April 11, 2000

MEMORANDUM TO: ACRS Members

/RA/

FROM: Noel Dudley, Senior Staff Engineer

SUBJECT: CERTIFICATION OF THE SUMMARY/MINUTES OF THE JOINT ACRS SUBCOMMITTEE MEETING ON MATERIALS AND METALLURGY AND ON RELIABILITY AND PROBABILISTIC RISK ASSESSMENT CONCERNING THE NRC PRESSURIZED THERMAL SHOCK TECHNICAL BASIS RE-EVALUATION PROJECT, MARCH 16, 2000 - ROCKVILLE, MARYLAND

The minutes of the subject meeting, issued on March 24, 2000, have been certified as the official record of the proceedings of that meeting. A copy of the certified minutes is attached.

Attachment: As stated

cc: Technical Support Branch
Operations Support Branch (3 copies)

cc via e-mail:
J. Larkins
H. Larson
S. Duraiswamy
ACRS Fellows and Technical Staff
E. Barnard

Issued: March 24, 2000 **CERTIFIED** ACRS-3197
CERTIFIED: April 7, 2000

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
MINUTES OF JOINT ACRS SUBCOMMITTEE MEETING ON
MATERIALS AND METALLURGY AND
RELIABILITY AND PROBABILISTIC RISK ASSESSMENT
PTS TECHNICAL BASIS RE-EVALUATION PROJECT
MARCH 16, 2000
ROCKVILLE, MARYLAND

The ACRS Subcommittees on Materials and Metallurgy and on Reliability and Probabilistic Risk Assessment met on March 16, 2000, to hold discussions with representatives of the NRC staff concerning the Pressurized Thermal Shock Technical Basis Re-evaluation Project. The meeting included presentations concerning the pressurized thermal shock (PTS) analysis methodology, probabilistic fracture mechanics, the status of the flaw distribution expert elicitation process, and the potential revisions to the PTS risk acceptance criterion. The entire meeting was open to public attendance. Mr. Noel Dudley was the cognizant ACRS staff engineer for this meeting. The meeting was convened at 8:35 a.m. and was adjourned at 2:15 p.m.

ATTENDEES

ACRS
W. Shack, Co-Chairman
G. Apostolakis, Co-Chairman
M. Bonaca, Member
T. Kress, Member
D. Powers, Member
N. Dudley, ACRS Staff

NRC REPRESENTATIVES
M. Cunningham, RES
E. Hackett, RES
S. Malik, RES
D. Jackson, RES
D. Kalinousky, RES
L. Abramson, RES
H. Woods, RES
N. Siu, RES
W. Galyean, INEEL

There were no written comments or requests for time to make oral statements received from members of the public. Nine members of the public attended the meeting. A list of meeting attendees is available in the ACRS office files.

INTRODUCTION

Dr. William Shack, Chairman of the Materials and Metallurgy Subcommittee, explained that the purpose of the meeting was to review activities related to the staff's PTS Technical Basis Re-evaluation Project. He called upon Mr. Edwin Hackett, Acting Chief of the Materials Engineering Branch in the Office of Nuclear Regulatory Research (RES), to begin.

PTS TECHNICAL BASIS RE-EVALUATION PROJECT - Mr. Edwin Hackett, RES

Mr. Edwin Hackett, RES, provided background information concerning the PTS Technical Basis Re-evaluation Project and explained the planned approach for re-evaluating the PTS screening criterion. He described the progress made by three groups of staff and industry experts, who are working in the areas of probabilistic fracture mechanics (PFM), thermal hydraulics, and probabilistic risk assessment (PRA). He identified the licensees participating in the Re-evaluation Project. Mr. Hackett explained the flow chart and schedule for completing the Re-evaluation Project.

The Subcommittee members and the staff discussed the following:

- amount of reactor vessel plate available for testing and analysis;
- characterizing the size, shape, and orientation of flaws;
- how clusters of flaws are treated;
- the use of feedback between the PFM and PRA groups; and
- benefits derived from industry participation.

PROGRESS IN PROBABILISTIC FRACTURE MECHANICS - Messrs. Shah Malik, Mark Kirk, and Doug Kalinousky, RES

Mr. Shah Malik, RES, provided the status of the PFM group's activities. He presented a flow diagram of the different activities associated with the Re-evaluation Project and explained how the activities were interrelated. Mr. Malik noted which activities required quantification of uncertainties and identified the technical issues under consideration, which included:

- fabrication flaw distributions in the reactor pressure vessel beltline,
- statistical distribution of fracture toughness,
- improved statistical distributions for material chemistry,
- beltline fluence maps, and
- revisions to the Fracture Analysis of Vessels - Oak Ridge (FAVOR) Code.

Mr. Malik described the objectives and status of the activities associated with fabrication flaw distributions.

The Subcommittee members and the staff discussed planning peer reviews of the FAVOR code, treatment of uncertainties for variables that may be correlated, and the use of nominal values instead of the results of integrated analyses.

Statistical Representation of Fracture Toughness: Mr. Mark Kirk, RES, explained how NRC contractors collected and assembled data for evaluating fracture toughness and how they developed interim fracture toughness curves. He described how uncertainties associated with the fracture toughness curves were established. Both the interim curves and the associated uncertainties will be inputs to the FAVOR Code. Mr. Kirk introduced root cause diagrams and explained how they could be used to display a complex process in a logical format and help

provide a more rigorous treatment of uncertainty. He demonstrated how the root cause diagrams were used to develop more robust procedures for selecting fracture toughness and uncertainty values for a specific reactor pressure vessel. He noted that the diagram could be entered at any level for which data was available or could be obtained.

Mr. Kirk described the staff's activities related to developing a model to predict the shift in the reference transition temperature for a reactor pressure vessel due to irradiation embrittlement. He explained how additional data and modeling of the physical processes associated with embrittlement has resulted in an improved equation for calculating irradiation embrittlement.

The Subcommittee members and the staff discussed the flaw distribution across the reactor pressure vessel wall and the long term effects of thermal-irradiation, the effect of not having an equation for copper saturation, and the rigor involved in the statistical analyses.

Statistical Distributions for Material Chemistry: Mr. Douglas Kalinousky, RES, described how the staff used available data to determine the mean and standard distribution of critical composition variables in reactor pressure vessels. He provided examples of how distributions of copper and nickel were determined for welds and plates. He further explained how data was used to determine a distribution of initial reference transition temperatures for reactor pressure vessels. The Subcommittee members and the staff discussed the meaning of the distributions for a specific heat of material, the use of standard deviations versus minimum and maximum correlations, the need to account for uncertainty in the mean values and the standard deviations, and how to validate the derived distributions.

Beltline Fluence Maps: Mr. Malik explained how the staff analyzed data from specific plants to estimate the uncertainties in end-of-life fluence maps for the beltline region of reactor pressure vessels. He described how PFM applications can be used to determine at what time in a plant's operating life the frequency of reactor pressure vessel failures would exceed an acceptable value and how integration and application of advanced technology can affect calculated results.

Revisions to the FAVOR Code: Mr. Malik stated that the staff initiated development of the FAVOR Code after the NRC's review of the Yankee Rowe reactor pressure vessel in the early 1990s. The FAVOR Code was intended to combine the best features of two earlier PFM codes that had been used in the development of the original rule. He explained that the FAVOR Code is being revised to incorporate the technology advances presented above in order to support a possible revision to the PTS rule. He noted that the revision of the FAVOR Code is a cooperative effort among the NRC staff, NRC contractors, and the industry. He described the results of validating the FAVOR Code against the ABAQUS Code, which is a commercial multi-dimensional finite element code with fracture mechanics capabilities. The staff validated the FAVOR Code results for temperature and hoop stress, distributions of the stress intensity factors, surface-breaking flaws, and embedded flaws. Mr. Malik explained how initial results from using the FAVOR Code alternative flaw distribution models show the potential for extending the operating life of a reactor pressure vessel. He concluded his presentation by describing the schedule for completing the PFM group's activities.

The Subcommittee members and the staff discussed location of cracks, variation of hoop stress with pressure, and the consideration of fracture toughness.

DEVELOPING A GENERALIZED FLAW DISTRIBUTION - Ms. Deborah Jackson and Mr. Lee Abrams, RES

Ms. Deborah Jackson, RES, presented the expert elicitation process being used to determine the flaw distribution in reactor pressure vessels. She described the expert panel process the staff is using to resolve specific technical issues for which there is significant scientific uncertainty. Ms. Jackson described the flaw distribution data obtained from detailed examination of the Pressure Vessel Research User Facility (PVRUF) vessel and the Shoreham vessel, and the comparison of this data to the Marshall flaw data distribution used for previous studies of PTS. She noted that all the flaws found in the Shoreham and PVRUF examinations were embedded, i.e. subsurface, flaws.

Ms. Jackson presented the schedule for completing the expert elicitation and some of the issues the panel is addressing. Mr. Lee Abrams, RES, described the elicitation sessions and the use of the interactive matrix to identify correlations between variables that are expected to affect the flaw distribution. The flaw distribution determined from examination of the PVRUF data is being used as a baseline, and the experts are being elicited for their views on how variations in a range of weld parameters will affect this distribution. The staff will then synthesize this information to develop flaw distributions. Ms. Jackson concluded that the expert elicitation process is complex and is expected to identify significant issues related to the development of a generalized flaw distribution. She noted that the flaw distribution may vary significantly among reactor pressure vessels because of differences in welding procedures.

The Subcommittee members and the staff discussed the definition of the flaw distribution, the use of expert judgement, the reason for using the Shoreham data, the PRODIGAL approach, the purpose of a Technical Facilitator Integrator, and treatment of flaw orientation and clusters of flaws. They also discussed the interactive matrix and how it accounted for variations in welder skill, procedure quality, and inspector expertise and how correlations between these variations affect the uncertainty of the flaw distribution.

POTENTIAL REVISIONS TO PTS ACCEPTANCE CRITERION : Mr. Mark Cunningham, RES

Mr. Mark Cunningham, RES, explained that the PTS rule issued in 1983 is an adequate protection rule with a probabilistic risk assessment criterion of less than 5×10^{-6} through-wall cracks per reactor year. He noted that the rule assumes that a through-wall crack is equivalent to a large opening in a reactor vessel, which results in core damage, and that containment performance would not be impaired. Mr. Cunningham noted that more recent severe accident information provided a better understanding of accident phenomenology and identifies possible adverse impacts on containment performance during PTS events. He presented the different regulatory approaches and assumptions used in more recent Commission guidance provided in the following:

- Safety Goal Policy Statement,

- Station Blackout and ATWS Rules,
- Backfit Rule, and
- Regulatory Guide 1.174.

On the basis of the above Commission guidance, Mr. Cunningham outlined the different approaches that the staff could use for revising the PTS acceptance criterion. He stated that the staff plans to provide the Commission an options paper on revising the criterion in May 2000. He added that the staff plans to discuss a draft of the paper with the ACRS in April or May 2000.

The Subcommittee members and the staff discussed different reactor pressure vessel failure modes that have not been analyzed, the relationship between adequate protection and backfit requirements, plant-specific versus generic rules, implications for license extension, and the criterion in terms of mean values, lower mean values, uncertainties, and confidence levels.

PRA FOR PTS RULE REVISION - Messrs. Hugh Woods, Nathan Siu, and Mark Cunningham, RES, and Mr. William Galyean, INEEL

Mr. Hugh Woods, RES, presented the objective of the PRA group and its approach for estimating PTS induced through-wall crack frequencies. He noted that open questions exist concerning the following:

- treatment of internal fires and floods, and external events;
- relationship of through-wall crack frequency and core damage frequency (CDF); and
- treatment of large early release frequency (LERF).

Mr. William Galyean, INEEL, presented the status of the PTS PRA model being developed. He compared the results of the original Oconee Integrated PTS study to the present model. He explained how results from ATHEANA were integrated into the PRA analysis. Mr. Nathan Siu, RES, described how uncertainties in the PRA event sequence analysis would be propagated through the thermal-hydraulics, PFM, and PRA integration analyses. Mr. Cunningham concluded that the development of the Oconee PTS PRA model is progressing well and that the uncertainty analysis framework has been developed and is being implemented in the FAVOR Code.

The Subcommittee members and the staff discussed the following:

- what information was gained from ATHEANA,
- the plant-specific nature of the analyses,
- whether the pilot plants are representative of all plants,

- use of Individual Plant Evaluation External Events (IPEEE) insights report findings,
- fire initiation of emergency core cooling system events,
- need for screening event scenarios when using Monte Carlo methods,
- lack of frequency uncertainties in time traces, and
- whether the treatment of imbedded flaws is a fatal flaw in the Re-evaluation Project.

SUBCOMMITTEE COMMENTS, CONCERNS, AND RECOMMENDATIONS

Dr. Powers stated that the PTS Technical Basis Re-evaluation Project plan was fine. He noted that the staff must be careful when using judgement to screen out event scenarios. He observed that the staff's development of various distributions represented a careful job of engineering but was not a rigorous statistical analysis. He noted that the Re-evaluation Project was a nifty research programs because it brings together three disciplines and uses a focused attack.

Dr. Mario Bonaca was favorably impressed with the coming together of the probabilistic and deterministic analyses. He expressed concerns regarding the criteria that would be used to modify the PTS rule. Dr. Apostolakis expected that difficulties would be encountered during the implementation of the Re-evaluation Project plan. Dr. William Shack stated that the Re-evaluation Project plan was comprehensive.

Dr. Thomas Kress stated that the Re-evaluation Project represented a model program on how to risk-inform regulations. He questioned how the uncertainties would be used in the decision making process. Dr. Kress stated a concern about the expert elicitation process being the only way to determine uncertainties. He noted that the staff should look for correlations between the factors being evaluated by the expert elicitation panel.

STAFF AND INDUSTRY COMMITMENTS

The staff agreed to brief the Subcommittee on the proposed Commission paper related to revising the PTS screening criterion in April 2000.

The staff agreed to brief the ACRS concerning the results of the flaw distribution expert elicitation when they become available.

SUBCOMMITTEE DECISIONS

The Subcommittee requested that the staff brief the Committee on the proposed Commission paper related to revising the PTS screening criterion at the April 5-7, 2000 ACRS meeting after it briefs the Subcommittee.

The Subcommittee requested that the staff brief the Committee on the results of the flaw distribution expert elicitation process at the June or July 2000 ACRS meeting.

The Subcommittee recommended that the Committee prepare letters concerning the proposed Commission paper related to revising the PTS screening criterion and the results of the flaw distribution expert elicitation process.

FOLLOW-UP ACTIONS

None

PRESENTATION SLIDES AND HANDOUTS PROVIDED DURING THE MEETING

The presentation slides and handouts used during the meeting are available in the ACRS office files or as attachments to the transcript.

BACKGROUND MATERIAL PROVIDED TO THE SUBCOMMITTEE:

1. Malik, S., et. al, "Pressurized Thermal Shock —A Program to Revisit the Technical Basis," paper presented at the 27th Water Reactor Safety Meeting in Washington, DC, on October 25, 1999.
2. Siu, N., "Uncertainty Analysis and Pressurized Thermal Shock: An Opinion," white paper revised September 3, 1999.
3. Dickerson, T., et. al., "Revisiting the Integrated pressurized Thermal Shock Studies of an Aging Pressurized Water Reactor," paper presented at the ASME Pressure Vessel and Piping Conference, August 1999.
4. Jackson, D., "Summary of Information to be Presented to ACRS on Developing Generic Flaw Distributions for RPV Beltline Materials," received March 7, 2000.

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NOTE: Additional details of this meeting can be obtained from a transcript of this meeting available in the NRC Public Document Room, 2120 L Street, N.W., Washington, D.C. 20006, (202) 634-3274, or can be purchased from Ann Riley & Associates, LTD., 1025 Connecticut Ave., NW, Suite 1041, Washington, D.C. 20036, (202) 842-0034.

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