SUMMARY REPORT

PRESSURE/TEMPERATURE CURVE BASIS FOR SUSQUEHANNA STEAM ELECTRIC STATION

	Rev. 0	Rev. 1
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TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Purpose

This report was prepared as a follow-up to Pennsylvania Power & Light's response to enforcement action 89-042. It deals with Technical Specification requirements regarding pressure/temperature limits.

The purpose of this report is to:

- o Discuss the design bases for the reactor coolant system pressure/temperature limits.
- o Provide the technical justification for our position that the appropriate method for determining compliance with the heatup/cooldown limit of 100°F in any 1-hour period is to use saturation temperature (T_{SAT}) derived from steam dome pressure.
- o Demonstrate that the previous exceedances of the 100°F limit which were based on the reactor drain line temperatures were not Tech Spec violations.
- o Form the technical basis for any future procedural changes and/or Tech Spec interpretations related to this topic.

1.2 Background

As discussed in NRC Enforcement Action Report 89-042, Susquehanna Unit 1 experienced an apparent cooldown rate in excess of the limits required by Technical Specification Section 3/4.4.6. This event occurred on January 12, 1989. On March 21, 1989 we participated in an Enforcement Conference to discuss this event.

During this conference, we demonstrated that there were no safety significant issues or concerns associated with the apparent cooldown rate violation. There was some concern regarding the proper way to determine vessel cooldown rates. As a follow-up to this issue, PP&L initiated on evaluation of the design bases for reactor pressure vessel fatigue and brittle fracture analyses which include their relationship to Tech Spec requirements. We committed to send the results of the evaluation to NRR for review. These results and conclusions are contained herein.

To help us better understand and have in-house documentation for the design bases supporting the pressure/temperature limits section of Tech Specs, we contracted General Electric to assist us. They prepared a report for us which provides the basis for our interpretations, conclusions and position described herein. Reference to the General Electric report is made throughout this summary report. It is intended that these two documents complement each other with the GE work supporting this report.

2.0 EVALUATION AND ANALYSIS OF FINDINGS

2.1 Technical Specification Design Bases

2.1.1 General

The pressure/temperature curves for the Susquehanna reactor pressure vessels are mandated by the requirements of 10CFR50 Appendix G. These requirements deal with the prevention of brittle fracture. Fatigue effects, which are related to pressure/temperature variations are addressed by the ASME Class 1 vessel design requirements and are documented in the vessel stress report. For example, the fatigue analysis computes thermal stresses and fatigue usage for a normal startup/shutdown transient based on a temperature change of 100°F/hour.

However, the Tech Spec limits are not imposed to force compliance with any fatigue related criteria. Therefore, we conclude that the underlying design basis for Tech Spec requirements on pressure/temperature limits is brittle fracture mitigation.

The brittle fracture analysis considers both the beltline region and non-belt regions where discontinuities exist. In the beltline, which is free of discontinuities, irradiation effects can make this region limiting. In the non-beltline regions, which have little irradiation effects, high stress conditions particularly at discontinuities can make these regions limiting. The pressure/temperature curves in the Tech Specs are based on the limiting locations.

Beltline irradiation effects are accounted for according to Regulatory Guide 1.99. Section 1.1 of the GE report describes the revision level of the Regulatory Guide used as well as compliance with other 10CFR50 Appendix G requirements. The design basis discussion herein will focus on the thermal boundary conditions (i.e. heatup/cooldown rates) used in the fracture analysis since this was the issue which prompted the enforcement conference and subsequent evaluation.

A final comment regarding RPV fatigue design is in order here. During our work on this project, the issue of whether the Tech Spec was written to preserve fatigue and/or fracture margins repeatedly surfaced. Specifically, the 100°F/hour criteria was questioned. This rate is depicted on the vessel design basis thermal cycle drawings for normal startup/shutdown transients. We acknowledge that the fatigue analysis uses this rate when calculating cumulative design life fatigue usage due to these transients. Therefore, one can say that this particular requirement is related to the fatigue design bases.

Our position, however, is that the intent of the Tech Spec was to satisfy 10CFR50 Appendix G requirements. Hence our conclusion that this Tech Spec was written to mitigate brittle fracture. We will make every effort to maintain the 100°F/hour rate during heatup/cooldown evolutions. We also note that any significant exceedance (i.e. temperature change greater than 100°F in any one

hour period) of this rate may require an engineering review of the vessel fatigue analysis since this rate is what is used for calculating fatigue usage due to normal heatup/cooldown transients.

2.1.2 Fracture Analysis Design Bases For Beltline Region

Beltline pressure/temperature curves are developed according to the methods of ASME Section III Appendix G. A 1/4T flaw is assumed with a 6:1 aspect ratio. The flaw is oriented normal to the maximum stress.

During heatup and cooldown, the thermal stresses in the vessel wall are caused by a radial thermal gradient which is created by changes in the adjacent reactor coolant temperature. For Susquehanna, the math model used to compute the through-wall temperature gradient is based on one-dimensional heat conduction through an insulated flat plate. Section 3.2 of the GE report shows that the shape of the temperature gradient using this model is very close to the gradient shape required by ASME Section III Appendix G thus validating the Section III methodology for computing K_{It}.

The heatup/cooldown limit assumed for beltline limits analysis is a rate of 100°F/hr. This is an assumed rate. Rates in excess of 100°F/hr are permitted as long as a temperature change of 100°F in a one hour period is not exceeded. This is based on the fact that the 1/4T location of the assumed flaw sees little if any effect of small perturbations in the 100°F/hr rate due to the thermal inertia of the vessel wall.

In summary, the beltline design bases for pressure/temperature limits in Tech Specs include:

- Compliance with ASME Section III Appendix G.
- Through wall temperature gradient ΔT_w, based on heat conduction through an insulated flat plate.
- A heatup/cooldown rate of 100°F/hr used to calculated ΔT_w.
- Allowance for heatup/cooldown rates greater than 100°F/hr <u>provided that</u> a temperature change of the coolant adjacent to the beltline region does not exceed 100°F in a one hour period.

Section 3.2 of the GE report provides additional discussion of these bases.

2.1.3 Fracture Analysis Design Bases For Non-Beltline Regions

Two non-beltline regions have been considered for the Tech Spec pressure/temperature limits for Susquehanna. These are the feedwater nozzle and control rod drive (CRD) penetration region. The non-beltline limits in the latest Susquehanna evaluation are based on brittle fracture analyses for these regions. These analyses were based on GE BWR/6 251 inch vessels. General Electric concludes that these analyses are applicable to the Susquehanna BWR/4 vessel as discussed in Section 4.0 of the GE report.

For the feedwater nozzle fracture analysis, the methods detailed in Welding Research Council Bulletin 175 were used. A 1/4T radial flaw at the blend radius and oriented parallel to the nozzle axis was assumed.

Stresses considered for the feedwater nozzle included pressure, piping load stresses and thermal due to rapid temperature changes as defined by the design basis thermal transients for the nozzle. The most severe of these transients and therefore the one used for the analysis was normal operation with a cold (40°F) feedwater injection. The thermal boundary condition used is a 521°F step change at the nozzle.

For the CRD penetration fracture analysis the methods of ASME Section III Appendix G were used. Nominal pressure stresses in the bottom head region were conservatively adjusted by a factor of three to account for stress concentration at the CRD penetration hole and to establish a simplified stress limit for comparison to the thermal stress analysis results. A 1/4T flaw was assumed. Orientation of the flaw in the spherical bottom head is not important since the tangential and hoop stresses are equal.

For the thermal analysis, several emergency condition design basis transients involving severe bottom head thermal conditions were investigated. For the cooldown, a step change of 178°F was considered. This corresponds to the cooldown portion of the sudden start of an idle recirculation loop transient. For the heatup a step change of 348°F was used. This corresponds to the heatup portion of the improper startup, or black start event. The result of the CRD penetration region fracture analysis for these conditions showed comparable pressure/temperature limits to those established assuming three times nominal pressure stress. Section 4.1.2 and 4.2.2 of the GE report provide additional discussion on the CRD analysis.

As can be seen from the fracture analyses for the non-beltline regions, heatup/cooldown limits well in excess of 100°F/hour have been considered in the design bases for the pressure/temperature limits established in Tech Specs. The thermal events considered for the non-beltline regions were taken from the design basis thermal transients for the reactor vessel and nozzles. For the cooldown event in question which prompted the enforcement conference, bottom head region temperature as measured by the drain line temperature were enveloped with substantial margin by the 178°F step change used in the fracture analysis. Based on this, we conclude that the heatup/cooldown design bases used in the fracture analysis for the CRD penetration region in the bottom head area are conservative and enveloping of actual plant events.

In summary, the non-beltline design bases for pressure/temperature limits in Tech Specs include:

- o Consideration of two non-beltline critical discontinuity regions namely the feedwater nozzle and the CRD penetration region.

- o Consideration of heatup/cooldown rates well in excess of 100°F/hr. Specifically these are:

  Feedwater nozzle - Step change of 521°F
  CRD penetration - Step change cooldown of 178°F
  - Step change heatup of 348°F

- o Compliance with ASME Section III Appendix G and Welding Research Council Bulletin 175.

2.2 Interpretation of Tech Spec Requirements

2.2.1 General

Having established the design bases surrounding the pressure/temperature limits considered for Susquehanna we will now use this as our rationale for interpreting the Technical Specification in terms of heatup/cooldown requirements. To conservatively bound the vessel, both beltline and non-beltline regions are addressed.

The applicable Tech Spec is 3/4.4.6 Pressure/Temperature Limits. This Susquehanna Tech Spec section as well as its corresponding bases section parallel the Standard Technical Specifications for General Electric Boiling Water Reactors, BWR/4. Regarding heatups and cooldowns and pressure/temperature limitations, two requirements are prescribed by the Tech Specs:

1. A maximum heatup or cooldown of 100°F in any 1-hour period.

2. Vessel pressure and temperature shall be determined to be to the right of the applicable limit lines of the pressure/temperature curves.

We will now look at interpretation of these requirements as applicable to the two vessel regions addressed by the fracture design bases.

2.2.2 Beltline Region

For the beltline region fracture analysis, a 100°F/hour heatup/cooldown rate was used. Small perturbations from this rate are permitted based on thermal inertia considerations provided that 100°F in a one hour period is not exceeded. Based on this we conclude that the 100°F in a 1-hour period is specifically required for the beltline region.

Operating to the right of the pressure/temperature curve is applicable to the beltline region. The curves for this region have been shifted to account for irradiation effects.

2.2.3 Non-Beltline Regions

As discussed earlier, the fracture analysis for the non-beltline regions has considered thermal transients well in excess of 100°F in any one hour period. We therefore conclude that the 100°F in a one hour period requirement does not apply to non-beltline regions considered in the fracture analysis namely the feedwater nozzle and bottom head region.

The requirement for maintaining pressure and temperature to the right of the pressure/temperature curve is applicable. Specific curves are provided for non-beltline regions as discussed earlier. The bottom head region now becomes important because it generally has the coolest water in the vessel. Accordingly, temperatures in this region should bound the remainder of the vessel.

2.3 Temperature Monitoring

2.3.1 General

The application of the pressure/temperature limits section of Tech Specs depends on the proper monitoring of reactor vessel temperatures. General Electric issued Services Information Letter (SIL) 430 in 1985 to address proper monitoring of vessel temperatures to assure compliance with brittle fracture temperature limits and vessel thermal stress limits during heatup and cooldown.

The acceptable set of temperature indications for monitoring temperature/pressure limits are as follows:

- To satisfy the requirement for a maximum heatup or cooldown of 100°F in one hour - use saturation temperature (T_{SAT}) as derived from steam dome pressure. Below 212°F use the recirculation loop suction temperature element. (See note below)

- To satisfy the requirement for reactor pressure and temperature being to the right of the applicable limits on the pressure/temperature curve - use the bottom head drain line temperature element. In the event of a loss of drain line flow use the bottom head thermocouples. (See note below.)

  Note: Since the bottom head is usually the point of lowest temperature in the vessel, monitoring either of these requirements on the basis of drain line temperature, regardless of the presence of flow, will yield conservative results.

3.0 SUMMARY

3.1 Conclusions

- The design basis for Tech Spec requirements on heatup/cooldown limits and pressure/temperature limits is brittle fracture mitigation.

- Both beltline and non-beltline regions are considered in the fracture analysis. Non-beltline regions investigated for Susquehanna are the feedwater nozzle and CRD penetration region.

- A 100°F/hour heatup/cooldown rate was used in the fracture analysis for the beltline region. A 521°F step change was considered in the feedwater nozzle analysis. A 178°F step change cooldown and a 348°F step change heatup were considered in the CRD penetration region analysis. Therefore, exceedance of the 100°F in one hour requirement solely on the basis of reactor drain line temperature is not a Tech Spec violation.

- For the beltline region, deviation from a 100°F/hour rate is permitted provided that the temperature change of the coolant adjacent to the beltline does not exceed 100°F in any one hour period. This is permitted based on the thermal inertia effects of the vessel wall. We will, however, make every attempt to maintain the 100°F in one hour rate during heatup and cooldown.

- The Tech Spec limit on a heatup or cooldown not exceeding 100°F in a 1-hour period applies to the beltline region only. Non-beltline regions have been analyzed for the most severe applicable design basis thermal event and therefore do not require monitoring for this limit.

- The appropriate method to monitor for Tech Spec compliance with the 100°F in a 1-hour period requirement is to use saturation temperature based on steam dome pressure. When coolant temperature is less than 212°F recirculation suction line temperatures should be used. Bottom head drain line temperatures provide a conservative method for monitoring for this requirement.

- Bottom head drain line temperatures should be used to verify the Tech Spec requirement that pressure and temperature are to the right of the appropriate pressure/temperature curve. This is conservative since this temperature generally represents the coolest portion of the vessel. Drain line flow must be present to validate this temperature. The alternate source of temperature data should be the bottom head thermocouples.

4.0 ATTACHMENT

General Electric Company report, "Pressure-Temperature Curve Basis For Susquehanna Steam Electric Station Units 1 and 2", SASR 89-40, DRF 137-0010, June 1989.

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GENERAL ELECTRIC COMPANY

AFFIDAVIT

I, David J. Robare, being duly sworn, depose and state as follows:

1. I am Manager, Licensing Services, General Electric Company, and have been delegated the function of reviewing the information described in paragraph 2 which is sought to be withheld and have been authorized to apply for its withholding.

2. The information sought to be withheld is contained in the GE proprietary report SASR 89-40 (DRF 137-0010), "Pressure-Temperature Curve Basis for Susquehanna Steam Electric Station, Units 1 and 2", June 1989. This report presents the bases for the pressure-temperature curves to address beltline, non-beltline and other 10CFR50 Appendix G requirements. It also discusses the application of the curves to temperature measurements.

   "A trade secret may consist of any formula, pattern, device or compilation of information which is used in one's business and which gives him an opportunity to obtain an advantage over competitors who do not know or use it... A substantial element of secrecy must exist, so that, except by the use of improper means, there would be difficulty in acquiring information... Some factors to be considered in determining whether given information is one's trade secret are (1) the extent to which the information is known outside of his business; (2) the extent to which it is known by employees and others involved in his business; (3) the extent of measures taken by him to guard the secrecy of the information; (4) the value of the information to him and to his competitors; (5) the amount of effort or money expanded by him developing the information; (6) the ease or difficulty with which the information could be properly acquired or duplicated by others."

3. Some examples of categories of information which fit into the definition of Proprietary Information are:

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   b. Information consisting of supporting data and analyses, including test data, relative to a process, method or apparatus, the application of which provide a competitive economic advantage, e.g., by optimization or improved marketability;

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d. Information which reveals cost or price information, production capacities, budget levels or commercial strategies of General Electric, its customers or suppliers;

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5. The procedure for approval of external release of such a document typically requires review by the Subsection Manager, Project Manager, Principal Scientist or other equivalent authority, by the Subsection Manager of the cognizant Marketing function (or delegate) and by the Legal Operation for technical content, competitively effect and determination of the accuracy of the proprietary designation in accordance with the standards enumerated above. Disclosures outside General Electric are generally limited to regulatory bodies, customers and potential customers and their agents, suppliers and licensees then only with appropriate protection by applicable regulatory provisions or proprietary agreements.

6. The document mentioned in paragraph 2 above has been evaluated in accordance with the above criteria and procedures and has been found to contain information which is proprietary and which is customarily held in confidence by General Electric.

7. The information to the best of my knowledge and belief has consistently been held in confidence by the General Electric Company, no public disclosure has been made, and it is not available in public sources. All disclosures to third parties have been made pursuant to regulatory provisions of proprietary agreements which provide for maintenance of the information in confidence.

8. Public disclosure of the information sought to be withheld is likely to cause substantial harm to the competitive position of the General Electric Company and deprive or reduce the availability of profit making opportunities because it would provide other parties, including competitors, with valuable information.

GENERAL ELECTRIC COMPANY

STATE OF CALIFORNIA)
) ss:
COUNTY OF SANTA CLARA)

David J. Robare, being duly sworn, deposes and says:

That he has read the foregoing affidavit and the matters stated therein are true and correct to the best of his knowledge, information, and belief.

Executed at San Jose, California, this 27th day of July 1989.

David J. Robare
General Electric Company

Subscribed and sworn before me this 27th day of July 1989.

Lydia M. Simpson
Notary Public, State of California

OFFICIAL SEAL
LYDIA M SIMPSON
NOTARY PUBLIC - CALIFORNIA
SANTA CLARA COUNTY
My comm. expires DEC 26, 1989