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MEMORANDUM FOR: B. C. Rusche, Director
Office of Nuclear Reactor Regulation

R. B. Minogue, Director
Office of Standards Development

FROM: S. Levine, Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER - 10, PRESSURE VESSEL FAILURE PROBABILITY PREDICTION

This memorandum transmits the results of completed research on evaluation of the probability of pressure vessel failure from pressure transients which can occur during PWR operation. The draft report which is enclosed briefly describes the computer code which has been developed and discusses the application of the code to Surry 1. Since the work was done within Nuclear Regulatory Research, there has been no review by a Research Review Group. Peer review within the NRC will determine the applicability of this work to NRC problems. Broader peer review will be obtained in time by publication of this information in a technical journal.

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1. The computer code OCTAVIA has been developed by the Probabilistic Analysis Branch and the Metallurgy and Materials Research Branch. The code uses historical nuclear data to estimate the frequency of pressure transients along with the maximum pressure which is achieved in the transient. Fracture mechanics is used to calculate the failure pressure of the particular vessel for different sized flaws existing in the beltline of the vessel. The vessel failure probability is equal to the probability that a given flaw exists times the probability that a pressure transient occurs and has a maximum pressure exceeding the vessel failure pressure.

2. The failure probability calculations consider the particular pressure vessel characteristics such as copper content, wall thickness, and initial RT_{NDT}. Also considered are the effects

of temperature and neutron fluence (vessel aging). Any of the parameters in the code can be changed to determine the impact of potential licensing decisions.

3. The table below gives the median failure probabilities for Surry 1 for different operating temperatures and fluences. The table illustrates some of the results obtainable from the OCTAVIA code. The table also serves to extend WASH-1400's calculations which were performed for Surry 1. The vessel age in calendar years is shown above the equivalent fluence value. More complete evaluations are contained in the enclosed report.

(AGE)*	(0 yrs.)	(2.5 yrs.)	(10 yrs.)	(40 yrs.)
FLUENCE →	0.0	3.8E+18	1.5E+19	6.0E+19
TEMP (F)				
70	3.3E-09	2.4E-06	1.7E-05	3.5E-05
110	2.0E-09	6.3E-07	1.1E-05	3.0E-05
150	2.0E-09	3.4E-08	5.5E-06	2.5E-05

*Age in calendar years assuming effective full power years = 0.8 x calendar years.

4. From past nuclear experience, the median temperature of transients which have occurred is approximately 110°. The present age of Surry 1 is approximately 2.5 calendar years. Using this information in the above table, the median pressure vessel failure probability predicted for Surry, at the present time, from the types of overpressurization transients that have been occurring is 6.3×10^{-7} per reactor year. This value is within the overall value of pressure vessel failure probability predicted in WASH-1400 of 10^{-8} - 10^{-6} per reactor year.

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5. At 40 years the vessel failure probability is predicted to increase to 3.0×10^{-5} per reactor year. This probability can be significantly reduced by system or operational modifications which are now being studied by the regulatory staff. The OCTAVIA code has the ability to determine the impact of these modifications on the final failure probability. For instance, the probability of vessel failure will vary linearly with the frequency of occurrence of transients; however, a reduction in amplitude of transients from say 1600 psig to 1200 psig, would reduce the likelihood of failure by a factor of about 20 at the end of life. More generally, it is also interesting to note a reduction in copper content of vessel steel from .25 to .10% would reduce the predicted failure probability by a factor of 10 to 100.

We would be happy to be of assistance in the implementation of this information into standards or licensing procedures.

Original Signed by
Saul Levine

Saul Levine, Director
Office of Nuclear Regulatory Research

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Draft Report

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of temperature and neutron fluence (vessel aging). Any of the parameters in the code can be changed to determine the impact of potential licensing decisions.

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4. From past nuclear experience, the median temperature of transients which have occurred is approximately 110°. The present age of Surry 1 is approximately 2.5 calendar years. Using this information in the above table, the median pressure vessel failure probability for Surry, at the present time, is 6.3×10^{-7} per reactor year. At 40 years the vessel failure probability will have increased to 3.0×10^{-5} per reactor year. The vessel failure probabilities can be significantly reduced by system or operational modifications which might be instituted. The computer code has the ability to determine the impact of these modifications on the final failure probability.

Saul Levine, Director
Office of Nuclear Regulatory Research

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