January 29, 2004

MEMORANDUM TO: ACRS Members

FROM: Michael Snodderly, Senior ACRS Staff Engineer,

SUBJECT: CERTIFICATION OF THE MINUTES OF THE MEETING OF THE ACRS SUBCOMMITTEE ON REGULATORY POLICIES AND PRACTICES, NOVEMBER 21, 2003 - ROCKVILLE, MARYLAND

The minutes of the subject meeting, issued December 23, 2003, have been certified as the official record of the proceedings of that meeting. A copy of the certified minutes is attached.

Attachment: As stated

electronic cc: J. Larkins
S. Bahadur
H. Larson
S. Duraiswamy

MEMORANDUM TO: M. R. Snodderly, Senior ACRS Staff Engineer

FROM: W. J. Shack, Chairman
Regulatory Policies and Practices Subcommittee

SUBJECT: CERTIFICATION OF THE MINUTES OF THE MEETING OF THE ACRS SUBCOMMITTEE ON REGULATORY POLICIES AND PRACTICES, NOVEMBER 21, 2003 - ROCKVILLE, MARYLAND

I do hereby certify that, to the best of my knowledge and belief, the minutes of the subject meeting on November 21, 2003, are an accurate record of the proceedings for that meeting.

William J. Shack,
Subcommittee Chairman

1/26/04
Date

PRE-DECISIONAL

December 23, 2003

MEMORANDUM TO: W. J. Shack, Chairman
Regulatory Policies and Practices Subcommittee

FROM: M. R. Snodderly, Senior ACRS Staff Engineer

SUBJECT: WORKING COPY OF THE MINUTES OF THE MEETING OF THE ACRS SUBCOMMITTEE ON REGULATORY POLICIES AND PRACTICES, NOVEMBER 21, 2003 - 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: Regulatory Policies and Practices Subcommittee Members
P. Ford
J. Sieber
G. Wallis
S. Bahadur
S. Duraiswamy
J. Larkins
H. Larson

CERTIFIED BY: W. Shack

Issued:12/23/03
Certified: 01/26/04

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
MEETING OF THE ACRS SUBCOMMITTEE ON
REGULATORY POLICES AND PRACTICES
MEETING MINUTES - NOVEMBER 21, 2003
ROCKVILLE, MARYLAND

INTRODUCTION

The ACRS Subcommittee on Regulatory Policies and Practices held a meeting on November 21, 2003, in Room T-2B3, 11545 Rockville Pike, Rockville, MD. The purpose of this meeting was to discuss the "LOCA failure analysis and frequency estimation" developed by the staff in response to the Commission's March 31, 2003, Staff Requirements Memorandum on recommendations for risk-informed changes to 10 CFR 50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors." The meeting was open to public attendance. Mike Snodderly was the Designated Federal Official for this meeting. There were no written comments or requests for time to make oral statements received from members of the public. The meeting was convened by the Subcommittee Chairman at 8:30 a.m. and adjourned at 3:03 p.m. on November 21, 2003.

ATTENDEES

ACRS Members

W. Shack, Subcommittee Chairman
P. Ford, Member
T. Kress, Member
G. Leitch, Member
V. Ransom, Member
J. Sieber, Member
G. Wallis, Member
M. Snodderly, Designated Federal Official

Principal NRC Speakers

L. Abramson, RES
E. McKenna, NRR
R. Tregoning, RES

Other Principal Speakers

D. Harris, Engineering Mechanics Technology, Inc.

There was approximately one other member of the public in attendance at this meeting. 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 SHACK

William Shack, Chairman of the ACRS Subcommittee on Regulatory Policies and Practices convened the meeting at 8:30 a.m. Dr. Shack stated that the purpose of this meeting was to discuss the LOCA failure analysis and frequency estimation being developed by the staff in response to the Commission's March 21st, 2003 Staff Requirements Memorandum on recommendations for risk-informed changes to 10 CFR 50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors," with representatives of the Office of Nuclear Regulatory Research (RES) and the Office of Nuclear Reactor Regulation (NRR). He said the Subcommittee will 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 November 10, 2003.

DISCUSSION OF AGENDA ITEMS

Overview of Expert Elicitation in Support of Risk-Informing 10 CFR 50.46

Robert Tregoning, RES, began by reminding the Subcommittee that they were provided an overview of the expert elicitaion being conducted in support of risk-informing 10 CFR 50.46 at the July 2002 Full Committee meeting. As a result of the July 2002 meeting, it was decided to have this Subcommittee meeting to probe the details of the expert elicitation. Mr. Tregoning said the objective of the expert elicitation was to develop piping and non-piping passive system LOCA frequencies as a function of flow rate and operating time up to the end of the license extension period. The expert panel will estimate LOCA frequency distributions for generic plants and conditional LOCA probability distributions for rare, emergency faulted load conditions. Mr. Tregoning said that the elicitation of the twelve experts had been recently completely.

General Comments and Observations From the Subcommittee Members

- Dr. Shack asked if probabilistic fracture mechanics (PFM) analyses with PRAISE and PRODIGAL had been completed yet. Mr. Tregoning said they had been and that a detailed comparison would be provided. He characterized the PRAISE work as more refined and the PRODIGAL work as more preliminary. Mr. Tregoning said that the expert panel meeting in June 2002 identified additional sensitivity cases they wanted to conduct.

- Dr. Ford asked why the BWR base case used 304 stainless steel piping operating under normal water conditions when very few plants currently operate under those conditions. Mr. Tregoning responded that it was chosen for the base case because they had the most data for this case. He emphasized that the base case is used to estimate relative frequencies.

- Dr. Wallis asked how evolving degradation mechanisms are accounted for. Mr. Tregoning said a rule of thumb is a new mechanism every seven years based on operating experience. Dr. Shack commented that when you reduce the oxygen in your feedwater to protect your steam generator from denting, you made your flow assisted corrosion problem worse. He cautioned that this type of unintended effect should be considered in the future.

Description of Elicitation Process Used

Lee Abramson, RES, then described how the expert elicitation process was carried out. He said that quantitative assessments by the individual expert panel members were delayed until after group training on expert elicitation and panel discussions to establish a common understanding of objectives. Dr. Abramson discussed development of the base cases and how all quantities will be judged relative to the base cases. He described how during the individual elicitations the experts will be asked to provide three point estimates. The first point estimate is the median. Then to get the uncertainty, they asked for the lower 5^{th} percentile and the upper 95^{th} percentile.

Dr. Abramson then broke down the expert elicitation being conducted into 11 elements and he described each element in detail. The 11 major elements included the following:

- Selection of expert panel,
- Technical background development,
- Formulation of issues,
- Panel discussions,
- Elicitation training,
- Elicitation questionnaire,
- Two pilot elicitation sessions,
- Twelve individual elicitation sessions,
- Recomposition and aggregation,
- Wrap-up meeting, and
- Documentation.

Dr. Abramson discussed sources of bias for this type of exercise. He than summarized the training he had given the panel members. He walked the Subcommittee through the same analogous exercise he had given the panel. The exercise asked, according to the 2000 census, how many men 65 or over were there in the United States. He then asked how many men age 65 or older suffered from specific disorders. Dr. Abramson then had asked the panel for ratios relative to a known value, such as the ratio of the rate for men 45-65 years old to the rate for men 65 and older for each of the conditions listed. He said the exercise served several purposes. First, Dr. Abramson wanted to give the panel members some experience with the process. Second, he wanted to show the participants that collectively they could successfully estimate the 5^{th} percentile and 95^{th} percentile values for a topic they only had cursory knowledge of. Third, he wanted to demonstrate that the group was better at estimating ratios to a known value or base case as opposed to absolute values. Dr. Abramson cleverly chose an example, death rate due to chronic conditions as a function of age, that was analogous to the problem at hand, LOCA failure frequency due to degradation mechanisms that are a function of aging. Dr. Abramson ended by saying that they planned to have a wrap-up meeting in February 2004.

General Comments and Observations From the Subcommittee Members

- Dr. Shack asked if PFM analyses with PRAISE and PRODIGAL had been completed yet. Mr. Tregoning said they had been and that a detailed comparison would be provided. He characterized the PRAISE work as more refined and the PRODIGAL work as more preliminary. Mr. Tregoning said that the expert panel meeting in June 2002 identified additional sensitivity cases they wanted to conduct.

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- Dr. Wallis asked evolving degradation mechanisms are accounted for. Mr. Tregoning said a rule of thumb is a new mechanism every seven years based on operating experience. Dr. Shack commented that when you reduce the oxygen in your feedwater to protect your steam generator from denting, you made your flow assisted corrosion problem worse. He cautioned that this type of effect should be considered in the future.

- Mr. Sieber commented that the extent to which you control the information provided determines to some extent whether they are the experts or you are the expert. Mr. Sieber asked how much influence the information provided by the staff had on the individual elicitations. Mr. Tregoning said that the staff set up a website for the expert panel to assist them in the exercise. He said they only put information on the site that the panel members requested.

- Mr. Leitch asked if sabotage was considered as a LOCA contributor. Mr. Tregoning said it had been explicitly not included in the scope of this exercise and that it was to be addressed separately as a safeguards and security issue. Mr. Leitch felt that sabotage may well be the dominant contributor to LBLOCA frequency. Mr. Tregoning responded that the conditional LOCA failure probabilities being developed given a certain stress magnitude could be used to help evaluate the sabotage issue.

Base Case Descriptions

Mr. Tregoning said that a previous expert elicitation, using NRC staff, had already been conducted. The internal elicitation was conducted to assess the feasibility of developing the LOCA frequency distributions and to identify areas of technical expertise needed to conduct the more formal elicitation. The results of the internal elicitation were not shared with the expert panel for fear of forming a preconceived notion.

Mr. Tregoning than gave an overview of the quantification of the base case frequencies. Four panel members were tasked with developing estimates for well defined piping conditions. Two estimates were made using PFM analysis and two estimates were made using operating experience analysis. The base case conditions specify the piping system, piping size, material, loading, degradation mechanism, and mitigation procedures. The LOCA frequency for each base case condition is calculated as a function of flow rate and operating time.

General Comments and Observations From the Subcommittee Members

- Dr. Shack asked if the operating experience analysis was an empirical D^n type scaling analysis to extrapolate from small diameter piping where data are more available to large diameter piping. Mr. Tregoning replied that first you look for precursor events and then you make assumptions for how the precursor events translate into a probability of the LOCA.

- Dr. Ford noted that coolant conductivity in BWRs has changed by an order of magnitude over the years and he asked if this was considered in the base case analyses. Dr. Harris said it was a variable input to PRAISE and they used a representative value.

An Example of a Base Case Calculation and Results

Dr. Harris said that he estimated the base case LOCA frequencies using the PRAISE computer model. He accounted for the expected dominant degradation mechanism for each of the analyzed systems. He considered intergranular stress corrosion cracking for the BWR cases and, in some PWR cases, primary water stress corrosion cracking. He did not consider corrosion assisted fatigue because PRAISE does not have a probabilistic model for corrosion assisted fatigue. Dr. Harris said the expert panel would have to factor this in to their later estimates of what the influence of corrosion assisted fatigue would be in a feedwater nozzle. Dr. Harris cautioned that he did not believe some of the PRAISE results and they needed to be adjusted to take into account some realistic assumptions.

Mr. Tregoning said that the biggest area of uncertainty for these analyses was the load history. Dr. Harris said that many of the sensitivity analyses were based on feed back from the expert panel. For example, an expert panel member would say the stresses are too high and the transient is occurring too often and would suggest a different stress history. Dr. Harris felt that initial crack depth distribution is probably the most important single variable, and the distribution used is based on results from PRODIGAL runs performed by Vic Chapman for Pacific Northwest National Laboratory (Monte Carlo simulation of weld defects in multi-pass welds).

Dr. Harris then explained that the base case calculations were performed for the most likely failure location within a system and then extended by the number of locations with a similar dominant LOCA frequency. Base case calculations were performed as a function of leak rate (probability of a through-wall crack of length exceeding that required for a given leak rate). Leak rates were calculated using SQUIRT (developed by Battelle with NRC support). Credit was taken for being able to immediately detect a leak greater than 5 gpm.

Mr. Tregoning then gave an example of how the base cases are to be used in conjunction with the elicitation questions. He choose the elicitation question on safety culture for his example. The question asked the expert panel member to consider the current utility safety culture that exists after approximately 25 years of plant operation and how it influences Category 1 LOCAs. Mr. Tregoning explained that the experts were then asked to express the relative change, or ratio, in the utility safety culture's effect on LOCA frequencies after 15 additional years compared to its current day effect. Next, they were asked to express the ratio of the utility safety culture's effect on LOCA frequencies ratio in 35 years to its current day effect.

Ms. McKenna, NRR, discussed upcoming interactions with the Commission on the proposed rulemaking to 10 CFR 50.46. She said that the staff plans to forward some type of communication to the Commission. Whether it's a memo or paper has not been decided. The communication will point out some of the issues that have been identified as having a major impact on any proposed rulemaking involving 10 CFR 50.46. The staff also plans to make a proposal to the Commission as to how they are going to proceed to resolve those issues. She reminded the Subcommittee that these issues were included in the background information the staff provided.

<u>General comments and observations from the Subcommittee members</u>

- Dr. Ford asked why another corrosion assisted fatigue model, such as the EPRI model was not used. Dr. Harris responded because it was not probabilistic. Dr. Ford suggested putting in a distribution of inputs. Dr. Harris countered that this was theoretically possible but it had not been done yet. Mr. Tregoning added that Westinghouse's SARA code had a corrosion assiste fatigue model and there is a representative from Westinghouse on the expert panel. Mr. Tregoning said that a corrosion assisted fatigue model will be a prominent sub-module when they develop their probabilistic LOCA code. Dr. Shack added that corrosion assisted fatigue cracking is only dominant for feedwater systems.

- Dr. Kress asked if seismic events are treated the same as operating transients. Dr. Harris replied they are treated as another stress cycle just as fatigue. He went to say that PRAISE stands for Piping Reliability Analysis Including Seismic Events. PRAISE was originally developed to look at the effect of seismic events on the failure probabilities. They looked at the normal operating conditions and the day-to-day expected transients and then superimposed them on a seismic event.

- Dr. Shack asked what was the crack size distribution for initiated cracks. Dr. Harris said they used a depth of 0.3 inches which is the number that Argonne National Laboratory used in their correlation.

- Dr. Shack asked whether the residual stresses in the initiation model for stress corrosion cracking needed to be adjusted. Dr. Harris replied that had to be adjusted down by approximately a factor of five in order for the model to agree with the service data.

- Dr. Shack recalled that in the 1980s because they couldn't do stratified sampling for stress corrosion cracks, it was difficult to compute probabilities because computers weren't fast enough to do the computations directly. Dr. Shack asked if this was still a problem. Dr. Harris said computer time's still a problem and he could probably do some Latin Hypercube sampling or stratified sampling and generate some numbers but that wasn't part of this task. He did come up with an ad hoc model to generate some results when he started to see some really small numbers.

- Dr. Ford asked for copies of NUREG/CR-4792, Volume 3, NUREG/CR-2189, Volume 5, and NUREG/CR-6674.

- Dr. Shack asked if what they really wanted was a hazard rate or are the cumulative probabilities so low that it doesn't make a difference. Dr. Harris replied that it really was a hazard rate, but the probabilities were so low that it made little difference.

- Dr. Shack asked why there wasn't a leak frequency for the hot leg. Dr. Harris said it was because he selected PWSCC as his base case, and always assumed a crack initiated. The predicted leak frequency was thus really off and the results were not realistic. Dr. Harris noted that the leaks would be small in virtually all cases.

- Mr. Leitch asked if the results from experts A and D were still pending. Mr. Tregoning said that Expert D's models weren't rigorous enough and Expert A had a less precise database. Mr. Tregoning said that the panel agreed that Experts B and C's results were the best to use for the base cases. Dr. Wallis added that he found this disturbing because it defeated the purpose of having independent confirmatory analyses.

- Dr. Wallis questioned the results on Slide 25. He didn't understand how the failure frequency for 100 gpm leak and a 500,000 gpm leak could be the same. Mr. Tregoning replied that Dr. Wallis may be right. Mr. Tregoning committed to checking the plots. He said that he may have plotted ranges instead of thresholds.

- Mr. Sieber asked if they were any utility representatives on the expert panel to answer the elicitation question on safety culture. Mr. Tregoning said there were not. He said they had representatives from Exelon, GE and Westinghouse. He said they have not decided how the safety culture results will be factored into the final results but while none of the experts are an expert in safety culture, they have been around the industry long enough to have perceptions as to are we safer now culturally than we were, is the safety climate improving or degrading in the future. This is the type of information the staff was trying to capture. Mr. Sieber said that he felt safety culture did have an impact on LOCA frequency and that he had a hard time with non-utility people making this judgement. Mr. Tregoning argued that the expert panel members had enough experience working with numerous utilities to make the judgement and in fact could judge it more objectively. Mr. Tregoning summarized the results on safety culture as fairly static for the median and the variability is between the best plants and the worse plants.

- Dr. Shack asked how do you determine the total LOCA contribution without going through the branch that has you compare with the base case. Mr. Tregoning replied that they ask the experts to list the significant failure mechanisms. Significant is defined as those that would contribute at least 80 percent to the LOCA frequency. Mr. Tregoning said this was used as a normalizing factor. It's the difference between normalizing by .8 or 1.

STAFF AND INDUSTRY COMMITMENTS

Mr. Tregoning committed to checking the Failure Frequency vs. LOCA Category plots given on Slide 25 and resubmitting it to the Committee. Dr. Shack and Mr. Tregoning agreed that there will be a subsequent Subcommittee was the results were analyzed and documented. The Full Committee would then review and comment upon the NUREG documenting the LOCA frequencies developed by the expert elicitation.

SUBCOMMITTEE DECISIONS AND ACTIONS

Mr. Leitch has difficulty relaxing 10 CFR 50.46 break size criteria if sabotage is not addressed as a contributor. He felt that sabotage may well be the dominant contributor to LBLOCA frequency. Dr. Shack proposed to give a summary of this Subcommittee meeting at the December Full Committee meeting. It was agreed that the Subcommittee would recommend that the Full Committee review and comment upon the staff's response to the Commission's March 31, 2003 SRM during either its February or March meetings.

BACKGROUND MATERIALS PROVIDED TO THE SUBCOMMITTEE PRIOR TO THIS MEETING

1. Subcommittee status report, including agenda.

2. Staff Requirements Memorandum dated March 31, 2003, from Annette L. Vietti-Cook, Secretary, to William D. Travers, EDO, Subject: Staff Requirements - SECY-02-057 - Update to SECY-01-0133, "Fourth Status Report on Study of Risk-Informed Changes to the Technical Requirements of 10 CFR Part 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 CFR 50.46 (ECCS Acceptance Criteria)".

3. Slide Presentation dated July 10, 2003, by Robert Tregoning, RES, to ACRS, Subject: Expert Elicitation in Support of Risk-Informing 10 CFR 50.46.

4. Memorandum dated November 7, 2003, from Catherine Haney, NRR, to John Larkins, Executive Director, ACRS, Subject: Subcommittee Meeting on Large Break Loss-of-Coolant Accident Redefinition (Pre-Decisional For Internal ACRS Use Only).

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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 20005 (202) 234-4433.

10:45 a.m.–11:30 a.m.: EPRI Workshop on Natural Analogues (Open)—The Committee will hear presentations by and hold discussions with representatives of the Electric Power Research Institute (EPRI) regarding its recent workshop on natural analogues and their potential applicability to Yucca Mountain repository programs.

12:45 p.m.–2 p.m.: Presentation by Affected Units of Local Government (Open)—The Committee will hear presentations by and hold discussions with representatives of affected units of local government and Native American Organizations regarding their views on the proposed high-level waste repository at Yucca Mountain.

2:15 p.m.–3 p.m.: Stakeholder Interactions (Open)—The Committee will reserve this time for interactions with stakeholders and meeting participants.

3 p.m.–5:45 p.m.: Preparation of ACNW Reports (Open)—The Committee will discuss possible reports on the Pre-Closure Safety Assessment Tool, Drift Degradation at Yucca Mountain, and Public Interactions.

5:45 p.m.–6 p.m.: Miscellaneous (Open)—The Committee will discuss matters related to the conduct of Committee activities and matters and specific issues that were not completed during previous meetings, as time and availability of information permit.

Procedures for the conduct of and participation in ACNW meetings were published in the **Federal Register** on October 16, 2003 (68 FR 59643). In accordance with these procedures, oral or written statements may be presented by members of the public. Electronic recordings will be permitted only during those portions of the meeting that are open to the public. Persons desiring to make oral statements should notify Mr. Howard J. Larson, Special Assistant (Telephone 301/415–6805), between 7:30 a.m. and 4 p.m. ET, as far in advance as practicable so that appropriate arrangements can be made to schedule the necessary time during the meeting for such statements. Use of still, motion picture, and television cameras during this meeting will be limited to selected portions of the meeting as determined by the ACNW Chairman. Information regarding the time to be set aside for taking pictures may be obtained by contacting the ACNW office prior to the meeting. In view of the possibility that the schedule for ACNW meetings may be adjusted by the Chairman as necessary to facilitate the conduct of the meeting, persons planning to attend should notify Mr. Howard J. Larson as to their particular needs.

Further information regarding topics to be discussed, whether the meeting has been canceled or rescheduled, the Chairman's ruling on requests for the opportunity to present oral statements and the time allotted therefore can be obtained by contacting Mr. Howard J. Larson.

ACNW meeting agenda, meeting transcripts, and letter reports are available through the NRC Public Document Room at *pdr@nrc.gov*, or by calling the PDR at 1–800–397–4209, or from the Publicly Available Records System (PARS) component of NRC's document system (ADAMS) which is accessible from the NRC Web site at *http://www.nrc.gov/reading-rm/adams.html* or *http://www.nrc.gov/reading-rm/doc-collections/* (ACRS & ACNW Mtg schedules/agendas).

Videoteleconferencing service is available for observing open sessions of ACNW meetings. Those wishing to use this service for observing ACNW meetings should contact Mr. Theron Brown, ACNW Audiovisual Technician (301/415–8066), between 7:30 a.m. and 3:45 p.m. ET, at least 10 days before the meeting to ensure the availability of this service. Individuals or organizations requesting this service will be responsible for telephone line charges and for providing the equipment and facilities that they use to establish the video teleconferencing link. The availability of video teleconferencing services is not guaranteed.

Dated: November 4, 2003.

Andrew L. Bates,

Advisory Committee Management Officer.

[FR Doc. 03–28180 Filed 11–7–03; 8:45 am]

BILLING CODE 7590–01–P

NUCLEAR REGULATORY COMMISSION

Advisory Committee on Nuclear Waste; Meeting on Planning and Procedures; Notice of Meeting

The ACNW will hold a Planning and Procedures meeting on November 19, 2003, Dallas Ballroom D, at the Texas Station Hotel, 2101 Texas Star Lane, Las Vegas, Nevada.

The entire meeting will be open to public attendance, with the exception of a portion that may be closed pursuant to 5 U.S.C. 552b(c) (2) and (6) to discuss organizational and personnel matters that relate solely to internal personnel rules and practices of ACNW, and information the release of which would constitute a clearly unwarranted invasion of personal privacy.

The agenda for the subject meeting shall be as follows:

Wednesday, November 19, 2003—8:30 a.m.–10:15 a.m.

The Committee will discuss proposed ACNW activities and related matters. The purpose of this meeting is to gather information, analyze relevant issues and facts, and formulate proposed positions and actions, as appropriate, for deliberation by the full Committee.

Members of the public desiring to provide oral statements and/or written comments should notify the Designated Federal Official, Mr. Howard J. Larson (Telephone: 301/415–6805) between 7:30 a.m. and 4:15 p.m. (ET) five days prior to the meeting, if possible, so that appropriate arrangements can be made. Electronic recordings will be permitted only during those portions of the meeting that are open to the public.

Further information regarding this meeting can be obtained by contacting the Designated Federal Official between 7:30 a.m. and 4:15 p.m. (ET). Persons planning to attend this meeting are urged to contact the above named individual at least two working days prior to the meeting to be advised of any potential changes in the agenda.

Dated: November 4, 2003.

Sher Bahadur,

Associate Director for Technical Support, ACRS/ACNW.

[FR Doc. 03–28181 Filed 11–7–03; 8:45 am]

BILLING CODE 7590–01–P

NUCLEAR REGULATORY COMMISSION

Advisory Committee on Reactor Safeguards; Meeting of the ACRS Subcommittee on Regulatory Policies and Practices; Notice of Meeting

The ACRS Subcommittee on Regulatory Policies and Practices will hold a meeting on November 21, 2003, Room T–2B3, 11545 Rockville Pike, Rockville, Maryland.

The entire meeting will be open to public attendance.

The agenda for the subject meeting shall be as follows:

Friday, November 21, 2003—8:30 a.m. until the conclusion of business.

The purpose of this meeting is to discuss the "LOCA failure analysis and frequency estimation" developed by the staff in response to the Commission's March 31, 2003, Staff Requirements Memorandum on recommendations for risk-informed changes to 10 CFR 50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors." The

Subcommittee will hear presentations by and hold discussions with representatives of the NRC staff and other interested persons regarding this matter. The Subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions, as appropriate, for deliberation by the full Committee.

Members of the public desiring to provide oral statements and/or written comments should notify the Designated Federal Official, Mr. Michael R. Snodderly (Telephone: 301–415–6927) five days prior to the meeting, if possible, so that appropriate arrangements can be made. Electronic recordings will be permitted during the meeting.

Further information regarding this meeting can be obtained by contacting the Designated Federal Officials between 7:30 a.m. and 4:15 p.m. (ET). Persons planning to attend this meeting are urged to contact the above named individual at least two working days prior to the meeting to be advised of any potential changes to the agenda.

Dated: November 4, 2003.

Sher Bahadur,

Associate Director for Technical Support, ACRS/ACNW.

[FR Doc. 03–28179 Filed 11–7–03; 8:45 am]

BILLING CODE 7590–01–P

SECURITIES AND EXCHANGE COMMISSION

Proposed Collection; Comment Request

Upon Written Request; Copies Available From: Securities and Exchange Commission, Office of Filings and Information Services, Washington, DC 20549

Extension: Rule 12g3–2, OMB Control No. 3235–0119, SEC File No. 270–104. Rules 7a–15 thru 7a–37, OMB Control No. 3235–0132, SEC File No. 270–115. Rule 13e–1, OMB Control No. 3235–0305, SEC File No. 270–255

Notice is hereby given that, pursuant to the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 *et seq.*) the Securities and Exchange Commission ("Commission") is soliciting comments on the collections of information summarized below. The Commission plans to submit these existing collections of information to the Office of Management and Budget for extension and approval.

Rule 12g3–2 (OMB 3235–0119; SEC File No. 270–104) provides an exemption from Section 12(g) of the Securities Exchange Act of 1934 for foreign private issuers. Rule 12g3–2 is designed to provide investors in foreign securities with information about such securities and the foreign issuer. It estimated that 1,800 foreign issuers make submissions pursuant to Rule 12g3–2 annually and it takes approximately one burden hour per response for a total annual burden of 1,800 hours. It is estimated that 100% of the burden is prepared by the filer.

Rules 7a–15 through 7a–37 (OMB 3235–0132; SEC File No. 270–115) set forth the general requirements relating to applications, statements and reports that must be filed under the Trust Indenture Act of 1939 by issuers and trustees qualifying indentures under that Act for offerings of debt securities. The respondents are persons and entities subject to the Trust Indenture Act requirements. Rules 7a–15 through 7a–37 are disclosure guidelines and do not directly result in any collection of information. The Rules are assigned only one burden hour for administrative convenience.

Rule 13e–1 (OMB 3235–0305; SEC File No. 270–255) makes it unlawful for an issuer who has received notice that it is the subject of a tender offer made under 14(d)(1) of the Act and which has commenced under Rule 14d–2 to purchase any of its equity securities during the tender offer unless it first files a statement with the Commission containing information required by the Rule. This rule is in keeping with the Commission's statutory responsibility to prescribe rules and regulations that are necessary for the protection of investors. Public companies are the respondents. Rule 13e–1 submissions take approximately 10 burden hours to prepare and are filed by 20 respondents. It is estimated that 25% of 200 total burden hours (50 hours) is prepared by the company. The remaining 75% of the total burden is attributed to outside cost.

Written comments are invited on: (a) Whether these proposed collections of information are necessary for the proper performance of the functions of the agency, including whether the information will have practical utility; (b) the accuracy of the agency's estimate of the burden of the collection of information; (c) ways to enhance the quality, utility, and clarity of the information collected; and (d) ways to minimize the burden of the collection of information on respondents, including through the use of automated collection techniques or other forms of information technology. Consideration will be given to comments and suggestions submitted in writing within 60 days of this publication.

Please direct your written comments to Kenneth A. Fogash, Acting Associate Executive Director/CIO, Office of Information Technology, Securities and Exchange Commission, 450 Fifth Street, NW., Washington, DC 20549.

Dated: October 30, 2003.

Jill M. Peterson,

Assistant Secretary.

[FR Doc. 03–28186 Filed 11–7–03; 8:45 am]

BILLING CODE 8010–01–P

SECURITIES AND EXCHANGE COMMISSION

[Release No. 34–48742; File No. SR–CHX–2003–35]

Self-Regulatory Organizations; Notice of Filing and Immediate Effectiveness of Proposed Rule Change by the Chicago Stock Exchange, Inc. Relating to the Trading of Nasdaq/NM Securities

November 3, 2003.

Pursuant to section 19(b)(1) of the Securities Exchange Act of 1934 (the "Act"),[1] and Rule 19b–4 thereunder,[2] notice hereby is given that on October 31, 2003, the Chicago Stock Exchange, Incorporated ("CHX" or "Exchange") filed with the Securities and Exchange Commission ("SEC" or "Commission") the proposed rule change as described in Items I, II and III below, which Items have been prepared by the self-regulatory organization. The Commission is publishing this notice to solicit comments on the proposed rule change from interested persons.

I. Self-Regulatory Organization's Statement of the Terms of Substance of the Proposed Rule Change

The Exchange has requested a one-year extension of the pilot relating to the trading of Nasdaq/NM securities on the Exchange. Specifically, the pilot amended CHX Article XX, Rule 37 and CHX Article XX, Rule 43. The pilot currently is due to expire on November 1, 2003. The Exchange proposes that the pilot remain in effect on a pilot basis through November 1, 2004. The text of the proposed rule change is available at the principal offices of the CHX and at the Commission. This proposed extension of the pilot does not alter the text of the pilot language, but simply extends the expiration date of the pilot through November 1, 2004.

[1] 15 U.S.C. 78s(b)(1).

[2] 17 CFR 240.19b–4.

Mike Snodderly

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
MEETING OF THE SUBCOMMITTEE ON REGULATORY POLICIES AND PRACTICES
ROOM T-2B3, 11545 ROCKVILLE PIKE, ROCKVILLE MD
NOVEMBER 21, 2003

Contact: Michael Snodderly (301-415-6927, mrs1@nrc.gov)

-PROPOSED SCHEDULE-

	TOPICS	PRESENTERS	TIME
I.	**Opening Remarks**	W. Shack, ACRS	8:30-8:35 a.m.
II.	**Overview of Expert Elicitation in Support of Risk-Informing 10 CFR 50.46**	R. Tregoning, RES	8:35-9:20 a.m.
III.	**Description of Elicitation Process Used**	L. Abramson, RES	9:20-10:00 a.m.
	BREAK		**10:00-10:15 a.m.**
IV.	**Base Case Descriptions**	R. Tregoning, RES	10:15-11:00 a.m.
V.	**Base Case Calculation and Results**	D. Harris, Engineering Mechanics Tech, Inc.	11:00-12:00 p.m.
	LUNCH		**12:00-1:00 p.m.**
VI.	**Technical Issues for Redefinition of LBLOCA**	E. McKenna, NRR	1:00-2:45 p.m.
VII.	**General Discussion and Adjournment**	W. Shack, ACRS	2:45-3:00 p.m.

NOTE:
- Presentation time should not exceed 50 percent of the total time allocated for specific item. The remaining 50 percent of the time is reserved for discussion.
- 35 copies of the presentation materials to be provided to the Subcommittee

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBCOMMITTEE MEETING ON REGULATORY POLICIES
AND PRACTICES

NOVEMBER 21, 2003
Date

NRC STAFF SIGN IN FOR ACRS MEETING

PLEASE PRINT

NAME	NRC ORGANIZATION
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Art Buslik	RES/DRAA/PRAB
Stephen Dinsmore	NRR/DSSA
Eileen McKenna	NRR/DRIP
ROB TREGONING	RES/DET/MEB
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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBCOMMITTEE MEETING ON REGULATORY POLICIES AND PRACTICES

NOVEMBER 21, 2003
Date

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NAME	AFFILIATION
Wayne Harrison	STPNOC, WOG

Master

Expert Elicitation in Support of Risk-Informing 10 CFR 50.46

Robert L. Tregoning
Lee Abramson
US Nuclear Regulatory Commission

David Harris
Engineering Mechanics Technology, Inc.

ACRS Subcommittee on Regulatory Policies and Practices
November 21, 2003

Meeting Agenda: Expert Elicitation Presentation

■ Overview	Tregoning, NRC
■ Expert Elicitation Process	Abramson, NRC
■ Technical Issue & Piping Base Case Development	Tregoning, NRC
■ Piping Base Case Development: One Approach	Harris, EMT Inc.
■ Base Case Summary, Elicitation Questions, & Status	Tregoning, NRC

Previous ACRS Briefings and Program Milestones Since Last Briefing

- Previous ACRS briefings
  - July, 2003: ACRS main committee on the status and approach of expert elicitation.
  - May, 2002: Combined M&M, THP, R&PRA Subcommittee briefing on interim LOCA frequency elicitation and LOCA break size redefinition plans.
  - June, July, November, 2001: Overviews of LOCA frequency and break size redefinition effort provided to outline its importance within 10 CFR 50.46 revision framework.
  - March, 2001: Technical issues necessitating LOCA reevaluation.
- Program milestones since Jan 2003
  - Conducted kick-off meeting: February.
  - SRM Issued on SECY-02-0057 (Option III plan for risk-informing 10 CFR 50.46, Appendix K and GDC-35): March.
  - Conducted base case review meeting: June.
  - Public Meetings to discuss 10 CFR 50.46 effort: February, June, July, September.
  - Participated in CSNI/CNRA-sponsored international workshop on LB LOCA redefinition: June.
  - Completed individual elicitations: October.

Expert Elicitation: Executive Summary

- Elicitation objective and approach are consistent with SRM guidance for development of near-term LOCA frequencies.
- Elicitation process will develop LOCA frequencies as a function of flow rate and operating time considering both piping and non-piping contributions.
- The conditional LOCA probabilities of larger, "emergency faulted" loadings are being estimated.
- Elicitation process combines aspects of group and individual elicitation approaches as appropriate to achieve objectives.
- Approach is based on quantitative base case frequency estimates. Elicitation responses are provided relative to the base case frequencies.
- Plans are in place to provide alternative estimates of the elicitation frequencies and to develop a methodology for continually assessing LOCA challenges.

Elicitation Scope and Objectives

- Develop piping and non-piping passive system LOCA frequencies as a function of flow rate and operating time up to the end of the license extension period.
- Estimate LOCA frequency distributions for generic plant operational cycle and history.
- Estimate conditional LOCA probability distributions for rare, emergency-faulted load conditions.
  - Seismic loading.
  - Other large, unexpected internal and external loads.

LOCA Frequency Reevaluation: General Approach

1. **Operating Experience Assessment**
2. **Expert Elicitation.**
   - Develop relationship between flow rate/break size and LOCA frequency.
   - Provide input to probabilistic LOCA computer code development.
3. **Probabilistic LOCA Code Development**
   - More rigorously combine operating experience and PFM insights.
   - Explicitly consider contributions from piping and non-piping components, and the evolution of new degradation mechanisms.
4. **Continuous LOCA Assessment.**
   - Develop and maintain LOCA precursor database through expansion of existing pipe failure database.
   - Identify emerging degradation mechanisms and conduct anticipatory research to assess LOCA significance.

EXPERT ELICITATION PROCESS

LEE ABRAMSON
OFFICE OF NUCLEAR REGULATORY RESEARCH
U. S. NUCLEAR REGULATORY COMMISSION

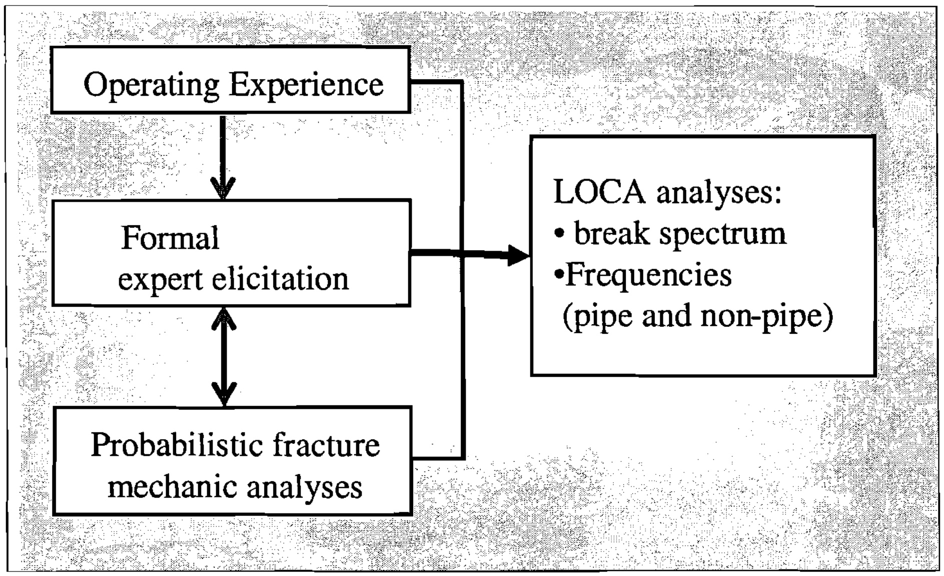
ACRS SUBCOMMITTEE ON REGULATORY POLICIES AND PRACTICES

ROCKVILLE, MARYLAND

NOVEMBER 21, 2003

LB-LOCA Frequency Reevaluation

"The staff should conduct … expert elicitation to converge the results"



Formal Elicitation Approach

- **Conduct preliminary elicitation**
- Select panel and facilitation team.
- Develop technical issues.
  - Construct approach for estimating LOCA frequencies.
  - Determine significant issues affecting LOCA frequencies.
- Quantify base case frequencies.
  - Develop estimates for well-defined piping conditions.
  - Two estimates used PFM analysis and two estimates used operating experience analysis.
- Formulate elicitation questions.
- Conduct individual elicitations.
- Analyze quantitative results and qualitative rationale.
- Summarize and document results.

Preliminary Elicitation

- Conducted last year using 11 internal (NRC) experts with broad knowledge.
- Discussed during May 2002 ACRS meeting on 10 CFR 50.46 revision status.
- Provided interim LOCA frequency results for use in 10 CFR 50.46 re-evaluation effort.
- Developed possible framework for subsequent elicitation and identified strengths and weaknesses to address in formal elicitation.
- Identified some technical issues for consideration within formal elicitation.
- Results predicted a modest increase (factor of 2) in NUREG/CR-5750 LOCA estimates for internal events.

Formal Elicitation Approach

- Conduct preliminary elicitation
- Select panel and facilitation team.
- **Develop technical issues.**
  - **Construct approach for estimating LOCA frequencies.**
  - **Determine significant issues affecting LOCA frequencies.**
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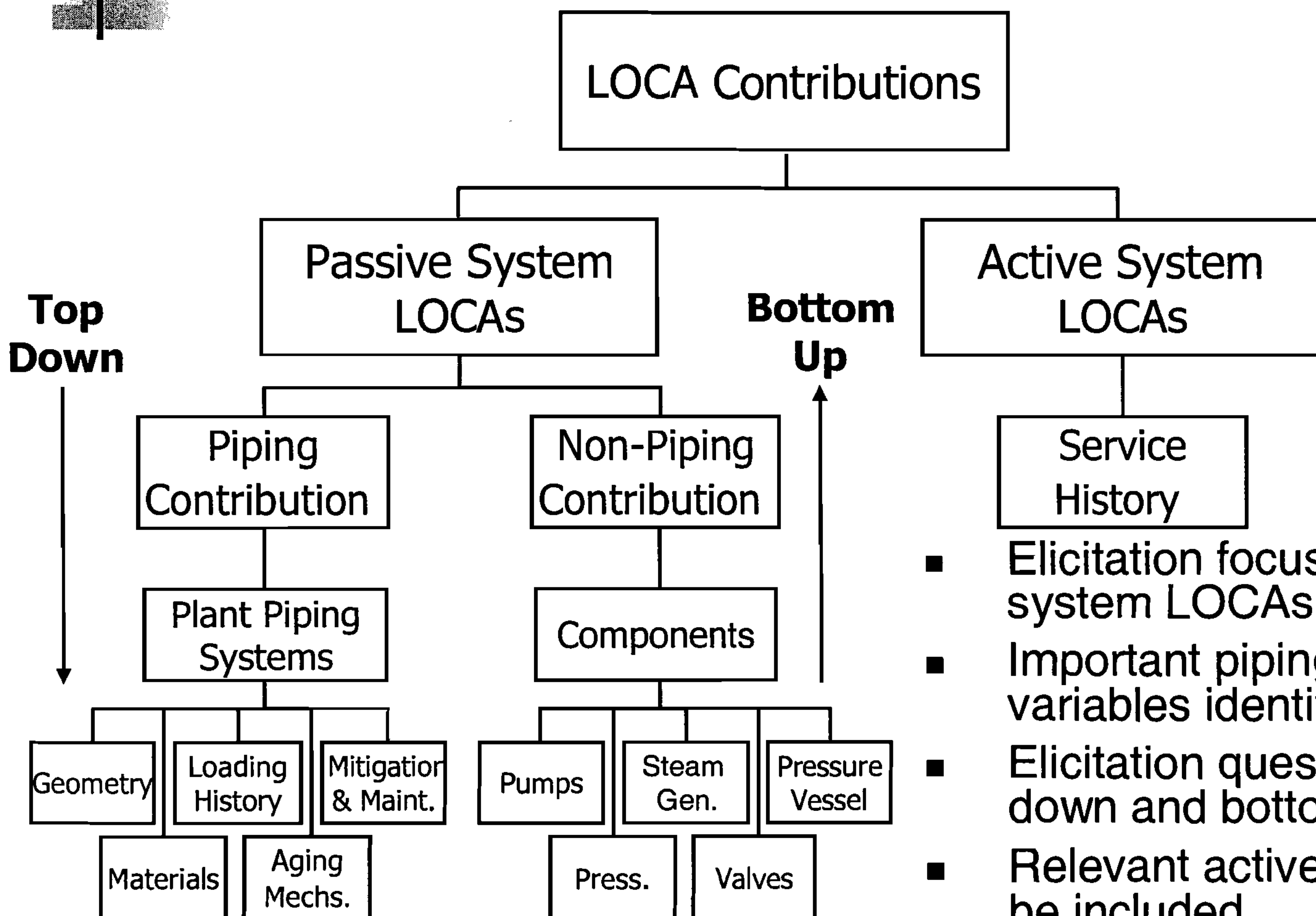
LOCA Sizes and Operating Time Periods Evaluated

- LOCA sizes based on flow rate required for mitigating system equipment.
- First three categories encompassed traditional definitions utilized in NUREG-1150 and NUREG/CR-5750.
- Three more LBLOCA categories added to evaluate larger break sizes.
- Correlation between leak rate and break size developed for relevant BWR and PWR systems.

Category	Flow Rate Threshold (gpm)	LOCA Size
1	> 100	SB
2	> 1500	MB
3	> 5000	LB
4	> 25,000	LB a
5	> 100,000	LB b
6	> 500,000	LB c

- Three time periods evaluated.
  - Current (industry average of 25 years of operation).
  - End of design life (40 years of operation).
  - End of life extension (60 years of operation).

General Issue Structure



- Elicitation focuses on passive system LOCAs.
- Important piping and non-piping variables identified.
- Elicitation questionnaire supports top down and bottom up analysis.
- Relevant active system LOCAs will be included.

Piping Issue Classification

- Panel brainstormed variable categories which influence the LOCA frequencies: materials, geometry, loading, mitigation & maintenance, degradation mechanisms.
- Panel determined that variable categories and their effects are a function of the piping system.
- Panel developed applicable inputs for each variable category.
- Panel determined LOCA sensitive piping systems for BWR and PWR plants.
- Panel determined the individual variables that were relevant for each piping system considering existing plant variability.
- Panel developed master tables for BWR and PWR plants.

Piping Issue Classification

Loading Categories

Main Category	Sub-Category 1	Sub-Category 2	Sub-Category 3	Sub-Category 4	Sub-Category 5
Thermal	Differential Expansion	Restrained Expansion	Radial Gradient	Stratification	Cycling & Striping
Water Hammer	Steam Hammer				
Seismic	Inertial	Displacement			
Pressure	Normal	Transients			
Residual Stress	Design	Repair welds	Fabrication	Mitigation-Induced, eg. Weld overlay	
Dead Weight Loading					
SRV Loading					
Overload (Ext. and Int.)	Pipe Whip	Jet Impingement	Deflagration	External Weight Drops	
Support	Snubber malfunction	Hanger Misadjust.			
Vibration	Mechanical	Cavitation			

- Example classification table for loading variable.

Piping Issue Classification

- LOCA sensitive piping systems for BWR and PWR plants.
- Geometry, materials, degradation mechanisms, loading, and mitigation procedures applicable for each piping system.
- Master table for BWR & PWR plants for use during the elicitation process.

BWR: LOCA Sensitive Piping Systems

System	Piping Matls.	Piping Size (in)	Safe End Matls.	Welds	Sig. Degrad. Mechs.	Sig. Loads.	Mitigation /Maint.
RECIRC	304 SS, 316 SS, 347 SS	4, 10, 12, 20, 22, 28	304 SS, 316 SS, A600*	SS, NB	UA, FDR, SCC, LC, MA	RS, P, S, T, DW, SUP, SRV, O	ISI w TSL, REM
Feed Water	CS	10, 12 (typ), 12 - 24	304 SS, 316 SS*	CS, NB	UA, FDR, MF, TF, FS, LC, GC, MA	T, TFL, WH,P, S, SRV, RS, DW, O	ISI w TSL, REM
Steam Line	CS – SW	18, 24, 28	CS	CS	UA, FDR, FS, GC, LC, MA	WH, P, S, T, RS, DW, SRV, O	ISI w TSL, REM
HPCS, LPCI	CS (bulk), 304 SS, 316 SS	10, 12	304 SS, 316 SS, A600*	CS, SS, NB	UA, FDR, SCC, TF, LC, GC, MA	RS, T, P, S, DW, TS, WH, SUP, SRV, O	ISI w TSL, REM
RHR	CS, 304 SS, 316 SS	8 - 24	CS, 304 SS, 316 SS	CS, SS, NB	UA, FDR, SCC, TF, FS, LC, GC, MA	RS, T, P, S, DW, TS, O SUP, SRV	ISI w TSL, REM
RWCU	304 SS, 316 SS, CS	8 – 24	CS, 304 SS, 316 SS	CS, SS, NB	UA, FDR, SCC, TF, FS, LC, GC, MA	RS, TS, T, P, S, DW, SUP, SRV, O	ISI w TSL, REM
CRD piping	304 SS, 316 SS (low temp)	< 4	Stub tubes – A600 and SS*	Crevice A182 to head	UA, FDR, MF, SCC	RS, T, P, S, DW, V, O, SRV	ISI w TSL, REM
SLC	304 SS, 316 SS	< 4	304 SS, 316 SS	SS, NB	UA, FDR, MF, SCC	RS, T, P, S, DW, V, O, SRV	ISI w TSL, REM
INST	304 SS, 316 SS	< 4	304 SS, 316 SS	SS, NB	UA, FDR, MF, SCC, MA	RS, T, P, S, DW, V, O, SRV	ISI w TSL, REM
Drain lines	304 SS, 316 SS, CS	< 4	304 SS, 316 SS, CS	SS, NB	UA, FDR, MF, SCC, LC, GC	RS, T, P, S, DW, V, O, SRV	ISI w TSL, REM
Head spray	304 SS, 316 SS, CS	< 4	304 SS, 316 SS, CS	SS, NB	UA, FDR, SCC, TF, LC, GC	RS, P, S, T, DW, SRV, O	ISI w TSL, REM
SRV lines	CS	6, 8, 10, 28	CS	CS	UA, FDR, MF, FS, GC, LC, MA	RS, P, S, T, DW, SRV, O	ISI w TSL, REM
RCIC	304 SS, 316 SS, CS	6, 8	304 SS, 316 SS	SS NB	UA, FDR, SCC, LC, MA	RS, P, S, T, DW, SRV, O	ISI w TSL, REM

Non-Piping Issue Classification

- Panel identified approximately 25 different locations within primary components (i.e. pressurizer, reactor, steam generator, pumps, valves) where passive system failures could lead to a LOCA.
- Panel characterized failure mechanisms which could lead to LOCAs in these components.
- Panel identified components with possible existing failure data.
- Panel developed inputs for each of the five variable categories that were relevant for each non-piping system.
- Panel developed master tables for non-piping LOCA contributors for use during the elicitation.

Non-Piping Issue Classification

Pressurizer Failure Mechanisms

Failure Mechanism	Geometry	Material	Degradation Mechanisms	Loading	Mitigation/ Maintenance	Comment
Shell		A600C-LAS, SSC-LAS	GC, SCC, MF, FDR, UA			Boric acid wastage from OD
Manway		NB-LAS, SSC-LAS, LAS, HS-LAS (Bolts)	GC, SCC, MF, SR, FDR, UA			Bolt failures
Heater Sleeves	Small diam. (3/4 to 1 in)	A600, SS	TF, MF, SCC, FDR, UA			Req. multiple failures
Bolted relief valves		C-SS	MA, FDR, UA			
Nozzles		SSC-LAS C-SS	CD, TF, SCC, MA, FDR, UA, GC			Same as surge line

- Example of relevant failure mechanisms for pressurizer.
- Values for five variable categories included as appropriate.

Formal Elicitation Approach

- Conduct preliminary elicitation
- Select panel and facilitation team.
- Develop technical issues.
  - Construct approach for determining LOCA frequencies.
  - Determine significant issues affecting LOCA frequencies.
- **Quantify base case frequencies.**
  - **Develop estimates for well-defined piping conditions.**
  - **Two estimates used PFM analysis and two estimates used operating experience analysis.**
- Formulate elicitation questions.
- Conduct individual elicitations.
- Analyze quantitative results and qualitative rationale.
- Summarize and document results.

Piping Base Case Development

- The base cases anchor the elicitation responses.
- Base case conditions specify the piping system, piping size, material, loading, degradation mechanism(s), and mitigation procedures.
- Five Base Cases Defined.
  - BWR
    - Recirculation System (BWR-1)
    - Feedwater System (BWR-2)
  - PWR
    - Hot Leg (PWR-1)
    - Surge Line (PWR-2)
    - High Pressure Injection makeup (PWR-3)
- The LOCA frequency for each base case condition is calculated as a function of flow rate and operating time.
- Four panel members individually estimated frequencies: two using operating experience and two using probabilistic fracture mechanics.

Piping Base Case Approach

- Iterative process involved facilitation team and expert panel.
- Evaluated LOCA frequencies at 25 (current), 40 (end-of-license), and 60 years (end-of-license extension) after plant startup.
- Each base case participant attempted to benchmark results using service experience for leaking cracks.
- All base case calculations attempted to capture as closely as possible the conditions established by the expert panel.
- Sensitivity analyses of PFM results conducted to evaluate:
  - Effect of seismic loading
  - Effect of ISI
  - Loading history variability
  - Effectiveness of mitigation

Piping Base Case Conditions: Summary Table

Plant Type	System	Piping Size	Piping Material	Safe End Material	Weld Material	Degradation Mechanism	Loading	Mitigation/ Maint.
BWR-1	RECIRC	12 – 28	Original 304 SS	Non creviced A600	NB	IGSCC	Nominal Service Loading	NWC, leak detection, ISI (88-01), Stress improvement
BWR-2	Feed water	12	CS			FAC, TF	Nominal Service Loading	NWC, leak detection, ISI (88-01)
PWR-1	RCP – Hot Leg	30	304 SS	A600	NB	TF, PWSCC	Nominal Service Loading	ISI, leak detection
PWR-2	Surge Line	10	304 SS	A600	NB at Pressurizer	TF, PWSCC	Nominal Service Loading	ISI, leak detection
PWR-3	SIS: DVI HPI/mak eup	4	SS/CS			TF	Nominal Service Loading	ISI, leak detection

Piping Base Case Summary Results: Leak Frequency Results (per Reactor year)

Base Case	Expert A	Expert B	Expert C	Expert D
BWR-1	NA	5.8 E-03	1.3 E-02	NA
BWR-2	NA	1.5 E-03	< 1.6 E-09	NA
PWR-1	NA	4.0 E-04	1.1 E-01	NA
PWR-2	NA	1.6 E-05	<1.1 E-07	NA
PWR-3	NA	1.4 E-03	3.7 E-04	NA

- Leak frequencies for average of 25 years of service.
- Expert B's results represent the service history experience for the base case systems and degradation mechanisms. These calculations are not trivial.
- Expert C's results require no additional benchmarking for BWR-1, PWR-1, and PWR-3 base cases.
- Sensitivity analyses evaluated to examine effect of benchmarking Expert C's BWR-2 and PWR-2 base case leak rates to the service history.

Estimation of LOCA Frequencies for Expert Panel by Use of Probabilistic Mechanics Models

D.O. Harris

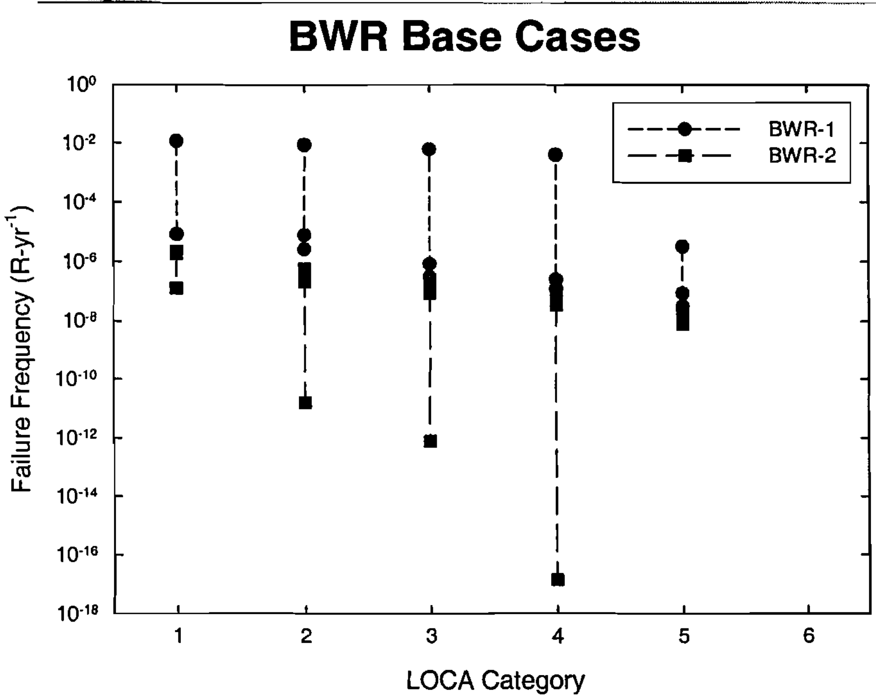
Engineering Mechanics Technology, Inc.

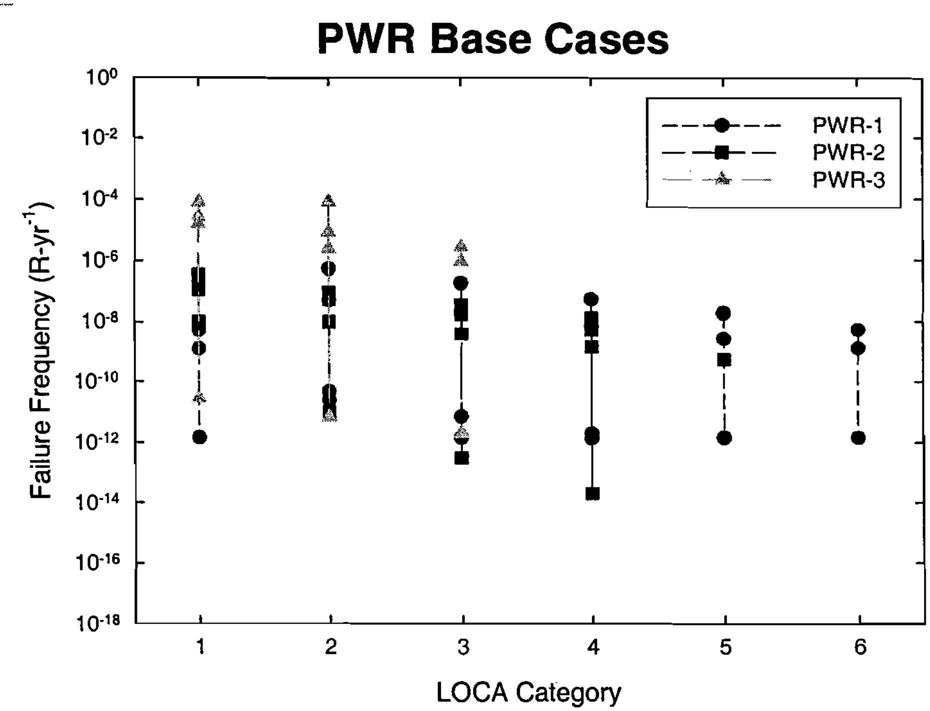
ACRS SUBCOMMITTEE ON REGULATORY POLICIES AND PRACTICES

ROCKVILLE, MARYLAND

NOVEMBER 21, 2003

Piping Base Case Summary Results: 25 Year Operating Period





- Large variability due to inconsistencies in both the conditions evaluated and differences in approaches.
- Each base case participant presented their approach and results to entire panel.
- Each panel member was asked to critique approaches & results during their elicitation session.

Non-Piping Base Case Development

- The non-piping base cases could have been developed in a similar manner to the piping base cases.
  - Choose several representative systems.
  - Examine and extrapolate operating experience through modeling
- However, the variety and complexity of the non-piping failure mechanisms makes this assessment intractable.
- Approach adopted conducts database searches for each non-piping failure mechanism identified to estimate component leak and crack frequencies.
- These frequencies are used to anchor the non-piping responses for each expert.
- Each expert determines the relationship between leak and crack frequencies and LOCA frequencies.

Non-Piping Base Case Approach

- Searched LER database for precursor events in relevant PWR and BWR components.
  - Events are leaks, through-wall cracks, and partial through-wall cracks.
  - Broad search initially conducted back to 1990.
  - Events screened to ensure relevance to LOCA-sensitive components.
- The partial through-wall crack information is not complete.
  - Variable interpretation of LER reporting requirements for serious degradation.
  - Lack of detection during ISI.
- MS ACCESS database of events was linked to LERs and available to the panel.
- Other databases are being used to develop separate frequency estimates for steam generator tube and control rod drive mechanism cracking.

Non-Piping Base Case Summary Results

Event Summary

- Function of subcomponent failure.
- Function of flaw type (leak, etc.)
- Failures as a function of calendar year also determined.

Event Summary by Degradation Mechanism

Plant Type	Component		Degradation Mechanism (see legend)							
			MA	FDR	SCC	LC	MF	TF	FS	UNK
BWR	RPV	10		1	9					
		100%	0%	10%	90%	0%	0%	0%	0%	0%
	Valve	1					1			
		100%	0%	0%	0%	0%	100%	0%	0%	0%
	Pump	2		2						
		100%	0%	100%	0%	0%	0%	0%	0%	0%
	Totals	13	0	3	9	0	1	0	0	0
	Adjusted*	17	0.5	3.5	9.5	0.5	1.5	0.5	0.5	0.5
		100%	3%	21%	56%	3%	9%	3%	3%	3%
			MA	FDR	SCC	LC	MF	TF	FS	UNK
PWR	Pzr	28	1	3	23	1				
		100%	4%	11%	82%	4%	0%	0%	0%	0%
	RPV	42		5	27	5				5
		100%	0%	12%	64%	12%	0%	0%	0%	12%
	Valve	3	1		1	1				
		100%	33%	0%	33%	33%	0%	0%	0%	0%
	SG	124	2	29	85				3	5
		100%	2%	23%	69%	0%	0%	0%	2%	4%
	Pump	2		2						
		100%	0%	100%	0%	0%	0%	0%	0%	0%
	Instr nozzles	4			4					
		100%	0%	0%	100%	0%	0%	0%	0%	0%
	Totals	203	4	39	140	7	0	0	3	10
	Adjusted*	207	4.5	39.5	140.5	7.5	0.5	0.5	3.5	10.5
		100%	2%	19%	68%	4%	0%	0%	2%	5%

Formal Elicitation Approach

- Conduct preliminary elicitation
- Select panel and facilitation team.
- Develop technical issues.
  - Construct approach for determining LOCA frequencies.
  - Determine significant issues affecting LOCA frequencies.

Quantify base case frequencies.

  - Develop estimates for well-defined piping conditions.
  - Two estimates used PFM analysis and two estimates used service history analysis.

- **Formulate elicitation questions.**
- Conduct individual elicitations.
- Analyze quantitative results and qualitative rationale.
- Summarize and document results.

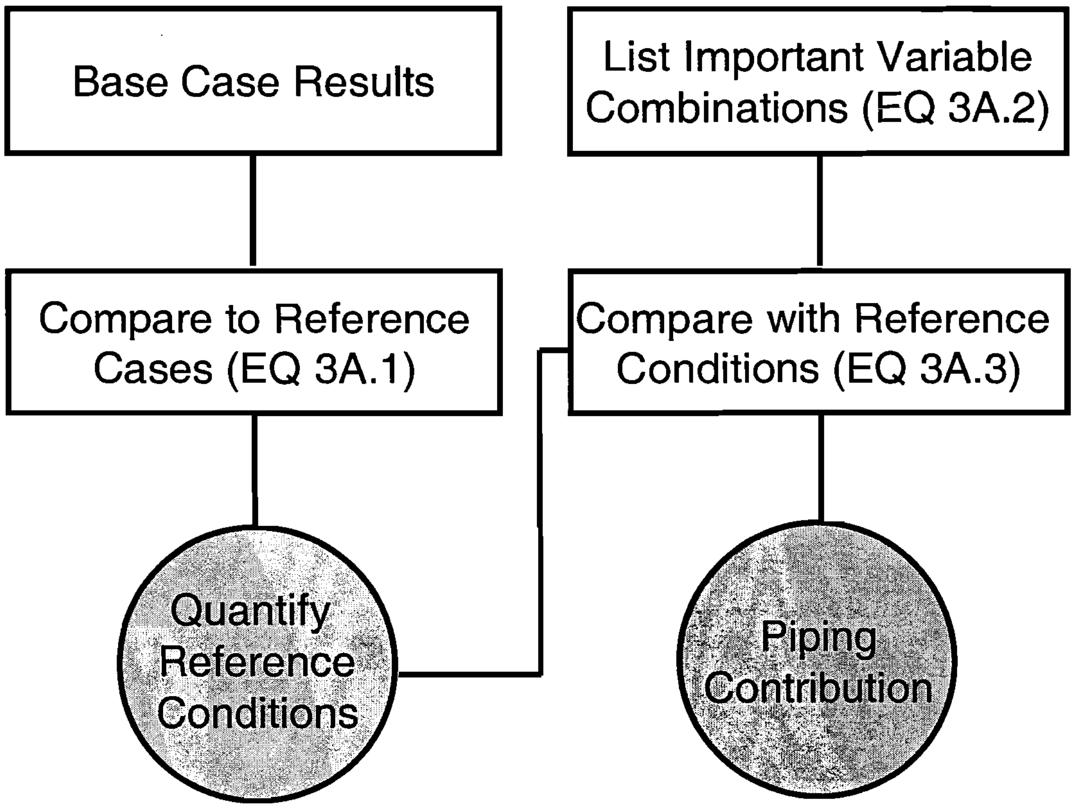
Elicitation Question Development

- Questions focus on the following topic areas.
  - Base Case Evaluation.
  - Regulatory and Utility Safety Culture pertaining to LOCA frequencies.
  - LOCA frequencies of Piping Components.
  - LOCA frequencies of Non-Piping Components.
  - Conditional piping failure under Emergency Faulted Loading.
  - Conditional non-piping failure under Emergency Faulted Loading.
- Questions are asked relative to a set of conditions and quantitatively linked to the base case results.
- Each question asks for mid, low, and high values as well as appropriate rationale or comments.
- Questions can be answered using a top-down or bottom-up approach.
- Possible inconsistencies between answers and rationales discussed for important technical issues.

Elicitation Questions: Safety Culture

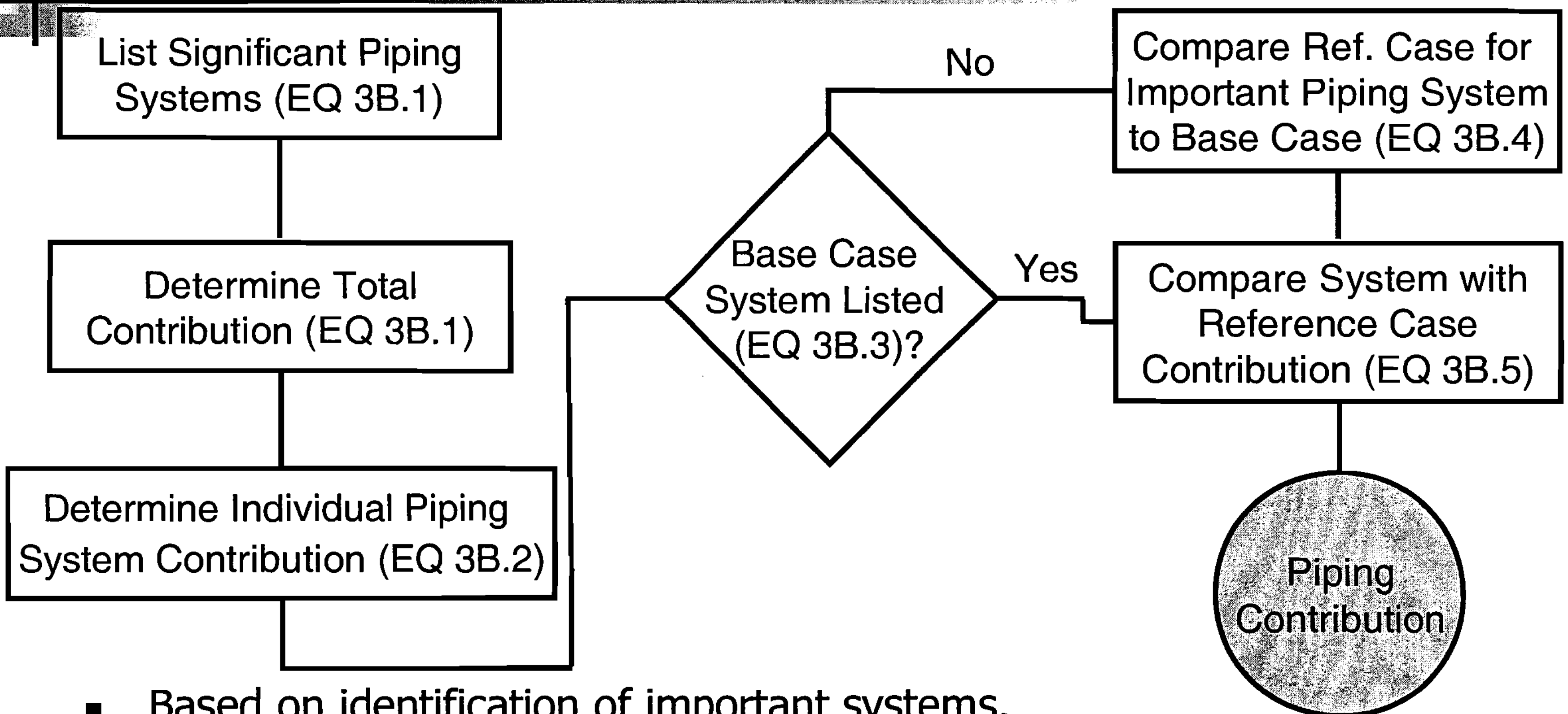
- **EQ 2: Safety Culture**
  - Consider the current utility safety culture that exists after approximately 25 years (current day) of plant operation and how it influences Category 1 LOCAs. Express the relative change, or ratio, in the utility safety culture's effect on LOCA frequencies after 15 additional years (40 years of operation) compared to its current day effect. Next, express the ratio of the utility safety culture's effect on LOCA frequencies ratio in 35 years (60 years of plant operation) to its current day effect. Include the 90% coverage interval for all estimates.
  - Repeat 2A.1 but now considering the effect of the regulatory safety culture on LOCA frequencies.
  - If you believe that safety culture effects are a function of leak rate category, repeat 2A.1 and 2A.2 for Category 2 through Category 6 LOCA frequencies.
  - Do you believe that the utility safety culture and regulatory safety culture are correlated? If so, is the correlation high, medium, or low?

Piping Components: Bottom-Up Approach (EQ 3A)



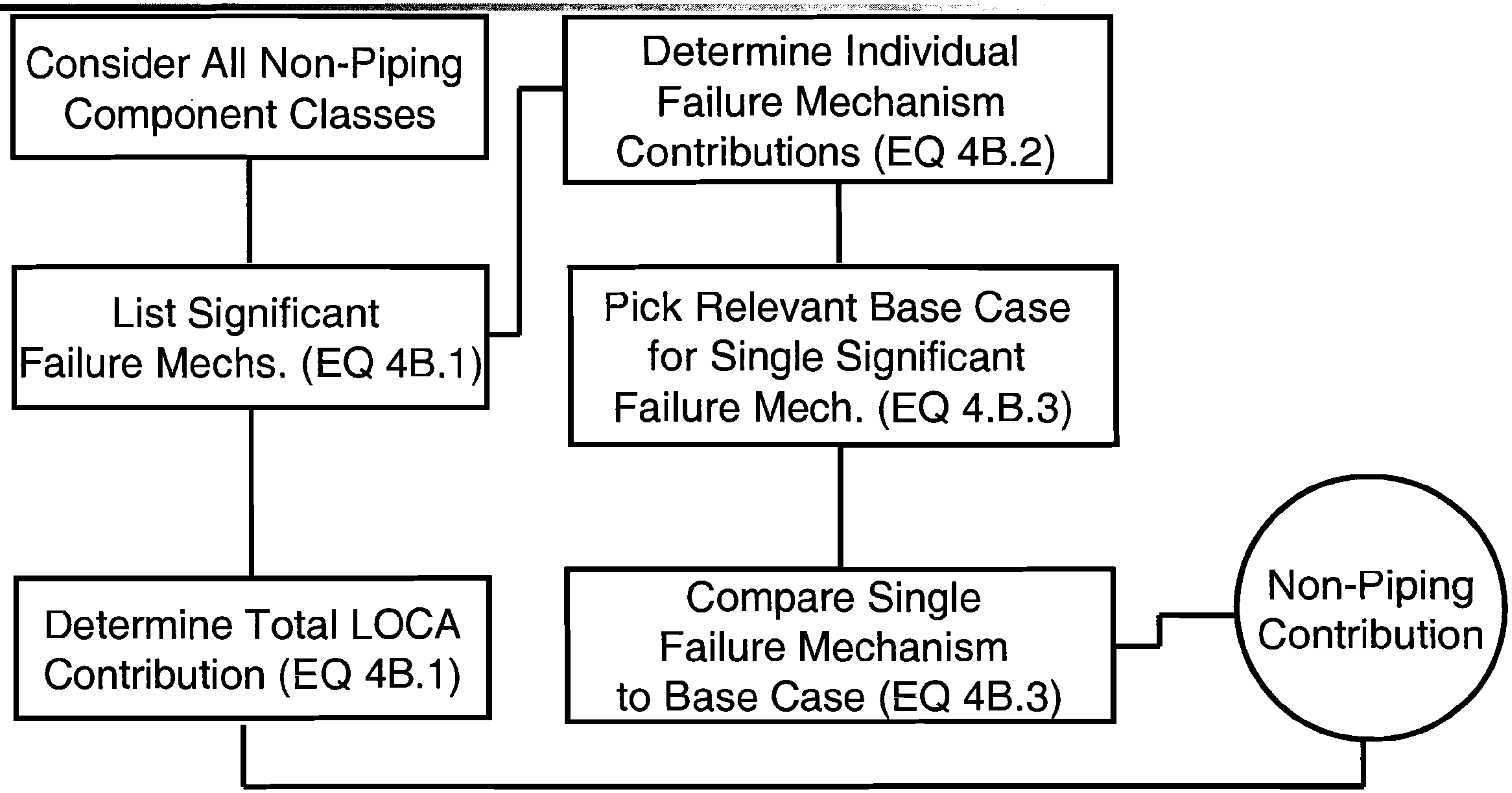
- Requires assessment of all significant variable combinations for each piping system.
- Contribution of significant variable combinations are added.
- All system contributions are then summed to determine the LOCA frequency.

Piping Components: Top-Down Approach (EQ 3B)



- Based on identification of important systems.
- Only relates one system to the base case results.
- Must still determine base case contribution to the total system performance.

Non-Piping Components: Top-Down Approach (EQ 4B)



- Considers independent failure mechanism contributions regardless of component type.
- Only comparison of a single failure mechanism to base case results is required.

Conditional LOCAs Due to Emergency Faulted Loading

$$f_{EFL} = \sum_i f_{Si} P_{L|Si}$$

where

f_{EFL} = frequency of emergency faulted LOCA

f_{Si} = frequency of stress with magnitude i

$P_{L|Si}$ = Conditional failure probability given S_i

$$f_{Si} = \sum_j f_{ej} g_{pj}$$

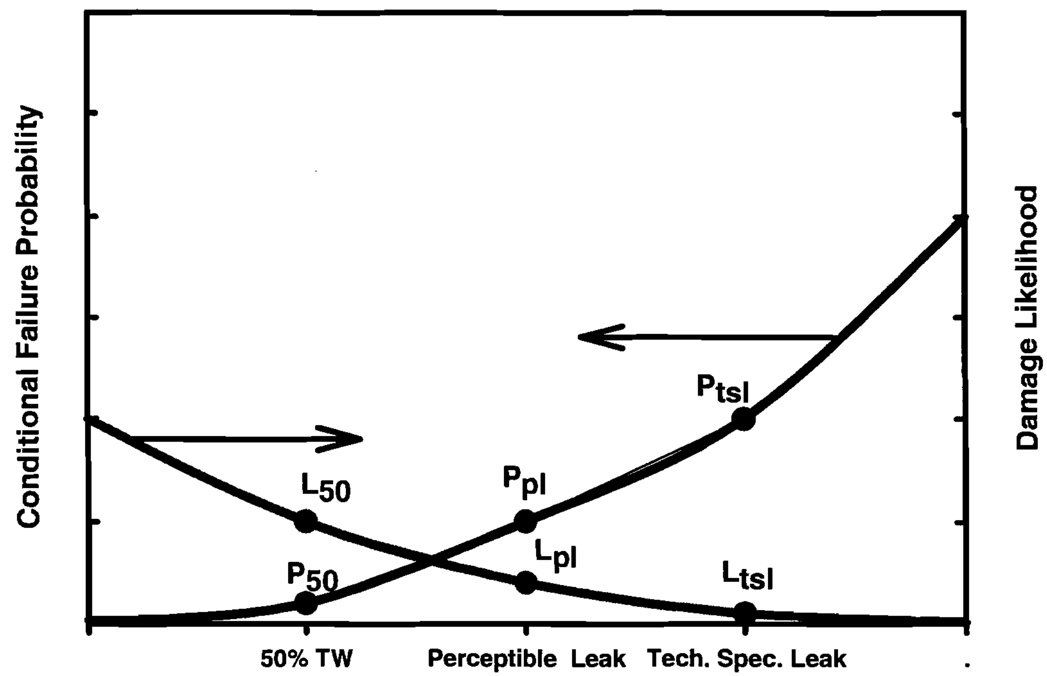
f_{ej} = frequency of event j

g_{pj} = plant response characteristics for event j

- Plant Specific Estimation: (f_{si})
  - Determine event frequencies
  - Determine component stress distribution for each event
- Generic Estimation: ($P_{L|Si}$)
  - Elicitation question.

Conditional LOCAs Due to Emergency Faulted Loading

- Elicitation requirements.
  - Determine systems/components most susceptible to LOCAs for a prescribed stress amplitude (Cat. B & D loading).
  - Determine most likely failure mechanisms.
  - For each system and failure mechanism develop relative ratios between damage states
- Emergency faulted base case developed for P_{tsl} assuming idealized damage.
- Damage likelihood referenced to likelihood of perceptible leak using operating experience data.



$$P_{L|Si} = \sum_k L_{Dk} P_{L|Dk}$$

Ongoing and Future Elicitation Work

- Complete individual elicitations.
  - Initial interviews finished.
  - Most panel members have submitted updated responses.
  - Adequacy of updated responses needs to be determined.
- Analyze quantitative results and summarize rationales.
  - Calculate results for each expert if appropriate.
  - Combine answers for individual questions and calculate results.
  - Characterize uncertainties.
- Conduct wrap-up meeting.
  - Summarize quantitative and qualitative results.
  - Summarize analysis methodology and LOCA results.
  - Obtain feedback from the expert panel.
- Document results.

Summary

- NRC is using expert elicitation process to estimate LOCA frequencies as a function of break size.
- Elicitation process will develop LOCA frequencies as a function of flow rate and operating time considering both piping and non-piping contributions.
- The conditional LOCA probabilities of larger, "emergency faulted" loadings are being estimated.
- Elicitation process is designed to capture uncertainties expressed by wide-ranging technical opinions for a complex topic area where the underlying data is sparse.
- The process has developed quantitative estimates for base cases which are simplified conditions used to anchor subsequent elicitation responses. The base cases are extrapolations of operating experience.
- Experts determine relevant issues/parameters which govern LOCA frequencies and provide the relationships between these issues/parameters and the base cases.

Master

EXPERT ELICITATION PROCESS

LEE ABRAMSON

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U. S. NUCLEAR REGULATORY COMMISSION

ACRS SUBCOMMITTEE ON REGULATORY POLICIES AND PRACTICES

ROCKVILLE, MARYLAND

NOVEMBER 21, 2003

FORMAL USE OF EXPERT JUDGMENT

- APPLICATIONS
  - SCENARIO DEVELOPMENT
  - MODEL DEVELOPMENT
  - DISTRIBUTION ESTIMATION
  - PARAMETER ESTIMATION

- PREDETERMINED STRUCTURE
  - COLLECTION
  - PROCESSING
  - DOCUMENTATION

- INDICATORS FOR USE
  - LACK OF DATA
  - COMPLEX ISSUES
  - EXTENSIVE REVIEW EXPECTED

FORMAL VS. INFORMAL USE

- ADVANTAGES
  - IMPROVED ACCURACY AND CREDIBILITY
  - REDUCED LIKELIHOOD OF BIAS
  - ENHANCED CONSISTENCY
  - IMPROVED SCRUTABILITY AND DOCUMENTATION

- DRAWBACKS
  - INCREASED TIME AND RESOURCES
  - REDUCED FLEXIBILITY
  - ENHANCED VULNERABILITY TO CRITICISM

- USE EXPERIENCED PRACTIONERS
  - SAVE TIME AND RESOURCES
  - AVOID POTENTIAL PITFALLS

ELICITATION OF LOCA FREQUENCIES

- DELAY QUANTITATIVE ASSESSMENTS UNTIL AFTER PANEL DISCUSSIONS AND ISSUE ANALYSES

- DEVELOP BASE CASES

- ALL QUANTITIES RELATIVE TO BASE CASES OR OTHER QUANTITIES

- QUANTITATIVE ASSESSMENT

X = Quantity to be assessed

X_M = Mid value
X_L = Low value
X_H = High value

Chance { $X < X_M$ } ≈ Chance { $X > X_M$ } ≈ 50%
Chance { $X < X_L$ } ≈ 5%
Chance { $X > X_H$ } ≈ 5%

(X_L , X_H) is an approximate 90% coverage interval for X

EXPERT ELICITATION PROCESS

1. **SELECTION OF EXPERT PANEL**
   - FULL RANGE OF DISCIPLINES
   - VARIETY OF APPROACHES

2. **TECHNICAL BACKGROUND DEVELOPMENT**
   - PROJECT STAFF
   - INDIVIDUAL PANEL MEMBERS
   - FILL IN KNOWLEDGE GAPS AND AUGMENT INDIVIDUAL EXPERTISE

3. **FORMULATION OF ISSUES**
   - PROJECT STAFF
   - INITIAL DECOMPOSITIONS

EXPERT ELICITATION PROCESS (CONT'D)

4. **PANEL DISCUSSIONS**
   - FINAL FORMULATION AND DECOMPOSITIONS
   - ELICITATION QUESTIONS

5. **ELICITATION TRAINING**
   - IDENTIFY BIASES
   - ELICITATION EXERCISES

6. **ELICITATION QUESTIONNAIRE**
   - MANY ITERATIONS BETWEEN PROJECT STAFF AND EXPERT PANEL

7. **TWO PILOT ELICITATION SESSIONS**
   - REVISED QUESTIONNAIRE
   - NEW APPROACH TO EMERGENCY FAULTED LOADING

EXPERT ELICITATION PROCESS (CONT'D)

8. **TWELVE INDIVIDUAL ELICITATION SESSIONS**
   - PREPARATION BY EXPERT
     - COMPLETE QUESTIONNAIRE
     - STATE RATIONALES
   - ELICITATION TEAM
     - NORMATIVE EXPERT
     - SUBSTANTIVE EXPERT
     - RECORDER
   - PURPOSES
     - CLARIFY QUESTIONS AND ISSUES
     - REVIEW RESPONSES FOR COMPLETENESS AND CONSISTENCY
     - FEEDBACK ON ELICITATION PROCESS
   - FOLLOW-UP
     - COMPLETE QUESTIONNAIRE
     - COMPLETE RATIONALE DEVELOPMENT

9. **RECOMPOSITION AND AGGREGATION**
   - INDIVIDUAL LOCA FREQUENCIES
   - PANEL LOCA FREQUENCIES
   - SUMMARY OF RATIONALES

EXPERT ELICITATION PROCESS (CONT'D)

10. **WRAP-UP MEETING**
    - **PRESENTATION OF RESULTS AND RATIONALES**
    - **PANEL RESPONSE AND DISCUSSION**
      - **OPPORTUNITY TO REVISE RESPONSES**
    - **FINAL FEEDBACK**

11. **DOCUMENTATION**

SOURCES OF BIAS

1. MOTIVATIONAL BIASES
   - SOCIAL PRESSURE
   - MISINTERPRETATION
   - MISREPRESENTATION
   - WISHFUL THINKING

2. COGNITIVE BIASES
   - INCONSISTENCY
   - ANCHORING
   - AVAILABILITY
   - UNDERESTIMATION OF UNCERTAINTY

ELICITATION EXERCISE

1. According to the 2000 census, how many men 65 or over were there in the U.S.?

Low Value	Mid Value	High Value
5th Percentile	Median	95th Percentile

   - Coverage by (LV, HV) intervals: 15/17 = 88%

2. Consider the following chronic conditions: Arthritis, Cataracts, Diabetes, Hearing Loss, Heart Disease, Prostate Disease

- How many American men age 65 or older suffered from these chronic conditions in 1995?
   - Coverage by (LV, HV) intervals: 55/90 = 61%

3. What is the ratio of the rate for men 45- 64 years old to the rate for men 65 and older for each of the conditions listed?
   - Coverage by (LV, HV) intervals: 69/96 = 72%

4. What is the ratio of the rate for men under 45 years old to the rate for men 45 - 64 years old for each of the conditions listed?
   - Coverage by (LV, HV) intervals: 68/96 = 71%

Master

Estimation of LOCA Frequencies for Expert Panel by Use of Probabilistic Mechanics Models

Presented to ACRS
Rockville, Maryland
November 21, 2003

D.O. Harris
Engineering Mechanics Technology, Inc.
San Jose, California

- LOCA frequencies (as a function of flow rate) for base case systems estimated by probabilistic models for crack initiation and growth

- Base case systems selected by expert panel based on estimated contribution to overall LOCA frequencies
  - PWR main coolant system
  - PWR surge line
  - PWR HPI make-up nozzle
  - BWR recirculation line
  - BWR feedwater

- LOCA frequencies estimated for expected dominant degradation mechanism
  - IGSCC
  - PWSCC
  - fatigue

- Initiation and growth can be considered for each of these mechanisms

- Material aging and overload events considered

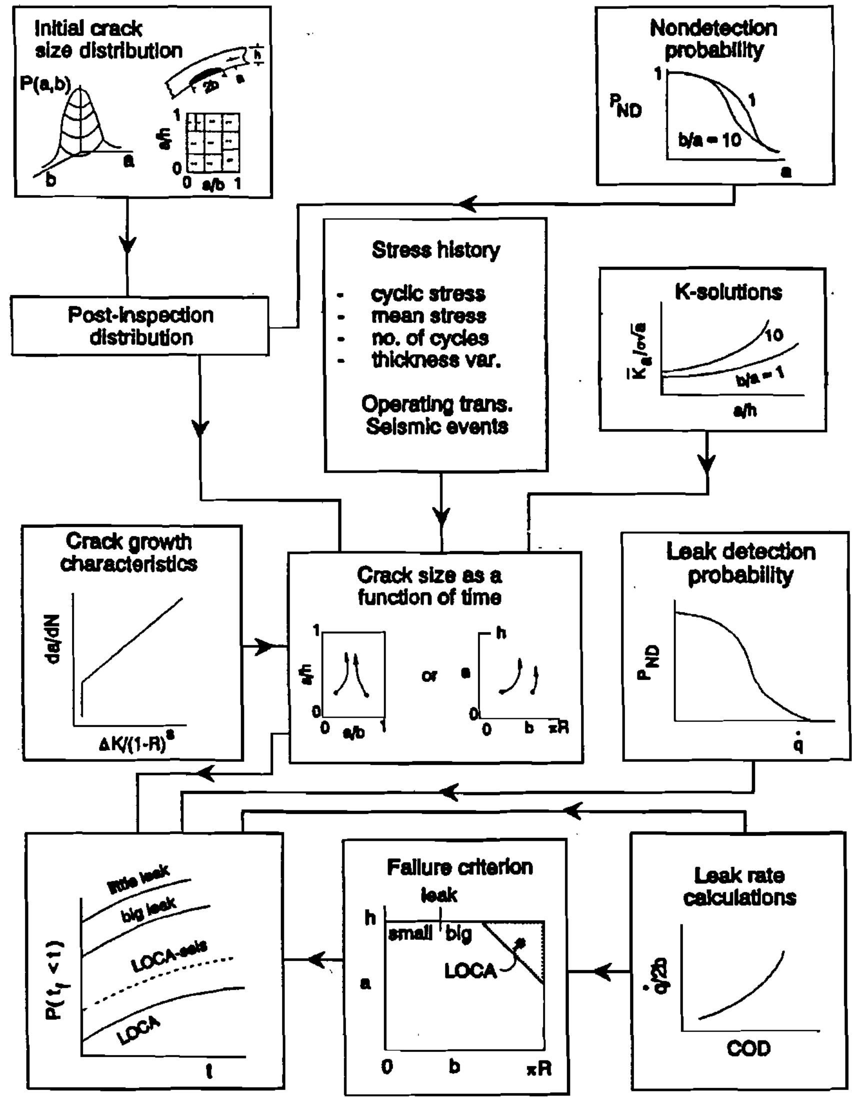
- Some of the inputs to the mechanics-based models of crack initiation and growth are considered to be random variables

- Monte Carlo simulation used to generate results

- Computations performed using PRAISE software
  - originally developed in 1980 with NRC support for probabilistic analysis of fatigue crack growth from pre-existing weld defects (NUREG/CR-2189, Vol. 5)
  - IGSCC initiation and growth models developed in mid 1980s (NUREG/CR-4792, Vol. 3)
  - Fatigue crack initiation capability developed in 1999 (NUREG/CR-6674) using probabilistic strain-life correlations developed by Argonne National Lab

Overview of PRAISE methodology for fatigue crack growth

similar modules available for
- initiation(fatigue and SCC)
- SCC growth



- Random variables – fatigue crack growth
  - Initial crack depth
  - Initial aspect ratio
  - Fatigue crack growth rate (da/dN) for a given cyclic stress intensity factor (ΔK)
  - Critical net section stress (σ_{flo})
  - Probability of detection during an inspection [P_{ND}]

- Additional random variables – SCC
  - Time to initiation for a given set of conditions (stress, temperature, sensitization, dissolved oxygen and coolant conductivity)
  - Residual stress distribution (also useable for fatigue)
  - Crack growth rate

- Additional random variables – fatigue crack initiation
  - Cycles-to-initiation for a given cyclic stress
  - Aspect ratio of initiated cracks (depth set at 0.3 inches per ANL)

- Stratified sampling of crack sizes (*a* and *a/b*) employed to allow evaluation of extremely small probabilities

- Note that operating conditions are considered as deterministic (stresses and frequency of loading, temperatures and pressures)

- Characterization of random variables key to model

- Initial crack depth distribution is probably the most important single variable, and is based on PRODIGAL runs performed by Vic Chapman for PNNL (Monte Carlo simulation of weld defects in multi-pass welds)

Example of characterization of scatter in fatigue crack growth characteristics (based on test data 1980 austenitic stainless steel)

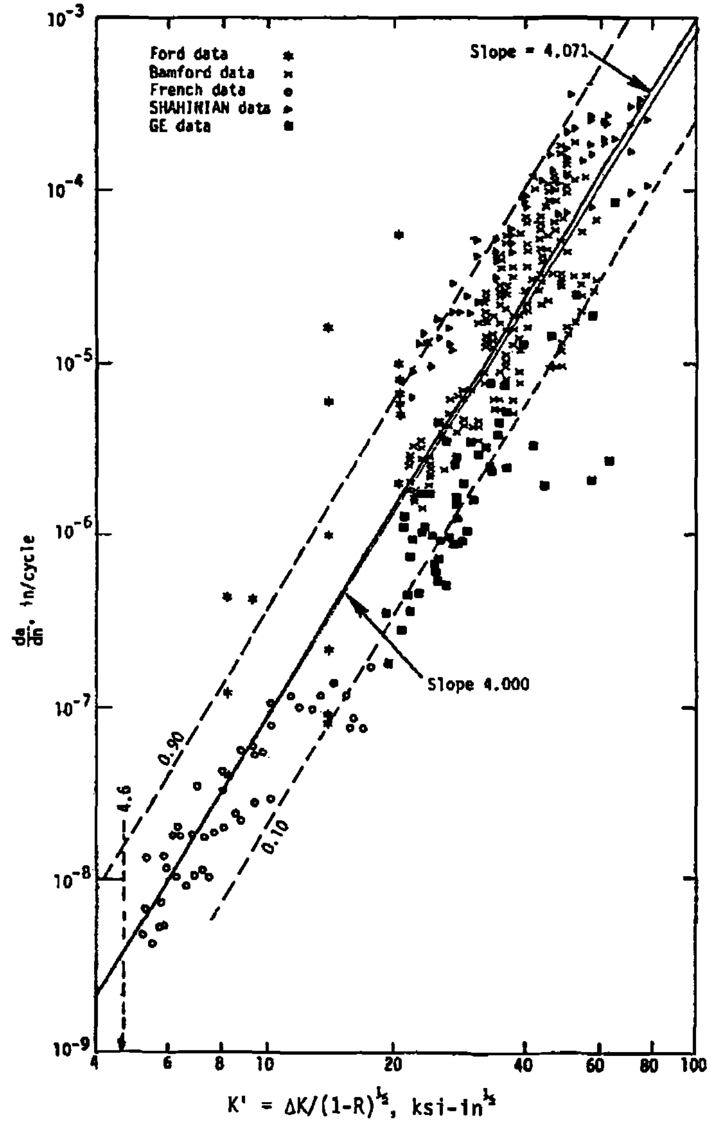
$da/dN=C[\Delta K/(1-R)]^m$

m=4

lognormal C

median = 9.14×10^{-12}

μ=1.042



- Calculations are performed for most likely failure location within a system, then extended to system by number of locations with similar dominant LOCA frequency

- Calculations performed as a function of flow rate (probability of a through-wall crack of length exceeding that required for flow rate)

- Flow rates calculated using SQUIRT (developed by Battelle with NRC support).

- Credit taken for leak detection (>5 gpm immediately detected).

- Stresses and frequency of occurrence required for the dominant location in the system

- The stresses were drawn from a variety of sources

hot leg/PV	NUREG/CR-2189, vol 5	includes var EQ
surge line	NUREG/CR-6674	with and without EQ
HPI	NUREG/CR-6674	
recirculation	an old analysis (DOH)	includes seismic
feedwater	NUREG/CR-6674	

(NUREG/CR-6674, "Fatigue Life Analysis of Components for 60-year Plant Life", PNNL, June 2000)

- The stresses and operating conditions drawn from NUREG/CR-6674 were modified in some instances based on more complete information

Example of Stresses: Surge Line Elbow with no Seismic Stresses

LOAD PAIR	AMP(KSI)	NUM/40 YR
HYDRO-EXTREME	190.17	6
9B-HYDRO	149.86	4
8A-UPSET 4	140.42	14
9B-UPSET4	139.43	10
8B-UPSET4	105.89	14
9A-UPSET4	105.13	2
9A-LEAK	103.86	12
8F-18	63.40	68
9C-11	63.38	68
9F-LEAK	63.37	68
8C-LEAK	63.37	35
2A-8C	62.30	33
8G-18	52.38	22
8G-17	52.35	90
9D-11	52.35	22
2A-8D	51.20	72
8H-9G	51.18	400
8G-UPSET3	51.00	30
9D-12	50.96	50
8G-12	50.96	40
8G-16	50.93	90
8G-9H	50.92	128
2A-8E	40.10	90
8H-9H	40.09	100
9H-10A	40.09	272
9E-13	39.82	90
3A-10A	33.10	4120
6-10A	33.10	200
3B-10A	33.10	4120
7-10A	33.10	4580
2B-SLUG1	32.87	100
2B-SLUG2	32.87	500
5-10A	29.90	9400
4A-10A	29.90	17040
4B-10A	29.90	17040
2B-10A	20.60	14400
2A-10A	20.60	14805
10A-UPSET1	20.59	70
10A-UPSET5	20.59	30
10A-UPSET6	20.59	5
10A-UPSET2	20.59	95
1B-10A	20.59	1533
1B-10B	20.00	87710

- These are the surface stresses that govern crack initiation

- These stresses will generally have a steep radial gradient which will not grow cracks as rapidly as a uniform stress

- The relative amounts of uniform and radial gradient defined by procedures in NUREG/CR-6674, unless additional information allowed refinement (details in reference)

- The stresses in some cases were very large

- The calculation procedure employed depended on the degradation mechanism

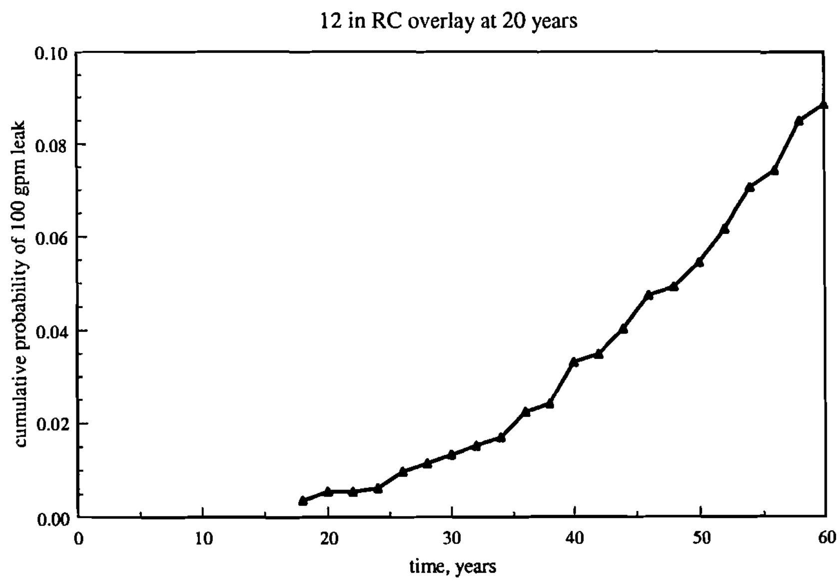
HL/PV	fatigue crack growth	WinPRAISE
	(PWSCC initiation & growth)	(modified WinPRAISE)
surge line	fatigue initiation & growth	pcPRAISE & ad hoc
HPI	fatigue initiation & growth	pcPRAISE & ad hoc
recirc	SCC initiation & growth	WinPRAISE
feedwater	fatigue initiation & growth	pcPRAISE & ad hoc

  - WinPRAISE is a windows version of pcPRAISE that is much easier to use, and provides same result as pcPRAISE for the same problem analyzed in the same manner

- An ad hoc procedure was used with pcPRAISE in order to obtain results for larger flow rates with reasonable computer time (the stratified sampling that is available for fatigue crack growth is not available for initiation)
  - The ad hoc procedure uses pcPRAISE for Monte Carlo simulation of failures (through-wall crack), with the length of any through-wall crack and the time that it first becomes through-wall printed out
  - The statistical distribution of through-wall cracks within a given time is analyzed and extrapolated to crack lengths corresponding to a given flow rate (which is a standard result from pcPRAISE)

- These analyses provide the failure probability of the dominant joint (highest failure probability)

- The <u>cumulative</u> probability of flow exceeding a given rate is obtained as a function of time



- Times of 25 years (now), 40 and 60 years are concentrated upon

- The average LOCA frequency within a given time interval is computed from the cumulative results

$$p(t_2) = \frac{P(t_2) - P(t_1)}{t_2 - t_1}$$

- The system LOCA frequency is obtained by multiplying by the number of locations within the system that have the high stresses of the dominant location

- Sensitivity calculations performed for each component

- One case for each component selected for system

- Hot leg/pressure vessel joint dominant for large piping in main coolant piping (highest stresses and temp)

- Sensitivity studies for HL/PV
  - fatigue crack growth relation (ASME code vs original PRAISE)
  - design limiting stresses (seismic)
  - PWSCC (initiation and growth)
  - material aging (reduced toughness with time)
  - proof test

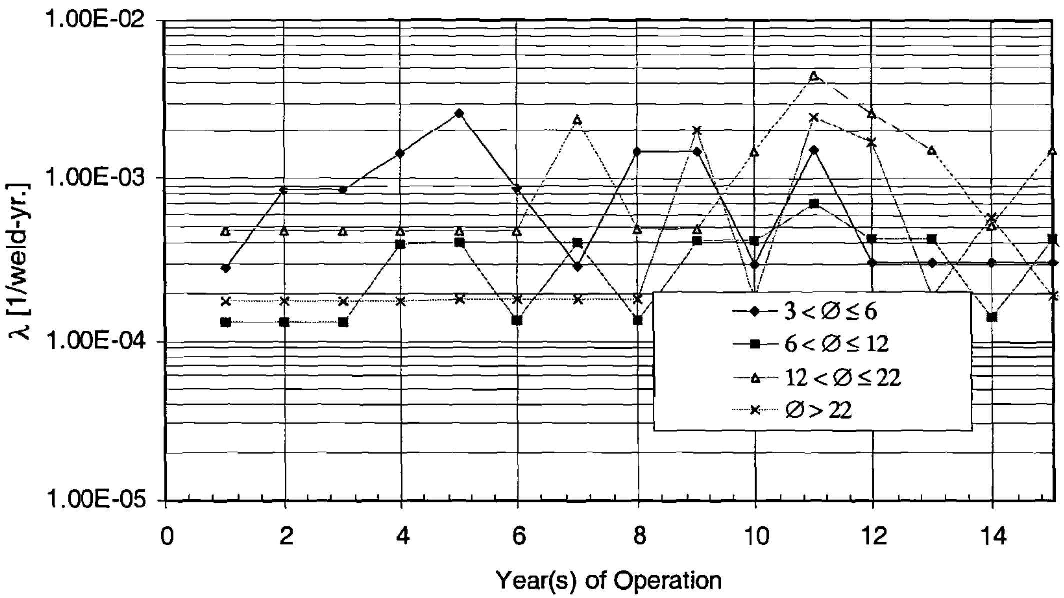
- PWSCC growth from initial defect with proof, no aging, residual stresses or seismic events selected as reference case

- Refined stresses used in surge line elbow analysis

- HPI/makeup nozzle analyzed with failed thermal sleeve (which has been observed in service), with immediate fatigue crack initiation and stresses as before.

- 12 inch recirculation line benchmarked with reported leaks and observations of cracks

- Leak observations in recirculation lines



from B. Lydell

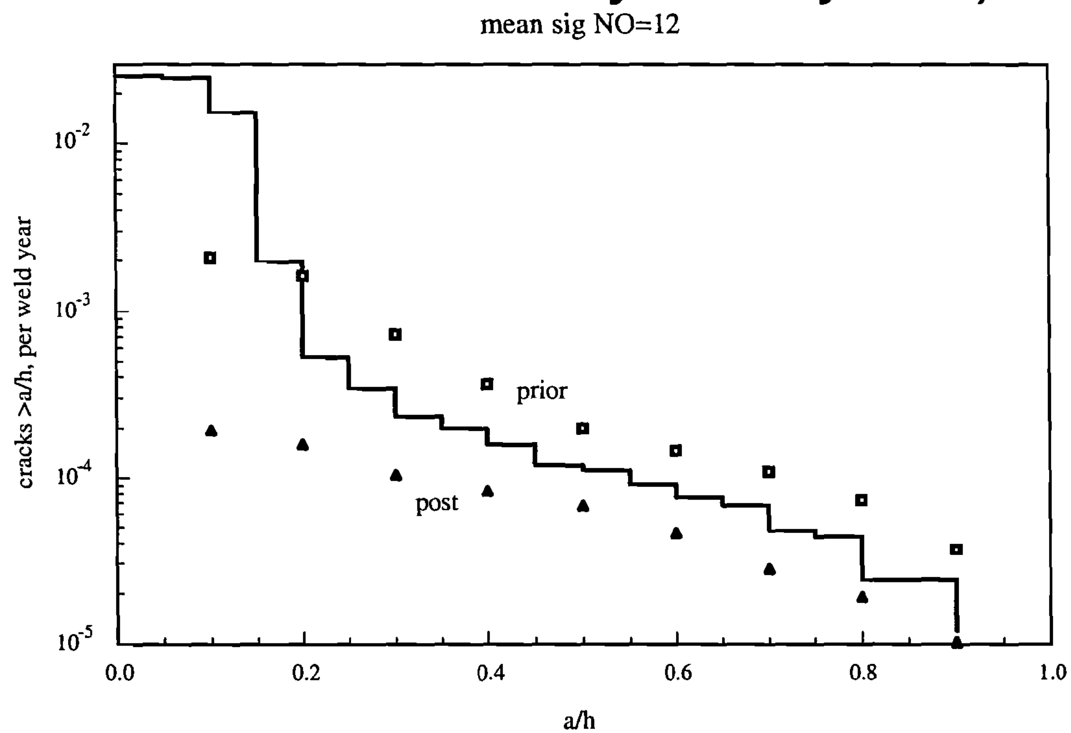
$10^{-4} - 10^{-3}$ per weld-year

- Results of PRAISE calculations
(12 in, leak frequencies, overlay at 20 years)

mean σ_{NO}	12	20
mean σ_{te}	5.32	13.32
cov	0.3	0
stdev of σ_{te}	1.6	0
	per weld joint	
0-25	6.15×10^{-4}	1.19×10^{-2}
25-40	2.36×10^{-4}	5.57×10^{-3}
40-60	9.25×10^{-4}	2.19×10^{-3}
no. dom. joints	49	2
no. in system	49	49
	system(x no. dom. joints)	
0-25	3.01×10^{-2}	2.38×10^{-2}
25-40	1.16×10^{-2}	1.11×10^{-2}
40-60	4.53×10^{-3}	4.38×10^{-3}
	ave per joint($\div$49)	
0-25	6.15×10^{-4}	4.86×10^{-4}
25-40	2.36×10^{-4}	2.24×10^{-4}
40-60	9.25×10^{-4}	8.94×10^{-5}

- Similar results for dominant joints vs all joints

- Comparison of observed and predicted cracks (PRAISE results for overlay at 20 years)



PRAISE results – lines. B. Lydell prior and post for with and without overlay. (outstanding P_{ND})

- Feedwater elbow selected as dominant joint. FAC is expected dominant degradation mechanism, but no probabilistic model available

- Results of sensitivity studies and benchmarking provided to panel

- Reference case for each base case recommended and summary of results provided to panel

Summary of Results for Reference Systems (July 2003)

			hot leg	surge	HPI	recirculation 12	recirculation 28	feedwater
		OD, in	34	14	3.44	12.75	28	12.75
		h, in	2.5	1.406	0.4375	0.687	1.201	0.687
		A, in^2	661	98.3	5.167	102	515	102
		Q_{max}	423	63	3.6	38	193	38
		matl	cast SS	SS	SS	SS	SS	CS
		degr mech	PWSCC growth	fatigue init&gro	fatigue init&gro	SCC init&gro	SCC init&gro	fatigue init&gro
		σ	Table 1	refined	Table 4	Table 5	Table 5	Table 6
		case	base no EQ	no EQ, no DL		overlay		σ_{flo}
		insp	0,20,40	none	none	0,20,40	0,20,40	none
dominant joint freq	>0	0-25	--	--	1.48×10^{-4}	1.19×10^{-2}	3.1×10^{-4}	$<4\times10^{-10}$
		25-40	--	5.8×10^{-3}	5.94×10^{-4}	5.57×10^{-3}	2.6×10^{-4}	3.8×10^{-7}
		40-60	--	1.6×10^{-6}	8.60×10^{-4}	2.19×10^{-3}	2.2×10^{-4}	1.3×10^{-5}
	>0.1	0-25	1.33×10^{-8}	--	2.60×10^{-5}	5.71×10^{-3}	3.0×10^{-5}	[redacted]
		25-40	1.33×10^{-8}	[illegible]$\times10^{-32}$	1.35×10^{-4}	1.30×10^{-3}	1.0×10^{-5}	
		40-60	1.33×10^{-8}	$<5\times10^{-9}$	1.32×10^{-4}	3.55×10^{-4}	$<5\times10^{-7}$	
	>1.5	0-25	1.6×10^{-11}	--	2.60×10^{-5}	4.26×10^{-3}	2.7×10^{-6}	
		25-40	1.6×10^{-11}	4.4×10^{-74}	1.35×10^{-4}	1.23×10^{-3}	--	
		40-60	1.6×10^{-11}	5.0×10^{-12}	1.32×10^{-4}	3.10×10^{-4}	3.0×10^{-6}	
	>5	0-25	4.6×10^{-13}	--		3×10^{-3}	2.4×10^{-6}	
		25-40	4.6×10^{-13}	--		1.23×10^{-3}	5.8×10^{-7}	
		40-60	4.6×10^{-13}	1.6×10^{-17}		3.10×10^{-4}	1.5×10^{-6}	
	>25	0-25	4.6×10^{-13}	--		1.96×10^{-3}	1.6×10^{-6}	
		25-40	4.6×10^{-13}	--		1.23×10^{-3}	$\sim2\times10^{-6}$	
		40-60	4.6×10^{-13}	9.8×10^{-15}		3.10×10^{-4}	1.7×10^{-6}	
	>100 **	0-25	3.6×10^{-14}				1.6×10^{-6}	
		25-40	3.6×10^{-14}				$\sim2\times10^{-6}$	
		40-60	3.6×10^{-14}				1.7×10^{-6}	
	field		22	3		20	22	29
	shop		12	9		20	30	22
	safe end		16	1		9	3	12
	dominant		**3**	**2**	**3**	**2**	**2**	**4**
system frequencies	>0	0-25	--	--	4.44×10^{-4}	2.38×10^{-2}		$<1.6\times10^{-9}$
		25-40	--	1.06×10^{-7}	1.78×10^{-3}	1.17×10^{-2}		1.5×10^{-6}
		40-60	--	3.2×10^{-6}	2.58×10^{-3}	4.82×10^{-3}		5.2×10^{-5}
	>0.1	0-25	4.0×10^{-8}	--	7.80×10^{-5}	1.15×10^{-2}		[redacted]
		25-40	4.0×10^{-8}	2×10^{-32}	4.05×10^{-4}	2.62×10^{-3}		
		40-60	4.0×10^{-8}	$<10^{-8}$	3.96×10^{-4}	7.10×10^{-4}		
	>1.5	0-25	4.8×10^{-11}	--	7.80×10^{-5}	8.52×10^{-3}		
		25-40	4.8×10^{-11}	8.8×10^{-74}	4.05×10^{-4}	2.46×10^{-3}		
		40-60	4.8×10^{-11}	1.0×10^{-11}	3.96×10^{-4}	6.20×10^{-3}		
	>5	0-25	1.4×10^{-12}	--		6×10^{-3}		
		25-40	1.4×10^{-12}	--		2.46×10^{-3}		
		40-60	1.4×10^{-12}	3.2×10^{-13}		6.20×10^{-4}		
	>25	0-25	1.4×10^{-12}	--		3.92×10^{-3}		
		25-40	1.4×10^{-12}	--		2.46×10^{-3}		
		40-60	1.4×10^{-12}	2.0×10^{-14}		6.20×10^{-4}		
	>100 **	0-25	1.1×10^{-13}			3.2×10^{-6}		
		25-40	1.1×10^{-13}			4×10^{-6}		
		40-60	1.1×10^{-13}			3.7×10^{-6}		

shaded areas are estimates based on alternative procedure
flow rates in thousands of gallons per minute
cross-hatched cells are beyond maximum leak capability for that pipe size
** also applicable to >500kgpm if hot leg is of sufficient diameter