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

INTERIM SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

CONSUMERS POWER COMPANY

PALISADES PLANT

DOCKET NO. 50-255

1. BACKGROUND

The Pressurized Thermal Shock (PTS) rule, 10 CFR 50.61, adopted on July 23, 1985, establishing a screening criterion that is a measure of a limiting level of embrittlement beyond which operation cannot continue without further plant-specific evaluation. The screening criterion is given in terms of reference temperature, RT_{PTS}. The screening criterion is 270°F for plates and axial welds and 300°F for the circumferential weld. The RT_{PTS} is defined as the sum of (a) the unirradiated reference temperature, (b) the margin to be added to cover uncertainties in the initial properties, copper and nickel contents, fluence, and calculation procedures, and (c) the adjusted reference temperature, ΔRT_{PTS}, caused by irradiation. The amount of ΔRT_{PTS} is based on the amount of neutron irradiation and the amount of copper and nickel in the material. The greater the amounts of copper, nickel and neutron fluence, the greater the ΔRT_{PTS} for the material and the lower its fracture resistance.

The PTS rule was amended on May 15, 1991. The amended rule requires licensees to consider the effect of reactor vessel operating temperature and surveillance results on the calculated RT_{PTS} value. In addition, the amended rule required licensees to submit an assessment by December 16, 1991, if the RT_{PTS} for any material in the beltline is projected to exceed the PTS screening criterion before expiration of the operating license. In a letter dated December 16, 1991, the licensee submitted an assessment of the projected RT_{PTS} for the Palisades reactor vessel beltline materials. Additional information was presented at meetings on February 11, February 26, and March 3, 1992, and was provided by Consumers Power Company (CPC) correspondence dated March 11, March 13, and April 2, 1992.

2. EVALUATION

Materials

The Palisades reactor vessel was fabricated by Combustion Engineering. The Palisades reactor vessel beltline consists of six axially oriented welds, one circumferentially oriented weld and six plates. The axially oriented welds were fabricated using a submerged arc process with tandem hot electrically charged primary wire electrodes and a separate cold (not electrically charged) wire feed of pure nickel. The circumferentially oriented weld was fabricated using a submerged arc process with a single hot primary electrode. A separate cold wire feed was not used during fabrication of the circumferentially oriented weld. Combustion Engineering maintained adequate records to determine the heat numbers of all plates and weld wire used in the fabrication of the beltline welds and plates.

Chemical Composition of Plates

The amount of copper and nickel in each plate was determined from either chemical analysis of each plate by the plate fabricator or from analysis of surveillance material. These data indicate that the plates will not be limiting with respect to embrittlement.

Chemical Composition of Axial Welds

The amount of copper and nickel in each axial weld was determined from measurements of weld deposits fabricated using the same heat number of weld wire as used in the fabrication of the Palisades welds. The Palisades axial welds were fabricated using weld wire heat numbers W-5214 and 34B009 as the primary electrodes and using heat number N7753A as the cold nickel wire. The amount of copper is dependent upon the amount of copper in the primary electrodes. The primary source of nickel is the cold nickel wire. The amount of copper in heat number W-5214 welds was determined from chemical analysis of a population consisting of 7 welds fabricated using heat number W-5214 weld wire. The welds in the population were fabricated using single and tandem arc process. The licensee reported three values for the amount of copper in heat number W-5214 welds. The three values are: (a) 0.201 percent, the average of all welds, (b) 0.190 percent, the weighted average of single and tandem welds to account for the difference in number of coils used in the tandem and single arc processes, and (c) 0.178 percent, the average of all welds with the Robinson surveillance weld excluded. The licensee reported two values for the amount of nickel. The two values are 1.03 percent, the average of all data and 1.06 percent, the average of all data with the Robinson surveillance weld excluded. The licensee believes that the best estimate of the amount of copper and nickel in heat number W-5214 is the average value with the Robinson surveillance weld excluded. The licensee believes that the Robinson surveillance weld data should be excluded because a normalized plot of the data indicates that the Robinson surveillance weld data is an outlier.

The staff considered that the amount of copper reported from a surveillance weld fabricated using a single arc process would be the amount contributed by one coil of weld wire, while the amount using a tandem arc process would be the average of the amount contributed by two separate coils. The staff used 0.19 percent copper and 1.06 percent nickel as conservative values for its restart evaluation. The amount of copper in heat 34B009 was determined from chemical analysis of a population consisting of two welds fabricated using heat number 34B009 weld wire. Further, the amount of copper and nickel for welds fabricated using heat number 34B009 were in the range for the welds fabricated using heat number W-5214. Hence, the staff believes that its chemical composition should be similar to heat number W-5214.

Chemical Composition of Circumferential Weld

The amount of copper and nickel in the circumferential weld was determined from measurements of weld deposits fabricated using the same heat number of weld wire as used in the fabrication of the Palisades weld. The Palisades circumferential weld was fabricated using weld wire heat number 27204. The licensee reported two values for the amount of copper and nickel in heat number 27204. The values are the average of all data and the average of all data with a data point, which appears to be an outlier, excluded. The licensee believes that the best estimate of the amount of copper and nickel in heat number 27204 is the average of all data with the outlier excluded.

Estimates of Embrittlement

Table 1 (attached) identifies the licensee's estimate of the year that the Palisades reactor vessel will reach the screening criteria. Using the licensee's best estimate for weld chemistry and neutron fluence, the Palisades reactor vessel is predicted to reach the screening criteria in 2008.

Surveillance Material Test Results

The Palisades reactor vessel surveillance program contains weld metal and plate material. The surveillance plate material was removed from plates that are in the Palisades beltline. However, the surveillance weld metal is not from a Palisades beltline weld. Hence, it has no value in determining the effect of neutron irradiation on the Palisades beltline welds.

The test results from the surveillance plates indicate that the measured increase in reference temperature resulting from neutron irradiation is less than the sum of the margin used to calculate the RT_{PTS} and the calculated ΔRT_{PTS}. Hence, it is appropriate to assume that the rate of embrittlement of the plates for the purposes of PTS analyses is that predicted by the formula and tables in the PTS rules.

Since the weld material in its surveillance program is not applicable to the Palisades reactor vessel beltline welds, the licensee provided surveillance test results from other reactor vessel surveillance programs, with irradiated welds that were fabricated using the same heat number as the welds used to fabricate the Palisades reactor vessel beltline welds. The tests results from these surveillance welds indicate that the measured increase in reference temperature resulting from neutron irradiation is less than the sum of the margin used to calculate the RT_{PTS} and the calculated ΔRT_{PTS}. Hence, it is also appropriate to assume that the rate of embrittlement of the welds is that predicted by the formula and tables in the PTS rule.

Irradiation Temperature

The method of calculating the RT_{PTS} was empirically derived from surveillance data from U.S. commercially operated nuclear reactor vessels. The method is valid for a nominal irradiation temperature of 550°F and irradiation below 525°F is considered to produce embrittlement greater than the value predicted in the PTS rule.

The licensee has reported that during cycle 1 and half of cycle 2 the reactor vessel operated at temperatures slightly below 525°F. The staff believes that irradiation at this lower temperature may result in a slightly greater amount of embrittlement than irradiation at 525°F. However, the staff concludes that the embrittlement which occurred at this lower radiation temperature is not a significant factor in determining whether Palisades should be permitted to restart. The effects of radiation at this lower temperature will be evaluated in connection with the staff's review of the licensee's forthcoming comprehensive submittal.

Fluence

In the course of this review three issues have emerged which the staff believes remain unresolved at this time. These issues are:

1. The applicability of an apparent bias of 13% in the methodology traditionally used by Westinghouse for fluence calculations.

2. A potential non-conservatism resulting from the use of the ENDF/B-IV cross section data base, particularly with regard to iron (Fe) cross sections.

3. The uncertainty estimates of a revised fluence methodology which "corrects" the calculation based upon both capsule and reactor cavity dosimetry measurements.

Each of these items should be thoroughly addressed by the licensee in its upcoming topical report. Our position on each item is given below.

Applicability of a 13% Bias in the Traditional Westinghouse Method

In the course of the Yankee Rowe review, the staff determined that the method traditionally used by Westinghouse (and accepted by the staff) under-predicts the fluence found in capsule measurements by 13% on the average. This average is based upon calculated/measured (C/M) estimates for about 45 capsules. CPC has indicated that this bias does not apply to Palisades because they have compared results for Palisades capsule and found that they slightly overpredict the fluence. CPC also contends that data from six cavity dosimetry measurements suggest that the bias does not apply to plants without a thermal shield.

It is the staff's position that uncertainty in capsule measurements is such that a single data point is inadequate justification. The spread in the C/M data presented at the meetings is 38% and hence conclusions from any single measurement are very questionable. With regard to the cavity dosimetry, first we note that uncertainty in cavity measurements is even less well established than for capsules. Also, Westinghouse report WCAP-11815, states that "calculations applicable to reactor cavity locations tend to be biased low by approximately 20% depending on the thickness of the pressure vessel wall." We note also that the referenced measurements were not for Palisades. Thus, a study of the characteristics of the plants where the measurements were taken is necessary to rule out other possible reasons for a systematic difference in measurements. While the arguments provided by the licensee are plausible, they are insufficient to justify that the bias does not apply to Palisades.

Potential Non-conservatism in ENDF/B-IV Cross Section Data Base

Recent studies have suggested that the ENDF/B-IV cross sections, (particularly Fe) may be non-conservative by as much as 20% for deep metal penetrations, and that ENDF/B-VI should be used. While a rigorous assessment by CPC of the impact of using ENDF/B-VI is not required, the potential non-conservatism of lower inelastic scattering cross sections for iron should be considered and addressed in the licensee's topical report.

Uncertainty Estimates in the Revised Methods

The PTS Rule includes a margin term "M" which adjusts RT_{PTS}. This term (M) was determined assuming an uncertainty in the fluence calculation of 20%. The revised method proposed by Westinghouse employs an update of the calculation based upon capsule dosimetry and cavity dosimetry measurements. The revised method is based upon the assertion that the measured dosimetry values are the best available information. The staff, however, is concerned that the uncertainty in capsule measurements is often large and that cavity dosimetry measurements are even less accurate. The uncertainties discussed in meetings with the licensee do not explicitly account for such apparent sources of uncertainty (among others) as location, vessel ovality, neutron streaming in the cavity, and dosimeter foil orientation. There appears to be an assertion of an uncertainty level rather than a value determined from the various contributing sources. Furthermore, the plant measurement uncertainties discussed appear to imply greater accuracy than those estimated in the PCA experiments. This is doubtful since PCA was a very carefully controlled experiment under laboratory conditions. Therefore, the $\pm$ 20% fluence assumption used in the determination of the margin term "M" may not be satisfied in the updated method.

In its upcoming topical report, the licensee should address each contribution to uncertainty separately and discuss its method for estimation of overall uncertainty.

3. CONCLUSION

a. The surveillance test results indicate that the value of PTS calculated using the methodology in the PTS rule is applicable to the Palisades reactor vessel.

b. Based on the reported material chemistry, irradiation temperature, and neutron fluence, the NRC staff determines that the Palisades plant may be restarted because the reactor vessel will not reach the PTS screening criteria until well after 1995. The staff will evaluate the licensee's forthcoming comprehensive submittal to determine if further action is required prior to the plant reaching the end of its current operating license. This evaluation will be documented in a final PTS Safety Evaluation for the Palisades Plant.

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TABLE 1

Palisades Reactor Vessel Materials
With Respect to Pressurized Thermal Shock Criteria

	Material Chemistry Wt%		CF	RT-PTS Constants Degrees F		RT-PTS Screening Criteria Degrees F	December 1991 Fluence		Fluence Limit (E19)	Year Screening Crit Met
	Cu	Ni		I	M		RT-PTS	(E-19)		
AXIAL (w/o HBR-2) Best Estimate	0.178[1]	1.06[1]	217	-56	66	270	237	1.18	2.07	2010
HBR Weighted	0.190[2]	1.03[3]	222	-56	66	270	242	1.18	1.83	2006
HBR Unweighted	0.201[4]	1.03[3]	226	-56	66	270	246	1.18	1.70	2003
GIRTH (w/o D5207) Best Estimate	0.207	1.00	228	-56	66	300	268	1.61	2.78	2008
With D5207	0.224	0.973	229	-56	66	300	269	1.61	2.71	2007
PLATE Worst Case	0.240	0.55	165	0	34	270	221	1.61	5.80	2050

[1]Does not include HBR data point of Cu.34% and Ni .66%.

[2]Includes HBR Cu data (Cu .34%) averaged to account for one spool of HBR wire and one spool of W5214 average wire (Cu .178%). This hybrid data point (Cu .259%) is then averaged with all the W5214 Cu data. This approach was used because Palisades axial welds were made with the tandem arc welding process versus a single arc used by HBR.

[3]Includes HBR data point of Ni .66%.

[4]Includes HBR data point of Cu .34%.