ENCLOSURE 1

MFN 12-112 Sup 2

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Non-Proprietary Information – Class I (Public)

S.1.2 Vessel Pressure ASME Code Compliance

The ASME Boiler and Pressure Vessel Code and other codes and standards require that the pressure relief system prevent excessive overpressurization of the primary system process barrier and the pressure vessel. The allowable pressure and prescribed evaluations are determined by these requirements. The analysis performed to demonstrate conformance to the requirements is documented in Section S.3.

S.1.3 Stability Analysis

Stability requirements are set forth in 10CFR50 Appendix A, General Design Criterion (GDC). GDC 10 states that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated occurrences. GDC 12 states that power oscillations that can result in conditions exceeding specified acceptable fuel design limits either should not be possible, or can be reliably and readily detected and suppressed.

All US BWRs including BWRs 2-6 and the ABWR have selected one of the NRC approved BWROG long–term stability solutions described in References S–79, S–80, ~~and~~ S-104, and S-111 to meet the GDC criteria. Long–term solutions are of the prevention type (i.e., power oscillations are not possible), the detect and suppress type (i.e., power oscillations can be reliably and readily detected and suppressed), or are a combination of the two types. Stability compliance with GDC 10 and GDC 12 must be demonstrated on a plant and cycle–specific basis for each of the long–term solutions.

If the long–term solution is declared inoperable due to Part 21 issues or hardware failures, the Interim Corrective Action (ICA) as outlined in Reference S–91 or an equivalent solution (e.g., the Backup Stability Protection (BSP) as outlined in Reference S–90) can be used on an interim basis. These are described in Section S.4.2.

The plant and cycle–specific calculations required for each long–term stability solution are described in Section S.4.1.

S.1.4 Analysis Options

Several analysis options are available, on a commercial basis, to all owners of BWRs fueled by GE. As these options are selected by the BWR owners, plant–specific and/or generic–bounding analyses will be submitted for NRC approval. The first set of options provides MCPR margin improvement. The second set of options provides additional operating flexibility for BWRs. In some cases, these options are included only to describe their impact on the reload license, and separate approval must be obtained before they can be used on a specific plant. The currently available options are discussed in Section S.5.

S.2 AOO and Accident Analysis

AOOs and accident events are divided among eight individual categories in the FSARs as required by Reference S–4. The categories are as follows.

- CPR response calculations are performed to demonstrate the SLMCPR protection against a thermal hydraulic instability event using the detect and suppress methodology outlined in Reference S-85. The plant and cycle-specific core-wide mode DIVOM (Delta CPR over Initial CPR Vs. Oscillation Magnitude) data is required for Option I-D plant stability analysis and must be calculated in accordance with the BWROG plant-specific core-wide mode DIVOM procedure guideline specified in Reference S-102. The plant and cycle-specific regional mode DIVOM data is required for Option II and Option III plant stability analyses and must be calculated in accordance with the BWROG plant-specific regional mode DIVOM procedure guideline specified in Reference S-103. This is applicable to Option I-D, Option II and Option III.

- CPR margins calculations are performed to demonstrate the SLMCPR protection against a thermal hydraulic instability event using the integrated TRACG methodology outlined in References S-104 and S-111. The demonstration of new fuel types beyond the currently approved fuel designs (up to GE14) and the BWR product line (up to BWR/6) must be demonstrated in accordance with the integrated TRACG methodology outlined in Section 6 of References S-104 or Reference S-111. This is applicable to DSS-CD.

The core and channel decay ratios are calculated with a NRC approved frequency domain model. The ODYSY code (References S-106 and S-96) is used in the frequency domain evaluations, even though the older FABLE code may be used in some legacy calculations (e.g., the E1A Standard Cycle). This calculation provides assurance that plants with prevention based long–term stability solutions will not have to unreasonably increase the size of their stability–based regions for the evaluated fuel design.

The continued applicability of the interim/backup stability solution is based on exclusion regions and reload validation of these exclusion regions is required to ensure full stability protection.

The applicability of the plant and cycle-specific DIVOM curve is demonstrated with a best–estimate coupled neutronic – thermal hydraulic model using TRACG. This is the same model that was used to generate the plant and cycle-specific DIVOM data. The DIVOM data is required for plants with a detect and suppress solution to demonstrate safety limit MCPR compliance.

The plant-specific CPR margins demonstration based on integrated TRACG model is required of all plants implementing the DSS-CD solution for the first time to ensure the safety limit MCPR compliance.

S.4.1 Long–Term Stability Solutions

S.4.1.1 Enhanced Option I–A

The BWROG Enhanced Option I–A (EIA) is a prevention solution. EIA was reviewed and approved by the USNRC as documented in References S–80 through S–84 and Reference S–

S.4.1.5 DSS-CD

The GEH Detect and Suppress Solution – Confirmation Density (DSS-CD) is a detect and suppress solution. DSS-CD was reviewed and approved by the USNRC as documented in Reference S–104 for operation up to and including the Maximum Extended Load Line Limit Analysis Plus (MELLLA+) domain. A revision of the DSS-CD solution supporting the migration to a TRACG04/PANAC11 methodology and improvements in the implementation of the BSP function was submitted to the USNRC and it is documented in Reference S-111. Continued safety limit MCPR protection is demonstrated for each fuel cycle using the methodology documented in References S-104 and S-111.

The results of the safety limit MCPR protection ~~calculation~~ evaluation are documented in the supplemental reload licensing report.

S.4.2 Interim/Backup Stability Solution

S.4.2.1 Interim Corrective Action (ICA)

The ICA is an interim prevention solution based on exclusion regions for EIA, Option I-D, Option II and Option III. The currently used ICA regions were established in Reference S–91 based on original licensed thermal power, generally shorter fuel cycles, and more stable core designs. These regions are defined based on relative core flow and rod line points and not on specific stability criteria. New aggressive core design changes may have reduced stability margins. GE recommends that the impact of core design changes be included in plant/cycle–specific evaluations to assess the continued applicability of the ICA regions. The results of the ICA analysis are documented in the supplemental reload licensing report.

S.4.2.2 Backup Stability Protection (BSP) for Option III

The BSP for Option III is an alternative interim prevention solution based on exclusion regions. The currently used BSP regions were established in Reference S–90 based on revised ICA regions. These regions are defined based on relative core flow and rod line points and not on specific stability criteria. New aggressive core design changes may have reduced stability margins. GEH recommends that the impact of core design changes be included in plant/cycle–specific evaluations of the BSP regions.

The BSP for Option III is generated in accordance with Reference S-90. The BSP for Option III methodology is applied in the fuel cycle reload stability analysis. To calculate the BSP Scram and Controlled Entry Region boundaries, ODYSY decay ratio calculations are performed on the High Flow Control Line (HFCL) and on the Natural Circulation Line (NCL). Rated feedwater temperature and rated xenon concentrations are assumed for calculating the BSP Scram Region boundary endpoints. The two endpoints (A1 and B1 in Figure S-3), where the ODYSY acceptance criteria are met, are connected using either the Generic or Modified Shape Function to define the Scram Region boundary. The BSP Controlled Entry Region is calculated in a similar manner, also using the ODYSY acceptance criteria to define the two endpoints (A2 and B2), with either the Generic or Modified Shape Function as the connecting curve. Off-rated equilibrium feedwater temperature is assumed for calculating the Controlled Entry Region endpoints (A2 and B2). Equilibrium xenon condition is assumed for the HFCL endpoint (A2) while xenon-free condition is assumed for the NCL endpoint (B2).

If the MSF is used, each calculated BSP region boundary must be validated at a mid-point against the DR acceptance criterion, respectively. This mid-point MSF validation should be performed based on the calculated BSP boundaries. A mid-point can be defined as a state point that its flow is the average flow of the two corresponding bounding state points, i.e., A1 and B1 or A2 and B2 or another power/state point close to the mid-point on the MSF. The MSF validation point should be based corresponding to the HFCL conditions and its associated limiting exposure.

The typical calculated stability region boundaries are illustrated in Figure S-3 where the four calculated endpoints A1, A2, B1, B2 are based on a core decay ratio criterion of 0.80. Please note that the actual implemented BSP boundaries might be larger due to the Base BSP region definitions. The Base BSP regions for Option III are defined in Reference S-90.

According to Reference S-90, deliberate entry into the BSP Controlled Entry Region requires compliance with at least one of the stability controls outlined below:

1. Maintain core average Boiling Boundary (BB) ≥ 4.0 feet,

2. Maintain core average BB > Reference value (demonstrated to produce stable operation) and ≥ 3.0 feet,

   Maintain radial peaking factor ≤ Reference value (demonstrated to produce stable operation),

3. Maintain core decay ratio (DR) < 0.6 as calculated by an on-line core stability monitor,

4. The individual owner will determine appropriate limits for core DR (< 0.60) as calculated by a core stability monitor, or by pre-analysis of a reactor state trajectory through the Controlled Entry Region, or

5. Continuous dedicated monitoring of real time control room neutron monitoring instrumentation with manual scram required upon indication of a reactor instability induced power oscillation.

Usually, two sets of BSP regions may be generated for different rated feedwater temperature ranges. The results of the BSP for Option III analysis are documented in the supplemental reload licensing report.

S.4.2.3 Backup Stability Protection (BSP) for DSS-CD per Reference S-104

The BSP for DSS-CD is a backup solution based on exclusion regions in case the DSS-CD solution is not operational.

The BSP for DSS-CD is generated in accordance with Reference S-~~103~~104 and it’s applicable to plants licensed with DSS-CD per Reference S-104. The BSP for DSS-CD methodology is applied in the fuel cycle reload stability analysis. To calculate the BSP Scram and Controlled Entry Region boundaries, ODYSY decay ratio calculations are performed on the HFCL and on the NCL. Rated feedwater temperature and rated xenon concentrations are assumed for calculating the BSP Scram Region boundary endpoints. The two endpoints (A1 and B1 in Figure S-4), where the ODYSY acceptance criteria are met, are connected using the Generic Shape Function to define the Scram Region boundary. The BSP Controlled Entry Region is calculated in a similar manner, also using the ODYSY acceptance criteria to define the two endpoints (A2 and B2), with the Generic Shape Function as the connecting curve. Off-rated equilibrium feedwater temperature is assumed for calculating the Controlled Entry Region endpoints (A2 and B2). Equilibrium xenon condition is assumed for the HFCL endpoint (A2) while xenon-free condition is assumed for the NCL endpoint (B2).

Please note that there are several differences between the BSP for DSS-CD and BSP for Option III:

a) The ODYSY core decay ratio (DR) acceptance criterion used for the Controlled Entry Region boundary intercept (A2) along the HFCL is different between the methodologies. The BSP for Option III uses a core DR acceptance criterion of 0.80 while the BSP for DSS-CD uses a core DR acceptance criterion of 0.60.

b) For BSP for Option III, the HFCL is defined as the highest licensed load line, up to the MELLLA boundary. For BSP for DSS-CD, the HFCL is defined as the MELLLA+ boundary.

c) The BSP for DSS-CD solution imposes the BSP Boundary restriction on the DSS-CD solution for short-term manual operation if the OPRM system is inoperable.

d) The Generic Shape Function is used in the BSP for DSS-CD.

The typical calculated stability region boundaries and the BSP Boundary are illustrated in Figure S-4; the three endpoints A1, B1 and B2 are calculated based on a core DR criterion of 0.80 while the A2 endpoint is calculated based on a core DR criterion of 0.60. The 0.60 criterion for the A2 endpoint (as illustrated in Figure S-4) provides additional stability margins for operation at off-rated conditions and for a two-pump trip to natural circulation flow.

Please note that the actual implemented BSP region boundaries might be larger due to the Base BSP region definitions. The Base BSP regions for DSS-CD are defined in Reference S-~~103~~104.

Deliberate entry into the Manual BSP Controlled Entry Region requires compliance with at least one of the stability controls outlined in Section 7.2.3.2 of Reference S-~~103~~104.

Usually, two sets of BSP regions may be generated for different rated feedwater temperature ranges. Only the Automated BSP option is approved for use ~~as~~ for an extended time as backup solution to DSS-CD. The results of the BSP for DSS-CD analysis are documented in the supplemental reload licensing report.

S.4.2.4 Backup Stability Protection (BSP) for DSS-CD per Reference S-111

The BSP for DSS-CD is a backup solution based on exclusion regions in case the DSS-CD solution is not operational.

The BSP for DSS-CD is generated in accordance with Reference S-111, and it's applicable to plants licensed with DSS-CD per Reference S-111. The BSP for DSS-CD methodology is applied in the fuel cycle reload stability analysis. To calculate the BSP Scram and Controlled Entry Region boundaries, ODYSY decay ratio calculations are performed on the HFCL and on the NCL. Rated feedwater temperature and rated xenon concentrations are assumed for calculating the BSP Scram Region boundary endpoints. The two endpoints (A1 and B1 in Figure S-4), where the ODYSY acceptance criteria are met, are connected using either the Generic Shape Function or Modified Shape Function to define the Scram Region boundary. The BSP Controlled Entry Region is calculated in a similar manner, also using the ODYSY acceptance criteria to define the two endpoints (A2 and B2), with the Generic Shape Function or Modified Shape Function as the connecting curve. Off-rated equilibrium feedwater temperature is assumed for calculating the Controlled Entry Region endpoints (A2 and B2). Equilibrium xenon condition is assumed for the HFCL endpoint (A2) while xenon-free condition is assumed for the NCL endpoint (B2).

Please note that there are a few differences between the BSP for DSS-CD implemented per Reference S-111 and the BSP for DSS-CD implemented per Reference S-104:

a) The ODYSY core decay ratio (DR) acceptance criterion used for the Controlled Entry Region boundary intercept (A2) along the HFCL is different between the methodologies. The BSP for DSS-CD per Reference S-111, consistent with Option III, uses a core DR acceptance criterion of 0.80 while the BSP for DSS-CD per Reference S-104 uses a core DR acceptance criterion of 0.60.

b) The application of BSP Boundary as described in Section S.4.2.3 is limited to MELLLA+ region in the BSP DSS-CD per Reference S-111.

c) The Modified Shape Function (MSF) is added as an option for the determination of the BSP region boundaries in the BSP DSS-CD per Reference S-111.

Please note that the actual implemented BSP region boundaries might be larger due to the Base BSP region definitions. The Base BSP regions for DSS-CD are defined in Reference S-111.

Deliberate entry into the Manual BSP Controlled Entry Region requires compliance with at least one of the stability controls outlined in Section 7.2.3.2 of Reference S-111.

Usually, two sets of BSP regions may be generated for different rated feedwater temperature ranges. Only the Automated BSP option is approved for use for an extended time as backup solution to DSS-CD. The results of the BSP for DSS-CD analysis are documented in the supplemental reload licensing report.

S.5 Analysis Options

Three groups of analysis options are presented in the following sections. The first group involves options that may be chosen to improve MCPR margin. The second group of improvements represents a collection of possible operating flexibility options. Also noted in the second group is the GE Licensing Topical Report, *Applicability of GE Methods to Expanded Operating Domains* (Reference S-101), which may be part of the licensing basis for EPU and MELLLA+ plants. The third group includes the requirements for applying the generic analysis in Reference S-99 for the Fuel Loading Error event. In some cases separate plant specific reports are submitted for approval before the option is available. Other options are supported by generic analyses that have been approved and only require that the plant choose to activate the option. In each case, the plant options are selected for each cycle and documented in the cycle design documentation and the plant supplemental reload licensing report (SRLR).

S.5.1 Available MCPR Margin Improvement Options

The following margin improvement options have been developed for operating BWRs:

(1) Recirculation Pump Trip

(2) Rod Withdrawal Limiter

(3) Thermal Power Monitor

(4) Exposure–Dependent Limits

(5) Improved Scram Times
   (a) Measured Scram Time
   (b) Generic Statistical Scram Time (ODYN Option B or TRACG Option B)

These margin improvement options will be made available, on a commercial basis, to all owners of operating BWRs.

As these options are selected by the BWR owners, plant–specific and/or generic bounding analyses will be submitted for approval. The plant supplemental reload licensing report will designate the options selected by that BWR owner.

S.5.1.1 Recirculation Pump Trip

For many of the plant operating cycles, the limiting AOOs are the turbine trip, generator load rejection, or other AOOs that result in a turbine trip. A significant improvement in thermal margin can be realized if the severity of these transients is reduced. The Recirculation Pump

(1) **LOCA** – The applicability of previous LOCA analyses to the extended operating region must be verified for each plant during each cycle.

(2) **AOOs** – The consequences of AOOs are evaluated to determine if operating limit adjustments are necessary for operation in the extended operating range.

BWR/5 and 6 are designed with expanded operating flexibility that supports plant operation in an extended region above the rated load line up to rated power. This expanded flexibility is validated whenever a fuel design with different transient response characteristics is introduced.

S.5.2.3 Extended Load Line Limit (BWR/2–6)

The Extended Load Line Limit Analysis (ELLLA) is similar to the LLLA described in Subsection S.5.2.2. However, the extended operating domain for ELLLA, instead, has an upper bound of the APRM rod block line to rated power for BWR/2–6.

Once ELLLA has been performed for a specific plant and cycle, it is reverified for applicability to subsequent cycles as described in Sub–section S.5.2.2. Because of the different extended operating regions for ELLLA and LLLA, the power/flow points chosen for analysis may be different.

Some plants have, in plant specific submittals, relaxed the APRM rod block setpoints. For these plants, the ELLLA region no longer corresponds to the APRM rod block line. The APRM setpoints and the analyzed operating domain are defined in the plant specific licensing documentation.

S.5.2.4 Increased Core Flow (ICF) Operation

Analyses are performed in order to justify operation at core flow rates in excess of the 100% rated flow condition. The analyses are done for application through the cycle or for application at the end of cycle only.

The limiting AOOs that are analyzed at rated flow as part of the supplemental reload licensing report are reanalyzed for increased core flow operation. In addition, the loss–of–coolant accident (LOCA), fuel loading error evaluated as an AOO only, rod drop accident, and rod withdrawal error are also re–evaluated for increased flow operation to assure that the higher flow and exposure capability does not significantly impact these analyses.

The effects of the increased pressure differences on the reactor internal components, fuel channels, and fuel bundles as a result of the increased flow are analyzed in order to ensure that the design limits will not be exceeded.

The thermal–hydraulic stability is not re–evaluated for increased core flow operation because ICF has no effect on thermal-hydraulic stability.

T~~, and t~~he effects of flow–induced vibration are ~~also~~ evaluated to assure that the vibration criteria will not be exceeded.

S.5.2.5 Feedwater Temperature Reduction (FWTR)

Analyses are performed in order to justify operation at a reduced feedwater temperature at rated thermal power. Usually, the analyses are performed for end–of–cycle operation with the last–stage feedwater heaters valved out in order to increase the core rated power exposure capability. However, throughout cycle operation, some feedwater temperature reduction can be justified by analyses at the appropriate operating conditions for accommodating the potential of a feedwater heater being out of service.

The limiting AOOs are reanalyzed for operation at a reduced feedwater temperature. In addition, the loss–of–coolant accident (LOCA), fuel loading error evaluated as an AOO only, rod drop accident, and rod withdrawal error are also re–evaluated for operation at a reduced feedwater temperature to assure that the higher subcooling and exposure capability does not significantly impact these analyses.

The reactor core and thermal–hydraulic stability are re–evaluated, along with the increase in the feedwater nozzle fatigue usage factor, for operation at a reduced feedwater temperature throughout the cycle.

S.5.2.6 ARTS Program (BWR/3–5)

The ARTS program is a comprehensive project involving the Average Power Range Monitor (APRM), the Rod Block Monitor (RBM), and Technical Specification improvements.

Implementing the ARTS program provides for the following improvements that enhance the flexibility of the BWR during power level monitoring.

(1) The average power range monitor (APRM) trip setdown requirement is replaced by a power–dependent MCPR operating limit similar to that used in the BWR/6, and a flow–dependent MCPR operating limit to reduce the need for manual setpoint adjustments. In addition, another set of LHGR power– and flow–dependent limits will also be specified for more rigorous fuel thermal protection during postulated transients at off–rated conditions. These power– and flow–dependent limits are verified for plant–specific application during the initial ARTS licensing implementation and are applicable to subsequent cycles provided that there are no changes to the plant configuration as assumed in the licensing analyses. A plant may also include the power– and flow–dependent limits for MAPLHGR.

(2) The RBM system may be modified from flow–biased to power–dependent trips to allow the use of a new generic non–limiting analysis for the rod withdrawal error (RWE) and to improve response predictability to reduce the frequency of nonessential alarms. The applicability of the generic RWE analysis to GE fuel designs is discussed in Reference S–2.

S-111 *GE Hitachi Boiling Water Reactor Detect and Suppress Solution – Confirmation Density*, NEDC–33075P-A, Revision 7, TBD.

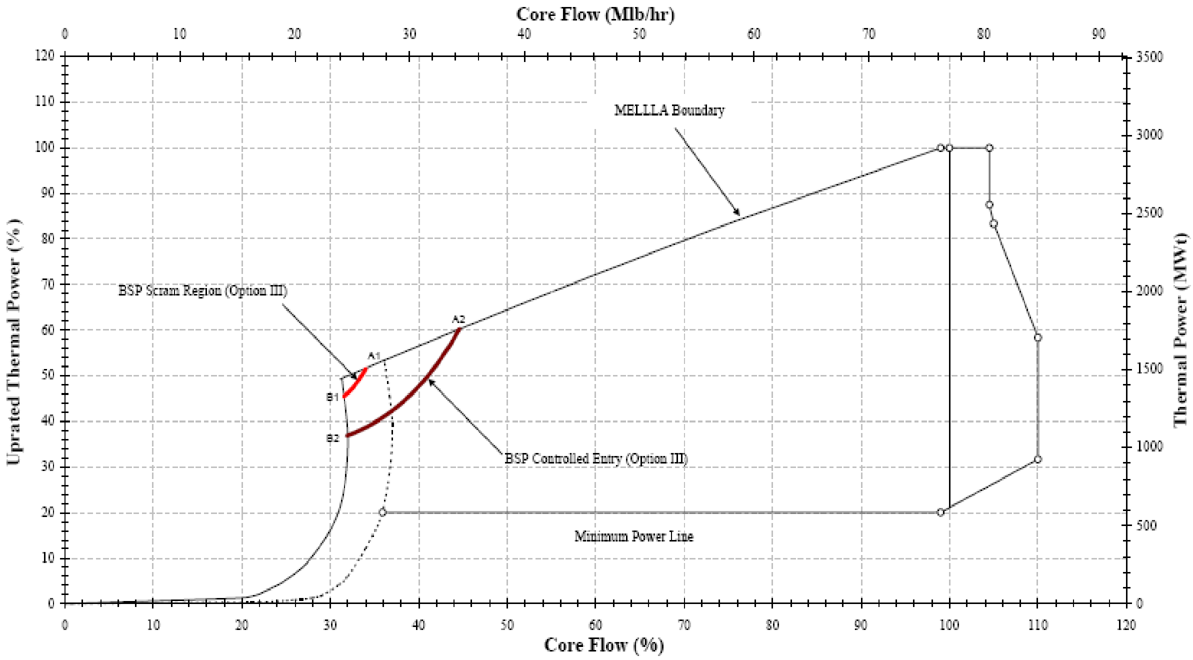

Figure S-3. Illustration of Scram and Controlled Entry Region Boundaries for BSP for Option III

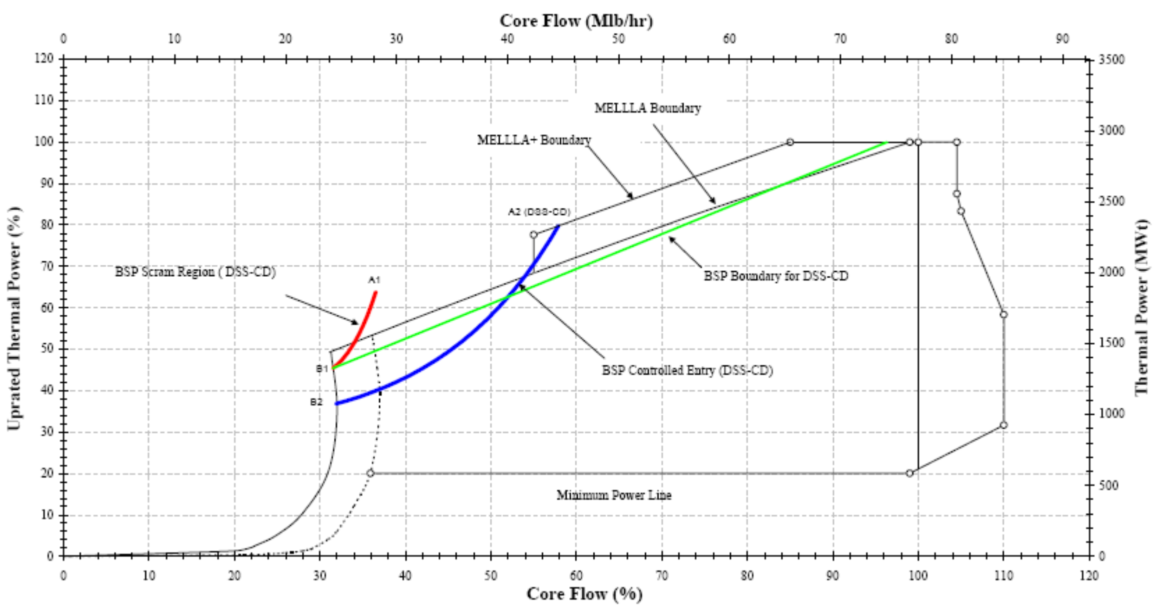

Figure S-4. Illustration of Scram and Controlled Entry Region Boundaries, and the BSP Boundary for BSP for DSS-CD per Reference S-104