July 15, 2015

Mr. Edward D. Halpin
Senior Vice President and Chief Nuclear Officer
Pacific Gas and Electric Company
Diablo Canyon Power Plant
P.O. Box 56, Mail Code 104/6
Avila Beach, CA 93424

SUBJECT: DIABLO CANYON POWER PLANT, UNIT NOS. 1 AND 2 – REQUEST FOR ALTERNATIVE REP-SI, REVISION 2, PROPOSED ALTERNATIVE TO REQUIREMENTS FOR REPAIR/REPLACEMENT ACTIVITIES FOR CERTAIN SAFETY INJECTION PUMP WELDED ATTACHMENTS (TAC NOS. MF4476 AND MF4477)

Dear Mr. Halpin:

By letter dated July 21, 2014, as supplemented by letters dated February 5, March 30, and June 18, 2015, Pacific Gas and Electric Company (the licensee) submitted a Relief Request REP-SI to the U.S. Nuclear Regulatory Commission (NRC) for the use of alternatives to certain requirements of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), Section XI, IWA-4000, "Repair/Replacement Activities," at Diablo Canyon Power Plant (DCPP), Unit 1 and 2.

Specifically, pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) paragraph 50.55a(z)(2) (formerly 10 CFR 50.55a(a)(3)(ii)), the licensee proposed an alternative, Inservice Inspection Request for Alternative REP-SI, Revision 2, which is related to the acceptance of socket welds, as is, at the vent and drain lines associated with safety injection (SI) pumps 1-1 and 1-2 for Unit 1 and 2-1 for Unit 2, on the basis that complying with the specified ASME Code requirement to repair the degraded piping would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

The NRC staff has completed its review of the relief request as discussed in the enclosed safety evaluation. The NRC staff concludes that the proposed alternative provides reasonable assurance of structural integrity and leak tightness of the subject socket welds associated with SI pumps 1-1 and 1-2 for Unit 1 and 2-1 for Unit 2. The NRC staff determines that complying with the requirements of the ASME Code, Section XI, would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety. Accordingly, the NRC staff concludes that the licensee has adequately addressed all of the regulatory requirements set forth in 10 CFR 50.55a(z)(2). Therefore, the NRC staff authorizes the use of Alternative Request REP-SI, Revision 2, at DCPP, Units 1 and 2, for a period of time from the date of issuance of this safety evaluation until these pumps are removed from service.

All other ASME Code, Section XI requirements for which relief was not specifically requested and authorized in the subject proposed alternative remain applicable, including third-party review by the Authorized Nuclear Inservice Inspector.

If you have any questions, please contact the DCPP Project Manager, Siva Lingam, at 301-415-1564 or via e-mail at Siva.lingam@nrc.gov.

Sincerely,

CFLyon for

Michael T. Markley, Chief
Plant Licensing Branch IV-1
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket Nos. 50-275 and 50-323

Enclosure:
Safety Evaluation

cc w/encl: Distribution via ListServ

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

REQUEST FOR RELIEF REQUEST REP-SI, REVISION 2

ALTERNATIVE TO REQUIREMENTS FOR REPAIR/REPLACEMENT ACTIVITIES FOR

SAFETY INJECTION PUMP WELDED ATTACHMENTS

PACIFIC GAS AND ELECTRIC COMPANY

DIABLO CANYON POWER PLANT, UNITS 1 AND 2

DOCKET NOS. 50-275 AND 50-323

1.0 INTRODUCTION

By letter dated July 21, 2014 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML14202A613), as supplemented by letters dated February 5, March 30, and June 18, 2015 (ADAMS Accession Nos. ML15036A606, ML15089A594, and ML15169A368, respectively), Pacific Gas and Electric Company (the licensee) submitted Relief Request REP-SI in which it requested an alternative to the requirements of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), Section XI, IWA-4000, "Repair/Replacement Activities," at Diablo Canyon Power Plant (DCPP) Units 1 and 2.

Specifically, pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) paragraph 50.55a(z)(2) (formerly 10 CFR 50.55a(a)(3)(ii)), the licensee proposed an alternative, which is related to the acceptance of socket welds, as is, at the vent and drain lines associated with safety injection (SI) pumps 1-1 and 1-2 for DCPP, Unit 1 and 2-1 for DCPP, Unit 2 on the basis that complying with the specified ASME Code requirement to repair the degraded piping would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

2.0 REGULATORY EVALUATION

The licensee requested authorization of an alternative to the requirements of article IWA-4000 of the ASME Code, Section XI, pursuant to 10 CFR 50.55a(z)(2).

Adherence to Section XI of the ASME Code is mandated by 10 CFR 50.55a(g)(4), which states, in part, that ASME Code Class 1, 2, and 3 components (including supports) will meet the requirements, except the design and access provisions and the pre-service examination requirements, set forth in the ASME Code, Section XI.

Enclosure

The regulations in 10 CFR 50.55a(z) state, in part, that alternatives to the requirements of paragraph (g) of 10 CFR 50.55a may be used, when authorized by the U.S. Nuclear Regulatory Commission (NRC), if the licensee demonstrates that: (1) the proposed alternative provides an acceptable level of quality and safety, or (2) compliance with the specified requirements would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety. The proposed alternative must be submitted and authorized prior to implementation.

Based on the above, and subject to the following technical evaluation, the NRC staff determined that regulatory authority exists for the licensee to request the use of an alternative and the NRC to authorize the proposed alternative. NRC staff consider that "prior to implementation" shall be interpreted as prior to issuance of this safety evaluation (SE), and that the authorization of alternatives in this SE covers the period starting from the date of issuance of this SE and ending when the components covered by the authorization of alternatives are removed from service.

3.0 TECHNICAL EVALUATION

REQUEST FOR ALTERNATIVE RELIEF REQUEST REP-SI, REVISION 2

3.1 ASME Code Components Affected

DCPP, Unit 1, ASME Code Class 2, Safety Injection (SI) pump 1-1, four 3/4-inch vent and drain connection socket weld attachments.

DCPP, Unit 1, ASME Code Class 2, SI pump 1-2, two 3/4-inch drain connection socket weld attachments.

DCPP, Unit 2, ASME Code Class 2, SI pump 2-1, two 3/4-inch drain connection socket weld attachments.

The remaining two vent and drain attachment welds on SI pump 1-2 and pump 2-1 were fabricated in conformance with applicable requirements and are not covered in this alternative request.

DCPP, Unit 2, SI pump 2-2 vent and drain connections were manufactured differently, are not affected, and are not covered in this alternative request.

3.2 Applicable Code Edition and Addenda

ASME Code, Section XI, 2001 Edition through 2003 Addenda.

3.3 Applicable Code Requirement (as stated by the licensee)

> [The ASME Code, Section XI,] 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 [nominal pipe size] 3/4 inch socket welds on SI Pump 1-1 and two affected welds each on SI Pumps 1-2 and 2-1.

3.4 Reason for Request

The licensee requested an alternative to implementing the repair/replacement rules of the ASME Code, Section XI, IWA-4000, for nonconforming attachment socket welds on the 3/4-inch vent valve and drain pipe fitting. The socket welds connect to four integrally attached stub piping nipples on SI pump 1-1 and two nipples each on SI Pumps 1-2 and 2-1.

In its letter dated March 30, 2015, the licensee stated, in part,

> The pump casings [of the subject SI pumps 1-1, 1-2 and 2-1] are fabricated from martensitic stainless steel and were each supplied with integrally attached 3/4 inch 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, tees, or a coupling) were welded to each of the integral drain stub nipple connections supplied with each pump. The valve- or [pipe] fitting-to-stub nipple attachment welds were made using the pipe and equipment installation contractor's welding procedure specification [WPS] number 149 [(see Attachment 1 to Enclosure to the licensee's letter dated July 21, 2014)] 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) [of the valves and pipe fittings]. Procedure 149 was not qualified for welding martensitic stainless steel (ASME material Type P-6) [of the vent and drain stubs] to austenitic stainless steel (ASME material Type P-8). The procedure would be [technically] satisfactory for the application with the exception that it does not contain provision for post-weld heat treatment that would potentially be required by a Type P-6 to P-8 procedure. Heat treatment would be required for welding Type P-6 to P-8 material when the carbon content of the Type P-6 base metal exceeds 0.08 percent. 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.

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[*] Defined as "Group" by ASME Code, Section IX.

At the time of the discovery of the nonconformance, the licensee attempted to determine carbon content of the existing SI pumps' Type 410 stainless steel pipe nipples using an Arc-Met alloy analyzer. The licensee's attempt was unsuccessful due to the size of the equipment contact head and the adverse geometry of the components. Later, using a new Arc-Met alloy analyzer, the licensee was successfully able to measure the carbon content of the following stub nipples in February 2015. Below is the as-measured, uncorrected carbon content (percentage) for the vent and drain stubs:

Percent Carbon Content

Pump	Vent	Case Drain	Suction Drain	Discharge Drain
SI pump 1-1	0.17	Inaccessible	0.17	0.15
SI pump 1-2	0.05	Inaccessible	Inaccessible	0.02
SI pump 2-1	0.04	Inaccessible	0.08	Inaccessible

In its letter dated March 30, 2015, the licensee further stated, in part, that:

> The vent and discharge drain on Pump 1-2 and the vent and suction drain on Pump 2-1 are 0.08 percent carbon or less; therefore they do not require post-weld heat treatment per the construction code and are not included in [Revision 2 of this relief request]. The measurements for Pump 1-1 showed abnormally high carbon content. To check the accuracy of these results, the weld test coupon material having certified mill test report (CMTR) carbon content of 0.13 percent was checked using the Arc-Met [machine], with a resulting measurement of 0.163 percent. Using the difference between the CMTR and the measured value as a correction factor, the results are consistent with the material specification and correspond with the carbon content of the weld test coupon.

As shown above, the four welds (vent, case drain, suction drain, and discharge drain) on SI pump 1-1 either exceed 0.08 percent carbon or are inaccessible. Two welds each on SI pumps 1-2 and 2-1 are inaccessible for testing.

3.5 Proposed Alternative

In lieu of repair or replacement in accordance with the ASME Code, Section XI, IWA-4000, the licensee proposed to accept, as-is, the existing attachment socket welds associated with the vent and drain lines on SI pumps 1-1, 1-2, and 2-1.

As part of the proposed alternative, in its letter dated March 30, 2015, the licensee stated that it has performed the following:

- confirmed by Arc-Met testing that the carbon content of the vent stub and one drain stub each on SI Pumps 1-2 and 2-1 have carbon content equal to or less than 0.08 percent, thus meeting the applicable requirement for welding Type 410 stainless steel to austenitic stainless steel without post-weld treatment [and are not covered by this alternative request]. The remaining two stubs on these two pumps are inaccessible for testing [and are covered by this alternative request]. The case drain on Pump 1-1 is also inaccessible [and is covered by this alternative request].

- conducted welding procedure qualification tests with representative Type 410 stainless steel and Type 304 stainless steel base materials using Type 309 filler metal as per the original Welding Procedure Specification (WPS) 149 parameters without post-weld heat treatment [(see Attachment 2 to Enclosure of the licensee's letter dated July 21, 2014)];
- performed a Stress and Fracture Mechanics Evaluation of Type 410 Stainless Steel Weldments in SI pumps at DCPP [(see Attachment 3 to Enclosure of the licensee's letter dated July 21, 2014)];
- performed NDE [nondestructive examinations] of the subject welds to determine and verify current conditions; and
- performed a review of the SI pumps' operating histories including pressure test records.

Additionally, in its letter dated March 30, 2015, the licensee proposed that the inservice inspection (ISI) program plan will include visual examination of the subject socket welds for leakage during scheduled quarterly surveillance tests and to perform liquid penetrant examinations on an ISI periodic basis (every 40 months) for the remaining service life of the SI pumps, including any authorized license extension period.

3.6 Basis for Use

3.6.1 Welding Procedure Qualification Tests

The licensee proposes to qualify after-the-fact the welding of group P-6 to group P-8 base material without post-weld heat treatment. The licensee performed a welding procedure qualification for this material combination in accordance with the requirements of Section IX of the ASME Code. The licensee submitted the results of the welding procedure qualification to the NRC as Attachment 2 to Enclosure of its letter dated July 21, 2014.

As stated in its letter dated March 30, 2015, in part,

> Welding Procedure Qualification Test Report is presented in Attachment 2 of [Enclosure to the licensee's letter dated July 21, 2014]. For the weld qualification tests, Arc-Met testing to determine carbon content of the existing SI pumps Type 410 stainless steel pipe nipples was attempted but initially 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 weld 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 [degrees Fahrenheit (°F)] was used with maximum interpass temperature of 297°F recorded. No use of planned weld bead placement in conjunction with controlling heat input (also known as "temperbead welding") was performed. 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 the ASME Code, 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.

A tensile test was performed on two specimens in accordance with ASME Section IX, Table QW-451.1 and QW-150, 2013 Edition, with required ultimate tensile strength of 65 kips 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 Type 410 stainless steel parent metal in both instances.

3.6.2 Stress and Fracture Mechanics Evaluation

The licensee analyzed the stresses, evaluated allowable flaw size, and calculated crack growth for the subject socket welds. The licensee performed the stress analysis, including residual stresses, and stresses due to uniaxial loads and pressure, to obtain stress distributions along the path of postulated flaws for use in the fracture mechanics and flaw growth analyses. The licensee used a fracture mechanics approach analogous to the methods of ASME Code, Section XI, supplemented with procedures from American Petroleum Institute (API) Standard API-579, because the ASME Code, Section XI methods do not address Type 410 martensitic stainless steels, evaluation of postulated flaws on piping outer diameter (OD) surfaces, or evaluation of flaws in piping of diameter 4 inches or less.

To analyze crack stability, the licensee postulated a semi-elliptical circumferential flaw initiated on the outside surface of the pipe. The length of the OD flaw extends from the root of the socket weld to the toe of the socket weld on the Type 410 stainless steel nipple. The initial length of the OD flaw is approximately 0.236 inches long. The flaw is postulated to propagate towards the inside surface of the pipe through the pipe wall thickness. The licensee postulated various flaw sizes from an initial depth of 1 percent of the pipe wall thickness to 80 percent of the pipe wall thickness. The flaw is postulated at this location because this region has the largest cyclic stresses. The licensee also postulated a flaw initiated from the inside diameter. The inner diameter (ID) flaw is postulated to grow toward the OD caused by tensile stresses as a result of residual stress from welding. The depth and length of the ID flaw are the same as that of the OD flaw.

The licensee evaluated 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. The allowable flaw depth for an OD flaw was determined to be 0.110 inch, approximately 71.6 percent of the 0.154-inch wall thickness. The allowable flaw depth for an ID flaw was found to exceed 80 percent of the wall thickness.

To analyze fatigue crack growth, for cyclic loading, postulated ID flaws are not predicted to grow as all cyclic stress intensity factors are below the fatigue threshold. For the growth of the postulated OD flaw, the licensee considered 7000 thermal transient cycles, 400 design earthquake cycles, and 20 Hosgri earthquake cycles.

The licensee postulated four OD flaws: (1) an OD flaw with a length of 1/16 inch (detection limit using liquid penetrant) and a depth of 0.03125 inches; (2) a postulated 10 percent through-wall OD flaw; (3) a flaw that exceeds threshold stress intensity factor, $\Delta K_{th,}$ of 5 ksi $\sqrt{in}$; and (4) an initial flaw of approximately 67.5 percent of the pipe wall thickness that grows to the allowable flaw depth of 71.6 percent of pipe wall thickness at the end of evaluation period. The licensee's results show that the evaluations of the postulated OD and ID flaws show that crack growth under anticipated cyclic loading is minimal.

3.6.3 Nondestructive Examinations

The licensee has performed VT-2 visual examinations of the subject socket welds every 40 months during scheduled system pressure tests in accordance with the ASME Code, Section XI. No leakage from any of the welds has ever been identified.

The licensee performed liquid penetrant examinations of all subject welds between December 18 and 20, 2013, and did not find any linear or crack-like indications.

3.6.4 Review of SI Pumps Operating History

The licensee stated that the cyclic loading on the subject pumps is based on the cumulative number of starts. As such, the SI pumps were each started several times during testing prior to plant operation. During plant operation, the pumps normally function in a standby capacity and are periodically started for pump readiness testing and system pressurizations for leak testing and a small number of starts in support of the SI function.

The licensee estimated that each pump has had 25 preoperational starts and 11 starts per year for operational starts. 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 licensee estimated that SI pumps 1-1 and 1-2 have had a total of 688 starts and that SI pump 2-1 has had 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.

The licensee assumed 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. The licensee stated that 1400 cycles are well under the 7000 thermal transient cycles assumed in the fatigue crack growth analysis.

3.6.5 Hardship

In its letter dated March 30, 2015, the licensee stated, in part, that:

> The existing vent stub nipple to vent valve and drain stub nipples to drain pipe fittings socket welds were made in accordance with the original construction contractor's WPS 149 which did not provide for post weld heat treatment. The stub nipples are short, typically less than 4 inches in length, with the casing drain nipple being less than one inch long. Photographs of each attachment to Pump 1-1, which are typical of all of the pumps, are included for reference in [Attachment 1 of Enclosure 2 of the licensee's letter dated February 5, 2015]. Attempting to perform localized heat treatment would jeopardize the factory heat treatment of the entire pump casing. Heat treatment of the entire pump casing to include these small welds cannot be performed in situ under the same controlled conditions available during factory fabrication. Either means of attempting heat treatment could result in warping or damage to the pump casing. These factors constitute a hardship for compliance with the specified requirements.

3.6.6 Proposed Alternative Visual Examination and NDE

In its letter dated June 18, 2015, the licensee proposed the following alternative visual examination and NDE in support of this relief request (as stated):

> To provide continued assurance of the integrity of the affected safety injection (SI) pump welds, the following alternative surveillance tests and nondestructive examinations (NDE) are proposed:
>
> 5.6.1 Alternative Visual Examinations for Leakage.
>
> Surveillance test procedures (STPs) for quarterly testing of SI pumps 1-1, 1-2, and 2-1 will be revised (within 90 days after NRC approval) to require the test performer to visually examine the subject vent and drain connections for evidence of external leakage during all future tests. Leakage at these locations would be readily detectable due to accumulation of boric acid crystals at the leak site.
>
> 5.6.2 Alternative Periodic Surface Nondestructive Examinations
>
> Liquid penetrant examinations conducted in December 2013 demonstrated absence of pre-existing outer diameter (OD) surface flaws in support of the OD flaw growth analysis. The Inservice Inspection (ISI) Program Plan for the fourth ISI Interval is being prepared to require NDE surface examination (liquid penetrant method) of the SI pump vent and drain connection welds where the carbon content of the 410SS base metal exceeds 0.08 percent or is not measurable due to insufficient

access for Arc-Met testing. The alternative liquid penetrant examinations will be performed on an ISI periodic basis (once every 40 months), with the interval starting May 7, 2015, for Unit 1 and March 13, 2016, for Unit 2. The alternative liquid penetrant NDE examinations on an ISI periodic basis will provide continued assurance that no flaws exist at these locations. These alternative examinations will be included in all future ISI interval Program Plans for the subject pumps.

3.7 Duration of Proposed Alternative (as stated)

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.

4.0 NRC Staff Evaluation

The NRC staff has evaluated the following topics of interest: welding procedure specification, stress and fracture mechanics analyses, pump vibration, safety significance and consequence of a leakage, leakage detection systems, inspection, hardship justification, and duration of the proposed alternative.

4.1 Welding Procedure Specification

The use of a welding procedure, qualified to join ASME material group P-1 to P-8 in order to fabricate a production joint of ASME material group P-6 to P-8, does not meet the requirements of QW-251.2, QW-253, and QW-256 of Section IX of the ASME Code, which do not allow a change in ASME material group, or P-number, without a supporting welding procedure qualification. Welding of group P-6 material, especially P-6 with carbon content toward the high side of its specified range, has the potential to form martensite in the heat affected zone of the weld. Martensite that is untempered can crack, and the presence of cracks in the weld joint can lead to failure of the joint as a result of crack growth due to high stress or cyclic fatigue. Post-weld heat treatment after welding can mitigate the potential for cracking by relieving internal stresses and tempering the martensite. However, since the group P-1 to P-8 welding procedure which was erroneously used does not specify post-weld heat treatment, the nonconforming socket welds were not post weld heat treated.

Procedure specifications for group P-6 Type 410 material typically limit carbon content to 0.15 percent. High carbon content increases the probability and severity of the formation of untempered martensite. As stated previously, post-weld heat treatment after welding can mitigate the potential for cracking. Section IX of the ASME Code recognizes that group P-6 is sensitive to changes in post-weld heat treatment and requires modifications to post-weld heat treatment to be supported by welding procedure qualification. When the carbon content of Type 410 material is less than 0.08 percent, the probability and severity of untempered martensite formation is less and post-weld treatment may not be required. For Type 410 material with carbon content less than or equal to 0.08 percent, the chemical composition typically conforms to the specified requirements for group P-7 Type 410S. The ASME Code recognizes that group P-7 is less sensitive to changes in post-weld heat treatment and allows for modifications to post-weld heat treatment, other than addition or deletion of post weld heat treatment, without the necessity for welding procedure requalification. At the time of the July 21, 2014 submittal, the licensee had not been able to determine the carbon content of the nonconforming socket welds. In February 2015, the licensee attempted to measure the carbon content of the nonconforming socket welds, with varying success. Five of the 12 nonconforming socket welds could not be measured and three of the 12 nonconforming socket welds have carbon contents that are reasonably certain to exceed 0.08 percent. Therefore, eight of the 12 nonconforming socket welds are potentially susceptible to cracking due to the presence of untempered martensite in the heat affected zone of the group P-6 material.

As stated in Section 3.6 of this SE, the licensee's justification for accepting the nonconforming welds as-is without repair or replacement includes the performance, after the discovery of the discrepancy, of a welding procedure qualification in accordance with Section IX of the 2013 Edition of the ASME Code, using the material combinations and heat treatments used in the production welding. Section IX of the Code requires requalification for any change to essential variables in the welding procedure. The licensee made the nonconforming welds using Weld Procedure Code No. 149, Spec. No. P8/P1-K1-F5-SMAW-6G, which the licensee submitted for information in its relief request. The NRC staff confirmed that Weld Procedure Code No. 149, Spec. No. P8/P1-K1-F5-SMAW-6G could only be used to weld group P-1 material to P-8 material and its use to weld group P-6 material to group P-8 material is a change in essential elements which would require procedure requalification.

The licensee performed the welding procedure requalification using a dissimilar metal (P-6 to P-8) groove weld joint design. Groove weld joint designs are allowed by Code to qualify socket weld joint designs and have the advantage that mechanical tests such as tensile tests and bend tests can be performed. The qualification test assembly joined a Type 410 plate to a Type 304/304L plate using Type 309 filler metal. The Type 410 plate used in the qualification is the same material type and ASME material group (P-6) as the pipe nipple stubs that are common to all the nonconforming weld joints. The licensee purposely chose a Type 410 plate with as high a carbon content (0.13 percent) obtainable so as to adequately represent the nonconforming welds, which had high carbon content or which were unmeasurable. The Type 304/304L plate used in the qualification is a dual certified material type which may have lower carbon but which also complies with the Type 304 specification used for the pipe fittings in some of the nonconforming weld joints. More importantly, the Type 304/304L plate is the same ASME material group (P-8) as used for the Type 316 valves and the Type 304 pipe fittings in all the nonconforming weld joints. The Type 309/309L filler metal used in the qualification is a dual certified material type which may have lower carbon but which also complies with the Type 309 specification used in the nonconforming weld joints. NRC staff considers that the joint design and material types used in the procedure qualification meet the requirements of Section IX of the ASME Code and are appropriate for the engineering evaluation performed by the licensee.

The welding procedure qualification was performed using the GTAW process for the first four passes, and SMAW for the remaining passes. This will qualify either the use of GTAW process for the entire socket weld, or GTAW initial passes with SMAW fill for the remaining passes. Both of these process options are permitted by Weld Procedure Code No. 149, Spec. No. P8/P1-K1-F5-SMAW-6G, which was used to make the nonconforming welds.

The nonconforming welds were fabricated using a procedure that specified no preheat, an interpass temperature of 350 °F, and no post-weld heat treatment. The welding procedure qualification was performed using no preheat (ambient conditions with a measured temperature of 67 °F), a maximum interpass temperature measured as 297 °F, and no post-weld heat treatment. From the perspective of technical evaluation, it was necessary that no post-weld heat treatment be performed during the qualification since it would allow potential untempered martensite that could form during welding to persist through the testing phase of the qualification. In the worst case scenario, if there were sufficient untempered martensite in the heat affected zone of the qualification weldment, cracking would be likely to be observed during the testing phase of the qualification. The NRC staff considers that the preheat (67 °F), interpass (297 °F) and post-weld heat treatment (none) recorded in the procedure qualification meets the requirements of Section IX of the ASME Code and is appropriate for the engineering evaluation performed by the licensee.

The destructive tests were performed in accordance with the requirements of QW-202 and Table QW-451.1 of Section IX of the ASME Code and included two tensile tests, two 180-degree root bends, and two 180-degree face bends. During the review of the licensee's initial submittal, NRC staff noted that no hardness testing was performed in the heat affected zone and that the destructive test specimens were machined down from 3/8-inch (roughly 0.375-inch) to 0.300-inch for the bend tests and 0.3010-inch and 0.3150-inch for the tensile tests. In a request for additional information (RAI) dated December 23, 2014 (ADAMS Accession No. ML14351A047), the NRC staff requested that the licensee discuss (1) whether hardness testing was performed in the P-6 heat affected zone of the qualification weldment to objectively measure the possibility and extent of untempered martensite; and (2) whether the machined test specimens are representative of the qualification weldment in terms of microstructure, and if the possibility exists for untempered martensite to be formed during welding but to be removed during preparation of the destructive test specimens.

In its RAI response dated February 5, 2015, the licensee clarified that:

- Hardness testing was not performed in the heat affected zone, but that the fracture mechanics evaluations conservatively assume a worst case K_{IC}, fracture toughness for untempered martensite. The qualification test assembly was chosen to have a high carbon content in the Type 410 plate in order to mimic the production conditions and to encourage the formation of untempered martensite.

- During machining of the test specimens, no weld layer was completely removed. For the bend test specimens, all machining was performed on the intrados (interior) surface such that two bend specimens would be subject to maximum tensile stress on the unmachined face side, and two bend specimens would be subject to maximum tensile stress on the unmachined root side.

With respect to the lack of the hardness testing in the qualification weldment, NRC staff notes that hardness testing is not required by Section IX of the ASME Code. Hardness testing would have resulted in a superior engineering evaluation, but the testing as performed is satisfactory and meets ASME Code requirements. With respect to the machining of the destructive test specimens, NRC staff accepts the licensee's justification for the performing destructive tests using specimens that were machined down from the as welded thickness. Based on the licensee's description, the staff considers that if untempered martensite had formed during the qualification welding, sufficient martensitic microstructure would remain after machining so as to be representative of the as welded microstructure and to yield valid destructive test results. NRC staff considers that the destructive testing used in the procedure qualification meets the requirements of the ASME Code and is appropriate for the engineering evaluation performed by the licensee.

4.2 Stress Analysis and Fracture Mechanics Analyses

The licensee has postulated an OD flaw and ID flaw, growing toward ID and OD, respectively. The licensee has demonstrated by analysis that the growth of OD flaws by fatigue is minimal and the OD flaws would not reach the critical size before the end of the evaluation period, including the period of extended operation. The NRC staff notes that even a fairly deep initial flaw will not exceed the allowable flaw size before the end of the evaluation period. The licensee's analysis also shows that the ID flaw would not grow because cyclic stress intensity factors are below the threshold for fatigue crack growth.

The NRC staff determined that the licensee has used worst-case operating loads in the fracture mechanics analysis. For example, worst-case material toughness values for untempered martensitic Type 410 stainless steel are considered in the fracture mechanics analysis.

The NRC staff noted that the licensee's fracture mechanics analysis did not consider crack growth due to stress corrosion cracking (SCC). The licensee stated that SCC is unlikely to occur, due to the controlled water purity and low temperature (less than 200 °F) of the SI system. The licensee further stated that it is difficult to initiate SCC at temperatures below 200 °F. In general, lower temperatures require higher strain and higher water impurity levels to initiate SCC. For these reasons, SCC is not a concern. The licensee noted that service experience to date at DCPP has not shown any evidence of SCC for the SI system. The NRC staff noted that SCC may still occur because of other factors such as being in contact with chlorides. However, the NRC staff determined that the licensee will perform periodic visual and surface examinations of the subject welds which should detect potential cracking in the subject welds.

The NRC staff questioned why residual stresses would not contribute to fatigue crack growth for the ID flaw in the licensee's fracture mechanics evaluation. The NRC staff is of the opinion that although residual stresses are steady state in nature, they affect the maximum tensile stress and R [stress ratio] and may, therefore, affect fatigue crack growth. The licensee explained that although residual stresses are steady-state in nature and would influence the R-ratio and, therefore, affect the fatigue crack growth rate, for an ID flaw, the cyclic intensity factor, ΔK, values are found to be smaller than the threshold stress intensity factor, ΔK_{th}, except for deep flaws at least 50 percent through-wall. Because the applied ΔK is below the threshold ΔK_{th} except for deep flaws, no fatigue crack growth is predicted. The NRC staff concluded that since the applied ΔK is below the threshold ΔK_{th}, the ID flaw would not grow due to fatigue.

Based on the licensee's calculation, the allowable flaw depth for an ID flaw exceeds 80 percent of the wall thickness. The NRC staff noted that IWB-3643 of the ASME Code, Section XI, 2003 Addenda limits the maximum allowable flaw depth to 75 percent through-wall, not 80 percent. The licensee explained the allowable flaw depth to thickness ratio could be as high as 80 percent, which is the limit of validity of the stress intensity factor based on fracture mechanics calculations (K Solution). For the ID flaw, the stress intensity factor, K, does not exceed the fracture toughness K_{Ic} for all flaw depths over which the stress intensity factor fracture solution is valid (80 percent of wall thickness), as defined by API-579. The 80 percent of wall thickness refers to the limit of validity of the K solution rather than the allowable flaw depth. The licensee stated that the allowable flaw depth for the ID flaw can be conservatively set to the ASME Code, Section XI maximum allowable flaw depth of 75 percent through-wall. The NRC staff notes that the licensee's allowable flaw size of more than 80 percent for the ID flaw is only a theoretical value for the demonstration purposes. The licensee is required to follow the maximum allowable flaw depth of 75 percent through-wall based on the ASME Code, Section XI, IWB-3643.

Based on the above, the NRC staff concludes that the licensee's stress and fracture mechanics analyses demonstrate the reasonable assurance that should an OD or ID flaw exist, the flaw would not grow rapidly to cause catastrophic failures and that it would not grow to the allowable flaw size for the remaining life of the SI pumps.

4.3 Pump Vibration

The NRC staff requested the licensee to address the impact of pump vibrations on the vent and drain lines because high cycle vibrations may cause the subject welds to crack. The licensee collected vibration data on all affected vent and drain lines for SI pumps 1-1, 1-2, and 2-1 to determine if the level of vibration is acceptable. The data was collected when the pumps were running in "Recirculation Mode." The vibrations during the "Recirculation Mode" of operation are expected to be higher when compared to the vibrations during full-flow conditions since each pump's efficiency is about 10 percent during the "Recirculation Mode," whereas each pump's efficiency is greater than 70 percent during the full-flow conditions.

The licensee reported that the maximum measured vibration velocity is equal to or less than 0.5-inch per second. The licensee noted that per the criteria in Part 3, "Vibration Testing of Piping Systems," of the Operation and Maintenance (OM) Standards, of the ASME OM Code, for assessing vibration in nuclear power plant piping, this is an acceptable level of vibration to prevent vibration-induced crack initiation and growth. The NRC staff concludes that impact of the pump vibration on the vent and drain line would be minimal; therefore, this issue is closed.

4.4 Safety Significance and Consequence of a Leakage

The proposed alternative is based on the premise that existing SI pump vent and drain socket welds may be determined acceptable as-is for continued service. However, the NRC staff questioned the safety significance and the impact to the safety function of nearby equipment and personnel if all vent and drain weld connections are severed on a single SI pump.

In its letter dated March 30, 2015, the licensee stated, in part,

> One safety injection (SI) pump is required to be credited for the intermediate break loss of coolant accident (LOCA) where its parallel SI pump is assumed to fail (single failure). Failure of the subject socket welds on SI pump vent and drain connections are not a part of the Diablo Canyon Power Plant (DCPP) design bases calculations.

Should one or more vent and drain weld connections develop a through-wall crack or be completely severed on the operating SI pump, leakage would develop with severity corresponding to the flaw characteristics. In the worst hypothetical case of complete severances, the safety function of the SI pump would be lost.

In case of complete severance of one or more vent and drain weld connections on a single SI pump, the safety function of its parallel SI pump could potentially be affected if the water level in the room rose to the level of the pump motor casing ventilation openings, since they are in the same pump room, separated by a partial dividing wall. There are floor drains in the room, which may mitigate the water intrusion. Any personnel in the room would have adequate time to evacuate the room prior to the flood water level rising to more than a few inches.

Small leaks resulting from through wall cracks would first manifest as visually detectable buildups of boric acid crystals around the leak path, with leakage pooling locally and eventually making its way to the drains. More extensive postulated active fluid leaks (e.g., resulting from complete severance of a vent or drain line within the room) would gravity drain to the Auxiliary Building sump (ABS) via the previously described open drains. The ABS level is monitored remotely at the Auxiliary Building Control Board (HMI) and has both Hi [high] and Hi-Hi [high-high] Level alarms. In addition to their normal rounds in the Auxiliary Building (including [SI Pump] rooms), operators on-watch at the Auxiliary Control Board are required to investigate the cause of the ABS Hi-Hi Level alarms. Additionally, if the postulated break(s) were to occur during a non-accident situation, the Refueling Water Storage Tank (RWST) Low Level Alarm would come in as RWST level approached Technical Specification operational limits.

With non-vital power available, on an ABS Hi-Level alarm, one ABS pump automatically starts pumping down the ABS to the 15,000 gallon Floor Drain Receiver (FDR) Tank. On an ABS Hi-Hi Level alarm, both ABS pumps auto start and discharge to the FDR. With non-vital power unavailable (i.e., Loss of Off Site Power), no ABS level indication, no level alarm, and no auto ABS pump starts will occur and the ABS, if in-leakage continues, will spill over onto the 54-foot level of the Auxiliary Building. The 54-foot level can contain approximately 100,000 gallons of water before the level will reach the 58-foot level of the Auxiliary Building, challenging the residual heat removal (RHR) pump room sump.

Based on the above, the NRC staff concludes although the subject welds may have a low probability of failure, their failure would be safety significant and that monitoring of the structural integrity of the subject welds is important.

However, the handling of worst-case system leakage by means of floor drains and sump systems as described above, and the measures described in SE Section 4.5, "Leakage Detection Systems," provide additional assurance that should leakage occur, the licensee would be able to take corrective action before the safety function of the SI pumps is lost.

The leakage detection capabilities are discussed in the following section.

4.5 <u>Leakage Detection Systems</u>

The above discussion shows that failure of the subject welds will have significant safety consequences. The NRC staff questioned whether leakage detection systems are available to detect any potential leak from the subject socket welds and whether the operators in the control room would be notified of the leakage.

In its letter dated March 30, 2015, the licensee stated, in part,

> Each unit's safety injection pumps [SI pumps] are located within a common room--two pumps per room, one room per unit--on the 85 foot level of the Auxiliary Building. Each train of each Unit's [SI pumps] are physically separated by a concrete partition wall which runs parallel to either [SI pump] shaft's long axis and has open passage ways at each end of the partition. Each [SI pump] is sled mounted atop an equipment pedestal and adjacent to each [SI pump] pedestal is an open floor drain. Each [SI pump] pedestal also has an open equipment drain. The two open floor drains and two open pedestal drains within each Unit's [SI pump] rooms gravity feed directly to the Auxiliary Building Sump.
>
> There is no dedicated leakage detection system within the [SI pump] rooms. However, given a line break in the [SI pump] room during a time when [SI pumps] are supplying cooling water to the reactor core, the operators in the control room would see a reduced [SI pump] flow rate and discharge pressure. If the break is severe enough to challenge the capability of the pumps, the control room could receive alarms on [SI pump] motor temperatures and/or overcurrent trip, and/or increased activity in the Auxiliary Building Ventilation System (ABVS). The control room may also be notified of increasing sump levels.
>
> Additionally, operators walk down the [SI pump] rooms at least daily basis during normal rounds. Engineers perform system walkdowns on at least a quarterly basis and also perform Emergency Core Cooling System leakage assessment surveillances (Surveillance Test Procedures M-86 and M-87) and it is required that abnormal system leakage would be reported to the on-shift operations Shift Foreman.

Based on the above, the NRC staff concludes that the plant has detection systems and alarms in the control room to monitor potential leakage from the subject socket welds. Should leakage occur, the licensee will be able to take corrective actions before the safety function of the SI pumps is challenged. Therefore, the NRC staff concludes that the leakage detection capability at the plant for the subject socket welds is acceptable.

4.6 <u>Inspections</u>

As described in Section 3.6.6 of this SE, the licensee has proposed to visually examine the subject socket welds during the quarterly testing of the SI pumps 1-1, 1-2, and 2-1.

The licensee also has proposed to perform liquid penetrant examinations of the subject socket welds where the carbon content of the 410 stainless steel base metal exceeds 0.08 percent, or is not measurable due to insufficient access for Arc-Met testing. The liquid penetrant examinations will be performed on an ISI periodic basis (once every 40 months), with the interval starting May 7, 2015, for Unit 1 and March 13, 2016, for Unit 2. This examination will be included in all future ISI interval Program Plans.

The licensee also performs routine walk downs in the SI pump rooms daily.

The NRC staff concludes that the proposed inspections are acceptable because the subject welds will be monitored daily, visually examined quarterly, and liquid penetrant tested every 40 months.

4.7 Hardship Justification

The NRC staff has determined that requiring the licensee to perform the required post-weld heat treatment on the individual socket welds or the entire casing of the affected SI pumps may cause damage to the SI pump casing. In addition, the localized post-weld heat treatment on the welds or heat treating the SI pumps is impractical and presents a hardship. The NRC staff concludes that compliance with the specified requirements would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

4.8 Duration of the Proposed Alternative

The licensee requested to use the proposed alternative for the remaining life of the subject SI pumps, including the duration of the current operating licenses plus a contemplated license extension period of 20 years. In general, the NRC staff approves alternative requests only for specific 10-year ISI interval, not for the remaining life of the plant, because inspection requirements may change and NDE technology may improve from one 10-year ISI interval to the next. However, for DCPP, it is reasonable to allow the use of the proposed alternative for the remaining life to the subject SI pumps because the proposed alternative is not a repair and the subject welds are not degraded at the time of submittal. The licensee has demonstrated the soundness of the subject socket welds by performing WPS qualification and stress and fracture mechanics calculations and has proposed to perform alternative periodic inspections.

5.0 CONCLUSION

The NRC staff determines that the proposed alternative provides a reasonable assurance of structural integrity and leak tightness of the subject socket welds associated with SI pumps 1-1, 1-2, and 2-1. The NRC staff concludes that complying with the requirements of the ASME Code, Section XI, would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety. Accordingly, the NRC staff concludes that the licensee has adequately addressed all of the regulatory requirements set forth in 10 CFR 50.55a(z)(2). Therefore, the NRC staff authorizes the use of Alternative Request REP-SI, Revision 2, at DCPP, Units 1 and 2, for a period of time from date of issuance of this SE until these pumps are removed from service.

All other requirements of the ASME Code, Section XI, for which relief has not been specifically requested and authorized by NRC staff remain applicable, including a third-party review by the Authorized Nuclear Inservice Inspector.

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Date: July 15, 2015

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Sincerely,

/RA Fred Lyon for/

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Docket Nos. 50-275 and 50-323

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