UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

PRESSURIZED THERMAL SHOCK EVALUATION

BALTIMORE GAS AND ELECTRIC COMPANY

CALVERT CLIFFS NUCLEAR POWER PLANT, UNIT NOS. 1 AND 2

DOCKET NOS. 50-317 AND 50-318

## 1.0 INTRODUCTION

By letter dated July 21, 1995, the Baltimore Gas and Electric Company (the licensee) submitted for review and approval an updated pressurized thermal shock (PTS) evaluation for the Calvert Cliffs Nuclear Power Plant (CCNPP), Unit Nos. 1 and 2. The NRC staff previously reviewed the licensees PTS evaluations and provided the results of its evaluations in letters to the licensee dated July 15, 1992, May 24, 1993, and July 29, 1994.

The PTS rule, 10 CFR 50.61, adopted on July 23, 1985, and revised on May 15, 1991, established screening criteria that are a measure of a limiting level of reactor vessel material embrittlement beyond which operation cannot continue without further plant-specific evaluation. The screening criteria are given in terms of reference temperature, $RT_{PTS}$. The screening criteria are 270 °F for plates and axial welds and 300 °F for circumferential welds. The $RT_{PTS}$ is defined as:

$$RT_{PTS} = I + \Delta RT_{PTS} + M$$

where: (a) I is the initial reference temperature, (b) $\Delta RT_{PTS}$ is the mean value in the adjustment in reference temperature caused by irradiation, and (c) M is the margin to be added to cover uncertainties in the initial reference temperature, copper and nickel contents, fluence, and calculational procedures.

The initial reference temperature is the measured unirradiated value as defined in the American Society of Mechanical Engineers (ASME) Code, Paragraph NB-2331. If measured values are unavailable for the heat of material of interest, generic values may be used. The generic values are based on the data for materials of all heats that were made by the same vendor using similar processes. The generic values of initial reference temperature for welds are defined in the PTS rule. The licensee used generic and measured initial reference temperature for the CCNPP welds and plates. The limiting materials in the CCNPP reactor vessels are in the lower shell axial welds in Unit No. 1, which were fabricated by Combustion Engineering using heat number

Enclosure

21935 weld wire. The initial reference temperature for this weld is -56 °F, the generic value for Combustion Engineering fabricated welds.

The $\Delta RT_{PTS}$ depends upon the amount of neutron irradiation and the amounts of copper and nickel in the material and is calculated as the product of a fluence factor and a chemistry factor. The fluence factor is calculated from the best estimate neutron fluence at the clad-weld-metal interface on the inside surface of the vessel at the location where the material receives the highest fluence at the end of the period of evaluation. The chemistry factor may be determined using credible surveillance data or from the chemistry factor tables in the PTS rule. The chemistry factors in the tables are dependent upon the best-estimate values of the amount of copper and nickel in the material. Regulatory Guide (RG) 1.99, Revision 2, contains criteria for determining whether surveillance data is credible. The term "best-estimate" is not well defined statistically, but has normally been interpreted as the mean of the measured values.

The margin term is intended to account for variability in initial reference temperature and the adjustment in reference temperature caused by irradiation. The value of the margin term is dependent upon whether the initial reference temperature was a measured or generic value and whether the adjustment in reference temperature was determined from credible surveillance data or from the chemistry factor tables in the PTS rule.

Paragraph (b)(1) of the PTS rule, 10 CFR 50.61 requires licensees to update their PTS submittal whenever there is a significant change in the projected $RT_{PTS}$ value of its beltline materials. The $RT_{PTS}$ value for many of the CCNPP, Unit Nos. 1 and 2, beltline materials has changed as a result of information received by the licensee from: (a) Combustion Engineering fabrication records, (b) chemical analyses from samples of Shoreham reactor vessel weldments and an archived surveillance block from Pilgrim Station, (c) surveillance capsule data from McGuire, Unit No. 1, and CCNPP, Unit No. 2, and (d) the most recent flux reduction measurements for CCNPP, Unit Nos. 1 and 2.

## 2.0 DISCUSSION

The information received by the licensee has: (a) reduced the reactor pressure vessel (RPV) projected neutron fluence at the expiration of the CCNPP, Unit Nos. 1 and 2 licenses, (b) revised the best-estimate chemical composition for many of the RPV beltline welds and (c) provided additional surveillance data to be used to calculate the $RT_{PTS}$ value for RPV beltline materials.

### 2.1 Projected Neutron Fluence

The staff's review of the methodology used by the licensee for calculating the neutron fluence is limited to Chapter 6, "Neutron Fluence and Dosimetry Analysis," in BAW-2160 and BAW-2199 reports. The licensee provided these reports by letters dated June 22, 1993, and March 18, 1994. The methodology has been based on the DOT-IV code. A $P_3$ scattering approximation and a $S_3$ quadrature approximations were used. Both $(r,\theta)$ and $(r,z)$ solutions were used with pin wise power distributions. The methodology employed The CASK cross section set. Cask is based in an early ENDF/B version which is known to have an iron scattering cross section error, which was corrected in ENDF/B-VI. However, we know from experience that this error appears only during neutron transmission through significant amounts of iron, as for example the thermal shield or the vessel. Neither of the Calvert Cliffs Units is equipped with a thermal shield; thus, the staff does not expect the results to have been affected by the use of the CASK cross sections.

At the end of Cycle 10 (11.07 effective full power years), the neutron fluence at the inner surface of the CCNPP-1 RPV was computed to be 1.97E19 n/cm$^2$. The current 24-month, low leakage core design results in a neutron flux at the inner surface of approximately 2.27E10 n/cm$^2$/sec. Based on these values of fluence and flux, the updated neutron fluence at the inner surface of the RPV is 3.27E19 n/cm$^2$ at the end of the current license period (2014), and 4.48E19 n/cm$^2$ at the end of a 20-year renewed license period (2034).

At the end of Cycle 9 (10.97 effective full power years), the neutron fluence at the inner surface of the CCNPP-2 RPV was computed to be 1.44E19 n/cm$^2$. The current 24-month, low leakage core design results in a neutron flux at the inner surface of approximately 3.69E10 n/cm$^2$/sec. Based on these values of fluence and flux, the updated neutron fluence at the inner surface of the RPV is 3.80E19 n/cm$^2$ at the end of the current license period plus 1 year (2017), and 5.77E19 n/cm$^2$ at the end of an additional 20-year period plus one year (2037).

The NRC staff has determined, based on the above, that the methodology for calculating the neutron fluence and the projected neutron fluences are acceptable.

## 2.2 Best-Estimate Chemical Composition

The best-estimate chemical composition for the beltline welds were changed as a result chemical analyses from: (a) weld deposits obtained through detailed search of fabrication records by the Combustion Engineering Reactor Vessel Group, (b) samples of Shoreham reactor vessel weldments and (c) archived surveillance blocks from Pilgrim, Maine Yankee, CCNPP, Unit Nos. 1 and 2. These chemical analyses data were determined from welds that were fabricated using the same heats of weld wire as used to fabricate welds in the CCNPP, Unit Nos. 1 and 2, reactor vessel beltlines.

The CCNPP, Unit Nos. 1 and 2, beltline welds were welded by Combustion Engineering with copper coated primary electrodes and with nickel in the primary electrode. The staff's review of other reactor vessels with welds fabricated using this type of electrode indicates that there could be large coil to coil variability in the amount of copper because of variability of the amount of copper coating on the electrode. To account for the large coil to coil variability in the amount of copper, the best-estimate copper content for a particular heat of weld metal was determined from a weighted average of the test results. The weighted average for each heat of weld material was determined by: (a) determining the average amount of copper for each weld, (b) determining the number of coils used in the fabrication of the weld, and (c) dividing the sum of the products of the average amount of copper for a weld and the number of coils used to fabricate the weld by the number of coils to produce the welds. The Shoreham vessel welds and the archived surveillance blocks from Maine Yankee, Pilgrim, CCNPP, Unit Nos. 1 and 2, had chemical analyses performed at multiple levels within the blocks to determine their coil to coil variability. As a result, the best-estimate copper (weighted average) for beltline welds fabricated from heat numbers 12008/20291, 21935, 33A277, and 10137 were 0.22%, 0.17%, 0.23% and 0.21%, respectively. Each of these values satisfy the intent of the PTS rule, which is to determine from the available information the best-estimate copper for each heat of weld metal.

The best-estimate nickel content for each of these heats of weld metal was the average of all the measurements for that heat. This method of determining the best-estimate nickel is acceptable because of the small variability of nickel in welds when the source of nickel is the primary electrode.

## 2.3 Surveillance Data

The licensee used surveillance data to calculate the $\Delta RT_{PTS}$ for the beltline welds fabricated using heat numbers 20291/12008, 33A277 and 10137 and for the beltline plates D-7206-3 and D-8907-2. The surveillance data for heat number 20291/12008 welds were from McGuire, Unit No. 1, capsules. The surveillance data for heat number 33A277 welds and for the D-7206-3 plate were from CCNPP, Unit No. 1, capsules. The surveillance data for heat number 10137 welds and for the D-8907-2 plates were from CCNPP, Unit No. 2, capsules. The staff approved the use of the McGuire surveillance capsule data for determining the $\Delta RT_{PTS}$ for heat number 20291/12008 welds in CCNPP, Unit No. 1, in a letter to the licensee dated July 29, 1994.

The licensee followed the methodology documented in Section 2.1 of RG 1.99, Revision 2, to calculate the $\Delta RT_{PTS}$ and the margin term in the PTS rule. This section of the RG allows the margin term to be calculated with the standard deviation for $\Delta RT_{PTS}$ reduced in half, if the data meets the credibility criteria in the RG. Data is credible when the scatter of measured $\Delta RT_{PTS}$ values about the predicted values is less than 28 °F for welds and 17 °F for plates. All the surveillance data meets the credibility criteria except for the surveillance weld data from heat number 20291/12008. Since the surveillance weld data for heat number 20291/12008 did not meet the credibility criteria, the licensee calculated the $RT_{PTS}$ for heat number 20291/12008 without reducing the standard deviation for $\Delta RT_{PTS}$ in half.

This section of the RG also requires that the measured values of $\Delta RT_{PTS}$ should be adjusted when the copper or nickel content of the surveillance weld differs from that of the vessel weld. When an adjustment is necessary, the RG indicates that the measured values of $\Delta RT_{PTS}$ are to be multiplied by the ratio of the chemistry factors for the vessel weld and the surveillance weld. Since the chemical composition for heats 20291/12008 and 33A277 surveillance welds were different than that of the best-estimate value for these heats of weld metal, the licensee used the ratio procedure in RG 1.99, Revision 2, to calculate the $\Delta RT_{PTS}$ for welds fabricated with these heats of materials.

The licensee also increased the chemistry factor by 10 °F for welds fabricated using heat numbers 20291/12008 to account for the difference in inlet water temperature in the CCNPP, Unit No. 1, and McGuire, Unit No. 1, reactor vessels. This factor was recommended by the staff and was discussed in the July 29, 1994, letter to the licensee.

2.4 Projected $RT_{PTS}$ Values

The licensee calculated the $RT_{PTS}$ value for all CCNPP, Unit Nos. 1 and 2, beltline plates and welds following the methodology in the PTS rule and RG 1.99, Revision 2. The $RT_{PTS}$ values are projected to be below the PTS screening criteria 20 years beyond the expiration date of the licenses. Since these projections are based on the available surveillance and chemistry data, they are subject to change when additional data becomes available.

The mean value of copper from all Combustion Engineering surveillance welds fabricated with copper coated primary electrodes is 0.226%. The weighted average copper for each heat of weld discussed above is near the generic value for Combustion Engineering welds except for heat 21935, which has a weighted average copper of 0.17%. This value was determined from three measurements from Combustion Engineering wire and weld deposit analyses and nine measurements from a sample from a Shoreham vessel weld fabricated using heat 21935 weld wire. The staff is concerned that the use of a weighted average from this small amount of data could under-estimate the amount of embrittlement. Hence, the staff calculated the $RT_{PTS}$ value for heat number 21935 welds using a copper content of 0.226%.

The staff's calculation indicates that the $RT_{PTS}$ value for CCNPP, Unit No. 1, welds fabricated using heat number 21935 and an assumed copper content of 0.226% are projected to be below the PTS screening criteria 20 years after the expiration date of the license.

3.0 <u>CONCLUSIONS</u>

a) The licensee has used an acceptable method for determining the best-estimate copper and nickel for its beltline materials.

b) The licensee has used an acceptable method for determining the $\Delta RT_{PTS}$ from surveillance data.

c) The licensee has used an acceptable methodology for determining the neutron fluence.

d) The $RT_{PTS}$ values for the CCNPP, Unit Nos. 1 and 2, beltline materials are projected to be below the PTS screening criteria 20 years after the expiration of their licenses. Since this conclusion is dependent upon the available chemistry data and surveillance data, it is subject to change when new data become available.

Principal Contributors: B. Elliot
L. Lois

Date: January 2, 1996