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U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

Serial No. 19-055
NSSL/MLC R0
Docket No. 50-423
License No. NPF-49

DOMINION ENERGY NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3
PROPOSED ALTERNATIVE REQUEST IR-3-39, ALTERNATIVE TO ASME CODE, SECTION XI, IWA-4221(C), TO PERMIT TWO FILLET WELDS NOT IN COMPLIANCE WITH THE CONSTRUCTION CODE TO REMAIN IN SERVICE

Pursuant to 10 CFR 50.55a(z)(2), Dominion Energy Nuclear Connecticut, Inc. (DENC) requests Nuclear Regulatory Commission (NRC) approval of Alternative Request IR-3-39 for Millstone Power Station Unit 3 (MPS3). This alternative request would allow a deviation from the requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code), Section XI, IWA-4221(c) to permit two fillet welds which are not in compliance with the construction code to remain in-service.

In June 2017, it was identified that two inside diameter (ID) fillet welds, FW-12 and FW-30, fabricated during the 'B' Reactor Plant Component Cooling Water (CCP) heat exchanger (HX) replacement project in spring 2016, were made without a 200°F preheat as required by the code of construction (ASME III, Table ND-4622.7 (b)-1, Exemptions to Mandatory PWHT [Post Weld Heat Treatment]) for P-1 materials greater than 1½ inches thick. These welds are part of the double fillet-welded slip-on flange connections joining the 'B' CCP HX 24-inch diameter inlet and outlet nozzles to the Reactor Building Component Cooling Water piping headers. Following fabrication of these welds, final visual and magnetic particle examinations were performed. No recordable indications were found and in service leak testing confirmed no leakage.

Studies and tests conducted in support of this alternative request demonstrate that multi-pass, gas tungsten arc welding fillet welds FW-12 and FW-30, made without the 200°F preheat on 1.81-inch thick SA105 low carbon material, produce comparable/more refined microstructures and lower hardness of the weld and heat affected zone (HAZ) as compared to equivalent, Code-compliant, single-pass fillet welds made on 1.9-inch thick material with the 200°F preheat.

The overall global stresses in these flanges are low (limited to less than or equal to ¼ of the allowable stress) and stresses in the inside corner (in the proximity of the ID fillet welds), are even lower and are predominantly compressive. This provides little, if any, driving force for either crack initiation or growth in these ID fillet welds or their HAZs. In the unlikely event of a failure at the ID fillet weld, the most likely path would either be through the weld throat or along the HAZ parallel to the weld fusion line. Neither of these paths would result in a breach of the flange wall or fluid boundary, and the outside diameter fillet welds, which are fully Code-compliant, are adequate to carry up

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to four times the anticipated loads and maintain the pressure boundary and structural integrity.

Testing has shown that fillet welds FW-12 and FW-30, made without the 200°F preheat, have sufficient strength, ductility, and toughness to perform satisfactorily, and are less prone to cracking as evidenced by the mock-up welds when compared to Code-compliant single-pass fillet welds. Because repair or replacement of these welds would present a hardship or unusual difficulty without a compensating increase in the level of quality and safety, DENC proposes continued use of the welds without repair or replacement. The supporting basis for this request is provided in the attachment to this letter.

DENC requests approval of this proposed alternative by March 1, 2020.

This proposed alternative request has been approved by the Millstone Facility Safety Review Committee.

If you have any questions in regard to this submittal, please contact Mr. Shayan Sinha at (804) 273-4687.

Sincerely,

Mark D. Sartain
Vice President – Nuclear Engineering & Fleet Support

Commitments made in this letter: None

Attachment:

Proposed Alternative Request IR-3-39, Alternative to ASME Code, Section XI, IWA-4221(c) to Permit Two Fillet Welds not in Compliance with the Construction Code to Remain in Service

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ATTACHMENT

PROPOSED ALTERNATIVE REQUEST IR-3-39

ALTERNATIVE TO ASME CODE, SECTION XI, IWA-4221(C), TO PERMIT TWO FILLET WELDS NOT IN COMPLIANCE WITH THE CONSTRUCTION CODE TO REMAIN IN SERVICE

MILLSTONE POWER STATION UNIT 3 (MPS3)
DOMINION ENERGY NUCLEAR CONNECTICUT, INC. (DENC)

Proposed Alternative
In Accordance with 10 CFR 50.55a(z)(2)

-- Hardship Without a Compensating Increase in Quality and Safety --

1.0 American Society of Mechanical Engineers Code Components Affected

ASME Code Class: Code Class 3

Reference: American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code), Section XI, IWA-4221(c)

Examination Category: N/A

Item Number: See Table 1 below

Table 1

Weld Number	Description
FW-12	'B' CCP HX N-4 outlet slip-on flange to pipe ID fillet weld
FW-30	'B' CCP HX N-3 inlet slip-on flange to pipe ID fillet weld

Materials Involved: 24 inch diameter, 3/8" wall, SA-106 Grade B pipe, 24 inch diameter, 150 lb., SA-105 slip-on flange, ER70S-2, SFA 5.18, Gas Tungsten Arc Welding (GTAW) weld filler metal

Description: Inside diameter (ID) fillet welds, FW-12 and FW-30, welded without 200°F preheat or post weld heat treatment (PWHT).

Components: 24 inch inlet and outlet slip-on flanges from the 'B' Reactor Plant Component Cooling Water (CCP) system heat exchanger (CCP*E1B HX) to the Reactor Plant Component Cooling Water (RPCCW) system piping header.

System Design Temperature/Pressure: 150°F (inlet), 160°F (outlet) / 185 psig

2.0 Applicable Code Edition and Addenda

ASME Code, Section XI, 2004 Edition (No Addenda)

ASME Code, Section III, 1971 Edition with Addenda through Summer 1973 (original Code of Construction)

ASME Code, Section III, 2007 Edition through 2008 Addenda (Code of Construction used for Repair/Replacement Activity)

3.0 Applicable Code Requirements

ASME Code, Section XI, 2004 Edition (No Addenda)

- IWA-4221 (c) states in part, "As an alternative to (b), the item may meet all or portions of the requirements of different Editions and Addenda of the Construction Code, or Section III when the Construction Code was not Section III ... Construction Code Cases may also be used."

ASME Code, Section III, 2007 Edition, through 2008 Addenda

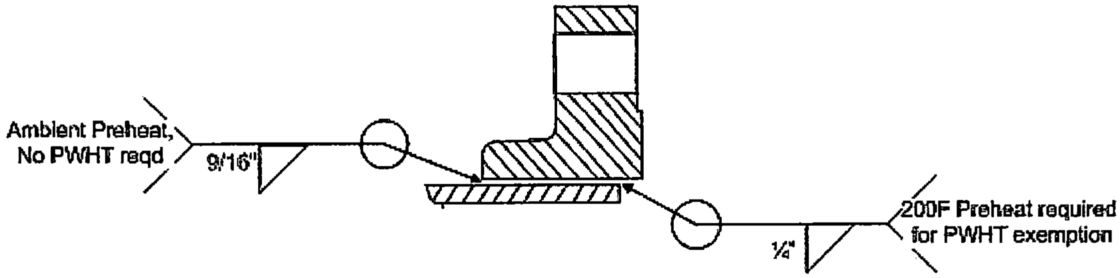
ASME Section III, ND-4600 contains the following requirements regarding postweld heat treatment of ASME III Class 3 welds:

- ND-4622.1 states, "Except as otherwise permitted in ND-4622.7, all welds, including repair welds, shall be postweld heat treated."
- ND-4622.7 states, postweld heat treatment is not required for welds exempted in Table ND-4622.7(b)-1.
- Table ND-4622.7(b)-1, "Exemptions to Mandatory PWHT," requires that all welds in P No.1 material over 1½ inches thick with a nominal thickness of ¾ inches or less are exempt from postweld heat treatment provided a minimum preheat of 200°F is applied.

4.0 Reason for Request

In June 2017, during work order preparation for the MPS3 'A' CCP HX replacement project, it was identified that two ID fillet welds, FW-12 and FW-30, fabricated during the 'B' CCP HX replacement project in spring 2016, were made without a 200°F preheat as required by the code of construction (ASME III, Table ND-4622.7(b)-1, Exemptions to Mandatory PWHT). As illustrated in Figure 1, these welds are part of the double fillet-welded slip-on flange connections joining the 'B' CCP HX 24-inch diameter inlet and outlet nozzles to the RPCCW piping headers.

Figure 1
Schematic of Slip-on Flange Welds



These slip-on flanges are welded to 3/8-inch wall SA106 Grade B piping using an outside diameter (OD) 9/16-inch fillet weld and a 1/4-inch ID fillet weld. In this case, the larger OD fillet welds did not require a 200°F preheat since the thickness of the flange hub was less than 1½ inches. However, the smaller ID fillet welds, FW-12 and FW-30, welded to the 1.81-inch thick flange required a 200°F preheat for PWHT exemption. Multi-pass GTAW was employed to complete these welds. The completed welds satisfied Code-required visual and magnetic particle examinations and in service leak tests. These welds have been in place since the spring of 2016 when the 'B' CCP HX was replaced.

5.0 Proposed Alternative and Basis for Use

5.1 Proposed Alternative

Pursuant to 10 CFR 50.55a(z)(2), DENC requests Nuclear Regulatory Commission (NRC) approval of Alternative Request IR-3-39 for MPS3. This alternative request would allow a deviation from the requirements of the ASME Code, Section XI, IWA-4221(c) to permit fillet welds, FW-12 and FW-30, which are not in compliance with the construction code to remain in-service.

DENC considered the option of replacing fillet welds FW-12 and FW-30; however, restoring these welds to full Code compliance would require the 'B' CCP HX to be out of service. As required by the MPS3 technical specifications, two CCP pumps and HXs must be operable during Modes 1, 2, 3, 4, 5, and 6 (until the water level above the reactor vessel flange is greater than or equal to 23 feet). Taking one CCP HX out of service for weld repair eliminates the system's defense-in-depth should either one of the other two CCP HXs become inoperable during this time.

Additionally, since the three MPS3 CCP pumps and HXs are located in the same area of the auxiliary building, repair of the 'B CCP HX fillet welds would require establishment of two protected equipment zones for the 'A' and 'C' CCP pumps and HXs. Because the weld repair evolution would require rigging and movement of large piping elements in an area where other safety related equipment is located, work in this area is difficult and poses an industrial safety risk to plant personnel and risk of damage to plant equipment.

The technical basis of the request demonstrates that fillet welds FW-12 and FW-30, made without the 200°F preheat, have sufficient strength, ductility, and toughness to perform satisfactorily, and are less prone to cracking as evidenced by the mock-up welds when compared to Code-compliant single-pass fillet welds. Therefore, any decrease in the level of quality of the welds due to not performing the 200°F preheat is not commensurate with the hardship associated with replacing the welds. Thus, DENC proposes continued use of the welds without repair or replacement on the basis that repair or replacement would present a hardship or unusual difficulty without a compensating increase in the level of quality and safety.

5.2 Basis for Use

The basis for this alternative request is supported by the following:

1) The subject welds have passed the Code-required final visual and magnetic particle examinations and post installation in-service leak testing. No cracking or other recordable indications were observed or are anticipated due to the omitted 200°F weld preheat.

2) Representative weld mock-ups and welding procedure qualification testing demonstrate that the subject welds and HAZs have acceptable properties with 75°F minimum preheat.

3) The stresses around the ID fillet welds are very low (<25% of the stress allowable) and are primarily compressive. Therefore, the chances of crack initiation or propagation are remote.

4) Code stress analysis demonstrates that if the ID fillet welds are not present (or are postulated to have failed completely) the OD fillet welds alone are fully capable of maintaining structural and pressure boundary integrity.

5) In the highly unlikely event of a failure of both the ID and OD fillet welds, the failure would be evident as a leak that would be detected during routine walkdowns before the failure would compromise the system or component structural integrity.

5.3 Code Requirements for Weld Qualification, Preheat/PWHT

ASME III requires that welding procedure specifications (WPS) be qualified in accordance with ASME IX. The WPS used for making FW-12 and FW-30 was qualified for welding up to an 8-inch thick material without elevated preheat or PWHT. Specifically, Dominion Corporate Welding Manual procedure qualification record (PQR) 135 joined a 1½-inch SA-516 Grade 60/70 plate using the GTAW process with: ER70S-2 filler metal, a 70°F minimum preheat, and no PWHT. All mechanical test results, including impact tests of the welds and HAZs, met ASME IX and ASME III (Class 1, 2, and 3 requirements) for piping welds. Impact testing at -20°F averaged 90 ft-lbs. for the weld and 119 ft-lbs. for the HAZ compared to the ASME III requirement for SA-516 of 20 ft-lbs. and SA-105 of 15 ft-lbs. The system does not require impacts, but if it had been required, the ASME III (71/73) requirement would have been 15 ft-lbs. The WPS used for making FW-12 and FW-30 is fully qualified per ASME IX and III for welding with the minimum preheats used.

ASME III, Table ND-4622.7(b)-1 also specifies additional conditions on base metal thickness, weld thickness, preheat, and maximum carbon content for which mandatory PWHT may be exempt. DENC did not satisfy the minimum 200°F preheat required by this table for P-No. 1 (carbon steel) material greater than 1½ inches thick to be exempt from the PWHT requirement.

The preheat and PWHT rules of the Code are intended to be conservative because they must address multiple material specifications, products forms, chemistry variations, and weld joint configurations. ASME III, Sections NB, NC, and ND (Classes 1, 2, and 3) have similar conservative preheat and PWHT rules. A likely reason for establishing limits on thickness and carbon content was to address base material hardenability and the potential for hydrogen-induced cracking from monatomic hydrogen that is introduced during some welding processes. Increasing carbon content increases hardenability. Thicker base metals are more effective heat sinks that cool the weld and HAZ faster. Rapid cooling rates in combination with higher hardenability may lead to undesirable hard welds and HAZ microstructures such as untempered martensite. These microstructures, when present, along with sufficient monatomic hydrogen and high tensile stresses, can lead to hydrogen-induced cracking in the weld and/or base metal HAZ. Application of preheat is one method to reduce the potential for hydrogen cracking because it slows the cooling rate offsetting a portion of the rapid cooling caused by thick materials. It may also drive off surface moisture (a potential source of hydrogen) and increases the temperature which may increase diffusion of hydrogen out of the weld and HAZ over time. Use of the GTAW process provides ultra-low hydrogen (typically <2 ml/100 grams) as another mitigating factor against hydrogen cracking.

Although the ASME III Code sets a thickness limit of 1½ inches for P-No 1 materials, there is no step change in cooling rates and/or the resultant weld and HAZ microstructures that occur as thickness exceeds 1½ inches. In fact, the mock-up test results described below demonstrate that the subject slip-on flange ID, multi-pass, GTAW fillet welds on the 1.9-inch nominal material made without the Code-required 200°F preheat will produce more optimal microstructures and lower HAZ hardness than Code-compliant single-pass fillet welds made with 200°F preheat under the same conditions.

5.4 Mock-Up Testing Results

Mock-ups were prepared for testing and evaluation of fillet weld specimens using the same welding technique and parameters used in the fabrication of fillet welds FW-12 and FW-30. A section of 24-inch diameter, 3/8-inch wall, SA106 Grade B pipe and a spare 24-inch, 150 lb., SA-105 slip-on flange* was selected for mock-up testing. The flange material matched the carbon content and slightly overmatched the carbon equivalent (calculated using ASME IX QW-403.26 formula) and strength of the production flanges. Sample specimens were fabricated which consisted of single pass and multi-pass fillet welds made with the same 75°F ambient preheat as the production welds, as well as single and multi-pass fillet welds with a 200°F preheat. Samples at 1½-inch thickness (max allowed without 200°F preheat) and 1 inch (representative of the flange hub weld joint) were also made for comparison. The carbon content and carbon equivalent for the installed flanges, the mock-up flange, the original PQR 135, and the SA105 base material and filler metal are provided in Table 2.

Table 2
Material, Description, Heat No., Carbon Content, and Carbon Equivalent

Item	Description/Heat Number	Carbon Content %	Carbon Equivalent (CE)
"B" CCP HX Nozzles N3 & N4	24" 150 LB Slip-On Flange SA105 Heat No. 217W891	0.19	0.42
Mock-up	24" 150 LB Slip-On Flange SA105 Heat No. 227J800	0.19	0.43
PQR 135	1 ½" SA-516 Grade 60/70 Bethlehem/Lukins HT# R 4981	0.19	0.42
SA105	Base Material Specification Maximum Permissible	0.35	0.67
ER70S-2 3/32	Production & Mock-up Weld Metal	0.04	0.26
ER70S-2 1/8	Production Weld Metal	0.05	0.25
ER70S-2 1/8	Production Weld Metal	0.05	0.26
ER70S-2 1/8	Mock-up Weld Metal	0.06	0.26
SFA 5.18 ER70S-2	Weld Filler Metal Spec Maximum	0.07	0.41

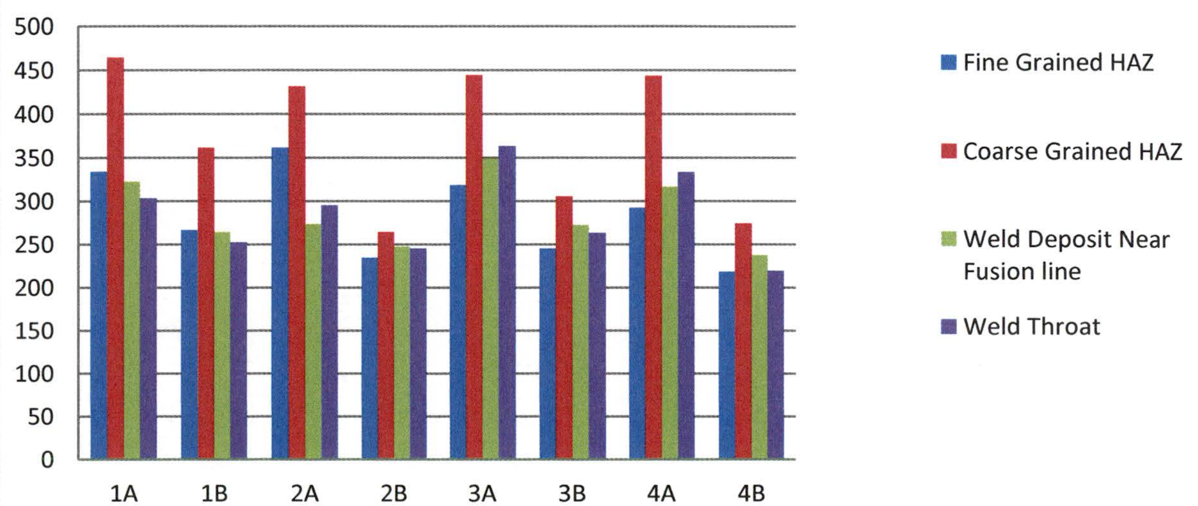
* One flange was used to mock up the ID fillet weld to 1.9" material, the OD fillet weld to 1" hub material, and a section was machined down to mock up an ID fillet weld to 1 ½" material.

The hardness evaluations of the test specimens showed the highest levels of hardness to be in the coarse-grained HAZs (CGHAZ) of the flange (nearest the weld fusion line) of the single pass welds shown as 1A, 2A, 3A, and 4A in Table 3 and Figure 2 below. The hardness of the fine-grained HAZ (FGHAZ), the weld metal, and the pipe is substantially less than that in the CGHAZ of the heavy flange. Therefore, DENC's evaluation focused on the CGHAZ of the flange as it is the area where the highest hardness will occur and is thus the limiting area from the standpoint of excessive hardness causing degradation in the weldment.

Table 3
Mock-Up Vickers Micro-Hardness Results

Mockup Description	FG HAZ			CG HAZ			Weld Near FL			Weld Throat		
	Low	Avg	High	Low	Avg	High	Low	Avg	High	Low	Avg	High
1A Single pass 1.9" 75°	289	334	395	450	464	488	281	322	348	245	303	331
1B Multi-pass 1.9" 75° (Represents FW-12 & FW-30)	212	266	338	221	361	444	243	264	295	238	252	261
2A Single pass 1.9" 200°	228	316	352	399	431	450	261	273	289	279	295	316
2B Multi-pass 1.9" 200°	193	234	289	209	264	355	217	247	309	235	245	252
3A Single pass 1 ½" 75°	263	318	393	333	444	523	339	349	364	353	363	374
3B Multi-pass 1 ½" 75°	209	245	285	223	305	409	255	272	293	250	263	271
4A Single pass 1" 75°	263	292	315	432	443	451	282	316	352	316	333	354
4B Multi-pass 1" 75° (Represents Installed Compliant Hub OD Fillet Welds)	194	218	257	205	274	378	208	237	260	202	219	238

Figure 2 - Average Vickers Micro-Hardness Results



5.5 Effect of Carbon Content on Peak HAZ Hardness

ASME III does not specify hardness limitations or microstructural requirements for exemption from PWHT. The applicable PWHT exemptions provided by the Code in Table ND-4622.7(b)-1 are for P-No. 1 with carbon contents up to 0.35% as allowed in SA-105. Research by the Electric Power Research Institute has shown that this Table can be conservative when applied to materials with lower carbon contents (<0.20%) as these have inherently lower hardenability (Ref. 1 and 2). Using the Creusot–Loire equation (per ASME Pressure Vessel and Piping paper – Ref. 3) to calculate predicted peak HAZ hardness of the production and mock-up flange materials and for SA105 material with the maximum carbon content/carbon equivalent for comparison, provides the following predicted peak hardnesses:

TABLE 4A
Flange Base Material: Creusot–Loire Predicted Peak Hardness

Heat#	C	Si	Mn	Ni	Cr	(^{o}C/sec)	(HVm)	Notes
217W891	0.19	0.24	1.14	0.06	0.08	270	454	SA-105 Production Flanges
227J800	0.19	0.23	1.19	0.08	0.07	270	454	SA-105 Mock-up Flange
-	0.35	0.35	1.05	0.4	0.3	270	614	SA-105 Material Spec Max.

As shown in Table 4A above, the predicted peak hardness of the 0.35% maximum carbon content allowed by the SA-105 base material specification is 614 HVm. This is 160 HVm higher than that of the 0.19% carbon content production and mock-up flanges. This 35% (i.e., 160/454 x 100%) increase in peak hardness could indicate a significant increase in the potential for brittle and crack susceptible microstructures in the CGHAZ. Thus, in comparing their peak hardness, the worst case allowed by the Code is predicted to be up to 35% higher than that of the mock-up and the actual production flanges.

It should be noted that the predicted peak hardness value of 454 HVm is very close to the actual measured average CGHAZ hardness values from Table 3 for the mock-up flange single pass fillet welds (464 – 431 HVm) with differences in cooling rates from the 200^{o}F preheat in specimen 2A accounting for the largest deviation. This along with similar results comparing Table 4B predicted peak hardness to Table 3 measurements for the lower carbon equivalent weld metal single pass welds (363 – 295 HVm), confirms a strong positive correlation between the predicted and measured values with a Correlation Coefficient (R) of 0.96.

Table 4B
Weld Filler Metal: Creusot-Loire Calculated Peak Hardness

Heat#	C	Si	Mn	Ni	Cr	(°C/sec)	(HVm)	Notes
65767	0.04	0.48	1.12	0.06	0.07	270	318	Production & Mock-up 3/32
1195Y	0.05	0.52	1.09	0.03	0.04	270	327	Production Flanges 1/8
1263V	0.05	0.53	1.1	0.03	0.05	270	328	Production Flanges 1/8
1274Y	0.06	0.52	1.08	0.03	0.03	270	336	Mock-up 1/8 dia filler

It is already well established that increasing carbon content increases hardenability and Martensite hardness. Therefore, no attempt was made to procure special material at or near the maximum carbon content to be used for a direct comparison as the above predicted peak hardness values and general metallurgical knowledge were considered sufficient to make it apparent that the effect of lowering the carbon content from the maximum allowed 0.35% to 0.19% drastically reduces the hardenability and peak hardness of the HAZ. In this case, the use of the lower carbon content (0.19%) is estimated to reduce peak hardness by 26% (i.e., 160/614 x 100%).

Although this 26% reduction in peak hardness is reasonable and supported by literature, this value is not used as a quantitative measurement in support of this alternative request as it was not derived directly by experimental measurements. It does, however, provide additional qualitative margin for consideration when comparing the maximum reasonable expected hardness of a worst-case ASME III Code-acceptable weld to that of fillet welds FW-12 and FW-30.

5.6 Effect of Multi-pass vs. Single Pass on CGHAZ Hardness

In addition to the benefits of the relatively low carbon content and carbon equivalent, fillet welds FW-12 and FW-30 also benefited from the fact that they were deposited using multiple weld passes. Single-pass welds are not restricted by the Code. Single-pass welds are used successfully throughout the industry and were used to establish Code-acceptable bounding conditions for comparison to the multi-pass fillet welds FW-12 and FW-30.

The metallurgical microstructures and hardnesses that result from following ASME III Code rules were used to make a comparison of the metallurgical microstructures and hardness of ASME III Code-compliant welds with the results of the mockup representing non-compliant welds FW-12 and FW-30.

Table 5 below shows a comparison of the Vickers micro-hardness measurements of the CGHAZ of Code-compliant single-pass fillet welds with those of the mock-up representing FW-12 and FW-30 multi-pass fillet welds. Other variables not presented in Table 5 were maintained constant.

Table 5
Comparison of Micro-Hardness for
Code-Compliant Single-Pass Welds vs. Multi-Pass Production Weld

No.	Single/ Multi	Thickness (in.)	Preheat (^{o}F)	ASME III Code-Compliant	Vickers Micro-Hardness CGHAZ		
					Min	Avg.	Max
2A	Single	1.9	200	Yes	399	431	450
3A	Single	1.5	75	Yes	333	444	523
4A	Single	1.0	75	Yes	432	443	451
1B	Multi	1.9	75	No	221	361	444

It is noted that in each column the hardness of the multi-pass fillet weld representing FW-12 and FW-30 (1B), made without preheat, is lower than the corresponding hardness of the Code-compliant single-pass fillet welds, including the single-pass weld made with the 200°F preheat (2A).

The effect of multi-pass versus single-pass with all other variables being constant is calculated by comparing the CGHAZ hardness of the single-pass weld (A) to the multi-pass weld (B) for each set of conditions (1 through 4). The results are shown in Table 6 below.

Table 6
Comparison of Micro-Hardness for Single-Pass vs. Multi-Pass Welds

No.	Single/ Multi	Thickness (in.)	Preheat (^{o}F)	ASME III Code Compliant	Vickers Micro-Hardness CGHAZ	
					Avg.	% change
1A	Single	1.9	75	No	464	
1B	Multi	1.9	75	No	361	
					-103/464	-22%
2A	Single	1.9	200	Yes	431	
2B	Multi	1.9	200	Yes	264	
					-167/431	-39%
3A	Single	1.5	75	Yes	444	
3B	Multi	1.5	75	Yes	305	
					-139/444	-31%
4A	Single	1.0	75	Yes	443	
4B	Multi	1.0	75	Yes	274	
					-169/443	-38%
					-578/1782	**-32%**

The average effect of multi-pass welding versus single-pass welding is a 32% reduction in hardness of the CGHAZ.

5.7 Effect of 200°F Preheat vs. Ambient (75°F)

The effect of preheat was calculated by comparing the average CGHAZ hardness for single-pass without preheat (1A) to single pass with 200°F preheat (2A) and multi-pass without preheat (1B) to multi-pass with 200°F preheat (2B) and averaging the two. The results are shown in Table 7 below.

Table 7
Comparison of Micro-Hardness for Single-Pass and Multi-Pass Welds With and Without Preheat

No.	Single/ Multi	Thickness (in.)	Preheat (°F)	ASME III Code Compliant	Vickers Micro Hardness CGHAZ	
					Avg.	% change
1A	Single	1.9	75	No	464	-7%
2A	Single	1.9	200	Yes	431	
					-33/464	
1B	Multi	1.9	75	No	361	
2B	Multi	1.9	200	Yes	264	
					-97/361	-27%
					-130/825	**-16%**

The average effect of welding with the 200°F preheat as compared to welding without the 200°F preheat is a 16% reduction in hardness of the CGHAZ.

5.8 Comparison of the Effects of 200°F Preheat vs. Multi-Pass Welding

From the tables above, the reduction in average CGHAZ hardness on P-No.1 material matching the carbon content and thickness of the actual production welds (FW-12 and FW-30) as a result of using 200°F preheat is 16%, over a range from 7% to 27%. This is specific to conditions representative of the actual production welds.

The effect of multi-pass welding was similarly shown to reduce the average CGHAZ hardness by 32%, over a range from 22% to 39%. While the ranges have some overlap, the effect of multi-pass welding was significantly greater than that of the 200°F preheat for conditions bounding the actual production welds (FW-12 and FW-30).

This is evident in the direct comparison of the three ASME III Code-compliant single-pass fillet welds 2A, 3A, and 4A with the multi-pass weld 1B representative of the actual production welds (FW-12 and FW-30):

Table 8
Comparison of Micro-Hardness for
Code-Compliant Single-Pass Welds vs. Multi-Pass Production Weld (same data as Table 5)

No.	Single/ Multi	Thk (in.)	Preheat (°F)	ASME III Code Compliant	Vickers Micro Hardness CGHAZ		
					Min	Avg.	Max
2A	Single	1.9	200	Yes	399	431	450
3A	Single	1.5	75	Yes	333	444	523
4A	Single	1.0	75	Yes	432	443	451
1B	Multi	1.9	75	No	221	361	444

In each case, the hardness of the multi-pass fillet weld (1B), representing FW-12 and FW-30 made without preheat, is lower than the corresponding hardness of the Code-compliant single-pass fillet welds, including the single-pass weld made with the 200°F preheat (2A).

While it is recognized that the highest reduction in CGHAZ hardness is achieved by combining both 200°F preheat and multi-pass welding, as in specimen 2B, requiring both 200°F preheat and multi-pass welding exceeds the requirements of the applicable code. In a direct comparison of the effectiveness of 200°F preheat versus that of multi-pass GTAW welding for the specific conditions representing FW-12 and FW-30, multi-pass welding was determined to be approximately twice as effective at reducing the average CGHAZ hardness.

Thus, it has been demonstrated that the CGHAZ hardness of the 1B multi-pass fillet weld, representative of the production welds (FW-12 and FW-30), is well within the range of hardness found in the other three ASME III Code-compliant single-pass fillet welds (2A, 3A, and 3B). As such, this evaluation of representative welds concludes that the omission of ASME III Code-required 200°F preheat while depositing FW-12 and FW-30 will not result in excessive hardness or degradation beyond conditions bounded by the three Code-compliant single pass fillet welds.

6.0 Photomicrographs

Single Pass	Multi-Pass Toe - last bead	Multi-Pass Root - first bead


1A- CGHAZ 1.9" 75° F Single Pass


1B- CGHAZ 1.9" 75° F Multi-Pass Toe


1B – CGHAZ 1.9" 75° F Multi-Pass Root

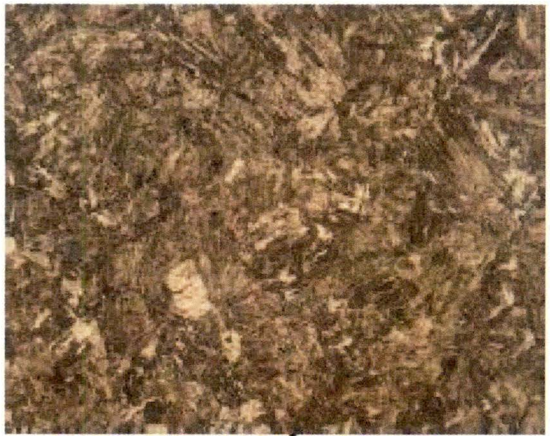

2A- CGHAZ 1.9" 200° F Single Pass


2B- CGHAZ 1.9" 200° F Multi-Pass Toe


2B- CGHAZ 1.9" 200° F Multi-Pass Root

All Micrographs are 400x prior to reproduction 3% Nital Etch

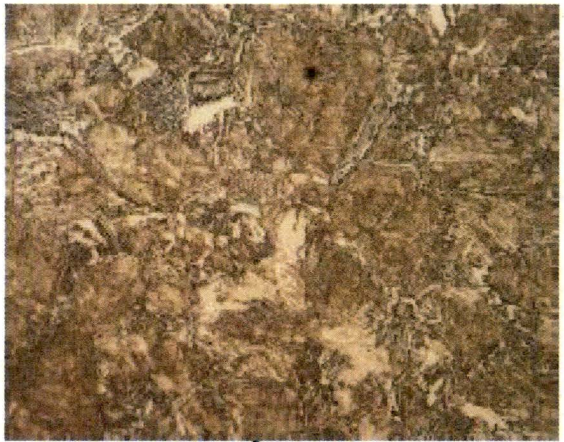
Single-Pass	Multi-Pass Toe - last bead	Multi-Pass Root - first bead


3A- CGHAZ 1 ½" 75° F Single-Pass


3B- CGHAZ 1 ½" 75° F Multi-Pass Toe


3B – CGHAZ 1 ½" 75° F Multi-Pass Root


4A- CGHAZ 1" 75° F Single-Pass


4B- CGHAZ 1" 75° F Multi-Pass Toe


4B- CGHAZ 1" 75° F Multi-Pass Root

All Micrographs are 400x prior to reproduction 3% Nital Etch

6.1 Evaluation of Photomicrographs and Microstructure

The microstructures of all single pass welds (left column - 1A, 2A, 3A, and 4A) consist of a phase mixture of low carbon Martensite, Bainite, and Ferrite. The corresponding multi-pass welds (middle and right columns - 1B, 2B, 3B, and 4B) all show the same phases to varying degrees with evidence of grain refinement commensurate with the number of subsequent weld passes (higher at the root and less at the toe).

Comparing the individual photomicrographs for each row moving from left to right, the initial pass entitled, "Single Pass" has coarser and predominantly columnar grains with a mix of different structures and phases. As the images are viewed from left to right, the grains become more refined, with smaller and much more equiaxed grains in the last column. These smaller, more equiaxed grains are evidence of grain refinement from the multiple reheat cycles experienced during multi-pass GTAW welding as numerous small beads are deposited one over another. The resulting fine equiaxed grains contribute to the high values for impact properties produced in the HAZ of the multi-pass GTAW weld as reported in PQR 135.

For comparison, the microstructures in photomicrographs 1B, which are representative of the actual production welds (FW-12 and FW-30), have a more uniform and more refined appearance than the Code-compliant single-pass fillet welds shown in 2A, 3A, and 4A. There is none of the lighter colored phase present in the 1B photomicrographs. The presence of carbon and/or carbides darkens the image, thus the lack of the lighter phase areas would be indicative of increased tempering-releasing carbon from the interstitial sites to either dislocations or other higher energy locations in the matrix. This is significant in that it provides evidence that there is no untempered Martensite.

6.2 Combination of Hardness and Microstructural Evaluations

Hardness alone is not a good predictor of strength, ductility, or toughness unless the microstructure from which it was measured is known. In carbon steels, the best combination of strength, ductility, and toughness comes from fine grained tempered Martensite. Evaluation of the micrographs and micro-hardness measurements together indicate that the CGHAZ microstructures contained some Martensite since neither Bainite nor Ferrite can reach the peak hardnesses that were measured.

Combining the contributions of both the mock-up hardness and microstructural evaluations, it can be seen that the 1B specimens (representing the actual production multi-pass fillet welds FW-12 and FW-30) have both a finer, more equiaxed grain structure with no indications of any untempered Martensite and lower hardness compared to the Code-compliant single-pass fillet welds in 2A, 3A, and 4A. The combination of improved microstructure and reduced hardness provides confidence that fillet welds FW-12 and FW-30 have a better combination of mechanical properties and are less prone to contain small areas of brittle or crack-susceptible microstructural elements than the Code-compliant single-pass fillet welds represented by specimens 2A, 3A and 4A. As such, the mock-up has demonstrated that production welds FW-12 and FW-30 have a combination of microstructures and micro-hardness properties that provide assurance of mechanical properties and resistance to cracking at least equal to that of ASME III Code-compliant single-pass fillet welds represented by specimens 2A, 3A, and 4A.

7.0 Stress Evaluation

To determine the global stress on the 24-inch diameter inlet and outlet nozzle slip-on flanges, the ASME Code pipe stress equations for dead load, thermal, occasional upset, and occasional faulted were used. Stresses for the specified inlet and outlet flanges on the MPS3 'B' CCP heat exchanger are not explicitly stated in the pipe stress calculation NP(B)-X7202, Rev. 4 (Ref. 4); however, they may be derived from the moments calculated within the pipe stress programmatic output. These Code equations calculate pipe stress based upon longitudinal stress (pressure) and bending stress (loading). As the longitudinal stress is constant at a specific location and pressure, variations in the bending moment have non-linear effects on the total stress.

The piping flanges at the specified location in NP(B)-X7202, Rev. 4 are represented by node 110/115. To determine the maximum bending moment (M_A, M_B, or M_C), the directional moments are combined using the Square Root of the Sum Squares (SRSS) method. The moments for each are specified below. Calculation NP(B)-X7202, Rev. 4 shows the absolute maximum moments for the flanges at nodes 110/115 for each scenario.

Table 9
Absolute Maximum Moments for the Flanges at Nodes 110/115

<table>
<tr><td colspan="3">Deadload (ft-lb)</td><td colspan="3">Thermal (ft-lb)</td><td colspan="3">OBEI (ft-lb)</td><td colspan="3">OBEA (ft-lb)</td><td colspan="3">SSEI (ft-lb)</td><td colspan="3">SSEA (ft-lb)</td></tr>
<tr><td>M_x</td><td>M_y</td><td>M_z</td><td>M_x</td><td>M_y</td><td>M_z</td><td>M_x</td><td>M_y</td><td>M_z</td><td>M_x</td><td>M_y</td><td>M_z</td><td>M_x</td><td>M_y</td><td>M_z</td><td>M_x</td><td>M_y</td><td>M_z</td></tr>
<tr><td>6,138</td><td>2,198</td><td>6,777</td><td>5,643</td><td>16,135</td><td>6,328</td><td>5,570</td><td>8,477</td><td>4,228</td><td>195</td><td>237</td><td>209</td><td>8,285</td><td>12,106</td><td>6,278</td><td>1213</td><td>779</td><td>639</td></tr>
<tr><td>M_A</td><td>=</td><td>9,404</td><td>M_C</td><td>=</td><td>18,227</td><td colspan="12"></td></tr>
<tr><td colspan="6" rowspan="4"></td><td colspan="6">OBE = OBEI + OBEA</td><td colspan="6">SSE = SSEI + SSEA</td></tr>
<tr><td colspan="2">M_x</td><td colspan="2">M_y</td><td colspan="2">M_z</td><td colspan="2">M_x</td><td colspan="2">M_y</td><td colspan="2">M_z</td></tr>
<tr><td colspan="2">5,765</td><td colspan="2">8,714</td><td colspan="2">4,437</td><td colspan="2">9,498</td><td colspan="2">12,885</td><td colspan="2">6,917</td></tr>
<tr><td colspan="2">M_{BUpset}</td><td colspan="2">=</td><td colspan="2">11,351</td><td colspan="2">$M_{BFaulted}$</td><td colspan="2">=</td><td colspan="2">17,438</td></tr>
</table>

Where:
I = Inertia
A = Anchor Motion
OBE = Operating Basis Earthquake
SSE = Safe Shutdown Earthquake

The stress equations are as follows from Section III of the 1971 Edition of the Code, up to and including, summer of 1973 addendum. For conservatism, the section modulus of the pipe is used below when in actuality the section modulus of the flange is much larger, which would reduce the calculated stresses. One half of the OBEA/SSEA moment is used in Equation 9. This is consistent and acceptable for piping design at MPS3 (Ref. 6).

Equation 8 – Sustained Loads (Deadload)

$$\frac{PD_O}{4t_n}+\frac{0.75iM_A}{Z}\leq 1.0S_h,\ \frac{185\frac{lb}{in^2}\cdot 24.0\,in}{4\cdot 0.375\,in}+\frac{112{,}847\,in-lb}{161.9\,in^3},\ 3{,}657\frac{lb}{in^2}\leq 15{,}000\frac{lb}{in^2}$$

Where:
P = Internal design pressure, 185 psig (Ref. 4)
D_o = Outside diameter of pipe, 24.0 in
t_n = Nominal wall thickness, 0.375 in
i = Stress intensification factor Fig. NC-3672.9(a)-1, 0.75i ≥ 1.0, Conservative Slip-on Flange SIF assuming single welded slip-on flange i = 1.3 ∴ 0.75·1.3 ≈1.0, Flange assembly is a double welded slip-on flange, which per Table NC-3672.9(a)-1 would utilize an SIF of 1.2.
M_A = Resultant moment loading due to weight and other sustained primary loads, 112,847 in-lb,
Z = Section modulus of pipe, 161.9 in^3 (Ref. 5),
S_h = Basic material allowable stress at maximum (hot) temperatures for SA-181 Gr. 1, 15,000 psi (Ref. 7).
Note: Piping material is ASME SA-106 Gr. B, Sc/Sh = 15,000 psi, (Ref. 7)
Flange material is ASME SA-105, Sc/Sh = 15,000 psi

Equation 9 (Upset)

The effects of pressure, weight, other sustained mechanical loads, and occasional loads, including Operating Basis Earthquake (OBE) must meet the requirements of Equation 9 from NC-3652.2. As noted above, one half of the OBEA moment is used in Equation 9.

$$\frac{P_{max}D_O}{4t_n}+0.75i\left(\frac{M_A+M_{B-U}}{Z}\right)\leq 1.2S_h,\ \frac{185\frac{lb}{in^2}\cdot 24.0\,in}{4\cdot 0.375\,in}+\frac{249{,}065\,in-lb}{161.9\,in^3},\ 4{,}498\frac{lb}{in^2}\leq 18{,}000\frac{lb}{in^2}$$

Where:
P_{max} = Maximum operating pressure for Normal or Upset operating conditions, Design P conservatively used.
M_{B-U} = Resultant moment loading due to occasional loads, 136,218 in-lb.

Equation 9 (Faulted)

The effects of pressure, weight, other sustained mechanical loads, and occasional loads, including Design Basis Earthquake (DBE) must meet the requirements of Equation 9 from NC-3652.2. As noted above, one half of the SSEA moment is used in Equation 9.

$$\frac{P_{max}D_O}{4t_n} + 0.75i\left(\frac{M_A + M_{B-F}}{Z}\right) \leq 2.4S_h, \frac{185\frac{lb}{in^2}\cdot 24.0\,in}{4\cdot 0.375\,in} + \frac{322{,}102\,in-lb}{161.9\,in^3}, 4{,}950\frac{lb}{in^2} \leq 36{,}000\frac{lb}{in^2}$$

Where:
P_{max} = Maximum operating pressure for Normal or Upset operating conditions, Design P conservatively used.
M_{B-F} = Resultant moment loading due to occasional loads, 209,255 in-lb.

Equation 10

The requirements of either Equation 10 or 11 from NC-3652.3 must be met. The effects of thermal expansion may be met by satisfying the requirements of Equation 10, as follows:

$$\frac{iM_c}{Z} \leq S_A, \frac{1.3\cdot 218{,}725\,in-lb}{161.9\,in^3}, 1{,}756\frac{lb}{in^2} \leq 22{,}500\frac{lb}{in^2}$$

Where:
S_A = Allowable stress range for expansion stress = 1.25 S_c + 0.25 S_h.
S_c = Basic material allowable stress at minimum (cold) temperatures, 15,000 psig.
M_c = Range of resultant moment loading due to thermal expansion, 218,725 in-lb.

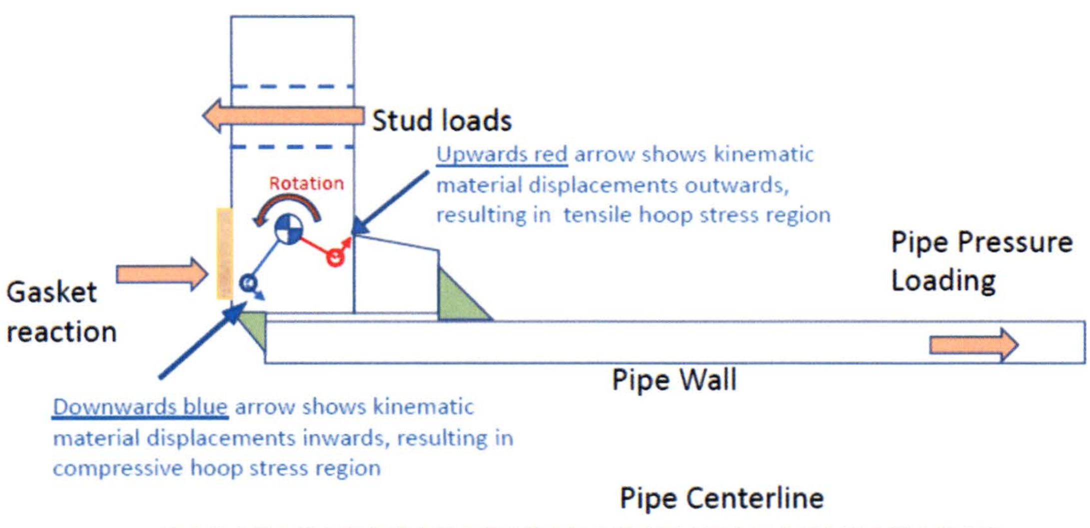
A summary of the stresses calculated above and the ratio of applied stress versus the allowable is provided in Table 10 below.

Table 10
Calculated Stresses for 24-Inch Diameter Slip-On Flange and Ratio of Applied Stress vs. Allowable Stress

Condition	Allowable Stress (psi)	Maximum Stress (psi)	Ratio
Equation 8	1.0 S_h = 15,000	3,657	0.24
Equation 9U	1.2 S_h = 18,000	4,498	0.25
Equation 9F	2.4 S_h = 36,000	4,950	0.14
Equation 10	S_A = 22,500	1,756	0.08

The stresses associated with the ID fillet welds (shown schematically below) were considered. The overall global stresses in the flange are low (limited to less than or equal to ¼ of the allowable stress) and most of the bolting, tensile, and bending loads are transferred through the outer portion of the flange, into the hub, across the OD fillet weld, and into the pipe. The stresses in the inside corner of the ID fillet weld are even lower and are predominantly compressive. These stresses are a fraction of the allowable stresses for the materials used. In the unlikely event of a failure at the ID fillet weld, the most likely path would either be through the weld throat or along the HAZ parallel to the weld fusion line. Neither of these paths would result in a breach of the flange wall or fluid boundary. Instead, a failure would simply result in a leak path past the ID fillet weld into the annulus between the pipe and the flange. Even in the unlikely event that the ID weld should fail, the OD fillet weld, which is fully Code-compliant, is more than adequate to carry all of the anticipated loads and maintain the pressure boundary and structural integrity. A pressure boundary leak would require breaching both the ID and the OD fillet welds and is extremely unlikely.

Figure 3
Kinematic Sketch of Stresses



8.0 Evaluation of Potential Corrosion in Annulus Between Pipe and Flange

The MPS3 RPCCW system is treated with Hydrazine at 10 to 30 ppm to protect the carbon steel material surfaces by creating a protective film that prevents oxidation and corrosion. The water is also maintained at a pH of around 9.7 with low oxygen. This environment limits the amount of oxidation and corrosion to protect the exposed and wetted carbon steel surfaces.

In the event that the ID fillet weld should fail and allow a path for RPCCW treated water to enter the annulus between the pipe and the flange, the void would fill with treated water. Any oxygen in the annulus would be used to depletion resulting in a very limited amount of general corrosion that would slow to zero as the oxygen is depleted. Since there is no exchange of water out of the annulus, what enters will remain trapped in that space. Eventually the Hydrazine will decompose into ammonia, but the environment will remain quasi-static with just a very slow corrosion rate as only a limited amount of oxygen enters the space through the path in the ID fillet weld. This process is expected to be very slow and would produce minimal wall loss over the remaining life of the plant, including license extensions.

In the extremely unlikely event that a corrosive environment develops and ion or other exchange feeds reactants directly into a corrosion cell, the majority of that corrosion would still be localized in the immediate area nearest the source of oxygen. This kind of localized corrosion has been observed in other systems with much more corrosive environments such as in aerated seawater service. The resulting localized corrosion cell might eventually produce a small slowly growing leak; however, this component is located in a routinely accessed area of the auxiliary building. Therefore it would be expected that any significant leak would be detected during routine Operations activities before it can cause any kind of loss of system function or component integrity.

9.0 Conclusions

Studies and tests conducted in support of this alternative request demonstrate that multi-pass, GTAW fillet welds, FW-12 and FW-30, fabricated without the 200°F preheat on 1.81-inch thick SA105 low carbon material, produce comparable or more refined microstructures and lower hardness (of the weld and HAZ) as compared to equivalent, Code-compliant, single-pass fillet welds made on 1.9-inch thick material with 200°F preheat and on material ≤ 1½-inch thick without preheat.

During installation, fillet welds FW-12 and FW-30 were final visual and magnetic particle examined and no recordable indications were found. Post installation in-service leak testing confirmed no leakage.

The overall global stresses in these flanges are low (limited to less than or equal to ¼ of the allowable stress) and are transferred through the outer portion of the flange, into the hub, across the OD fillet weld, and into the pipe. The stresses in the inside corner of the ID fillet welds are even lower and are predominately compressive. This provides little, if any, driving force for either crack initiation or growth for these ID fillet welds or their HAZs. In the unlikely event of a failure at the ID fillet weld, the most likely path would either be through the weld throat or along the HAZ parallel to the weld fusion line. Neither of these paths results in a breach of the flange wall or fluid boundary. In the unlikely event that the ID weld should fail, the OD fillet weld, which is fully Code-compliant, is adequate to carry up to four times the Code design loads and will maintain the pressure boundary and structural integrity.

In the extremely unlikely event that the ID fillet weld fails and the OD fillet weld also fails, the only conceivable failure would produce a small slowly growing leak. This component is located in a routinely accessed area of the auxiliary building and any significant leak would be detected during routine Operations activities before causing loss of system function or component integrity.

Testing has shown that the fillet welds made on 1.9-inch thick material without 200°F preheat (or PWHT) will continue to provide sufficient strength, ductility, and toughness to perform satisfactorily. These fillet welds are less prone to cracking as evidenced by the welding process (ultra-low hydrogen multi-pass GTAW), microstructures (primarily tempered Martensite improved by grain refinement), and hardness (reduced peak and average) when compared to Code-compliant single-pass fillet welds.

Repair or replacement of these welds online or during an outage eliminates the CCP system's defense-in-depth should either one of the other two CCP pumps or HXs become inoperable during this time. Additionally, due to the physical location of the CCP HXs, the tight work area poses an industrial safety risk to plant personnel and risk of damage to plant equipment. Based on mockup testing and evaluation of the production welds, DENC concludes that repair or replacement of the FW-12 and FW-30 welds presents a hardship without a compensating increase in the level of quality of safety. Thus, DENC proposes continued use of the welds without repair or replacement.

10.0 Duration of the Proposed Request

This proposed alternative is requested for the remaining useful life of fillet welds FW-12 and FW-30.

11.0 Precedent

This proposed alternative request is similar to an alternative request submitted by Entergy on August 19, 2013 for River Bend Station Unit 1 (ADAMS Accession No. ML13239A074). This alternative request was approved by the NRC on January 28, 2014 (ADAMS Accession No. ML13353A608).

12.0 References

1. EPRI Technical Report 1008277, "PWHT Exemptions for Low Hardenability Materials"
2. EPRI Technical Report 1022883, "2009-2010 Post Weld Heat Treatment Exemption Thickness Test Results"
3. American Society of Mechanical Engineers PVP2012-78571, "Alternative

Approach for Qualification of Temperbead Welding in the Nuclear Industry."

4. Dominion Calculation NP(B)-X7202, Rev. 004-00, "Reactor Plant Component Cooling Piping: Auxiliary Building."
5. Crane Technical Paper 410, "Flow of Fluids through Valves, Fittings, and Pipe," 1981.
6. Millstone Specification, SP-ME-572, Rev. 003-02, "Specification for Piping Classes for Millstone Unit 3."
7. ASME Boiler & Pressure Vessel Code, Section III, Division 1, "Rules for Construction of Nuclear Power Plant Components," 1971 Edition, addenda through Summer 1973.