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U.S. Nuclear Regulatory Commission
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Subject: **Response to Portion of NRC Request for Additional Information Letter No. 208 - Related To NEDO-33338, "ESBWR Feedwater Temperature Operating Domain For Transient And Accident Analysis" – RAI Number 4.3-17**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) response to the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) sent by the Reference 1 NRC letter. GEH response to RAI Number 4.3-17 is addressed in Enclosure 1. DCD and Licensing Topical Report markups associated with this response are provided in Enclosure 2.

If you have any questions or require additional information, please contact me.

Sincerely,

Richard E. Kingston

Richard E. Kingston
Vice President, ESBWR Licensing

D068
NRO

Reference:

1. MFN 08-508, Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, Request For Additional Information Letter No. 208 Related To NEDE-33338P, "ESBWR Feedwater Temperature Operating Domain For Transient And Accident Analysis", dated June 3, 2008.

Enclosures:

1. MFN 08-869 – Response to Portion of NRC Request for Additional Information Letter No. 208 - Related to NEDO-33338, "ESBWR Feedwater Temperature Operating Domain For Transient And Accident Analysis" – RAI Number 4.3-17
2. MFN 08-869 – Response to Portion of NRC Request for Additional Information Letter No. 208 - Related to NEDO-33338, "ESBWR Feedwater Temperature Operating Domain For Transient And Accident Analysis" – RAI Number 4.3-17 – DCD and LTR Markups

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**Enclosure 1**

**MFN 08-869**

**Response to Portion of NRC Request for**

**Additional Information Letter No. 208**

**Related to NEDO-33338, "ESBWR Feedwater Temperature**

**Operating Domain For Transient And Accident Analysis"**

**RAI Number 4.3-17**

## NRC RAI 4.3-17

*Put lines for rod block, control system action, and protection system actuation in FWTOD map.*

*Provide in graphical form the power-temperature operating map showing the most relevant lines for alarms (e.g. rod block), control system action, and protection system actuation.*

## GEH Response

GEH response to RAI 4.3-16 (submitted in MFN 08-790 dated October 20, 2008) provides an updated Core Power – Feedwater Temperature Operating Domain (P-FWTOD) or map. Figure 4.3-17-1 of this response provides the lines for rod block, control system action and protection system actuation in the updated P-FWTOD.

The control systems relevant to the ESBWR Power – Feedwater Temperature Operating Domain (P-FWTOD) are discussed in Chapter 7, particularly in Subsection 7.7.3 (Feedwater Control System - FWCS), of DCD Tier 2, Rev 5 (Reference 4.3-17-1). If the reactor thermal power versus FW temperature combination is outside of the area allowed by the reactor power versus FW temperature map, the Rod Control and Information System (RC&IS)/Automated Thermal Limit Monitor (ATLM) initiates a control rod withdrawal block and/or a FW temperature control valve one-way block. If the reactor thermal power versus FW temperature combination further departs from the area allowed by the reactor thermal power versus FW temperature map (high reactor thermal power, high feedwater temperature or low feedwater temperature), the Reactor Protection System (RPS) initiates a reactor shutdown or scram.

The specific protective action lines in Figure 4.3-17-1 are as follows:

1. To limit the power increase above the SP1M-to-SP0 line, a control rod withdrawal block (along with alarm) is initiated at 108% power as per Table 7.2-4 of Reference 4.3-17-1. This is shown as the horizontal 'black dashed line' 1-0 in Figure 4.3-17-1. For feedwater temperatures above 222.2°C (432°F), this rod withdrawal block line (with alarm) is sloped downward parallel to the RPS scram line (Feedwater Temperature Biased Simulated Thermal Power – High), discussed below, with 7% lower reactor rated power from the RPS scram line. This rod withdrawal block line is shown as the 'black dashed line' 0-2. The core power and FW temperature at State Point 0 are 108% and 222.2°C (432°F), and those at State Point 2 are 92.1% and 256.2°C (493.2°F).

   If the reactor power reaches 108%, i.e., Line 1-0, because of FW temperature reduction due to open high-pressure FW heaters bypass valves, a FW temperature control valve one-way block (to prevent further opening of these bypass valves) is initiated along with alarm. This is to limit FW temperature reduction, and thereby limit further power increase. Similar one-way valve block is discussed in Item # 3 below.

2. If the reactor power increases further (above the SP1M-to-SP0 line), RPS trips and scrams the reactor at 115% power (shown by the horizontal 'red solid line' 1'-0') as per Table 7.2-4 of Reference 4.3-17-1. The RPS scram line (Feedwater Temperature Biased Simulated Thermal Power – High) is shown as the 'red solid line' 0'-2' as per Table 15.2-1 (for feedwater water temperatures above 222.2°C (432°F)) of Reference 4.3-17-1. The core power and FW temperature at State Point 0' are 115% and 222.2°C (432°F), and those at State Point 2' are 97.3% and 260.2°C (500.4°F).

3. To limit FW temperature reduction, and thereby power increase, a FW temperature control valve one-way block (to prevent further opening of the high-pressure FW heaters bypass valves) is initiated along with alarm beyond the Left Hand Side of the SP1M-SP5 line. This is shown as the 'purple dashed line' 1-5, which is parallel to the SP1M-SP5 line with a constant FW temperature offset of 11.1°C (20°F). If the reactor departs further to the left of this purple dashed line, the RPS scram (Simulated Thermal Power Biased Feedwater Temperature – Low) is initiated, which is shown as the 'red solid line' 1'-5', parallel to the SP1M-SP5 line with a constant FW temperature offset of 22.2°C (40°F). This scram is terminated at 85% power (Horizontal Line 5'-6') to allow Generator Load Rejection/Turbine Trip with Turbine Bypass to proceed without scram (Subsections 15.2.2.2 and 15.2.2.4 of Reference 4.3-17-1). No one-way valve block is implemented at powers below 50% of rated power, which is depicted by the horizontal 'purple dashed' line 5-6 at 50% power.

4. To limit the FW temperature increase at the Right Hand Side of the SP2-SP3-SP4 line, a similar FW temperature control valve one-way block (to prevent further opening of the steam valves for the 7th stage FW heaters) is initiated along with alarm. This is depicted by the 'purple dashed line' 2-3-4 (with a constant FW temperature offset of 4°C [7.2°F] from the SP2-SP3-SP4 line). If the reactor departs further to the right of this purple dashed line, the RPS scram (Simulated Thermal Power Biased Feedwater Temperature – High) is initiated, which is shown by the 'red solid line' 2'-3'-4' with a constant FW temperature offset of 8°C (14.4°F) from the SP2-SP3-SP4 line.

   From 50% to 25% power, these valve block and scram lines (2-3-4 and 2'-3'-4') are extended as 4-7 and 4'-7' lines parallel to the "Normal Power Ascension Line" with constant FW temperature offsets of 54°C (97.2°F) and 58°C (104.4°F), respectively. These valve block and scram lines (4-7 and 4'-7') are terminated at 25% power since there is significant margin to thermal limits and thermal limit monitoring is not required at powers below 25%.

**Reference:**

4.3-17-1 GE Hitachi Nuclear Energy, "ESBWR Design Control Document, Tier 2," 26A6642, Revision 5, May 2008.

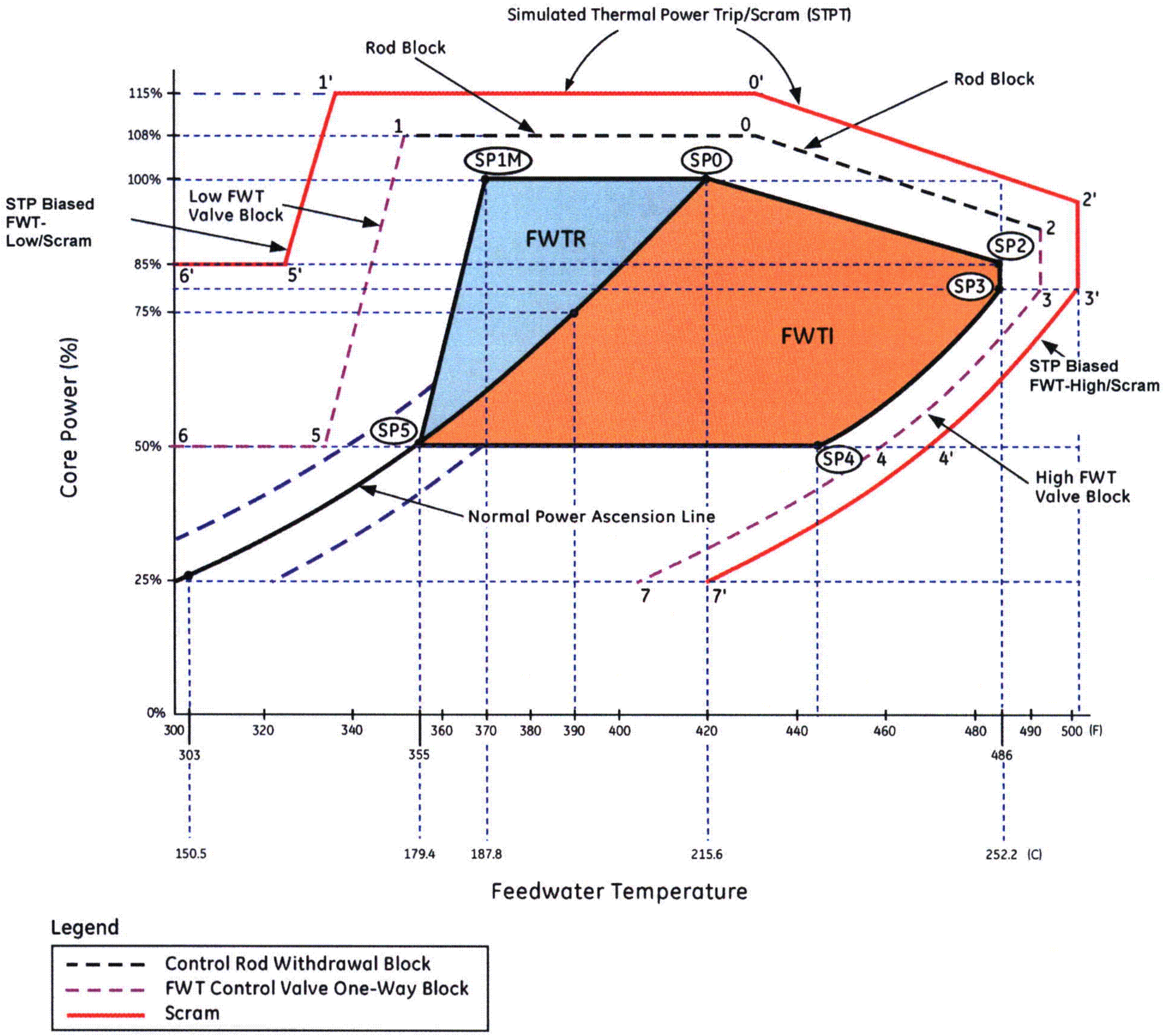


**Figure 4.3-17-1 ESBWR Core Power-FW Temperature Operating Domain with Representative Rod/FW Temperature Block and Scram Lines**

## DCD Impact

DCD Chapter 15 Section 15.2 and Figure 15.2-17 will be revised as per the DCD markup in Enclosure 2 in response to this RAI.

The subject LTR (NEDO-33338), Section 4.2, will be revised as per the LTR markup in Enclosure 2 in response to this RAI.

Enclosure 2

MFN 08-869

Response to Portion of NRC Request for

Additional Information Letter No. 208

Related to NEDO-33338, "ESBWR Feedwater Temperature

Operating Domain For Transient And Accident Analysis"

RAI Number 4.3-17

DCD and LTR Markups

## 15.2 ANALYSIS OF ANTICIPATED OPERATIONAL OCCURRENCES

Each of the anticipated operational occurrences (AOOs) addressed in the Section 15.1, "Nuclear Safety Operations Analysis" (NSOA), is evaluated in the following subsections. Appendix 15A provides a determination of event frequency to categorize AOOs as defined in 10 CFR 50 Appendix A. Tables 15.2-1, 15.2-2, and 15.2-3 provide the important input parameters and initial conditions used/assumed in the AOO analyses. Table 15.2-23 provides the response time limits for initiation signals used/assumed in AOO analyses.

In the analysis of AOOs and Infrequent Events in Section 15.3 nonsafety-related systems or components are considered to be operational in the following situations:

- When assumption of a nonsafety-related system results in a more limiting event;
- When a detectable and nonconsequential random, independent failure must occur in order to disable the system; and
- When nonsafety-related systems or components are used as backup protection (i.e. not the primary success path, included to illustrate the expected plant response to the event).

For the core power-feedwater temperature operating domain as discussed in Subsection 4.4.4.3, Figure 15.2-17 shows the lines for rod block, control system action and protection system actuation. The details are discussed in Reference 15.2-5.

### 15.2.0 Assumptions

Assumptions are listed in the event discussions and Table 15.2-1.

### 15.2.1 Decrease In Core Coolant Temperature

#### *15.2.1.1 Loss Of Feedwater Heating*

##### 15.2.1.1.1 Identification of Causes

A feedwater (FW) heater can be lost in at least two ways:

- Steam extraction line to heater is closed; and/or
- FW is bypassed around heater.

The first case produces a gradual cooling of the FW. In the second case, the FW bypasses the heater and no heating of the FW occurs. In either case, the reactor vessel receives colder FW. The maximum number of FW heaters that can be tripped or bypassed by a single event represents the most severe event for analysis considerations.

The ESBWR is designed such that no single operator error or equipment failure causes a loss of more than 55.6°C (100°F) FW heating.

The loss of FW heating causes an increase in core inlet subcooling. This increases core power due to the negative void reactivity coefficient. However, the power increase is slow.

A LOFWH that results in a significant decrease in feedwater temperature is independently detected by the ATLMs and by the Diverse Protection System (DPS), either of which mitigates the event by initiating SCRRI and SRI functions as discussed in Subsections 7.7.2.2.7.7, 7.7.3.3

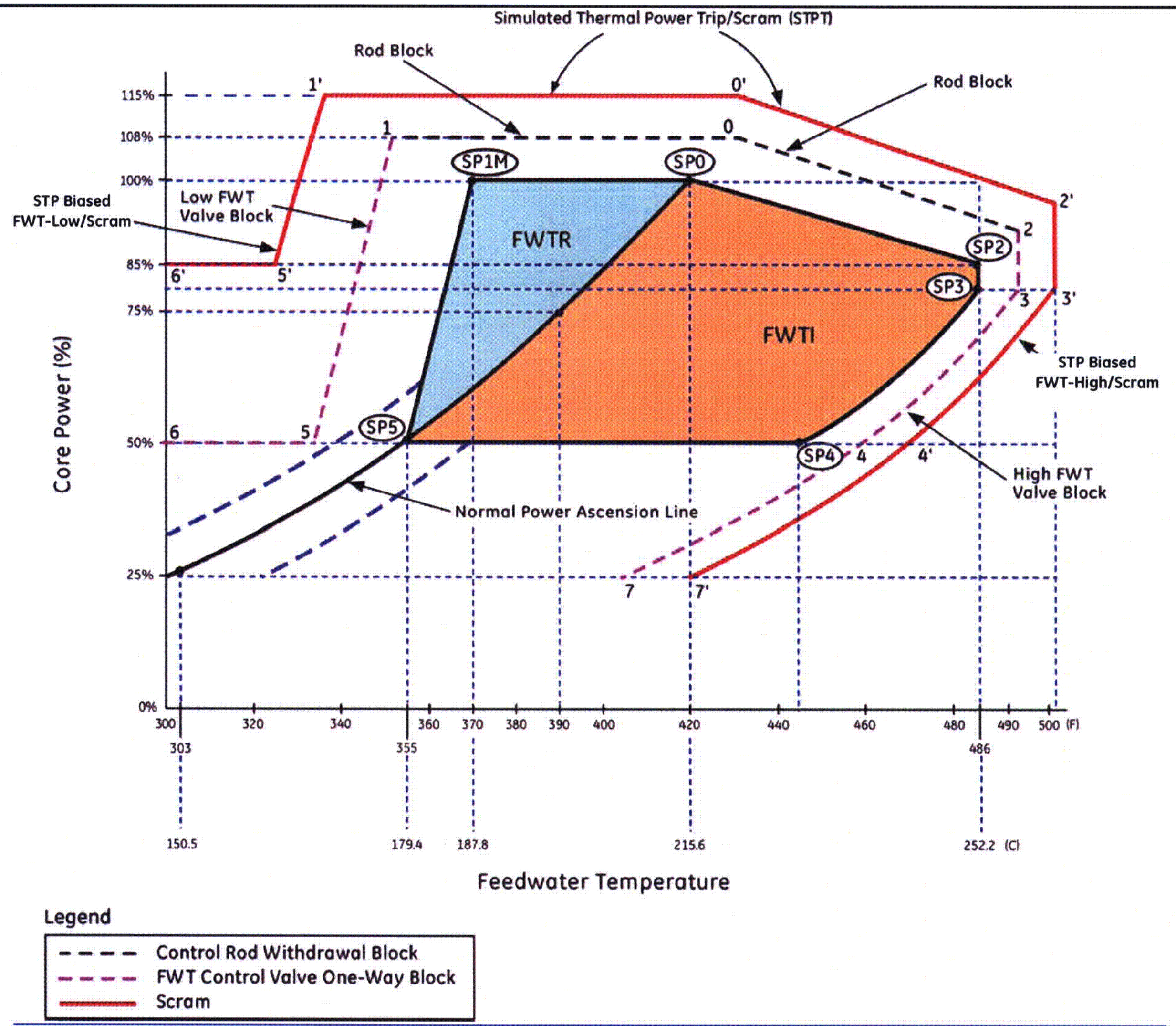


**Figure 15.2-17. ESBWR Core Power-FW Temperature Operating Domain with Representative Rod/FW Temperature Block and Scram Lines**

## 4.2 Power – Feedwater Temperature Map/Domain

Based on the comparison results presented in Section 4.1, it is concluded that ESBWR operates safely at the following operating states:

- Nominal or SP0 condition (100% rated power and FW temperature of 215.6°C/420°F)
- High Feedwater temperature or SP2 condition (85% rated power and FW temperature of 252.2°C/486°F)
- Low Feedwater temperature or SP1M condition (100% rated power and FW temperature of 187.8°C/370°F).

Based on above, the ESBWR Power – FW temperature operating domain or map, as shown in Figure 4.2-1, is developed. The normal power ascension line (from Hot Zero power (~ 0 power, 80°C/176°F) to the rated operating state (SP0)) with 6 feedwater heaters on-line is shown in the middle of the Map. To account for various uncertainties, a FW temperature band of +/- 8.3°C (15°F) is provided on this normal power ascension line for ESBWR operating domain Bbetween the Hot zero power25% and the 50% rated power (SP5)., ESBWR is expected to operate on this normal power ascension line with a band at both sides of the line.This band is not extended below 25% power since there is significant margin to thermal limits and thermal limit monitoring is not required at powers below 25%.

With the use of the 7th FW heater, discussed in Chapter 10 of the DCD (Reference 4.2-1), the ESBWR can be operated at the Right Hand Side (RHS) of the normal power ascension line from 50% to 100% rated power (from SP5 to SP0), i.e., in the "Light Orange" or FWTI (Feedwater Temperature Increase) region. Operation in this region is envisaged only at higher powers (> 60% rated power). The SP2-SP3-SP4-SP5 line defines the Right Hand boundary of this "FWTI" region. The straight line SP2 to SP3 is a vertical line at FW temperature of 252.2°C (486°F) from 85% power (at SP2) to 80% power (at SP3). The line SP3 to SP4 is parallel to the normal power ascension line SP5 to SP0 with a constant FW temperature offset of 50°C (90°F). Line SP4 to SP5 is a horizontal line at 50% power.Right Hand boundary of this "FWTI" region depends on the design and operational details of the BOP equipment, which is outside the scope of this report as mentioned in Section 1.3

ESBWR may be operated at the Left Hand Side (LHS) of the normal power ascension line from 50% to 100% rated power (from SP5 to SP0), or in the "Light Blue" or FWTR (Feedwater Temperature Reduction) region as part of operational or control blade maneuvering flexibility by utilizing the high pressure FW heater bypass system discussed in Chapter 10 of the DCD (Reference 4.2-1). However, as discussed in Chapter 1 of this report, these operating regions (both FWTI and FWTR regions) are developed to add operational flexibility in a manner that tends to further decrease the probability of duty-related fuel failure.

Figure 4.2-2 provides the lines for rod block, control system action and protection system actuation in the ESBWR Power – FW temperature operating domain or P-FWTOD. The details are discussed below:

(1) To limit the power increase above the SP1M-to-SP0 line, a control rod withdrawal block (along with alarm) is initiated at 108% power as per Table 7.2-4 of Reference 4.2-1. This is shown as the horizontal 'black dashed line' 1-0 in Figure 4.2-2. For feedwater temperatures above 222.2°C (432°F), this rod withdrawal block line (with alarm) is sloped

downward parallel to the RPS scram line (Feedwater Temperature Biased Simulated Thermal Power – High), discussed below, with 7% lower reactor rated power from the RPS scram line. This rod withdrawal block line is shown as the 'black dashed line' 0-2. The core power and FW temperature at State Point 0 are 108% and 222.2°C (432°F), and those at State Point 2 are 92.1% and 256.2°C (493.2°F).

If the reactor power reaches 108%, i.e., Line 1-0, because of FW temperature reduction due to open high-pressure FW heaters bypass valves, a FW temperature control valve one-way block (to prevent further opening of these bypass valves) is initiated along with alarm. This is to limit FW temperature reduction, and thereby limit further power increase. Similar one-way valve block is discussed in Item # 3 below.

(2) If the reactor power increases further (above the SP1M-to-SP0 line), RPS trips and scrams the reactor at 115% power (shown by the horizontal 'red solid line' 1'-0') as per Table 7.2-4 of Reference 4.2-1. The RPS scram line (Feedwater Temperature Biased Simulated Thermal Power – High) is shown as the 'red solid line' 0'-2' as per Table 15.2-1 (for feedwater water temperatures above 222.2°C (432°F)) of Reference 4.2-1.

(3) To limit FW temperature reduction, and thereby power increase, a FW temperature control valve one-way block (to prevent further opening of the high-pressure FW heaters bypass valves) is initiated along with alarm beyond the Left Hand Side of the SP1M-SP5 line. This is shown as the 'purple dashed line' 1-5, which is parallel to the SP1M-SP5 line with a constant FW temperature offset of 11.1°C (20°F). If the reactor departs further to the left of this purple dashed line, the RPS scram (Simulated Thermal Power Biased Feedwater Temperature – Low) is initiated, which is shown as the 'red solid line' 1'-5', parallel to the SP1M-SP5 line with a constant FW temperature offset of 22.2°C (40°F). This scram is terminated at 85% power (Horizontal Line 5'-6') to allow Generator Load Rejection/Turbine Trip with Turbine Bypass to proceed without scram (Subsections 15.2.2.2 and 15.2.2.4 of Reference 4.2-1). No one-way valve block is implemented at powers below 50% of rated power, which is depicted by the horizontal 'purple dashed' line 5-6 at 50% power.

(4) To limit the FW temperature increase at the Right Hand Side of the SP2-SP3-SP4 line, a similar FW temperature control valve one-way block (to prevent further opening of the steam valves for the 7th stage FW heaters) is initiated along with alarm. This is depicted by the 'purple dashed line' 2-3-4 (with a constant FW temperature offset of 4°C [7.2°F] from the SP2-SP3-SP4 line). If the reactor departs further to the right of this purple dashed line, the RPS scram (Simulated Thermal Power Biased Feedwater Temperature – High) is initiated, which is shown by the 'red solid line' 2'-3'-4' with a constant FW temperature offset of 8°C (14.4°F) from the SP2-SP3-SP4 line.

From 50% to 25% power, these valve block and scram lines (2-3-4 and 2'-3'-4') are extended as 4-7 and 4'-7' lines parallel to the "Normal Power Ascension Line" with constant FW temperature offsets of 54°C (97.2°F) and 58°C (104.4°F), respectively. These valve block and scram lines (4-7 and 4'-7') are terminated at 25% power since there is significant margin to thermal limits and thermal limit monitoring is not required at powers below 25%.

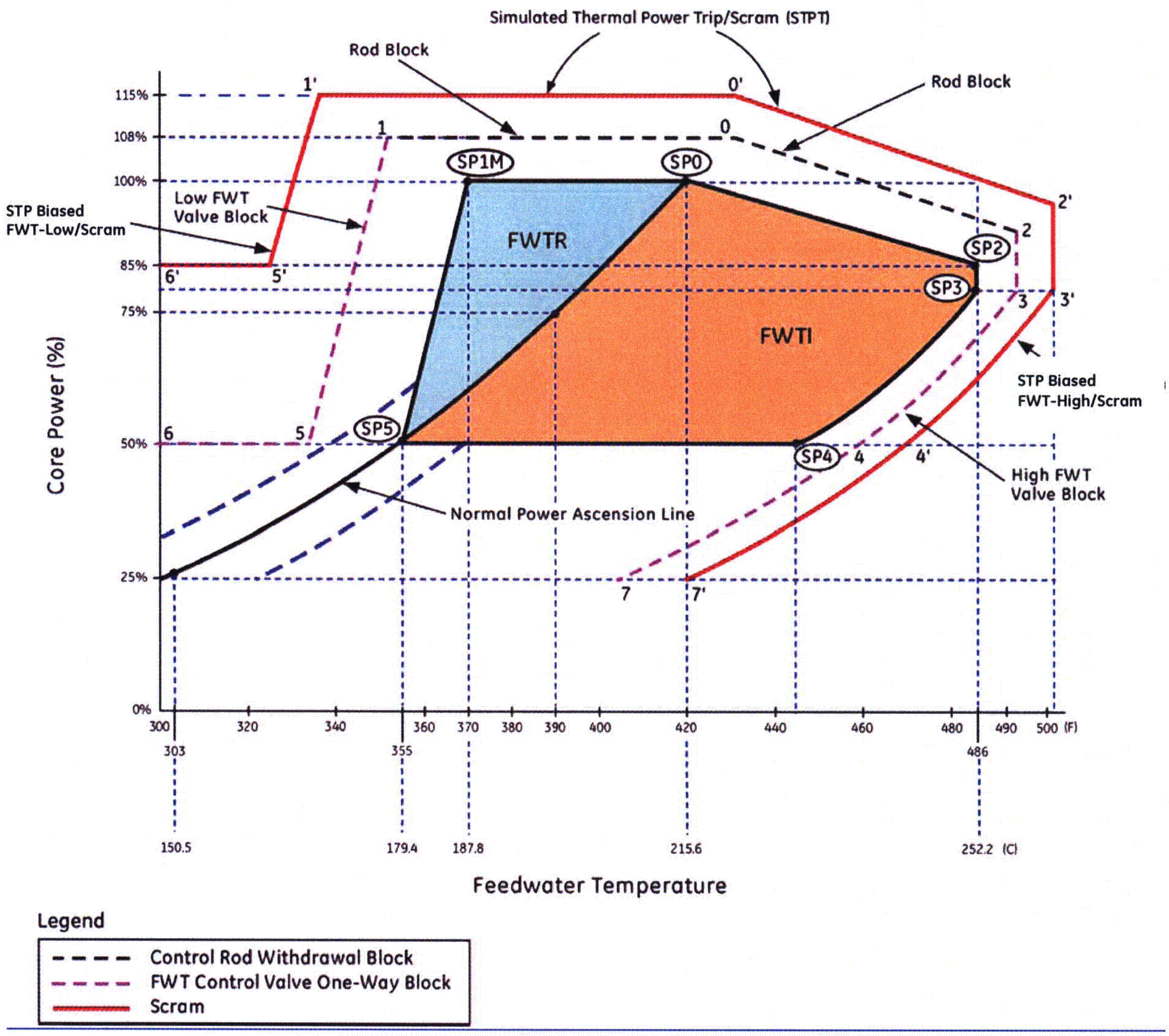


**Figure 4.2-2 ESBWR Power-FW Temperature Operating Domain with Representative Rod/FW Temperature Block and Scram Lines**