INL USQ PROCESS
REASONABILITY DETERMINATION/POTENTIAL INADEQUACY IN THE SAFETY ANALYSIS (PISA) FORM
(DO NOT USE FOR PROPOSED CHANGES)

Facility or Activity: Advanced Test Reactor

USQ Process No.: ATR Complex-USQ-2009-631

Subject: ATR Primary Coolant System pH Control

Describe the New Information/Discovery:

Engineering Calculations and Analysis Report ECAR-571, ATR Primary Coolant System Filterable Solids Limits, states, "if the ATR PCS [primary coolant system] is operated at the lower pH limits allowed by TSR-186 [LCO-3.3.5], it would be dangerously close to, or may even begin to dissolve the boehmite layer on the fuel. The main concern is that upon pH adjustment back into the normal operating range the dissolved aluminum can replate out on the hot surfaces of the fuel. However, it would not be in a crystalline boehmite form but rather a gelatinous boehmite which can significantly impede heat transfer. The transformation of gelatinous boehmite to crystalline boehmite is further impeded by dissolved carbonates (which are present in the ATR PCS). Thus, there is a danger that ATR could buckle fuel as was observed at the ETR (cycle 108) after a pH excursion."

ECAR-571 further states "a bulk water pH of less than 4.9 is dangerously low."

jcc 9-14-09

TRS-186 LCO-3.3.5 allows the PCS pH to be ≥4.8 but ~~>~~ ≤ 5.4 during power operations.

zp 5/14/09

Identify the applicable safety basis document(s) (e. g., DSA, SAR, BIO, TSRs, etc.):
SAR-153, Upgraded Final Safety Analysis Report for the Advanced Test Reactor, Revision 26
TSR-186, Technical Safety Requirements for the Advanced Test Reactor, Revision 22
Pending SAR-153, Upgraded Final Safety Analysis Report for the Advanced Test Reactor, Revision 27
Pending TSR-186, Technical Safety Requirements for the Advanced Test Reactor, Revision 23

I. REASONABILITY DETERMINATION (Reasonability determinations made as part of the ATR Design Basis Reconstitution effort may be documented per SP-10.2.4.9)

Is it reasonable that the potential for an inadequate safety analysis exists based on the new information or discovery described above? ☒ Yes ☐ No

If "Yes," proceed to Sections II, III, and IV.
If "No," provide an explanation and basis for the reasonability determination.

USQ Evaluator Print/Type Name	USQ Evaluator Signature	Date
Nuclear Facility Manager Print/Type Name	Nuclear Facility Manager Signature	Date

If the answer to the question above is "No," file the completed form. Do not complete Section II, III, or IV.

If the answer to the question above is "Yes," complete Section II, III, and IV.

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II. PISA DECLARATION

What is the basis for concern that the safety basis may not be bounding or may be otherwise inadequate? Provide an explanation.

After an excursion of pH to less then approximately 5.0, e.g., pH between 4.8 and 5.0, the passivated crystalline boehmite, hydroxide, surface may dissolve in the acidic PCS. The LCO-3.3.5 actions allow the power operations to continue and to raise the pH to ≥5.0. The higher pH may cause the dissolved aluminum hydroxide to reform as gelatinous boehmite, but not re-passivate and continue to thicken. The thicker gelatinous boehmite could inhibit heat transfer from the fuel element to the PCS.

A PISA exists. Complete the following actions

- Nuclear Facility Manager document actions (below) including interim operating restrictions taken to place or maintain the facility in a safe condition.
- Nuclear Facility Manager execute reporting process for PISA per LWP-9301 and LWP-13830.
- Qualified USQ evaluator proceed to Section III.

ACTIONS TAKEN TO PLACE OR MAINTAIN FACILITY IN A SAFE CONDITION AND THE BASIS FOR THE SELECTION OF ANY INTERIM CONTROLS.

At the time of discovery the ATR was in a scheduled outage. No immediate actions were necessary to place the plant in a safety conditions.

Interim controls: Primary coolant pH shall be ≥5.0 but ≤5.4.
Applicability: POWER OPERATION

ACTIONS:

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. PCS pH: ≥4.9 but < 5.0 **OR** > 5.4 but ≤5.5	A.1 Restore pH. **OR** A.2.1 Verify reactor scram. **AND** A.2.2 Maintain PCS flow.	8 Hours Until SR 4.5.1.2 cooling time is met
B. PCS pH as verified on 2 of 2 or 2 of 3 samples taken at ≤30 minute intervals: < 4.9 **OR** > 5.5	B.1 Verify reactor scram. **AND** B.2 Maintain PCS flow. **AND** B.3 For low pH, verify the presence of the specified oxide on affected FUEL ELEMENTS ≤1.0 mil for planned operation.	IMMEDIATELY Until SR 4.5.1.2 cooling time is met Prior to reuse of affected FUEL ELEMENTS for POWER OPERATION

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SURVEILLANCE REQUIREMENTS:

SR #	SURVEILLANCE REQUIREMENT	FREQUENCY
4.3.5.1	Verify pH by analysis	Each Shift
4.3.5.2	Verify recycled FUEL ELEMENTS have NOT been exposed to pH < 4.9 during POWER OPERATION	Prior to reuse of recycled FUEL ELEMENTS in POWER OPERATION

J C Chapman	See Original	8/20/09
Safety Analyst Print/Type Name	Safety Analyst Signature	Date
E J Schuebert	See Original	8/20/09
Nuclear Facility Manager Print/Type Name	Nuclear Facility Manager Signature	Date

Is independent technical review required? Yes ☐ No ☐

See Original
Nuclear Facility Manager Signature or Initials

Independent Reviewer Print/Type Name	Independent Reviewer Signature	Date

III. USQ DETERMINATION

Identify applicable section(s) of the safety basis document(s) (e.g., DSA, SAR, BIO, TSRs, etc.).

SAR-153 §4.2.1.5.3 Fuel Element Structural Design:

Chemical compatibility among core components is maintained by the use of high aluminum-content alloys for most of the components in the active core region. Allowable limits on pH, conductivity, and filterable solids in the primary coolant prevent excessive corrosion product buildup on the fuel plates.

SAR-153 §4.2.3.1.1 Chemical Evaluation:

Extensive ex-reactor corrosion studies performed by Oak Ridge National Laboratory (ORNL) tests in support of the ATR design (Griess, Savage, and English 1964) showed that the corrosion rate decreases with exposure time and increases with surface temperature. The controlling temperature is at the corrosion product-water interface (i.e., surface temperature). For a coolant pH of 5.0 and heat fluxes between 1×10^6 and 2×10^6 Btu/hr·ft^2 (3×10^6 and 6×10^6 W/m^2).

The ORNL tests also showed that the pH of the coolant is an important variable affecting the rate of corrosion-product buildup. On the basis of the ORNL experiments, it was concluded that 6061 aluminum would have adequate corrosion resistance for use as ATR fuel plate cladding provided the pH of the primary coolant was maintained at 5.0 with nitric acid. PCS pH was originally controlled at 5.0 ± 0.2 during power operation. The method of control was changed from nitric acid addition to use of the bypass demineralizer system. After a trial period (Durney 1980), the upper limit was raised to 5.4 giving an allowable range of 4.8 to 5.4 starting with Cycle 49A (Durney 1982). Many years of operating experience have shown that the current limits (4.8 to 5.4 for reactor operation at greater than 3 MW) are sufficient to control corrosion.

The measured fuel plate oxide thickness vs. accumulated exposure data from Cycle 22B through Cycle 100C (1974 to 1994) are summarized in McCracken (1993). Except for a small number of observations around 1 mil, the data show the oxide thickness tends to be self-limiting in the range of 0.4 to 0.6 mil. PCS water chemistry limits on pH and filterable solids are established in

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part to control oxide growth. PCS pH is controlled at 4.8 to 5.4.

SAR-153 Table 4.4-6 Reactor Coolant System Component Thermal and Hydraulic Data

This table notes that Nominal PCS pH is 4.8 to 5.4.

SAR-153 Section 5.1.4 System Description

Primary Coolant pH and purity (which is concerned primarily with radioactivity and dissolved and suspended solids) are maintained by processing primary coolant through an anion-cation bypass demineralizer system before returning to the PCS through a 6-in. pipe.

SAR-153 §5.2 Integrity of the Primary Coolant Pressure Boundary:

Control of PCPB [primary coolant pressure boundary] materials, chemistry, and environment to prevent brittle fracture failure modes or overtemperature. Critical parameters are controlled by TSRs such as those for pressure, temperature, and primary coolant pH.

SAR-153 §5.2.3.2 Compatibility with Primary Coolant:

Table 5.1-2, Item (f) lists nominal operating ranges for the primary coolant chemistry. Limits on pH, conductivity, dissolved minerals, and filterable solids help ensure that excessive oxide deposition on the fuel elements or aluminum corrosion does not occur as a result of primary coolant chemistry.

SAR-153 Table 5.1-2 Primary Coolant System design and performance characteristics:

(f) Nominal operating primary coolant chemistry:
pH, Reactor power > 3 MW, 5.0-5.2
pH, Reactor power < 3 MW, 4.9-5.8

(These ranges are changed to 4.8 to 5.4 and 4.8 to 6.0 in the 2009 annual update of SAR-153)

SAR-153 §9.2.10.1 ATR Chemistry Control:

The pH of the purified coolant is kept slightly acidic to minimize the formation, transportation, and deposition of aluminum corrosion products and to reduce aluminum fuel cladding corrosion rates.

SAR-153 §16.2.2.4 Coolant System:

The performance of the aluminum fuel elements is affected by the oxide layer formed during operation. The oxide layer is influenced by the pH of the water and by the impurities. Consequently, the chemistry parameters of the coolant are important controls. The oxide development has been shown acceptable with the pH maintained ≥4.8 and ≤5.4 when the fuel element is at temperature and initially has a thin layer of Boehmite. The fuel element temperatures are considered significant when the power level is at 3 MW or more. When the power level is less than 3 MW, there is negligible oxide formation due to the reduced temperature, and the pH range is expanded to ≥4.8 and ≤6.0. Since the oxide formation is negligible under these conditions, the control of pH at powers ≤3 MW is contained in operating documents and is not a LCO. The conductivity for these two pH ranges is ≤6 micro mhos/cm for power operation and ≤10 micro mhos/cm at other times. The limits on pH in concert with quality controls during manufacture and handling provide assurance that the oxide layer on the fuel element cladding will be within the range assumed for the accident analysis and in the range for adequate heat removal during normal operation. The formation of the initial oxide layer (Boehmite) is a requirement included in the LCOs. The pH represents a process variable considered in the accident analysis as an initial condition. Control of the pH at power levels above 3 MW is a LCO. The verification of conductivity is appropriate for operating documents.

SAR-153 §16.3.2.4 Coolant System:

The pH of the primary coolant is to be verified during reactor operation when power level is greater than 3 MW.

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TSR-186 LCO 3.3.5 Primary Coolant pH:

Primary coolant pH shall be ≥4.8 but ≤5.4

TSR-186 Bases 3.3.5 Primary Coolant pH:

Chemistry of the PCS coolant may have a significant effect on the oxides formed on the operating fuel element cladding. The oxide results in a resistance to transfer of heat and affects the operating temperature of the fuel plate. The significant chemistry parameter is the acidity or pH of the water. The pH of the coolant is specified to minimize the amount of oxides formed and deposited on the heated surfaces of the fuel plate. The pH range has been shown from research and verified by experience to result in acceptable oxide thickness.

The pH is controlled within the range of 4.8 to 5.4 to minimize the development of oxide thickness on the fuel plate cladding and to minimize dissolved aluminum in the coolant.

Without proper control of the pH, there is potential for excessive oxide development. Oxides represent a resistance to transfer of heat to the coolant. Retaining heat in the plate will result in excessive temperatures and potential melting of the cladding. A compromise of the cladding will result in release of fission products.

The pH range is required as an LCO since it represents control of the oxide thickness. The oxide thickness is modeled into the SINDA code used to calculate fuel plate temperatures.

TSR-186 Bases 3.6.3 Oxide Thickness:

The initial oxide layer in concert with the pH limits provides assurance that the oxide thickness on the fuel element cladding will be consistent with the historical observations. The accident analysis assumed an oxide thickness that envelops the historical observations.

References:

Durney, J. L., 1980, letter to A. L. Bowman, "ATR Power Limit for Higher pH in the PCS," JLD-21-80 (Rev. 1), EG&G Idaho, Inc., October 17, 1980.

Durney, J. L., 1982, letter to D. R. Mousseau, "Effect of pH on ATR Oxides," JLD-17-82, EG&G Idaho Inc., July 9, 1982.

Griess, J. C., H. C. Savage, and J. L. English, 1964, *Effect of Heat Flux on the Corrosion of Aluminum by Water*, Part IV, Tests Relative to the Advanced Test Reactor and Correlation with Previous Results, ORNL-3541, Oak Ridge National Laboratory, February 1964.

McCracken, R. T., 1993, "ATR Fuel Element Oxide Data Summary," EDF TRA-ATR-891, EG&G Idaho, Inc., November 15, 1993.

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IIIa: POTENTIAL FOR AN INCREASE IN PROBABILITY OR CONSEQUENCE OF AN ACCIDENT OR MALFUNCTION EVALUATED IN THE SAFETY BASIS

ATR fuel elements have a thin (~ 0.1 mil) crystalline boehmite (aluminum hydroxide) corrosion layer applied during fabrication. Aluminum hydroxide is highly resistant to corrosion within a pH ranged defined by passivation of the hydroxide layer. The fabrication process ensures the passivation of the boehmite layer. In SAR-153 this corrosion layer (the aluminum hydroxide, or boehmite) is generally called the oxide layer. Passivation breaks down in low pH aqueous solutions in which high hydrogen ion concentration dissolve the hydroxide. When the pH is raised, the dissolved aluminum hydroxide preferentially precipitates onto hot aluminum surfaces as gelatinous boehmite. In addition, the corrosion layer will continue to grow, as gelatinous boehmite. The high radiation in the core inhibits the passivation of the boehmite, while the gelatinous boehmite layer continues to thicken limited only by spalling. (Reference ECAR-571) If the low pH is not raised, the fuel cladding will continue to corrode.

1. Could the PISA increase probability of occurrence of an accident previously evaluated in the safety basis?
Yes ☒ No ☐
Explain:

TSR-186 LCO 3.3.5 allows restoring the primary coolant pH provided that the pH remained greater than 4.7 and continuing power operation with the primary coolant pH of 4.8 or greater (not considering the high primary coolant pH condition). The low pH will dissolve the passivated boehmite layer and corrode the aluminum, thinning the aluminum cladding and the structural aluminum components of the fuel elements. Restoring the primary coolant pH (to the nominal operating range ~ 5.0) will precipitate the dissolved aluminum hydroxide on to hot aluminum surfaces in a gelatinous hydroxide form. The PISA identifies the possibility of the oxide layer on ATR fuel elements thickening due to performing actions permitted by TSR-186 after a low primary coolant pH excursion. The thickening of the oxide layer ~~on~~ could adversely affect the assumptions in the safety basis analyses. 8/9/10/09

The accidents for which the oxide thickness is an important parameter are all accidents in which heat energy must be transferred from the fuel elements to the primary coolant. These accidents include: a) decrease in heat removal, b) decrease in reactor primary coolant flow rate, c) reactivity and power distribution anomalies, d) decrease in primary coolant inventory, e) dropping an irradiated fuel element, f) fuel channel blockage, and g) gas leakage into fuel channel. Of these accidents, only SAR-153 section 15.10.7, Fuel Plate buckling Due to an Excessive Buildup of Oxide on Fuel Plate Surface, addresses potential oxide buildup on fuel element plates. No causes for the excessive oxide buildup were identified. Section 15.10.7, however, states "Excessive oxide buildup is considered a Condition 3 event because of the meticulous chemistry control of the primary coolant and routine oxide surveillance measurements at the end of each cycle." The thicker gelatinous boehmite could reduce or occlude flow thorough the fuel element coolant channels. Reduced or occluded flow would impede adequate heat transfer and could increase the pressure drop, the flow force, across the core. The resultant higher fuel temperatures and forces on the fuel element could result in fuel plate buckling which will further obstruct the flow through the fuel element channel. The PISA identifies the potential for allowed, but inappropriate primary coolant pH control, which may cause excessive oxide buildup; restoring pH after a low pH excursion could increase the frequency of occurrence of excessive oxide buildup.

2. Could the PISA increase the consequences of an accident previously evaluated in the safety basis?
Yes ☒ No ☐
Explain:

LCO 3.3.5 allows restoring the primary coolant pH provided the pH remained greater than 4.7 and continuing power operation with the primary coolant pH of 4.8 or greater (not considering the high primary coolant pH condition). The low pH will dissolve the passivated boehmite layer and corrode the aluminum, thinning the aluminum cladding and the structural aluminum components of the fuel elements. Restoring the primary coolant pH (to the nominal operating range ~ 5.0) will precipitate the dissolved aluminum hydroxide on to hot aluminum surfaces in a gelatinous hydroxide form. The PISA identifies the possibility of the oxide layer on ATR fuel elements thickening due to performing actions permitted by TSR-186 after a low primary coolant pH excursion. The thickening of the oxide layer ~~on~~ could adversely affect the assumptions in the safety basis analyses. 8/9/10/09

The ATR Plant Protection Criteria (PPC), in part, are based on calculated thermal-hydraulic margins (i.e., standard deviations to departure from nucleate boiling [DNB] and flow instability) for the primary coolant flow through the core during hypothesized design basis accidents. The SINDA-SAMPLE analysis software is used to calculate core flow thermal-hydraulic margins. SINDA-SAMPLE uses Monte Carlo sampling to determine the statistical distribution of a specific phenomenon (e.g., DNB

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margin) given the statistical distribution of each parameter used to quantify that phenomenon. The parameters used to evaluate thermal-hydraulic margins and their variations are listed in SAR-153 Table 4.4-4. The corrosion film (oxide) thickness on ATR fuel elements is one of those sampled parameters. Fundamental to the statistical distribution is that during normal power operations nothing is done to skew the distribution. Inappropriate primary coolant pH control could skew the statistical distribution of the oxide thickness from that assumed in the SINDA-SAMPLE analyses. In addition, the gelatinous layer may have excess water intercalated between the boehmite crystalline structure; the intercalated water may change the thermal properties of the oxide layer. Thus, the PISA could increase the consequences of all of the accident analyses that used SINDA-SAMPLE to calculate the thermal-hydraulic margins. The consequences would include reduced heat transfer from the fuel element due to the thicker oxide layer. The reduced heat transfer from the fuel would result in reduced thermal-hydraulic margins, increased fuel and fuel plate temperatures, increased fuel cladding failures and the resultant fission product release, and increased fuel melt. Increased fuel cladding failures and increased fuel melt would increase the consequences of the analyzed accidents. These accidents include: a) decrease in heat removal, b) decrease in reactor primary coolant flow rate, c) reactivity and power distribution anomalies, d) decrease in primary coolant inventory, e) fuel channel blockage, and f) gas leakage into fuel channel.

In addition, the analysis of a dropped irradiated fuel element, SAR-153 section 15.8.5, assumes a thin boehmite layer on the fuel element cladding. This Condition 2 accident resulted in no fuel damage provided sufficient cooling time is allowed prior to fuel handling. Inappropriate pH control could result in an increased oxide thickness by causing the boehmite layer to dissolve and reform in the thicker gelatinous form. Decay heat removal could be impeded by the thicker gelatinous boehmite layer. The PISA could mean that the cooling times specified by TSR-186 LCO 3.5.1 prior to fuel handling are insufficient after a low pH excursion to preclude fuel damage from a dropped fuel element. Thus the PISA could increase the consequence of dropping an irradiated fuel element if handled as permitted by the safety basis.

3. Could the PISA increase the probability of occurrence of a malfunction of equipment important to safety previously evaluated in the safety basis? Yes ☒ No ☐

Explain:

LCO 3.3.5 allows restoring the primary coolant pH provided the pH remained greater than 4.7 and continuing power operation with the primary coolant pH of 4.8 or greater (not considering the high primary coolant pH condition). The low pH will dissolve the passivated boehmite layer and corrode the aluminum, thinning the aluminum cladding and the structural aluminum components of the fuel elements. Restoring the primary coolant pH (to the nominal operating range ~ 5.0) will precipitate the dissolved aluminum hydroxide on to hot aluminum surfaces in a gelatinous hydroxide form. The PISA identifies the possibility of the oxide layer on ATR fuel elements thickening due to performing actions permitted by TSR-186 after a low primary coolant pH excursion. The thickening of the oxide layer ~~on~~ could adversely affect the assumptions in the safety basis analyses.
9/11/09

The ATR fuel element cladding is the primary barrier against the release of fission products. Heat energy during reactor operations and during and following upset conditions must be adequately removed, or the integrity of the fuel element cladding can not be assured. The PISA suggests the possibility of a gelatinous boehmite layer reforming on the fuel element surface after a low pH excursion. The gelatinous layer could impede the removal of heat from the cladding which could result in cladding failure. Also the gelatinous boehmite could reduce or occlude the primary coolant flow through fuel element flow channels. Reduced or occluded flow could result in fuel channel buckling and fuel failure. Thus, inappropriate pH control could increase the probability of fuel element cladding and fuel element failure.

4. Could the PISA increase the consequences of a malfunction of equipment important to safety previously evaluated in the safety basis? Yes ☐ No ☒

Explain:

LCO 3.3.5 allows restoring the primary coolant pH provided the pH remained greater than 4.7 and continuing power operation with the primary coolant pH of 4.8 or greater (not considering the high primary coolant pH condition). The low pH will dissolve the passivated boehmite layer and corrode the aluminum, thinning the aluminum cladding and the structural aluminum components of the fuel elements. Restoring the primary coolant pH (to the nominal operating range ~ 5.0) will precipitate the dissolved aluminum hydroxide on to hot aluminum surfaces in a gelatinous hydroxide form. The PISA identifies the possibility of the oxide layer on ATR fuel elements thickening due to performing actions permitted by TSR-186 after a low primary coolant pH excursion. The thickening of the oxide layer ~~on~~ could adversely affect the assumptions in the safety basis analyses.
9/11/09

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The fuel element cladding is the primary barrier against the release of fission products. Failure of the cladding could release fission products into the primary coolant, the storage canal, or the environment depending on the event scenario. Although, as discussed, the frequency of occurrence of fuel element cladding failure could increase due to the PISA, the consequences of fuel failure, however, would remain unchanged.

IIIb: POTENTIAL FOR CREATION OF AN UNANALYZED ACCIDENT OR MALFUNCTION OF A DIFFERENT TYPE

5. Could the PISA create the possibility of an accident of a different type than previously evaluated in the safety basis? Yes ☒ No ☐

Explain:

LCO 3.3.5 allows restoring the primary coolant pH provided the pH remained greater than 4.7 and continuing power operation with the primary coolant pH of 4.8 or greater (not considering the high primary coolant pH condition). The low pH will dissolve the passivated boehmite layer and corrode the aluminum, thinning the aluminum cladding and the structural aluminum components of the fuel elements. Restoring the primary coolant pH (to the nominal operating range ~ 5.0) will precipitate the dissolved aluminum hydroxide on to hot aluminum surfaces in a gelatinous hydroxide form. The PISA identifies the possibility of the oxide layer on ATR fuel elements thickening due to performing actions permitted by TSR-186 after a low primary coolant pH excursion. The thickening of the oxide layer ~~on~~ could adversely affect the assumptions in the safety basis analyses.
9/16/09

After sufficient cooling time, for the purposes of fuel element storage requirements, ATR fuel elements are not longer defined as "irradiated" and can be and are transferred to the unprotected section of the ATR storage canal, that is the fuel is not protected from large canal draining accidents. The safety analysis determined that these "unirradiated" fuel elements would be sufficiently cooled in air and that no fuel melt, or fission product release, would result from draining the unprotected storage canal area. The safety analysis assumes that a thin boehmite layer is on the fuel element cladding. The PISA suggests the possibility of a thick gelatinous boehmite layer reforming on the surface after a low pH excursion. The gelatinous boehmite layer could impede the removal of decay heat from the fuel which could result in cladding and fuel failure. In addition, the potential change in thermal properties of the oxide layer due to intercalated water could also adversely affect the heat transfer from the fuel. The safety basis analyses do not consider melting unirradiated fuel, i.e., fuel stored in the unprotected section of the storage canal, due to a canal drain event to be a design basis accident. Since adequate cooling may not be accomplished due to the thicker, gelatinous boehmite layer, the PISA suggests the possibility of a new type of design basis accident.

6. Could the PISA create the possibility of a malfunction of equipment important to safety of a different type than previously evaluated in the safety basis? Yes ☐ No ☒

Explain:

LCO 3.3.5 allows restoring the primary coolant pH provided the pH remained greater than 4.7 and continuing power operation with the primary coolant pH of 4.8 or greater (not considering the high primary coolant pH condition). The low pH will dissolve the passivated boehmite layer and corrode the aluminum, thinning the aluminum cladding and the structural aluminum components of the fuel elements. Restoring the primary coolant pH (to the nominal operating range ~ 5.0) will precipitate the dissolved aluminum hydroxide on to hot aluminum surfaces in a gelatinous hydroxide form. Although there are other hot aluminum surfaces in the core region, the dissolved aluminum hydroxide will preferential precipitate on the hottest surfaces, i.e., the fuel element cladding. Boehmite buildup on other in-core components (e.g., flux trap baffle tubes, safety rod guide tubes and flux tape fillers), which have comparatively large water gaps or annuli, would not adversely affect their safety function.

Except for aluminum, the effect of the current primary coolant pH control on the primary coolant system is addressed in the safety basis. The PISA does not create the possibility of a malfunction of any equipment important to safety of a different type.

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IIIc: POTENTIAL FOR REDUCTION IN A MARGIN OF SAFETY

7. Could the PISA reduce a margin of safety as defined in the safety basis? Yes ☒ No ☐

Explain:

LCO 3.3.5 allows restoring the primary coolant pH provided the pH remained greater than 4.7 and continuing power operation with the primary coolant pH of 4.8 or greater (not considering the high primary coolant pH condition). The low pH will dissolve the passivated boehmite layer and corrode the aluminum, thinning the aluminum cladding and the structural aluminum components of the fuel elements. Restoring the primary coolant pH (to the nominal operating range ~ 5.0) will precipitate the dissolved aluminum hydroxide ~~on to~~ onto hot aluminum surfaces in a gelatinous hydroxide form. EJ 9/14/09

The SINDA-SAMPLE analyses assume a nominal thickness, variation in thickness and type (boehmite) of fuel element cladding corrosion layer, but not its form, i.e., crystalline or gelatinous. The PISA suggests the possibility of a gelatinous oxide layer reforming on the surface after a low pH excursion. In addition, the gelatinous layer may have excess water intercalated between the octahedral boehmite crystalline structure, which may affect the thermal properties of the oxide layer. The gelatinous layer could be thicker than assumed in the analyses and could have different thermal properties. The thicker gelatinous layer could impede the heat transfer from the cladding. In this case, the calculated margins to the ATR thermal-hydraulic PPC would be reduced. In addition, the potential change in thermal properties of the oxide layer could also adversely affect the thermal-hydraulic margins.

IIId: USQ DETERMINATION CONCLUSION

8. Based on the responses to questions 1 – 7 above, does the PISA constitute an Unreviewed Safety Question?
Yes ☒ No ☐

Explain:

LCO 3.3.5 allows restoring the primary coolant pH provided the pH remained greater than 4.7 and continuing power operation with the primary coolant pH of 4.8 or greater (not considering the high primary coolant pH condition). The low pH will dissolve the passivated boehmite layer and corrode the aluminum, thinning the aluminum cladding and the structural aluminum components of the fuel elements. Restoring the primary coolant pH (to the nominal operating range ~ 5.0) will precipitate the dissolved aluminum hydroxide ~~on to~~ onto hot aluminum surfaces in a gelatinous hydroxide form. The PISA identifies the possibility of the boehmite oxide layer on ATR fuel element cladding thickening due to performing actions permitted by TSR-186 LCO 3.3.5 after a low primary coolant pH event. Oxide thickness is assumed to be 1 mil in the safety analyses; thicker oxide layer could impede heat energy removal from the fuel elements. Insufficient heat removal both increases the probability of analyzed accidents (fuel damage due to draining the unprotected section of the ATR storage canal and excessive thickening of the oxide layer) and the consequences of many analyzed accidents and create a design basis accident of a different type (draining the unprotected storage canal area). EJ 9/14/09

If "No," is a Safety Basis document revision required at next annual update? ☐ Yes ☐ No

NOTE: If USQ determination result is positive, additional notification for ORPS is required per LWP-9301.

IV. APPROVAL/CONCURRENCE SIGNATURES

APPROVAL:

J C Chapman USQ Evaluator Print/Type Name	J C Chapman USQ Evaluator Signature	14 Sep 2009 Date
E J Schuebert Nuclear Facility Manager Print/Type Name	E J Schuebert Nuclear Facility Manager Signature	9/14/09 0945 Date

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CONCURRENCE:

J A Jacobi	Jack A Jacobi	9/17/09
Independent Review Committee Chair Print/Type Name	Independent Review Committee Chair Signature	Date