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BWR Suppression Pool Temperature Technical Specification Limits

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TECHNICAL SPECIFICATION LIMITS

Prepared For

The BWR Owners' Group

Suppression Pool Temperature Limit Committee

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ABSTRACT

Currently, Technical Specification (T/S) limits are specified for the GE BWR suppression pool. These include a plant-specific limiting condition for operation (LCO), typically 90-95°F, a generic limit which requires reactor scram at 110°F and a generic limit which requires controlled reactor depressurization at 120°F. This report was prepared for the BWR Owners' Group (BWROG) Suppression Pool Temperature Limit (SPTL) Committee and presents an updated basis for these T/S limits. Results of the findings should be useful to the NRC and the industry in raising the normal operating limits for the pool temperature to avoid plant shutdowns or excessive operation of pool cooling systems during periods of high ambient temperatures.

This updated basis considered, for design basis events, pressure suppression capability and containment loads during S/RV actuations and loss of coolant accidents (LOCA). The updated basis utilizes the latest available test data. The updated basis assumes NRC approval of the conclusions reported in the GE report NEDO-30832, "Elimination of Limit on BWR Suppression Pool Temperature for SRV Discharge with Quenchers." NEDO-30832 was also prepared for the BWROG-SPTL Committee and showed that no local pool temperature limit is necessary to avoid unstable steam condensation with safety/relief valve discharge with quenchers.

The updated basis has been used to justify an increase in the LCO. A generic suppression pool temperature LCO of 100°F was set for all plants with Mark I, II, and III containments which participated in the BWROG Suppression Pool Temperature Limit Program with one exception. An LCO of 95°F was set for this one exception.

Additional considerations have been identified which were not within the scope of this report but which should be addressed on a plant-specific

basis to justify an LCO of 100°F. These include: 1) an evaluation of the effect of higher suppression pool temperature on the operability of ECCS pumps taking suction from the suppression pool; 2) the implementation of an increase in the suppression pool temperature used as an entry condition for primary containment control in the plant-specific Emergency Operating Procedures (EOPs); 3) an assessment of temperature increase on any containment load which was defined in a manner different from that specified in the generic load definition documents for Mark I, II and III containments; 4) an assessment of the impact on events beyond the design basis, Station Blackout (SBO), Anticipated Transient Without Scram (ATWS) and Appendix R fire events.

1.0 INTRODUCTION

Technical Specification (T/S) limits are specified for the suppression pool temperature for BWR plants using pressure suppression containments. These limits include a plant-specific limit for the limiting condition for operation (LCO), which is typically 90-95°F, a limit which requires reactor scram at a suppression pool temperature of 110°F and a limit which requires initiation of controlled reactor depressurization at a suppression pool temperature of 120°F. These limits are specified to assure that the design limits for the primary containment are not exceeded. The bases for these T/S limits and application of these limits are discussed in this report.

Seasonal high ambient temperatures can cause the suppression pool temperature to approach and possibly exceed the LCO. This can result in excessive operation of pool cooling systems, and ultimately, in a plant shutdown if the suppression pool temperature cannot be reduced with pool cooling. Some utilities have been required to seek emergency relief on the LCO to continue operation. This has required plant-specific evaluations to justify continued operation. In response to this issue, an updated basis for the T/S limits is established. The updated basis, as described in this report, is used to justify a generic LCO of 100°F by showing that this increased T/S limit does not impact plant safety.

The T/S reactor scram and depressurization limits were not impacted by the seasonal high ambient temperatures and therefore did not require revision. Further study beyond the scope of the discussion in this report would be required to justify an update of the T/S scram and depressurization limits.

1.1 BACKGROUND

The purpose of the suppression pool is to provide pressure suppression for events which result in the discharge of steam into the primary containment. This occurs during a loss-of-coolant accident (LOCA) or operation of safety/relief valves (S/RVs). If either of these events were to occur, steam would be directed to the suppression pool either through the vent system connecting the drywell to the suppression chamber or through the S/RV discharge lines (SRVDLs) which are routed from the S/RVs to the suppression pool. The suppression pool condenses the steam, thereby mitigating the pressurization of the primary containment.

The suppression pool is designed to absorb all the energy from the reactor vessel and its fluid inventory with the reactor initially at full power. The containment design limits are based on this assumption. The T/S temperature limits ensure that the suppression pool temperature during a LOCA or S/RV blowdown would be sufficiently subcooled to condense all the blowdown steam.

The current T/S limits were also developed to address concerns regarding unstable condensation during S/RV operation. These concerns were raised following observation of high suppression pool boundary hydrodynamic loads during high steam mass flux discharge from straight down open-ended pipes into a suppression pool with temperatures higher than 160^{0}F (Reference 1). The current T/S limits produce an envelope of suppression pool temperature and reactor operating conditions which assures that the reactor can be shut down and depressurized in a timely manner to avoid the regime of high loads.

Subsequent temperature limits were specified by the NRC in NUREG-0783 (Reference 1), which allowed S/RV operation at high mass fluxes up to a local suppression pool temperature of approximately 200^{0}F for plants equipped with quencher devices at the end of the discharge lines. The local pool temperature is the temperature of the water in the vicinity of the quencher.

Recent evaluations showed that quencher devices will allow stable condensation of high steam mass fluxes even at temperatures approaching the saturation temperature. These evaluations were documented in NEDO-30832 (Reference 2) which was submitted to the NRC as part of the BWR

Owners' Group Suppression Pool Temperature Limit (BWROG SPTL) Program. The results and conclusions of NEDO-30832 are applied in the development of the updated T/S bases presented here, and NRC approval of those conclusions is assumed.

1.2 PURPOSE

In this report of the BWROG SPTL Program, the bases and key applications of the current suppression pool temperature T/S limits are reviewed. An updated basis is established which can be used to justify a revision to the suppression pool temperature T/S. The updated basis considers the LOCA steam condensation capability of the suppression pool, the LOCA containment pressure and temperature response and the LOCA dynamic loads. The dynamic loads resulting from S/RV operation are also considered. The updated basis is used to justify a generic suppression pool temperature LCO of 100°F.

Updated bases are also provided for the T/S limits which require scram with a suppression pool temperature above 110°F and controlled vessel depressurization with a suppression pool temperature above 120°F. However, the values for these T/S limits are not revised in this report.

Plant-specific considerations were identified which may be required for some plants to justify use of the 100°F suppression pool temperature LCO. These considerations include: 1) an assessment of suppression pool temperature increase on ECCS operability for pumps taking suction from the suppression pool; 2) implementation of an increase in the suppression pool temperature used as the entry condition for primary containment control in the plant-specific Emergency Operating Procedures (EOPs); 3) an assessment of temperature increase on any plant-specific containment load which is defined in a manner different from that specified in the generic containment load definition documents for Mark I, II and III containments (References 3,4 and 5 respectively); and 4) an assessment of the impact on the following events beyond the design basis, Station Blackout (SBO), Anticipated Transient Without Scram (ATWS) and Appendix R fire events.

The updated basis and plant-specific considerations specified in this report could be used by any plant considering increasing its suppression pool temperature LCO above the 100°F value given in this report.

2.0 CURRENT T/S LIMITS

The three T/S limits for suppression pool temperature which are addressed in this report are: 1) the limiting condition for operation (LCO),typically 90°F-95°F; 2) the T/S limit requiring reactor scram at a suppression pool temperature of 110°F; and 3) the T/S limit requiring controlled reactor depressurization at a suppression pool temperature of 120°F. The following discussion describes these limits and their original basis. The key applications which need to be considered in developing the updated basis, given in Section 3, are also presented.

2.1 LIMITING CONDITION FOR OPERATION (LCO)

2.1.1 Description of the LCO

This limit is the suppression pool temperature limit for full power operation. Pool cooling is initiated if the LCO is exceeded. If the suppression pool temperature cannot be returned to the LCO within a set time period (typically 24 hours), reactor shutdown must be initiated. The LCO for pool temperature is a plant-specific value, typically 90-95°F.

2.1.2 Basis for the LCO

The LCO is based on the maximum expected service water temperature at the site location.

2.1.3 Key Applications of the LCO

(1) Confirmation of Suppression Pool Volume and Pool Cooling Capacity

The suppression pool temperature LCO has been used as an input initial condition in analysis used to confirm the volume and cooling capacity of the suppression pool.

(2) LOCA Evaluations

The suppression pool temperature LCO is used as an input initial condition for LOCA FSAR evaluations, including: 1) the analysis of the containment pressure and temperature response presented in the FSAR; 2) the containment dynamic condensation loads including condensation oscillation (CO) and chugging; and 3) evaluations of the available NPSH for pumps taking suction from the suppression pool.

(3) S/RV Air-Clearing Load Evaluations

The suppression pool temperature LCO is used in evaluating the S/RV air-clearing loads for some load cases. It is used to help define the Mark I S/RV air-clearing loads described in the Load Definition Report (Reference 3). It is also part of the methodology (References 4 and 5) used to calculate S/RV air-clearing pool boundary pressures for Mark II and III plants equipped with X-quencher devices at the SRVDL discharge exit.

(4) S/RV Steam Condensation Evaluations

Reference 1 identifies analyses that must be performed to demonstrate compliance with the suppression pool temperature limits specified to avoid unstable condensation with SRV discharge into the suppression pool. These analyses evaluate the suppression pool temperature response to events which result in suppression pool heatup with S/RV operation. The suppression pool temperature LCO is an input initial condition to these analyses.

(5) Required Operator Actions Per EOPs

The LCO is an entry condition for the containment control guideline to the Emergency Procedures Guidelines (EPGs), (Reference 6), and to the plant-specific Emergency Operating Procedures (EOPs) developed from the EPGs.

2.2 REACTOR SCRAM LIMIT

2.2.1 Description of the Reactor Scram Limit

With thermal power greater than or equal to 1% of rated thermal power, the reactor shall be scrammed if the suppression pool temperature is greater than 110°F.

2.2.2 Basis for Reactor Scram Limit

This limit was established as part of a set of operating guidelines developed in SIL-106 (Reference 7) to address unstable steam condensation during S/RV operation at high mass flux and elevated suppression pool temperature. This limit is part of the envelope of reactor operating conditions specified to allow timely depressurization of the reactor to avoid high mass flux through open-ended pipes with a suppression pool bulk temperature higher than 160°F. As discussed in Reference 1, 160°F was the maximum tested temperature which showed no high loads due to unstable condensation for a high mass flux steam discharge into a suppression pool through an open-ended pipe (i.e., no quencher device at the discharge line exit).

2.2.3 Key Applications for Reactor Scram Limit

(1) The suppression pool heatup analyses, required by Reference 1, assume reactor scram at a suppression pool temperature of 110°F for events which do not scram on high drywell pressure.

(2) The EPGs and EOPs specify reactor scram or initiation of boron injection during an ATWS event at 110°F.

2.3 REACTOR DEPRESSURIZATION LIMIT

2.3.1 Description of Reactor Depressurization Limit

With the suppression pool temperature greater than 120°F, and with isolation of the main steam line isolation valves following a scram, a controlled depressurization of the reactor shall be initiated.

2.3.2 Basis for Reactor Depressurization Limit

(1) The 120°F reactor depressurization limit was originally specified to ensure that the maximum post-LOCA blowdown suppression pool temperature would not exceed 170°F. This was based on the Bodega Bay and Humboldt Bay tests, which showed complete condensation with a maximum tested end of blowdown suppression pool temperature of 170°F (Reference 8). Since the suppression pool heatup during a LOCA blowdown is approximately 50°F, the 120°F limit will assure a 170°F pool temperature at the end of the blowdown.

(2) The 120°F reactor depressurization limit was also included as part of the operating reactor envelope specified in Reference 7 to address unstable steam condensation with S/RV discharge.

2.3.3 Key Applications for Reactor Depressurization Limit

(1) The T/S limit for reactor depressurization is used as an input to define the S/RV air-clearing loads at full reactor pressure.

(2) The suppression pool temperature response analyses specified in Reference 1 assume that controlled reactor depressurization is initiated when the suppression pool temperature reaches 120°F.

3.0 UPDATED BASES FOR SUPPRESSION POOL TEMPERATURE T/S LIMITS

This section provides updated bases for the suppression pool temperature T/S limits. The updated bases for the suppression pool temperature LCO are derived from a review of the application of the suppression pool temperature LCO in containment analyses and include LOCA containment evaluations and containment S/RV loads analyses. These updated bases are subsequently used to justify a generic suppression pool temperature LCO.

Updated bases are also given for the T/S limits which specify reactor scram at suppression pool temperatures above 110°F and reactor depressurization at suppression pool temperatures above 120°F.

3.1 UPDATED BASIS FOR LCO

3.1.1 LOCA Evaluations

The suppression pool temperature prior to a LOCA may influence several parameters associated with the LOCA event, including: 1) the containment pressure and temperature response; 2) the LOCA condensation loads (i.e., condensation oscillation, chugging); and 3) the performance of pumps taking suction from the suppression pool. The LCO is used as the initial suppression pool temperature for evaluation of these parameters. The following provides an updated basis for the LCO considering these parameters.

3.1.1.1 Containment LOCA Pressure and Temperature

The initial suppression pool temperature will affect the peak containment temperature and pressure during a LOCA. A higher initial temperature will produce a higher peak suppression pool water temperature and suppression chamber airspace temperature and, consequently, a higher peak containment pressure. Therefore, the suppression pool temperature prior to a LOCA is limited to ensure that the design limits on the containment pressure and temperature are not exceeded.

Containment pressure and temperature design limits are plant-specific. These limits are higher for the Mark I and Mark II containments, which have a smaller free volume and therefore experience a higher pressurization during a LOCA, than the Mark III containments. Typical pressure and temperature design limits for the Mark I containment are 56 psig and 281°F, respectively. Typical values for the Mark II containment are 45 psig and 275°F. The Mark III containment has generic pressure and temperature limits of 15 psig and 185°F, respectively.

For the Mark I, II, and III containment types, a maximum initial suppression pool temperature was established which will limit the peak LOCA containment pressures and temperatures below the design limits for the plants included within each containment type. This temperature was calculated assuming: 1) all the non-condensible gas in the drywell is transferred to the suppression chamber airspace; 2) this non-condensible gas is heated up to the peak suppression pool temperature; and 3) there is 100% relative humidity in the suppression chamber. It was also conservatively assumed that an increase in the initial temperature will produce an equal increase in the peak LOCA suppression pool temperature. This is conservative since RHR pool cooling is more effective at higher suppression pool temperatures and therefore mitigates the increase in the peak suppression pool temperature. Typically a 10°F increase in the initial suppression pool temperature will result in less than a 5°F increase in the peak suppression pool temperature.

The maximum initial suppression pool temperatures given below assure that the design pressure and temperature are not exceeded for most of the plants participating in the BWROG SPTL Program. Some plants, due to their configuration, will have lower maximum initial suppression pool temperatures (see Table 4-1).

(1) Mark I

The maximum initial suppression pool temperature which will result in values within containment pressure and temperature design limits for the Mark I plants participating in the BWROG SPTL Program is 120°F.

(2) Mark II

The maximum initial suppression pool temperature which will result in values within containment pressure and temperature design limits for the Mark II plants participating in the SPTL Program is 100°F.

(3) Mark III

The maximum initial suppression pool temperature which will result in values within containment pressure and temperature design limits for the Mark III plants participating in the BWROG SPTL Program is 100°F, except as noted in Table 4-1.

3.1.1.2 Containment Dynamic Loads

The LOCA containment dynamic loads occur as a result of the LOCA containment thermal-hydraulic response, which forces air, and, subsequently, steam to flow through the vents from the drywell to the suppression pool. The major containment dynamic LOCA loads include pool swell, condensation oscillation (CO), and chugging. The pool swell loads result from the expulsion of air initially in the drywell into the suppression pool immediately after the LOCA. The pool swell loads are controlled by the drywell pressurization rate immediately following the LOCA. There is a negligible influence of suppression pool temperature on these loads. The CO and chugging loads result from the condensation of steam at the vent exit into the suppression pool. These loads are influenced by the vent steam mass flux, air content in the vent flow and suppression pool temperature. The impact of suppression pool temperature on the CO and chugging loads is discussed in this section.

3.1.1.2.1 Condensation Oscillation

Condensation Oscillation (CO) follows pool swell and occurs when the vent flow is predominantly steam at high mass flux. The condensing steam produces pressure oscillations at the vent exit which are transmitted to submerged boundaries and structures. The CO pressure amplitude generally increases with increased vent steam mass flux and suppression pool temperature. Decreased air content in the vent flow will also increase the CO pressure amplitude.

(1) Mark I

The Mark I CO load definition is described in Section 4.4 of the Load Definition Report (LDR, Reference 3). The CO loads were derived from a conservative application of the maximum pool boundary pressures measured during the Mark I FSTF tests (Reference 9) with an initial pool temperature of 68°F. The conservatisms in the LDR CO loads were demonstrated by a subsequent test conducted at an increased initial pool temperature of 93°F. A comparison of the calculated plant structural responses based on the results from the test at 93°F initial pool temperature and the conservatively derived LDR CO loads indicated that the responses were similar in magnitude (Reference 10). This indicated that the LDR CO loads have sufficient conservatism for the range of tested pool temperatures.

Data from the design basis FSTF tests and from the FSTF tests with the elevated pool temperature were used to predict CO loads for the range of expected LOCA conditions throughout the blowdown period for the Mark I plants participating in the SPTL Program and to establish the effect of increased initial pool temperature on CO loads. This analysis showed that a maximum initial temperature of 110°F will assure the CO loads do not exceed the CO load definition for the Mark I plants. This is attributed to the conservatism in the FSTF test conditions relative to expected plant conditions and the added conservatism introduced in developing the LDR CO load definition from the FSTF tests.

(2) Mark II

The generic Mark II condensation oscillation (CO) load definition is given in Reference 11 and is based on an envelope of all CO pool boundary pressures measured during the Mark II 4TCO tests (Reference 12). Test conditions included a range of vent steam mass fluxes and suppression pool temperatures (up to 160^{0}F) designed to envelope the expected range of conditions in Mark II plants during the postulated LOCA. For the Mark II plants which used the generic CO load without modifications, analyses show that the initial suppression pool temperature can be as high as 110^{0}F without going outside the envelope of 4TCO tested conditions.

Some plants took advantage of expected lower suppression pool temperatures during CO based on plant-specific analysis. These Mark II plants derived their CO load definition from 4TCO data for tests conducted at suppression pool temperatures less than 160^{0}F. These plants require a lower initial suppression pool temperature to stay within the envelope of test data used to define the CO load for these plants. This initial suppression pool temperature reqirement applied to one plant participating in the BWROG-SPTL Program (see Table 4.1).

(3) Mark III

The Mark III CO load definition is described in Appendix 3B of Reference 5. The bases for the Mark III load definition are the 1/3 area scaled PSTF tests (Reference 13). The Mark III CO load is defined as a pressure-time history which can be applied to the pool boundary, after attenuating the CO amplitude from the vent exit. Attenuation factors are derived from plant-specific geometries.

The Mark III CO load was developed from a correlation of the 1/3 area scaled PSTF CO data. This correlation considered vent steam mass flux, suppression pool temperature and air content in the vent flow. The containment thermal-hydraulic responses to a DBA LOCA, predicted using the Reference 27 model, were input to the Mark III CO correlation to produce the load definition pressure-time history. This correlation was also used in this analysis to determine the effect of suppression pool temperature on the CO loads and to determine a maximum allowable initial suppression pool temperature for the range of participating Mark III plants. This analysis showed that a maximum allowable initial suppression pool temperature of $100^{\circ}F$ will result in CO loads that do not exceed the Mark III CO load definition.

3.1.1.2.2 Chugging

When the vent steam mass flux falls to a lower value (typically, 2-10 $lbm/sec\text{-}ft^2$), the steady steam condensation interface present at the vent exit during CO cannot be maintained, and the mode for steam condensation passes from the CO phase to the chugging phase. During chugging, a steam bubble forms at the vent exit, grows and ultimately collapses when the heat transfer to the suppression pool water is greater than the steam energy feeding the bubble. The collapsing bubble produces a pressure spike which is transmitted to the submerged boundaries and structures. These spikes occur intermittently and with varying amplitude. Chugging, like CO, is influenced by the vent steam mass flux, suppression pool temperature and air content in the vent flow. However, the chug amplitude dependence on these parameters is more complex. Therefore, the chugging load definitions for the Mark I, II, and III containments are based on bounding chugging test data obtained over a range of test conditions which envelope the plant conditions expected during a LOCA.

(1) Mark I

The Mark I chugging load definition is described in Section 4.5 of lateral chugging load amplitude with increased suppression pool temperature, there is no adverse impact of an increase in the suppression pool temperature LCO on the Mark II vent lateral chugging load.

(3) Mark III

The bases for the Mark III chugging load definition are the full-scale Mark III PSTF tests (Reference 16). The tested conditions for the PSTF tests enveloped the range of vent steam mass flux and suppression pool temperature expected during chugging in Mark III plants. The Mark III chugging load is given in Appendix 3B of Reference 5 and represents a bound of all full-scale PSTF chugging data.

For the Mark III plants participating in the SPTL Program, a maximum initial suppression pool temperature of 100°F assures that the expected range of conditions during a LOCA will remain within the tested range of conditions for the PSTF tests used to define the Mark III chugging load.

3.1.1.3 ECCS Considerations

Since the suppression pool is the emergency water source for ECCS equipment, the impact of changes to the suppression pool temperature LCO need to be evaluated. This includes the direct effect of the increased water temperature on the core cooling capability and the indirect effect on the pump operability, such as NPSH requirements and pump seal integrity.

3.1.1.3.1 Core Cooling Capability

Available analyses (Reference 20) have shown that an increase in the water source temperature does not adversely affect ECCS performance. That is, a 50°F increase in the temperature of the water injected into the RPV by the ECCS to cool the reactor fuel during a LOCA will only change the

Reference 3. The basis for the Mark I torus shell and downcomer load definition is the Mark I FSTF tests. The Mark I FSTF test data indicate that chugging does not occur above 135^{O}F (Reference 9). Raising the initial pool temperature would only decrease the time to reach 135^{O}F thereby reducing the duration and total number of chugs expected during a LOCA. Therefore there is no impact of increasing the initial suppression pool temperature on the Mark I chugging load.

(2) Mark II

The generic Mark II chugging load on the pool boundary is defined in Reference 15. The bases for the generic Mark II chugging load definition are the Mark II 4TCO full-scale tests (Reference 12). These tests were conducted with a range of vent steam mass fluxes and suppression pool temperatures designed to envelope the expected range of conditions in Mark II plants. The generic Mark II chugging load definition bounds all 4TCO chugging data.

For the Mark II plants participating in the BWROG SPTL Program, a maximum initial suppression pool temperature of 110^{O}F assures that the range of conditions expected during a LOCA will remain within those of the 4TCO tests used to define the Mark II chugging pool boundary load.

The Mark II vent lateral chugging load is defined by the NRC in NUREG-0808 (Reference 17). The basis for this load definition is primarily the chugging data from cold suppression pool temperature tests conducted by a foreign licensee (Reference 18). Chugging lateral load amplitudes are higher with cold suppression pool temperatures based on a comparison of the cold pool chugging test data with chugging data obtained with a warmer pool during the Mark II 4T tests (Reference 19). For this reason, the NRC chose the cold pool chugging test data as the primary basis for the Mark II vent lateral chugging load definition. With this trend of decreased vent peak cladding temperature (PCT) by 6°F. Therefore, core cooling capability would be negligibly impacted by an increase in the suppression pool temperature.

3.1.1.3.2 Pump NPSH Availability

For most plants, ECCS pumps taking suction from the suppression pool are required to meet Regulatory Guide 1.1 (Safety Guide 1), which requires adequate NPSH for these pumps with no dependence on positive containment pressure during the worst case LOCA event. Some older plants take credit for containment positive pressure.

In either case, the available NPSH is partially dependent on water density and vapor pressure at the peak calculated suppression pool temperature. A higher value of the peak suppression pool temperature will decrease the water density and increase the saturation vapor pressure, both of which will reduce the available NPSH.

The effect of suppression pool temperature on NPSH availability was not within the scope of this report and, therefore, should be evaluated on a plant-specific basis to confirm that the generic suppression pool LCO does not adversely affect the existing plant-specific NPSH margins.

3.1.1.3.3 Impact on ECCS Pump Seal Integrity

The seals on the HPCI and RCIC pumps are designed for fluid temperatures of up to 212°F. An increase in the LCO would not significantly impact the pump seal integrity of the HPCI or RCIC pumps because these pumps would only be required when the RPV is still at pressure which would coincide with lower suppression pool temperatures (typically less than 140°F).

The RHR pumps in most plants are designed to operate with pumping fluid temperatures of up to 360°F; therefore in these plants, an increase in the post-LOCA pool temperature is insignificant for the pump seal integrity. However some older plants may not have this high temperature specification for their RHR pumps. The design operating RHR pump temperature for these plants should be reviewed on a plant-specific basis to confirm that there is no adverse impact of increased suppression pool temperature on their RHR pump operability.

For the core spray pumps, the seals are usually designed for a fluid temperature of up to 212°F. An increase in the LCO will result in a higher peak suppression pool temperature which for some plants will exceed 212°F. For these plants, plant-specific assessments should be performed to confirm that an increase in the LCO will not adversely impact the core spray pump seal integrity.

3.1.2 Safety/Relief Valve (S/RV) Evaluations

Steam discharged from a S/RV is routed into the suppression pool via the discharge line and quencher discharge end of the line. Prior to the S/RV actuation, the S/RV discharge line (SRVDL) above the water level in the suppression pool is filled with noncondensible gas (usually nitrogen in Mark I and Mark II containments due to the inerting of the containment during normal operation). The sudden opening of the S/RV and the ensuing rapid steam discharge results in pressurization of the line and creates a large force which pushes the gas and water leg out of the discharge line through the quencher and into the suppression pool. The gas then forms bubbles which oscillate and impart loads to the submerged boundaries and structures in the suppression pool. This mechanism is known as S/RV air-clearing. After the S/RV air-clearing phase, steam is discharged into the suppression pool. The rapid condensation of the steam also causes a loading on the submerged structures and boundaries. The S/RV steam condensation loads are much lower than the air-clearing loads. The following is an evaluation of the impact of suppression pool temperature on the S/RV loads.

3.1.2.1 Steam Condensation Loads

The steam condensation S/RV loads occur following air clearing. These result from the steady condensation of steam at the quencher exit holes. It was shown in Reference 2 that high loads, which can occur with high steam mass flux and high suppression pool temperature for flow through open-ended pipes, do not occur with steam flow through quencher devices. Since all BWROG SPTL Committee participants use quencher devices at the ends of their S/RV discharge lines, Reference 2 establishes that there will be no adverse effect of increased suppression pool temperature on steam condensation loads which occur during S/RV operation.

3.1.2.2 Air-Clearing Load on the SRVDL

When the S/RV opens, the SRVDL experiences a transient pressurization load and thrust loads due to the acceleration and expulsion of water in the submerged portion of the piping. These loads are controlled by the S/RV flow rate, pipe geometry and SRVDL quencher submergence. There is a negligible effect of suppression pool temperature on the SRVDL air-clearing loads. Therefore, there is no impact of changes to the suppression pool temperature on the SRVDL load.

3.1.2.3 Air-Clearing Load on the Pool Boundary

The air-clearing pool boundary loads have been developed with the use of extensive test data. These data have shown that the S/RV pool boundary loads are influenced by S/RV flow rate, initial gas mass, submergence and suppression pool temperature. S/RV loads increase slightly with higher pool temperatures, with about a 2% increase in loads resulting from a 10^{O}F increase in suppression pool temperature.

3.1.2.3.1 Mark I Air-Clearing Loads

For Mark I containments the SRV air-clearing loads in the Load

Definition Report (Reference 3) were evaluated for the following pool temperature conditions :

For single-valve actuation, the pool temperature is at 120°F.

For multiple-valve actuations, not related to ADS, the pool temperature is the high Tech Spec value permitted during normal power operation (the LCO); typically, 90-95°F.

For ADS actuation, during intermediate and small break accidents (IBA and SBA), the pool temperature is the predicted value at the expected time of ADS actuation in the accident scenario.

The effects of an increase in the suppression pool temperature on the Mark I S/RV load cases are as follows.

(1) Impact on Single-Valve Actuation Load

The pool temperature condition for the single-valve actuation is specified at 120°F because the T/S requires that the RPV be depressurized at the normal cooldown rate if the pool temperature reaches 120°F with the RPV at pressure. Since this Tech Spec requirement is unchanged, an increase in the normal operating temperature (the LCO) will not affect this design load.

(2) Impact on Multiple-Valve Actuation Load

The pool temperature condition for the multiple-valve actuations not related to ADS is specified at the LCO for the following reasons. The S/RV loads for Mark I containments during the initial multiple-valve S/RV actuation produce higher SRV loads than subsequent S/RV actuations. The initial actuation of multiple valves can occur during an isolation event or the early part of an intermediate break accident (IBA) or small break accident (SBA) when the reactor energy is high enough to cause rapid pressurization of the RPV. The initial pool temperature assumed for these events is the maximum pool temperature allowed by the LCO.

For the multiple-valve actuation case, an increase in the initial pool temperature will result in a slight increase in the torus shell pressures from S/RV air clearing. The S/RV air-clearing loads are calculated with the model described in Reference 21. Based on a conservative application of this model, an increase in the initial pool temperature of $10^{o}F$ would result in an increase in the calculated torus shell pressure of approximately 2% over the current load definition values. However, this slight increase in the torus shell pressure due to the higher initial pool temperature would not affect the integrity of the suppression pool. This is because the load definition procedure for Mark I containments, which is based on the Monticello in-plant test data (Reference 22), includes a large margin of conservatism. Even if the S/RV air-clearing load were to increase up to 10% due to an increase in pool temperature during normal operation, the margin assures that the non-exceedance probability would remain greater than 99.9%.

Based on the above evaluation, it is concluded that a change in the suppression pool temperature LCO to $100^{o}F$ for the Mark I plants participating in the BWROG SPTL Program will have an insignificant impact on the S/RV air-clearing load margin and will not have an adverse impact on the integrity of the suppression pool during S/RV actuation.

(3) Impact on ADS Actuation Load

The pool temperature condition for ADS actuation is specified to match the calculated pool temperature at the time of ADS during an IBA or SBA. The pool temperature at the time of ADS is evaluated based on the initial pool temperature prior to IBA or SBA and considers the temperature increase due to energy discharge into the pool via S/RV actuations or break flow. The initial pool temperature for ADS actuation is raised by an amount equal to the increase in the LCO temperature. This increase in suppression pool temperature produces a slight increase in the S/RV air-clearing load. As discussed above for the multiple-valve load case, this load increase in insignificant compared to the large margin in the S/RV air clearing load. Therefore there is no adverse impact on the structural integrity of the torus of raising the suppression pool temperature LCO to 100°F.

3.1.2.3.2 Mark II (T-Quencher) Air-Clearing Loads

The Mark II S/RV air-clearing loads are defined in Section 3.3.1 of the DFFR (Reference 4). They are also described in NUREG-0802 (Reference 23), which gives the NRC acceptance criteria for S/RV air-clearing loads for plants equipped with quencher devices at the end of the S/RV discharge lines. Two alternative methods are provided in References 4 and 24 to evaluate the Mark II T-quencher S/RV loads. One method is based on a series of T-quencher tests conducted by Kraftwerk Union (KWU). The second alternative method (used for most Mark II plants) is based on the KWU X-quencher tests. Both methods use experimental results with the highest pressure amplitudes from each respective test series to conservatively define the T-quencher S/RV air clearing loads.

The KWU T-quencher tests cover a range of reactor pressures and suppression pool temperatures and are intended to envelope the expected conditions during S/RV operation. The S/RV air-clearing tests with full reactor pressure were conducted with suppression pool temperatures up to 130°F. The maximum tested pool temperature was 176°F. The five KWU

T-quencher test runs with the maximum air-clearing pressures were chosen to define the S/RV air-clearing loads.

The KWU X-quencher tests include 200 test runs. The three runs with the maximum amplitude air-clearing pressures were chosen and used directly to define the T-quencher S/RV air-clearing loads. The pressure amplitude for these runs is increased by a factor of 1.5 to provide additional conservatism. For response analysis, the time scale for the pressure-time histories of the three load definitions is adjusted to cover a large range of frequencies. This time scale and frequency adjustment is plant-specific and corresponds to the discharge line air volumes. Air volume is the dominant controlling parameter for the frequency content of the S/RV air-clearing loads.

The T-quencher S/RV load definition, which uses the X-quencher test data base, was prescribed by the NRC in Reference 23 as the more conservative method of the two alternatives. This implies that either method considers and conservatively treats S/RV air-clearing loads at suppression pool temperatures up to $130^{O}F$ with full reactor pressure. Therefore, the Mark II T-quencher SRV air-clearing load definition is applicable for pool temperatures of up to $130^{O}F$ with full reactor pressure. Since the T/S requirement for controlled RPV depressurization with a suppression pool temperature greater than $120^{O}F$ is unchanged, a change in the LCO to $100^{O}F$ will not impact the Mark II T-quencher S/RV air-clearing load.

3.1.2.3.3 Mark II (X-Quencher) Air-Clearing Loads

The Mark II S/RV air-clearing loads for plants equipped with X-quencher devices at the end of the SRVDLs are calculated with the same methodology and the same temperature considerations as are used for the Mark III plants which are equipped with X-quencher devices. The following describes this methodology. Section 3.1.2.3.4 which follows, applies equally to Mark II plants and Mark III plants with X-quenchers.

3.1.2.3.4 Mark III (X-Quencher) Air-Clearing Loads

The methodology for calculating the Mark III X-quencher loads is described in Appendix 3B, Attachment A of Reference 5. This methodology is based on data accumulated from small-scale and large-scale tests (Reference 24) and in-plant S/RV tests (References 25, 26). A multiple regression analysis of the small-scale and large-scale data (Reference 24) was used to develop a correlation for defining peak boundary pressures as a function of plant conditions and geometry, including suppression pool temperature. Statistical considerations were employed to establish these load values at a 95-95% confidence level. To obtain design values, a load reduction factor was developed based on the results of the Caorso in-plant test which provided a 95-95% bound of the Caorso data when extrapolated to the Mark III standard plant conditions.

Five load cases are defined in Reference 5:

(1) First actuation of a single valve - 100°F Pool Temp.

(2) First actuation of two adjacent valves - 100°F Pool Temp.

(3) Subsequent actuation of a single valve - 120°F Pool Temp.

(4) First actuation of ADS valves - 120°F Pool Temp.

(5) First actuation of all valves - 100°F Pool Temp.

Cases 1, 2, and 5 are specified to evaluate the air-clearing loads due to the initial opening of S/RVs at full reactor pressure and at the maximum expected normal operating suppression pool temperature.

Case 3 evaluates the loads due to the subsequent actuation of a single valve at full reactor pressure with the pool heated up to the technical specification value for controlled reactor depressurization.

Case 4 evaluates the loads due to the actuation of ADS valves at full reactor pressure with the pool temperature at the T/S limit for controlled reactor depressurization.

Note that it is possible to have events where subsequent single-valve and ADS valve actuations occur at suppression pool temperatures higher than 120^{0}F. However, these will occur at reduced reactor pressures. Therefore, the load cases identified in Reference 5 are bounding.

Since three of the five Mark III S/RV load definition cases assume a pool temperature of 100^{0}F, the suppression pool temperature LCO should not exceed 100^{0}F for Mark III plants equipped with X-quenchers.

3.2 UPDATED BASES FOR SCRAM LIMIT

With NRC approval of the conclusions of NEDO-30832, the bases given in Section 2 for the scram limit which addressed unstable S/RV steam discharge need not be included here. However, there are remaining applications for the scram limit which require reactor scram at 110^{0}F, including:

(1) Application as an entry condition to the EPG RPV Control Guideline per step SP/T-2 of the EPG Primary Containment Control Guideline (Boron Injection Initiation Temperature).

(2) Application as the boron injection initiation temperature during ATWS events.

Therefore, any proposed change in the suppression pool temperature T/S scram limit must consider the impact on these applications. This report does not change the current T/S suppression pool temperature scram limit of 110^{0}F.

3.3 UPDATED BASES FOR REACTOR DEPRESSURIZATION LIMIT

With NRC approval of the conclusions of NEDO-30832, those bases for the reactor depressurization limit which considered unstable S/RV steam condensation will no longer be included. However, assurance of complete steam condensation during a LOCA and mitigation of S/RV air-clearing loads remain as bases for the reactor depressurization limit.

The BWR suppression pool is designed to mitigate the maximum containment pressure during a LOCA by condensing the steam discharged into the containment from the primary system break. The capability of the suppression pool to condense the steam is dependent on the subcooling during the blowdown. The original limit for the end of LOCA blowdown suppression pool temperature is 170°F, based on the Bodega Bay and Humboldt Bay tests (Reference 8). The 120°F depressurization limit along with appropriate sizing of the suppression pool ensures that this limit is not exceeded. Subsequent test data obtained at the Mark I Full-Scale Test Facility (FSTF-Reference 9) and at the Mark III Pressure Suppression Test Facility (PSTF-Reference 11) have shown that higher end of blowdown suppression pool temperatures will assure complete condensation. This confirms the current depressurization limit of 120°F for complete condensation.

The reactor depressurization limit of 120°F also remains an input to the load definition methodology for the Mark I T-quencher and the Mark II and III X-quencher S/RV air-clearing loads.

To address these remaining bases, any proposed increase in the reactor depressurization limit must consider the impact on assurance of complete condensation during a LOCA and on the S/RV air-clearing loads. This report does not change the current T/S suppression pool temperature reactor depressurization limit of 120°F.

4.0 INCREASED SUPPRESSION POOL TEMPERATURE LCO

4.1 GENERIC LCO OF 100^{O}F

4.1.1 Generic Justification

The maximum suppression pool temperatures shown in Table 4-1 can be used to define a single generic value for the suppression pool temperature LCO. The temperatures shown in Table 4-1 assure that the containment design loads are not exceeded. The generic suppression pool temperature LCO which assures non-exceedance of design basis loads based on the latest test data and revised basis for the plants participating in the BWROG SPTL Program is 100^{O}F. One plant which could not, by this report alone, justify an LCO of 100^{O}F is identified in Table 4-1.

4.1.2 Plant-Specific Considerations for Applying the 100^{O}F LCO

The plant-specific considerations which are not within the scope of this report and which should be addressed if the generic LCO of 100^{O}F is to be applied include:

(1) NPSH Availability for ECCS Pumps taking Suction from the Suppression Pool

NPSH availability for ECCS pumps was discussed in Section 3.1.1.3.2. Individual plants should evaluate the impact of increased peak suppression pool temperature on available NPSH with an increase in the LCO.

(2) ECCS Pump Seal Integrity

ECCS pump seal integrity was discussed in Section 3.1.1.3.3. Individual plants should evaluate the impact of increased suppression pool temperature on the pump seal integrity with an increase in the LCO.

(3) Impact on the EPGs or EOPs

One entry condition to the Primary Containment Control Guidelines of the EPGs and plant-specific EOPs is the suppression pool temperature LCO. These documents should be reviewed by the individual plants and appropriate changes made to the EOPs to reflect the change in the LCO value.

(4) Impact on Containment Loads

The updated bases of Chapter 3 in this report, used to justify a generic suppression pool temperature LCO of 100°F, assume that plant specific containment load definitions are consistent with the generic containment load definitions given in References 3, 4 or 5 for Mark I, II or III containments respectively. Therefore, a plant specific containment load which has been defined in a manner different from that given in the applicable generic containment load definition document should be assessed to determine the impact of an increase in the LCO to 100°F.

(5) Impact on Events Beyond the Design Basis

This report addresses the impact of an increase in the LCO to 100°F on design basis events. Events beyond the design basis for which rules have been established, SBO, ATWS and fire events, should be evaluated on a plant specific basis to determine the impact of the increased LCO.

4.2 CONSIDERATIONS FOR A PLANT-SPECIFIC LCO HIGHER THAN 100°F

For plants desiring a higher suppression pool temperature LCO value, a plant-specific evaluation can be performed using the updated basis described in Section 3. This would include:

(1) Evaluation of peak LOCA containment pressures and temperatures with comparisons to existing design basis values.

(2) Evaluation of the containment LOCA condensation loads, including CO and chugging.

(3) Evaluation of ECCS pump operability, including available NPSH to ECCS pump taking suction from the suppression pool and pump seal integrity.

(4) Evaluation of S/RV air-clearing loads for plants with Mark I or Mark III containments.

In addition, the suppression pool temperature used as an entry condition for primary containment control in the plant-specific EOPs must be revised to reflect the change in the LCO value.

Table 4-1

MAXIMUM SUPPRESSION POOL TEMPERATURE LCO , °F

	BWR Containment Type		
Basis	Mark I	Mark II	Mark III
1. LOCA Evaluations			
Containment Pressure and Temperature	120	100	100[1]
Containment Dynamic Loads			
CO	110	110[2]	100
Chugging	no limit	110	100
2. S/RV Air-Clearing Loads	100	130	100

Exceptions:

1) Maximum LCO for Perry for containment pressure and temperature is 95°F.

2) Maximum LCO for LaSalle for LOCA CO load is 100°F.

5.0 REFERENCES

1. NUREG-0783, "Suppression Pool Temperature Limits for BWR Containments," November 1981.

2. NEDO-30832, "Elimination of Limit on BWR Suppression Pool Temperature for SRV Discharge with Quenchers," December 1984.

3. NEDO-21888, "Mark I Containment Program Load Definition Report," Rev. 2, November 1981.

4. NEDO-21061, "Mark II Containment Dynamic Forcing Function," Rev. 4, November 1981.

5. General Electric Co., 22A7007,"General Electric Standard Safety Analysis Report" (GESSAR-II), Appendix 3B, February 25,1982.

6. NEDO-31331, "BWR Owners' Group Emergency Procedures Guidelines," March 1987.

7. SIL No. 106, "Suppression Pool Temperature," October 25, 1974.

8. "Preliminary Hazards Summary Report, Bodega Bay Park Unit No. 1," Pacific Gas and Electric Company, December 28, 1962.

9. NEDO-24539, "Mark I Containment Program Full-Scale Test Program Final Report," April 1979.

10. SMA 12101.04-R001D, "Evaluation of FSTF Test M-12 and M-11B Condensation Oscillation Loads and Response." Structural Mechanics Associates, Inc., July 1980.

11. NEDO-24288, "Generic Condensation Oscillation Load Definition Report," November 1980.

12. NEDO-24811, "4T Condensation Oscillation Test Program Final Test Report," May 1980.

13. NEDO-21596, "Mark III Confirmatory Test Program - 1/3-Scale Condensation and Stratification Phenomena - Test Series 5807," March 1977.

14. NEDO-10320, "General Electric Pressure Suppression Containment Analytical Model," April 1971.

15. NEDO-24302, "Generic Chugging Load Definition Report," April 1981.

16. NEDO-21853, "Mark III Confirmatory Test Program - Full-Scale Condensation and Stratification Phenomena - Test Series 5707," August 1978.

17. NUREG-0808, "Mark II Containment Program Load Evaluation and Acceptance Criteria," August 1981.

18. NEDO-24794, "Dynamic Laterial Loads on Mark II Main Vent Downcomer - Correlation of Independent Reference Data," March 1980.

19. NEDO-24106, "Dynamic Laterial Loads on a Main Vent Downcomer - Mark II Containment," March 1978.

20. NEDO-23785, "The GESTR-LOCA and SAFER Models for the Evaluation of the Loss of Coolant Accident," October 1984.

21. NEDO-21878, "Mark I Containment Program Analytical Model for Computing Air Bubble and Boundary Pressures Resulting from an S/RV Discharge through a T-Quencher Device," January 1979.

22. NEDO-21864, "Mark I Containment Program - Final Report, Monticello T-Quencher Test, Task Number 5.1.2," July 1978.

23. NUREG-0802, "Safety/Relief Valve Quencher Loads: Evaluation for BWR Mark II and Mark III Containments," October 1982.

24. NEDO-21078, "Test Results Employed by GE for BWR Containment and Vertical Vent Loads," October 1975.

25. NEDO-24757, "Mark II Containment Supporting Program--Caorso Safety Relief Valve Discharge Tests-- Phase II Test Report," May 1980.

26. NEDO-25100, "Caorso SRV Tests--Phase I Test Report," May 1979.

27. NEDO-20533, "The GE Mark III Pressure Suppression Containment System Analytical Model," June 1974.

APPENDIX

LIST OF PARTICIPANTS IN THE BWR OWNERS' GROUP SUPPRESSION POOL T/S TEMPERATURE LIMIT PROGRAM

Mark I

Plant	Utility
Quad Cities 1, 2	Commonwealth Edison Company
Dresden 2, 3	Commonwealth Edison Company
Pilgrim	Boston Edison Company
Duane Arnold	Iowa Electric Light & Power Company
Cooper	Nebraska Public Power District
Browns Ferry 1, 2, 3	Tennessee Valley Authority
Hope Creek	Public Service Electric & Gas Company
Monticello	Northern States Power Company
Brunswick 1, 2	Carolina Power & Light Company
Hatch 1, 2	Georgia Power Company
Enrico Fermi 2	Detroit Edison Company

Mark II

Plant	Utility
Susquehanna 1, 2	Pennsylvania Power & Light Company
La Salle 1, 2	Commonwealth Edison Company

Mark III

Plant	Utility
Perry 1, 2	Cleveland Electric Illuminating Company
Clinton	Illinois Power Company

GE Nuclear Energy

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San Jose, CA 95125