

ENCLOSURE 2

**Clinch River Nuclear Site
Construction Permit Application
Exemptions and Variances
CPA Enclosure 4 (Public Version)**



**TENNESSEE
VALLEY
AUTHORITY**

Clinch River Nuclear Site Exemptions and Variances

Construction Permit Application – Enclosure 4
Revision 1

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LIST OF ACRONYMS AND ABBREVIATIONS

Acronym	Explanation
CFR	Code of Federal Regulations
CRDA	Control Rod Drop Accident
CRN	Clinch River Nuclear
ESP	Early Site Permit
ESPA	Early Site Permit Application
FMCRD	Fine Motion Control Rod Drive
GDC	General Design Criterion
MCR	Main Control Room
PPE	Plant Parameter Envelope
PSAR	Preliminary Safety Analysis Report
RG	Regulatory Guide
SSAR	Site Safety Analysis Report
TVA	Tennessee Valley Authority
USNRC	U.S. Nuclear Regulatory Commission

LIST OF EFFECTIVE SECTIONS

ENCLOSURE 4 EXEMPTIONS AND VARIANCES

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ENCLOSURE 4: EXEMPTIONS AND VARIANCES

1.0 Exemptions

1.0.1 Introduction

An exemption is required if information proposed in the Construction Permit Application does not comply with one or more requirements of 10 Code of Federal Regulations (CFR) Part 50. Exemptions are submitted pursuant to 10 CFR 50.12, "Specific exemptions." The U.S. Nuclear Regulatory Commission (USNRC) may grant exemptions which are, "authorized by law, will not present an undue risk to the public health and safety, and are consistent with the common defense and security," as described in 10 CFR 50.12(a)(1), and show that the special circumstances in 10 CFR 50.12(a)(2) are present.

10 CFR 50.35 establishes the ability for the USNRC to issue a Construction Permit to an applicant as long as there is reasonable assurance that the proposed facility can be constructed and operated at the proposed location without undue risk to the health and safety of the public. Issuance of a Construction Permit allows an applicant to begin construction activities but does not indicate approval of the safety of any design feature or specification unless the applicant specifically requests such approval, and such approval is incorporated in the permit (10 CFR 50.3(b)).

The BWRX-300 design supporting this Construction Permit Application is preliminary and continues to progress to the final design. The exemptions presented in this enclosure are necessary to support approval of the final BWRX-300 design. If additional technical information is required to make a final determination on granting the exemption, allowances under 10 CFR 50.35(a)(2) are used to support the issuance of a Construction Permit, and the additional information is provided in a supplement to the Construction Permit Application after approval or in the Final Safety Analysis Report.

1.1 10 CFR 50, Appendix A, Principal Design Criterion 28 - Reactivity Limits - Rod Dropout

1.1.1 Summary of Requested Exemption

Pursuant to 10 CFR 50.12, the Tennessee Valley Authority (TVA) requests an exemption for Clinch River Nuclear (CRN) Unit 1 (CRN-1) from a portion of the requirements of 10 CFR 50, Appendix A, General Design Criterion (GDC) 28, "Reactivity Limits." Specifically, an exemption is requested to exclude the postulation of the rod dropout accident as a Design Basis Accident from the requirements of GDC 28. The basis used to support this request will show that the Control Rod Drive System design utilizes positive means to prevent the conditions which would result in the dropout accident (hereafter referred to as a Control Rod Drop Accident (CRDA)), thereby meeting the intent of the rule.

The GDC 28 limiting CRDA event is based on the conclusion that releases of radioactive material from the fuel with the nuclear system process barrier, primary containment, and secondary containment initially intact are the result of various failures of the Control Rod Drive System. For

a BWR, the single failure of the Control Rod Drive System associated with the potentially greatest release of radioactive material from the fuel is when a single control rod drops out of the core after being disconnected from its drive and after the drive has been retracted to the fully withdrawn position.

1.1.2 Regulatory Requirements

10 CFR 50, Appendix A, GDC 28, states:

“The reactivity control systems shall be designed with appropriate limits on the potential amount and rate of reactivity increase to assure that the effects of postulated reactivity accidents can neither (1) result in damage to the reactor coolant pressure boundary greater than limited local yielding nor (2) sufficiently disturb the core, its support structures or other reactor pressure vessel internals to impair significantly the capability to cool the core. These postulated reactivity accidents shall include consideration of rod ejection (unless prevented by positive means), rod dropout, steam line rupture, changes in reactor coolant temperature and pressure, and cold water addition.”

1.1.3 Technical Basis

A postulated CRDA may be described as follows:

1. The plant administrative and/or instrumentation controls on the rod pattern sequence are in operation.
2. The operator begins to withdraw control rods following a predetermined withdrawal sequence.
3. A control rod becomes decoupled from its drive and remains stuck at the full-in position.

Later in the startup sequence, the rod falls at the maximum velocity and produces a high local reactivity increase in a small region of the core. The reactor attains a positive period; however, the initial power burst is limited by the Doppler reactivity feedback. The primary protection system flux - and/or period-based trip signals scram the reactor, but the transient is largely terminated by the Doppler reactivity feedback before the scram has time to influence the power. Other inherent feedback mechanisms, primarily in the form of steam voids, also decrease reactivity and reduce the power and enthalpy rise in the fuel.

Related to this postulation of a CRDA, the consideration of a scram condition for the BWRX-300 design would result in a similar configuration, i.e. a fully inserted rod which is physically separated from its normal driver. In addition to the postulated start-up CRDA described above, this condition is also considered and addressed in the following technical basis discussion.

Further, as described in Regulatory Guide (RG) 1.236, a highly improbable combination of actual events is required in order for a CRDA to occur:

1. failure of the rod-to-drive coupling,

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2. sticking of the control rod in its fully inserted position as the drive is withdrawn,
3. full withdrawal of the control rod drive,
4. failure of the operator to notice the lack of response of neutron monitoring channels as the rod drive is withdrawn, and
5. failure of the operator to verify rod coupling.

The BWRX-300 Fine Motion Control Rod Drive (FMCRD) design provides the following positive means to prevent a CRDA from occurring:

- Redundant switches are provided to detect the separation of the FMCRD hollow piston from the ball nut or between the control rod and the hollow piston. During normal operation, there is no coupled connection between the hollow piston and the ball nut. The hollow piston and control rod rest on top of the ball nut and their weight is used to depress a spring within the FMCRD housing. Since the weight of the hollow piston alone is not enough to depress the spring, unloading of this spring provides the indication that separation at either the hollow piston/control rod or hollow piston/ball nut has occurred. In either condition, the separation switches cause a rod withdrawal block, thereby preventing a rod drop accident.
- The hollow piston is also provided with two latches, each independently capable of supporting the control rod following a scram or separation from the ball nut. The interface between the control rod and the FMCRD occurs at a bayonet coupling at the top end of the hollow piston which engages and locks into a mating socket at the base of the control rod. The coupling requires a 45° rotation for engaging or disengaging. Once locked, the drive and rod form an integral unit that must be manually unlocked before the components can be separated.
- Simultaneously with the initiation of any hydraulic scram, a scram follow signal is generated such that each FMCRD motor drives the ball nut upward to a position just below the fully inserted and latched hollow piston. With the ball nut below the hollow piston, the hollow piston remains latched to maintain the control rod in the fully inserted position.

Further information on FMCRD design and operation are provided in the CRN Preliminary Safety Analysis Report (PSAR), Chapter 4, "Reactor," and NEDC-33912P-A, "BWRX-300 Reactivity Control" ([Reference 1.0-1](#)).

The aforementioned design creates the positive means of preventing a CRDA and directly addresses the following prerequisite conditions of a CRDA described in RG 1.236:

- Failure of Coupling Between the Control Rod and Hollow Piston

The interface between the control rod and the FMCRD occurs at a bayonet coupling at the top end of the hollow piston which engages and locks into a mating socket at the base of the control rod. The coupling requires a 45° rotation for engaging or disengaging. Once locked, the drive and rod form an integral unit that must be manually unlocked before the

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components can be separated. This ensures that the hollow piston travels with the control rod supporting the function of the latches to effectively maintain the control rod position when the latches are engaged.

- Full withdrawal of the FMCRD with the Control Rod Stuck in the Fully Inserted Position

The redundant separation switches sense if the ball nut is ever unloaded, indicating a disconnect between the FMCRD and the control rod/hollow piston assembly. A control rod withdrawal block is provided to prevent the withdrawal of the FMCRD ball nut, preventing separation between the control rod/hollow piston assembly and the FMCRD ball nut which is a necessary prerequisite for a CRDA to occur.

Additionally, separation of the hollow piston from the ball nut releases spring loaded latches in the hollow piston that maintain the control rod latched in position or latched fully inserted following a scram.

In the event of a hydraulic scram, a simultaneous scram follow signal is generated such that each FMCRD motor drives the ball nut upward to a position just below the fully inserted and latched hollow piston.

This exemption request does not consider operator recognition as a positive means of preventing rod withdrawal. Operator recognition is being included here to address the remaining conditions described in RG 1.236:

- Failure of the Operator to Notice a Stuck Control Rod During Full Withdrawal of FMCRD

As previously noted, dual FMCRD separation detection switches sense separation and block control rod withdrawal. Actuation of either FMCRD separation switch initiates an alarm in the Main Control Room (MCR), alerting the operator to the control rod separation.

- Failure of the Operator to Notice the Lack of Response of Neutron Monitoring Channels as the FMCRD is Withdrawn

The operators will be alerted to separation through an alarm in the MCR from actuation by either of the FMCRD separation switches. Control rod withdrawal is automatically blocked upon FMCRD separation, thus preventing rod withdrawal. Therefore, operator attention to changes in neutron monitoring channels is unnecessary.

- Failure of the Operator to Notice Control Rod Uncoupling

As stated above, uncoupling of the hollow piston from the control rod is physically impossible during operation. Uncoupling of the hollow tube from the FMCRD ball nut is not applicable to the design given that the two components are not mechanically attached. Actuation of either FMCRD separation switch initiates an alarm in the MCR, alerting the operator to the hollow piston and ball nut separation.

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Based on the design features described above and roles in preventing the prerequisite conditions for a potential CRDA, the necessary, redundant positive means exist within the BWRX-300 design to prevent a CRDA.

Probability Analysis

To further support a technical basis for this exemption, a rod drop probability analysis is performed. The analysis evaluates the likelihood of experiencing a stuck rod condition under low power conditions coincident with a FMCRD component failure that could result in a rod drop event. Conservatively assuming a control rod gets stuck in the core with a frequency of once (1.0) per year and that the drop can occur at any time in the reactor cycle, the coincident occurrence of a stuck rod and a FMCRD component failure that can result in a CRDA produces an event frequency of 3.47×10^{-6} per year. Due to Doppler and void feedback characteristics, a CRDA is only of concern under low power conditions (i.e., below 5% rated thermal power). The probability that a reactor is in a low power state is estimated as follows:

$$\text{Probability of low power state} = 3 \text{ days per year} = 8.2 \times 10^{-3}$$

When multiplying the FMCRD rod drop frequency by the conditional probability that a reactor is in a low power state, the resulting CRDA frequency is approximately 2.85×10^{-8} per year. Note, this result still assumes a stuck rod frequency of once per year, which is conservative given that there have been zero incidences of a stuck rod in over 25,000 drive-years of FMCRD European operating experience. Considering a more realistic estimate stuck rod frequency not equal to once per year would likely yield a frequency of occurrence much less than the 2.85×10^{-8} per year estimate.

1.1.4 Regulatory Basis

Exemptions are submitted pursuant to 10 CFR 50.12 and must be authorized by law, will not present an undue risk to the public health and safety, and are consistent with the common defense and security as described in 10 CFR 50.12(a)(1), and shown that the special circumstances in 10 CFR 50.12(a)(2) are present.

As required by 10 CFR 50.12(a)(1):

- The requested exemption is authorized by law. This exemption is not inconsistent with the Atomic Energy Act of 1954, as amended. The USNRC has authority under 10 CFR 50.12 to grant exemptions from the requirements of this regulation. Therefore, the proposed exemption is authorized by law.
- The requested exemption will not present an undue risk to the public health and safety. This exemption does not impact the consequences of any design-basis event. Therefore, this exemption does not present an undue risk to the public health and safety.

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- The requested exemption is consistent with the common defense and security. This exemption does not affect the design, function, or operation of structures or plant equipment necessary to maintain the secure status of the plant. This exemption has no impact on plant security or safeguards procedures. Therefore, this exemption is consistent with the common defense and security.

As required by 10 CFR 50.12(a)(2)(ii):

- Special circumstances are present (10 CFR 50.12(a)(2)(ii)) in that application of the regulation in the particular circumstances achieves the underlying purpose of the rule by the inherent nature of the design. The underlying purpose of the GDC 28 is to protect the Reactor Coolant Pressure Boundary and the ability to cool the core from the consequences of inadvertent rod movements. Use of positive means to prevent CRDA events fulfills the GDC 28 goal of protecting the fuel by preventing rod motion that results in localized reactivity increases in the core. Therefore, this exemption achieves the underlying purpose of the rule. Such a condition has already been applied to the Control Rod Ejection Event described in the regulation with the allowance of positive means of prevention as justification for exclusion from consideration.
- Special circumstances are present (10 CFR 50.12(a)(2)(iv)) in that the exemption would result in benefit to the public health and safety. Use of positive means to prevent CRDA events protects the fuel and enhances safety by precluding the CRDA event described in GDC 28. Therefore, there is no decrease in safety as a result of this exemption.

The nature of the control rod ejection and control rod drop accidents are described for their applicable reactor types in RG 1.236. It is reasonable to conclude that, based on the foregoing discussion, the implementation of a positive means of prevention for the Control Rod Ejection Accident in a PWR is equally applicable and justifiable for the prevention of Control Rod Drop in the BWRX-300 CRN-1.

1.1.5 Conclusion

On the basis of the information presented, TVA requests that the USNRC grant an exemption for CRN-1 from the GDC 28 requirement to postulate a CRDA on the basis that multiple positive means exist to prevent its prerequisite conditions.

1.1.6 References

- 1.0-1 NEDC-33912P-A, "BWRX-300 Reactivity Control," Revision 2, February 2023.

2.0 Variances

2.0.1 Introduction

A *variance* is a plant-specific deviation from one or more of the site characteristics, design parameters, or terms and conditions of an Early Site Permit (ESP) or from the Site Safety Analysis Report (SSAR).

The following sections provide requests for variances from the site characteristics for the CRN Early Site Permit No. ESP-006 ([Reference 2.0-1](#)) and from the CRN SSAR ([Reference 2.0-2](#)). To support a decision whether to grant a variance, each variance request provides the technical justification for meeting the technically relevant regulatory acceptance criteria.

This CPA requests a variance where the CRN Preliminary Safety Analysis Report (PSAR) references the CRN ESP or the CRN SSAR and: a) the CRN PSAR does not demonstrate that the design of the BWRX-300 falls within the ESP site characteristics; or b) the CRN PSAR does not demonstrate that the design of the BWRX-300 falls within the ESP (design) controlling parameters. Accordingly, this CPA includes the following requests for variances:

2.1 Variance: CRN ESP VAR 2.0-1 – Site Grade Level

Request

TVA requests to use a finished elevation for the remediated nuclear island excavation area of approximately 814.5 ft. In the CRN Early Site Permit Application (ESPA) the finished elevation was set at approximately 821 ft.

Justification

The CRN ESPA was prepared using the Plant Parameter Envelope (PPE) conceptual design. The CRN-1 site layout for BWRX-300 design was optimized at a lower elevation. The new elevation of 814.5 ft. has been used in evaluations for the CRN PSAR.

2.2 Variance: CRN ESP VAR 2.0-2 – Ground Water Level

Request

TVA requests to use a maximum ground water level under foundation structures in power block area of 814.5 ft. In the CRN ESPA, the ground water level was 816.1 ft.

Justification

The CRN ESPA groundwater modeling software was Groundwater Vistas, Version 6.07, Build 10 (see CRN ESP VAR 2.4.12C-1). The more recent versions of the software, together with the site layout and grading, predicts the maximum groundwater to be at grade level of 814.5 ft.

2.3 Variance: CRN ESP VAR 2.0-3 – Single Unit Thermal Megawatts

Request

TVA requests to use the BWRX-300 SMR technology with a thermal output of 870 MWt for CRN-1 at the CRN Site. A single unit thermal megawatts SSAR PPE value of 800 MWt was assumed for the CRN ESP and CRN SSAR.

Justification

The BWRX-300 SMR design has an 870 MWt nominal output. The 70 MWt exceedance for a single unit is acceptable for the CRN Site because, as shown in the PPE comparison tables provided in CRN PSAR Section 2.0, CRN-1 meets all other SSAR PPE performance requirements (radiological release, structural design, etc.) for both the site and a single unit. The Maximum Hypothetical Accident evaluation provided in CRN PSAR Appendix 15C uses an analytical value of 887.4 MWt (Subsection 15C-5) based on the 2% measurement uncertainty allowance required by RG 1.183, Position 3.1. Calculated onsite and offsite radiological consequences from a postulated Maximum Hypothetical Accident were within applicable regulatory limits.

2.4 Variance: CRN ESP VAR 2.1-1 – 2020 Census Data

Request

TVA requests to use 2020 census data to replace the 2010 census data.

Justification

TVA has updated the 2010 census data in the CRN SSAR with data collected in 2020. The refreshed data shows a more accurate picture of the demographics near the CRN Site. While the numbers have changed slightly, the trends remain the same.

2.5 Variance: CRN ESP VAR 2.2-1 – Nearby Industrial, Transportation, and Military Facilities.

Request

TVA requests to use refreshed data to include updates to nearby industrial, transportation, and military facilities.

Justification

TVA has refreshed the data in CRN SSAR Section 2.2 to include updates to nearby industrial, transportation, and military facilities. As provided in RG 1.78, chemicals stored or situated at distances greater than 5 mi from CRN Site do not need to be considered because if a release occurs at such a distance, atmospheric dispersion will dilute and disperse the incoming plume to such a degree that either toxic limits will never be reached or there would be sufficient time for the control room operators to take appropriate action. Although several of the facilities are

located greater than 5 mi from the CRN Site, some of these were identified for further analysis because of their use of anhydrous ammonia, chlorine or sulfur dioxide. The update identified several industrial facilities, one major highway, four major roads, and two natural gas pipelines that are significant enough to be considered for further review (CRN PSAR Figure 2.2-1R). CRN PSAR Table 2.2-6R shows the result of evaluations performed on potential hazards nearby and on the CRN Site. Except where noted, these evaluations concluded that potential accidents involving explosions, flammable vapor clouds, collisions with intake structures, and liquid spills do not pose a threat to the CRN Site.

2.6 Variance: CRN ESP VAR 2.4.12-1 – Groundwater Levels Model

Request

TVA requests to use the proposed BWRX-300 design to perform pre- and post-construction modeling to estimate the response of groundwater levels to the inclusion of the adjacent non-Reactor Building power block structures.

Justification

Pre- and post-construction modeling in the CRN ESPA was performed based on the PPE conceptual design. Using the BWRX-300 site layout results in a more representative groundwater model.

2.7 Variance: CRN ESP VAR 2.4.12C-1 – Groundwater Vistas, Version 8.19, Build 4.

Request

TVA requests to use an updated version of the pre- and post-processor groundwater modeling software, Groundwater Vistas, Version 8.19, Build 4.

Justification

The CRN ESPA groundwater modeling software was Groundwater Vistas, Version 6.07, Build 10. The more recent versions of the software result in a more representative model.

2.8 Variance: CRN ESP VAR 2.0-4 – LOCA Bounding Design Basis Accident Radioactive Release

Request

TVA requests to use the radioactive releases associated with the BWRX-300 Loss-of-Cooling Accident (LOCA) Bounding Design Basis Accident.

Justification

LOCA: Design basis accidents for the GE Verona Hitachi Nuclear Energy BWRX-300 SMR are evaluated in CRN PSAR Chapter 15. The Feedwater Line Break Accident is the most limiting DBA. Releases for several radionuclides for the FWLB accident exceed the release in the LOCA

DBA evaluated in the CRN SSAR as shown in CRN PSAR Table 2.0-3R. However, the dose consequence of the postulated FWLB accident (CRN PSAR Table 15.7-6) is below applicable acceptance criteria and therefore the exceedances shown in CRN PSAR Table 2.0-3R are acceptable.

2.9 Variance: CRN ESP VAR 2.0-5 – Annual Normal Gaseous Radioactive Release

Request

TVA requests to use the radioactive releases associated with the BWRX-300 Annual Normal Gaseous source.

Justification

Annual Normal Gaseous Radioactive Release: Releases for several radionuclides for Annual Normal Gaseous Radioactive Release exceed the release evaluated in the CRN SSAR as shown in CRN PSAR Table 2.0-4R. As described in CRN PSAR Table 2.0-4R footnotes, the exceedances have been evaluated and show that CRN-1 calculated site boundary concentration limits and offsite receptor annual average doses are bounded by values presented in CRN SSAR Table 11.2-7, and Tables 11.3-3 through 11.3-5; and remain within regulatory limits.

2.10 Variance: CRN ESP VAR 2.0-6 – Accidental Liquid Radwaste Release

Request

TVA requests to use the radioactive releases associated with the BWRX-300 Accidental Liquid Radwaste source.

Justification

Accidental Liquid Radwaste Release: Releases for several radionuclides for the Accidental Liquid Radwaste Release accident exceed the release evaluated in the CRN SSAR as shown in CRN PSAR Table 2.0-5R. However, the dose consequence of the postulated Accidental Liquid Radwaste Release (CRN PSAR Subsection 2.4.13.8) is less than the 10 CFR 20.1301 limit of 100 mrem TEDE and therefore the exceedances shown in CRN PSAR Table 2.0-5R are acceptable.

2.11 Variance: CRN ESP VAR 2.0-7 – Annual Normal Liquid Radioactive Release

Request

TVA requests to use the radioactive releases associated with the BWRX-300 Annual Normal Liquid Radioactive Release source.

Justification

Annual Normal Liquid Radioactive Release: Releases for several radionuclides for Annual Normal Liquid Radioactive Release exceed the release evaluated in the CRN SSAR as shown in CRN PSAR Table 2.0-6R. The specific radionuclides that exceed SSAR PPE are minor dose contributors with respect to the considered dominant dose contributing radionuclides. The dominant dose contributing radionuclides (e.g., I-131, Cs-137, and H-3) calculated for CRN-1 are exceeded by many orders of magnitude by the corresponding SSAR PPE values. Therefore, the normal operation dose consequence from liquid effluents to members of the public from CRN-1 is expected to be bounded by SSAR PPE.

2.12 References

- 2.0-1 "Clinch River Nuclear Site Early Site Permit No. ESP-006," U.S. Nuclear Regulatory Commission, December 2019 (ML19352D868) and Final Safety Evaluation Report (ML19162A157).
- 2.0-2 "Clinch River Nuclear Site Early Site Permit Application Part 2, Site Safety Analysis Report," Tennessee Valley Authority, Revision 2, January 2019.