STAFF EVALUATION RE: CORRECTIVE ACTION PLAN FOR RESOLUTION OF CONTROL ROOM EMERGENCY VENTILATION SYSTEM ISSUES FOR BROWNS FERRY NUCLEAR PLANT UNITS 2 AND 3 (TAC NOS. M83348, M83349, AND M83350)

## 1.0 INTRODUCTION

By letter dated July 31, 1992, the Tennessee Valley Authority (TVA or the licensee) described the corrective actions which will be implemented to resolve certain control room emergency ventilation system (CREVS) deficiencies at Browns Ferry Nuclear Plant (BFN) Unit Nos. 1, 2 and 3. The U.S. Nuclear Regulatory Commission (NRC or the staff) also performed an onsite review during the week of December 8, 1992. TVA and the NRC staff met in Rockville, MD, on February 3, 1993, to discuss the CREVS issue. By letter dated August 10, 1994, TVA provided additional information in response to NRC staff requests.

By letter dated October 1, 1997, as supplemented October 14, 1997, March 16 and 20, April 1 and 28, May 1, 20, and 22, June 12, 17, and 26, and July 17 and 24, 1998, TVA submitted a license amendment request to increase the licensed rated thermal power from 3293 MWt to 3458 MWt, an increase of 5 percent. Since the core inventory of radionuclides (i.e., those significant in consequence assessments) is largely proportional to rated power, there could be an increase in accident radiological consequences, including increased dose to control room operators. Because of this, the staff has considered information provided by TVA in these submittals as it relates to control room habitability corrective actions. As part of its review, the staff performed confirmatory calculations to evaluate the suitability of TVA's analyses. The parameters used by the staff are listed in Tables 1 and 2.

## 2.0 BACKGROUND

Title 10 of the Code of Federal Regulations, Part 50 (10 CFR 50), Appendix A, General Design Criterion (GDC) 19 - Control Room, requires that adequate radiation protection be provided to permit access and occupancy of the control room under accident conditions. Accordingly, the CREVS is designed to automatically start on receipt of a control room isolation signal and pressurize the main control bay habitability zone with filtered outdoor air during accident conditions that could result in radioactive releases. This filtered air maintains the control room at a positive pressure so that all leakage should be outleakage. Charcoal absorbers and high efficiency particulate absolute (HEPA) filters in the CREVS assure removal of radioactive iodine and particulate matter.

The Control Bay ventilation towers, located on the north wall of the reactor building, provide the outside air for the Control Building supply duct work. Ventilation fans, which are located in the ventilation towers, pressurize the supply duct work that traverses the main control bay habitability zone. These fans operate during the accident recovery period (30 days) and supply necessary cooling for essential equipment. The existing CREVS units take suction from these positively pressurized ducts.

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During the Unit 2 Cycle 5 outage, TVA identified a specific condition that could potentially impact the ability of the CREVS to provide an environment suitable for personnel occupancy. The Control Building air supply ducts are not designed or fabricated to be leaktight. Unfiltered outside air could leak from the seams/joints of the supply air ducts that traverse the control bay habitability zone. This duct leakage could result in make-up air bypassing the CREVS and introducing potentially contaminated and unfiltered outside air into the control bay habitability zone.

During the Unit 2 operating cycle (Cycle 6), TVA temporarily modified the CREVS operability requirements and implemented certain compensatory measures. The compensatory actions included operation of all three trains of the Standby Gas Treatment System (SGTS) following an accident to maximize the negative pressure inside secondary containment, and monitoring of plant radiological conditions to provide an early indication that the control room habitability zone may become degraded. Upon determination that there was a possibility that the iodine uptake dose to the thyroid could exceed 10 rem, potassium iodide (KI) tablets would be distributed to control room and Technical Support Center personnel.

The licensee indicated that these corrective actions represent a change in BFN's previously approved approach to meeting GDC-19 requirements and, therefore, requested staff review of the proposed corrective actions. These actions include, but are not limited to, modification of control bay ventilation towers to reduce the concentration of effluents into the control bay habitability zone, increasing the leak tightness of the control bay habitability zone, establishing procedures and performance of periodic testing of control bay habitability zone, and increasing the CREVS capacity.

## 3.0 DISCUSSION

The staff's review involves the following three issues: atmospheric dispersion factor; loss -of-coolant-accident (LOCA) release pathways; and applicability of findings on control room habitability to BFN Unit 1. These aspects of the staff review are discussed below.

### 3.1 Atmospheric Dispersion Factors

In performing the reviews on the control room habitability corrective actions, the staff evaluated the atmospheric dispersion factors (X/Q) used in control room assessments. The Browns Ferry facility has a tall plant stack that towers above the control room ventilation intakes. Since the control room is relatively close to the base of the stack, releases via the stack tend to leapfrog the control room ventilation intakes, reducing the amount of radioactivity intake during accidents. In 1989, TVA identified deficiencies in ventilation system configurations that could result in as much as 3700 cfm of unfiltered inleakage to the control room. While mitigative actions were taken (e.g., higher flow filtered pressurization intake, new intake locations), the design basis inleakage remains at about 3700 cfm. TVA has been able to demonstrate control room doses within the GDC-19 criteria, largely due to the favorable X/Q values. In this review, the staff closely considered the determination of the X/Q values used in TVA's analyses to ensure the acceptability of the large unfiltered infiltration. The staff performed confirmatory calculations using the NRC PAVAN and ARCON96 codes for selected release points. The staff identified a non-conservative assumption regarding the distance between the stack and the

limiting control room intake. TVA provided acceptable values and updated their control room dose analysis results in a letter dated May 1, 1998. This review indicated that TVA's X/Q values were comparable to those developed by the staff, and in many cases, were slightly more restrictive. The staff concluded that TVA's X/Q values were acceptable.

3.2 LOCA Release Pathways

TVA evaluated the offsite doses associated with a release of radioactivity from the containment atmosphere via leakage through the drywell into the secondary containment, where it is collected and filtered by the standby gas treatment system (SGTS) and released via the plant stack. These assumptions are typical of the LOCA analyses performed at the time that BFN was original licensed. There are two other release pathways which are applicable to BWRs such as BFN. The first is leakage from systems that recirculate suppression pool water outside the drywell following a design basis LOCA. The second is the design leakage through the main steam isolation valves (MSIVs). Both of these release pathways are potentially significant in that they represent drywell bypasses. TVA stated that the MSIV leakage component was modeled as part of the overall primary containment leak rate. The staff notes that TVA modeled all primary containment leakage as being collected and processed by SGTS. However, the MSIV leakage bypasses the secondary containment and is released at ground level. TVA's model underestimates the doses associated with MSIV leakage. Since the difference in magnitude between stack and ground level X/Qs at BFN is on the order of two to three decades more restrictive, the MSIV leakage release could be limiting for the control room, especially given the large unfiltered infiltration rate.

In a letter dated June 12, 1998, TVA indicated that the MSIV and emergency core cooling system (ECCS) leakage from outside containment are not considered within the BFN licensing basis. Based on its review of the BFN docketed information, the staff has determined that consideration of MSIV and ECCS leakage is within the BFN licensing basis as a result of TVA's commitments related to NUREG-0737 Item III.D.3.4 and the related confirming orders as described below.

Pursuant to §50.34, an applicant for a construction permit must include the principle design criteria for a proposed facility. Part 50, Appendix A, General Design Criteria, establishes minimum requirements for the principle design criteria for structures, systems, and components important to safety. GDC-19, Control Room, establishes a requirement that:

> "...Adequate radiation protection be provided to permit access and occupancy of the control room under accident conditions without personnel receiving radiation exposures in excess of 5 rem whole body, or its equivalent to any part of the body, for the duration of the accident...."

In 1990, the NRC published NUREG-0737, "Clarification of TMI Action Plan Requirements." Item III.D.3.4 of NUREG-0737, Control Room Habitability Requirements, provided the following:

> "...The design-basis-accident (DBA) radiation source term should be for the loss-of-coolant-accident (LOCA) containment leakage and engineered safety features (ESF) leakage contribution outside containment as described in Appendices A

and B of Standard Review Plan Chapter 15.6.5. In addition, boiling-water reactor (BWR) facility evaluations should add any leakage from main steam isolation valves (MSIV)(i.e., valve-stem leakage, valve seat leakage, main steam isolation valve leakage control system release) to the containment leakage and ESF leakage following a LOCA...."

By letter dated October 31, 1980, the NRC notified licensees of its expectation that the requirements in NUREG-0737 would be met and requested that licensees furnish confirmation that the implementation dates would be met. This letter also noted:

- "...A licensee or applicant seeking relief from any element of our criteria should submit a request for relief, along with supporting justification, in response to this letter..."

By letter dated December 23, 1980, TVA provided the requested confirmation, with the statement that "...TVA intends to be fully responsive to these requirements..." On March 17, 1981 and July 27, 1981, TVA provided additional information on Item III.D.3.4. None of these letters requested a deviation from the requirements of III.D.3.4 with regard to sources of radiation exposure. The NRC issued a confirmatory order to TVA on July 10, 1981. Section III of that order provided:

- "...The licensee's submittals dated December 23, 1980, March 17, April 9 and June 1, and July 2, 1981, the references stated therein, which are incorporated by reference, committed to complete each of the actions specified in the Attachment...."

A search of the TVA docket identified some requests for deviation from requirements of various sections of NUREG-0737. With the exception of some chlorine toxic gas issues, none of these deviations were related to Item III.D.3.4. By letter dated August 30, 1982, the NRC issued a safety evaluation that concluded that the Browns Ferry units acceptably met the requirements in NUREG-0737 Item III.D.3.4. Based on the information provided by TVA in the March 17, 1981, and July 27, 1982, letters, this safety evaluation concluded that the design meets the criteria identified in Item III.D.3.4. Since TVA did not request a deviation, and the staff did not explicitly accept a deviation in its safety evaluation, the staff is of the opinion that the requirements of Item III.D.3.4, including MSIV and ECCS leakage considerations, are applicable, and are a part of the licensing basis for BFN.

In support of a temporary technical specification (TS) change to allow plant operation with CREVS technically inoperable, in 1989 TVA performed analyses of control room dose during DBAs, including an analysis of the LOCA dose due to leakage from MSIVs and by letter dated February 14, 1989, TVA proposed a compensatory measure to have KI available for control room personnel. Further, on September 10, 1992, in a subsequent request for a TS change to relax conditions (including the use of KI as a compensatory measure), the licensee addressed MSIV leakage consideration by referring to its July 31, 1992, CREVS corrective action letter as the basis for concluding that doses were acceptable. By letter dated April 9, 1993, the NRC approved the proposed license amendment. The control room habitability corrective action

issue was not within the scope of this license amendment. Accordingly, the staff has determined that consideration of MSIV and ECCS leakage is within the BFN licensing basis.

TVA calculation ND-Q2031-9200075, Control Room Doses, was revised (Revision 1) in 1992 to incorporate 3717 cfm unfiltered inleakage, 3000 cfm CREVS flow, X/Q values associated with new CREVs intakes, and to address MSIV leakage. The MSIV leakage dose was determined using the General Electric, BWR Owner's Group (BWROG) method documented in NEDC-31858P, BWROG Report for Increasing MSIV Leakage Rate Limits and Elimination of Leakage Control Systems, dated October 1991. The results from this analysis are documented in the current BFN Final Safety Analysis Report. The BWROG method has been submitted for staff review as a generic topical report. While the NRC has considered this report on a case-by-case basis for a limited number of facilities, the report has not been accepted on a generic basis. The BWROG method is predicated on the ability of the licensee to demonstrate seismic suitability of main steam lines and the main condenser. In response to the staff's request for additional information relating to TVA's power uprate request (which is currently under staff review), by letter dated June 12, 1998, TVA identified that certain prerequisites for the methodology used in the earlier analyses may not have been met. TVA has now proposed a license condition that will make KI available in the control room as a compensatory measure until such time as the TVA demonstrates that LOCA doses, including MSIV and ECCS leakage, are within the GDC-19 criterion.

The staff has performed preliminary calculations and has determined that the inclusion of these MSIV and ECCS release pathways would result in acceptable doses. Nonetheless, the staff requested TVA to evaluate the offsite and control room doses due to MSIV and ECCS leakage and to docket the results. As discussed above, by letter dated June 12, 1998, TVA proposed a license condition to evaluate these pathways and to submit the results of these additional analyses by March 31, 1999. The staff has concluded that the licensee's corrective actions are acceptable on the basis that: (1) MSIV and ECCS leakage are not explicitly part of the original BFN licensing basis; (2) the staff's analyses of the doses associated with MSIV and ECCS leakage show acceptable results; and (3) the licensee has proposed a license condition for TVA to perform necessary analysis and design modifications to demonstrate compliance with GDC-19.

3.3 Applicability of Findings on Control Room Habitability to BFN Unit 1

TVA's analysis of control room doses contains disclaimers limiting applicability to postulated accidents occurring at Units 2 and 3. Similarly, the staff did not consider accidents occurring at Unit 1. Therefore, the staff finding on the acceptability of TVA's control room corrective action plan, although docketed for all three units, is limited to Units 2 and 3. Further, as part of the staff's issuance of license amendment No. 234 for conversion to Improved Standard TS, the staff included a license condition that "...[T]he licensee shall review the Technical Specification (TS) changes made by License Amendment No. 234 and any subsequent TS changes, verify that the required analyses and modifications needed to support the changes are complete, and submit them for NRC review and approval prior to entering the mode for which the TS applies."

## 4.0 LICENSEE COMMITMENTS

As part of its application for license amendment for power uprate and implementation of corrective action for CREVS issues, TVA has made the following commitments:

> TVA will perform an analysis of the design basis loss of coolant accident to confirm compliance with General Design Criteria-19 and offsite limits considering main steam isolation valve leakage and emergency core cooling system leakage. The results of this analysis will be submitted to the NRC for review and approval by March 31, 1999. Following NRC approval any required modifications will be implemented during the refueling outages scheduled for Spring 2000 for Unit 3 and Spring 2001 for Unit 2. TVA will maintain the ability to monitor radiological conditions during emergencies and administer potassium-iodine (KI) to control room operators to maintain doses within GDC-19 guidelines. This ability will be maintained until the required modifications, if any, are complete.

The licensee's commitment to have thyroid prophylaxis available to control room operators is a compensatory measure deemed necessary while TVA resolves issues associated with its MSIV and ECCS analyses.

## 5.0 CONCLUSION

Based on the information above, and upon the license conditions proposed by the licensee, the staff finds reasonable assurance that the consequences of postulated DBA accidents will remain within 10 CFR Part 50, Appendix A, GDC-19 acceptance criteria and Part.100 limits and the BFN control room will provide adequate radiological protection such that control personnel will not receive radiation exposures in excess of 5 rem whole body, or its equivalent to any part of the body, from postulated accidents occurring at Units 2 or 3. Therefore, the staff finds the TVA's proposed corrective action acceptable.

Table 1

BFN Accident Analysis Parameters Used by Staff

| | |
|---|---|
| **All Accidents** | |
| Reactor power (3458 x 1.02), MWt | 3527 |
| Core peaking factor | 1.5 |
| Number of fuel rods in core | 47,368 |
| Iodine species distribution | |
| Elemental | 0.91 |
| Organic | 0.04 |
| Particulate | 0.05 |
| Main condenser volume, $ft^3$ | 125,000 |
| SGTS Flow, cfm | |
| Stack, Elevated | 21,995 |
| Damper bypass, ground level | 5 |
| SGTS drawdown time, sec *(assume release is ground level during drawdown)* | 75 |
| SGTS Filter Efficiency, all species, % | 90 |
| Dose conversion factors | FGR11/FGR12 |
| Breathing rate, offsite, $m^3/s$ | |
| 0-8 hours | 3.47E-4 |
| 8-24 hours | 1.75E-4 |
| >24 hours | 2.32E-4 |
| Breathing rate, control room,$m^3/s$ | 3.47E-4 |
| Control room unfiltered infiltration, cfm | 3717 |
| Control room filtered pressurization, cfm | 3000 |
| Control room volume, $ft^3$ | 210,000 |
| Control room intake filter efficiency, all species, % | 90 |
| Control room occupancy factor | |
| 0-24 hrs | 1.0 |
| 1-4 days | 0.6 |
| 4-30 days | 0.4 |
| **Control Rod Drop Accident (RDA)** | |
| Fraction of core Inventory in gap | |
| Iodine | 0.1 |
| Noble gases | 0.1 |
| Failed rods | 850 |

| | |
|---|---|
| Failed rod gap release fraction to vessel | |
| Iodine | 1.0 |
| Noble Gases | 1.0 |
| Failed rods that reach melt | 0.0077 |
| Melted fuel release fraction to vessel | |
| Iodine | 0.5 |
| Noble gases | 1.0 |
| Fraction of activity released to vessel that enters main condenser | |
| Iodine | 0.1 |
| Noble gases | 1.0 |
| Main condenser plateout fraction | |
| Iodine | 0.9 |
| Noble gases | 0.0 |

<u>Case 1 Release from main condenser leakage</u>

| | |
|---|---|
| Release rate from main condenser, %/day | 1.0 |
| Release duration, hrs | 24 |
| X/Q values | Table 2, Turbine Building |

<u>Case 2 Release from main condenser via MVP to SGTS</u>

| | |
|---|---|
| Release rate from main condenser, cfm | 1850 |
| Release duration, hrs | 24 |
| X/Q values | Table 2, Top of Stack |

<u>Case3 Release via recirculation sample line to SGTS</u>

| | |
|---|---|
| Reactor coolant volume, $ft^3$ | 26,500 |
| Sample line release, $ft^3$ (lbm/hr) | 220 (10651) |
| Flash fraction | 0.36 |
| Roof ventilator release prior to isolation, cfm | 95,000 |
| Roof ventilator isolation time, sec | 7 |
| X/Q values | Table 2, Reactor Building & Top of Stack |

**<u>Loss of Coolant Accident</u>**

<u>Containment Leakage Source</u>

| | |
|---|---|
| Core release fraction to CNMT | |
| Iodine | 0.25 |
| Noble gases | 1.0 |

| | |
|---|---|
| Primary CNMT volume, $ft^3$ | 285,200 |
| Drywell | 159,000 |
| Supression pool air space | 126,200 |
| CNMT leakrate, %/day | 2.0 |
| Secondary containment volume (50% of free volume) | 1,932,000 |
| SGTS ground level leakage (base of stack), cfm | 10 |
| Volume at base of stack (50% of free volume), $ft^3$ | 34,560 |
| X/Q | Table 2, Top & Base of Stack |

CAD System Release

| | |
|---|---|
| Activity same as CNMT leakage case | |
| Flow rate, cfm | 139 |
| CAD operation, days post accident | 10, 20, 29 |
| CAD operation duration, hours | 24 |
| No mixing in RB | |
| X/Q | Table 2, Top & Base of Stack |

MSIV Leakage*

| | |
|---|---|
| Activity same as CNMT leakage case | |
| MSIV leak rate (T/S allowed corrected for temperature/pressure), $ft^3/hr$ | 32.5 |
| Release from main condenser, %/day | 0.625 |
| Plateout fraction | 0.9 |
| X/Q values | Table 2, Turbine Building |

ECCS Leakage*

| | |
|---|---|
| Core release fraction to CNMT sump | |
| Iodine | 0.5 |
| Noble gases | 0.0 |
| Suppression pool liquid volume, $ft^3$ | 128,700 |
| Estimated leakage, gpm | 5 |
| Iodine Flash Fraction | 0.1 |
| Release mixes in secondary containment and released via SGTS | |
| X/Q | Table 2, Top & Base of Stack |

*These parameters are from NRC staff analysis. As provided in license condition, licensee is re-performing analyses to incorporate these release pathways in the design basis.*

## Fuel Handling Accident

| | |
|---|---|
| Fuel rods damaged | 125 |
| Decay period, hrs | 24 |
| Fraction of core in gap | |
| I-131 | 0.12 |
| Kr-85 | 0.3 |
| Other iodines | 0.1 |
| Other noble gases | 0.1 |
| Pool decontamination factor | 100 |
| Roof ventilator release prior to isolation, cfm | 95,000 |
| Roof ventilator isolation time, sec | 15 |
| Mixing volume, ft3 | 4900 |
| X/Q | Table 2, Top of Stack & Refuel Floor Bypass |

## Main Steam Line Break

| | |
|---|---|
| Reactor coolant activity, uCi/gm dose equivalent I-131 | |
| Normal | 3.2 |
| Spike | 26 |
| Noble gas release, uCi/sec | 100,000 |
| Mass release, lbm | |
| Steam | 25,000 |
| Liquid | 160,000 |
| Release flash fraction (pressure=1020 psia) | 0.38 |
| Release duration, sec | 10.5 |
| X/Q values | Table 2, Turbine Building |

Table 2

BFN METEOROLOGY

| Time Period | Control Room Unit 1 | Control Room Unit 3 | Site Boundary EAB | LPZ |
|---|---|---|---|---|
| Top of Stack Releases | | | | |
| 0-0.5 hrs | 3.40E-5 | 3.02E-5 | 2.40E-5 | 1.30E-5 |
| 0.5-2 hrs | 5.90E-15 | 9.64E-7 | 9.70E-7 | 8.00E-7 |
| 2-8 hrs | 4.29E-15 | 1.89E-7 | | 8.00E-7 |
| 8-24 hrs | 3.65E-15 | 8.37E-8 | | 4.00E-7 |
| 1-4 days | 2.58E-15 | 1.43E-8 | | 2.00E-7 |
| 4-30 days | 1.57E-15 | 1.13E-9 | | 6.50E-8 |

*ref: Control Room Data from TVA ltr to NRC dtd May 1, 1998; EAB/LPZ from FSAR Table 14.6-8*

| Base of Stack Releases | | | | |
|---|---|---|---|---|
| 0-2 hrs | 3.70E-3 | 1.2E-3 | 1.22E-4 | 5.65E-5 |
| 2-8 hrs | 2.38E-3 | 7.91E-4 | | 5.65E-5 |
| 8-24 hrs | 1.91E-3 | 6.42E-4 | | 2.24E-5 |
| 1-4 days | 1.19E-3 | 4.09E-4 | | 7.94E-6 |
| 4-30 days | 5.97E-4 | 2.14E-4 | | 1.71E-6 |

*ref: Control Room Data from TVA ltr to NRC dtd May 1, 1998; EAB/LPZ from FSAR Table 14.6-8*

| Turbine Building Releases | | | | |
|---|---|---|---|---|
| 0-2 hrs | 3.48E-4 | 3.48E-4 | 2.70E-4 | 1.32E-4 |
| 2-8 hrs | 2.94E-4 | 2.92E-4 | | 6.02E-5 |
| 8-24 hrs | 2.53E-4 | 2.50E-4 | | 4.07E-5 |
| 1-4 days | 2.01E-4 | 1.97E-4 | | 1.73E-5 |
| 4-30 days | 1.44E-4 | 1.40E-4 | | 5.10E-6 |

*ref: Control Room Data from TVA ltr to NRC dtd August 10, 1994--need to be divided by two prior to use to reflect dual intakes; EAB/LPZ from TVA ltr to NRC dtd April 12, 1996*

| Refuel Floor Damper Bypass | | | | |
|---|---|---|---|---|
| 0-15 secs | 1.46E-4 | 1.46E-4 | 1.22E-4 | 5.65E-5 |

*ref: Control Room/EAB/LPZ from FSAR Table 14.6-8*

ENCLOSURE 2