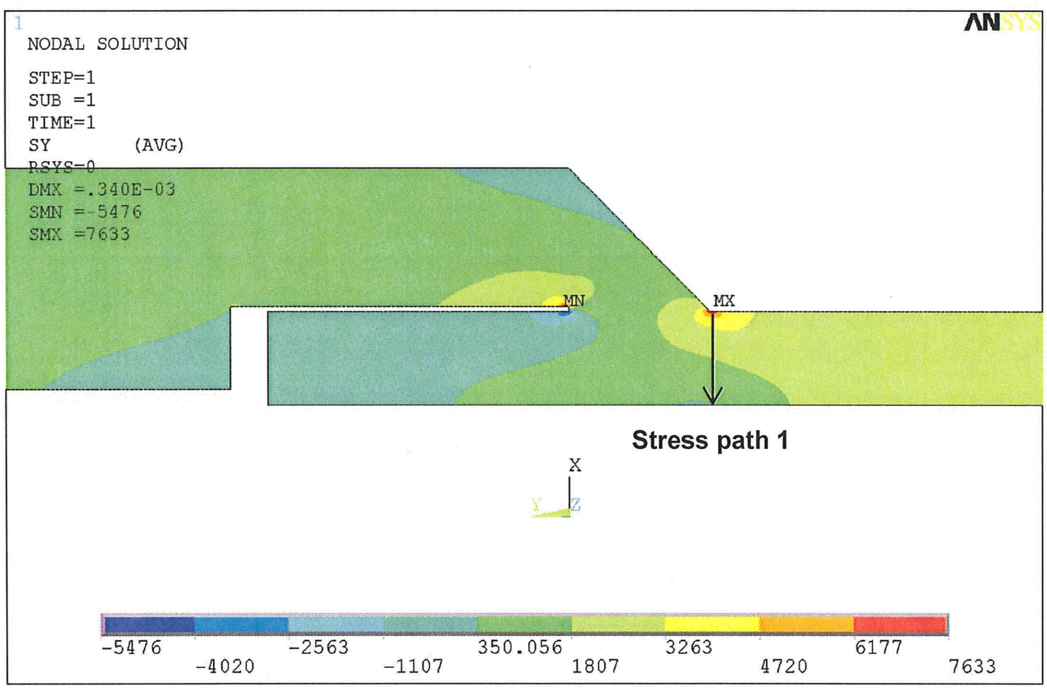


Figure 2-4. Contour plot of axial stress due to unit axial load of 1000 lb.

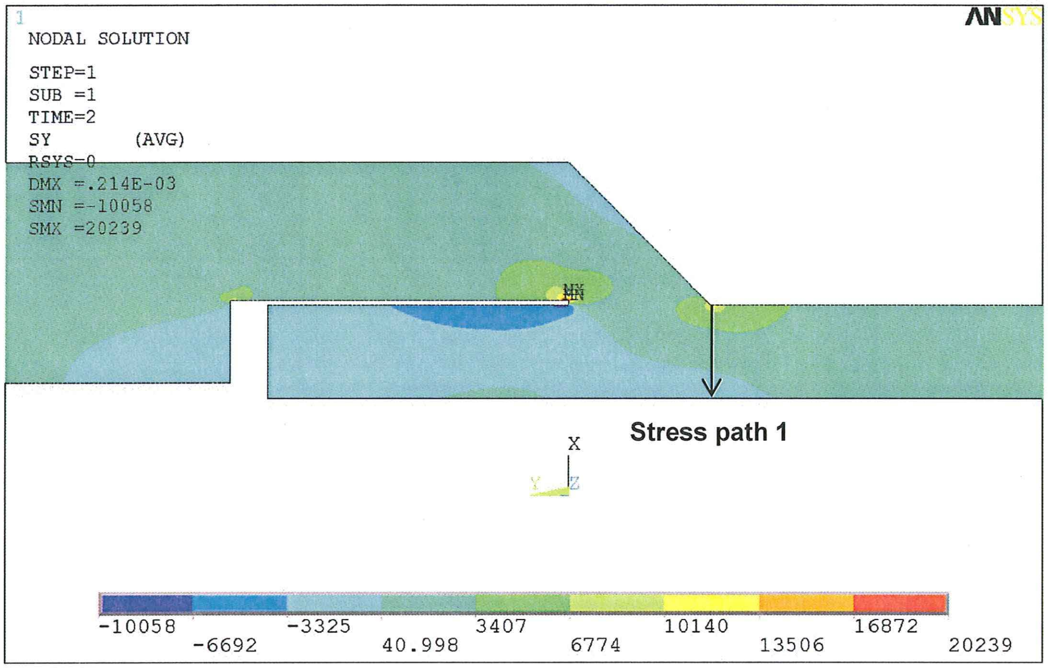
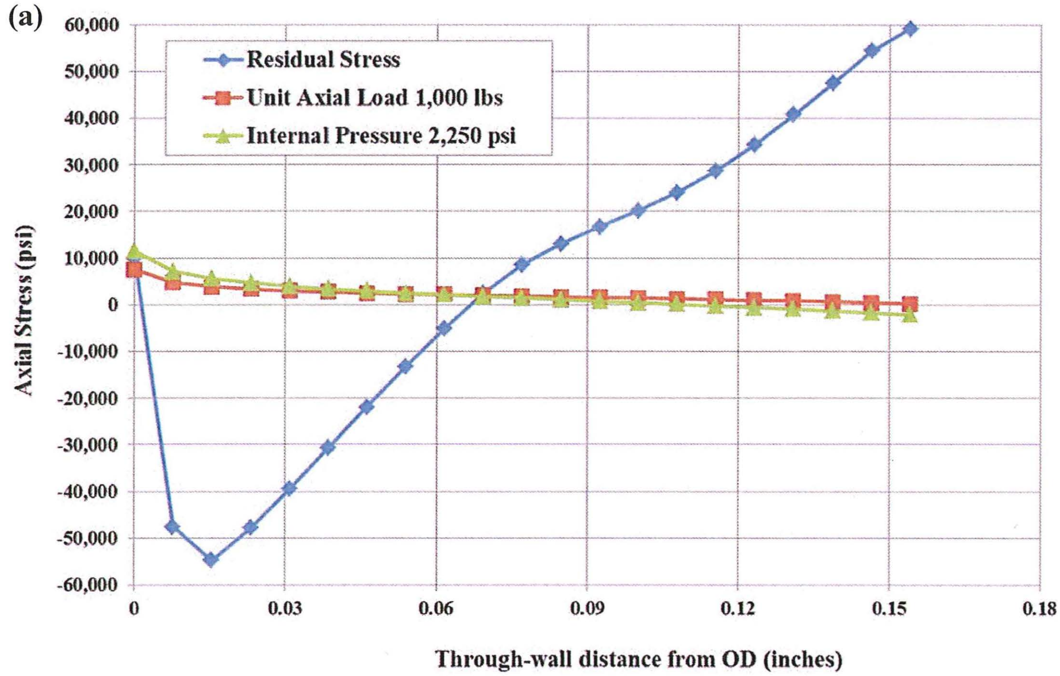


Figure 2-5. Contour plot of axial stress due to internal pressure of 2,250 psi.



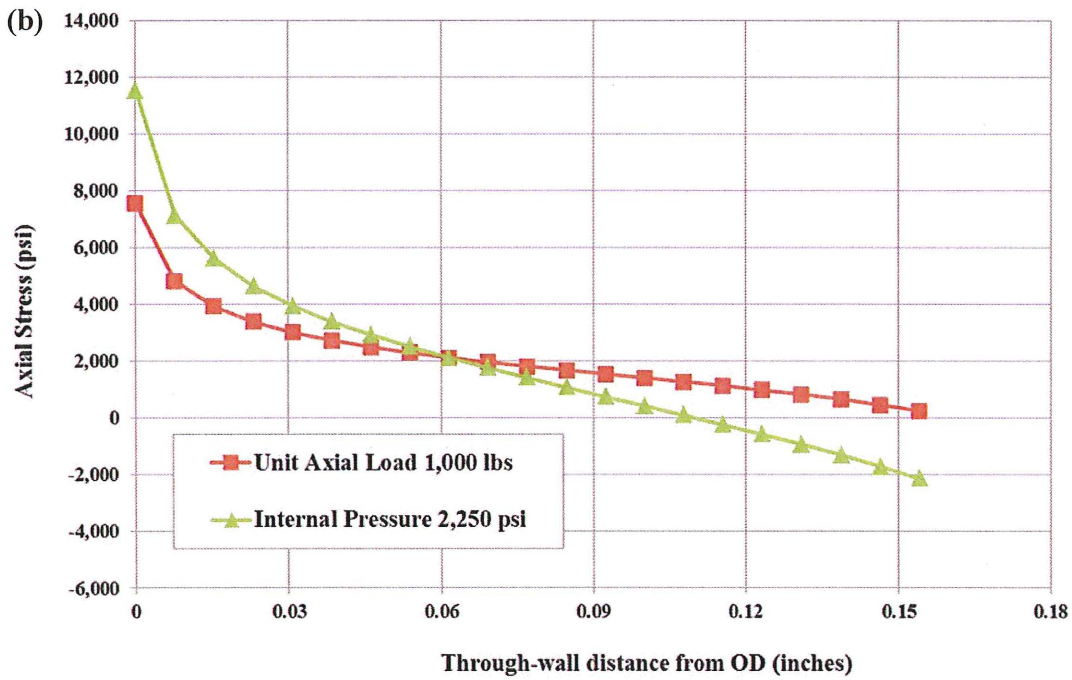


Figure 2-6. Axial stresses along Stress Path 1, which originates at the weld toe at the OD and goes toward the ID (stresses also apply to the same path originating at the ID and going toward the OD). Positive stress denotes tensile stress and negative stress denotes compressive stress. (a) All axial stress. (b) Unit axial and pressure stresses only.

3.0 EVALUATION OF ALLOWABLE FLAW SIZE

3.1 Objective

The objective of this analysis is to evaluate the stability of hypothetical cracks in the Type 410 stainless steel joints under anticipated maximum operating loads.

The purpose of this analysis is to determine allowable flaw sizes for two types of flaws: a flaw located on the pipe OD and a flaw located on the pipe ID.

3.2 OD Flaw

3.2.1 Evaluation Methodology

The methodology for determining acceptability of postulated OD flaws for continued service of the DCPP SI pump Type 410 welds is based on linear elastic fracture mechanics (LEFM), in accordance with the criteria of ASME Section XI, Article C-7200 [2]. The criterion used for crack stability is that the crack will become unstable if the applied value of the stress intensity factor (K) exceeds a critical value, which is called the fracture toughness (K_{IC}). This criterion is applicable to the relatively high strength low toughness material under consideration. The stress intensity factor is a parameter that controls the stresses near the crack tip in a predominantly elastic material.

The relevant geometry for the postulated flaw is a semi-elliptical circumferential flaw originating on the OD of the pipe and growing toward the ID of the pipe. Stress intensity factor K for the postulated flaw is evaluated as a function of crack depth and compared to the material fracture toughness K_{IC}. The flaw depth at which the applied K exceeds K_{IC} is the critical crack size. The *allowable* flaw size for operability determination is obtained by multiplying the applied stress intensity factors by the appropriate structural factors.

3.2.2 Flaw Geometry

A semi-elliptical circumferential flaw is postulated on the outer surface of the pipe, extending from the root of the weld toe (see Figure 2-1). This location forms a geometric stress concentration and is the region where the cyclic stresses are largest. The flaw is therefore considered to grow from the outer surface of the pipe inward. This flaw geometry is illustrated in Figure 3-1a.

The stress intensity factor solutions provided for circumferential flaws in ASME Section XI, Article C-7300 [2], do not address a flaw located on the OD nor the stress concentration factor associated with the weld toe. Article C-7300 provides no stress intensity factor solution for residual stresses, which must be obtained from other sources, such as finite element stress analysis. The use of an influence function can accurately treat a general through-thickness stress gradient with a highly nonlinear stress distribution for subsequent calculation of stress intensity factors. An influence function for an OD flaw in a pipe with finite radius-to-thickness ratio R_i/t is therefore desired and is available from API-579 [3]. The stress intensity factors for the evaluated flaw are therefore calculated by the influence function procedures described in API-579 [3].

The influence function approach is useful for obtaining stress intensity factors for cracks that emanate from stress concentrations, such as a surface crack at a weld toe. Stress intensity factors can be estimated using the influence function for the crack geometry, along with the stress distribution at the weld toe for the uncracked case. The present analysis uses finite element calculated stresses mapped along Stress Path 1 (Figure 2-6) for weld residual stress, unit axial load, and internal pressure. Stress intensity factors for each load case are calculated for a range of crack sizes and aspect ratios.

The influence function can be thought of as a K solution for a point force on the crack face. The value of K can be obtained by the summing of a set of point forces that match the stresses on the crack face, in the absence of a crack. The summing (linear superposition) is performed by integration, which usually must be done numerically. If $\sigma(x)$ is the stress on the crack surface as a function of position x, and $h(x,a,R/t,a/c)$ is the influence function, then K is obtained from the expression:

$$K(a,R_i/t,a/c)=\int_0^a \sigma(x)\, h(x,a,R_i/t,a/c)\, dx \qquad (1)$$

The influence function $h(x,a,R_i/t,a/c)$ for an OD crack is conveniently provided in API-579 [3]. It should be noted that that the influence function required to compute stress intensity factor for the relevant flaw geometry is restricted to axisymmetric loading [3]. Hence, bending loads cannot be directly used, but must be converted to an equivalent axial tension loading for calculation of stress intensity factors. In this report, the influence function for an OD flaw, which is available from Reference [3], is employed.

3.2.3 Operating Loads

3.2.3.1 Definition of Loads

Loads considered are dead weight, internal pressure, stresses due to thermal transients and seismic events, and weld residual stresses. Table 3-1 summarizes the load and moment information obtained from [15] for six weld locations. The left hand column in Table 3-1 identifies the transient associated with the forces using the nomenclature directly from [15], with the thermal load cases described below per [16]:

Stress Analysis 9-323 (Safety Injection Pump 1-1) Load Case: THRMN1 – 100% Power & Refueling Mode @ 110˚F THRMN2 – Injection Mode @ 40 ˚F THRMA1 – Abnormal Mode @ 295 ˚F for Code Class 'B' and 110˚F for Code Class 'E'
Stress Analysis 9-537 (Safety Injection Pump 2-1) Load Case: THRMN1 – 100% Power & Refueling Mode @ 110˚F THRMN2 – Injection Mode @ 35 ˚F & 110˚F THRMA1 – Abnormal Mode @ 295 ˚F THRMA2 – Recirculation Mode @ 190˚F & 110˚F
Stress Analysis 9-536 (Safety Injection Pump 2-2) Load Case: THRMN1 – 100% Power & Refueling Mode @ 110˚F THRMN2 – Injection Mode @ 35 ˚F THRMA1 – Abnormal Mode @ 295 ˚F

It should be noted that that the influence function required to compute stress intensity factor for the relevant flaw geometry (a semi-elliptical OD-connected circumferential crack at the weld toe) is restricted to axisymmetric loading [3]. Hence, the bending loads in Table 3-1 cannot be directly used, but must be converted to an equivalent axial tension loading for calculation of stress intensity factors.

3.2.3.2 Calculation of Equivalent Axial Loads

The axial loads from the various transients in Table 3-1 are considered in combination. For evaluation of allowable flaw size, the maximum operating loads are combined. The Hosgri seismic event is combined with deadweight load (DL or DW) and the largest abnormal thermal load (THERMA1 or THERMA2). Stress intensity factors due to internal pressure loading and residual stresses are considered separately, and the total stress intensity factors are obtained by adding these individual contributors. Calculation of stress intensity factors is discussed in Section 3.2.4.

Table 3-2 summarizes the load combinations and equivalent loads for the six weld locations. For a given load combination, the values of the force and moment components are added to provide the components of the combined load or moment:

$$F_{i(\text{combined load})} = \sum_{\text{load contributors}} F_i \qquad (2)$$

where i refers to the x, y, and z components. The combination is performed for each component.

The effective force is then evaluated as the SRSS of the x, y, and z components. This is done for the force and the moment, thereby providing F_{eff} and M_{eff} for each location.

The nominal stresses due to the force and moment are obtained by conventional means and an equivalent axial tensile force, F_{eq}, that produces the same stress is computed. The following relation is employed:

$$F_{\text{eq}} = A\left[\frac{F_{\text{eff}}}{A} + M_{\text{eff}}\frac{R_o}{I}\right] \qquad (3)$$

where F_{eff} and M_{eff} are the effective force and moment, A is the pipe cross-sectional area, R_o is the outer radius, and I is the moment of inertia.

3.2.4 Stress Intensity Factor versus Crack Size

The total stress intensity factors are obtained by adding the individual K-contributors, accounting for the magnitude of the equivalent axial tensile load. Equivalent pipe loads are summarized in Table 3-2, which shows that the maximum load during seismic or abnormal events ("DL + HOSGRI + Abnormal thermal") is bounded by a force of 5,275 lbs. This will be used as the load for analysis of crack stability. Residual stresses and internal pressure of 2,250 psi are present in addition to these forces. Stress intensity factors for an OD flaw due to pressure, residual stress and a unit axial tension load of 1,000 lbs are included in Table 3-3 and Table 3-4, for crack aspect ratios $c/a = 4$ and 1 respectively, where crack half-length c and depth a are as illustrated in Figure 3-1a. K solutions are not provided in Reference [3] for crack aspect ratios larger than $c/a = 4$ or smaller than $c/a = 1$ for the thickness-to-radius ratio t/R_i of the subject pipe nipples.

Figure 3-2 presents stress intensity factor K as a function of OD flaw depth a/t for crack aspect ratio c/a of 4 and 1 for maximum loads. Results are shown with and without the contribution of residual stresses. Note that the stress intensity factor solutions are valid for crack depths a/t up to 0.8 [3].

The results of Figure 3-2 show that the stress intensity factors for OD flaws are either negative or very small when residual stresses are included. Consequently, postulated OD flaws would not be