



UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

June 28, 2007

MEMORANDUM TO: ACRS Members

FROM: Charles G. Hammer, ACRS Senior Staff Engineer */RA/*

SUBJECT: CERTIFICATION OF THE MINUTES OF THE MEETING OF THE ACRS
SUBCOMMITTEES ON MATERIALS, METALLURGY, AND REACTOR
FUELS, MARCH 6, 2006 - ROCKVILLE, MARYLAND

The subcommittee chairman has certified the minutes of the subject meeting, issued June 27, 2007, as the official record of the proceedings of that meeting. A copy of the certified minutes is attached.

Attachment: As stated
electronic cc: FGillespie SDuraiswamy C. Santos



UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

April 3, 2007

MEMORANDUM TO: ACRS Members

FROM: Charles G. Hammer, ACRS Senior Staff Engineer */RA/*

SUBJECT: CERTIFICATION OF THE MINUTES OF THE MEETING OF THE ACRS
SUBCOMMITTEES ON MATERIALS, METALLURGY, AND REACTOR
FUELS, DECEMBER 6, 2006 - ROCKVILLE, MARYLAND

The subcommittee chairman has certified the minutes of the subject meeting, issued April 3, 2007, as the official record of the proceedings of that meeting. A copy of the certified minutes is attached.

Attachment: As stated
electronic cc: FGillespie SDuraiswamy C. Santos

June 4, 2007

MEMORANDUM TO: William J. Shack, Acting Chairman
Materials, Metallurgy, and Reactor Fuels Subcommittee

FROM: Charles G. Hammer, ACRS Senior Staff Engineer

SUBJECT: WORKING COPY OF THE MINUTES OF THE MEETING OF THE ACRS
SUBCOMMITTEE ON MATERIALS, METALLURGY, AND REACTOR
FUELS, MARCH 6, 2007 - ROCKVILLE, MARYLAND

A working copy of the minutes for the subject meeting is attached for your review. Please review and comment on them. If you are satisfied with these minutes, please sign, date, and return the attached certification letter.

Attachment: Minutes (DRAFT)

cc: Materials, Metallurgy, and Reactor Fuels Subcommittee Members
CSantos

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
MEETING OF THE ACRS SUBCOMMITTEE ON
MATERIALS, METALLURGY, AND REACTOR FUELS
MEETING MINUTES - MARCH 6, 2007
ROCKVILLE, MARYLAND

INTRODUCTION

The ACRS Subcommittees on Materials, Metallurgy, and Reactor Fuels held a meeting on March 6, 2007, in Room T-2B3, 11545 Rockville Pike, Rockville, MD. The purpose of this meeting was to review issues related to the technical basis associated with the proposed NRC staff actions for addressing the dissimilar metal weld issue resulting from the Wolf Creek pressurizer nozzle weld flaw inspection results. Gary Hammer was the Designated Federal Official for this meeting. The Subcommittee received no written statements or requests for time to make oral statements from the public. The Subcommittee Chairman convened the meeting at 1:00 p.m. on March 6, 2007, and adjourned at 4:03 p.m.

ATTENDEES

ACRS Members

W. Shack, Acting Subcommittee Chairman
M. Bonaca, Member

D. Powers, Member
T. Kress, Member

ACRS Staff

G. Hammer, Designated Federal Official

Principal NRC Speakers

E. Sullivan, NRR

A. Csontos, RES

Principal Industry Speakers

J. Riley, NEI
Craig Harrington, EPRI

D. Covill, Progress Energy

Other members of the public attended this meeting. A complete list of attendees is in the ACRS Office File and is available upon request. The presentation slides and handouts used during the meeting are attached to the office copy of these minutes.

OPENING REMARKS BY CHAIRMAN SHACK

Dr. William J. Shack, Acting Chairman of the ACRS Subcommittee on Materials, Metallurgy, and Reactor Fuels, convened the meeting at 1:00 p.m. Chairman Shack stated that the purpose of this meeting was to discuss the technical basis associated with the regulatory activities for dealing with the dissimilar metal weld issue stemming from the Wolf Creek pressurizer nozzle weld flaws and the associated industry activities. He stated that the

Subcommittee would hear presentations by the NRC's Office of Nuclear Regulatory Regulation (NRR), the Office of Nuclear Regulatory Research (RES) and their contractor Engineering Mechanics Corporation of Columbus (EMCC), the Nuclear Energy Institute (NEI), and the Electric Power Research Institute (EPRI). He said the Subcommittee would gather information, analyze relevant issues and facts, and formulate proposed positions and actions, as appropriate, for deliberation by the full Committee. The rules for participation in the meeting were announced as part of the notice of the meeting published in the Federal Register on February 15, 2007. Chairman Shack acknowledged that the Committee had received no written statements or requests for time to make oral statements from members of the public.

DISCUSSION OF AGENDA ITEMS

Technical Basis Associated with the Proposed NRC Staff Actions for Dealing with the Dissimilar Metal Weld Issue

Mr. Ted Sullivan, with the NRR staff, and Mr. Al Csontos, with the RES staff, presented the technical basis associated with the proposed NRC staff action for dealing with the dissimilar metal weld issue in PWR pressurizer nozzle welds. The proposed actions are the result of pressurizer weld flaws discovered during an October 2006 inservice inspection at the Wolf Creek plant. Mr. Sullivan noted that the staff and industry had previously provided an information briefing to the full Committee on February 2, 2007, and described the nature of the large circumferential flaws found at Wolf Creek in three different locations. The pressurizer surge line nozzle contained three flaws: (1) 4 inches long and 31% through-wall (TW); (2) 2.2" long and 25% TW; and (3) 0.8" long at the inner surface. The pressurizer relief valve nozzle contained a circumferential flaw that was 7.7" long and 26% TW. The pressurizer safety valve nozzle contained a circumferential flaw that was 2.5" long and 23% TW.

Mr. Sullivan and Mr. Csontos described the NRC staff evaluation of the significance of these flaws and the safety implications to other plants with similar welds. They also described the analysis of the primary water stress corrosion cracking (PWSCC) growth of these flaws. They attempted to address large uncertainties such as the weld residual stresses and the crack growth rates. The results of this analysis revealed that in some cases the flaws may lead to a rupture at the same time or very soon after they begin to leak. As a result, the staff has determined that the inspections or mitigations of these welds currently scheduled during spring 2008 at nine plants may need to be accelerated. The other plants either do not have these type welds or will have inspected or mitigated the welds by the end of 2007. The staff also determined that enhanced reactor coolant leakage monitoring needed to be implemented at some plants in order to ensure timely plant shutdown should leakage occur. Mr. Sullivan and Mr. Csontos stated that the staff is working closely with the industry on an advanced finite element fracture mechanics analysis effort wherein the PWSCC crack growth is modeled to vary along the crack length as a function of the local stress intensity. The modeling is unlike previous analyses which constrain the crack shape to remain semi-elliptical. Results from the analysis effort are expected by about June 2007. They stated that if the industry advanced analyses provide reasonable assurance that PWSCC will remain stable and not lead to rupture without significant time from the onset of detectable leakage, the plants with planned spring 2008 outages will not have to shutdown in 2007. They stated that licensees have submitted commitments addressing the requested actions and stated that confirmatory action letters will be issued in the near future to confirm the commitments.

Mr. Jim Riley, with NEI, and Mr. Dana Covill, with Progress Energy, presented the industry basis for their position that the currently scheduled inspections or mitigations of these welds do not need to be accelerated. They provided the basis for the current schedule of inspections or mitigations of these flaws. They stated that there is essentially no difference in risk between inspections or mitigations performed in 2007 and spring 2008. They also described the advanced finite element fracture mechanics analysis effort intended to demonstrate adequate margin for leak-before-break and stated they are closely coordinating with the staff on this effort. They also indicated that if the Committee desires, they would discuss the results of the analyses with the ACRS later in the summer of 2007.

Following the discussion about the implications of the Wolf Creek cracking, the Committee was provided a briefing regarding the recent inspection results at Duane Arnold where large circumferential flaws were detected in a jet pump riser safe end-to-reactor nozzle weld. Mr. Matthew Mitchell with the NRR staff provided the briefing. He stated that it is believed that there were problems with the test probe pulling away from the weld surface during an earlier 1999 inspection, and re-evaluation of the data indicates that the flaw may have existed at that time. This would mean that the crack is not rapidly propagating. The staff is going to independently verify the data to make an independent evaluation. The licensee for Duane Arnold weld repaired this weld and implemented an inspection at other similar piping locations. The staff has requested industry to provide information regarding which plants may have similar welds to those at Duane Arnold.

COMMENTS AND OBSERVATIONS FROM THE SUBCOMMITTEE MEMBERS

- Chairman Shack asked the staff if their analysis addressed uncertainties in the weld residual stresses and if they considered the residual stresses in MRP-106. Mr. Dave Rudland, with EMCC, stated that the MRP-106 stress results were compared to other assumptions the staff made and were found to provide similar results.
- Chairman Shack asked if the staff analysis modeled the crack growth through the center of the weld. Mr. Rudland responded that the growth is modeled to occur through the highest stress location through the weld.
- Chairman Shack stated that the MRP-106 residual stresses assumed by EPRI are consistently less than those assumed in the staff analysis. He asked if the staff evaluation indicated that the hoop stress was consistently greater than the axial stress when using the MRP-106 residual stress assumptions. Mr. Rudland stated they did, except where a weld was repaired.
- Chairman Shack asked if moment loads were modeled in the staff evaluation, which produces a stress gradient with both tension and compression. Mr. Rudland responded that the solutions did include a bending stress gradient, but they were idealized solutions formulated from "Fracture Mechanics", by Dr. Ted Anderson. For very long aspect ratio cracks, the solutions do not reflect the actual condition where compression in part of the crack would close the crack. He also stated that this only affected a few results and was not a problem with the overall study.
- Chairman Shack asked about the validity of the PWSCC crack growth rates assumed in

the staff analysis. These rates would result in estimating the cracks beginning to grow only a short time ago, with no crack initiating for the first 20 or so years of plant operation. Mr. Rudland responded that it is possible that the cracks observed were actually multiple cracks which linked at some point in time, which would result in the observed fast crack growth.

- Chairman Shack pointed out that the use of a higher residual stress will result in faster crack growth, but may not be conservative for evaluating leak-before-break. With a lower stress, the crack will grow longer in the length direction before the crack goes through-wall.
- Chairman Shack asked how restrained the pressurizer nozzle weld locations were and how that could reduce the leakage rate by compressing a postulated crack. Mr Rudland and Mr. Csontos responded that the amount of restraint either from pressurizer nozzle ends or piping restraints is unknown, but they realize that there can be a nonconservative effect of reducing leakage if compressive loads develop.
- Chairman Shack asked when plants are planning to complete inspection or mitigation activities. Mr. Sullivan responded that the last plant will complete these activities by June 2008.
- Chairman Shack asked how many plants are planning to inspect these welds in early 2007. Mr. Sullivan responded that there will not be very many inspections because many plants can not perform the inspections and some others are opting to perform mitigations without performing inspections.
- Chairman Shack asked if the purpose of the advanced finite element analysis effort is to justify delaying the inspections or mitigations by six months. Mr. Sullivan responded that the analysis effort may provide additional assurance, but not absolute assurance, that leak-before-break would occur and that the additional time period which may be justified is still being evaluated.
- Member Powers asked what would be the implication of finding large flaws at other plants as a result of upcoming inspections. Mr. Sullivan responded that such findings could cause the dissimilar metal weld issue to be revisited, depending on the severity of the flaws.
- Chairman Shack asked if all plants were planning to apply mitigation to the welds even if they inspect them and find them acceptable. Mr. Sullivan responded that there was at least one plant who did not plan to perform mitigation after inspecting. Mr. Harrington clarified that there may be three such plants.
- Chairman Shack asked if the industry analysis would predict cracks occurring similar to those at Wolf Creek. Mr. Covill responded that he did not believe that such an industry analysis would predict such cracks.
- Member Powers asked for the inspection frequency imposed by EPRI guidance for visually inspecting Alloy 600 for leakage and boric acid. Mr. Covill responded that the

inspections were to be performed one time only.

- Member Powers asked how the Performance Demonstration Initiative (PDI) process creates a stress corrosion crack for mock-up qualification of ultrasonic (UT) inspectors. Mr. Covill responded that the cracks are generated in a laboratory under fluid pressure conditions.
- Member Powers asked if there is information indicating the direction of crack growth, either along metallurgical dendrites or across them. Mr. Covill indicated that it is difficult to determine the growth direction, especially in repaired welds where the residual stresses are difficult to predict.
- Chairman Shack emphasized that the weld residual stresses and bending moments are large variable uncertainties whose probabilities are difficult to characterize. In addition, assumed parameters which are conservative from a structural margin viewpoint may not be conservative for leak-before-break. Mr. Covill and Mr. Glen White indicated that a large range of values for parameters are being considered in the analyses for assessing leak-before-break, including residual stresses, crack shapes, and crack sizes.
- Member Powers asked why a probabilistic characterization of crack likelihood is appropriate when it is known that the probability of the large circumferential cracks occurring at Wolf Creek was indeed equal to 1.0. Mr. White responded that the probabilistic characterization is for showing that the probability of a Wolf Creek type crack for all facilities is low.
- Member Powers asked what the industry has to validate the non-elliptical crack shape assumptions. Mr. White responded that the validation effort is ongoing and will include: some actual PWR and BWR operating experience, some residual stress information, laboratory testing data, and a review of published literature. He added that because of metallurgical non-uniformities, there are expected to be portions of crack fronts which tend to grow faster than other portions.
- Member Powers asked what factors of safety were being used in the staff's evaluations of the flaws and how uncertainties would be treated, e.g., Monte Carlo or Latin Hypercube sampling. Mr. Sullivan and Mr. Csontos responded that the staff was only beginning to consider the necessary factors of safety and how uncertainties should be treated, but that they would be addressed in some way. They also thought that the factors of safety and uncertainty analysis would be interrelated. Mr. Csontos also mentioned that RES is developing a probabilistic fracture mechanics model for this purpose as a longer term effort.
- Member Powers asked if the fractal nature of crack shapes and growths suggested by industry would lead to a percolation theory for crack propagation. Mr. White responded that the ongoing modeling was being based on stress variations on a larger versus a microstructural scale, but that the suggested crack growth "fingers" are consistent with a percolation phenomenon.
- Chairman Shack asked if it was being considered to ask Wolf Creek to take a

metallurgical sample of the cracked area. Mr. Marion responded that discussions were continuing with Wolf Creek management to request that samples be taken, but it is uncertain whether that will occur.

- Member Powers asked why other plants should not be considered to have cracks as significant as those at Wolf Creek. If there is not an understood reason why the cracks would occur only there, then the results of the fracture mechanics analysis could not provide a significant basis for the other plants to defer inspections. Mr. Sullivan and Mr. Csontos responded that the larger purpose of the advanced finite element fracture mechanics analyses is to provide a basis for the assumption of leak-before-break, if large cracks continue to occur.
- Chairman Shack re-emphasized that all of the ranges of the parameters which are input into the analyses should have a reasonable basis, and it was not clear how that can be done. Mr. Csontos responded that information was being obtained regarding the residual stresses in the welds at the nine plants where licensees wish to inspect or repair in 2008, and that this would help define the range of that parameter.
- Regarding the Duane Arnold inspection results of the 11 inch inside diameter jet pump riser Inconel 82/182 safe end-to-reactor nozzle weld, Chairman Shack asked if the weld material is sensitized Alloy 600 material. Mr. Mitchell responded that the original nozzle was replaced in the late 1970s with improved Alloy 600.
- Member Bonaca asked if the failure to accurately characterize the Duane Arnold weld flaw in 1999 was in and of itself a concern. Mr. Mitchell stated that the staff also has this concern and that this is being communicated to the industry.
- Member Bonaca asked if there was margin to failure even for the 6 inch long, 74% through-wall flaw at Duane Arnold. Mr. Mitchell responded that based on an ASME limit load analysis, there is still margin to failure.
- Chairman Shack suggested that hydrogen water chemistry does not completely eliminate the potential for cracking in Alloy 182, but that cooler temperatures would reduce the likelihood of cracking at low potentials. Mr. Mitchell agreed. Member Powers asked for the basis of using an Arrhenius temperature dependent model for cracking. Chairman Shack responded that while the physical mechanisms which cause cracking are not well understood, data suggests that it is strongly temperature dependent.
- Chairman Shack asked if the Duane Arnold weld configuration is unique. Mr. Mitchell responded that he currently has no basis to assume that it is, but that a survey of BWRs was being made and would reveal if there are differences.

SUBCOMMITTEE DECISIONS AND ACTIONS

Following the staff and industry presentations and discussions, Chairman Shack requested that the presentations to the full Committee on March 8, 2007, be an abridged version of their presentations to the Subcommittee, focusing on the future activities to address the implications

of the Wolf Creek flaws. He thanked everyone for their presentations and discussions and then adjourned the meeting at 4:03 pm.

BACKGROUND MATERIALS PROVIDED TO THE SUBCOMMITTEE PRIOR TO THIS MEETING

1. Memorandum from C.G. Hammer to ACRS Members transmitting status report, review materials, and proposed schedule regarding technical basis associated with proposed NRC staff actions for addressing dissimilar metal weld issue resulting from Wolf Creek pressurizer weld flaw inspection results, dated February 16, 2007 (ADAMS MLML070750115)
2. NUREG/CR-6921 (ANL-05/55) Crack Growth Rates in a PWR Environment of Nickel Alloys from the Davis-Besse and V.C. Summer Power Plants, November 2006 (ADAMS ML063520366 and ML063520369)
3. **PROPRIETARY** Materials Reliability Program: Primary System Piping Butt Weld Inspection and Evaluation Guidelines (MRP-139), August 2005 (ADAMS ML060170531)
4. Transmittal memo from M. Cunningham to F. Gillespie dated February 13, 2007 (ADAMS ML070460127) with **PROPRIETARY** RES Draft Summary Report - Evaluation of Circumferential Indications in Pressurizer Nozzle Dissimilar Metal Welds at Wolf Creek, January 2007 (ADAMS ML070460305)
5. Commitment letters for the following nine plants:
 - Braidwood 2 (letter dated 1-30-07, ADAMS ML070310279)
 - Comanche Peak 2 (letter dated 1-30-07, ADAMS ML070320129)
 - Diablo Canyon 2 (letter dated 1-31-07, ADAMS ML70370394)
 - Vogtle 1 (letter dated 1-30-07, ADAMS ML070310331)
 - Palo Verde 2 (letter dated 1-31-07, ADAMS ML070430378)
 - South Texas 1 (letter dated 1-30-07, ADAMS ML070370319)
 - Seabrook (letter dated 1-31-07, ADAMS ML070330591)
 - Summer (letter dated 1-31-07, ADAMS ML070330144)
 - Waterford 3 (dated 1-31-07, ADAMS ML070370403)
6. Letter from NEI, "Industry Actions Associated with Potential Generic Implications of Wolf Creek Inspection Findings", dated January 26, 2007
7. EPRI report 2007-003, Attachment 1, "Implications of Wolf Creek Pressurizer Butt Weld Indications Relative to Safety Assessment and Inspection Requirements", January 2007 (ADAMS ML070240159)
8. Letter from Christine King, MRP, "PWR Fleet Survey – MRP-139 Implementation Plans for Pressurizers – Revision 1", dated December 18, 2007 (ADAMS ML063560374)
9. Email transmittal from C.G. Hammer to ACRS members regarding Duane Arnold pipe flaws, dated February 27, 2007.

Note: Additional details of this meeting can be obtained from a transcript of this meeting available for downloading or viewing on the Internet at <http://www.nrc.gov/reading-rm/doc-collections/acrs/tr/subcommittee/2006/> or purchase from Neal R. Gross and Co., Inc., (Court Reporters and Transcribers) 1323 Rhode Island Avenue, NW, Washington, DC 20005 (202) 234-4433.