

# CERTIFIED

ACRS-3017

PDR 10/3/96

**CERTIFIED BY:** Robert Seale, July 18, 1996  
Date Issued: July 5, 1996

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS  
JOINT SUBCOMMITTEE MEETING MINUTES:  
MATERIALS & METALLURGY AND SEVERE ACCIDENTS  
JUNE 3-4, 1996  
ROCKVILLE, MARYLAND

The ACRS Joint Subcommittee on Materials & Metallurgy and Severe Accidents met on June 3-4, 1996, at 11545 Rockville Pike, Rockville, Maryland, in Room T-2 B3. The purpose of the meeting was to gather information on the status of activities associated with the development of a proposed rule concerning steam generator integrity. 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 8:30 a.m. on June 3, 1996, and adjourned at 2:30 p.m. on June 4, 1996.

### ATTENDEES

#### ACRS

R. Seale, Chairman  
M. Fontana, Chairman  
I. Catton, Member  
T. Kress, Member

D. Powers, Member  
W. Shack, Member  
C. Wylie, Member  
N. Dudley, ACRS Staff

#### NRC STAFF

R. Jones, NRR  
J. Strosnider, NRR  
K. Karwoski, NRR  
E. Murphy, NRR  
J. Donoghue, NRR

S. Long, NRR  
C. Tinkler, RES  
J. Muscara, RES  
J. Staudenmeier, NRR  
D. Lynch, NRR

#### INDUSTRY

A. Marion, NEI  
R. Mullins, Southern Nuclear Operating Company  
M. Kenton, Dames & Moore  
D. Steininger, EPRI

There were no written comments or requests for time to make oral statements received from members of the public. An attendance list of members of the NRC staff and public is available in the ACRS office files.

### INTRODUCTION:

Dr. Robert Seale, Chairman of the Materials & Metallurgy and Severe Accident Joint Subcommittee, explained that the purpose of the meeting was to gather information concerning operating experience, technical issues, and rulemaking efforts associated with steam generator integrity. He noted that material related to the presentation had been previously provided to the members. Dr. Seale turned the meeting over to the staff.

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Minutes: Materials & Metallurgy and Severe Accidents  
June 3-4, 1996

**STAFF PRESENTATION:**

**Introduction:** Mr. Jack Strosnider, NRR, presented the schedule for issuance of the proposed steam generator rule. The schedule included an ACRS review of the proposed rule and regulatory guide in September 1996. He explained that the staff and the Nuclear Energy Institute (NEI) have met periodically to discuss and resolve differences related to the development of the proposed rule, regulatory guide, and industry implementing documents. Mr. Strosnider and the Subcommittee discussed different alternate repair criteria that the staff has approved or reviewed.

**Steam Generator Operational Experience:** Mr. Ken Karwoski, NRR, stated that the current regulatory framework for assuring steam generator tube integrity consists of monitoring operating experience and processing relief requests on a case-by-case basis. He explained the different types of steam generator tube degradation and the associated repair actions or alternate repair criteria. Mr. Karwoski reviewed the following steam generator tube inspection issues:

- advantages and limitations of the different types of non-destructive examination (NDE) probes,
- use of historical tube inspection information to plan future inspections,
- difficulties in sizing cracks,
- length of time to approve alternate repair criteria, and
- assessments required to ensure tube integrity.

Mr. Karwoski concluded by explaining NRC regional program inspection findings and associated enforcement activities.

The staff and the Subcommittee discussed validating NDE indications, the susceptibility of steam generator tubes to different types of degradation, and the types of repair sleeves that are susceptible to cracking. They also discussed requirements for qualifying repair techniques, free span tube cracks at Oconee, and recent enforcement actions.

**Proposed Steam Generator Rule and Regulatory Guide:** Mr. Emmett Murphy, NRR, explained the safety importance of steam generator tube failures as a potential containment bypass path for release of radioactive fission products to the environment. He presented current regulatory requirements, tube degradation mechanisms, and NDE techniques.

Mr. Murphy stated that the revised rule should be risk-informed, performance-based, and adaptable. Additionally, the rule should provide incentives for better defect detection methods and a framework for developing degradation specific management techniques. He described the rule, which was being developed, and the associated risk considerations. Mr. Murphy noted that the revised rule would need to be compatible with the requirements of 10 CFR Part 100.

Minutes: Materials & Metallurgy and Severe Accidents  
June 3-4, 1996

Mr. Murphy stated that the performance criteria developed for the rule must be measurable and tolerable. He described the following criteria, which are contained in the preliminary draft for the regulatory guide:

- tube structural integrity,
- operational leakage integrity,
- accident-induced leakage integrity,
- condition monitoring assessments,
- operational assessments, and
- corrective actions.

Mr. Murphy explained the preventive activities that were contained in the preliminary draft of the regulatory guide, such as, secondary water chemistry control programs, loose part monitoring programs, and measures to mitigate active tube degradation mechanisms.

Mr. Murphy identified the following outstanding issues that require staff action:

- completing a risk assessment to support the proposed rule,
- developing a strategy for implementing the proposed rule,
- identifying program elements that require NRC review and approval,
- defining the relationship between industry implementing documents and the regulatory guide,
- eliminating unnecessary prescriptive guidance,
- specifying requirements for addressing degradation mechanisms that cannot be identified by qualified NDE techniques, and
- developing appropriate deterministic and probabilistic margins for the structural performance criteria.

The staff and the Subcommittee discussed the basis for using a tube rupture conditional probability of  $5 \times 10^{-2}$  per year, the conduct of situ tube tests, and the selection of the risk assessment scenarios. They also discussed the advantages of a revised rule, the approach for developing a risk assessment, and the program elements that would be subject to NRC review. The staff and the Subcommittee discussed the use of the defense-in-depth philosophy, the setting of measurable goals in the development of the proposed rule, and the difficulty of measuring growth rates when every identified defect is required to be repaired.

**Safety Analysis Technical Issues:** Mr. Joseph Donoghue, NRR, presented an overview of the elements of the safety analysis and the key technical issues associated with the development of the revised rule. He discussed the steam generator tube rupture consequence assessment related to fission product release calculation and the iodine spiking model. Mr. Donoghue explained the potential for a spontaneous tube rupture and the impact of pressure-induced or thermally-induced tube ruptures. He noted that the staff was analyzing thermally-induced ruptures scenarios and the effects of tube defects on the probability of offsite releases. Mr. Donoghue explained key technical issues,

Minutes: Materials & Metallurgy and Severe Accidents  
June 3-4, 1996

such as, quantifying event trees, identifying reactor coolant pressure boundary weak points, and modeling steam generator tube performance. He provided additional details concerning the uncertainties related to the thermal-hydraulic models, the assumed flaw distribution in steam generator tubes, and the radiological consequence assessment.

Mr. Donoghue and the Subcommittee discussed how defense-in-depth was integrated into the risk analysis, the different heating and mechanical mechanism that could lead to tube failure, the effect of multiple tube ruptures, and the analysis of airborne releases resulting from tube ruptures. The staff and the Subcommittee discussed modeling fission product deposition, modeling hot gas flows in the hot leg and steam generator, and the differences in the results between the RELAP5/MOD3 and MAAP4 codes. The Subcommittee members discussed the shortcomings of the severe accident models used to evaluate the tube failure probability.

Mr. Bob Jones, NRR, committed to provide an answer to Dr. Catton concerning the probability of multiple tube ruptures occurring as a result of a single tube rupture. The staff stated that the probability of tube failures at plants without power operated relief valves would be evaluated at a later date.

**Predictions Of Tube Integrity Under Severe Accident Conditions:** Dr. Joseph Muscara, RES, presented the preliminary results of experiments that studied the temperatures at which pressurized tube specimens fail. The intent of the experiments is to develop a correlation between the failure of sound and degraded steam generator tubes and severe accident conditions. He explained the size of tube specimens, the types of imposed tube defects, and the derivation of the temperature ramps used in the experiments. He reviewed the severe accident test matrix, the test facility, and the test results.

Dr. Muscara explained the flow stress model and creep rupture model associated with steam generator tube failures. He presented the model predictions compared to observed tube failures. He stated that preliminary analyses indicate that the INEL/PNL flow stress model provided slightly better agreement with test results than the creep rupture model. Dr. Muscara indicated that continuing experimental work would emphasize the high-stress, short time-to-failure regime, and that the staff would develop recommendations regarding which model to use.

Dr. Muscara and the Subcommittee discussed the expected point in severe accident transients at which primary pressure boundaries are expected to fail, the characterization of tube specimens prior to testing, and the capability of models to predict realistic temperature transients.

**Byron/Braidwood Safety Evaluation:** Mr. Donoghue presented background information on the safety evaluation report (SER), which granted Byron Station and Braidwood Station regulatory relief to leave degraded steam generator tubes in service based on locking the tube support plates. He presented the



Minutes: Materials & Metallurgy and Severe Accidents  
June 3-4, 1996

major areas reviewed in the SER, such as, the integrity of steam generator internal components, the estimated differential pressure loadings across the support plates, and the evaluations of structural and leakage integrity.

Mr. Donoghue explained the licensee's approach for determining the differential pressure loadings and for performing calculations of hydrodynamic loads. The licensee based the analysis on calculations performed using the RELAP5/MOD3 code. The licensee performed nodalization and sensitivity studies to confirm the code calculations.

Mr. Donoghue explained that the staff based the conclusions in the SER on the licensee analysis, audit calculations, and comparison of the calculations' results to test data. He noted that the staff reviewed the licensee submittal as a generically applicable method for computing tube support plate loads. He concluded that the licensee's estimate of loads provided a reasonable basis for calculating tube support plate deflection.

The staff and the Subcommittee discussed the interim voltage-based repair criteria, the results from different thermal hydraulic codes, the need for experimental facilities, the cross-flow velocities model, the potential for a failed tube to cause other tube failures, the conservatism in the analyses, and the non-uniformities of hot gas flow in steam generator tubes.

#### NEI PRESENTATION:

**Introduction:** Mr. Alex Marion, NEI, outlined the NEI presentation and introduced the speakers. He provided a definition of risk-based and performance-based regulations. He noted that performance based-regulations should include measurable parameters, objective criteria to assess performance, and flexibility for licensees to determine how to meet established performance criteria.

Mr. Marion presented the NEI proposed framework for the steam generator rule. The rule would state the safety objectives. The regulatory guide would define performance criteria and endorse industry documents. The industry documents, such as the EPRI Steam Generator Degradation Specific Management (SGDSM) Guidelines, would define acceptable performance measures and methodologies for meeting performance criteria. Mr. Marion concluded that the proposed framework would allow licensees to implement SGDSM without NRC approval and provide licensees incentives to develop alternate repair criteria.

Mr. Marion and the Subcommittee discussed how risk-based regulation incorporates defense-in-depth, what program changes would require NRC review and approval, and the benefits of the SGDSM concept.

**NEI Implementation Document:** Mr. Rick Mullins, Southern Nuclear Operating Company, explained the NEI industry steam generator tube integrity rule implementing document, which describes a method to fulfill rule requirements and prescribes performance measures for meeting performance criteria. Mr.

Minutes: Materials & Metallurgy and Severe Accidents  
June 3-4, 1996

Mullins explained the following performance criteria proposed by the industry:

- structural integrity,
- leakage integrity, and
- operational leakage.

Mr. Mullins described the issues that were under discussion with the staff, such as, the relationship between the staff regulatory guide and the NEI implementation document, methods for resolving new tube degradation mechanisms, and processes for shortening NRC review time of alternate repair criteria. He used facility operating experience as an example of the advantage of implementing an alternate repair criteria. He refuted the staff statement, "Utilities frequently lack incentive to apply NDE technology and practices which may be available."

The staff, NEI, and the Subcommittee discussed the basis for using a tube rupture conditional probability of  $5 \times 10^{-2}$  per year, the basis for and the ability to accurately measure the daily allowable steam generator leakage, possible advanced NDE techniques, and the level of detail required in the regulatory guide performance criteria.

**MAAP Code Predictions:** Mr. Marc Kenton, Dames & Moore, explained that MAAP4 calculations were performed for various high pressure severe accidents to estimate hot leg, surge line, and steam generator tube temperatures. The calculated temperatures were then used to evaluate the likelihood of thermally-induced tube ruptures. Mr. Kenton explained the assumptions and models used in the probabilistic and deterministic analyses. He noted the factors, which affected the analyses results, such as, failure of safety valves, loss of reactor coolant pump loop seals, the sequence of primary pressure boundary components failures, and the modeling of the hot gas mixing process in the steam generator inlet plenum.

Mr. Kenton detailed the basis of the MAAP4 model and presented the results of the analysis. A typical sequence of events used for MAAP4 calculations was loss of all AC and DC power combined with an assumed loss of the turbine drive auxiliary feedwater pump, failure of a secondary safety relief valve to shut, and two-phase flow through the pressurizer safety valve. The results of the calculation indicated that the hot leg would fail first, but the margin between the hot leg failure and the steam generator tube failure was reduced if degraded tubes were assumed. Mr. Kenton stated that a similar MAAP calculation, which assumes a failure of a pressurized safety valve to shut, indicates that the surge line and hot leg would fail well before any steam generator tube. Mr. Kenton noted that due to the sensitivity of MAAP4 calculations to safety valve failures, tests and analyses were being conducted to better assess the failure probability of steam generator and pressurizer safety valves.

Mr. Kenton and the Subcommittee discussed the expected minimum temperature in the core, the model for counter currents heat transfer in the hot leg, the

Minutes: Materials & Metallurgy and Severe Accidents  
June 3-4, 1996

model for hot gas mixing in the steam generator inlet plenum, the core conditions during the event, and the change in flow resistance due to particle deposition. Mr. Kenton stated that he would review the effect on the probability of a steam generator tube failure of reducing the hot leg nozzle and the surge line heat transfer coefficients in the MAAP model.

#### SUBCOMMITTEE DISCUSSION:

Dr. Catton stated that the Subcommittee should hear about the uncertainty in the area of predicting steam generator temperatures, since that was the area with the most uncertainty. Dr. Catton stated that the steam generator conditional tube failure of  $5 \times 10^{-2}$  seemed arbitrary and not really tied to the overall risk. He believed the staff should make a clear statement that the conditional tube failure was unrelated to risk.

Dr. Powers express concerns regarding the integration of defense-in-depth during the development of the revised rule. Dr. Powers stated that the general outlines provided by Mr. Strosnider and Mr. Marion should be presented to the full Committee.

#### FOLLOWUP ACTIONS:

During the meeting the staff agreed to review the following issues:

- the probability of multiple tube ruptures occurring as a result of a single tube rupture,
- the uncertainty associated with the steam generator tube temperature predictions, and
- the existence of any information concerning the three dimensional behavior of fluid flow in steam generators.

During the meeting Mr. Steininger, EPRI, agreed to provide the following documents:

- report on the Westinghouse 1/7 scale severe accident water test,
- report on the Westinghouse 1/7 scale severe accident  $SF_6$  gas test, and
- hand calculations of the ratio of steam generator recirculation flows to the hot leg flows. [Note: The staff will forward the hand calculations after receiving NEI's formal submittal.]

#### SUBCOMMITTEE RECOMMENDATIONS:

The Subcommittee recommended that the staff and NEI summarize the status of activities associated with the development of a proposed rule concerning steam generator integrity at the June 12-14, 1996 ACRS meeting.

Minutes: Materials & Metallurgy and Severe Accidents  
June 3-4, 1996

**BACKGROUND MATERIAL PROVIDED TO THE SUBCOMMITTEE:**

1. EPRI draft Report TR-106194, "Risk from Severe Accidents Involving Steam Generator Tube Leaks or Ruptures," dated January 1996 [INTERNAL ACRS COMMITTEE USE ONLY]
2. SECY-95-131 issued May 22, 1995, from James Taylor, Executive Director for Operations, to the Commissioners, Subject: Continuance Of Proposed Rulemaking On Steam Generator Maintenance and Surveillance
3. Memorandum dated April 22, 1996, from Timothy Reed, Senior Project Manager, NRR, to Jack Strosnider, Branch Chief, NRR, Subject: Summary of the April 8 and 12, 1996 Meeting With Nuclear Energy Institute and Industry to Discuss Steam Generator Issues
4. Report dated September 12, 1994, from T.S. Kress, ACRS Chairman, to Ivan Selin, Chairman NRC, Subject: Proposed Generic Letter 94-XX, "Voltage-Based Repair Criteria For Westinghouse Steam Generator Tubes"

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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 Neal R. Gross and Company Incorporated, Court Reporters and Transcribers, 1323 Rhode Island Avenue, N.W., Washington, D.C. 20005, (202) 234-4433.