# ATTACHMENT 2

# TO P-91298

# PROPOSED CHANGES

top casing. In this case, the local temperature in the concrete would be less than 250°F, an allowable and acceptable concrete temperature. (FSAR Section 5.4.5.3).

## Specification LCO 4.2.15 - PCRV Cooling Water System Temperatures, Limiting Conditions for Operation

The limiting conditions for the PCRV cooling water system temperatures utilize the following water temperature definitions:

Inlet Water Temperature - is the water temperature measured at the common PCRV cooling water heat exchanger outlet in each loop.

Outlet Water Temperature - is the water temperature measured at the common PCRV cooling water discharge from the Core Support Floor, Lower Barrel Section, and Upper Barrel Section and Top Head in each loop.

With the reactor shut down, the temperature of the PCRV cooling water system shall be maintained within the limits stated below:

a) The maximum temperature difference between the outlet water temperature of the PCRV cooling water system, and the PCRV external concrete surface temperature, averaged over 24 hours, shall not exceed 50°F.

b) The maximum outlet water temperature of the PCRV cooling water system shall not exceed 105°F.

c) The maximum temperature difference between the outlet water temperature and the inlet water temperature of the PCRV cooling water system shall not exceed 20°F.

d) The maximum rate of change of the PCRV concrete temperature shall not exceed 14°F per week, as indicated by the weekly average outlet water temperature of the PCRV cooling water system.

e) The minimum average of the inlet and outlet cooling water temperatures shall be greater than or equal to 85°F.

Basis for Specification LCO 4.2.15

The PCRV concrete may experience non-uniform temperature distribution since the PCRV liner will generally be at temperatures greater than Reactor Building ambient temperatures. These non-uniform temperatures result in thermal stresses in the self-strained structure, but these stresses tend to relax due to creep and other inelastic effects, particularly in areas of local stress concentration. Therefore, only the bulk temperature of the PCRV concrete is considered in establishing the acceptable thermal loading of the PCRV.

In addition to temperature gradients through the walls, the concrete temperature varies locally between cooling tubes; this, however, involves only a small amount of concrete. The original cooling system specification which applied during reactor power operation ensured that the temperature of the concrete between cooling tubes was limited to 150°F. In certain cases, local concrete temperatures of 250°F would be acceptable, if the affected area is small, since the resulting possible small loss in concrete strength can be tolerated. The 105°F limit on the maximum PCRV cooling water outlet temperature will also conservatively serve to ensure concrete temperature does not exceed 150°F.

Due to the very large bulk of concrete, and the relatively long time-constant for response for temperature changes, short-term variations in the temperature of the air in contact with the vessel, or the PCRV liner, can be tolerated without development of undesirable stresses. Similarly, significant changes in the bulk concrete temperature must be performed slowly such that the average bulk temperature changes at a rate no greater than 14°F per week.

The 85°F minimum average PCRV cooling water temperature restriction provides assurance that average fuel temperature cannot decrease below 80°F, under conditions of interruption of all forced circulation (when primary coolant temperatures cannot be accurately measured), with very low decay heat generation rates. The shutdown margin assessments identified in LCO/SR 3/4.1.4 and 3/4.1.6, and discussed in their bases, assume an average fuel temperature of 80°F in determining the reactivity contribution due to the negative temperature coefficient of reactivity. Maintaining the average PCRV liner temperature above 85°F will provide assurance that average fuel temperature remains above 80°F, even under conditions of interruption of all forced circulation, so that the temperature assumption associated with the shutdown margin assessment remains valid.

FSAR Sections 5.7.2.2 and E.24.5 discuss the experimentally determined nil ductility transition (NDT) temperatures of all heats of liner material (including weldment material), before and following exposure to an integrated neutron dose of 2.3 E18 $n/cm^2$ ($E \geq 1$ MeV). This value represents the maximum dose to the most highly irradiated portion of the liner, at the top head, assuming a 30 year operational lifetime with an 80% capacity factor (24 effective full power years or 8760 effective full power days - EFPD).

The reactor was permanently shut down after having accumulated 890 EFPD, approximately one-tenth of the liner design lifetime. Therefore, the NDT temperatures of the liner and weldment materials would only increase approximately one-tenth of the range observed in the experimental tests, whose results are documented in FSAR Table E.24-16. The end-of-life fracture transition elastic (FTE) temperature, approximately equal to the end-of-life NDT + 60°F, is calculated to be less than 15°F for both the liner and weldment materials.

Maintaining the liner temperature above the FTE temperatures of the liner and weldment materials ensures that crack propagation in the liner at any tensile membrane stress up to yield stress would be incredible, and in this respect the liner meets the same criteria as are prescribed for steel nuclear pressure vessels, but is more conservative since the liner is in general compression for all normal operation modes.

Limiting the average cooling water temperature to a minimum of 85°F and the maximum inlet to outlet temperature difference to 20°F ensures that the top head liner material average temperatures will be in excess of 85°F at all times.

# ATTACHMENT 3

# TO P-91298

# NO SIGNIFICANT HAZARDS CONSIDERATION ANALYSIS

# NO SIGNIFICANT HAZARDS CONSIDERATION ANALYSIS

## BACKGROUND

Technical Specification LCO 4.2.15.e) requires that *"The minimum average of the inlet and outlet cooling water temperatures shall be greater than or equal to 100°F."* PSC is proposing to revise this minimum average temperature requirement from 100°F to 85°F. The reason for the proposed change is to reduce the amount of heat input necessary to the PCRV liner cooling water system from the auxiliary steam system.

In addition to LCO 4.2.15.e), PSC also proposes a revision to LCO 4.2.15.b), which states that *"The maximum outlet water temperature of the PCRV cooling water system shall not exceed 120°F."* The maximum outlet water temperature would be limited to 105°F. This maintains the existing 20°F limit on the difference between the maximum outlet cooling water temperature and the minimum average of the inlet and outlet cooling water temperatures. No changes are proposed to the remaining restrictions specified in LCO 4.2.15, including the maximum permissible difference between the PCRV liner cooling water inlet and outlet temperatures, the maximum rate of change of PCRV concrete temperature, and the maximum permissible difference between the PCRV cooling water outlet temperature and the PCRV external concrete surface temperature.

The decay heat generation rate from the fuel in the PCRV is insufficient to maintain average PCRV liner cooling water temperatures above 100°F when water in this system is recirculating with no heat removal. As of the end of August 1991, the decay heat generation rate of the fuel in the PCRV was approximately 20 KW. In order to heat the PCRV liner cooling water to an average temperature above 100°F, steam from an auxiliary boiler is supplied to heating coils in one or both of the PCRV liner cooling water surge tanks. FSAR Section 9.7.2 describes this method of adding heat as follows: *"Water supplied to the PCRV may be heated by supplying steam from the auxiliary steam system to submerged coils in the surge tanks. This permits heating the PCRV by means of the liner cooling tubes to maintain PCRV concrete temperatures within design limits when there is no appreciable heat source within the PCRV."* Reducing the minimum average PCRV liner cooling water temperature to 85°F will reduce reliance on the auxiliary boilers and decrease the fraction of time an auxiliary boiler must be maintained in operation.

## ANALYSIS

Reduction of the minimum average PCRV liner cooling water temperature raises the following three potential safety concerns, which are addressed in this section:

1) Will an adequate shutdown margin continue to exist with a reduction in PCRV liner cooling water temperature, which could potentially result in a reduction in the temperature of the fuel in the PCRV?

2) Will the temperature of the PCRV carbon steel liner be maintained well above the nil-ductility temperature of this material such that brittle fracture of the liner is not credible?

3) Will stresses within the PCRV liner and concrete remain within design allowable values at the lower temperatures?

1) **Shutdown Margin**

The shutdown margin assessments required by Technical Specifications LCO/SR 3/4.1.4 and LCO/SR 3/4.1.6 are based on the assumption of a limited reactivity contribution due to cooling the fuel to an average fuel temperature of 80°F. Average fuel temperatures below 80°F would result in a greater reactivity addition than assumed in shutdown margin assessments due to the negative temperature coefficient of reactivity. In PSC letter dated October 9, 1990, Crawford to Weiss (P-90310), PSC committed to maintain FSV average fuel temperatures between 80 and 200°F at all times when forced circulation is provided. In this letter PSC also committed to limit the calculated bulk core temperature (defined in Technical Specification LCO 4.0.4) to less than or equal to 400°F during planned interruptions of forced circulation (IOFC). It is conservatively postulated that at very low decay heat generation rates the average fuel temperature could approach the temperature of the PCRV liner during an extended IOFC. Restricting the minimum average PCRV liner cooling water temperature to 85°F assures that the average fuel temperature cannot decrease below 80°F, even during an extended IOFC when most of the fuel has been removed from the PCRV. (The instrumentation used to determine the average PCRV liner cooling water temperature is accurate to within 5°F). This assures that the 80°F minimum average fuel temperature assumption associated with the shutdown margin assessments is valid at all times.

2) **Brittle Fracture Prevention for the PCRV Liner**

Attachment 4 in this submittal package is EE-46-0007, Rev. B, "*Engineering Evaluation of Prestressed Concrete Reactor Vessel and Core Support Floor Structures for a Proposed System 46 Temperature Change.*" This document assesses the concern regarding the potential for brittle fracture of the PCRV liner, and concludes that with an 85°F average PCRV liner temperature, the margin above the nil-ductility transition (NDT) temperature is acceptable. The margin of safety will be greater than that currently delineated in the basis for Technical Specification LCO 4.2.15, which allows operation down to the fracture transition elastic (FTE) temperature, since the 85°F minimum average PCRV liner temperature is well above the FTE, as discussed below.

FSAR Sections 5.7.2.2 and E.24.5 discuss the experimentally determined initial and final NDT temperatures following exposure of each heat of liner material and a weldment of the liner material to an integrated neutron dose of 2.3 E18 $n/cm^2$ ($E \geq 1$ MeV). This integrated neutron dose utilized in the materials testing was the dose calculated for the most highly irradiated portion of the liner, at the top head, assuming a 30 year operational life at an 80% capacity factor (24 effective full power years, or 8760 effective full power days - EFPD). Each of the four heats of liner material had an initial NDT temperature below minus 60°F and experienced an increase in NDT temperature of less than 100°F (FSAR Table E.24-16) following exposure to the 2.3 E18 $n/cm^2$ integrated neutron flux. The weld metal had an initial NDT temperature of minus 75°F and experienced an increase in NDT temperature of 125°F (FSAR Table E.24-16) following exposure to this same integrated neutron flux.

The reactor was permanently shut down on August 18, 1989, having accumulated 890 EFPD, which represents approximately one-tenth of the design lifetime and which corresponds to a maximum integrated neutron dose at the top head liner of 2.4 E17 $n/cm^2$ (based on the integrated neutron flux equation in FSAR Section 5.7.2.2). Assuming a linear correlation between neutron exposure and increase in the NDT temperatures, this neutron exposure would cause a shift in the NDT temperatures of approximately one-tenth (890/8760) of the experimentally determined NDT temperature shifts. The NDT temperatures are calculated to shift from minus 60°F to minus 50°F for the liner material and from minus 75°F to minus 62°F for the weldment material over the actual operating life of the reactor. The FTE temperature is approximately equal to the NDT + 60°F. The end-of-life FTE temperatures are therefore calculated to be 10°F for the liner material and minus 2°F for the weldment material.

Maintaining the liner temperature above these FTE temperatures ensures that crack propagation in the liner at any tensile membrane stress up to yield stress would be incredible, and in this respect the liner meets the same criteria as are prescribed for steel nuclear pressure vessels, but is more conservative since the liner is in general compression during shutdown conditions, as it also was for all normal operating modes. Since the new 85°F minimum average operating temperature of the PCRV liner is above the calculated end-of-life FTE temperatures of the liner and weldment materials, it is acceptable.

### 3) PCRV Liner and Concrete Stresses

EE-46-0007, Rev. B (Attachment 4 of this submittal package), evaluates PCRV liner and concrete stresses associated with an 85°F minimum average PCRV liner cooling water temperature. Under steady state conditions at the new minimum average allowable temperature, PCRV liner and concrete stresses are slightly reduced due to thermal contraction of the steel and concrete at the lower temperature. Since these materials are maintained in a state of compression by the prestressing tendons, the thermal contraction results in a slight relaxation of stresses. Since the coefficients of thermal expansion are very similar for concrete and steel, the proposed 15°F reduction in the minimum average PCRV cooling water temperature does not give rise to significant stresses at the interfaces between the liner and concrete and the concrete and its bonded reinforcing steel due to differential thermal strains. Concrete and steel stresses associated with the steady state condition at the proposed minimum average temperature would be bounded by those previously analyzed for Cases 1 and 2 in FSAR Section 5.3.2.6.3, "*After Initial Prestress and at Atmospheric Pressure*" and "*Before Heating and at Atmospheric Pressure.*" These load combination analyses assumed the PCRV was at 70°F and depressurized with the tendons fully prestressed. The FSAR concludes that stresses for these cases are within allowables even with seismic stresses from a design basis earthquake superimposed. As concluded in EE-46-0007, Rev. B, reduced operating temperatures do not adversely affect the structural integrity of the PCRV.

EE-46-0007, Rev. B, also includes the results of analysis of stresses resulting from postulated transient conditions. It was conservatively assumed that the PCRV liner, including the penetration liners, and Core Support Floor (CSF) liner were instantly cooled 15°F from the initial temperature and that the adjoining concrete remains at the initial temperature. As stated in EE-46-0007, Rev. B, "*The assumption of instantaneous temperature change is very conservative as the thermal masses involved are very large and temperature variations of the System 46 cooling water tend to occur slowly.*" Stresses which could arise due to the 15°F temperature decrease were calculated for various PCRV and CSF components considered to be the most critical and added to previously calculated stresses. The resultant stresses were determined to be below the allowable stresses for the PCRV liner and penetration liners, the PCRV liner anchor studs, the PCRV concrete, the PCRV reinforcing rods, the CSF liner, the CSF concrete and CSF reinforcing bars, as documented in EE-46-0007, Rev. B. Based on this, it is concluded that a sudden decrease of the average liner cooling water temperature from 100 to 85°F does not adversely affect the structural integrity of the PCRV.

## CONCLUSION

Reduction of the minimum average PCRV cooling water temperature from 100 to 85°F will not impact nuclear safety at FSV. The assumption regarding minimum average fuel temperature in the shutdown margin assessment remains valid, as discussed above. At an average temperature of 85°F, the PCRV top head liner and weldment materials are above their calculated end-of-life fracture transition elastic temperatures, so brittle fracture is not a credible failure mode. PCRV liner and concrete stresses will not increase when temperatures equilibrate with the minimum average PCRV cooling water temperature at 85°F. Even if it is conservatively assumed that PCRV and CSF liner average temperatures decrease instantaneously from 100 to 85°F, resulting stresses are within allowable limits.

Based on the above evaluation, it is concluded that operation of Fort St. Vrain in accordance with the proposed changes will not involve a significant increase in the probability or consequences of an accident previously evaluated, create the possibility of a new or different kind of accident from any accident previously evaluated, or involve a significant reduction in a margin of safety. Therefore, this change will not increase any risk to the health and safety of the public nor does it involve any significant hazards.

ATTACHMENT 4

TO P-91298

ENGINEERING EVALUATION
EE-46-0007, REV. A