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RS-01-066

April 5, 2001

United States Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555-0001

Braidwood Station, Units 1 and 2
Facility Operating License Nos. NPF-72 and NPF-77
NRC Docket Nos. STN 50-456 and STN 50-457

Byron Station, Units 1 and 2
Facility Operating License Nos. NPF-37 and NPF-66
NRC Docket Nos. STN 50-454 and STN 50-455

Subject: Additional Information Supporting the License Amendment Request to Permit Uprated Power Operations at Byron and Braidwood Stations

References: (1) Letter from R. M. Krich (Commonwealth Edison Company) to U.S. NRC, "Request for a License Amendment to Permit Uprated Power Operations at Byron and Braidwood Stations," dated July 5, 2000

(2) Letter from R. M. Krich (Exelon Generation Company, LLC) to U.S. NRC, "Additional Information Supporting the License Amendment Request to Permit Uprated Power Operations at Byron and Braidwood Stations," dated March 26, 2001

In Reference 1, we submitted proposed changes to Facility Operating License Nos. NPF-72, NPF-77, NPF-37 and NPF-66, and Appendix A, Technical Specifications (TS), for Braidwood Station, Units 1 and 2, and Byron Station, Units 1 and 2, respectively. The proposed changes would revise the maximum power level specified in each unit's license and the TS definition of rated thermal power.

In Reference 2 we provided additional information regarding the calculation that addresses the maximum allowable time in which operators must direct some Emergency Core Cooling System (ECCS) circulation flow to the Reactor Coolant System (RCS) hot legs (i.e., known as "Hot Leg Switch-Over" (HLSO)) during a Loss of Coolant Accident (LOCA) scenario to prevent boron precipitation in the reactor core. During a follow-up telephone conference call among members of the NRC, Exelon Generation Company (EGC), LLC, and Westinghouse Electric Company, LLC, EGC's contractor, additional information was requested to further justify use of the reactor vessel barrel-baffle volume in the HLSO calculation. After further evaluation of the HLSO calculation assumptions, we have determined that the reactor vessel barrel-baffle volume in

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question may be removed from consideration in the calculation while maintaining the HLSO time at 8.5 hours which is the current value. Additional details regarding this conclusion are presented in Attachment 1, "Hot Leg Switchover and Long Term Core Cooling Assumptions Related to the Byron and Braidwood Stations Power Uprate Program."

In addition, the following information is provided as requested to clarify information previously submitted regarding the control of input parameters for the Small Break Loss of Coolant Accident (SBLOCA) analysis, and fuel cladding types considered in the Large Break Best Estimate Loss of Coolant Accident (BELOCA) analysis.

SBLOCA Input Parameter Control

EGC and its vendors have ongoing processes in place to assure that the Byron Station and Braidwood Station SBLOCA analysis input values for parameters having an important affect on accident peak cladding temperature (PCT) bound the as-operated plant values for those parameters.

Large Break BELOCA Fuel Cladding Considerations

Similar to the SBLOCA analysis, the Large Break BELOCA analysis has evaluated both Zirc-4 and ZIRLO fuel cladding for PCT considerations.

Should you have any questions or concerns regarding this information, please contact Mr. J. A. Bauer at (630) 663-7287.

Respectfully,

R. M. Krich
Director – Licensing
Mid-West Regional Operating Group

cc: Regional Administrator – NRC Region III
NRC Senior Resident Inspector – Braidwood Station
NRC Senior Resident Inspector – Byron Station
Office of Nuclear Safety – Illinois Department of Nuclear Safety

STATE OF ILLINOIS	**)**	
COUNTY OF DUPAGE	**)**	
IN THE MATTER OF	**)**	
EXELON GENERATION COMPANY, LLC	**)**	**Docket Numbers**
BYRON STATION UNITS 1 AND 2	**)**	**STN 50-454 AND STN 50-455**
BRAIDWOOD STATION UNITS 1 AND 2	**)**	**STN 50-456 AND STN 50-457**

SUBJECT: **Additional Information Supporting the License Amendment Request to Permit Uprated Power Operations at Byron and Braidwood Stations**

AFFIDAVIT

I affirm that the content of this transmittal is true and correct to the best of my knowledge, information and belief.

R. M. Krich
Director – Licensing

Subscribed and sworn to before me, a Notary Public in and

for the State above named, this 5th day of

April, 20 01.

" OFFICIAL SEAL "
Timothy A. Byam
Notary Public, State of Illinois
My Commission Expires 11/24/2001

Notary Public

ATTACHMENT 1

Hot Leg Switchover and Long Term Core Cooling Assumptions Related to the Byron and Braidwood Stations Power Uprate Program

Hot Leg Switchover

Introduction

Post Loss of Coolant Accident (LOCA) maximum allowable time before Hot Leg Switchover (HLSO) is calculated for inclusion in the emergency operating procedures to ensure there is no boron precipitation in the reactor vessel due to boiling in the core following a large-break LOCA (LBLOCA). This calculation is dependent upon power level and the various boron concentrations of the Reactor Coolant System (RCS) and Emergency Core Cooling System (ECCS).

Input Parameters/Assumptions and Description of Analysis

Currently, an HLSO time of 8.5 hours is used for Byron Station, Units 1 and 2, and Braidwood Station, Units 1 and 2. The current HLSO calculation is based on a core power level of 3411 Megawatts-thermal (MWt), an appropriately high ECCS recirculation flow water temperature of 170°F at the outlet of the Residual Heat Removal (RHR) system heat exchangers, which is used to establish an appropriate reactor core inlet water temperature assumption, and a conservatively calculated reactor core volume. The maximum HLSO time was calculated to be 8.94 hours. This value was conservatively rounded down to the nearest half-hour (i.e., 8.5 hours) for ease of implementation. Although the boron concentrations of the RCS and ECCS are not changing as a result of power uprate, the increase in reactor core power to 3586.6 MWt necessitates a recalculation of the HLSO time and hot leg recirculation minimum required flow.

An increase in core power alone would reduce the HLSO time from the current value. However, the new HLSO time calculation was based upon a more accurate reactor core volume than the current 8.5 hour HLSO time calculation. Additional reactor core volume between the top of the lower core plate and the bottom of the active fuel was considered part of the reactor core mixing volume, as it is considered to be within the reactor core circulation patterns in the post-LOCA period. This reactor core volume change, along with the core power change, were the only differences between the power uprate HLSO calculation and the current analysis. Similar to the previous calculation, an appropriately high ECCS recirculation flow water temperature of 170°F at the outlet of the RHR system heat exchangers was modeled during cold leg recirculation. The HLSO calculation neglects the effects of potential steam heating of the ECCS injection flow. The details of the HLSO time modeling which justify these assumptions are provided below.

Using a more accurate reactor core volume, the maximum HLSO time for an uprated reactor core power of 3586.6 MWt was determined to be 8.53 hours. Since the existing HLSO time of 8.5 hours bounds the newly calculated maximum HLSO time of 8.53 hours, 8.5 hours will continue to be the HLSO time used in the emergency operating procedures for Byron and Braidwood Stations.

Minimum ECCS flow requirements are calculated at the HLSO time to ensure that sufficient ECCS flow exists in the hot leg recirculation flow configuration to stop the buildup of boron in the reactor vessel and to ensure adequate reactor core cooling is maintained. For the spectrum of LBLOCAs, the minimum required flow delivered to the RCS hot legs is 1.3 times the calculated reactor core boiloff rate; and the minimum required flow delivered to the RCS cold legs must equal or exceed 1.5 times the calculated reactor core boiloff rate.

In the event of a hot leg small-break LOCA (SBLOCA) where RCS pressure remains high, there are two means of demonstrating the adequacy of flow at HLSO time. Credit may be taken for operator action to cool down and depressurize the RCS, using safety grade Steam Generator (SG) Power Operated Relief Valves (PORVs), prior to entering the hot leg recirculation mode. Alternatively, it may be demonstrated that available flows at high pressures meet or exceed the calculated reactor core boiloff rate, which is known to be conservative relative to the actual maximum calculated flow through the break. Reactor core boiloff rates at high RCS pressures are calculated for the minimum required flow delivered to both the hot and cold legs for a hot leg SBLOCA.

Hot Leg Switchover Modeling Utilizing ECCS Recirculation Subcooling

The calculation of HLSO time uses a simplified "boiling pot" model. This calculation assumes a constant, conservatively high, reactor vessel lower plenum inlet water enthalpy at 170°F based on a maximum RHR heat exchanger outlet water temperature of 170°F. No steam heating of the ECCS liquid flow is included in the simplified model. Initially, all sources of borated fluid for the calculation are assumed to mix in the containment sump. The fluid is assumed to be at the maximum allowable boron concentration and maximum deliverable volumes. Potential dilution sources, such as fluid from the spray additive tank, are conservatively neglected. The mixed liquid is then assumed to fill a conservatively small reactor core mixing volume.

Although the addition of boron can increase the boiling temperature, this simplified model conservatively neglects this beneficial effect. Similarly, no entrainment of liquid in the reactor core boiloff is modeled. This simplified model neglects any benefit from boron transport through droplets and neglects any benefits from boron volatility and transport with the steam.

A conservatively small reactor core mixing volume is calculated from the top of the lower core plate to the bottom of the reactor vessel nozzles. Voiding is not modeled. This simplified treatment has been demonstrated to be highly conservative (i.e., it reduces the potential HLSO time by several hours) in lieu of considering voiding and inclusion of the reactor vessel lower plenum mixing volume, which has been demonstrated to be a fully mixed volume through experimentation. In this calculation, any mixing in the baffle former region volume has been conservatively neglected as well, although flow paths to allow mixing in this region do exist for the Byron Station and Braidwood Station reactor vessels. Similarly, mixing in the fuel assembly thimble tubes is conservatively neglected. Flow through the hot leg nozzle gaps has also been conservatively neglected, as this has been shown to substantially extend the calculated HLSO time.

This simplified model assumes a conservatively high constant RHR heat exchanger outlet water temperature of 170°F. The temperature selected is conservatively based upon the maximum RHR heat exchanger outlet temperature calculated for a single RHR heat exchanger in operation, assuming a containment sump water temperature at saturation (i.e., 212°F and 14.7 psia) to remain consistent with this HLSO model.

This constant treatment of the RHR heat exchanger outlet water temperature is very conservative when compared to the most recent Byron Station and Braidwood Station containment sump water temperature calculation performed to determine minimum ECCS flow requirements and minimum cooling capability. A review of this calculation shows the time-averaged value, from the start of the cold leg recirculation phase to HLSO, of the RHR heat exchanger outlet water temperature, to be approximately 150°F. Therefore, the use of 170°F is judged to be sufficiently conservative for the reactor vessel lower plenum inlet water enthalpy in the simplified HLSO calculation.

In this simplified HLSO model, the 170°F ECCS liquid is assumed to only mix with the reactor core liquid as it replaces core boiloff. As previously noted, no lower plenum mixing is assumed. The reactor core barrel and baffle former regions are conservatively assumed to be adiabatic walls between the reactor core mixing volume and the downcomer. Any heat transfer through these structures would serve to reduce the boiling rate and slow the rate of boron buildup.

As previously noted, this simplified HLSO calculation approach does neglect the effect of steam which could pass into the top of the downcomer and the top of the cold legs where it could interact with the incoming ECCS fluid; thus raising its temperature. However, paths from the upper plenum to the downcomer include the spray nozzles (i.e., the upper internals bypass flow passages) which have a small flow area, on the order of 0.2 ft^2; and the hot leg nozzle gaps, which were conservatively neglected for flow mixing considerations as discussed above. The flow through these paths during normal operation is less than 2% of the total RCS flow.

During the cold leg recirculation period, the average steam flow rate out of the core is approximately 40 lb/sec. Most of this steam would be expected to flow out of the break. However, making the conservative assumption that any steam heating of the ECCS liquid will be thoroughly mixed, an enthalpy balance can be performed to show that even if up to 33% of all steam generated by the core condenses and mixes with the 150°F ECCS flows, the mixed fluid temperature would still be less than the 170°F reactor vessel lower plenum inlet fluid temperature assumed in the HLSO calculation. Simplified conservative calculations for spray nozzle steam flow estimate the flow to be approximately 12%; therefore, the mixing rate is judged to be substantially less than 33% of the steam generated.

Another potential flow path for steam into the ECCS fluid is from the containment through the broken RCS pipe stub. The condensation of the steam initially will draw a steam and air mixture from containment through the broken RCS cold leg into the top of the downcomer and top of the intact RCS cold legs. While the steam will condense on the colder ECCS liquid, a boundary layer of air will build up that reduces the rate of condensation. While some steam will penetrate or heat this boundary layer of air, a large portion of the higher temperature steam would be expected to flow above the air layer and out the broken loop without directly condensing on the ECCS liquid.

Similarly, any heating of the ECCS liquid by steam will occur at the surface of the ECCS flow in the RCS cold legs and the top of the downcomer. This will lower the density of the heated fluid and result in it being the least likely to descend to the bottom of the downcomer and most likely to flow out the broken loop cold leg.

Given the physical processes described above, it is judged that steam / water mixing would be substantially less than 33% (i.e., approximately 12%). As a result, the simplified assumption of using the maximum RHR heat exchanger outlet water temperature of 170°F as a bounding

steady state enthalpy at the lower plenum (i.e., neglecting steam heating of the ECCS fluid) is considered justified in view of the substantial enthalpy reduction of containment sump water temperatures and RHR heat exchanger outlet water temperatures (i.e., a time-averaged value of 150°F) following the initial switchover to cold leg recirculation up until HLSO. Additional conservatism is used in the simplified modeling described above, in particular the core volume simplifications provide additional assurance that the 8.5 hour HLSO time remains conservative for the Byron Station and Braidwood Station at uprated power operations.

Acceptance Criteria

Boron precipitation may result in a change in reactor core geometry which would not make it amenable to cooling or reduce the reactor core heat transfer capability such that heat cannot be sufficiently removed during the extended period of time required by long-lived fission products remaining in the reactor core. To ensure that boron does not precipitate in the core, the HLSO calculation was performed to show the acceptance criteria of 10 CFR 50.46, "Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors," continue to be met for the increase in core power from 3411 MWt to 3586.6 MWt. A maximum allowable time before HLSO was determined at the uprated power conditions, using the assumption that the boron concentration is four percent lower than the boron solubility limit.

In addition, the available ECCS flow rates must meet or exceed the minimum required flow criteria.

Results

A revised set of hot leg recirculation minimum required flows were calculated at the uprated power conditions. Table 1 provides the required ECCS flow rates for four different accident scenarios.

Conclusions

The acceptance criteria of 10 CFR 50.46 continue to be met at the uprated power conditions.

Table 1
ECCS Minimum Required Flow Rates
for Byron/Braidwood Uprating to 3586.6 MWt

Break Location and Size	ECCS Flow Spilling Assumption	Source of Flow to Meet Criteria	Pressure at Delivery Location	Flow Criteria at 8.5 Hr. HLSO (lbm/sec)	Available Flow (lbm/sec)
Cold Leg Large Break	One Cold Leg Spills to Containment Pressure.	Total Hot Leg Flow. (No lines spilling.)	Atmospheric Pressure	42.8 (1.3 × boiloff)	$\geq$ 42.8
Hot Leg Large Break	One Hot Leg Spills to Containment Pressure.	Total Cold Leg Flow. (No lines spilling.)	Atmospheric Pressure	49.4 (1.5 × boiloff)	$\geq$ 49.4
Hot Leg Small Break	One Hot Leg Spills to RCS Pressure.	Total of Hot and Cold Leg Delivered Flow.	1000 psi	31.7[1,2]	$\geq$ 31.7[2]
Hot Leg Small Break	One Hot Leg Spills to RCS Pressure.	Total of Hot and Cold Leg Delivered Flow.	1300 psi	32.1[1,2]	$\geq$ 32.1[2]

[1]Based on 1.0 x boiloff which greatly exceeds maximum break flow rates for break cases of one inch or smaller.

[2]These flows must be met where credit is not taken for operation of steam generator PORVs.

Post-LOCA Long Term Core Cooling

Introduction

The Long Term Core Cooling (LTCC) analysis is performed to demonstrate that during the post-LOCA period the core will remain subcritical. The post-LOCA containment sump boron curve is used to qualify the fuel and core loading arrangement on a cycle-specific basis. Changes to the Refueling Water Storage Tank (RWST) draindown volume, spray additive tank volume and their respective boron concentrations would result in a different post-LOCA containment sump boron curve for any given cycle. During post-LOCA LTCC, safety injection flow is drawn from the containment sump following switchover from the RWST. The Byron Station and Braidwood Station LTCC analysis at the uprated conditions was performed for two different assumed amounts of ECCS water drained from the RWST to the containment sump, i.e., two curves were generated as shown in Figure 2. The lower curve, based on an RWST delivered volume of 169,608 gallons, is calculated using the same methodology and general assumptions as are applied in the analyses performed for the current power level, with only minor differences due to input recalculations in support of the power uprate. The lower curve supports uprated power for the current core design limits. The higher curve, based on an RWST delivered volume of 326,972 gallons, is intended to provide additional margin for future cycles, where justification for its application can be provided.

Input Parameters/Assumptions and Description of Analysis

As stated in the introduction section, two post-LOCA containment sump boron curves were generated. The amount of ECCS water which was assumed to drain from the RWST for each curve was dependent upon the break size. The curves differ from current post-LOCA containment sump boron curves due to a more conservative calculation of RCS mass and due to a change in the RWST draindown volume for one curve.

For SBLOCAs (i.e., break sizes $\leq$ 1.0 ft^2) and LBLOCAs (i.e., break sizes > 1.0 ft^2), the minimum amount of water assumed to be drained from the RWST to the containment sump was 169,608 gallons (i.e., LO-2 level alarm, 46.7% level). This post-LOCA containment sump boron curve is considered bounding for both LBLOCA and SBLOCA breaks under all scenarios. As such, this curve was used to qualify the fuel and core loading arrangement for the power uprate program. This was done without taking credit for control rod insertion.

To provide additional margin for future core designs, the second curve was generated. For LBLOCAs only, the minimum amount of water assumed to be drained from the RWST to the containment sump was 326,972 gallons (i.e., LO-3 level alarm, 12% level). No plant specific calculations currently exist for Byron Station and Braidwood Station that demonstrate all control rods insert for large breaks. However, the containment sprays will be actuated and at least 326,972 gallons of ECCS water from the RWST will be drained to the containment sump. An analysis was performed for uprate conditions to demonstrate that containment sprays will actuate for break sizes greater than 1 ft^2 area. The analysis included conservative modeling appropriate for this application. The result of the additional RWST water drained to the containment sump is an increase in the amount of boron in the sump.

Credit for the effect of control rods on subcriticality generally results in a SBLOCA being less limiting than the LBLOCA despite the difference in RWST volume drained to the containment sump. Additional cycle specific core design calculations to support this statement could be performed to justify use of the higher curve.

Acceptance Criteria

The Westinghouse licensing position for satisfying the requirements of 10 CFR 50.46 Paragraph b, Item 5, "Long-term cooling," is documented in WCAP – 8339, "Westinghouse ECCS Evaluation Model - Summary," (Non-Proprietary), July 1974. The Westinghouse position is that the core will remain subcritical post-LOCA due to borated water from various ECCS water sources residing in the RCS and containment sump. Since credit for control rod insertion is not taken for a LOCA of greater than 1 ft^2 area (i.e., a LBLOCA), the borated ECCS water provided by the accumulators and RWST must have a sufficiently high boron concentration such that, when mixed with other sources of borated and non-borated water, the core will remain subcritical should all control rods remain withdrawn from the core.

Results

Figure 2 depicts the two post-LOCA containment sump boron concentration curves generated. One sump boron curve was based on RWST volume drained only to the LO-2 level alarm at 46.7% (i.e., 169,608 gallons), while the other curve was based on RWST volume drained to the LO-3 level alarm at 12% (i.e., 326,972 gallons). The 326,972 gallons of RWST volume drained increased the calculated containment sump boron concentration over the 169,608 gallon RWST draindown case by approximately 141 ppm at the 1250 ppm "Pre-Trip RCS Boron Concentration, Peak Xenon" condition.

Conclusions

Provided that the maximum critical boron concentration remains below the post-LOCA containment sump boron concentration curve demonstrated to be applicable for SBLOCA and LBLOCA (i.e., all rods out, no Xenon, 68°F – 212°F, RWST volume of 169,608 gallons), it is concluded that the uprated core will remain subcritical post-LOCA and that decay heat can be removed for the extended period required by the remaining long-lived fission products. The post-LOCA long term core cooling boron limit curve will continue to be reexamined to qualify the fuel and core loading arrangement on a cycle-by-cycle basis during the fuel reload process.

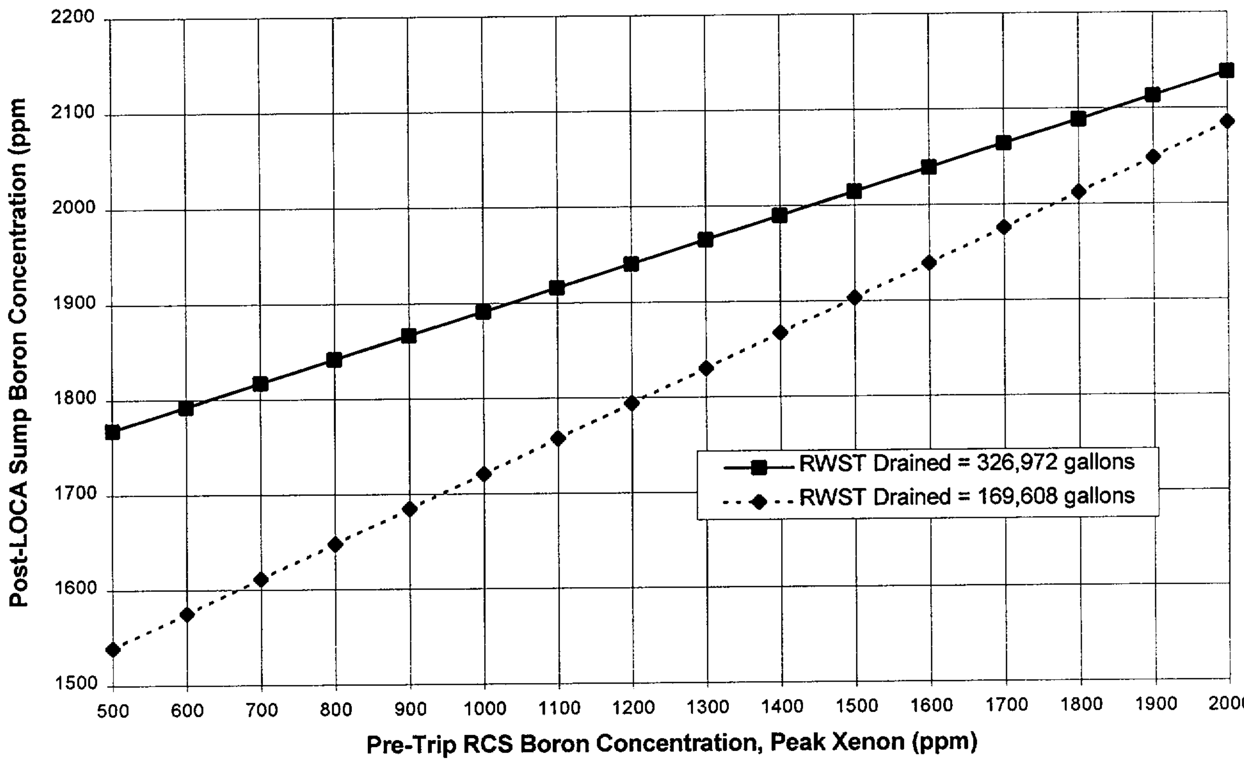

Figure 2

Post-LOCA Sump Boron Concentration, Peak Xenon Curve