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

February 1, 2008

MEMORANDUM TO: Sanjoy Banerjee, Chairman
Subcommittee on Thermal-Hydraulic Phenomena

FROM: Harold VanderMolen, Senior Staff Engineer, ACRS **/RA/**

SUBJECT: THE MINUTES OF THE MEETING OF THE JOINT SUBCOMMITTEES ON THERMAL-HYDRAULIC PHENOMENA AND RELIABILITY AND RISK ASSESSMENT REGARDING RESULTS OF THE CABLE RESPONSE TO LIVE FIRE (CAROLFIRE) TESTING AND FIRE MODEL IMPROVEMENT PROGRAM ON JANUARY 18, 2008 IN ROCKVILLE, MARYLAND

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

Attachments: Certification Letter
Minutes

cc w Attachments: ACRS Members

cc w/o Attachments: F. Gillespie
C. Santos
S. Duraiswami
A. Dias
J. Delgado

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MEMORANDUM TO: Harold VanderMolen, Senior Staff Engineer, ACRS

FROM: Sanjoy Banerjee, Chairman
Subcommittee on Thermal-Hydraulic Phenomena

SUBJECT: CERTIFICATION OF THE MINUTES OF THE MEETING OF THE JOINT SUBCOMMITTEES ON THERMAL-HYDRAULIC PHENOMENA AND RELIABILITY AND RISK ASSESSMENT REGARDING RESULTS OF THE CABLE RESPONSE TO LIVE FIRE (CAROLFIRE) TESTING AND FIRE MODEL IMPROVEMENT PROGRAM ON JANUARY 18, 2008 IN ROCKVILLE, MARYLAND

I hereby certify, to the best of my knowledge and belief, that the minutes of the subject meeting on January 18, 2008, are an accurate record of the proceedings for that meeting.

/RA/
Sanjoy Banerjee
Chairman, Subcommittee on
Thermal-Hydraulic Phenomena

8/8/08
Date

Certified by: Sanjoy Banerjee Issued: 8/8/2008
Certified: 8/8/08

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
MEETING OF THE JOINT SUBCOMMITTEES ON THERMAL-HYDRAULIC PHENOMENA
AND ON RELIABILITY AND PROBABILISTIC RISK ASSESSMENT
MEETING MINUTES – JANUARY 18, 2008
ROCKVILLE, MARYLAND

INTRODUCTION

The ACRS Joint Subcommittees on Thermal-Hydraulic Phenomena and on Reliability and Probabilistic Risk Assessment held a meeting on January 18, 2008, in Room T-2 B1, 11545 Rockville Pike, Rockville, MD. The purpose of this meeting was to discuss results of the Cable Response to Live Fire (CAROLFIRE) testing and fire model improvement program. Dr. Hossein Nourbakhsh was the Designated Federal Official for this meeting. There were no written comments or requests for time to make oral statements. The meeting was convened by the Subcommittee Chairman at 8:33 a.m. on January 18, 2008 and adjourned at 4:21 p.m.

ATTENDEES

ACRS Members

S. Banerjee, Chairman
S. Abdel-Khalik, Member
D. Bley, Member
W. Shack, Member
J. Sieber, Member

ACRS Staff

H. Nourbakhsh, Designated Federal Official
H. VanderMolen

Principal Speakers

M. Salley, RES
K. McGratten, NIST
S. Nowlen, SNL

NRC Staff

D. Dube, NRO/DSRA
D. Frumkin, NRR/DRA/AFPB
R. Gallucci, NRR/DRA/FRB
F. Gonzalez, RES/DRA/FRB
A. Klein, NRR/DRA/AFPB
D. Stroup, RES/DRA/FRB
G. Taylor, RES/DRA/FRB
R. Vettori, NRR/DRA/AFPB
R. Woods, RES/DRA/FRB

Public/Other

J. Rosenthal, Talisman Internation12l

A complete list of attendees is in the ACRS Office File and will be made 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 BANERJEE

Sanjoy Banerjee, Chairman of the ACRS Subcommittee on Thermal-Hydraulic Phenomena convened the meeting at 8:33 a.m. Chairman Banerjee stated that the purpose of this meeting was to discuss results of the Cable Response to Live Fire (CAROLFIRE) testing and fire model improvement program. He further stated that the Subcommittee would gather information, analyze relevant issues and facts, and formulate proposed positions and actions, as appropriate, for deliberation by the full Committee. Chairman Banerjee acknowledged that no written comments or requests for time to make oral statements had been received.

DISCUSSION OF AGENDA ITEMS

CAROLFIRE and Fire Model PIRT Overview

Mr. Mark Salley of RES then presented an overview of the CAROLFIRE and Fire Model PIRT project.

The first topic, CAROLFIRE, was performed in response to an NRR user need request. RES would like a letter of endorsement from the Committee for publishing the three volumes of the CAROLFIRE report.

Regarding the second topic, the Fire Model PIRT project, the Committee had previously expressed a desire to be kept informed of progress on this project. Although expert elicitations have been done before, this is the first time a formal PIRT (Phenomena Identification and Ranking Table) elicitation has been performed for fire modeling.

Mr. Alex Klein of NRR then went on to provide some further background information from the perspective of the Office of Nuclear Reactor Regulation. The Regulatory Information Summary (RIS) for fire had divided the inspection guidelines into three bins:

- Bin 1 contained circuit configurations most likely to fail and that must be inspected regularly
- Bin 2 contained circuit configurations where more research was needed
- Bin 3 contained circuit configurations that were unlikely or least likely to fail.

The user need request was intended to resolve the items contained in Bin 2.

Completion of CAROLFIRE Project

Mr. Steven Nowlen of Sandia National Laboratories then gave a presentation on the completion of the CAROLFIRE project. The primary objective of this project, which is largely complete, was to provide resolution of the various Bin 2 circuit configurations. In contrast, the fire modeling project (described later) was intended to reduce the uncertainty in the prediction of fire-induced cable damage.

Cables can be divided into two classes, those with thermoset insulation, which may char or burn to ash in a fire, and those with thermoplastic insulation, which melts when subjected to the heat of a fire. The Bin 2 items in the RIS are as follows:

Item A - Intercable shorting for thermoset cables. NEI/EPRI did not find any interaction within thermoset cables.

Item B - Intercable shorting between thermoplastic and thermoset cables. NEI/EPRI never tested such a mixed configuration. Such cables are unlikely to interact, but before the CAROLFIRE project, there was no data on a mixed configuration.

Item C - Spurious actuation associated with failures impacting three or more cables.

Item D - Multiple spurious operations in control circuits supplied by control power transformers ("CPTs"). CPTs are used to supply control system voltage from the power circuit, which is generally a much higher voltage. If a control circuit is supplied by a CPT, a hot short in the control circuit might not cause spurious actuation of other equipment because the hot short would overload the CPT, thereby degrading its output voltage.

Item E - Hot shorts lasting more than 20 minutes. (NEI/EPRI only observed a maximum of 11 minutes.)

Item F - Cold shutdown circuits. This was not included in the scope of the CAROLFIRE project, and was therefore not investigated. Fire PRAs usually consider the achievement of hot shutdown to be a "success."

Mr. Nowlen went on to discuss the fire modeling improvement program. This program was intended to improve the modeling of cable thermal response and of resulting electrical failure, and to reduce the associated uncertainties. The modeling was performed by the National Institute of Standards and Technology (NIST) and by the University of Maryland. Experimental testing of the modeling was performed by Sandia National Laboratories.

The testing was done in two facilities. The smaller facility, called "Penlight," used small-scale radiant heating to perform a larger set of tests fairly rapidly, and at fairly low expense. The larger facility was an intermediate-scale facility which permitted an "open burn."

A spectrum of cable types were tested, ranging from cables commonly used in nuclear applications to cables intended for general industrial applications. However, armored cables were not tested. Duke Power was independently testing armored cables during the same time period and using similar methods.

The Penlight facility did allow for cable burning, which was common during the testing. One observation was that, once an electrical failure occurred in a cable, the resulting spark often ignited the cable.

In the intermediate-scale test facility, which was about the size of a room fire test facility, a propene (not propane) burner was used to create a turbulent, smoky fire which then heated several cable samples located above the fire in the test facility. Cables could be located in trays, in conduits, or hang in a free span ("air drops") for testing.

Typically, two samples of a given cable configuration would be tested simultaneously, one sample instrumented with thermocouples and one not instrumented, so that interactions between the thermocouples and the electrical behavior could be properly accounted for.

Thermocouples were also embedded within cable bundles, on the surfaces of cable trays and conduits, etc. The cables themselves could be used as slug calorimeters to allow the calculation of fire-to-cable heat transfer. The cable electrical response was measured both for insulation resistance and using circuit simulators.

The results were as follows:

Item A – thermoset to thermoset

Inter-cable shorting did occur. Such shorting appears to be fairly improbable as long as the cable remains dry, but such a shorting event is plausible.

Item B – thermoset to thermoplastic

- The thermoplastic cable failed after about 10 minutes.
- When the thermoset cable failed, it generated voltage in the already-failed thermoplastic cable.

Item C – Concurrent for three or more cables

- Every test program, including CAROLFIRE, has seen as many as four out of four cables cause spurious actuation of the associated simulated control circuits.
- However, timing and duration varied considerably. More investigation appears to be warranted.

Item D – Concurrent spurious actuation given properly sized CPT

- CAROLFIRE could <u>not</u> confirm the NEI/EPRI results. There were no cases where voltage collapse prevented spurious actuation
- The issue is, what is meant by “properly sized” CPTs? These transformers appear to have considerable capacity in excess of their specifications.

Item E – Hot shorts lasting more than 20 minutes

- CAROLFIRE did not see any hot shorts lasting more than 7.6 minutes. NEI/EPRI saw up to 11.3 minutes.
- Once cable degradation begins, it will cascade through all modes relatively quickly. The thermoset cables lasted longest.
- 20 minutes appears to be a reasonable upper bound.

Mr. Nowlen then described the public comment process on the CAROLFIRE project.

- There were two sources of comments: Industry comments (submitted via NEI) and ACRS comments.
- NRC staff comments were also addressed, after inclusion of the public/ACRS comments.
- The substantive comments (as opposed to editorial comments) suggested an expanded data analysis, and clarification of how the results would be used. (The latter is beyond the scope of what a contractor can say in a NUREG/CR report.)

- The ACRS comments called for more information on cable physical characteristics. Unfortunately, these are generally not available from the cable manufacturers. (Material formulations are proprietary.)
- A table of Penlight test results was added in response to the comments.
- A number of clarifications and explanations were also added.

CAROLFIRE Fire Model Improvement Project

Mr. Kevin McGratten of the National Institutes of Science and Technology then gave a presentation on the improvements to the CAROLFIRE fire model.

Mr. McGratten described the current methodology for cable failure, as described in NUREG-1805. The limitations are that it does not account for

- Bulk cable properties (e.g., size)
- Time-dependent exposure
- Conduits, armor jacket, etc.

He went on to trace the development of fire models from hand calculations to two-zone models and finally to CFD models.

Most models are based on a fire of a known size and location, and calculate the impact of heat and smoke on a target. However, uncertainty is very high. The more sophisticated models did better. It is now possible to get a reasonable estimate of bulk temperature in the vicinity of the cable (target), but the models do not do as well with smoke concentration.

Once the environmental parameters in the vicinity of the cable have been estimated by a fire model, the temperatures in the area are used in the Thermally-Induced Electrical Failure ("THIEF") model. The THIEF model is a one-dimensional conduction model of a homogeneous cylinder.

The fire model provides the convective and radiative heat flux at the cable surface. The THIEF model just calculates the internal temperatures. It does not model ignition or electrical failure.

The Members had some questions regarding the level of modeling of a cable's ignition and combustion, which would affect the progress of the event. However, the emphasis of the THIEF model is on estimating the response of the cable up to the point of failure, not on response after the failure.

The THIEF model was then compared to data from the Penlight experiments, which showed reasonable agreement. However, the Penlight arrangement is a somewhat idealized situation with a uniform heat flux, etc., and thus is closer to the assumptions of the model than it is to a realistic fire scenario. Therefore, the THIEF model was also used to model cable bundles, armored cables, etc. in the intermediate scale facility. For this more realistic situation, and without giving credit for the effect of the surrounding cables within a bundle, the agreement was not as good as in the Penlight experiments, but tended to give a conservative estimate.

There was some discussion of the simplicity of the one-dimensional model. One member suggested trying a two-dimensional model (in effect, an $r - \theta$ model of the cable's cross

section) to see if it would give a different result. Mr. McGratten replied that the University of Maryland had tried modeling the conductors, fillers, etc. in this way, but this more detailed modeling had made very little difference in the results. The Chairman then suggested addressing this by giving more rationale for the one-dimensional model in the report.

Mr. Salley then asked for any further feedback or suggestions to be provided soon, so that Volume 3 of the report could be modified prior to the February full committee meeting.

Overview/Status of Fire Model Improvement Project

Mr. Salley gave a short introduction. Normally, a Phenomena Identification and Ranking Table ("PIRT") is performed when there is little or no real data available. However, it was decided to perform a PIRT to direct the available resources to the areas most in need of more work.

Mr. Steven Nowlen of Sandia National Laboratories then gave an overview and status report on the Fire Model PIRT project. The objective was to provide a complement to the RIS's ongoing verification and validation efforts, and to provide input to RES to identify areas of focus for further fire model improvement.

The meetings have been completed. Mr. Nowlen discussed the background of the various PIRT panel members.

The fire scenarios presented to the PIRT panel included:

- An electrical cabinet fire in a main control room.
- A cabinet fire in a switchgear room
- A turbine building oil fire
- A fire in a vertical cable tray in the containment annulus.

The preliminary results for these four scenarios are tabulated in the meeting handouts. A draft report is under review by the staff and will be submitted to the panel for review.

Discussion

Chairman Banerjee then opened the meeting for general discussion. The overall discussion was concerned primarily with the upcoming full committee meeting. Some highlights:

Member Sieber: The project met its objectives. The key result appears to be a better handle on the failure timing.

Member Bley: Again, good work. He would like more explanation in the reports on why many data points are not near the curves. (Chairman Banerjee asked him to help write the letter.) Also, an explanation of the differences between the EPRI tests and these results would be helpful.

Member Shack: This was interesting work and provided a lot of useful data. He would like more descriptive material on how the cable bundling and the conduit were modeled.

Member Abdel-Khalik: These results are useful, and will be useful for a long time to come. He would have liked to see an estimate of the uncertainty in the experimental data. Also, a list of the underlying assumptions in the models should be provided in the report.

Chairman Banerjee: Material describing the experimental uncertainty should be included in the report. Points that are outliers should have explanations, if possible.

Reply from Mr. Salley: At the full committee meeting, the staff will do a quick review of Volume 1 and 2 and the RIS, but leave more time for Volume 3. The staff will not discuss PIRT at the full committee.

SUBCOMMITTEE DECISIONS AND ACTIONS

The members agreed to report to the full Committee at the February meeting.

BACKGROUND MATERIALS PROVIDED TO THE SUBCOMMITTEE PRIOR TO THIS MEETING

1. Subcommittee status report, including agenda

2. U.S. NRC, "Cable Response to Live Fire (CAROLFIRE) Volume 1: Test Descriptions and Analysis of Circuit Response Data," NUREG/CR-6931, Vol. 1 SAND2007-600/V1, Final Prepublication Draft, December, 2007

3. U.S. NRC, "Cable Response to Live Fire (CAROLFIRE) Volume 2: Cable Fire Response Data for Fire Model Improvement," NUREG/CR-6931, Vol. 2 SAND2007-600/V2, Final Prepublication Draft, December, 2007

4. U.S. NRC, "Cable Response to Live Fire (CAROLFIRE) Volume 2: Modeling," NUREG/CR-6931, Vol. 3, NISTIR 7472, December, 2007

5. A summary of author responses to public comments on Draft NUREG/CR-6931 including the corresponding changes implemented in the report Revision 12/18/2007

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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/ACRSACNW or can be purchased from Neal R. Gross and Co., Inc., (Court Reporters and Transcribers) 1323 Rhode Island Avenue, NW., Washington, DC 20555 (202)234-4433