Attachment 4

Westinghouse Calculation TR-FSE-15-2-NP, Rev. 1, *Palo Verde Nuclear Generating Station Unit 3 Evaluation of Potential Loose Part – Reactor Coolant Pump Instrument Nozzle Weld Fragment*

TR-FSE-15-2-NP, Rev. 1
Palo Verde Nuclear Generating Station Unit 3
Evaluation of Potential Loose Part - Reactor Coolant Pump Instrument Nozzle Weld Fragment

This document has been prepared and approved in accordance with Westinghouse Procedure WEC 6.1.

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**** Electronically approved records are authenticated in the electronic document management system.***

SUMMARY

During the 3R18 Palo Verde Nuclear Generating Station (PVNGS) Unit 3 refueling outage, leakage from a pressure instrument nozzle on the CE-KSB Type 101 Reactor Coolant Pump (RCP) 2A safe end was identified. The Arizona Public Service (APS) repair strategy includes performing a half-nozzle repair. This repair involves removing a portion of the existing nozzle, inserting a replacement nozzle design in the same location, and then replacing the original pressure boundary partial penetration weld on the inside wetted surface with a weld located on the outside surface.

Because the repair process involves removing the external portion of the existing RCP nozzle and leaving a small nozzle remnant inside the existing penetration, APS has asked Westinghouse to address the possibility that fragments of the existing partial penetration weld could come loose inside the reactor coolant system (RCS) during the next cycle of operation (18 months is assumed). It was postulated that the crack (or cracks) which led to the leak were attributed to primary water stress corrosion cracking (PWSCC) and could propagate further until some portion(s) of the existing weld becomes a loose part. Westinghouse is aware of no prior industry experience where a half-nozzle repair has led to loose weld fragments.

This evaluation concluded that the postulated loose part or parts will have no adverse impact on the RCS and connected systems, structures, and components (SSCs). The SSCs continue to be capable of satisfying their design functions.

1.0 Introduction

During the 3R18 PVNGS-3 refueling outage, APS identified signs of leakage (i.e., boric acid) stemming from a pressure instrument nozzle located on the suction nozzle safe end of the 2A CE-KSB Type 101 RCP. Refer to Figure 1.

Figure 1
Pressure Instrument Nozzle – Showing Leakage

The APS repair strategy is to perform a "half-nozzle" repair to the 1-inch instrument nozzle. The modification will replace the instrument nozzle and leave in place a short segment of the original nozzle and nozzle weld at the inner surface of the pump safe end (see Figure 2).

Because the repair process involves leaving a small remnant of the nozzle inside the penetration, APS asked Westinghouse to address the possibility that some portion of the partial penetration weld holding the RCP nozzle remnant in place could further crack and become a potential loose part inside the RCS.

Where identified by revision bars in the left margin, Revision 1 of this report makes editorial changes recommended by APS to the Summary page and to Sections 2.0 and 7.0.

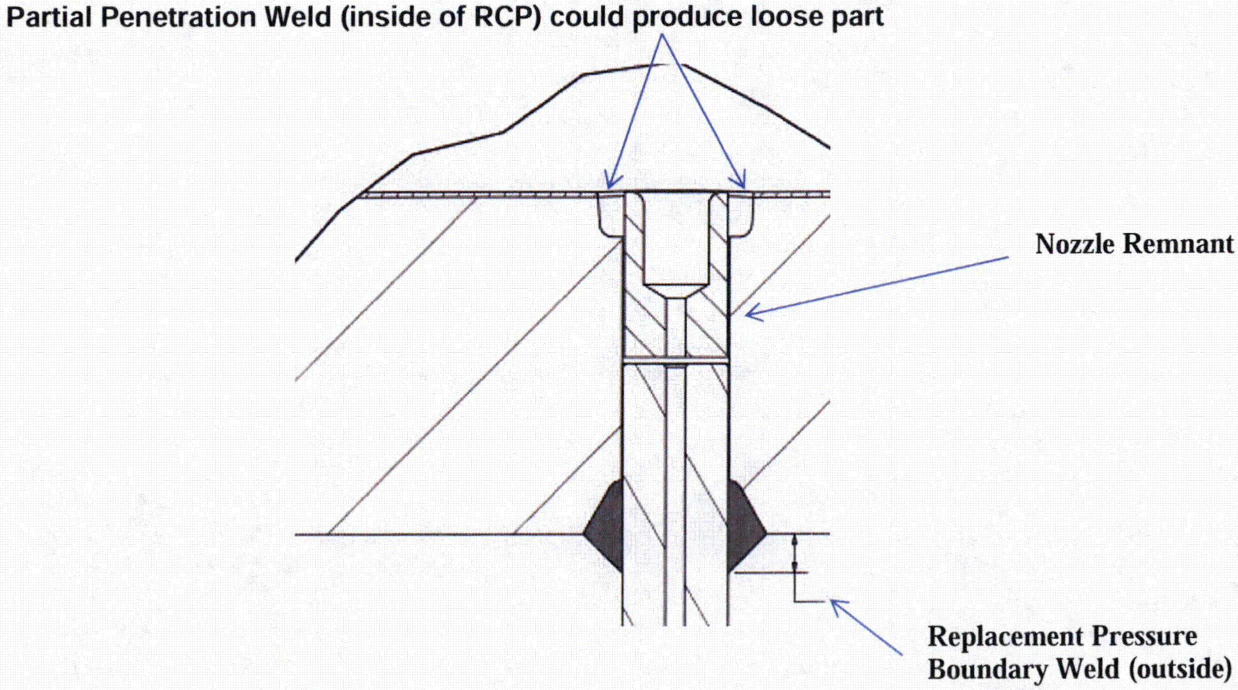
2.0 Description of Loose Part

At the time this report was prepared, APS had not specifically identified the degradation mechanism responsible for the leak. The topic was discussed with Westinghouse and it was postulated that the likely mechanism is PWSCC of the susceptible Inconel 600 nozzle and weld materials. Non-

destructive examinations (NDE) were performed by APS to describe the flaw. The examinations consisted of:

- injection of liquid penetrant at low pressure from the safe end outside diameter (OD) into the annulus between the bore and instrument nozzle;
- visual inspection using a boroscope of the nozzle inner diameter (ID) and partial penetration weld inside the safe end; and
- ultrasonic testing (UT) across the nozzle remnant length, from the end of the pipe. (This interrogation was not able to see the original partial penetration weld.)

Figure 2
Half-Nozzle Repair Illustration



Based on these inspections, APS identified no circumferential cracks in the nozzle (from UT inspection) and no external visually discernable degradation on the surface of the partial penetration weld or the nozzle inside diameter. Thus, it was reasoned that one or more part-through-wall cracks likely exist in the nozzle and/or the weld. This is consistent with the orientation previously observed by APS for this type of degradation mechanism (i.e., PWSCC) in instrument nozzles in the hot leg. This conclusion is important because both axial and circumferential flaws would be necessary to produce a loose part.

The remnant Inconel 600 instrument nozzle (approximately 1.5 inches in length) is recessed inside the safe end bore. It remains constrained by a relatively tight radial clearance between the nozzle

and the bore. This is further helped by the weld deposited in this annular gap during the welding process. Therefore, even if the majority of the partial penetration weld was to break, it is not credible to assume that the remnant nozzle could become a loose part and become ejected into the RCS flow during the next 18 month fuel cycle. Additional assurance is provided considering that the hypothetical cracks are likely longitudinal part-through-wall, and as such, the nozzle is able to maintain its structural integrity. Also the partial penetration weld, even if it had several longitudinal radial cracks, would require at least two other planes oriented in the circumferential direction in order to release a piece of any significant size. Since circumferentially-oriented cracks were not identified by the UT, the likelihood for a weld fragment to be released is very low.

Given this scenario, Westinghouse addressed the possibility that one or more fragments of the existing partial penetration weld separates from the nozzle and weld butter and becomes a loose part inside the RCS. For the purposes of this evaluation, the loose part has conservatively been defined to be a relatively large weld fragment weighing approximately 0.1 pounds and having cross-sectional dimensions no greater than the partial penetration weld depth (approximately 0.9 inches) and a length equal to one-quarter of the circumference of the instrument nozzle (approximately 0.8 inches). The weld filler material (i.e., down to the butter layer) is an Inconel alloy (Alloy 182) that is compatible with the ASME SB-166 (UNS N06600) instrument nozzle material (References 8.9 and 8.10).

Other smaller sizes and shapes of the weld fragments are possible and, with this taken into consideration, various weld fragment sizes and shapes have been postulated in the individual evaluations contained in this report, as applicable.

Additionally, it is noted that the postulated weld fragment would be native to the RCS and therefore, compatible with RCS chemistry.

3.0 Assumptions

The description of the loose part provided in Section 2.0 is based on an assumption that weld fragment(s) are generated. This is a conservative approach.

All other principle assumptions made for various analyses/evaluations are identified in the individual sections that follow.

4.0 Postulated Flow Path through the Reactor Coolant System

The following defines the postulated flow path of the weld fragments, and thus the portions and subcomponents of the RCS that need to be assessed.

The weld fragments will only enter the flow stream while the RCS is in operation. During normal operation, flow through the RCS would carry the weld fragments through the suction of the 2A RCP. The weld fragments could impact components of the RCP and then be passed through the pump discharge into the cold leg. Flow in the cold leg would carry the weld fragments down the pipe. Three cold leg resistance temperature detector (RTD) thermowells are present in the flow path on

the vertical half of the pipe perimeter. The weld fragments would likely be carried past the RTD thermowells. However, it is possible that the weld fragments could impact one of the thermowells.

At the end of the cold leg, the weld fragments would impact the core barrel, where flow and gravity would carry the weld fragments down the downcomer. At the bottom of the downcomer, the weld fragments would likely impact the flowskirt and could become trapped in the gap between the flowskirt and the reactor vessel (RV), or travel through the gap between the flowskirt and the RV. This would depend on the size and orientation of the fragment when it hits the flowskirt.

If the weld fragments pass through the gap between the flowskirt and the RV, or through one of the holes in the flowskirt, they would enter the reactor vessel lower plenum. In the lower plenum there is a relatively lower flow stream velocity, and the loose weld fragments could settle at the bottom of the vessel. Alternatively, the turbulent flow in this area may push the weld fragments along the bottom of the reactor vessel or lift it to where they would impact the lower internals, the lower core support plate, or the bottom of the fuel assemblies (i.e., the lower end fitting). The flow could also carry the weld fragments towards the gaps around the core and the core bypass flow paths. The starting postulated size of the weld fragment would be too large to pass through the fuel or the bypass flow gaps. Only smaller weld fragments would be able to pass through the fuel assemblies or bypass gaps.

Larger weld fragments would therefore remain in the lower reactor vessel plenum. It could be postulated that the lower plenum turbulence may cause the weld fragments to fracture into smaller pieces. In this case, the weld fragments could only pass through the core bypass path or the fuel assembly debris capture grid once divided into small enough pieces.

Other piping connected to the 2A cold leg includes the charging and safety injection lines. Both of these systems deliver to the RCS and therefore, flow would not carry the weld fragments out of the RCS through these lines. Larger weld fragments (i.e., those that cannot get past the fuel) could not be carried to the pressurizer because the pressurizer main spray lines are located on the 1A and 1B cold legs.

Similarly, weld fragments small enough to pass through the core could circulate around the RCS, through the hot leg and steam generators (SGs), to the 1A and 1B loops and into the pressurizer spray system. Weld fragments could also travel to systems connected to the RCS, such as the emergency core cooling system (ECCS), through the shutdown cooling system (SDCS) suction lines or chemical and volume control system (CVCS) through the letdown line. Only small weld fragments could reach the hot side of the RCS or connecting systems.

In the short periods of operation as the plant transitions to off-normal conditions, such as during startup or shutdown, an even less likely scenario is that the weld fragments could become loose during these off-normal conditions (i.e., when the RCS is operating with less than four pumps, such as when the 2B RCP is operating while 2A is idle). Because this condition represents a very infrequent mode of operation, these various off-normal conditions are not specifically addressed herein.

Based upon this predicted potential flow path, Sections 5.0 and 6.0 of this report specifically address the consequences that the weld fragments could have on the RCPs, piping, vessel

structure and internals, fuel assemblies, control element assembly (CEA) operability, pressurizer, SGs, and connected systems.

5.0 Affected Reactor Coolant System Components

5.1 Reactor Coolant Pumps

This section discusses the evaluation of the effect of the weld fragments on the RCPs provided by Reference 8.1.

The weld fragments, or smaller pieces of a larger weld fragment, are not expected to adversely affect RCP operation. All postulated sizes of weld fragments will likely remain in the flow stream, pass through the impeller, and discharge into the reactor vessel. As the flow propels the weld fragments through the suction pipe and into the impeller, the weld fragments are prevented from entering the plenum above the impeller due to seal injection inducing a positive flow of injection water into the pump casing (via the [ ]a,c A-gap between the impeller and diffuser). Furthermore, the radial velocity and momentum of the weld fragments within the flow stream will propel them toward the diffuser, as opposed to making an upward ninety-degree turn as they pass by the A-gap.

Due to the relatively small mass of the weld fragment(s), impact damage upon the impeller and diffuser vanes would be negligible. As a weld fragment passes through the impeller, the flow carries it past the vanes. A direct impact occurs only at the tip of the impeller cone and the leading edges of the impeller and diffuser vanes. All other impacts are postulated to hit the impeller and diffuser at a shallow angle. At most, weld fragment impacts would result in a minor peen mark, if there is a direct impact area, and superficial scratches on all other areas. Any weld fragments would pass directly into the diffuser due to the high exit velocity at the impeller. Once through the diffuser, the weld fragments may cause superficial scratches or minor impact marks on the pump casing cladding before exiting through the cold leg.

Therefore, it is concluded that the weld fragments, or smaller pieces of a larger weld fragment, passing through the RCP would not adversely impact the operation of the RCP.

5.2 RCS Cold Leg Piping

This section discusses the evaluation of the effect of the weld fragments on the RCS cold leg piping, including the tributary nozzles and RTD thermowells, provided by Reference 8.2. This evaluation is limited to the cold leg piping between the 2A RCP and the reactor vessel, and therefore, only the 2A safety injection nozzle, the charging inlet nozzle, and the RTD thermowells are evaluated.

The cold leg piping may be affected by the weld fragments since the weight of the weld fragments and the fluid velocities are great enough to cause the weld fragments to nick or gouge the clad surfaces of the piping. It is highly unlikely that the weld fragments will produce a gouge that extends down to the base metal.

The charging inlet and safety injection tributary nozzles/lines are located in the upper half of the cold leg piping and flow into the RCS. Therefore, the weld fragments do not pose a problem

because they cannot enter the nozzles due to the high velocity of the flow during operating conditions. During low or no-flow conditions, the weld fragments will settle to the bottom of the piping. Settled weld fragments would eventually make their way to the RV when higher flow rates are reached. Additionally, the charging and safety injection lines are either discharging or stagnant, eliminating the possibility of the weld fragments entering and traveling through the two respective systems.

Effects due to projectile impact on the thermowell have been previously evaluated by Westinghouse (References 8.7 and 8.8). Based on a comparison to prior evaluations, it is concluded that an impact from the limiting weld fragment of the size and mass described in Section 2.0 will not cause plastic instability in the thermowell. Hence, the pressure boundary will be maintained after such an impact. However, there remains a possibility that a thermowell could be bent or dented. If an impact occurs, monitoring data and/or alarms may indicate that a RTD has been rendered inoperable. If it is confirmed that a safety-related RTD has become inoperable, then continued plant operation is subject to technical specification requirements. If a RTD does become inoperable after startup with no associated pressure boundary breech occurring at the thermowell, it is conceivably possible that the thermowell could have sustained some damage from an impact. Performance of a visual inspection of the thermowells at the next outage would be advisable.

5.3 Reactor Vessel Structure

This section evaluates the potential consequences of the weld fragments on the structural integrity of the surveillance capsule holder, flowskirt, in-core instrumentation (ICI) nozzles, and RV structure in general, as provided in Reference 8.2.

Surveillance Capsule Holder

The weld fragments may be carried by the reactor coolant flow from the cold leg into the downcomer, and impact a reactor vessel surveillance capsule holder (RVSCH) support bracket. The RVSCH support system consists of pairs of brackets welded to either side of the RVSCH and the RV wall at several elevations.

The effect of such an impact was addressed previously for a [ ]^{a,c} bolt (Reference 8.3). Since the approximately 0.1 pound weight of the limiting weld fragment is less than the weight of the bolt, the conclusions of the previous evaluation are also applicable to the weld fragment being evaluated herein. The worst case scenario previously considered was that a loose bolt could strike a RVSCH and damage an intermediate bracket system so as to render one of the two bracket sections incapable of supporting the holder. The bracket section on the other side of the holder would remain intact and maintain support for the holder at that elevation. Because the damaged bracket system will continue to provide support from the remaining section, there should be no issues with the removal of the capsule from the holder at a later date.

Flowskirt

The weld fragments would be carried by the coolant flow and, in a worst case scenario, impact the flowskirt cylinder at one of its supports. The impact forces would generate stresses in the flowskirt cylinder and its support. The effect of such an impact was previously addressed for a [ ]^{a,c} bolt. Since the approximately 0.1 pound weight of the weld fragment is less than the weight of the bolt, the conclusions of the previously evaluation can also be applied to the loose weld fragments.

The previous stress evaluation for the [ ]^{a,c} bolt shows that the stress due to the impact exceeds the yield strength. In the worst case scenario, one of the nine supports is damaged and incapable of supporting the flowskirt but the other eight supports remain intact. Additionally, the current primary stresses and fatigue usage factors on the supports during operating conditions are negligibly small. There could be a localized plastic deformation on one of the nine supports or the flow baffle; however, the flowskirt assembly will remain intact.

ICI Nozzles
The ICI nozzles are welded to the RV bottom head. It is assumed that the weld fragments are either in the downcomer between the RV and core support barrel (CSB) or at the bottom of the RV. In either scenario, the weld fragments would be lifted, swept by the coolant flow, and impact one or more ICI nozzles. The impact forces generate stresses in the ICI nozzles and weld that, when added to stresses due to other design and operating load conditions, may result in stresses exceeding ASME Code stress criteria. The effect of such an impact was previously addressed for a [ ]^{a,c} bolt. Since the approximately 0.1 pound weight of the postulated weld fragment is less than the weight of the bolt, the conclusions of the previous evaluation can also be applied to the weld fragments as a loose part.

The cited ICI nozzle/weld stress evaluation including the weld fragment impact forces considered normal operating conditions of the RCS. In addition to a weld fragment impact force, the stresses previously evaluated include, as applicable, pressure, flow loads, thermal loads, pump induced mechanical excitation of the reactor vessel, operating basis earthquake (OBE), and safe shutdown earthquake (SSE). These loads were retained along with the impact loads, but they are negligible compared to the weld fragment impact load and therefore, do not impact the conclusions of the analysis.

The evaluated case yields the maximum loads and stresses on the ICI nozzle. The ASME Code stress criteria are not satisfied at the ICI nozzle weld. The stresses are evaluated on an elastic basis. However, the ASME Code, Appendix F provides stress criteria for elastic analyses that approach the material ultimate strength (Su) and allows for some plastic deformation. Since these criteria are also exceeded, there is a reasonable expectation that application of elastic/plastic analyses would also demonstrate localized failure or possibly marginal acceptance. Exceeding ASME Code limits at the ICI weld may result in crack initiation and/or leakage.

Since the limiting size weld fragment weighs [ ]^{a,c} less than the bolt previously analyzed, the stresses due to impact will be significantly less and will likely meet ASME Code, Appendix F allowable values.

The previous velocities considered are sufficient to lift the weld fragments and sweep them away from the ICI nozzle, thereby preventing the weld fragments from being wedged at the ICI nozzle. Therefore only one impact of the ICI nozzle would occur and the impact would not contribute to the fatigue usage.

RV Structure
The RV may be affected by weld fragments since the weight of the weld fragments and the fluid velocities are great enough to cause these loose parts to nick or gouge the clad surfaces of the RV. It is highly unlikely that the weld fragments will produce a gouge that extends down to the base metal.

The potential damage caused by the weld fragments would have minimal and acceptable effects on the interior cladding of the RV, the flowskirt, RVSCHs, and ICI nozzle. Postulated damage would not preclude continued plant operation for one cycle.

5.4 Reactor Vessel Internals

This section discusses the evaluation of the consequences of the weld fragments, either being in or passing through the reactor vessel internals (RVI), as provided by Reference 8.4. The weld fragments, being relatively small, could be carried by the flow into various portions of the RVI.

Evaluation of Weld Fragments Impacting the Core Support Barrel

Since the RCP suction nozzle is located in a RCS cold leg, the weld fragments would be carried by the RCS flow and impact the wall of the core support barrel when they exit the cold leg. The CSB is a large robust structure fabricated from 3-inch plate at the elevation of the cold leg where the weld fragments would impact. Therefore, the largest weld fragment, which is assumed to weigh approximately 0.1 pounds, is judged to impart minimal damage to the CSB. This judgment is further supported by industry experience with safety injection thermal sleeves, which are significantly heavier, having impacted the core barrel at other Combustion Engineering (CE) designed plants after coming loose.

After impacting the CSB, the weld fragments would be carried by the flow down the downcomer between the core barrel and the reactor vessel. Any impact with the core barrel during the traverse of the weld fragments in the downcomer would be less severe than the initial impact at the inlet nozzle location.

Evaluation of Small Weld Fragments

The possibility of small weld fragments being carried throughout the RCS and affecting the RVI is evaluated in the following sub-sections.

Core Support Barrel Alignment Keys and Keyways

The reactor internals alignment keys are part of the CSB assembly and provide the alignment system for the reactor internals, the RV, and the reactor vessel closure head. The alignment system consists of precise gaps between the alignment keys and their respective mating keys slots (i.e., keyways) in the interface components. There are four alignment keys at ninety degrees equally spaced azimuthally that are shrunk-fit into the CSB flange and retained in position by two radial dowel pins at each key location. The keyways are subjected to a small amount of inlet leakage flow into the RV head region that would have a tendency to keep those areas flushed of small particles if they were transported to that location. It is highly unlikely that the weld fragments could reach the alignment keys, which are located in the RV closure head region of the vessel, and if they did, and were not flushed away, the weld fragments still would not affect the alignment key function.

Hold Down Ring

The hold down ring is compressed between the top surface of the CSB flange and the underside of the upper guide structure flange. The function of the hold down ring is to prevent movement of the reactor internals during plant operation. In order to perform that function, the hold down ring is compressed, causing the ring to rotate. This exerts a preload on the interface surfaces of the UGS and the CSB. Since the interface surfaces of the hold down ring are in compression, there is no

possibility that weld fragments can enter the interface during RCS operation. Therefore, the weld fragments could not affect the hold down ring function.

Core Barrel Flange to Reactor Vessel Seating Surface Annulus
It is highly unlikely that weld fragments will move into this annular space during service since there is only a small amount of inlet coolant leakage flow to transport the fragments through the CSB alignment keys and into this region of the RV head.

Annular Space between the Core Shroud and Core Support Barrel Inside Diameter
It is possible that the weld fragments could enter the annular space between the core shroud and CSB inside diameter. There is a small amount of flow in this annular space to cool the backside of the core shroud and inside diameter of the CSB in this region. However, the weld fragments would tend to settle out in a low flow area and would not have an adverse effect on any of the large components in this region.

Snubbers
There are six snubbers spaced sixty degrees apart between the lower end of the CSB and the RV. These components have a tongue and groove arrangement with a small gap on each side. Weld fragments, if transported to these gaps, would be immediately flushed out, due to the high velocity flow. Therefore, the weld fragments would have no effect on the function of the snubbers.

The Upper Guide Structure (UGS) Support Barrel Assembly and CEA Shroud Assembly
There are no close fits in this region that would be impaired by the presence of weld fragments. Weld fragments, if deposited on the upper surface of the support plate of the UGS support barrel assembly, would most likely remain in position due to the low velocity flows in that region. However, if transported by the reactor coolant flow, the weld fragments would not impair the functions of the UGS support barrel assembly and CEA shroud assembly.

Other RVI Components

1. The interface between the guide post of the fuel assembly upper end fitting and the UGS tubes in the UGS support barrel assembly is a precise interface, for both the standard fuel design and Next Generation Fuel (NGF). The coolant flow exiting from the fuel assembly guide tubes will tend to flush this annular space of the weld fragments, but even if it did not, there will be no loss of function at the fuel-to-UGS tube interface.
2. At the periphery of the fuel alignment plate there are four keyways spaced ninety degrees apart that form a precise interface gap with the shims on the guide lugs. Weld fragments small enough to fit into these gaps would most likely be flushed out by the coolant flow, but even if they remained, they would cause no loss of function to this interface.

5.5 Fuel

This section summarizes the evaluation of the potential impact of the weld fragments on fuel performance (Reference 8.5).

Since the weld fragment mitigation features are essentially the same for the CE16STD GUARDIAN™[1] grid design and the CE16NGF GUARDIAN grid design, the evaluation is applicable to PVNGS Unit 3 cores containing either fuel product.

The weld fragments as described in Section 2.0 have been evaluated. Additionally, it has been postulated that some cladding material above or adjacent to the weld may also break off with the weld fragment. The composition, size, and shape of the weld fragment is not precisely known, so a mixture of Inconel 600 and stainless steel has been assumed specifically for the evaluation of the fuel. Given that the weld fragments evaluated below are assumed to be a mixture of Inconel alloys and stainless steel, there will be no metallurgical concerns with the presence of these materials within the reactor core region.

Passage of parts through the ICI guide path

The funnel on the fuel assembly lower end fitting (LEF) in non-ICI locations represents a very small percentage of the flow, so it is unlikely that the weld fragments would enter the funnel. If the weld fragments enter the funnel and are larger than the through-hole diameter, they would be caught and would fall out at the end of cycle or become wedged. If an unidentified wedged piece of weld fragment was in an assembly that is moved to an ICI location, the ICI could not be inserted prior to operation.

A weld fragment smaller than the minimum entrance diameter and larger than the exit hole [ ]^{a,c} would be retained in the guide tube during operation and may fall out at the end of the cycle or remain in the instrument tube. In this unlikely case, the weld fragment could interfere with the insertion of an ICI in a subsequent cycle. A weld fragment smaller than the exit hole would enter the flow stream above the fuel assemblies.

At ICI locations, there is a very small gap between the LEF funnel and ICI nozzle [ ]^{a,c}, so only very small weld fragments could enter this gap. A second location where the weld fragments could enter an ICI location is at the interface of the instrument nozzles. However, the tight radial clearance within the instrument nozzles would likely capture any weld fragment that may enter at that location. Therefore, there are no operational consequences of weld fragments entering the ICI flow paths. There is some risk of the ICI binding during withdrawal, but this risk is very small given that a weld fragment of a very specific size would have to be wedged between the ICI and wall.

Passage to and through the Lower End Fitting and GUARDIAN grid

The LEF is comprised of [ ]^{a,c} flow holes each with a diameter of [ ]^{a,c}. The LEF may or may not prevent weld fragments from passing. However, the largest circular size that can pass through the CE16STD fuel GUARDIAN grid is considerably smaller at [ ]^{a,c}. The largest circular size that could pass through the CE16NGF fuel GUARDIAN grid is [ ]^{a,c}.

Although weld fragments with dimensions greater than [ ]^{a,c} would likely be held against the GUARDIAN grid and/or LEF for both CE16STD and CE16NGF fuel designs, and would evenly distribute at one axial plane, it is conservatively assumed that all of the weld fragments are caught

in the LEF/GUARDIAN grid of one assembly (out of 241) for the purposes of evaluating flow starvation upstream of the beginning of the heated length to negatively impact departure from nucleate boiling (DNB). Based upon DNB test results for a four foot heated length, a [ ]^{a,c} at the inlet had no measurable impact on DNB performance at nominal conditions. Hence, the weld fragment size is bounded by these results.

For the weld fragment to impact fuel performance due to fretting wear, a small piece of weld fragment must pass through the GUARDIAN grid or around the LEF. For weld fragments to cause fretting wear, they need to be long enough so that the one end is trapped in a grid feature and the other end is free to vibrate due to coolant flow with a hammering or rubbing action on the cladding. Such a weld fragment that was able to pass through this region of the fuel assembly would likely not be of a configuration conducive to cause fragment fretting. However, the material of the weld fragment is harder than the ZIRLO® [1] cladding, so there exists some risk that a small number of fragment fretting failures could occur.

The operating history of the GUARDIAN grid has been excellent. Only one confirmed fretting-related leaker is known to have occurred (Waterford-3 Cycle 19) out of over 7200 16x16 assemblies. If the weld fragment is small and light enough to get through or around the LEF and GUARDIAN grid, it would either be carried through the grids and end fittings and exit the fuel assembly, or be captured in the grids above the GUARDIAN grid. It is unlikely that weld fragments caught in the mid grids above the GUARDIAN grid would be sufficiently long enough to cause fretting failure, but there is always some risk. Although a small risk, weld fragments in the RCS can result in a leaking rod. Therefore, continuous monitoring of the coolant activity to check for the presence of any new grid-to-rod fretting (GTRF) leakers is recommended.

Bypass Flow

The flow area corresponding to the [ ]^{a,c} holes in the lower support structure cylinder bypass flow region may result in large enough flow velocities to lift the weld fragments and transport them through the shroud cooling water passages. The much smaller velocities further downstream and the tight turns and small annular gaps would inhibit weld fragment passage beyond this region. Within the core support barrel and core shroud annulus, the flow area will result in very low flow velocities; hence, the weld fragments would be expected to settle to the bottom of the bypass region. Therefore, it is concluded that there is low probability that the postulated weld fragments will pass from the lower reactor vessel environs through the core barrel/core shroud annulus and into the outlet regions of the reactor vessel.

5.6 CEA Operability

This section discusses the evaluation of the effect of the weld fragments on CEA operability provided by Reference 8.5.

The only viable path for small weld fragments to make it through the GUARDIAN grid and enter the CEA guide path is if they are in the immediate vicinity of the bleed hole and the cooling hole in an outer guide tube. Although extremely unlikely, any weld fragments that might enter the CEA guide path would likely either drop to a benign location at the bottom of the guide tube or be swept up the guide tube and into the CEA shroud. Weld fragments would not be expected to impede the operation of the CEA by being wedged between the CEA and the guide tube based on the small size required to enter the CEA guide path. In the very unlikely event that a loose weld fragment did

impede the motion of the CEA, it is most likely to occur when the CEA finger is within the reduced clearance region of the guide tube dashpot. In this event, maneuvering of the CEA is expected to clear the obstruction, based on prior instances of obstructions in the dashpot regions.

6.0 Remaining SSCs in the RCS and Connected and Auxiliary Systems

The following subsections address the portions and major components of the RCS that will be affected by weld fragments that are sufficiently small to pass through the fuel and core bypass, and have access to downstream systems connected to the RCS (i.e., not otherwise addressed in Section 5.0).

Other systems connected to the 2A cold leg includes the charging and safety injection lines. Both of these systems deliver to the RCS and therefore, flow would not carry the initial weld fragments out of the RCS through these lines. As the weld fragments pass through the 2A RCP, the cold leg, and into the RV lower plenum, the fragments could break into much smaller pieces, which will ultimately pass into and remain in circulation within the RCS until they are drawn into the design filtration system of the CVCS or settle elsewhere in an auxiliary system. The following descriptions review the possibility of such effects on the individual auxiliary systems.

6.1 Remaining RCS Components

Upper RVI
All RVI (both upper and lower) are evaluated in Section 5.4.

RCS Hot Legs
The impact of weld fragments small enough to pass through the fuel on the RCS hot legs is bounded by the evaluation for the cold leg, documented in Section 5.2, as well as by the review documented in Reference 8.6.

Pressurizer
During normal operation, the pressurizer receives a continuous bypass spray flow from the cold leg and a corresponding continuous flow from the pressurizer to the hot leg. The smaller weld fragments would most likely remain in the main RCS flow path if they pass through the core. It is possible that if the pressurizer main spray is cycled and weld fragments are in the appropriate cold leg, that they could be drawn into the pressurizer spray line. The larger postulated weld fragments could not be carried to the pressurizer because the pressurizer main spray lines are located on the 1A and 1B cold legs. Only the weld fragments small enough to pass through the fuel assemblies could possibly reach the pressurizer.

There will be no consequence on the main spray piping and valves, or on main spray performance. The main spray valves are 3-inch full-port globe valves and, as such, have no likelihood of blockage due to the small weld fragments. The warm-up/bypass valves are ¾-inch globe valves understood to be throttled to a fairly open position. Even in the throttled position, the small weld fragments have a low likelihood of blockage in the valve.

Pressurizer Spray Nozzle

The pressurizer spray nozzle outlet is a hollow core design attached to the 3-inch nominal RCS spray piping. The flow path through the nozzle is large enough that the weld fragments would flow through the nozzle and into the pressurizer.

Pressurizer Heaters

The pressurizer heaters consist of cylindrical heating elements inserted in the bottom of the pressurizer and are supported by two support plates inside the lower region of the pressurizer. Should any weld fragments make it into the pressurizer, they would settle to the lower region of the pressurizer, settling onto the support plates or lower head. These weld fragments would either remain in place with no consequence or be swept back into circulation through the pressurizer surge line during a normal surge/swell. There is a small gap between the pressurizer heaters and the two horizontal support plates. As previously described, since the likelihood of weld fragments entering the pressurizer is very low, it is considered further unlikely that weld fragments would settle directly within this gap. The downflow out of the pressurizer, which would occur during a spray event, would tend to draw any weld fragments around the top support plate, making it considerably less likely that any weld fragments would land on the lower support plate. Thus, it is considered highly unlikely that any weld fragment would obstruct the gap and thus, have an appreciable effect on thermal growth or heat transfer efficiency of the heaters.

Pressurizer Surge Line

The pressurizer surge line connects to roughly the midpoint of hot leg 1. The surge line diameter is sufficient that the smaller weld fragments would not affect flow along the surge line. The surge line material is stainless steel, which is the same material as the RCS piping cladding. Therefore, there would be no consequence to the surge line piping due to the presence of the weld fragments in the coolant. Weld fragments entering through the spray line may settle in the lower head and not leave the pressurizer.

Steam Generators

During normal operation, the weld fragments could only reach the SG if they were small enough to pass through the fuel assemblies.

Reference 8.7 evaluated loose bolts, nuts, and washers of significantly more size and mass (up to [ ][a,c]) than any weld fragment that could pass through the fuel assemblies, and concluded they would not adversely impact the function of the SGs operationally or as part of the RCS pressure boundary. Therefore, the potential weld fragments in the system would not adversely impact the SGs from performing their design function.

6.2 Connected and Auxiliary Systems

The following subsections address the systems connected to the RCS. The conclusions of this section are based upon the prior evaluation of similar debris evaluated in Reference 8.7.

Safety Injection, Containment Spray, and Shutdown Cooling Systems

The safety injection system (SIS) and containment spray system (CSS), including the ECCS pumps and safety injection tanks (SITs), inject borated water into the RCS in the event of a loss of coolant accident (LOCA). This provides cooling to limit core damage and fission product release, and

ensures adequate shutdown margin. The SIS also provides continuous long-term, post-accident cooling of the core by recirculation of borated water that collects in the containment sump.

The shutdown cooling system (SDCS) is used in conjunction with the main steam and main or auxiliary feedwater systems to reduce the temperature of the RCS in post-shutdown periods from normal operating temperature to the refueling temperature.

The piping connected to the 2A cold leg includes one SIS injection nozzle. The SIS delivers flow to the RCS at this location and therefore, flow would not carry the weld fragments out of the RCS through these lines.

The shutdown cooling suction lines are connected to the hot legs of the RCS and this is the only credible flow path for the weld fragment to enter the SIS, CSS, or SDCS. Only weld fragments small enough to pass through the fuel assemblies could reach the shutdown cooling suction line on the hot leg. Weld fragments of this size would not adversely impact the ability of the SIS, CSS, or SDCS to fulfill their design functions.

Chemical and Volume Control System

The CVCS controls the purity, volume, and boric acid content of the reactor coolant. The coolant purity level in the RCS is controlled by continuous purification of a bypass stream of reactor coolant. Water removed from the RCS is cooled in the regenerative heat exchanger. From there, the coolant flows to the letdown heat exchanger and then through a filter and demineralizer where corrosion and fission products are removed. The filtered coolant is then sprayed into the volume control tank and returned by the charging pumps to the regenerative heat exchanger where it is heated prior to return to the RCS.

The letdown system components are not explicitly evaluated, as the purification system is fulfilling its design function. This is due, in part, to the fact that removal of system debris is within the design basis of the letdown system components. The larger weld fragments cannot pass the fuel assemblies GUARDIAN grid; therefore, the larger weld fragments will not be introduced into the letdown system, which connects to the RCS in the suction leg connected to the bottom of the cold side of the steam generator outlet.

In the event that the weld fragments break apart to the point of being able to pass through the fuel it is most likely that the weld fragments will be small enough and the flow sufficient that the weld fragments would flow past the letdown nozzle and not be introduced into the letdown system. In the event that they are introduced into the letdown system, the weld fragments would pass through the letdown system to the system filters where they would be retained.

Regarding the charging function of the CVCS, the charging pumps only draw inventory from the volume control tank (VCT) and the refueling water storage tank (RWST). The weld fragments will not enter either of these suction sources.

Seal injection water supplied to the RCPs is drawn from the VCT by the charging pumps. Consequently, per the explanation in the prior paragraph, the weld fragments cannot migrate into the RCP seal packages by seal injection.

It is unlikely the weld fragments will enter the CVCS. However, if they do, they would be retained in the system filter and not adversely impact the ability of the CVCS to fulfill its design functions.

Spent Fuel Pool

The spent fuel pool (SFP) is isolated from the refueling cavity and the RCS during normal operation. If the weld fragments came loose during normal operation, they would travel through the RCS and could reach the fuel. It is possible that weld fragments could become caught in the fuel assembly GUARDIAN grid.

During the following refueling cycle, the weld fragments could transfer with the fuel assemblies to the SFP. If the weld fragments entered the SFP during refueling operations (i.e., if they were to fall from the GUARDIAN Grid), they would settle to the floor of the pool and remain there. The weld fragments on the SFP floor would not migrate into the spent pool cooling system due to the relatively high location of the cooling system suction inlet above the pool bottom surface.

Based on this evaluation, the potential presence of the weld fragments in the RCS does not adversely impact the capability of the pool cooling system to fulfill its design function.

7.0 Conclusions

During the 3R18 Palo Verde Nuclear Generating Station (PVNGS) Unit 3 refueling outage, Arizona Public Service (APS) identified signs of leakage (i.e., boric acid) coming from a 1-inch pressure instrument nozzle on the 2A loop reactor coolant pump (RCP). The APS repair strategy included performing a half-nozzle repair, which would involve removing a portion of the existing nozzle, inserting a replacement nozzle design into the same location, and then replacing the original pressure boundary partial penetration weld (on the inside wetted surface) with a weld located on the outside surface of the pump safe end.

Because the repair process involves leaving a small remnant of the nozzle inside the existing penetration, APS asked Westinghouse to address the possibility that fragments of the existing partial penetration weld could come loose inside the RCS during the next cycle of operation (18 months is assumed). Westinghouse and APS postulated, based on non-destructive examinations (NDE) performed to describe the flaws, that the crack(s) on the nozzle and or weld are part through wall in the axial direction with no evidence of circumferential cracks. This is consistent with the orientation previously observed by APS for this type of degradation mechanism (PWSCC) in instrument nozzles in the hot leg.

The remnant Inconel Alloy 600 instrument nozzle (approximately 1.5 inches in length) is recessed inside the safe end bore. It remains constrained by a relatively tight radial clearance between the bore and the nozzle. This is further helped by the weld deposited in this annular gap during the welding process. Therefore, even if the majority of the partial penetration weld was to break, it is not credible to assume that the remnant nozzle could become a loose part and become ejected into the RCS flow during the next 18 month fuel cycle. Additional assurance is provided considering that the hypothetical cracks are likely longitudinal part through wall, and as such the nozzle is able to maintain its structural integrity. Also, even if the partial penetration weld had several longitudinal

radial cracks, it would require at least two other crack planes oriented in the circumferential direction in order to release a piece of any significant size. Since circumferentially-oriented cracks were not identified by the ultrasonic testing (UT), the likelihood for a fragment of the weld to be released is very low.

The pressure instrument nozzle partial penetration weld is an Inconel alloy compatible with the Inconel Alloy 600 nozzle. Based on the above, a conservatively sized fragment of weld was assumed to weigh approximately 0.1 pounds and have dimensions no greater than the partial penetration weld thickness at its cross-section, and a length of one-quarter of the circumference around the instrument nozzle.

Westinghouse evaluated the structural and functional impacts of the loose weld fragment(s) on affected SSCs. Engineering judgments were applied and prior PVNGS loose parts evaluation results were taken into consideration. The evaluation considered that although the aforementioned fragment represents one possible form of the loose part, it is possible that smaller fragments of different sizes, shapes, and weights could be released, or created. Additional smaller fragments are possible, for example, if a weld fragment were to make contact with a high-velocity RCP impeller blade, or perhaps make high-speed contact with the reactor vessel core barrel.

The evaluation concluded that the postulated loose parts will have no adverse impact on the RCS and connected SSCs after one cycle of plant operation. The evaluation addressed potential impacts to various SSCs where the loose parts might travel. This included the RCPs, the main coolant piping, the reactor vessel and its internals, the fuel, the pressurizer, steam generators, as well as other systems attached to the RCS, including the spent fuel pool. It was determined that all impacted SSCs would continue to be capable of satisfying their design functions.

8.0 References

8.1 LTR-KUAE-15-016, "Loose Parts Evaluation – Suction Nozzle Pressure Tap Reactor Coolant Pump, Palo Verde Unit 3, S/N 1111-2A," April 14, 2015.

8.2 LTR-MRCDA-15-35, Rev. 0, "Transmittal of MRCDA-I Input for the Analysis of Loose RCP Suction Nozzle Weld Fragments at PVNGS Unit 3 Considering One Cycle of Continued Operation," April 14, 2015.

8.3 LTR-MRCDA-10-79, "Structural Evaluation of the Palo Verde Unit 1 Reactor Vessel Surveillance Holders due to a Loose Bolt Impact," May 10, 2010.

8.4 LTR-RIDA-15-73, "Palo Verde Nuclear Generating Station Unit 3 Evaluation of Possible Reactor Coolant Pump Suction Nozzle Weld Fragment Loose Parts on the Reactor Vessel Internals," April 14, 2015.

8.5 CE-15-207, "PVNGS RCP Suction Nozzle Remnant Loose Part Evaluation for the Fuel and Core Components," April 14, 2015.

8.6 LTR-RC-14-55, Rev. 0, "Palo Verde Nuclear Generating Station Unit 3 Review of Bounding Evaluations for Loose Weld Material," December 2014.

8.7 DAR-SEE-II-10-3, Rev. 0, "Palo Verde Nuclear Generating Station Unit 1 Evaluation of Missing Bolt Shanks, Nuts and Washers," May 2010.

8.8 DAR-SEE-II-08-12, Rev. 0, "Disposition of Postulated Foreign Material in Palo Verde Nuclear Generating Station Units 1, 2, 3 Nuclear Steam Supply System Originating from Reactor Coolant Pump Wedge Assemblies," December 2008.

8.9 LTR-KUAE-15-017, "Documentation of References applicable to Palo Verde Unit 3 Pressure Tap Weld Details," April 16, 2015.

8.10 STD-009-0009, Rev. 2, "Coolant Pumps Weld Joint Identification and Fabrication Requirements."

Attachment 5

Westinghouse Letter, LTR-ME-15-30-NP, Rev. 2, *ASME Code Section XI Reconciliation for Arizona Public Service (APS), Palo Verde Nuclear Generating Station (PVNGS) Unit 3 Replacement Instrument Nozzle*

Westinghouse

To: Sarah E. Lax

Date: July 7, 2015

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Eric M. Weisel

From: Ana Bauer
Tel: 860-731-6529

Your ref:
Our ref: LTR-ME-15-30-NP, Rev. 2
Total Pages: 10

Subject: **ASME Code Section XI Reconciliation for Arizona Public Service (APS), Palo Verde Nuclear Generating Station (PVNGS) Unit 3 Replacement Instrument Nozzle**

Attachment 1: ASME Code Section XI Reconciliation Arizona Public Service (APS), Palo Verde Nuclear Generating Station (PVNGS) Unit 3 Replacement Instrument Nozzle

Attachment 1 of this letter contains the ASME Code Section XI Reconciliation for the Replacement Instrument Nozzle to be supplied to Arizona Public Service (APS), Palo Verde Nuclear Generating Station (PVNGS) Unit 3. This ASME Code Section XI Reconciliation is to be used in conjunction with CN-MRCDA-15-13.

If you have any questions or desire further information, please contact the undersigned.

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Attachment 1: ASME Code Section XI Reconciliation Arizona Public Service (APS), Palo Verde Nuclear Generating Station (PVNGS) Unit 3 Replacement Instrument Nozzle

1.0 Introduction

1.1 Purpose

The purpose of this ASME Code Section XI reconciliation is to demonstrate fulfillment of the requirements for the use of a later edition of the ASME Boiler and Pressure Vessel Code for the Replacement Instrument Nozzle to be supplied and installed at Arizona Public Service, Palo Verde Nuclear Generating Station (PVNGS) Unit 3. The Replacement Instrument Nozzle is part of the Reactor Coolant Pump (RCP) and is to be supplied in accordance with the contract requirements in [9] and the code years specified in the design specification [5].

The ASME Code Section XI program at PVNGS Unit 3 is governed by the 2001 Edition up to and including the 2003 Addenda of Section XI [4]. Section XI of the ASME Code requires reconciliation of changes to the original design basis when ASME Code replacement items (such as materials, parts, and components) are designed and fabricated to a later edition or addendum of the Construction Code.

This document is intended to reconcile the ASME Code Section III, 1995 up to and including 1997 Addenda [2] used in the analysis/qualification and the 1998 Edition up to and including the 2000 Addenda [3] used in the procurement of material, fabrication, and examination of the Palo Verde Nuclear Generating Station (PVNGS) Unit 3 Replacement Instrument Nozzle to the Original Construction Code. The Original Construction Code for Palo Verde Nuclear Generating Station (PVNGS) Unit 3 is the ASME Code Section III, 1974 Edition, no Addenda [1].

1.2 Limits of Applicability

This document is applicable to Palo Verde Nuclear Generating Station (PVNGS) Unit 3.

2.0 Summary of Results and Conclusion

2.1 Results

The Arizona Public Service, Palo Verde Nuclear Generating Station (PVNGS) Unit 3, Reactor Coolant Pump (RCP) Replacement Instrument Nozzle is analyzed to the requirements of the ASME Code Section III, 1995 up to an including the 1997 Addenda [2], and procured and fabricated to the requirements of the ASME Code Section III, 1998 Edition up to and including the 2000 Addenda [3], and the design specification [5] and reconciled herein to the Original Construction Code, 1974, no Addenda [1].

The design configuration changes, loadings, and different materials in the Palo Verde Nuclear Generating Station (PVNGS) Unit 3 Replacement Instrument Nozzle are identified in Section 4.0. The impact of these Owner's Requirements are evaluated in the ASME Section III Code design report and supporting analyses.

There are no pressure-temperature ratings associated with the design of the Replacement Instrument nozzles and the interfacing equipment.

2.2 Conclusion

The Replacement Instrument Nozzle meets the ASME Section XI Code Applicability and Reconciliation requirements since:

(1) Materials are compatible with the installation and system requirements.

(2) The requirements affecting design, fabrication, installation, and examination of the item to be used for replacement are reconciled with the Owner's Specification through the design drawings, design specification, and design report.

(3) Mechanical interfaces, fits, and tolerances that create the pressure boundary are compatible with the system and component requirements through the design report and supporting analysis.

3.0 Assumptions and Open Items

3.1 Assumptions

This reconciliation report contains no assumptions.

3.2 Open Items

This reconciliation report contains no open items.

4.0 Section XI – 2001 through 2003 Addenda – Summary of Requirements

In accordance with the APS contract [9] and Westinghouse Reactor Coolant Pumps Design Specification [5]:

- The Original Construction Code is the ASME Boiler and Pressure Vessel Code, Section III, 1974 Edition no Addenda [1]
- The ASME Code, Section III, 1995 Edition up to and including 1997 Addenda [2] is used for the design analysis/qualification of the Replacement Instrument Nozzle
- The ASME Code, Section III, 1998 Edition up to and including 2000 Addenda [3] is used for procurement, fabrication, and examination of the Replacement Instrument Nozzle
- The ASME Code Section XI program is governed by the 2001 Edition up to and including the 2003 Addenda [4]

This project involves both repair and replacement activities in accordance with ASME Code Section XI [4] per Article IWA-4220, "Code Applicability," as it is defined as a Code Class 1 item. Article IWA-4221(a) of Section XI states that:

> *An item to be used for repair/replacement activities shall meet the Owner's Requirements. Owner's Requirements may be revised, provided they are reconciled in accordance with IWA-4222. Reconciliation documentation shall be prepared.*

Additionally, Article IWA-4221(c) states:

> *As an alternative to (b) above, 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, provided the requirements of IWA-4222 through IWA-4226, as applicable, are met. Construction Code Cases may also be used. Reconciliations required by this Article shall be documented.*

4.1 IWA-4222 Reconciliation of Code and Owner's Requirements

(a)(1) *States that: "Only technical requirements that could affect materials, design, fabrication, or examination, and affect the pressure boundary, or core support or component support function, need to be reconciled."*

4.1.1 Owner's Design Requirements

There is no change to the design requirements since the instrument nozzles are considered a replacement and as such the design requirements in the design specification [5] remain unchanged. Therefore, there are no changes in the design parameters (e.g., design pressure, normal operating pressure, design temperature, no load temperature, normal operating inlet water temperature, and normal operating outlet water temperature).

4.2 IWA-4223 Reconciliation of Components

(a) *States that: "Reconciliation of later Editions or Addenda of the Construction Codes or alternative Codes as permitted by IWA-4221 is not required. The Owner shall evaluate any changes in weight, configuration, or pressure-temperature rating in accordance with IWA-4311."*

This article does not apply to this replacement. The Replacement Instrument Nozzle is reconciled under paragraph IWA-4225.

4.3 IWA-4224 Reconciliation of Material

IWA-4224.1 Identical Material Procured to a Later Edition or Addenda of the Construction Code, Section III, or Material Specification

IWA-4224.2 Identical Material Procured to an Earlier Construction Code Edition or Addenda or Material Specification

IWA-4224.3 Use of a Different Material

IWA-4224.4 Substitution of Material Specifications

4.3.1 Instrument Nozzle Materials

The Replacement Instrument Nozzle is fabricated from SB-166 Alloy UNS N06690 material certified to the 1998 Edition including the 2000 Addenda of the Code. Alloy N06690 is an improved Nickel alloy material, which has an improved resistance to Primary Water Stress Corrosion Cracking as compared to Alloy N06600 which is the original material for the Instrument Nozzle. This is considered a different material since Alloy N06690 material did not exist as an alternative in the Original Construction Code, which only included Alloy N06600.

Welding material used to weld the Replacement Instrument Nozzle to the RCP case and nozzle remnant is ERNiCrF-7A (Alloy 52M UNS N06054) weld filler metal [10]. Like for the SB-166 Alloy UNS N06690 material, this material did not exist as an alternative in the Original Construction Code.

4.3.2 Materials Requirements

Based on the material specifications described above, only the requirements of IWA 4224.3 apply to the Replacement Instrument Nozzle.

IWA-4224.3 – Use of a Different Material, states that:

(a) *Use of materials of a specification, grade, type, class, or alloy, and heat-treated condition, other than that originally specified, shall be evaluated for suitability for the specified design and operating conditions in accordance with IWA-4311.*

(b) Material examination and testing requirements shall be reconciled to the Construction Code requirements of the item.

4.3.3 Materials Evaluation

Alloy N06690 is an improved Nickel alloy material, which has an improved resistance to Primary Water Stress Corrosion Cracking as compared to Alloy N06600. As previously indicated, SB-166 Alloy UNS N06690 material did not exist as an alternative in the Original Construction Code. Therefore, no direct comparison can be made between the Original Construction Code and the Procurement Code for this material. In terms of the Original Construction Code Alloy N06600 is used. Table 1 shows a comparison of allowable stresses and material properties between the Construction and Procurement and as well as the Analysis Codes (1995 up to an including the 1997 Addenda) which is used as the basis for the analysis/qualification (CN-MRCDA-15-13).

Table 1: Comparison of Allowables and Material Properties

Material	SB-166, N06600 [1]	SB-166, N06690 [2, 11]	SB-166, N06690 [3]
Code Year	1974-No Addenda	1995-A'97	1998-A'00
Property/Allowable			
S_m (ksi) at 700°F	23.3	23.3	23.3
S_m (ksi) at 650°F	23.3	23.3	23.3
E (ksi) at 70°F	31,700	30,300	30,300
α (in/in/°F) at 70°F	7.13×10^{-6}	7.7×10^{-6}	7.7×10^{-6}

Table 1 shows that the allowable stress values for the Replacement Instrument Nozzle materials are the same as the allowable stress values of the Original Construction Code for the existing material. The values of the 1995 ASME Code Edition are added to reconcile the use of this code edition for the analysis/qualification as part of CN-MRCDA-15-13. Table 1 also indicates slight differences between the Construction and the later Codes in the material property α and E values. The differences may result from the chemical composition changes associated with the change in material and over time span of the Code editions. Differences may also result from the change in product form from the original to the replacement material. The differences in material properties are not significant and do not affect the performance of the material or design.

The Replacement Instrument Nozzle materials are acceptable for use because the later Code Editions have been accepted by the nuclear industry (including the Nuclear Regulatory Commission). The materials are similar in composition to those in the Original Construction Code, are examined and tested to similar requirements, and are shown to be compatible with the installation and system requirements for the specified design and operating conditions per the analysis/qualification. Therefore, it is concluded that, with respect to material, the later Code Editions are reconciled to the Construction Code and the Owner's Specification.

4.3.4 Material Examination and Testing Requirements

Per the requirements IWA-4224.3 (b): *"Material examination and testing requirements shall be reconciled to the Construction Code requirements of the item."*

In this case, this means the replacement item. The examination and testing requirements of the later edition of the Code are, in general, more stringent than those of the Construction Code; therefore, they envelop the Construction Code. In particular, the later Code is more prescriptive in requirements for qualification of nondestructive examination personnel. For the replacement project, other changes in the examination requirements are editorial in nature. Therefore, it is concluded that, with respect to examination and testing requirements, the use of the later Code is reconciled to the requirements of the Construction Code for all replacement materials.

4.4 IWA-4225 Reconciliation of Parts, Appurtenances, and Piping Subassemblies

(a) *Parts, appurtenances, and piping subassemblies may be fabricated to later Editions and Addenda of the Construction Code and later different Construction Codes, as permitted by IWA-4222(b),*

5.0 References

1. ASME Boiler and Pressure Vessel Code, Section III, "Nuclear Power Plant Components," 1974 Edition, no Addenda.
2. ASME Boiler and Pressure Vessel Code, Section III, "Rules for Construction of Nuclear Power Plant Components," 1995 Edition Up to and Including 1997 Addenda.
3. ASME Boiler and Pressure Vessel Code, Section III, "Rules for Construction of Nuclear Power Plant Components," 1998 Edition Up to and Including 2000 Addenda.
4. ASME Boiler and Pressure Vessel Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," 2001 Edition Up to and Including 2003 Addenda.
5. Westinghouse Design Specification 14273-PE-480, Rev. 06, "Project Specification for Reactor Coolant Pumps for Arizona Nuclear Power Project Units 1, 2 and 3," dated November 11, 2003.
6. Westinghouse Drawing, C-14473-220-002, Rev. 0, "Replacement Pressure Tap Nozzle."
7. Westinghouse Drawing, E-14473-220-001, Rev. 0, "Pump Casing – A, Pressure Tap Nozzle Modification Assembly."
8. Westinghouse Drawing, E-8111-101-2002, Rev. 00, "Pump Casing – A."
9. Arizona Public Service Order No. 500592766, dated 4/10/2015.
10. PCI Weld Procedure Supplement 143-F43 MN-GTA/SMA, Rev. 0, dated 01/08/97.
11. ASME Code Case N-474-2, "Design Stress Intensities and Yield Strength Values For UNS N06690 with a Minimum Specified Yield Strength of 35 ksi, Class 1 Components Section III, Division 1", Approval Date December 9, 1993.

Attachment 6

Westinghouse Calculation CN-NPE-06-03-NP, Rev. 1, *Plant X - Structural Evaluations of the RCP Pressure Tap Nozzles*

WESTINGHOUSE ELECTRIC COMPANY LLC

Calculation Note Number	Revision	Shop Order Number	Charge Number	Page
CN-NPE-06-XXXX-03-NP	1	NA	2400588 INTG	1
Project	Releasable (Y/N)	Open Items (Y/N)	Files Attached (Y/N)	Total No. Pages
Plant X RCP Project	Y	N	Y	219

Title: Plant X – Structural Evaluations of the RCP Pressure Tap Nozzles

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Westinghouse

Record of Revisions

Rev	Date	Revision Description
0	08/27/2009	Original Issue
1	3/16/2010	References 2, 11 and 13 were updated to Revisions 4, 2 and 1, respectively. Affected Pages: Cover, 2, 10, 97 and 98.
1	See EDMS	This –NP version adds proprietary brackets and the proprietary information has been redacted.

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1.0 Introduction

1.1 BACKGROUND / PURPOSE

The Plant X Reactor Coolant Pump (RCP) is shown in Figure 1-1. The components evaluated in this Calculation Note are the Pressure Tap Nozzles located at the Nozzle Safe Ends of the RCP Suction and Discharge Nozzle Safe Ends (Figures 1-2 through 1-5).

The analyses performed include the determination of the primary stress intensities and the fatigue capabilities of the RCP Pressure Tap Nozzles that are located at both the RCP Suction Nozzle Safe End and RCP Discharge Nozzle Safe End. Transient Thermal Analyses were performed to determine the stresses due to the operational temperature fluctuations and to compute the associated fatigue usage factor for the specified life time of the RCPs (60 years).

This evaluation was performed in accordance with ASME Code Section III (Reference 4) using the ANSYS computer program (Reference 5) and the RCP Design Specification (Reference 2). The ANSYS code was used to develop a 3-dimensional representation of a section of the RCP Suction/Discharge Nozzle Safe End that includes the Pressure Tap Nozzle. This model was used to determine the nozzle shank, the nozzle/weld interface, and the "free field" shell stresses due to internal RCP pressure. This model was also used to perform all the required stress (due to pressure) and thermal transient analyses according to the ASME Code.

Revision 1 updates Reference 2 to Revision 4, Reference 11 to Revision 2, Reference 12 to Revision 3, and Reference 13 to Revision 1. There was no impact on the previously documented results. Also, none of the computer runs changed. However, for convenience, the computer runs are also attached to this document revision.

This calculation note was prepared according to Westinghouse Procedure NSNP-3.2.6.

1.2 LIMITS OF APPLICABILITY

The results contained in this Calculation Note are applicable to the Plant X Reactor Coolant Pumps.

1.3 SER CONSTRAINTS

There are no Safety Evaluation Report (SER) Constraints that apply to this Calculation Note.

1.4 DOCUMENTATION OVERVIEW

This calculation note is one of a larger number of documents that comprise the evaluations of the Plant X RCP pressure boundary and support components. The document numbers and titles are:

a,c

a,c

Figure 1-1 Plant X Reactor Coolant Pump Sectional View

a,c

Figure 1-2 Detail of RCP Pressure Tap Nozzle Located in Discharge Nozzle Safe End

a,c

Figure 1-3 Detail of RCP Pressure Tap Nozzle Weld Pad Size for [ ]^{a,c} Cladding

a,c

Figure 1-4 Plant X RCP Discharge Side Pressure Tap Nozzle

a,c

Figure 1-5 Plant X RCP Suction Side Pressure Tap Nozzle

2.0 Summary of Results and Conclusions

2.1 PRIMARY STRESS RESULT SUMMARY

All primary stress intensities are satisfactory and meet the appropriate allowables from Reference 4. The following summarizes these results for each load category. Specifically Table 2-1 summarizes the Primary Membrane Stress and the Primary Membrane plus Bending Stress results obtained from ANSYS computer runs. These runs for four (4) nozzle locations did not consider the effects from external loads, only those from internal pressure. Table 2-2 provides the combined (internal pressure, external loads, SSE, BLPB and IRWST inertias loads) Primary Membrane Stress and the Primary Membrane plus Bending Stress results that were determined using the ASME Code hand equations. The location of these stresses is at the region where the Pressure Tap Nozzle shanks exit the narrow annulus (interference fit) with the wall of the RCP discharge/suction nozzle safe ends.

Table 2-1 Results of Primary Stress Evaluation for Plant X Pressure Tap Nozzles (Excluding Effects from External Loads)

RCP Pressure Tap Nozzles (Pressure and Temperature Effects)

a,c

[ ]a,c. The effects of any Faulted condition, inertia induced loads were shown to be negligible.

2.2 FATIGUE ANALYSIS RESULT SUMMARY

2.2.1 Assuming Negligible External SSE Loads

The fatigue capability of the Suction/Discharge Nozzle Safe End Pressure Tap Nozzles is demonstrated by meeting the requirements of NB-3222.4 (e), "Procedure for Analysis for Cyclic Loading." Specifically, the nozzle was evaluated at two (2) critical "Nozzle" (through-wall) cuts and at two (2) critical "Weld" (along weld seam) cuts. There are no "uphill" or "downhill" effects at this location since the nozzle penetrates the shell in a perpendicular fashion. The resulting Fatigue Usage Factors were determined to be well within the limit of one (1). They are summarized in Table 2-3.

Table 2-2 Fatigue Usage Factor Summary for Plant X RCS Pressure Tap Nozzle

a,c

The NB-3228.5(a) requirement for Primary plus Secondary Membrane plus Bending Stress Intensities, excluding thermal bending stresses, to be less than or equal to $3S_m$ was met in all instances. The narrowest margin for "through-nozzle" occurs at [ ]a,c, with a Primary Membrane plus Bending Stress Range of [ ]a,c [psi] versus a $3S_m$ limit of 69,900 [psi]. For the "along-weld" cuts, the narrowest margin is [ ]a,c [psi] versus a $3S_m$ limit of 69,900 [psi] and occurs at [ ]a,c. Consequently, all requirements for stress and fatigue of the Plant X Pressure Tap Nozzles are fully satisfied.

2.2.2 Considering External SSE Loads

External load limits specified in Reference 12 are used to assess their impact, if applicable, on fatigue. Table 2-3 lists the results and provides a comparison with the Table 2-2 values. The maximum usage factors are found for the [ ]a,c. Disregarding the effects

from external SSE loads, as may be permitted by NB-3337.3 [4], the maximum usage factor is [ ]a,c. Using a "realistic" limit for external SSE loads it increases to [ ]a,c. Assuming "worst" case SSE loads, the usage factor increases to [ ]a,c, still well within the allowable of 1.0.

Table 2-3 Summary of Fatigue Usage Factor Not Considering and Considering Contributions from External Nozzle Loads

a,c

3.0 Assumptions and Open Items

3.1 DISCUSSION OF MAJOR ASSUMPTIONS

There are no Major Assumptions associated with this Calculation Note.

3.2 OPEN ITEMS

There are no Open Items associated with this Calculation Note.

4.0 Acceptance Criteria

The acceptance criteria for this Calculation Note are the Analysis Requirements for the Plant X Reactor Coolant Pump in accordance with ASME Code Section III of Reference 4, as specified in Reference 2.

The allowables for Design, Faulted, Normal, Upset, Emergency and Test conditions are as follows:

4.1.1 Design Conditions

1. The primary stress intensity (produced by stresses which retain a P_m classification) across the minimum thickness of a section resulting from design pressure and normal operating plus operational basis earthquake loads shall not exceed S_m at design temperature (NB-3221.1 and NB-3227.5 of Reference 4).

2. The average local primary membrane stress intensity (P_L) across the thickness of a section from design pressure and normal operating plus operational basis earthquake loads shall not exceed $1.5 \cdot S_m$ at design temperature (NB-3221.2 and NB-3227.5 of Reference 4).

3. The maximum general or local primary membrane plus primary bending stress intensity ($P_m + P_b$ or $P_L + P_b$) across the thickness of a section resulting from design pressure plus operational basis earthquake loads shall not exceed $\alpha \cdot S_m$ at design temperature, where α is defined according to NB-3221.3 of Reference 4 as the lesser of plastic shape factor and 1.5.

   For a thick annular cross section, Reference 7 (Table 1, Case 15) gives the following formula for the plastic shape factor:

$$\alpha = \frac{16 \cdot r_o}{3 \cdot \pi} \cdot \frac{r_o^3 - r_i^3}{r_o^4 - r_i^4}$$

for $r_o = 12.6$ mm and $r_i = 2.4, 5$ or 6.35 mm,
α is 1.69, 1.63 and 1.58, respectively. Use $\alpha = 1.5$.

4. The triaxial stress, defined as the algebraic sum of the three primary principal stresses, shall not exceed 4 times the tabulated value of S_m (NB-3227.4(a) of Reference 4).

4.1.2 Normal and Upset Conditions

5. If the pressure for an upset condition exceeds the design pressure, the primary stress intensity shall be limited to the following values from NB-3223(a) of Reference 4.

   (a) $P_m \leq S_m' = 1.1 \cdot S_m$
   (b) $P_L + P_b \leq \alpha \cdot S_m' = \alpha \cdot 1.1 \cdot S_m$
   (c) $P_L \leq 1.5 \cdot S_m' = 1.65 \cdot S_m$

6. A fatigue evaluation for normal operating, upset, and applicable test conditions shall be performed to demonstrate that the critical components can withstand the specified number of operating cycles without failure. Per NB-3222.4 (e), the cumulative usage factor (U) is limited to:

$$U = \sum_{i=1}^{m} \frac{n_i}{N_i} \leq 1.0$$

   where m is the number of stress ranges considered, n_i is the number of cycles extended for range i, and N_i is the number of cycles indicated in the fatigue curves.

   In the evaluation of fatigue, sometimes a Simplified Elastic-Plastic Analysis is required as specified in Section NB-3228.5. This type of analysis is performed when the limit on maximum range on the primary-plus-secondary stress intensity is exceeded, and the requirements (a) through (f) of NB-3228.5 are met. In particular, requirement (b) of NB-3228.5 recommends a factor (K_e) to be applied to the alternating stress range before entering the fatigue curves. This factor is determined from the following expressions:

$$K_e = 1.0 \Rightarrow S_n \leq 3S_m$$

$$K_e = 1.0 + \left[\frac{(1-n)}{n(m-1)}\right]\left(\frac{S_n}{3S_m} - 1\right) \Rightarrow 3S_m \prec S_n \leq 3mS_m$$

$$K_e = \frac{1}{n} \Rightarrow S_n \geq 3mS_m$$

   m and n are material constants specified by the ASME Code of Reference.

   Requirement (a) of NB-3228.5 stipulates that the range of primary plus secondary membrane plus bending stress intensities, excluding thermal bending stresses, shall be $\leq 3S_m$.

7. The triaxial stress, defined as the algebraic sum of the three primary principal stresses, shall not exceed 4 times the tabulated value of Sm (NB-3227.4(a) of Reference 4).

4.1.3 Emergency Conditions (not Specified for this Project)

8. For emergency conditions the primary stress limits of NB-3221 shall be satisfied using an S_m value equal to the greater of $1.2 \cdot S_m$ or S_y (NB-3224). For ferritic material, the P_m elastic analysis limits for pressure alone shall be equal to the greater of $1.1 \cdot S_m$ or $0.9 \cdot S_y$.

9. The triaxial stress, defined as the algebraic sum of the three primary principal stresses, shall not exceed 4 times the tabulated value of S_m (NB-3227.4(a) of Reference 4).

4.1.4 Faulted Conditions

10. The primary membrane stress intensity (P_m) for the minimum thickness of a section resulting from faulted condition loads (Level D Service Limits) shall not exceed the lesser of $2.4 \cdot S_m$ or $0.7 \cdot S_u$ for austenitic material or $0.7 \cdot S_u$ for ferritic material at design temperature (NB-3225 and Appendix F, F-1331).

11. The local primary stress intensity (P_L) across the thickness of a section resulting from faulted condition loads shall not exceed the lesser of $1.5 \cdot (2.4 \cdot S_m)$ or $1.5 \cdot (0.7 \cdot S_u)$ for austenitic material or $1.5 \cdot (0.7 \cdot S_u)$ for ferritic material at design temperature (NB-3225 and Appendix F, F-1331).

12. The primary stress intensity ($P_L + P_b$) across the thickness of a section resulting from faulted condition loads shall not exceed a value equal to, or the lesser of $1.5 \cdot (2.4 \cdot S_m)$ or $1.5 \cdot (0.7 \cdot S_u)$ for austenitic material or $1.5 \cdot (0.7 \cdot S_u)$ for ferritic material at design temperature (NB-3225 and Appendix F, F-1331).

4.1.5 Test Conditions

13. Hydrostatic test condition - NB-3226 of Reference 4

    (a) $P_m \leq 0.90 \cdot S_y$
    (b) $P_m + P_b \leq 1.35 \cdot S_y$ when $P_m \leq 0.67 \cdot S_y$
    (c) $P_m + P_b \leq (2.15 \cdot S_y - 1.2 \cdot P_m)$ when $0.67 \cdot S_y < P_m \leq 0.90 \cdot S_y$ (S_y at test temperature)

    Where,
    S_y = Yield Strength
    S_u = Ultimate Tensile Strength
    S_m = Design Stress Intensity

14. The triaxial stress, defined as the algebraic sum of the three primary principal stresses, shall not exceed 4 times the tabulated value of S_m (NB-3227.4(a) of Reference 4).

5.0 Computer Codes Used In Calculation

Table 5-1 Summary of Computer Codes Used in Calculation

Code No.	Code Name	Code Ver.	Configuration Control Reference	Basis (or reference) that supports use of code in current calculation
1	ANSYS®	11.0	Reference 5	The ANSYS finite element computer code is a public domain code intended for and used extensively for static and dynamic finite element analyses. The code is used herein for structural and transient thermal analyses of an RCP nozzle and for computation of ASME code stresses and for evaluating the Fatigue aspect of the design.

6.0 Calculations

6.1 METHOD DISCUSSION

6.1.1 Calculation of Stresses in Nozzle

6.1.1.1 Primary Stress Evaluation

Primary stresses result from pressure and piping reactions applied to the Nozzle for Design, Upset, Emergency, Faulted and Test Conditions. The classification of the primary stresses in the nozzle is governed by the limit of reinforcement normal to the vessel wall which is determined in the nozzle sizing calculation. Paragraph NB-3227.5 of Reference 4 defines the classification of the stresses inside (ILOR) and outside (OLOR) the limit of reinforcement.

OLOR Primary Stresses

Outside the limit of reinforcement, a P_m classification is applicable to stress intensities resulting from general membrane stresses and the average stress across the nozzle due to externally applied pipe axial, shear and torsional loads (excluding thermal pipe loads). A P_m + P_b classification is applicable to the stress intensities that result from adding P_m stresses to the stresses due to external pipe bending moments (excluding thermal pipe loads). The following classical stress equations apply:

OLOR P_m Stress Equations

$$\sigma_A = \frac{PR_i^2}{R_o^2 - R_i^2} \pm \frac{N}{A} \qquad \sigma_H = \frac{PR_i}{t} \qquad \sigma_R = -\frac{1}{2}P$$

$$\tau_{HA} = \pm\frac{V}{A} \pm \frac{TR_m}{J}$$

OLOR P_m + P_b Stress Equations

$$\sigma_A = \frac{PR_i^2}{R_o^2 - R_i^2} \pm \frac{N}{A} \pm \frac{MR_o}{I} \pm \frac{(V \cdot L)R_o}{I} \qquad \sigma_H = \frac{PR_i}{t} \qquad \sigma_R = -\frac{1}{2}P$$

$$\tau_{HA} = \pm\frac{V}{A} \pm \frac{TR_o}{J}$$

Where:

P = Internal Pressure, [ksi]
R_I = Inside Radius of Nozzle (does not include cladding), [in]
R_o = Outside Radius of Nozzle, [in]
t = Nozzle Minimum Wall Thickness, [in]
N = Axial Load, [kips]
V = Shear Load, [kips]
M = Bending Moment, [in-kips]
T = Torsional Load, [in-kips]
R_m = Mean Radius of Nozzle, [in]
A = Cross Sectional Area, [in^2]
J = Torsional Constant, [in^4]
I = Moment of Inertia, [in^4]
L = Distance between the safe end/pipe interface and the cross section being evaluated, [in]
σ_A = Axial Stress, [psi or ksi]
σ_H = Hoop Stress, [psi or ksi]
σ_R = Radial Stress, [psi or ksi]
τ_{HA} = Shear Stress, [psi or ksi]

ILOR Primary Stresses

Inside the limit of reinforcement, a P_m classification is applicable to stress intensities resulting from pressure induced general membrane stresses and stresses due to pipe loads including thermally induced pipe loads (discontinuity stresses are not included). Stress results may be obtained from the ANSYS analyses (it is noted here that the ANSYS results include any effects due to geometry discontinuities). The following classical stress equations apply:

ILOR P_m Stress Equations

$$\sigma_A = \frac{PR_i^2}{R_o^2 - R_i^2} \pm \frac{N}{A} \pm \frac{MR_m}{I} \pm \frac{(V \cdot L)R_m}{I}$$

$$\sigma_H = \frac{PR_i}{t} \qquad \sigma_R = -\frac{1}{2}P \qquad \tau_{HA} = \pm\frac{V}{A} \pm \frac{TR_m}{J}$$

ILOR P_L Stresses

The local primary membrane stress intensities for ILOR include the discontinuity effects.

The pressure and piping load P_L stresses are calculated using the ANSYS finite element program. The linearized membrane plus bending stresses across the nozzle wall thickness for the cuts considered may be obtained from the computer output or be determined using simple hand calculations. The computer models may also be used to obtain linearized membrane stresses rather than applying the classical stress equations.

6.1.1.2 Computation of Principal Stresses and Maximum Stress Intensities

The following describes the method used for determination of the Maximum Stress Intensity Values. The Method is based on the Practical Approach to Solve Stress Cubic Equations of Reference 15. This method provides results that are consistent with those produced by the ANSYS computer code of Reference 5.

from ANSYS Runs :

$$\sigma_x = S_X = \text{Stress in Global } X - \text{Direction}$$
$$\sigma_y = S_Y = \text{Stress in Global } Y - \text{Direction}$$
$$\sigma_z = S_Z = \text{Stress in Global } Z - \text{Direction}$$
$$\tau_{xy} = S_{XY} = \text{Shear Stress in Global } X - Y \text{ Plane}$$
$$\tau_{yz} = S_{YZ} = \text{Shear Stress in Global } Y - Z \text{ Plane}$$
$$\tau_{xz} = S_{XZ} = \text{Shear Stress in Global } X - Z \text{ Plane}$$

Solution for Determination of the Roots of the Stress Cubic Equation

$$\sigma_p^3 - I_1\sigma_p^2 + I_2\sigma_p - I_3 = 0$$

Where

$$I_1 = \sigma_x + \sigma_y + \sigma_z$$

$$I_2 = \sigma_x\sigma_y + \sigma_x\sigma_z + \sigma_y\sigma_z - \tau_{xy}^2 - \tau_{yz}^2 - \tau_{xz}^2$$

$$I_3 = \sigma_x\sigma_y\sigma_z + 2\tau_{xy}\tau_{yz}\tau_{xz} - \sigma_x\tau_{yz}^2 - \sigma_y\tau_{xz}^2 - \sigma_z\tau_{xy}^2$$

Expressions for 3 – D Stress Values

$$\sigma_a = 2S[\cos(\alpha/3)] + \frac{1}{3}I_1$$

$$\sigma_b = 2S\{\cos[(\alpha/3) + 120^o]\} + \frac{1}{3}I_1$$

$$\sigma_c = 2S\{\cos[(\alpha/3) + 240^o]\} + \frac{1}{3}I_1$$

Here the Constants are as follows :

$$S = \left(\frac{1}{3}R\right)^{1/2}$$

$$\alpha = \cos^{-1}\left(-\frac{Q}{2T}\right)$$

$$R = \frac{1}{3}I_1^2 - I_2$$

$$Q = \frac{1}{3}I_1 I_2 - I_3 - \frac{2}{27}I_1^3$$

$$T = \left(\frac{1}{27}R^3\right)^{1/2}$$

Obtain the Maximum S_{Max} *and Minimum* S_{Min} *for all* S_a, S_b *and* S_c *Pairs*

Then Maximum Stress Intensity $= | S_{Max} - S_{Min} |$

6.1.1.3 Primary Plus Secondary Stresses

Primary plus secondary stresses in the nozzle are produced by internal pressure, applied piping reactions and temperature distributions in the nozzle and adjacent structure. The pressure and thermal stresses are the equivalent linearized stresses at each cut obtained from the ANSYS finite element model solution and post-processing routine. The temperature distributions developed in the primary nozzle thermal analysis are input into the finite element solution with the corresponding primary pressures. The stresses from the piping loads (if any loads are specified) are calculated by a separate finite element analysis, and the results are superimposed on the pressure and thermal stresses.

The primary plus secondary stress intensity ranges are calculated by introducing the linearized stresses into the ANSYS fatigue routine, which uses the procedures of NB-3216.2.

6.1.1.4 Fatigue Evaluation

In the fatigue evaluation, total stresses, which include primary plus secondary stresses and peak stresses, are evaluated. These stresses are produced by the combination of internal pressure, thermal loads, and external piping loads. The ANSYS Post1 Fatigue Module is used for post-processing the stresses for the ASME Code evaluation.

6.1.1.5 Application of Pipe Loads

Typically the ANSYS computer program is used to obtain stresses due to external forces and moments transferred into the safe-end from external piping. [

]a,c classical expressions can be used for evaluating their contributions to Normal, Upset and Faulted Load Conditions. Reference 12 determined the limit criteria for external loads. They are listed here in Section 6.3.2.1.

6.1.2 Calculation of Stresses in the Nozzle Safe End

The "free field" stresses in the Nozzle Safe End were not a direct objective of this calculation note. Nevertheless, the Linearized Stresses were obtained interactively for the Design Condition at two (2) cuts and are provided for general information and comparison with results typically obtained by hand calculations. No transient evaluations were performed for the Discharge Nozzle Safe End sections.

6.2 INPUT

6.2.1 Geometry Information

All geometry and materials data were obtained from the Plant X Reactor Coolant Pump Design Drawings of Reference 3.

Figures 6-1 and 6-2 show the main dimensions for the Plant X RCP Nozzle Safe End Pressure Tap Nozzles. It is seen that the Suction side nozzle is somewhat shorter and has a "bulkier" tip configuration (distance between nozzle end and centerline of exterior line connection is only [ ]a,c [mm], Figure 6-2, compared with [ ]a,c [mm], Figure 6-1). Furthermore, the inside bore diameter of [ ]a,c [mm] is less that the [ ]a,c [mm] bore for the Discharge side nozzle. Consequently analysis of the Discharge side nozzle is conservative and, therefore, covers both nozzle configurations.

Figures 6-3 and 6-4 show details of the weld preparation machining of the base metal and the [ ]a,c Buttering and Weld sections following installation of the Pressure Tap Nozzle.

Figure 6-5 shows the internal nozzle support arrangement provided by the specified clearances with the bore in the Safe End shell.

a,c

Figure 6-1 Main Dimensions of Plant X RCP Discharge Side Pressure Tap Nozzle

a,c

Figure 6-2 Main Dimensions of Plant X RCP Suction Side Pressure Tap Nozzle

[ ]a,c

Figure 6-3 Dimensions of Countersink Weld Preparation into Base Metal and SS Cladding

[ ]a,c

Figure 6-4 Dimensions of [ ]a,c Buttering (Yellow), [ ]a,c Weld (Green) following Installation of Pressure Tap Nozzle (12 mm Minimum Weld Length)

a,c

Figure 6-5 Pressure Tap Nozzle Showing Region of Interference Fit with Safe End Bore

6.2.2 Material Property Information

The material properties were obtained from Reference 9 of the 1995 Section II ASME Code Edition with 1996 and 1997 Addenda which, per the Design Specification (Reference 2), provide the Material Specifications and Properties for the Plant X Reactor Coolant Pump. The tables cited in the following Tables 6-1 through 6-4 refer to those of Reference 9.

6.2.2.1 RCP Casing and Nozzle Safe End Shell Material: ASME SA-508, Grade 3 Class 1

Table 6-1 RCP Casing and Nozzle Safe End Shell Material Properties

Temp. (°F)	TC TableTCD (p. 603)	TD TableTCD (p. 603)	ρC_P (Btu / ft^3-°F)	ρ (lbs/ft^3)	C_P (Btu / lb-°F)	α Table TE-1 (pp. 588-589)	E Table TM-1 (p. 614)	S_U Tensile Table U (pp. 434-435)	S_Y Yield Table Y-1 (pp. 504-507)	S_m Table 2A (pp.304-306)
70	21.8	0.420	51.90	483.8	0.107	6.41	27.8	80.0	50.0	26.7
100	22.0	0.415	53.01	483.8	0.110	6.50	27.6	80.0	50.0	26.7
150	22.3	0.407	54.79	483.8	0.113	6.57	27.4	80.0	48.6	26.7
200	22.4	0.399	56.14	483.8	0.116	6.67	27.1	80.0	47.2	26.7
250	22.4	0.390	57.44	483.8	0.119	6.77	26.9	80.0	46.3	26.7
300	22.4	0.382	58.64	483.8	0.121	6.87	26.7	80.0	45.3	26.7
350	22.4	0.373	60.05	483.8	0.124	6.98	26.4	80.0	44.9	26.7
400	22.3	0.364	61.26	483.8	0.127	7.07	26.1	80.0	44.5	26.7
450	22.1	0.355	62.25	483.8	0.129	7.15	25.9	80.0	43.9	26.7
500	22.0	0.345	63.77	483.8	0.132	7.25	25.7	80.0	43.2	26.7
550	21.8	0.335	65.07	483.8	0.134	7.34	25.5	80.0	42.6	26.7
600	21.5	0.325	66.15	483.8	0.137	7.42	25.2	80.0	42.0	26.7
650	21.3	0.315	67.62	483.8	0.140	7.52	24.9	80.0	41.4	26.7
700	21.0	0.305	68.85	483.8	0.142	7.59	24.6	80.0	40.6	26.7

TC is Thermal Conductivity, Btu/hr-ft-°F
TD is Thermal Diffusivity, ft^2/hr
ρ is Density (lb/ft^3)
C_P is Specific Heat (Btu / lb-°F)
ρC_P is Density x Specific Heat = TC / TD (Btu / ft^3-°F)
α is Mean Coefficient of Thermal Expansion x 10^{-6} (in./in./°F) in going from 70°F to Indicated Temperature.
E is Modulus of Elasticity x 10^6 psi

S_U, S_Y, S_m in Units of [ksi]

3/4Ni-1/2Mo-Cr-V

$$TD = \frac{TC\ (Btu/hr\text{-}ft\text{-}°F)}{Density\ (lb/ft^3) \times Specific\ Heat\ (Btu / lb\text{-}°F)}$$

Checked by DEK, 2/17/09

6.2.2.2 RCP Pressure Tap Nozzle, Weld and Weld Pad Material: ASME SB-166 (UNS N06690) and ASME SB-168 (UNS N06690)

Table 6-2 RCP Pressure Tap Nozzle, Weld and Weld Pad Material Properties

Temp. (°F)	TC TableTCD (p. 608)	TD TableTCD (p. 608)	ρC_P (Btu / ft^3-°F) TC/TD	ρ (lbs/ft^3)	C_P (Btu / lb-°F)	α Table TE-4 (pp. 596-597)	E Table TM-4 (p. 617)	S_U Tensile Table U (pp. 420-421)	S_Y Yield Table Y-1 (pp. 572-575)	S_m Table 2B (pp. 370-372)
70	6.8	0.125	54.40	506.3	0.107	7.73	30.3	80.0	35.0	23.3
100	7.0	0.128	54.69	506.3	0.108	7.76	30.1	80.0	35.0	23.3
150	7.3	0.131	55.73	506.3	0.110	7.80	29.8	80.0	33.9	23.3
200	7.6	0.134	56.72	506.3	0.112	7.85	29.5	80.0	32.7	23.3
250	7.9	0.137	57.66	506.3	0.114	7.89	29.3	80.0	31.9	23.3
300	8.2	0.140	58.57	506.3	0.116	7.93	29.1	80.0	31.0	23.3
350	8.5	0.144	59.03	506.3	0.117	7.98	29.0	80.0	30.4	23.3
400	8.8	0.147	59.86	506.3	0.118	8.02	28.8	80.0	29.8	23.3
450	9.1	0.151	60.26	506.3	0.119	8.06	28.6	80.0	29.3	23.3
500	9.4	0.153	61.44	506.3	0.121	8.09	28.3	80.0	28.8	23.3
550	9.7	0.157	61.78	506.3	0.122	8.13	28.2	80.0	28.4	23.3
600	10.0	0.161	62.11	506.3	0.123	8.16	28.1	80.0	27.9	23.3
650	10.3	0.164	62.80	506.3	0.124	8.20	27.9	80.0	27.4	23.3
700	10.6	0.167	63.47	506.3	0.125	8.25	27.6	80.0	27.0	23.3

TC is Thermal Conductivity, Btu/hr-ft-°F
TD is Thermal Diffusivity, ft^2/hr
ρ is Density (lb/ft^3)
C_P is Specific Heat (Btu / lb-°F)
ρC_P is Density x Specific Heat = TC / TD (Btu / ft^3-°F)
α is Mean Coefficient of Thermal Expansion x 10^{-6} (in./in./°F) in going from 70°F to Indicated Temperature.
E is Modulus of Elasticity x 10^6 psi

S_U, S_Y, S_m in Units of [ksi]

72Ni-15Cr-8Fe

TD = TC (Btu/hr-ft-°F) / Density (lb/ft^3) x Specific Heat (Btu / lb-°F)

Checked by DEK, 2/18/09

Notes: SB-166 and SB-168 have identical Properties, SB-166 is for the Nozzle, SB-168 is for the Weld.

Alloy 690 Weld Metal (Alloy 152 or Alloy 52)

6.2.2.3 RCP Cladding Material: ASME SA-240, Type 304L

Table 6-3 RCP Pressure Housing Cladding Material Properties

Temp. (°F)	TC TableTCD (p. 606)	TD TableTCD (p. 606)	ρC_P (Btu / ft^3-°F) TC/TD	ρ (lbs/ft^3)	C_P (Btu / lb-°F)	α Table TE-1 (pp. 590-591)	E Table TM-1 (p. 614)	S_U Tensile Table U (pp. 440-441)	S_Y Yield* Table Y-1 (pp. 524-527)	S_m * Table 2A (pp. 320-322)
70	8.6	0.151	56.95	501.1	0.114	8.46	28.3	70.0	25.0	16.7
100	8.7	0.152	57.24	501.1	0.114	8.55	28.1	70.0	25.0	16.7
150	9.0	0.154	58.44	501.1	0.117	8.67	27.9	68.1	23.2	16.7
200	9.3	0.156	59.62	501.1	0.119	8.79	27.6	66.2	21.4	16.7
250	9.6	0.158	60.76	501.1	0.121	8.90	27.3	63.6	20.3	16.7
300	9.8	0.160	61.25	501.1	0.122	9.00	27.0	60.9	19.2	16.7
350	10.1	0.162	62.35	501.1	0.124	9.10	26.8	59.7	18.4	16.3
400	10.4	0.165	63.03	501.1	0.126	9.19	26.5	58.5	17.5	15.8
450	10.6	0.167	63.47	501.1	0.127	9.28	26.2	58.2	17.0	15.3
500	10.9	0.170	64.12	501.1	0.128	9.37	25.8	57.8	16.4	14.8
550	11.1	0.172	64.53	501.1	0.129	9.45	25.6	57.4	16.0	14.4
600	11.3	0.174	64.94	501.1	0.130	9.53	25.3	57.0	15.5	14.0
650	11.6	0.177	65.54	501.1	0.131	9.61	25.1	56.6	15.2	13.7
700	11.8	0.179	65.92	501.1	0.132	9.69	24.8	56.2	14.9	13.5

TC is Thermal Conductivity, Btu/hr-ft-°F
TD is Thermal Diffusivity, ft^2/hr
ρ is Density (lb/ft^3)
C_P is Specific Heat (Btu / lb-°F)
ρC_P is Density x Specific Heat = TC / TD (Btu / ft^3-°F)
α is Mean Coefficient of Thermal Expansion x 10^{-6} (in./in./°F) in going from 70°F to Indicated Temperature.
E is Modulus of Elasticity x 10^6 psi

S_U, S_Y, S_m in Units of [ksi]
* taken for SA-240 Type 304L (conservative)

18Cr-8Ni

TD = TC (Btu/hr-ft-°F) / Density (lb/ft^3) x Specific Heat (Btu / lb-°F)

Checked by DEK, 2/16/09

6.2.2.4 RCP Pressure Tap Nozzle Material Property Summary for 650 °F

Table 6-4 RCP Pressure Tap Nozzle Material Property Summary for 650 °F

Component	Material	Properties at 650 °F (per Reference 9)		
		S_m [ksi]	E [ksi]	α [in/in/°F]
Nozzle Safe End	SA-508, Gr. 3 Cl. 1	26.7	24.9E3	7.52E-6
Nozzle and Weld Pad	ASME SB-166	23.3	27.9E3	8.2E-6
Cladding	SA-240, Type 304L(1)	13.7	25.1E3	9.61E-6

Note 1: Per Reference 3 ([ ]a,c RCP-ES-02), the stainless steel Cladding Material used in the fabrication of the RCP is SS309L/308L. SA-240, Type 304L base material properties are used here since it has equivalent material properties as SS309L/308L weld material for which specific properties are not listed in the ASME Code.

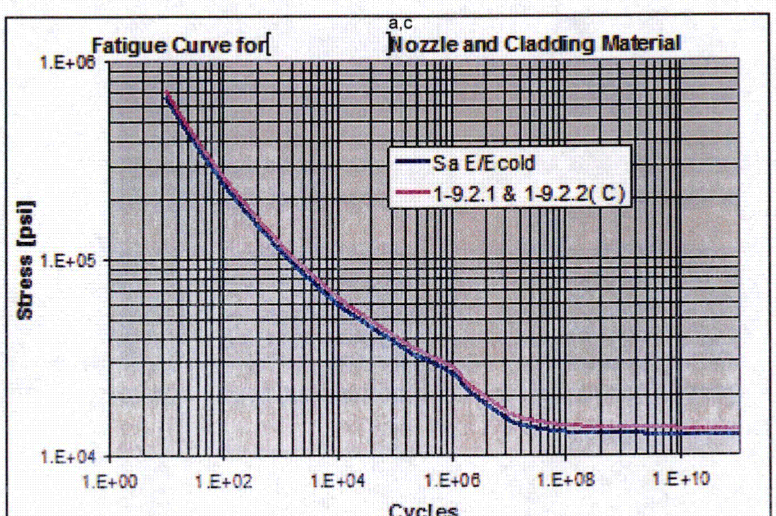
6.2.2.5 Fatigue Strength Properties for Nozzle and Weld Pad Materials

The Fatigue Strength Properties were obtained from [4, Figure I-9.2.1 and Tables I-9.1 and I-9.2.2]. The values used by ANSYS include an E/E_c multiplier of 0.927 to account for the ratio of the modulus of elasticity used in the analysis (here Design temperature of [ ]a,c) and the modulus of elasticity of the fatigue design curve temperature at 70°F (NB-3222.4(e)(4), [4]).

Table 6-5 ASME Code Fatigue Strength Properties for [ ]a,c Nozzle and Weld Pad Materials

Number of Cycles	Fatigue Strength, Ref. 4 Table I-9.1	
	Fig. I-9.2.1	E/E_c = 0.927(1)
[-]	S_a [psi]	$S_a E/E_c$ [psi]
10	708,000	656,599
20	512,000	474,829
50	345,000	319,953
100	261,000	242,051
200	201,000	186,407
500	148,000	137,255
1,000	119,000	110,361
2,000	97,000	89,958
10,000	64,000	59,354
20,000	55,500	51,471
100,000	40,800	37,838
200,000	35,900	33,294
1,000,000	28,300	26,245
2,000,000	22,800	21,145
10,000,000	16,400	15,209
20,000,000	15,200	14,096
100,000,000	14,100	13,076
1,000,000,000	13,900	12,891
10,000,000,000	13,700	12,705
100,000,000,000	13,600	a,c 12,613

Note 1: E = 30.3E6 for [ ] @ 70 °F was used rather than Design Curve Value of 28.3E6 [psi] which is conservative.
E = 28.1E6 for [ ] @ 600 °F



6.2.3 Specified Loads for Plant X RCPs

The Reference 2 Design Specification is the source for the applicable design data and dynamic loads.

6.2.3.1 Design Data

<u>Mechanical Design Data</u>

Design Pressure	[ ]a,c	[psia]
Design Temperature	[ ]a,c	[°F]

<u>Thermal-Hydraulic Design Data</u>

Normal Operating Pressure	[ ]a,c	[psia] (at Pump Suction)
Normal Operating Pressure	[ ]a,c	[psia] (RCS)
Normal Operating Temperature	[ ]a,c	[°F] (at Pump Suction)

<u>Nozzle Safe End Pressure Tap Nozzles Loads</u>

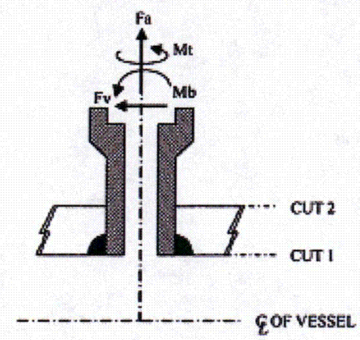
Reference 2, Section 6.5.2, specifies the following for Partial Penetration Welded nozzles.

The supplier shall provide the load criteria which satisfy the requirements of NB-3337.3 of Reference 4. The load criteria shall be defined in terms of axial (F_A), shear (F_S), Bending (M_B), and Torsional (M_T) loading at the end of the nozzle based on a maximum allowable stress of 10% of yield for Class 1 design at the critical section where the nozzle is welded to the component.

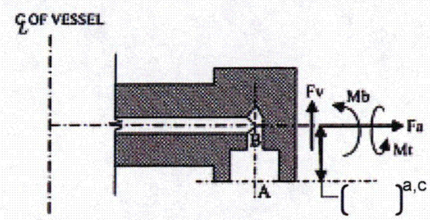
Reference 12 establishes the load criteria that meet these Section 6.5.2 requirements. They are repeated here in Table 6-6. It is seen that the NOp limits are based on the 10% of yield criterion for the weld region. The Faulted criteria are based on primary membrane stress limits for the nozzle shank section.

Table 6-6: External Nozzle Load Criteria for RCP Pressure Taps [12]

DDS 2 Nozzle Load Criteria for RCP Pressure Taps



Discharge Nozzle Pressure Tap



Suspection Nozzle Pressure Tap

The forces and moments at interface point "A" shall be transferred to point "B". The resulting nozzle loads shall meet the maximum nozzle load criteria shown below.

STRESS INTENSITY		LOADING CONDITION	CRITERIA (UNIT: KSI)
$P_m^{(5)}$=	[ ]a,c	DESIGN	P_m<[ ]a,c = 17.64
		LEVEL D(4)	P_m<[ ]a,c = 38.06
$P_L + P_b^{(5)}$=		DESIGN	P_L+P_b<[ ]a,c = 26.96
		LEVEL D(4)	P_L+P_b<[ ]a,c = 57.63
$P_L + P_b^{(6)}$=		Normal Operation	P_L+P_b<[ ]a,c = 2.2

NOTES:
1. Unit are kips and inch-kips.
2. All loads are absolute value.
3. [ ]a,c
4. Level D Service loads do not include pipe rupture loads in the ruptured pipe.
5. Zero clearance at Cut 2.
6. J-Weld at Cut 1.

6.2.3.2 Faulted Design Requirements (Optional)

[ ]a,c [Hz]. Consideration of Earthquake loads is also permitted by paragraph NB-3337.3 of [4].

Since, for Plant X, in addition to seismic loads, Reference 2 also specifies BLPB (Branch Line Pipe Break) loads and IRWST (In-Containment Refueling Water Storage Tank)

loads, some consideration of the dynamic effects during Faulted conditions was made. The region of amplification for the IRWST spectra is limited to frequencies below [ ][a,c] [Hz]. The BLPB spectra contain amplification up to [ ][a,c] Hz.

The Seismic SSE, BLPB and IRWST spectra were combined in Reference 11 into Faulted condition spectra. The combination method specified in Reference 2 was applied.

[

][a,c] However, Figure 6-8 presents the final Faulted condition spectra. The individual, global X, Y and Z direction spectra are plotted. Because of different nozzle orientations with respect to the global coordinates, the horizontal envelope spectrum is to be applied equally in all three local component coordinates (conservative).

a,c

Figure 6-6 IRWST RRS for RCP Components & Appurtenances (H & V-Dir.), [ ]a,c

a,c

Figure 6-7 SSE RRS for RCP Components & Appurtenances (H & V-Dir.), [ ]a,c

a,c

Figure 6-8 Faulted Condition Response Spectra, Global X, Y and Z Axes, Horizontal Envelope and RSS Spectra, [ ]a,c

6.2.3.3 Normal, Upset, Emergency, Faulted and Test Transient Conditions (Reference 2)

Table 6-7 Definition of Normal, Upset, Emergency, Faulted and Test Transient Conditions

a,c

6.3 EVALUATION, ANALYSIS, DETAILED CALCULATIONS AND RESULTS

The Plant X RCP Nozzle Safe End Pressure Tap Nozzles were evaluated in accordance with ASME Code Section III of Reference 4 for specified Design, Faulted, Normal, Upset, Emergency and Test conditions (per Design Specification of Reference 2).

6.3.1 Plant X Pressure Tap Nozzle ANSYS Model

6.3.1.1 Pressure Tap Nozzle ANSYS Model

The Discharge Nozzle Safe End Pressure Tap Nozzle is modeled in ANSYS as a [ ]a,c representation of the nozzle, [ ]a,c weld pad, and RCP Nozzle Safe End section. The entire model is made of ANSYS 3-D Structural Solid Elements [ ]a,c

The Discharge Nozzle Safe End is modeled with a relatively course mesh. The mesh density increases around the nozzle bore as it does for the weld pad. [ ]a,c The focus of the analysis are the stresses at this weld region, both in the longitudinal direction along the weld and in the radial direction, originating at the root of the weld and going towards the inside surface of the nozzle. [ ]a,c

The PRSECT command from ANSYS is used for "linearization" of stresses that become input into the ANSYS fatigue module.

[ ]a,c

Figure 6-9 shows the global model of the Pressure Tap Nozzle ANSYS model. Figure 6-10 shows a close-up view of the nozzle. Figures 6-11, 6-12, 6-13 and 6-14 provide detailed information regarding the nozzle to inside pad weld. They illustrate the mesh density used for each component, the three (3) different materials used in this region (namely RCP nozzle safe end, pressure tap nozzle and weld pad, and SS cladding materials), and also the "Model Area" pattern

used. The weld penetration is identified by the "common" line/surface along the nozzle and the shell inside areas and is a minimum of [ ]^{a,c} [mm] or [ ]^{a,c} [in] long (Reference 3 Drawing 8124-101-2001, Revision 01, Sheet 2 of 2 and Production Order [6]).

a,c

Figure 6-9 Plant X 3-D RCP Pressure Tap Nozzle ANSYS Model

a,c

Figure 6-10 RCP Pressure Tap Nozzle ANSYS Model Close-up View

a,c

Figure 6-11 RCP Pressure Tap Nozzle, ANSYS Model Details at Nozzle to Weld Pad Region

a,c

Figure 6-12 RCP Pressure Tap Nozzle, Cladding and Shell Materials at Nozzle to Pad Weld Region

a,c

Figure 6-13 RCP Pressure Tap Nozzle, Nozzle Shank/Tip Modeling Details

a,c

Figure 6-14 ANSYS Pressure Tap Nozzle Model Areas at Nozzle to Pad Weld Region

6.3.1.1.1 ANSYS Model Coordinate System

The ANSYS model used for the Plant X Nozzle Safe End Pressure Tap Nozzles uses a Global Coordinate System shown in Figure 6-9, with the X-Axis pointing from the Center Line of the RCP Nozzle Safe End radially outwards through the nozzle, with the Y-Axis representing the discharge pipe centerline toward the RCP outlet, and the Z-Axis following the "right-hand" rule. The nozzle stress results are provided in the Local Cylindrical Coordinate System 6 with the X-Axis representing the Radial Direction of the Pressure Tap Nozzle, the Y-Axis representing the Hoop Direction, and the Z-Axis following the axis of the Nozzle.

6.3.1.1.2 ANSYS Model Boundary Conditions

[

]a,c

( )a,c

Figure 6-15 Plant X ANSYS Pressure Tap Nozzle Model Boundary Conditions

a,c

Figure 6-16 Close-up View of Boundary Conditions at RCP Pressure Tap Nozzle to Pad Weld Region

6.3.1.2 ANSYS Model Material Properties

The material properties used for the 3-dimensional ANSYS model are those provided in Section 6.2.2.

6.3.1.3 ANSYS Model Applied Mechanical Load Conditions

External force components (e.g., F_A, F_V, M_B, and M_T) are specified in Reference 12. These were applied only to the nozzle shank region since the "narrow" annular region inside the nozzle/safe-end wall is intended to "unload" the weld region from these external loads. Whereas this radial restriction reduces the effects from both shear forces and bending moments, it is ineffective to reduce axial force and torsional moment loads. However, these were adequately evaluated as part of the "free-length" nozzle shank evaluation. The stress contribution at the weld region is considered in the fatigue analysis.

For evaluation of the nozzle for Primary Stresses, the Design, Upset and Test conditions

were evaluated using respective internal pressures of [ ]^{a,c} [psi]. The Upset pressure of [ ]^{a,c} [psi] occurs during the Upset Transient Event 2. No Emergency condition is specified. The Faulted condition pressure value is typically [ ]^{a,c} [psi]. However, the Faulted Transient Event 2 has a pressure spike as high as [ ]^{a,c} [psi]. This "higher" pressure of [ ]^{a,c} [psi] has been assumed for all Faulted condition evaluations; although, this is considered to be "quite conservative".

6.3.1.4 ANSYS Model Applied Thermal Transient Load Cases

Transient thermal analyses were performed for the Pressure Tap Nozzles using approximately twenty (20) transient runs. The transient definitions are provided in Appendix B.1 and are consistent with the listing in Table 6-7. There are no Emergency events and the Faulted transients are not considered in the fatigue evaluations. [ ]^{a,c} Hydrostatic Test cycles are specified, ten of which are exempted based on ASME code rules. Thus only [ ]^{a,c} are considered in the fatigue analysis. The [ ]^{a,c} Leak tests are included in the Heatup and Cool Down transients.

A Heat Transfer Coefficient of "Infinite" was used for wetted surfaces for all transients. This selection is conservative and reflects the high flow velocities that exist inside the RCP casing.

6.3.1.5 ANSYS Model Cut Locations

[ ]^{a,c} These controlling cuts are shown in the following Figure 6-17 and are identified by Key Points. The corresponding Nozzle Node Numbers are listed in Table 6-8.

Table 6-8 Association between Cuts, Keypoints and Nodes at Inside Weld

[ ]^{a,c}

a,c

Figure 6-17 ANSYS RCP Pressure Tap Nozzle Model Cuts, Through Nozzle [ ]^{a,c} and Along Weld Seam [ ]^{a,c}

In order to determine the Primary Membrane and Primary Membrane plus Bending Stress Intensities for the nozzle "shank" section, it was evaluated at [ ]^{a,c} cuts. Figure 6-18 shows cuts [ ]^{a,c} and [ ]^{a,c} at the straight nozzle portions near the "near-zero" gap region with the pipe wall. [ ]^{a,c}

The association between Keypoint and Node numbers is given in Table 6-9.

Table 6-9 Association between Cuts, Keypoints and Nodes at Nozzle Shank/Tip

a,c

Figure 6-18 Nozzle Tip Analysis Path Locations, Plant X RCP Pressure Tap Nozzle

Figure 6-19 shows two cuts through the RCP Discharge Nozzle Safe End section. The linearized stress results for both cuts are provided for general information, and were obtained from "interactive" analyses for a Design Condition run. These "PIPE_AXI and PIPE_RAD" results represent the "free-field" shell stress conditions in the Discharge Nozzle Safe End. Figure 6-20 shows the applied pressure loads on the discharge nozzle safe end and the pressure tap nozzle inside. Figure 6-21 is a close-up view of the pressure loading at the pressure tap nozzle inside.

a,c

Figure 6-19 Plant X RCP Pressure Tap Nozzle Safe End Cut Locations Pipe_Axi and Pipe_Rad

a,c

Note, applied Pressure in Units of [psi], Loads in Units of [lbs]

Figure 6-20 Plant X RCP Pressure Tap Nozzle, Applied Internal Pressure (Red) and Blow-off (Blue and Yellow) Load Vectors

a,c

Figure 6-21 Plant X RCP Pressure Tap Nozzle, Close-up View of Applied Pressures

6.3.1.6 ANSYS Model Input Listings

The input listings for the 3-dimensional ANSYS model are included in Appendix B.2. The basic analysis model was generated by "batch" files that called out the following "input" files:

[

]a,c

Detailed information about the input and output files for each run is provided in the Computer Run Logs of Appendix A.

6.3.2 Plant X RCP Pressure Tap Nozzle Stress Analysis Results

The primary stresses are calculated from the ANSYS output results obtained from the 3-D FEA model for Design Pressure and Temperature conditions. They are also calculated for the various Plant Transients. The ANSYS results are comprised of six (6) Membrane and (2x6, for Inside and Outside Walls) Membrane plus Bending stress components for each of the [ ]^{a,c} principal cut locations (in the case of the Design Condition, [ ]^{a,c} additional nozzle Tip cuts and [ ]^{a,c} Shell cuts were evaluated). The stress criteria and the required load cases are from References 2 and 4. External loads are from Reference 12. The material allowables are taken from Reference 9. The following Load Cases of Table 6-10 were investigated:

Table 6-10: Load Cases for Primary Stress Analysis

Condition	Description	Loading(2)	Load Components	References
I	Design	Design Pressure + DW Design Pressure + NOP	P_{Design} = [ ]^{a,c} [ksi]	Ref. 2, Page II2 and Ref. 4 Para. NB-3221.1, 2 & 3
II	Upset (Level B)	NOP + DW Upset Load + OBE(4)	P_{Upset} = [ ]$^{a,c(1)}$ [ksi]	Ref. 2, Page 16 and Ref. 4 Para. NB-3223(a)
III	Emergency (Level C)	None	n/a	Ref. 2, Page II3, but n/a in this case.
IV	Faulted (Level D)	NOP +(SSE^2 + (IRWST + BLPB)^2)$^{1/2}$	P_{NOP} = [ ]^{a,c} [ksi] $P_{Faulted}$ + T_{NOP} per Level D Transients(3)(5)	Ref. 2, Page II3 and Ref. 4 Para. NB-3225 and Appendix F, F-1331.
V	Test	Test Loading	P_{Test} = [ ]^{a,c} [ksi]	Ref. 2, Page II25 & Figure 12 and Ref. 4 Para. NB-3226

Notes:
(1) Maximum Pressure during Upset Event -2.
(2) SSE, IRWST and BLPB Loads are assumed to be "Zero" for the Inlet/Outlet Nozzle Safe End Pressure Tap Nozzles.
(3) Maximum Pressure during Faulted Event -2 is [ ]^{a,c} [ksi]. It is used here, conservatively, for all Faulted Condition Evaluations
(4) No OBE Loads are specified by Reference 2.
(5) External Nozzle Load Limits are specified in Reference 12.

The evaluation of the Pressure Tap Nozzles, located at the Suction and Discharge Nozzles, for Primary Membrane and Primary Membrane plus Bending stresses was confined to the conditions at the nozzle shank region rather than at the nozzle to interior pad weld location.

[

]a,c This fact justifies classification of the RCP pressure stresses as Secondary Stresses.

In order to satisfy the ASME Code requirements for evaluation of primary membrane and primary membrane plus bending stresses, [ ]a,c cuts were selected. [

]a,c

These ANSYS runs did not consider the effects from external loads. These results are summarized in the following Section 6.3.2.1.

The combined effects from specified pressure plus specified external loads are evaluated and summarized in Section 6.3.2.2.

The applicable evaluation criteria are repeated as follows:

Design Condition

Primary Membrane

Per Paragraph NB-3221.1 of Reference 4, the allowable is $P_m < S_m$. The value of S_m is 23.3 [ksi] for the Nozzle material (Section 6.2.2.5). In addition, the average Local Membrane Stress Intensity shall meet the criterion of Paragraph NB-3227.5 of Reference 4. Thus, the allowable is $P_L < 1.5\ S_m = 34.95$ [ksi]. The more conservative criterion of P_m shall be used.

Primary Membrane plus Bending

Per Paragraph NB-3221.3 of Reference 4, the Local Primary plus Bending Stress shall not exceed $\alpha\ S_m$. Assuming that α equals [ ]a,c [1], the allowable becomes $P_m + P_b <$ [ ]a,c S_m. The value of S_m is 23.3 [ksi] for the Nozzle material (Section 6.2.2.5). This means that the allowable stress is [ ]a,c [ksi].

Emergency Condition

No Emergency conditions are specified for the Plant X RCP Pressure Tap Nozzles.

[1] Using nozzle dimensions of [ ]a,c mm and [ ]a,c mm, α is [ ]a,c, thus maximum permissible value of [ ]a,c is used.

Faulted Condition

Primary Membrane

Per Paragraph NB-3225 of Reference 4, the allowable is the lesser of $2.4S_m$ or 0.7 S_U for austenitic (Nozzle) material. Using the material properties of Section 6.2.2 (assumed faulted condition temperature is [ ]^{a,c} °F) we find:

0.7 S_U = 0.7 x 80.0 = 56.0 [ksi] and 2.4 S_m = 2.4 x 23.3 = 55.92 [ksi] for the Nozzle. The lesser value is 55.92 [ksi].

It is noted that the maximum faulted condition transient pressure of [ ]^{a,c} [psi] is greater than the design pressure of [ ]^{a,c} [psi].

Primary Membrane plus Bending

The Primary Membrane plus Bending stress intensities for the Faulted Load condition must also be addressed. Per Paragraph NB-3225 of Reference 4, the allowable at design temperature of [ ]^{a,c} °F is the lesser of 1.5 ($2.4S_m$) or 1.5 (0.7 S_U) for non-ferrous (Nozzle) material. Using the material properties of Section 6.2.2 we find:

1.5 (0.7 S_U) = 1.5 x 0.7 x 84.0 = 88.2 [ksi] and 1.5 (2.4 S_m) = 1.5 x 2.4 x 23.3 = 83.88 [ksi] for the Nozzle. The lesser value is 83.88 [ksi].

Upset Condition

The [ ]^{a,c} is required to meet the primary stress criteria stated in NB-3223(a) of Reference 4, since the system pressure of [ ]^{a,c} [psi] exceeds the design pressure of [ ]^{a,c} [psi] by 4.2%. However, the allowable stress intensity for the Upset Condition is 10% greater than that for the Design Condition. Consequently, by satisfying the Design Condition, assurance is given that the Upset Condition stresses are acceptable.

Hydrostatic Test Condition

For the Hydro Test Condition, the RCP system pressure of [ ]^{a,c} [psi] is 25% higher than the Design Pressure of [ ]^{a,c} [psi]. The Primary Membrane Stress allowable, per NB-3226 of Reference 4, is 0.9 x S_y at maximum test temperature of [ ]^{a,c} °F. Using the material properties from Section 6.2.2 we find:

0.9 S_Y = 0.9 x 28.6 = 25.74 [ksi] for the Nozzle

6.3.2.1 Linearized Stress Results for the Primary Stress Evaluation for Design, Upset, Emergency, Faulted and Test Conditions for the Nozzle Cuts (Without External Load Effects)

The Table 6-11 stress results are based on the ANSYS computer runs (Tables 6-12 through 6-19 provide complete results for Design and representative [ ]a,c results for Upset, Faulted and Test conditions) made at the specified pressures and event temperatures. They are identical to those for assumed event temperatures of 70 °F. Use of 70 °F would be permitted according to the ASME code to eliminate the effects of thermal stresses due to any bi-metallic connections, such as the nozzle shank to safe end welds. This step is not necessary here. It is seen that the Primary Membrane Stress Criteria are met for all load cases, Design, Upset, Emergency, and Test.

Table 6-11: Results of Primary Stress Evaluation for RCP Pressure Tap Nozzles, Pressure and Temperature Effects

RCP Pressure Tap Nozzles (Pressure and Temperature Effects)

a,c

Table 6-12 Linearized Stresses for Plant X RCP Pressure Tap Nozzle [ ]a,c, Design Pressure and Temperature Conditions

a,c

Table 6-13 Linearized Stresses for Plant X RCP Pressure Tap Nozzle [ ]a,c, Design Pressure and Temperature Conditions

a,c

Table 6-14 Linearized Stresses for Plant X RCP Pressure Tap Nozzle [ ]^a,c^, Design Pressure and Temperature Conditions

a,c

Table 6-15 Linearized Stresses for Plant X RCP Pressure Tap Nozzle [ ]a,c, Design Pressure and Temperature Conditions

a,c

Table 6-16 Linearized Stresses for Plant X RCP Pressure Tap Nozzle [ ]^{a,c}, Design Condition without Temperature Effects

a,c

Table 6-17 Linearized Stresses for Plant X RCP Pressure Tap Nozzle [ ]^{a,c}, Upset Condition

a,c

Table 6-18 Linearized Stresses for Plant X RCP Pressure Tap Nozzle [ ]a,c, Test Condition

a,c

Table 6-19 Linearized Stresses for Plant X RCP Pressure Tap Nozzle [ ]a,c, Faulted Condition

a,c

6.3.2.2 Evaluation of the Effects from Faulted Condition Response Spectra

The allowable external nozzle loads were determined in Reference 12 and are provided in Table 6-6. Here only the effects from the Faulted condition spectra are examined.

As demonstrated below, the Pressure Tap nozzles have resonance frequencies greater than [ ]^{a,c} [Hz]. Using the longer "free nozzle length" geometric properties for the discharge side pressure tap nozzle (which offsets the somewhat heavier end of the suction side pressure tap nozzle), the following inertia loads are derived. Refer to Appendix B5 for details regarding the weight and CG properties.

Weight of "free" Nozzle Portion	[ ]^{a,c} [lbs]
Moment due to 1-G Load	[ ]^{a,c} [in-lbs]

The lowest natural frequency for the "free" portion of the Pressure Tap Nozzle is determined by assuming a conservative representation where the entire mass is lumped at the nozzle tip and the stiffness is represented by that of the nozzle shank section with a total (free) length of [ ]^{a,c} [mm] or [ ]^{a,c} [in]. The calculation is as follows:

$$\textit{Stiffness of a Cantilever Beam with End Load: } k = \frac{3EJ}{l^3}; \quad \textit{(Reference 7)}$$

$$\textit{Mass of Free Nozzle Portion: } m = \textit{Weight/G} = [\quad]^{a,c}/386.4$$

$$\textit{Natural Frequency: } f = \frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{k}{m}};$$

$$\textit{Assuming} \quad E = [\quad]^{a,c}\ [lb/in^2],\ \textit{Modulus of Elasticity}$$

$$l = [\quad]^{a,c}\ [in],\ \textit{Free Length}$$

$$J = [\quad]^{a,c}\ [in^4],\ \textit{Area Moment of Inertia}$$

Natural Frequency $f = [\quad]^{a,c}$ *[Hz], which is well above the Frequency Ranges of Amplification*
([ ]^{a,c} Hz for SSE and IRWST, and < [ ]^{a,c} Hz for BLPB)

A conservative Zero-Period-Acceleration (ZPA) value of [ ]^{a,c} Gs is obtained from Figure 6-8 for the three Faulted Load contributors. Resultant reaction loads are listed in Table 6-20. The table also lists the stress contribution in the nozzle shank due to the inertia loading. It is seen that the contribution to the primary membrane stresses would be less than [ ]^{a,c} psi. The bending moment stress contribution is [ ]^{a,c} psi. It is

small when compared with the allowable Faulted D stress [ ]a,c ksi of Reference 12, which also includes a [ ]a,c margin. Thus the inertia load stresses are negligible.

Table 6-20 Zero-Period-Acceleration Levels for Faulted Events and Resulting Nozzle Loads and Stresses

a,c

The nozzle properties are given in Table 6-21.

Table 6-21 Properties for RCP Pressure Tap Nozzles

Parameters	Symbols	Units	Pressure Tap Nozzle
Outside Radius	Ro	[in]	a,c
Inside Radius	Ri	[in]	
Mean Radius	Rm	[in]	
Wall Thickness	t	[in]	
Area	A	$[in^2]$	
Area Moment of Intertia	J (Bending)	$[in^4]$	
Torsional Moment of Inertia	I (Torsion)	$[in^4]$	
Free Length	L	[in]	
Section Modulus	SM	$[in^3]$	

6.3.2.3 RCP Suction/Discharge Nozzle Safe End Design Condition Stresses

The following provides stress results for the RCP Suction/Discharge Nozzle Safe End due to Design Pressure and Temperature Conditions. Figures 6-22 and 6-23 show the stress intensity distributions in the RCP Nozzle Safe End Pressure Tap Nozzles and in the vicinity of its attachment to the shell. Tables 6-22 and 6-23 provide the Linearized Primary Membrane and Primary Membrane plus Bending Stresses through the RCP Shell at two locations away from the Weld Pad region (Free Field).

a,c

Figure 6-22 Overall Stress Intensity Profile due to Design Pressure and Temperature Conditions

a,c

Figure 6-23 Stress Intensity Profile due to Design Pressure and Temperature Conditions

a,c

Figure 6-24 Linearized Stress Graph at Safe End Location [ ][a,c]

a,c

Figure 6-25 Linearized Stress Graph at Safe End Location [ ][a,c]

Table 6-22 Linearized Stress Results, Free-Field RCP Inlet/Outlet Nozzle Safe End [ ]a,c, Design Pressure and Temperature

a,c

Table 6-23 Linearized Stress Results, Free-Field RCP Inlet/Outlet Nozzle Safe End [ ]a,c, Design Pressure and Temperature

a,c

From the above tables the maximum free-field primary membrane stress intensity in the shell section is [ ]^{a,c} [psi]. It is also seen that the stresses at both cuts, as expected are virtually identical. The "free-field" stress of [ ]^{a,c} [psi] compares favorably with a Design Primary Membrane Stress Allowable of [ ]^{a,c} [psi]. The primary membrane plus bending stress is [ ]^{a,c} psi. The allowable is $\alpha \cdot S_m$ or [ ]^{a,c} psi.

6.3.2.4 Fatigue Analysis

6.3.2.4.1 Fatigue Analysis Methodology

The fatigue analysis for the Nozzle Safe End Pressure Tap Nozzles was performed in strict compliance with the ASME Code of Reference 4. The evaluations were based on the "Elastic" methods and allowed for the "Linearized Elastic-Plastic" methodologies. The ANSYS computer code of Reference 5 was used exclusively for generating the results, with some minor mathematical manipulations to invoke the "desired" Stress Intensification Factors for the [ ]^{a,c} significant nozzle/weld end cuts.

The ANSYS model was exercised to compute the transient responses to a total of [ ]^{a,c} transients, the majority, including [ ]^{a,c} transient events specified for Normal Operation, [ ]^{a,c} Zero Load Case, [ ]^{a,c} specified for Upset Condition, none specified for Emergency Condition, and [ ]^{a,c} Hydro Test cases. Since the ASME Code only permits exclusion of [ ]^{a,c} hydrostatic load cases, [ ]^{a,c} cycles needed to be considered here. With respect to the Leak Test cases, these were already accounted for in the [ ]^{a,c} Heatup/Cooldown cycles.

The transient analysis features of the ANSYS computer code first compute the thermal temperature distributions throughout the model for different steps in time that typically also signify changes in temperature and/or pressure conditions. Following the thermal computations, the ANSYS code converts the model into "stress" elements and computes the resulting stress information for each specified time step. The thermal results are written to filename.rth files, and the stress results to filename.rst files for additional processing. The POST1 processing consisted of computing the "Linearized Stress" information for each time step and also of tabulating the Linearized Membrane plus Bending Stress components as a function of time (steps). These stresses are provided in the Local Cylindrical Coordinate System 6 with the following identification:

S_X	Radial Direction Stresses in Nozzle
S_Y	Hoop Direction Stresses in Nozzle
S_Z	Axial Direction Stresses in Nozzle
S_{XY}	Shear Stress in Radial/Hoop Plane
S_{YZ}	Shear Stress in Hoop/Axial Plane
S_{XZ}	Shear Stress in Radial/Axial Plane

A Fatigue Stress Intensification Factor (FSIF)[2] of [ ]^{a,c} is applied to all [ ]^{a,c} weld root stress components. The [ ]^{a,c} stress components for the "inside the pressure boundary" nodes had FSIF factors of [ ]^{a,c}.

[2] Fatigue Stress Intensification Factor (FSIF or SIF) is interchangeable with Fatigue Strength Reduction Factor (FSRF).

[

]a,c

The [ ]a,c "filename.rst" files were stored in one directory and the "Fatigue" module of the ANSYS code was programmed to retrieve the pertinent information for the [ ]a,c cut locations, each for both inner and outer nodes. Specifically, the information was assembled sequentially for all transient events and within each event, sequentially for each loading step. The tabular information provided by the ANSYS fatigue module (filename.fatg) consisted of the six linearized membrane plus bending stress components and the six peak stress components, as well as the temperature values.

[

]a,c

From the tabulated ANSYS outputs, all usage factors were compared with the Reference 4 limit of one (1). A second ASME Code check requires that the Primary Membrane plus Bending Stress Ranges for the load pairings meet the $3S_m$ criterion (NB-3228.5, Item (a)). It is realized here that the ANSYS results also include the temperature induced bending moment contributions. Therefore, whenever the first $3S_m$ checks do not pass this criterion, the temperature induced bending stress components are subtracted to demonstrate compliance with the ASME Code criterion of NB-3228.5.

Typically, the SSE event is a Faulted Condition event which is not subject to fatigue considerations. [

]a,c

Using information from Section 6.3.2.2 Table 6-20 it is seen that the Faulted condition inertia stresses are less than [ ]^{a,c} [psi]. Consequently it is justifiable to ignore these loads since the fatigue contribution due to [ ]^{a,c} cycles with [ ]^{a,c} [psi] alternating stress is essentially "zero". Section 6.3.2.4.3 examines the impact of "external" IRWST and SSE piping loads that may be permitted by Reference 12.

Figures 6-26 and 6-27 show the temperature profiles in the Pressure Tap Nozzle and Safe End section during the [ ]^{a,c} time steps of the Heatup transient with "high" pressure.

Figure 6-28 shows the stress intensity profile with the fluid temperature at [ ]^{a,c} °F, immediately after stepping up to [ ]^{a,c} psi pressure. Figure 6-29 shows the stress intensity profile after reaching the maximum operating temperature at the end of the Heatup transient.

Figures 6-30 and 6-31 show the stress intensity profiles in the Pressure Tap Nozzle and Safe End section during the [ ]^{a,c} time steps of the Heatup transient with "high" pressure.

a,c

Figure 6-26 Temperature Profiles During Plant Heatup, [ ]a,c

a,c

Figure 6-27 Temperature Profiles During Plant Heatup, [ ]a,c

a,c

Figure 6-28 RCP Pressure Tap Nozzle Stress Intensity Profile, Heatup at [ ]^{a,c} °F and [ ]^{a,c} Psi

a,c

Figure 6-29 RCP Pressure Tap Nozzle Stress Intensity Profile, Heatup at [ ]^{a,c} °F and [ ]^{a,c} Psi

a,c

Figure 6-30 General Stress Intensities during Heatup Transient, [ ]a,c

a,c

Figure 6-31 General Stress Intensities during Heatup Transient, [ ]a,c

6.3.2.4.2 Fatigue Analysis Result Summary (Without SSE)

The results from the fatigue analyses for the [ ]^{a,c} cut locations were entered into Tables 6-27 through 6-34 to provide the typical complement of data considered relevant for fatigue evaluations. Table 6-24 identifies the Transient Events. Table 6-25 summarizes the Usage Factors for the [ ]^{a,c} cuts based on Fatigue Strength Reduction Factors (FSRFs) of [ ]^{a,c} for all six (6) Stress Components applied at the outside locations. This table summarizes the results for the [ ]^{a,c} different combinations of "low" and "high" pressure profiles associated with the heatup and cooldown transients.

The usage factors for all locations and load combinations were close to "zero". At [ ]^{a,c}, Outside location the highest usage factor of [ ]^{a,c} occurred for the loading combination with low pressure during heatup and high pressure during cooldown. Table 6-26 lists the maximum usage factors for the [ ]^{a,c} cuts.

The maximum resulting fatigue usage factors for the [ ]^{a,c} "through-nozzle" cuts is [ ]^{a,c} for [ ]^{a,c}. The maximum fatigue usage factor for the "along-the-weld" cuts is [ ]^{a,c} for [ ]^{a,c}, Outside Location. All fatigue usage factors are well within the limit of one (1). It is, therefore, concluded that the Nozzle Safe End Pressure Tap Nozzles meet the ASME Code (Reference 4) fatigue usage factor requirements when subjected to the complement of transients specified for the Plant X RCPs in Reference 2.

The computed Primary Membrane plus Bending stresses were always less than the $3S_m$ limit (NB3228.5, Item (a)). The narrowest margin for "through-nozzle" occurs at [ ]^{a,c}, Inside [ ]^{a,c}, with a Primary Membrane plus Bending Stress Range of [ ]^{a,c} [psi] versus a $3S_m$ limit of 69,900 [psi]. For the "along-weld" cuts, the narrowest margin is [ ]^{a,c} [psi] versus a $3S_m$ limit of 69,900 [psi] and occurs at [ ]^{a,c}, Outside [ ]^{a,c}. Table 6-35 summarizes the results for all fatigue analysis runs.

Section 6.3.2.4.3 provides a bounding evaluation that considers the effects of external SSE loads that may be permitted by Reference 12.

The discussion of Section 6.3.2.4.4 is offered as general information to further demonstrate absence of any concerns due to Thermal Ratcheting of the Pressure Tap Nozzles to Suction/Discharge Nozzle Safe End Weld region.

Table 6-24 Description of Transient Events with Event ID Numbers

a,c

Table 6-25 Plant X RCP Pressure Tap Nozzle Fatigue Usage Factor for [ ]^{a,c} Combinations of Heatup and Cooldown Pressure (High and Low) Conditions

a,c

Table 6-26 Plant X RCP Pressure Tap Nozzle Maximum Fatigue Usage Factor Summary with all Fatigue Strength Reduction Factors equal to [ ]^{a,c}

a,c

Table 6-27 Fatigue Analysis Summary, Plant X RCP Pressure Tap Nozzle Inside Node [ ]a,c, Through Nozzle [ ]a,c, LP Heatup & HP Cooldown

a,c

Table 6-28 Fatigue Analysis Summary, Plant X RCP Pressure Tap Nozzle Outside Node [ ]a,c, Through Nozzle [ ]a,c, LP Heatup & HP Cooldown

a,c

Table 6-29 Fatigue Analysis Summary, Plant X RCP Pressure Tap Nozzle Inside Node [ ]^{a,c}, Through Nozzle [ ]^{a,c}, LP Heatup & HP Cooldown

a,c

Table 6-30 Fatigue Analysis Summary, Plant X RCP Pressure Tap Nozzle Outside Node [ ]^{a,c}, Through Nozzle [ ]^{a,c}, LP Heatup & HP Cooldown

a,c

Table 6-31 Fatigue Analysis Summary, Plant X RCP Pressure Tap Nozzle Inside Node [ ]^{a,c}, Through Nozzle [ ]^{a,c}, LP Heatup & HP Cooldown

a,c

Table 6-32 Fatigue Analysis Summary, Plant X RCP Pressure Tap Nozzle Outside Node [ ]^{a,c}, Through Nozzle [ ]^{a,c}, LP Heatup & HP Cooldown

a,c

Table 6-33 Fatigue Analysis Summary, Plant X RCP Pressure Tap Nozzle Inside Node [ ]^{a,c}, Through Nozzle [ ]^{a,c}, LP Heatup & LP Cooldown

a,c

Table 6-34 Fatigue Analysis Summary, Plant X RCP Pressure Tap Nozzle Outside Node [ ]^{a,c}, Through Nozzle [ ]^{a,c} LP Heatup & LP Cooldown

a,c

a,c

Table 6-35: Summary of Primary Membrane plus Bending Stress Ranges for all Fatigue Runs

6.3.2.4.3 Fatigue Analysis Result Summary (Including [ ]a,c SSE Cycles)

The fatigue evaluations documented in Section 6.3.2.4.2 disregard contributions from any dynamic loads (IRWST, BLPB and SSE). While the effects from IRWST are small, SSE loads can be significant, although being part of the Faulted load complement, they are typically not considered in the fatigue evaluations. However, the Plant X specification of Reference 2 stipulates consideration of [ ]a,c SSE events (or [ ]a,c SSE Half cycles) and [ ]a,c IRWST discharge cycles. The SSE loads are to cycle about zero, no guideline is provided for the IRWST cycles.

In order to determine acceptable interface loads, Reference 2 refers to Section NB-3337.3 [4] and also stipulates that "the external loads be limited to those that produce a maximum allowable stress of 10% of yield at the critical weld section". NB-3337.3 cites that "partial penetration nozzles shall be used when there are no substantial piping reactions". Furthermore is stated that "earthquake loads need not be considered in determining whether piping reactions are substantial".

Reference 12 specifies the Pressure Tap Nozzle load criteria. It should be recognized that these limit equations are based on Nozzle Strength criteria. Whereas the external NOp loads are small, the permitted Faulted loads are quite large. Rather than ignoring the contributions from the [ ]a,c IRWST and the [ ]a,c SSE cycles on fatigue, the following conservative evaluation was made.

The nozzle weld region is considered the weakest portion of the nozzle. For Normal Operation, the permissible external loads are limited by the following equation [12].

$$P_L + P_b = \left[\quad \right]^{a,c} < 0.1S_Y = 2.208\,ksi$$

In further consideration of the effects of [ ]a,c IRWST cycles on fatigue, it is assumed that the permitted, total stress intensity of [ ]a,c ksi is additive to the stress intensities involving all Heatup and Cooldown transient events.

With respect to consideration of the SSE event, the following equation [12], providing the external Faulted condition load limits, controls:

$$P_L + P_b = \left[\quad \right]^{a,c} < 0.8 \cdot (1.05S_U - 0.5P) = 57.63\,ksi$$

[

]a,c

The stress levels stated so far are based on a "realistic" interpretation of Reference 12. Nevertheless, a "worst" case scenario was added where it is assumed that the external axial forces and torsional moments produce a Faulted stress of [ ]a,c ksi at the weld. This scenario uses the earlier values multiplied by 2.

The information of Tables 6-27 through 6-34 was reprocessed by adding both SSE and IRWST stresses and cycles. For convenience all pairings affected by the inclusion of IRWST or SSE used a fatigue curve based on [ ]a,c °F. The SSE cycles are paired with each other. Tables 6-37 through 6-44 document the fatigue usage factor computations for the [ ]a,c nodes. Table 6-36 summarizes the results and compares them with the fatigue

usage factors computed in Section 6.3.2.4.2 without considering the contributions from the external IRWST and SSE loads.

Referring to Table 6-36, the maximum usage factors are found for the outside location of [ ]^{a,c}. Disregarding the effects from external SSE loads, as may be permitted by NB-3337.3 [4] the usage factor is [ ]^{a,c}. Using a "realistic" limit for external SSE loads it increases to [ ]^{a,c}. Assuming a "worst" SSE case, the usage factor increases to [ ]^{a,c}, still well within the allowable of 1.0.

Table 6-36 Summary of Fatigue Usage Factor Not Considering and Considering Contributions from External Nozzle Loads

a,c

Table 6-37 Fatigue Usage Factors Considering "Realistic" and "Worst Case" External Nozzle Loads, Inside Node [ ]a,c, Through Nozzle [ ]a,c

a,c

Table 6-38 Fatigue Usage Factors Considering "Realistic" and "Worst Case" External Nozzle Loads, Outside Node [ ]a,c, Through Nozzle [ ]a,c

a,c

Table 6-39 Fatigue Usage Factors Considering "Realistic" and "Worst Case" External Nozzle Loads, Inside Node [ ]a,c, Through Nozzle [ ]a,c

a,c

Table 6-40 Fatigue Usage Factors Considering "Realistic" and "Worst Case" External Nozzle Loads, Outside Node [ ]a,c, Through Nozzle [ ]a,c

a,c

Table 6-41 Fatigue Usage Factors Considering "Realistic" and "Worst Case" External Nozzle Loads, Inside Node [ ]a,c, Through Nozzle [ ]a,c, LP Heatup & HP Cooldown

a,c

Table 6-42 Fatigue Usage Factors Considering "Realistic" and "Worst Case" External Nozzle Loads, Outside Node [ ]a,c, Through Nozzle [ ]a,c

a,c

Table 6-43 Fatigue Usage Factors Considering "Realistic" and "Worst Case" External Nozzle Loads, Inside Node [ ]a,c, Through Nozzle [ ]a,c

a,c

Table 6-44 Fatigue Usage Factors Considering "Realistic" and "Worst Case" External Nozzle Loads, Outside Node [ ]a,c, Through Nozzle [ ]a,c

a,c

6.3.2.4.4 Thermal Stress Ratchet Considerations

The evaluation of primary plus secondary stress intensity, without thermal bending, addresses a concern for progressive plastic deformation, which could result in unacceptable levels of distortion, displacement, or wall thinning.

The following discussions provide logic for accepting exceedances of the $3S_m$ criterion for the Plant X RCPs (which is not the case for the Pressure Tap Nozzles). The discussion addresses in detail why the intent of the ASME Code (Reference 4) is satisfied for thermal stress ratcheting. The same logic is applicable to the primary plus secondary, without thermal bending requirements and provides justification for why the intent of the Code requirement is satisfied (not applicable for the Pressure Tap Nozzles).

[

]a,c

[

]a,c

In summary,[ ]a,c the nozzle is not capable of thermal ratcheting. Any initial plastic deformation will be self-limiting since the majority of the pressure loading in the nozzle is due to a displacement controlled expansion process, rather than being caused by a true pressure load application.

Again, it is repeated that the Plant X RCP Pressure Tap Nozzles do not violate any of the Reference 4 criteria.

7.0 References

1. Not used.
2. Plant X Design Specification, XXXXX-FS-DS480, Rev. 04, "Design Specification for Reactor Coolant Pumps," December 29, 2009.
3. Westinghouse Design and Manufacturing Drawings for Reactor Coolant Pump.

   Drawing 8124-101-2001, Rev. 01, "Pump Casing 'A'," (2-Sheets)
   Drawing 5244, Rev. 00, "Pump Casing – Rough Machining"
   Drawing 8000-101-2036, Rev. 02, "Nozzle – Pressure, Wall Static"
   Drawing 8114-101-2008, Rev. 01, "Nozzle – Pressure, Wall Static"
   Drawing 5150, Rev. 04, "Welding – Joint Identification, RCP Casing"

4. ASME Boiler and Pressure Vessel Code, Section III, Nuclear Power Plant Components, 1995 Edition with 1997 Addenda.
5. "ANSYS 11.0 for XP Release Letter," LTR-SST-08-18, April 1, 2008.
6. Production Order "VBM-Machine Casing S/N (1124-A)," Job No. 2400360, Production No. 40022009.
7. Warren C. Young, "Roark's Formulas for Stress and Strain," 6th Edition, 1989 McGraw-Hill.
8. Not used.
9. ASME Boiler and Pressure Vessel Code, Section II, Material Specifications, 1997 Edition with 1997 Addenda.
10. ASME Code Case N-474-2, Approval Date, December 9, 1993.
11. Westinghouse Calculation Note CN-NPE-06-XXXX-22, Revision 2, "Plant X – Reactor Coolant Pump Transients and Design Loads," dated February 26, 2010.
12. Westinghouse Calculation Note CN-NPE-06-XXXX-23, Revision 3, "DDS 2 Nozzle Load Criteria for RCP Pressure Taps for Plant X Nuclear Power Plant Units X & X," dated March 12, 2010.
13. Westinghouse Calculation Note CN-NPE-06-XXXX-04, Revision 1, "Plant X - Structural Evaluation of the RCP Suction Nozzle and Safe End," dated March 8, 2010.
14. Not used.
15. E. E. Messal, "Finding True Maximum Shear Stress," Machine Design pp. 166-169, December 7, 1978.

Appendix A: Computer Run Logs

None of the computer runs was affected by issue of Revision 1. However, for convenience, all files are also attached to this version of the document.

Computer Run Log Summary

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Computer Run Log Summary (cont)

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Appendix B: Supporting Documentation

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CN-NPE-06-XXXX-03-NP	1	215

Checklist A: Proprietary Class Statement Checklist

Directions (this section is to be completed by authors): Authors are to determine the appropriate proprietary classification of their document. Start with the Westinghouse Proprietary Class 1 category and review for applicability, proceeding to Westinghouse Proprietary Class 2 – Non-Releasable and finally to Westinghouse Proprietary Class 2 – Releasable. The proprietary classification is established when the first criterion is satisfied.

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Checklist B: Calculation Note Methodology Checklist

(Completed By Author)

No.	Self Review Topic	Yes	No	N/A
1	Is all information in the cover page header block provided appropriately?	X		
2	Are all the pages sequentially numbered, and are the calculation note number, revision number, and appropriate proprietary classification listed on each page?	X		
3	Are the page numbers in the Table of Contents provided and correct?	X		
4	Are the subject and/or purpose of the calculation clearly stated in Section 1.1?	X		
5	Have the limits of applicability been identified in Section 1.2?	X		
6	Is the Summary of Results and Conclusions provided in Section 2.0 consistent with the purpose stated in Section 1.1 and calculations contained in Section 6.3?	X		
7	Are the assumptions clearly identified and justified in Section 3.1?			X
8	Are open items properly identified in Section 3.2 and the calculation note cover page?			X
9	Are the Acceptance Criteria clearly and appropriately provided in Section 4.0?	X		
10	Are the methods clearly identified in the Method Discussion in Section 6.1?	X		
11	Are the required inputs and their sources provided in Section 6.2, and are they appropriate for the current calculation?	X		
12	Does Section 6.3 sufficiently describe the analysis details and results?	X		
13	Is sufficient information provided for all References in Section 7.0 to facilitate their retrieval (e.g., from EDMS, NRC's ADAMS system, open literature, etc.), or has a copy been provided in Appendix B?	X		
14	Are all computer outputs documented in Appendix A and consistent with Table 5-1?	X		
15	Are all computer codes used under Configuration Control and released for use?	X		
16	Are the computer codes used applicable for modeling the physical and/or computational problem contained in this calculation note?	X		
17	Have the latest versions of all computer codes been used?	X		
18	Have all open computer code errors identified in Software Error Reports been addressed?	X		
19	Is Checklist A completed properly, and are the proprietary classification, proprietary clause and designation for release provided and consistent with the checklist?	X		
20	Are the units of measure clearly identified?	X		
21	Are approved design control practices followed without exception?	X		
22	Are all hand-annotated changes to the calculation note initialed and dated by author and verifier? Has a single line been drawn through any changes with the original information remaining legible?			X
23	Was a Pre-Job Brief held prior to beginning the analysis?		X(1)	
24	Was a Peer Check performed to review inputs documented in Section 6.2 prior to performing analyses?		X(1)	
25	Was a Peer Check performed to review results before documenting them in Section 6.3?		X(1)	
26	If required, have computer files been transferred to archive storage? Provide page number for list of files if not included in Appendix A. Page			X

If 'NO' to any of the above, provide page number of justification or provide additional explanation below or on subsequent pages. (1) Work commenced prior to deployment of new procedure.

Checklist C: Verification Methodology Checklist

(Completed By Verifier(s))

Verification Method (One or more must be completed by each verifier)		Initial If Performed
1	Independent review of document. (Briefly explain method of review below or attach.)	RFR
2	Verification performed by alternative calculations as indicated below.(1)	
	a. Comparison to a sufficient number of simplified calculations which give persuasive support to the original analysis.	
	b. Comparison to an analysis by an alternate verified method.	
	c. Comparison to a similar verified design or calculation.	
	d. Comparison to test results.	
	e. Comparison to measured and documented plant data for a comparable design.	
	f. Comparison to published data and correlations confirmed by experience in the industry.	
3	Completed Group-Specific Verification Checklist. (Optional, attach if used.)	
4	Other (Describe)	

(1) For independent verification accomplished by comparisons with results of one or more alternate calculations or processes, the comparison should be referenced, shown below, or attached to the checklist.

Verification: The verifier's signature (or Electronic Approval) on the cover sheet indicates that all comments or necessary corrections identified during the review of this document have been incorporated as required and that this document has been verified using the method(s) described above. For multiple verifiers, appropriate methods are indicated by initials. If necessary, technical comments and responses (if required) have been made on the "Additional Verifier's Comments" page.

Additional Details of Verifier's Review

Reviewed by the 3-pass method.

Additional Verifier's Comments

The signatures of the Author(s) and Verifier(s) on the cover page (or Electronic Approval) indicate acceptance of the comments and responses.

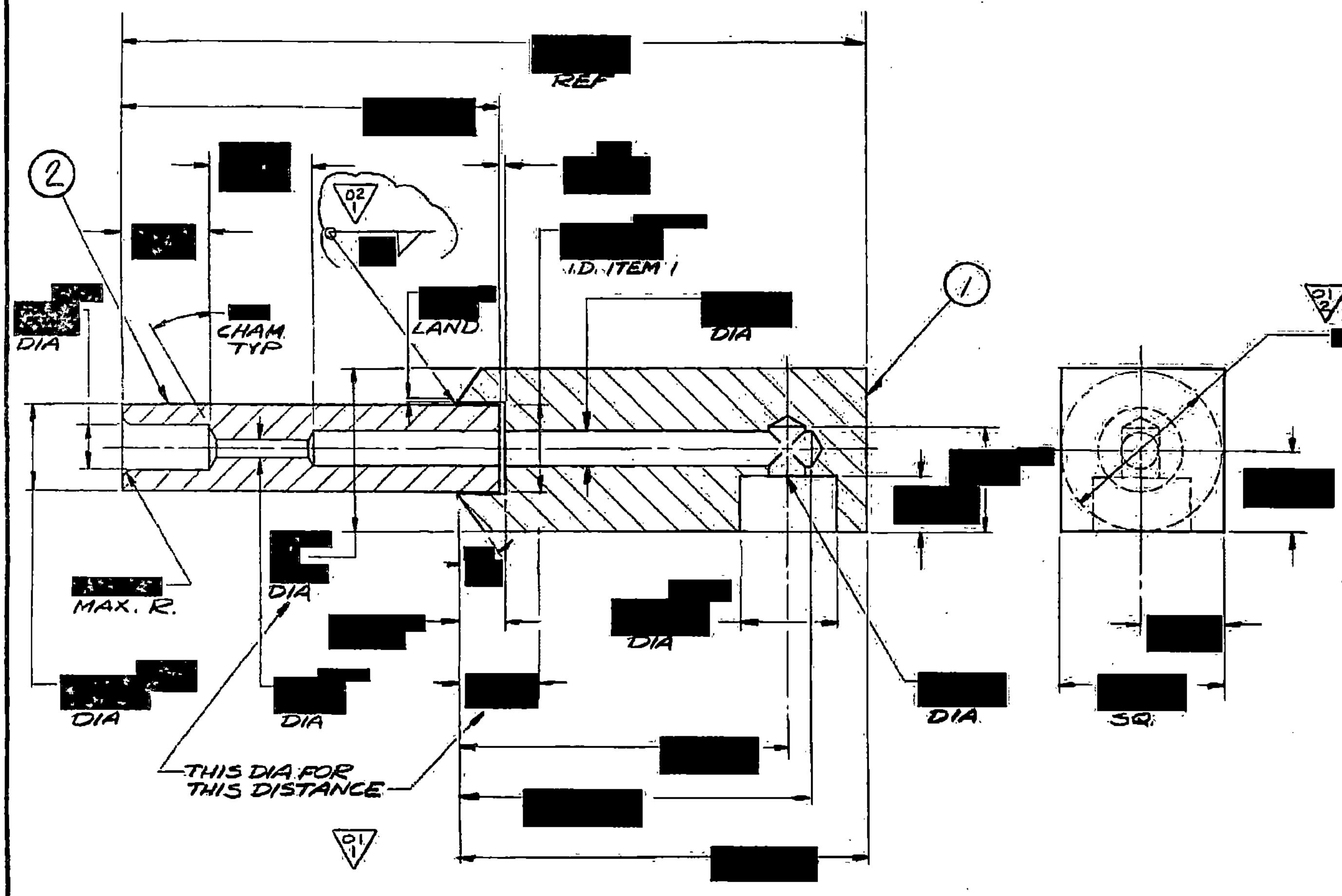
No.	Verifier's Comments	Author's Response (If Required)
1	Make editorial changes as noted in mark-up copy	Changes were made.
2	Make changes in weld geometry per discussion with author and revised ANSYS input file.	Changes were made.

Customer Review Comments and Reconciliations

Attachment 7

Drawings Referenced in Responses to NRC Questions

- **C-8000-101-2017-NP, Rev 2, *Wall Static Pressure Suction***
- **STD-009-0009-NP, Rev. 2, *Coolant Pumps Weld Joint Identification and Fabrication Requirements***
- **DWG 339-0054-NP, Rev. 0, *Safe End Mach. Of Pressure Tap Holes and Weld Prep. (Suction)***
- **C-14473-220-002-NP, Rev. 0, *Replacement Pressure Tap Nozzle***
- **E-14473-220-001-NP, Rev. 0, *Pump Casing – A Pressure Tap Nozzle Modification Assembly***
- **SE-14473-220-003-NP, Rev. 0, *Pressure Tap Nozzle Replacement Palo Verde Unit 3***



2. DIMENSIONING & TOLERANCING PER ANSI Y14.5 -1973
1. ALL DIMENSIONS ARE IN MM, METRIC SYSTEM, WITH U.S. EQUIVALENT IN PARENTHESIS FOR GUIDANCE ONLY.

C-8000-101-2017-NP
02

APPROVED

PER RFDS-WDSR-15-37

WESTINGHOUSE NON-PROPRIETARY CLASS 3

ELECTRONICALLY APPROVED RECORDS ARE AUTHENTICATED IN THE ELECTRONIC DOCUMENT MANAGEMENT SYSTEM
SIGNATURES ARE FOR CURRENT REVISION

DRAFTER	JOHN J. BEDNARZ
DFT CHKR	GARY M. TROCOLA
DES ENG	ERIC M. WEISEL
ENG VRFR	ATTILA Z. SZABO
REP ENG APRVD	JEFFREY R. STACK
MGR APRVD	RICHARD P. O'NEILL

REV.	DESCRIPTION	BY & DATE	CHK. & DATE	ENG. APPD.
01	[redacted]	9/2/82	9/2/82	RJN 9/2/82
02	[redacted]	MLP 1/31/83	1-31-83	RJN 1/31/83

UNLESS OTHERWISE SPECIFIED

UNDER 6 ± 0.1	6 TO 29 ± 0.2	30 TO 119 ± 0.3	120 TO 314 ± 0.5
315 TO 999 ± 0.8	1000 TO 1999 ± 1.2	2000 TO 3999 ± 2	OVER 4000 ± 3

1 INCH = 25.400 MM (EXACT) — ANGLES ± 1/2°
FINISH (√) AA 3.15 MICRO M — CHAMFER ± 5°
BREAK CORNERS 0.4 MAX. RAD. OR CHAMFER
FILLETS 0.4 TO 0.8 RADIUS — THREADS I.S.O. METRIC
DIMENSIONS IN MM BASED ON 20°C

DRAWN BY: 7-9-82
CHECKER: 7-16-82
APPROVALS: 8-9-82
SCALE: 1/1 — DO NOT SCALE DWG.

CE-KSB PUMP TYPE 101

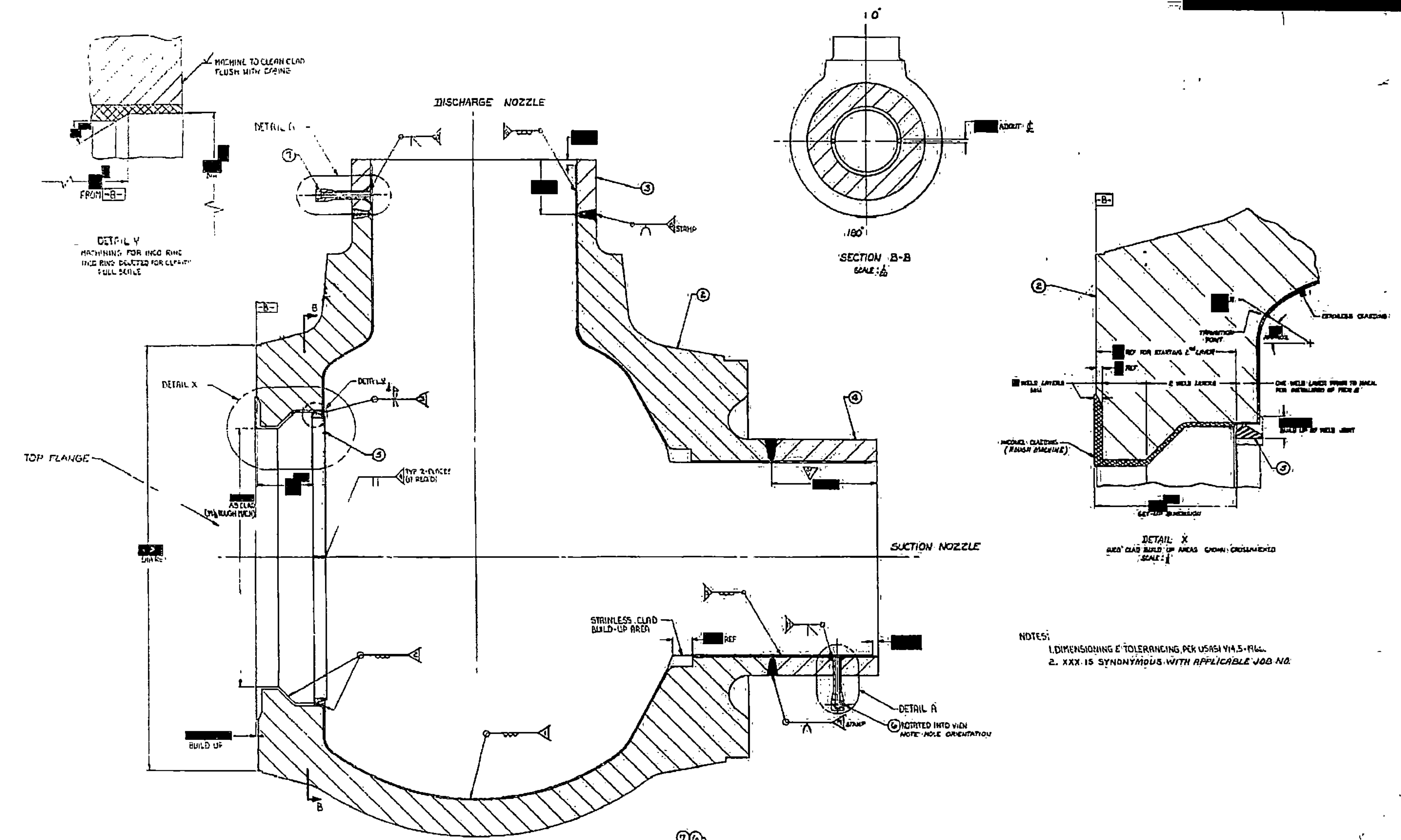
NEXT ASSY:
SUPERSEDES:
COMPONENT CODE NO:

CONTRACT NO.
CE-KSB PUMP CO. INC.
NEWINGTON, N.H. 03801

[redacted]

WALL STATIC PRESSURE NOZZLE SUCTION

C-8000-101-2017-NP — REV. 02
SHEET 1 OF 1



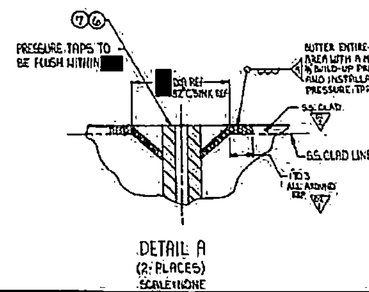
PER RFDS-WDSR-15-37

WESTINGHOUSE NON-PROPRIETARY CLASS 3

ELECTRONICALLY APPROVED RECORDS ARE AUTHENTICATED IN THE ELECTRONIC DOCUMENT MANAGEMENT SYSTEM. SEE EDMS FOR DRAWING APPROVAL DATE(S)

SIGNATURES ARE FOR CURRENT REVISION

DRAFTER:	JOHN J. BEDNARZ
DIST CHKR:	GARY M. TROCOLA
DES. ENG.:	ERIC M. WEISEL
ENG. VRFR.:	ATTILA Z. SZABO
RSP ENG. APRVL:	JEFFREY R. STACK
MGR. APRVL:	RICHARD P. O'NEILL



APPROVED

ITEM NO.	DWG NO. & OR PC. NO.	DESCRIPTION
7	B-XXX-0029	PRESSURE TAP ASSY.
6	B-XXX-0028	PRESSURE TAP ASSY.
5	C-XXX-0040	RING SEGMENT
4	C-XXX-0054	SAFE END (SUCTION)
3	C-XXX-0056	SAFE END (DISCHARGE)
2	C-[redacted]-0055	ONE-PIECE FORGING
1	E-STD-007-0001	PUMP ASSY.

LIST OF MATERIAL

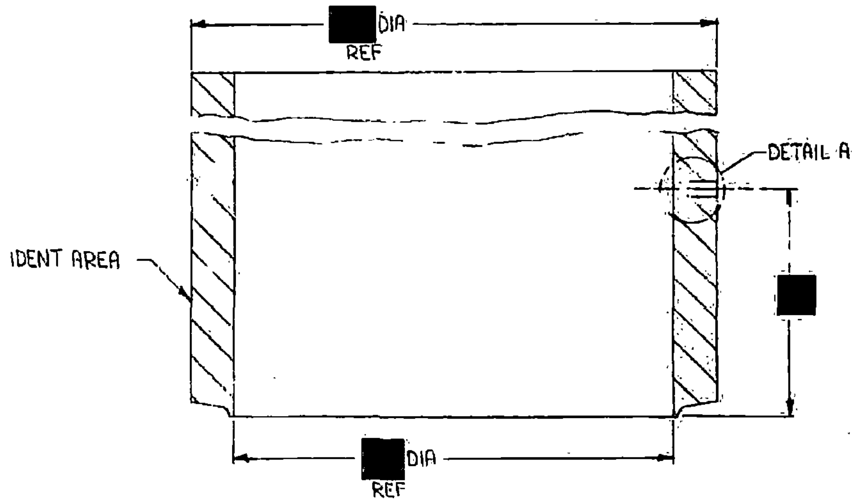
DWN: DHD DATE: 3-24-80 CHKD: RPL DATE: 3-26-80

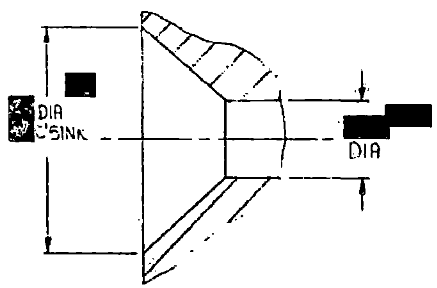
[redacted] AVERY

COOLANT PUMPS WELD JOINT IDENTIFICATION AND FABRICATION REQUIREMENTS

SIZE E DRAWING NO. STD-009-0009-NP REV 02

SCALE WT. 34,000 SHEET 1 OF 1





DETAIL A
WELD PREP

NOTES:
1. DIMENSIONING & TOLERANCING PER USASI Y14.5-1966

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

ELECTRONICALLY APPROVED RECORDS ARE AUTHENTICATED IN THE ELECTRONIC DOCUMENT MANAGEMENT SYSTEM - SEE EDMS FOR DRAWING APPROVAL DATE(S)

SIGNATURES ARE FOR CURRENT REVISION

DRAFTER	JOHN J. BEDNARZ
DFT CHECKER	GARY M. TROCOLA
DES. ENG.	ERIC M. WEISEL
ENG. VRFR.	ATTILA Z. SZABO
RESP. ENG. APRVL.	JEFFREY R. STACK
MGR. APRVL.	RICHARD P. O'NEILL

PER RFDS-WDSR-15-37

-6	-5	-4	-3	-2	-1	ITEM NO.	DWG NO. & OR PT. NO.	DESCRIPTION	MATERIAL	REMARKS
					1	2	C-339-0008-2	PUMP CASING SAFE END		
					X	1	C-339-0054	SAFE END MACH.		

ASSY NO. & QTY PER ASSY — E-8109-101-2002 — LIST OF MATERIAL

ASSY NO.	QTY REQD	NEXT ASSY	USED ON
-1	1		339

APPLICATION

TOLERANCES UNLESS OTHERWISE SPECIFIED
DIMENSIONS | UNDER 6 | 6-18 | OVER 18
DECIMAL DIMS
FRACTIONAL DIMS
FINISH (✓) AA-125 MICRO IN. ANGLES ±1/2°
THREADS UNIFIED CL-2A-2B CHAMFER ±5°
BREAK CORNERS 1/64 MAX RAD OR CHAMFER
FILLETS 1/64 TO 1/32 RADIUS
DIMENSION IN INCHES BASE ON 68°F (20°C)

CONTRACT NO.
DRAWN DAVE D.
DATE 8-17-79
CHKD DWG
ISSUED 9-6-79

APPROVED		DATE
ENGR.	PCB	10/2/79
MFG. QA	[illegible]	10-3-79

Q.C. INSPECTION CL. MATL. FAB. MACH.

CE AVERY

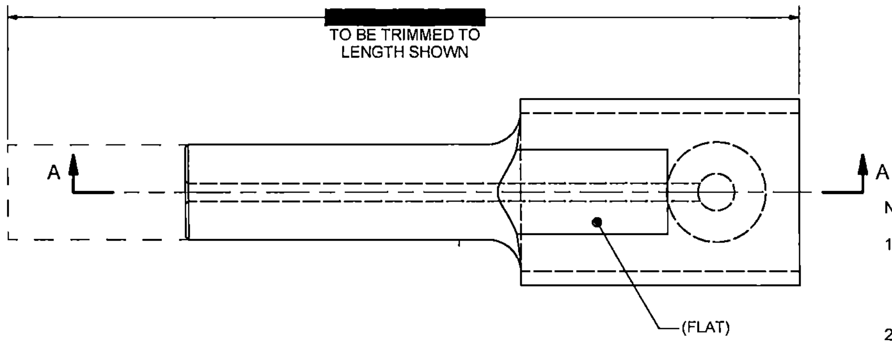
SAFE END MACH. OF PRESSURE TAP HOLES & WELD PREP (SUCTION)

SIZE	CODE IDENT NO.	DRAWING NO.	REV
C		339-0054-NP	00

SCALE NONE | WT. CALC. 1453# | SHEET 1 OF 1

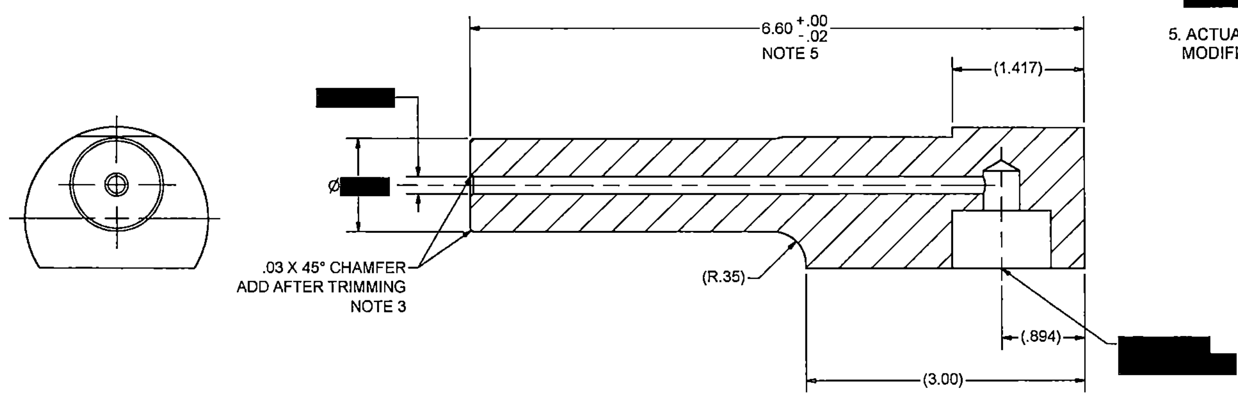
WESTINGHOUSE NON-PROPRIETARY CLASS 3

The Draftboard, Inc.

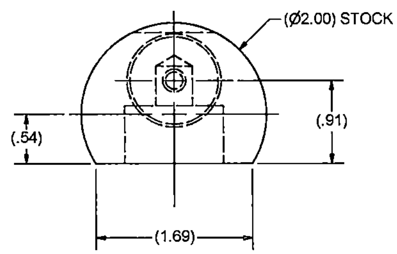


NOTES:

1. THIS ITEM IS A PRESSURE BOUNDARY COMPONENT PER SECTION III OF THE ASME CODE, FOR REACTOR COOLANT PUMP (RCP) PRESSURE TAP NOZZLE MODIFICATION APPLICABLE TO ARIZONA NUCLEAR POWER PROJECT (PVNGS) UNIT 3. MATERIAL: SB-166, ALLOY N06690.
2. EACH PIECE SHALL BE LOW STRESS STAMPED OR VIBROETCHED, WITH THE FOLLOWING INFORMATION, AFTER THE MODIFICATIONS SHOWN (IF NOT ON THE PART): HEAT NUMBER, WESTINGHOUSE PO NUMBER, PART/DRAWING NUMBER.
3. AFTER TRIMMING/MACHINING IS COMPLETED, MACHINED AREAS TO BE RE-INSPECTED BY PT LIQUID PENETRANT EXAMINATIONS / ACCEPTANCE CRITERIA PER SECTION III OF THE ASME CODE.
4. ORIGINAL PIECE PROCURED [redacted] BY WESTINGHOUSE, TO BE MODIFIED ON SITE.
5. ACTUAL CUT LENGTH DIMENSION TO BE DETERMINED AFTER EXISTING NOZZLE MODIFICATION, BEFORE FIELD TRIMMING OF REPLACEMENT NOZZLE.



SECTION A-A
SCALE 1 : 1



NOTE: DESIGN DIMENSIONS ARE IN INCHES. DIMENSIONS IN PARENTHESES ( ) ARE FOR REFERENCE ONLY.

STATUS: CERTIFIED FOR CONSTRUCTION

ELECTRONICALLY APPROVED RECORDS ARE AUTHENTICATED IN THE ELECTRONIC DOCUMENT MANAGEMENT SYSTEM SEE EDMS FOR DRAWING APPROVAL DATE(S)

SIGNATURES SHOWN ARE FOR CURRENT REVISION

DATABASE FILE ID
C-14473-220-002-NP.idw

REV.	S.O.	DESCRIPTION
0	N/A	RFDS-WDSR-15-22 REVISION

TOLERANCE & MACHINE NOTES
(UNLESS OTHERWISE SPECIFIED)

DRAWING PRACTICES, GEOMETRIC SYMBOLS, DIMENSIONING, TOLERANCING & INTERPRETATION BASED ON ASME Y14.5M-1994.

DIMENSIONS IN INCHES BASED ON 68°F.

TOLERANCES:

ONE PLACE DECIMAL	± .1
TWO PLACE DECIMAL	± .02
THREE PLACE DECIMAL	± .005
RADIUS OR CHAMFER ALL EDGES	.005 - .030
FILLET RADII	.03 ± .01
CHAMFERS	± 2°
ANGLES	± .5°

MAXIMUM MACHINED SURFACE - 125 µin Ra √
MAXIMUM SURFACE ROUGHNESS - 250 µin Ra √

WESTINGHOUSE NON-PROPRIETARY CLASS 3

DWG. REF.
NEXT ASSY.
THIRD ANGLE PROJECTION

DRAFTER	RONALD J. KOPREK
DRAFTING CHECKER	JOHN J. BEDNARZ
DESIGNER (IF APPLICABLE)	N/A
DESIGN ENGINEER	ATTILA Z. SZABO
ENGINEERING VERIFIER	ERIC M. WEISEL
OTHER APPROVAL (IF APPLICABLE)	RICHARD P. O'NEILL
OTHER APPROVAL (IF APPLICABLE)	N/A

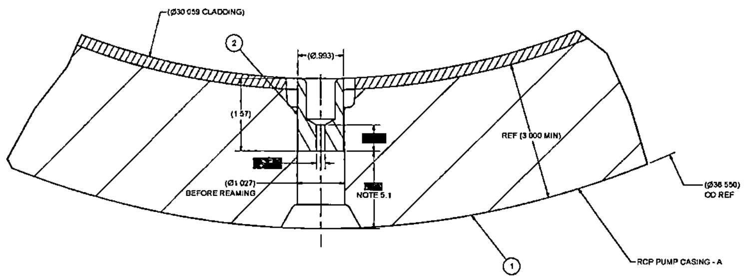
Westinghouse
WESTINGHOUSE ELECTRIC COMPANY LLC
WINDSOR, CT, U.S.A.

TITLE
REPLACEMENT PRESSURE TAP NOZZLE

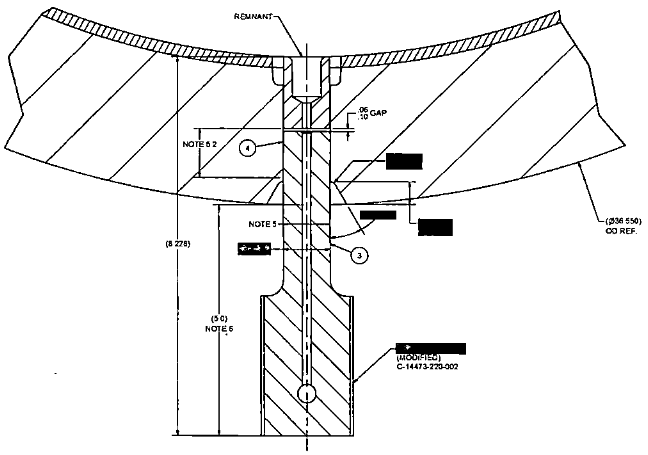
SIZE	FSCM NO.	DWG. NO.	REV.
C		C-14473-220-002-NP	0

SCALE AS NOTED | WEIGHT | SHT 1 OF 1 SHTS

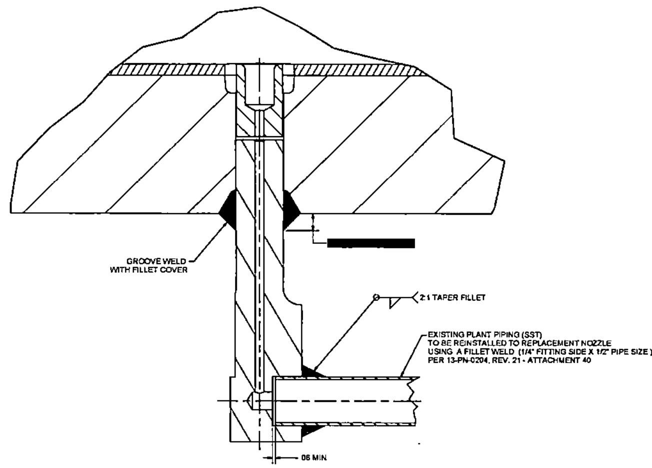
BILL OF MATERIALS					
QTY	ITEM	NOTE	PART NAME	DESCRIPTION	MATERIAL
1	1	1	CASING	NOTE 1	CS
1	2	2	REMNANT	NOTE 2	SB-167 N06600
1	3	3, 5	REPLACEMENT PRESSURE TAP NOZZLE	P/N C-14473-220-002	SB-167 N06690
AR	4	4, 5	WALL STATIC PRESSURE NOZZLE SHIM		SST



DETAIL A
SCALE 1:1
MODIFICATION FOR ITEM 3
ON E-8111-101-2002



DETAIL B
SCALE 1:1



DETAIL C
SCALE 1:1

NOTES

1 MODIFICATION TO THE PRESSURE TAP NOZZLE (ITEM 3) [redacted] FOR CE-KSB TYPE 101 REACTOR COOLANT PUMP (RCP). THIS MODIFICATION APPLIES TO ARIZONA NUCLEAR POWER PROJECT (PVNGS) UNIT 3.

2. ORIGINAL PRESSURE TAP NOZZLE [redacted] TO BE PARTIALLY REMOVED AS SHOWN REMAINING PIECE (REMNANT) APPROXIMATELY Ø 0.993 (OD) INCHES, 1.57 INCHES LONG.

3 REPLACEMENT PRESSURE TAP NOZZLE [redacted] TO BE MODIFIED BEFORE INSTALLATION. [redacted]

4. VARIOUS THICKNESS STAINLESS STEEL SHIMS (0 001, 0 005 INCHES THK.) TO BE UTILIZED TO REDUCE THE GAP BETWEEN THE AS FOUND BORE AND THE REPLACEMENT NOZZLE. [redacted] SEE NOTE 5. SHIM MATERIAL TO BE NON QUALITY RELATED (NQR)

5 ORIGINAL HOLE IN THE RCP TO BE MODIFIED BEFORE INSTALLATION OF ITEM 3 PROVISIONS FOR FOREIGN MATERIAL EXCLUSION (FME) SHALL BE UTILIZED DURING THE REPLACEMENT OPERATIONS.

5 1 REAMING OF THE RCP CASING BORE TO REMNANT (ITEM 2). [redacted] UPON REMOVAL OF THE EXISTING NOZZLE UP TO THE DISTANCE SHOWN, THE BORE DIAMETER IS TO BE MEASURED AND AN APPROPRIATE SIZE REAMER UTILIZED TO CLEAN UP THE BORE [redacted]

5 2 APPROPRIATE THICKNESS STAINLESS STEEL SHIMS (ITEM 4) TO BE INSTALLED INTO THE BOTTOM 1 INCH AREA OF THE REPLACEMENT PRESSURE TAP NOZZLE (ITEM 3) TO LIMIT THE RADIAL CLEARANCE [redacted]

6 REPLACEMENT WELD PER APPROVED PCI OR CUSTOMER WELD PROCEDURES REPLACEMENT PRESSURE TAP NOZZLE TO HAVE A 0 06 - 0.10 INCH GAP TO REMNANT BEFORE WELDING.

NOTE: DESIGN DIMENSIONS ARE IN INCHES. DIMENSIONS IN PARENTHESES ( ) ARE FOR REFERENCE ONLY.

STATUS CFC

ELECTRONICALLY APPROVED RECORDS ARE AUTHENTICATED IN THE ELECTRONIC DOCUMENT MANAGEMENT SYSTEM SEE EDMS FOR DRAWING APPROVAL DATE(S)

SIGNATURES SHOWN ARE FOR CURRENT REVISION

DATABASE FILE ID E-14473-220-001-NP.idw

TOLERANCE & MACHINE NOTES (UNLESS OTHERWISE SPECIFIED)
DRAWING PRACTICES, GEOMETRIC SYMBOLS, DIMENSIONING, TOLERANCING & INTERPRETATION BASED ON ASME Y14.5M-1994
DIMENSIONS IN INCHES BASED ON 68°F
TOLERANCES
ONE PLACE DECIMAL ± 1
TWO PLACE DECIMAL ± .02
THREE PLACE DECIMAL ± .005
RADIUS OR CHAMFER ALL EDGES .005 - .030
FILLET RADII .03 ± .01
CHAMFERS ± 2°
ANGLES ± 5°
MAXIMUM MACHINED SURFACE - 125 μin Ra
MAXIMUM SURFACE ROUGHNESS - 250 μin Ra

WESTINGHOUSE NON-PROPRIETARY CLASS 3

GARY M. TROCOLA
JOHN J. BEDNARZ
N/A
ATTILA Z. SZABO
ERIC M WEISEL
RICHARD P. O'NEILL
N/A

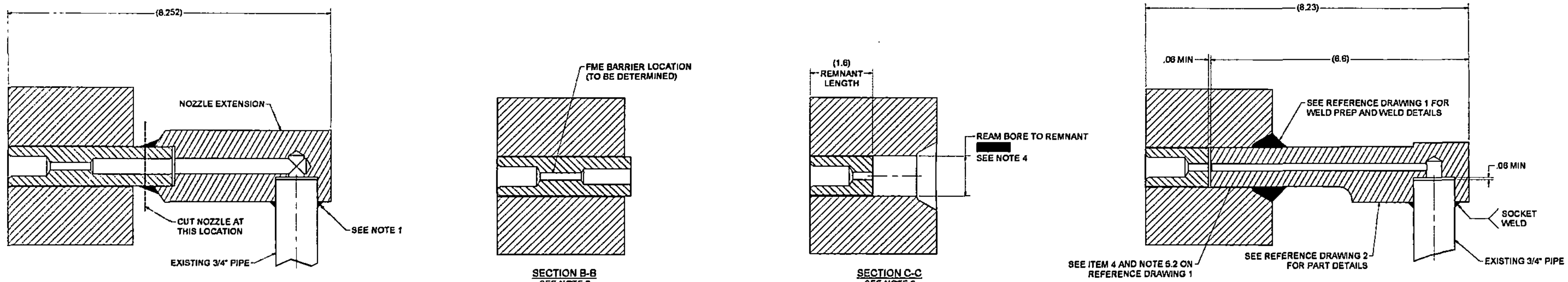
Westinghouse — WESTINGHOUSE ELECTRIC COMPANY LLC WINDSOR, CT U.S.A.

PUMP CASING - A
PRESSURE TAP NOZZLE MODIFICATION
ASSEMBLY

E | E-14473-220-001-NP | 0

AS NOTED | 1 of 1

0 | NA | RFDS-WSGR-15-22 | REVISION



SECTION A-A

SECTION B-B
SEE NOTE 2

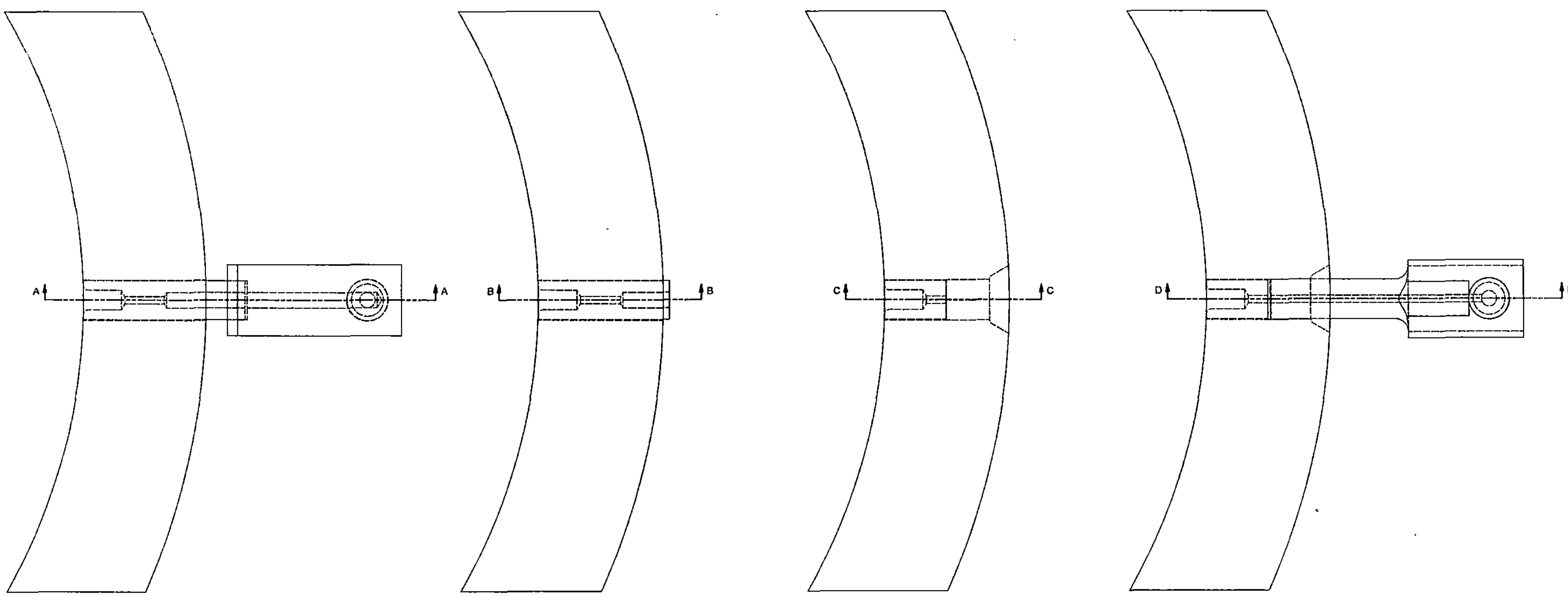
SECTION C-C
SEE NOTE 3

SECTION D-D
SEE NOTE 5

NOTES:

1. REMOVE WELD ON THE 3/4" PIPE TO SQUARE FITTING. AFTER CUTTING THE NOZZLE, THE SQUARE FITTING CAN BE ROTATED AND MOVED AWAY. ADJUST U-BOLT PIPE SUPPORT ON THE 3/4" PIPE AS NECESSARY TO ALLOW ADJUSTMENT OF PIPE.
2. REMOVE THE NOZZLE EXTENSION PIECE AND CONNECTING WELDS SHOWN IN SECTION A-A. INSTALL WATER PLUG INTO ORIFICE AS FME BARRIER.
3. DRILL AND REMOVE A LARGE PORTION OF THE NOZZLE LEAVING A SHORT REMNANT OF THE ORIGINAL ORIFICE. MACHINE/GRIND A NEW PARTIAL PENETRATION WELD PREP INTO THE CASING EXTENSION BASE MATERIAL.
4. PRIOR TO REAMING, MEASURE THE AS-FOUND BORE DIAMETER (HORIZONTAL & VERTICAL MEASUREMENTS) IN (3) LOCATIONS ALONG THE BORE. REPORT THESE MEASUREMENTS TO ENGINEERING FOR DETERMINATION OF THE REAMER SIZE, AND SHIMS USED.
5. INSTALL NEW REPLACEMENT ONE PIECE NOZZLE BY WELDING A NEW PARTIAL PENETRATION WELD. INSTALL THE VERTICAL STAINLESS STEEL PIPE WITH A SOCKET WELD.

REFERENCE DRAWINGS:
1. E-14473-220-001
2. C-14473-220-002



CURRENT CONFIGURATION

STEP 1

STEP 2

STEP 3

NOTE: DESIGN DIMENSIONS ARE IN INCHES. DIMENSIONS IN PARENTHESES ( ) ARE FOR REFERENCE ONLY.

STATUS:

TOLERANCE & MACHINE NOTES
(UNLESS OTHERWISE SPECIFIED)
DRAWING PRACTICES, GEOMETRIC SYMBOLS, DIMENSIONING, TOLERANCING & INTERPRETATION BASED ON ASME Y14.5M-1994
DIMENSIONS IN INCHES BASED ON 68°F.
TOLERANCES:
ONE PLACE DECIMAL ± .1
TWO PLACE DECIMAL ± .02
THREE PLACE DECIMAL ± .005
RADIUS OR CHAMFER ALL EDGES .005 - .030
FILLET RADII .03 ± .01
CHAMFERS ± 2°
ANGLES ± .5°
MAXIMUM MACHINED SURFACE - 125 μin Ra
MAXIMUM SURFACE ROUGHNESS - 250 μin Ra

ELECTRONICALLY APPROVED RECORDS ARE AUTHENTICATED IN THE ELECTRONIC DOCUMENT MANAGEMENT SYSTEM
SEE EDMS FOR DRAWING APPROVAL DATE(S)

WESTINGHOUSE NON-PROPRIETARY CLASS 3

SIGNATURES SHOWN ARE FOR CURRENT REVISION
KEVIN L. McCALL
JOHN J. BEDNARZ
N/A
KEITH E. COE
N/A
ATTILA Z. SZABO
N/A

DATABASE FILE ID
SE-14473-220-003-NP.idw

Westinghouse — WESTINGHOUSE ELECTRIC COMPANY LLC, WINDSOR, CT U.S.A.

PRESSURE TAP
NOZZLE REPLACEMENT
PALO VERDE UNIT 3

E | NA | SE-14473-220-003-NP | 0 | 1 of 1

0 | RFDS-WDSR-15-22 | REVISION