UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D.C. 20555-0001

June 18, 2003

MEMORANDUM TO: Maggalean W. Weston
Senior Staff Engineer
ACRS

FROM: F. Peter Ford
Chairman
Materials and Metallurgy Subcommittee
ACRS

John D. Sieber
Chairman
Plant Operations Subcommittee
ACRS

SUBJECT: CERTIFICATION OF THE MINUTES OF THE MEETING OF THE ACRS SUBCOMMITTEES ON MATERIALS AND METALLURGY AND ON PLANT OPERATIONS, APRIL 22-23, 2003, ROCKVILLE, MD

I hereby certify that, to the best of my knowledge and belief, the minutes of the Materials and Metallurgy and Plant Operations subcommittees meeting on vessel head penetration cracking and vessel head degradation issued June 18, 2003, are an accurate record of the proceedings for that meeting.

F. Peter Ford, Chairman — Date: 6-19-03

John D. Sieber, Chairman — Date: 6-18-03

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D.C. 20555-0001

June 18, 2003

MEMORANDUM TO: F. Peter Ford
Chairman
Materials and Metallurgy Subcommittee
ACRS

John D. Sieber
Chairman
Plant Operations Subcommittee
ACRS

FROM: Maggalean W. Weston
Senior Staff Engineer
ACRS

SUBJECT: WORKING COPY OF THE MINUTES OF THE ACRS SUBCOMMITTEES ON MATERIALS AND METALLURGY AND ON PLANT OPERATIONS, APRIL 22-23, 2003, ROCKVILLE, MD

A working copy of the minutes for the Materials and Metallurgy and the Plant Operations subcommittees meeting on vessel head penetration cracking and vessel head degradation held on April 22-23, 2003, is attached for your review. Please provide me with any comments you might have.

Attachment:
As Stated

Certified by F. Peter Ford and John D. Sieber
July 19, 2003 and July 18, 2003

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
MATERIALS AND METALLURGY AND PLANT OPERATIONS SUBCOMMITTEES
VESSEL HEAD PENETRATION CRACKING AND RPV HEAD DEGRADATION
ROOM T-2B3, 11545 ROCKVILLE PIKE
ROCKVILLE, MARYLAND
April 22-23, 2003

INTRODUCTION

The ACRS subcommittees on Materials and Metallurgy and on Plant Operations held meetings on April 22 and 23, 2003, with representatives of the NRC staff, the Nuclear Energy Institute (NEI), the Electric Power Research Institute (EPRI) Materials Reliability Program (MRP). The purpose of this meeting was to hear information regarding the reactor vessel head inspection results, the revision of the MRP inspection plan, reactor vessel head penetration inspection activities, and North Anna Unit 2 reactor vessel head. Also, discussed were the Office of Research programs and activities to address CRDM cracking issues and Davis-Besse cavity exams and safety assessment, the status of NRC reactor vessel head inspections, and the plans for addressing the Davis-Besse lessons learned task force recommendations. Maggalean W. Weston was the cognizant ACRS staff engineer and designated federal official (DFO) for this meeting. There were no written comments provided by the public. The meeting was convened by the Materials and Metallurgy Subcommittee Chairman, Peter Ford, at 8:30 p.m. on April 22, 2003, and adjourned at 4:50 p.m. that day. the meeting reconvened at 8:30 a.m. on April 23, 2003, and adjourned at 2:20 p.m. that day.

ATTENDEES

Attendees at the meeting included ACRS members and staff, NRC staff, representatives of NEI, EPRI-MRP, and members of the public as follows.

ACRS Members/Staff

P. Ford, Chairman,	D. Powers, Member	G. Wallis, Member
J. Sieber, Co-Chairman	S. Rosen, Member	M. W. Weston, DFO
T. Kress, Member	W. Shack, Member	

NRC Staff

B. Bateman, NRR	B. Fu, NRR	M. Marshall, NRR
S. Bloom, NRR	A. Hiser, NRR	S. Moore, NRR
T. Chan, NRR	J. Hixon, RES	E. Reichelt, NRR
N. Chokshi, RES	D. Kalinousky, RES	C. Santos, RES
W. Cullen, RES	S. Lee, NRR	L. Wert, RES
R. Davis, NRR	B. Maroney, NRR	K. Wichman, NRR

Industry

T. Alley, Duke Energy	L. Mathews, EPRI (SNOC)	W. Sims, EOI
A. Marion, NEI	J. Riley, NEI	D. Steininger, EPRI

There were 5 other members of the public in attendance at this meeting. A list of those attendees who registered is attached to the office copy of these minutes.

PRESENTATIONS AND DISCUSSION

The presentations to the subcommittees and the related discussions are summarized below. The presentation slides and handouts used during the meeting are attached to the office copy of the minutes.

Chairman's Comments

Peter Ford, Chairman of the Materials and Metallurgy subcommittee, convened the meeting. John D. Sieber, Chairman of the Plant Operations subcommittee, co-chaired this effort. Dr. Ford stated that the purpose of the meeting was to discuss the vessel head penetration (VHP) cracking and vessel head degradation issues. He noted that this was a two day meeting and that the Committee had had a number of full committee and subcommittee meetings on these issues. Dr. Ford indicated the VHP degradation issue has been the subject of three bulletins and an order in the last couple of years. It covers a wide range of degradation phenomena; cracking, boric acid corrosion, inspection methods and strategy, repair and replacement decisions, plus the associated understanding of the various physical phenomena. He further stated that questions have been raised at various meetings and/or communications relating to, for instance, adequacy of crack predictions, inspection prioritization, algorithms for Alloy 600 and 182; prediction and, therefore, management of boric acid corrosion in VHP assemblies; factors of improvement for replacement Alloy 690; qualification of the inspection methods and their application periodicity; the review of the safety analyses; and also the impact of VHP observations on cracking of other components, for instance, pressurizers and the bottom head penetrations for PWRs and BWRs.

Richard Barrett, NRR, opened the meeting with comments about the ACRS' role in review of this topic - technically complex, important to safety, and requiring attention over a long period of time. Further, he indicated that because the belief had been that the reactor coolant system was impervious to failure, it was not analyzed as a part of the design basis. The agency approach to this situation has been a cycle of three phases. The first being interim compensatory measures, the second phase has been the imposition of robust requirements, and the third phase is the reexamination of those robust requirements to see if adjustments are appropriate.

Industry and NRC Staff Presentations

The industry presentations were made by Larry Mathews, EPRI-MRP and Southern Nuclear Operating Company (SNOC), David Steininger, EPRI-MRP and SGMP, Craig Harrington, EPRI-MRP and Texas Utilities (TXU), and Tom Alley, EPRI-MRP and Duke Energy.

The NRC presentations were made by Allen Hiser and Brendan Moroney of NRR and William Cullen and Cayetano Santos of the Office of Nuclear Regulatory Research (RES). Meena Khanna made some comments about the BWRVIP and South Texas. The topics covered were:

Industry
- Reactor Vessel Head Inspection Results
- Process for Revising the MRP Inspection Plan
- Status of Reactor Vessel Head Penetration Inspection Activities
- North Anna Unit 2 Reactor Vessel Head

NRC
- RES Programs on CRDM Cracking issues and Davis-Besse Exams and Safety Assessment
- Reactor Vessel Head Inspections
- Plans for Addressing Lessons Learned Task Force Recommendations

APRIL 22, 2003

Subcommittee Comments

Reactor Vessel Head Inspection Results

Larry Mathews of Southern Nuclear Operating Company and Chairman of the Alloy 600 Issues Task Group of the Materials and Reliability Program detailed the reactor vessel head inspection results up through February. He gave an overview of results by plant, indicating that half of the plants were completed.

- P. Ford asked if the issues with Sequoia had gone away. The response was that they have inspected- UT, PT of the weld, zero degree UT for erosion in the interference fit - and found no indications of degradation. They concluded that it was residual boron from their canopy seal weld leak ten years ago.

- G. Wallis asked about the leaks at South Texas and whether or not it was popcorn. The response was that any answer now would be premature, but that it did appear to be popcorn and could have come from the cavity seals in a cold condition.

- W. Shack asked if other plants had conducted eddy current exams as had North Anna. The response was that a few had. Most are doing volumetric.

- P. Ford asked if any of the units were inspected 100 percent. The response was that this was true.

- W. Shack asked if all of the detected flaws were in the 12 and higher EDY category, except Millstone. The response was yes and even Millstone was also at the borderline of that category.

- P. Ford asked if, apart from the operating temperature, there were anything in the B&W design or fabrication that would make it more susceptible. The response was that there is not a lot of differences. The weld sizes and the manufacturing process might be slightly different resulting in slightly different stresses. Another parameter not it the models is material properties.

- P. Ford asked about the Rotterdam fabrications. The response was that many of the weld flaws are from Rotterdam. Also the four Rotterdam manufactured vessels that have high head temperatures are being replaced. Sequoia, a cold head plant is evaluating what they need to do. All B&W plants are replacing their heads.

- P. Ford asked if there were any plans to improve the prioritization algorithms. The response was yes. They will used the North Anna head to investigate and hopefully get some answers that will help with the algorithm.

- P. Ford commented that many of the heads will be replaced with 690, and asked if any will be fabricated by Rotterdam. The response was that he did not think anyone was using Rotterdam.

Process for Revising the MRP Inspection Plan

David Steininger of EPRI talked about the process to revise the recommended inspection program for the top head. He indicated that the MRP inspection plan was essentially replaced by the requirements or suggestions provided in NRC Bulletin 2002-02. However, nothing suggests that the plan was invalid.

- G. Wallis asked if the inspection intervals chosen to insure safety implied anything about how rapidly things can occur. The response was yes, they thought they did. It means that you have to know the crack growth rates, the stress intensity factors and the boric acid situation, and how boric acid corrodes carbon steel.

- G. Wallis asked about the probability of detection for UT and ET methods. The response that at some point you have to define it.

- P. Ford asked about low temperature embrittlement of Alloy 690. The response was that its being looked at.

- P. Ford asked about the completion date for the safety assessment for cracked VHP assemblies. The response was that the safety assessment for the nozzles will be completed by late summer. The schedule for the remainder of the project has not been established.

- W. Shack commented that MRP 75 looked at an average plant and asked if more would be done to address the kind of range of variations that be possible. The response was that they would provide the answer later.

- P. Ford asked what the prioritization was for the work they planned to do. The response was that changes made to the work schedule may not deviate much what has already been ordered. There may be some recommendations about reinspection frequencies.

- P. Ford asked if the industry will continue to support the argument that temperature is the sole driving parameter. The response was that, no, they would not make that argument, but they would say it is a major driver.

Status of Reactor Vessel Head Penetration Inspection Activities

Tom Alley of Duke Energy and chair of the Alloy 600 ITG inspection working group talked about the inspection demonstration program over the past year or two relative to the inspection volume or volumetric inspection techniques.

- W Shack asked if, while doing volumetric inspections in the spring, any through wall cracks were found that did not produce a visual indication. The response was no, but they have some that are being debated. Therefore, it takes some technique other than visual to find those leaks. This is another reason to revise MRP 75.

- G. Wallis asked if any of the flaws found give false indications. The response was yes, and sorting them out is a very difficult task. Typically in an NDE, you like to have more than one piece of information to rely on for conclusions. It is preferable to see visual signs of leakage on the head and have that supported by volumetric examination for the detection of flaws.

- P. Ford and G. Wallis asked if there were acceptance criteria for the inspection demonstration project. The response was no. NRC staff also responded that they had reviewed the MRP document and found them to be acceptable. Also, staff indicated that they found the demonstrations of the inspections to be acceptable.

- D. Powers asked about the applicability of the results of tests to develop cracks that are artificially generated rather than produced by chemistry. The response was that it would be very difficult to use the actual samples because you have to cut them up to determine what was missed.

- M. Weston asked if the heads that are being replaced are candidates for looking at actual flaws that may have been missed. The response was that North Anna is.

RES Programs on CRDM Cracking issues and Davis-Besse Exams and Safety Assessment

William Cullen, NRC Office of Research discussed the RES effort regarding control rod drive mechanism cracking issues and what the office is doing to address some of the issues raised by the Davis-Besse event.

- D. Powers asked if this was an industry problem to fix and NRC's role should just be to assure that the vessel has sufficient integrity to be allowed to keep operating. The response was that there are two reasons. One is that we must do an accident sequence precursor analysis as a congressional requirement. The second reason is that there is enormous interest from a large number of stakeholders, internally and externally, the licensee, and the general public. Therefore, a reasonable amount of research is being done to address those specific interests.

- D. Powers responded the stakeholder interest could be served if the RES acted as a clearinghouse and reviewer of information generated by the industry. The response was that data now available do not model accurately the Davis-Besse experience.

- D. Powers asked that because we have Alloy 600 which we don't like because of cracks, and 690 which we like better because it is slower to crack, why aren't we excited about Alloy 800 which the Europeans are excited about. The response was the he did not know the answer to that.

- L. Mathews commented that stress and material properties are important to stress corrosion cracking, but they do not know enough about them at this time to include them in the rankings.

- D. Powers indicated that the Committee never sees a quantification of what is important and what is not. There was no response.

- T. Kress asked if one of the questions would be how big the hole has to be before the vessel fails. The response was that they were not sure if that would be a part of this study.

APRIL 23, 2003

Subcommittee Comments

Reactor Vessel Head Inspections

Allen Hiser discussed the licensees' last two refueling outage inspections. First he provided background information on the Order issued and the inspection requirements resulting from the order. Finally he talked about some relaxation requests received.

- P. Ford commented that during discussions with the French, the conclusion that the one gallon per minute technical specification leakage rate is inappropriate for vessel head penetrations. The response was that they would agree. However, you do also have technical specifications that say no reactor coolant pressure boundary leakage.

- S. Rosen asked if the leak at South Texas was the first time that boron deposits have been reported on the lower head that have resulted from leaks on the lower head. The response was yes, it appears to be.

- W. Shack asked about the reliability of the inspections for detection of a leak path. The response was that for nozzles that have had deposits on the head, the leak paths have been identified in every case.

- A. Hiser commented that the requests for relaxations have been relatively minor except one licensee who wanted to make UT measurements from under the head.

Plans for Addressing Lessons Learned Task Force Recommendations

Brendan Moroney and Cayetano Santo discussed the plan for addressing the actions and recommendations contained in the Davis-Besse Lessons Learned Task Force Report. There were 51 recommendations. The Senior Management Review Team deleted two of those. From this evolved four action plans: Stress Corrosion Cracking (SCC); Operating Experience Assessment; Inspection, Assessment, and Project Management; and Barrier Integrity.

- P. Ford asked if the SCC action plan included the bottom head penetrations. The response was no, it is focused on the pressure vessel head.

- P. Ford asked if the worldwide information on experience on corrosion and cracking was for operating experience or on data. The response was that it was for both.

- S. Rosen followed that question with a clarification. He wanted to know is it were data on research on SCC or if it were data on operating experience with plants that operate with materials susceptible to stress corrosion. The response was that they think it is the latter.

- P. Ford asked what was meant by having inspectors going into the plants to oversee inspections, and what is being used for quantitative guidance that it is being done correctly. The response was that now, there is no quantitative guidance. There are guidelines, standards, and techniques.

- M. Weston asked that since some leakage detection systems are in technical specifications, do you plan to consider possible technical specification changes. The response was yes, that's possible.

- P. Ford asked what do the French and Japanese do with regard to crack propagation and sound. The response was they did not know.

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: March 28, 2003.

Sher Bahadur,

Associate Director for Technical Support, ACRS/ACNW.

[FR Doc. 03–8206 Filed 4–3–03; 8:45 am]

BILLING CODE 7590–01–P

NUCLEAR REGULATORY COMMISSION

Advisory Committee on Reactor Safeguards, Meeting of the ACRS Subcommittee on Materials and Metallurgy; Notice of Meeting

The ACRS Subcommittee on Materials and Metallurgy will hold a meeting on April 22–23, 2003, Commissioners' Conference Room O–1G16, 11555 Rockville Pike, Rockville, Maryland.

The entire meeting will be open to public attendance.

The agenda for the subject meeting shall be as follows:

Tuesday and Wednesday, April 22–23, 2003—8:30 a.m. until the conclusion of business

The purpose of this meeting is to review NRC inspection requirements and guidance, Wastage Research, and the Electric Power Research Institute Materials Reliability Program (EPRI/MRP) and industry efforts related to vessel head penetration cracking and reactor pressure vessel head degradation. The Subcommittee will hear presentations by and hold discussions with representatives of the NRC staff, the EPRI/MRP, 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, Ms. Maggalean W. Weston (telephone 301/415–3151) five days prior to the meeting, if possible, so that appropriate arrangements can be made. Electronic recordings will be permitted.

Further information regarding this meeting can be obtained by contacting the Designated Federal Official between 8 a.m. and 5:30 p.m. (e.t.). 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: March 28, 2003.

Sher Bahadur,

Associate Director for Technical Support, ACRS/ACNW.

[FR Doc. 03–8205 Filed 4–3–03; 8:45 am]

BILLING CODE 7590–01–P

NUCLEAR REGULATORY COMMISSION

Advisory Committee on Reactor Safeguards, Meeting of the Subcommittee on Reactor Fuels; Notice of Meeting

The ACRS Subcommittee on Reactor Fuels will hold a meeting on April 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:

Monday, April 21, 2003—10 a.m. until the conclusion of business

The purpose of this meeting is to review the Duke Cogema Stone & Webster construction application request resubmittal for a mixed oxide (MOX) fuel fabrication facility. The Subcommittee will hear presentations by and hold discussions with representatives of the NRC staff, Duke Cogema Stone & Webster, 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, Ms. Maggalean W. Weston (telephone 301/415–3151) five days prior to the meeting, if possible, so that appropriate arrangements can be made. Electronic recordings will be permitted.

Further information regarding this meeting can be obtained by contacting the Designated Federal Official between 8 a.m. and 5:30 p.m. (e.t.). 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: March 28, 2003.

Sher Bahadur,

Associate Director for Technical Support, ACRS/ACNW.

[FR Doc. 03–8207 Filed 4–3–03; 8:45 am]

BILLING CODE 7590–01–P

NUCLEAR REGULATORY COMMISSION

Notice of Availability of Model Application Concerning Technical Specification Improvement To Modify Requirements Regarding Mode Change Limitations Using the Consolidated Line Item Improvement Process

AGENCY: Nuclear Regulatory Commission.

ACTION: Notice of availability.

SUMMARY: Notice is hereby given that the staff of the Nuclear Regulatory Commission (NRC) has prepared a model application relating to the modification of requirements regarding technical specifications (TS) mode change limitations. The purpose of this model is to permit the NRC to efficiently process amendments that propose to modify requirements for TS mode change limitations as generically approved by this notice. Licensees of nuclear power reactors to which the model applies could request amendments utilizing the model application.

DATES: The NRC staff issued a Federal Register Notice (67 FR 50475, August 2, 2002) which provided a model safety evaluation relating to modification of requirements regarding TS mode change limitations;[1] similarly, the NRC staff, herein provides a Model Application, including a revised model safety evaluation. The NRC staff can most efficiently consider applications based upon the Model Application, which reference the model safety evaluation, if the application is submitted within a year of this **Federal Register** Notice.

FOR FURTHER INFORMATION CONTACT: Robert Dennig, Mail Stop: O–12H4, Division of Regulatory Improvement Programs, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, Washington, DC 20555–0001, telephone 301–415–1161.

[1] [In conjunction with the proposed change, technical specifications (TS) requirements for a bases control program, consistent with the TS Bases Control Program described in Section 5.5 of the applicable vendor's standard TS (STS), shall be incorporated into the licensee's TS, if not already in the TS. Similarly, the STS requirements of SR 3.0.1 and associated bases shall be adopted by units that do not already contain them.]

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
MATERIALS & METALLURGY AND PLANT OPERATIONS SUBCOMMITTEES
VHP CRACKING AND RPV HEAD DEGRADATION
ROOM T-2B3, 11545 ROCKVILLE PIKE, ROCKVILLE, MARYLAND

April 22, 2003

- PROPOSED AGENDA -

	SUBJECT	PRESENTER	TIME
I.	Introductory Remarks Subcommittee Chairmen	F.P. Ford, ACRS J.D. Sieber, ACRS	8:30 - 8:35 a.m.
II.	Overview of NRC Activities	Richard Barrett, NRR	8:35 - 8:50 a.m.
III.	Industry Positions on RPV Head and VHP Nozzle Inspections	Christine King, MRP Larry Mathews, MRP Craig Harrington, MRP Tom Alley, MRP	8:50 - 10:15 a.m.
		*******BREAK*******	10:15 - 10:30 a.m.
IV.	Industry Positions on RPV Head and VHP Nozzle Inspections (Continued)	Christine King, MRP Larry Mathews, MRP Craig Harrington, MRP Tom Alley, MRP	10:30 - 12:00 noon
		*******LUNCH*******	12:00 - 1:00 p.m.
V.	Industry Positions on RPV Head and VHP Nozzle Inspections (Continued)	Christine King, MRP Larry Mathews, MRP Craig Harrington, MRP Tom Alley, MRP	1:00 - 2:30 p.m.
		*******BREAK*******	2:30 - 2:45 p.m.
VI.	NRC Sponsored Research	William Cullen, RES	2:45 - 4:45 p.m.
VII.	General Discussion and Adjournment		4:45 - 5:30 p.m.

Note: Presentation time should not exceed 50% of the total time allocated for a specific item. Number of copies of presentation materials to be provided to the ACRS - 40.

ACRS CONTACT: Maggalean W. Weston, mww@nrc.gov or (301) 415-3151.

AGENDA DETAILS

	SUBJECT	"SUBTOPICS"
	April 22, 2003	
I.	Overview of NRC Activities	
II.	Discussion of Industry Positions re RPV Head and VHP Nozzles Inspection	Proposed Changes to MRP-75; Baseline Examinations; Recent RPV Head and VHP Nozzles Inspection Results; North Anna Unit 2 RPV Head; NDE Demonstration Program
III.	Discussion of NRC Sponsored Research	Low Alloy Steel Corrosion; Crack Growth Rate Propagation
	April 23, 2003	
IV.	Discussion of NRC Inspection Requirements and Guidance	Summary of Responses to BL 2002-02;Recent RPV Head and VHP Nozzles Inspection Results; Current NRC Inspection Requirements; Comparison to French Requirements
V.	Discussion of "LLTF" Action Plans	Overview of the four action plans

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
MATERIALS & METALLURGY AND PLANT OPERATIONS SUBCOMMITTEES
VHP CRACKING AND RPV HEAD DEGRADATION
COMMISSIONERS' CONFERENCE ROOM (O-1G16)
11545 ROCKVILLE PIKE, ROCKVILLE, MARYLAND

April 23, 2003

- PROPOSED AGENDA -

	SUBJECT	PRESENTER	TIME
I.	Introductory Remarks Subcommittee Chairmen	F.P. Ford, ACRS J.D. Sieber, ACRS	8:30 -8:35 a.m.
II.	NRC Inspection Requirements and Guidance	Allen Hiser, NRR	8:35 - 10:00 a.m.
		*****BREAK*****	10:00 - 10:15 a.m.
III.	NRC Inspection Requirements and Guidance (Continued)	Allen Hiser, NRR	10:15 - 11:30 a.m.
		*****LUNCH*****	11:30 - 12:30 p.m.
IV.	LLTF Action Plans	Brendan Moroney, NRR Cayetano Santos, RES	12:30 - 2:00 p.m.
V.	General Discussion and Adjournment		2:00 - 3:00 p.m.

Note: Presentation time should not exceed 50% of the total time allocated for a specific item. Number of copies of presentation materials to be provided to the ACRS - 40.

ACRS CONTACT: Maggalean W. Weston, mww@nrc.gov or (301) 415-3151.

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
SUBCOMMITTEE MEETING ON MATERIALS AND METALLURGY

APRIL 23, 2003

ATTENDEES PLEASE SIGN IN BELOW
PLEASE PRINT

NAME	AFFILIATION
Paul Gunter	NIRS
Larry Mathews	Southern Nuclear Op. Co.
Jim Riley	NEI
Daniel Horner	McGraw-Hill
Althea Wyche	SERCH Licensing/Bechtel

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
SUBCOMMITTEE MEETING ON MATERIALS AND METALLURGY

APRIL 22-23, 2003

APRIL ~~23,~~ 22 2003
TODAY'S DATE

NRC STAFF PLEASE SIGN IN BELOW

PLEASE PRINT

NAME	NRC ORGANIZATION
✓ Bill Cullen	RES/DET/MEB
✓ Allen Hiser	NRR/DE/EMCB
Terence Chan	NRR/DE/EMCB
Richard Barrett	NRR/DE
Leonard Wert	RES/DET/MEB
E Reichelt	NRR/DE/EMCB
✓ Keith Wichman	NRR/DE/EMCB
✓ Michael Marshall	NRC/NRR/DLPM
✓ Steve Bloom	NRC/NRR/DLPM

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
SUBCOMMITTEE MEETING ON MATERIALS AND METALLURGY

APRIL 22-23, 2003

APRIL 22, 2003
TODAY'S DATE

NRC STAFF PLEASE SIGN IN BELOW

PLEASE PRINT

NAME	NRC ORGANIZATION
✓ Steve Bloom	NRR/DLPM
Tom	
Cayetano Santos	RES/DET
JEFF HIXON	RES/DET/MEB
BRENDAN MORONEY	NRR/DLPM
Bob DAVIS	NRR/EMCB
Nilesh Chokshi	RES/DET/MEB

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
SUBCOMMITTEE MEETING ON MATERIALS AND METALLURGY

APRIL 22-23, 2003

APRIL 23, 2003
TODAY'S DATE

NRC STAFF PLEASE SIGN IN BELOW

PLEASE PRINT

NAME	NRC ORGANIZATION
ERIC REICHELT	NRR/DE/EMCB
✓Allen Hiser	NRR/DE/EMCB
✓KEITH W	"
Bart Fu	NRR/DE/EMCB
✓~~Mich~~ Michael Marshall	NRR/DLPM/PDII
✓Steve Bloom	NRR/DLPM/PDII
Samuel Lee	NRR/DRIP/RORP
Scott W Moore	NRR/DLPM/PDII

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
SUBCOMMITTEE MEETING ON MATERIALS AND METALLURGY

APRIL 22-23, 2003

APRIL 23, 2003
TODAY'S DATE

NRC STAFF PLEASE SIGN IN BELOW

PLEASE PRINT

NAME	NRC ORGANIZATION
Steve Bloom	NRR/DLPM
Brendan Moroney	NRR/DLPM
Jeff Hixon	RES/DET/MEB
Don Dube	RES/DRAA/OERAB
Cayetano Santos	RES/DET/MEB
Nilesh Chokshi	RES/DET/MEB
Douglas Kalinousky	Res/DET/MEB

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
SUBCOMMITTEE MEETING ON MATERIALS AND METALLURGY

APRIL 22-23, 2003

ATTENDEES PLEASE SIGN IN BELOW
PLEASE PRINT

NAME	AFFILIATION
A MARION	NEI
Laniel Horner	McGraw-Hill
Paul Gunter	NIRS
William Sims	FOI
Altheia Wyche	Bechtel/SERCH

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
SUBCOMMITTEE MEETING ON MATERIALS AND METALLURGY

APRIL 22-23, 2003

ATTENDEES PLEASE SIGN IN BELOW
PLEASE PRINT

NAME	AFFILIATION
Tom Alley	DUKE-ENERGY
Larry Mathews	Southern Nuclear
JIM RILEY	NEI
DAVID STEININGER	EPRI

Process for Revising the MRP Inspection Plan

Advisory Committee on Reactor Safeguards
Materials & Metallurgy and
Plant Operations Subcommittees

Vessel Head Penetration Cracking and
RPV Head Degradation

April 21, 2003
Room T-2B3
11545 Rockville Pike
Rockville, Maryland

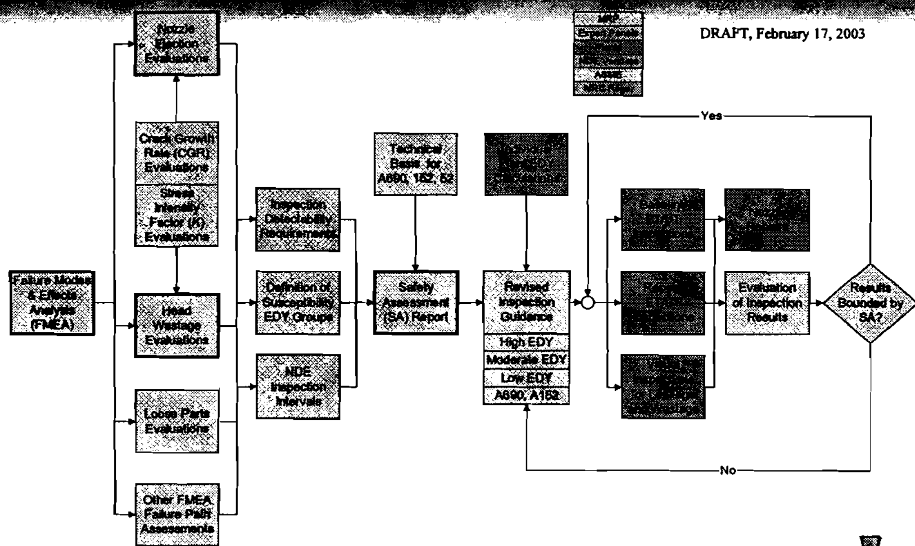
David A. Steininger
EPRI, MRP and SGMP
Craig Harrington, TXU
MRP Alloy 600/82/182 ITG
RV Head Working Group Chairman

Lead Mgr at EPRI — Christine King and Craig Harrington } Both work for him

Topics

- Overall Safety Assessment Process
- Transition to Combination Baseline Inspections with Inspection Intervals Chosen to Ensure Safety
- Failure Modes and Effects Analysis
- Main Evaluations
  - Nozzle Ejection
  - Head Wastage
- Supporting Evaluations
  - Crack Growth Rates
  - Stress Intensity Factors
  - Proposed Additional Boric Acid Corrosion Testing
- Schedule for Issuing Revised Inspection Plan and Safety Assessment Report

Overall Process Flowchart



Safety Assessment Process: Key Points

- The MRP approach is transitioning to ensuring safety through "combination" baseline inspections at all plants with:
  - The timing for the baseline inspection and the re-inspection interval based on the technical evaluations and
  - More frequent bare metal visual (BMV) inspections providing backup to the program of periodic combination inspections
- The revised MRP inspection plan will be formed on the basis of a comprehensive safety assessment (SA) report
- The SA report:
  - Begins with a failure modes and effects analysis (FMEA) to anticipate the possibility of failure modes that have not been observed in the field and
  - Includes the analysis tools previously developed and described in MRP-75

Safety Assessment Process: Key Points (cont'd)

- The results of the FMEA are used to establish the required technical evaluations and ultimately the inspection detectability requirements
- Existing calculations show that non-visual inspections do not have to be performed every refueling outage to ensure safety
  - Extremely low probability of nozzle ejection and significant wastage
  - Extremely small consequential increase in core damage frequency, consistent with NRC Reg. Guide 1.174

Combination Baseline Inspections

- Subsequent to the release of the MRP-75 inspection plan and technical bases and in light of the most recent inspections results, the MRP has released a letter to the industry recommending a transition to combination baseline inspections
- Three types of combinations inspections:
  - (UT/BMV) UT of the base metal from the tube ID and bare-metal visual (BMV)
  - (UT/ET) UT of the base metal from the tube ID and ET/PT of the weld surface
  - (ET/ET) ET of the base metal ID and OD and ET/PT of the weld surface
- The timing of the baseline inspection and the inspection interval will be based on the technical evaluations to ensure safety

Combination Baseline Inspections (cont'd)

- Time at temperature (EDYs) will continue to form the basis for the susceptibility groups
- It is expected that high susceptibility plants will perform the combination baseline inspection by the next refueling outage
- It is expected that moderate susceptibility plants will perform the baseline inspection by approximately 2005 at the latest
- It is expected that low susceptibility plants will perform the baseline inspection by approximately 2007 at the latest

Failure Modes and Effects Analysis: Introduction

- FMEA is a technique of TQM (Total Quality Management) to ensure product reliability
- Typically, a table of the following characteristics of the possible failure modes is prepared:
  - Cause
  - Effect (consequence)
  - Detectability
  - Frequency of Occurrence
- Relationships among the failure modes are illustrated using a block diagram
- FMEA is a tool that helps anticipate new failure modes

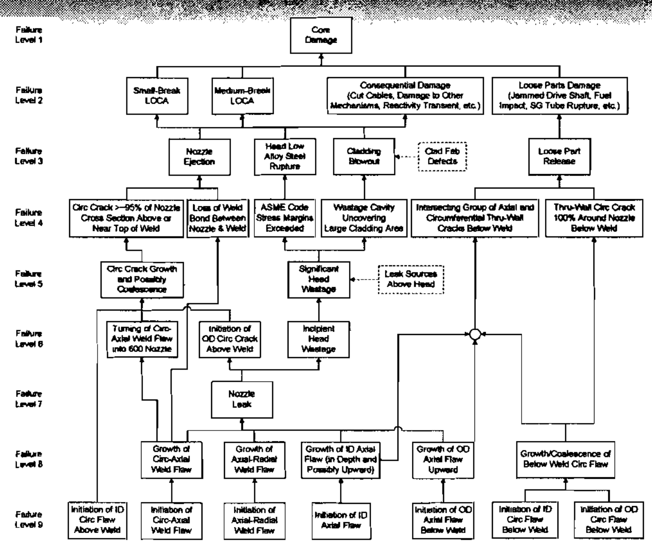
Failure Modes and Effects Analysis: Application to RVH Nozzles

- For RVH penetrations, there are three principal failure modes:
  - Nozzle Ejection Due to Net Section Collapse
  - Cladding Blowout Due to Wastage
  - RCS Damage Due to Loose Parts Generation
- There are several levels in the failure process for these modes:
  - PWSCC initiation (nozzle ID, nozzle OD below weld, weld surface)
  - PWSCC growth (axial and circ in nozzle, axial-radial and circ-axial in weld; weld to nozzle and nozzle to weld; turn from axial to circ)
  - Leakage to annulus (new crack initiation and low-alloy steel wastage)
  - Growth to allowable size / wastage until code allowable stresses are reached
  - Growth to net section collapse or loose parts release / wastage to cladding blowout
  - Small/medium LOCA and possible consequential damage / loose parts damage
  - Effect on core damage frequency (CDF)

EPRI

Failure Modes and Effects Analysis: Simplified Block Diagram

PRELIMINARY



EPRI

Failure Modes and Effects Analysis: Classification of Failure Conditions

- Each failure condition will be classified as:
  - Not credible,
  - Not actionable, or
  - Actionable
- A classification as "not credible" will require a strong technical argument and thorough documentation with a high threshold
- A classification as "not actionable" requires that adequate protection be provided at a higher level in the failure process
- Conditions classified as "actionable" will be inputs to the probabilistic and deterministic evaluations and will ultimately shape the detectability requirements specified in the inspection plan

Failure Modes and Effects Analysis: Additional Higher Order Factors

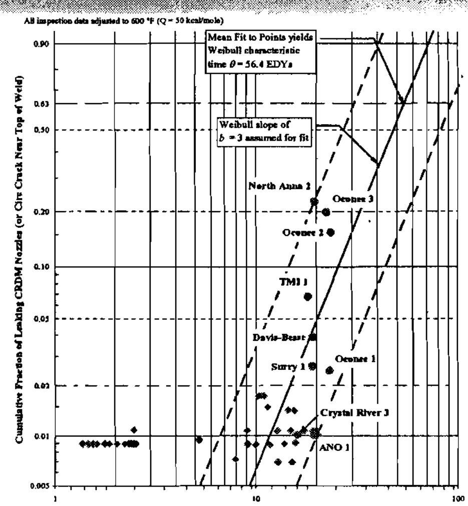
- Additional factors being considered in the FMEA include:
  - Environmental fatigue
  - Fabrication practices such as nozzle straightening or nickel plating
  - Surface and imbedded flaws produced during fabrications such as welding lack of fusion and hot cracking
  - The condition of the inside surface cladding
  - Primary water chemistry factors such as resin intrusions
  - Leaks from sources above the head
  - Plant-specific differences in the air flow across the head top surface

Failure Modes and Effects Analysis: Frequency of Occurrence

- Weibull reference curves based on the latest inspection results
  - Plant experience may support different curves for different nozzle material suppliers and different weld fabricators
- Crack growth rates based on MRP-55 and stress intensity factor calculations
- Existing small- and medium-break LOCA analyses
- Consequential damage assessments
- Loose parts damage assessments

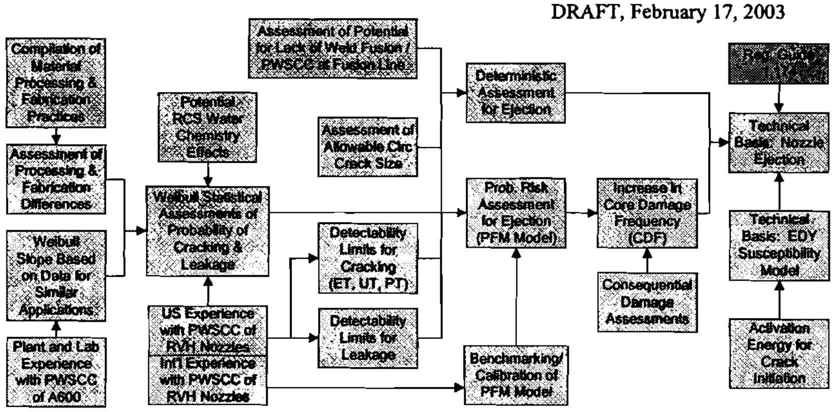
Failure Modes and Effects Analysis: Example Weibull Plot

- Plot covers all plants
- Leakage (or circ crack near weld root) due to base metal and weld metal initiated cracking combined on this plot
- Diamonds conservatively represent 42 plants that did not detect any leakage during BMV inspections



Main Evaluations: Nozzle Ejection

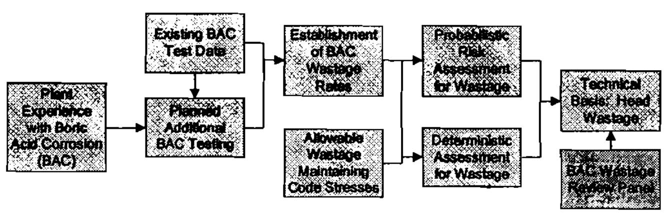
DRAFT, February 17, 2003



EPRI

Main Evaluations: Head Wastage

DRAFT, February 17, 2003



EPRI

Supporting Evaluations: Crack Growth Rates

- The MRP report addressing the crack growth rates (CGRs) of Alloy 600 base metal (MRP-55) was formally submitted to the NRC in September 2002
- The EPRI-MRP expert panel on CGRs has completed preliminary assessments of Alloy 182 and 82 weld metal
- A report addressing the weld metal will be produced after additional data is produced, collected, and evaluated
- The expert panel will meet in late March in Washington, DC around the NRC conference to discuss the weld metal evaluations

Supporting Evaluations: Stress Intensity Factors

- Stress intensity factor calculations have been completed for several CRDM nozzle geometries
- Comparison to date with the results produced by the NRC contractor have shown good agreement
- Additional work will be used to bound the magnitude of the stress intensity factors as a function of nozzle and weld geometry and material properties (e.g., nominal nozzle tube yield strength)
- The stress intensity factors are a secondary influence behind the crack growth rates on the probability of nozzle ejection

Supporting Evaluations: Boric Acid Corrosion (BAC) Testing

- The MRP has completed scoping work to define the types of testing that are appropriate to produce key BAC data that are not available
  - Analysis work to understand the thermal-hydraulic and chemical environments along the leak path
  - Analysis work to define the key parameters that drive the corrosion and erosion processes in the nozzle crevice
  - A probabilistic wastage model to assess the risk of producing a wastage cavity large enough to result in shell stresses exceeding the ASME code allowables (Appendices C, D, and E of MRP-75, Rev. 1)
  - An expert panel to review the probabilistic wastage model
- The MRP is in the process of requesting proposals for performing the needed testing including mock-up testing
  - BAC testing work is expected to be awarded in May 2003

Deliverables and Schedule

- A comprehensive safety assessment (SA) report will form the basis for a revised MRP inspection plan
- As appropriate, the SA report will reference other reports (e.g., the MRP report on crack growth rates of Alloy 600—MRP-55)
- Some calculations remain to be revised and extended, but much of the material to be incorporated into the SA report has already been completed in support of MRP-75
- Data developed subsequent to the initial release of the SA report will be evaluated for consistency with the SA evaluations once such data become available
- The MRP expects to be prepared to discuss the contents of the SA and the revised inspection plan summer 2003
- In the meantime, technical discussions with the NRC staff will continue

Reactor Vessel Head Inspection Results

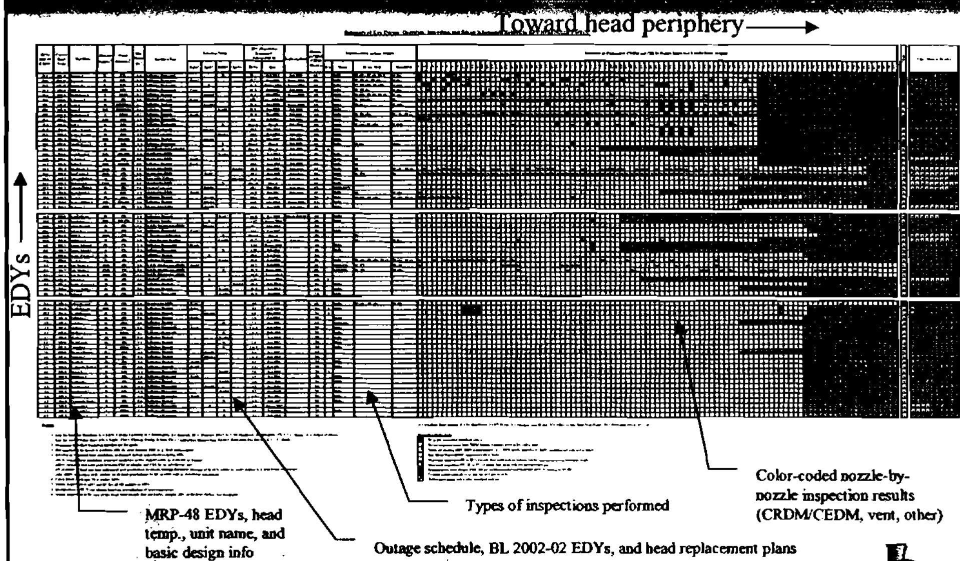
Advisory Committee on Reactor Safeguards
Materials & Metallurgy and
Plant Operations Subcommittees

Vessel Head Penetration Cracking and
RPV Head Degradation

April 21, 2003
Room T-2B3
11545 Rockville Pike
Rockville, Maryland

Larry Mathews, SNOC
MRP Alloy 600/82/182
Issue Task Group Chairman

- Overview Table of Inspection Results by Plant
- Subpopulation Summary Statistics
  - By EDY Group
  - By Head Fabricator and Tubing Supplier
  - Detected Circumferential Cracks
- Inspection Plans for Spring 2003 Outages



EPRI

- The overview table graphically shows:
  - The extent to which the fleet has been inspected
  - The extent of detected cracking, leakage, and wastage correlated with effective degradation time (EDYs) and position on the head
  - Key operating and design data
  - Refueling outage schedule and current head replacement plans
- The overview table complements more detailed outage-specific and defect-specific inspection results tables that are used to generate statistical (i.e., Weibull) fits
- The MRP plans to release a revision to the table at the end of each outage season

EPRI

No.	Unit	NSSS Supplier	Approx. EDYs at Inspection	Date	*Number of Nozzles on Head* CRDM	CEDM	ICI	*Total*	*Nozzles Inspected by Non-Visual* *Total*	*Total %*	*No. Leaking Nozzles/ Welds* *Leaking*	*% of Total Inspected*	*No. Cracked Nozzles/ Welds* *Cracked*	*% of Total Inspected*	*No. Nozzles with Base Metal Cracks*	*No. Nozzles with Weld Metal Cracks*	*No. Nozzles with Axial Cracks*	*No. Nozzles with Circ. Cracks*
1	ANO 1	B&W	19.6	Mar-2001	69			69	1	1.4%	1	100.0%	1	100.0%	1	0	1	1
2	ANO 1	B&W	21.1	Oct-2002	69			69	69	100.0%	1	1.4%	8	11.6%	8	8	8	0
3	Cook 2	W	13.9	Jan-2002	78			78	78	100.0%	0	0.0%	2	2.6%	2	0	2	0
4	Crystal River 3	B&W	16.2	Oct-2001	69			69	9	13.0%	1	11.1%	1	11.1%	1	1	1	1
5	Davis-Besse	B&W	19.2	Apr-2002	69			69	69	100.0%	3	4.3%	5	7.2%	5	0	5	1
6	Millstone 2	CE	11.2	Feb-2002		69	8	77	77	100.0%	0	0.0%	3	3.9%	3	1	3	2
7	North Anna 1	W	20.0	Oct-2001	65			65	30	46.2%	0	0.0%	6	20.0%	6	0	6	0
8	North Anna 2	W	19.0	Nov-2001	65			65	3	4.6%	3	100.0%	3	100.0%	3	3	3	0
9	North Anna 2	W	19.7	Sep-2002	65			65	65	100.0%	6	9.2%	42	64.6%	7	42	1	6
10	Oconee 1	B&W	21.8	Nov-2000	69			69	18	26.1%	1	5.6%	1	5.6%	1	1	1	0
11	Oconee 1	B&W	23.2	Mar-2002	69			69	5	7.2%	1	20.0%	3	60.0%	3	1	3	0
12	Oconee 2	B&W	22.2	Apr-2001	69			69	4	5.8%	4	100.0%	4	100.0%	4	4	4	1
13	Oconee 2	B&W	23.7	Oct-2002	69			69	69	100.0%	7	10.1%	15	21.7%	15	5	10	0
14	Oconee 3	B&W	21.7	Feb-2001	69			69	18	26.1%	9	50.0%	10	55.6%	10	0	10	5
15	Oconee 3	B&W	22.5	Nov-2001	69			69	52	75.4%	5	9.6%	7	13.5%	7	2	7	2
16	Surry 1	W	19.1	Oct-2001	65			65	16	24.6%	2	12.5%	6	37.5%	0	6	0	0
17	TMI 1	B&W	18.1	Oct-2001	69			69	12	17.4%	5	41.7%	7	58.3%	7	4	7	0
Totals for Inspections Since First U.S. Leakage (11/2000)					3871	1090	94	5055	1462	28.9%	47	3.2%	120	8.2%	82	75	71	19

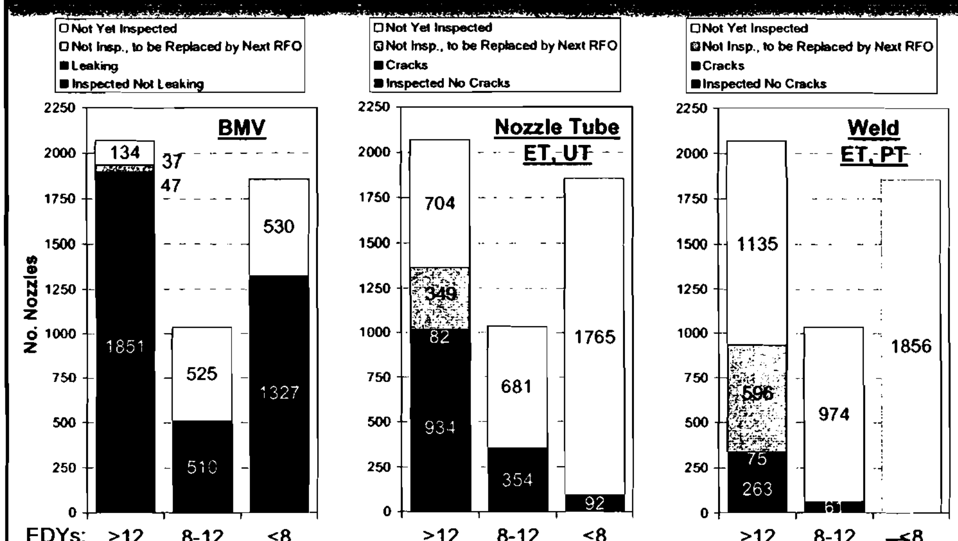
NOTE: The table does not reflect the small-diameter thermocouple nozzles found to be cracked and leaking at Oconee 1 and TMI 1. (These are the only two plants that have this type of nozzle.)

EPRI

EDY at Next RFO	No. Units	BMV No. Units 100% Inspected	BMV No. Nozzles Inspected	Nozzle Tube ET/UT No. Units 100% Inspected	Nozzle Tube ET/UT No. Nozzles Inspected	Weld ET/PT No. Units 100% Inspected	Weld ET/PT No. Welds Inspected
>12 EDY	30	27 (90%)	1898 (92%)	13 (43%)	1016 (49%)	3 (10%)	338 (16%)
8–12 EDY	15	8 (53%)	510 (49%)	4 (27%)	354 (34%)	0 (0%)	61 (6%)
< 8 EDY	24	17 (71%)	1327 (71%)	0 (0%)	92 (5%)	0 (0%)	1 (0%)
Totals	69	52 (75%)	3735 (75%)	17 (25%)	1462 (29%)	3 (4%)	400 (8%)

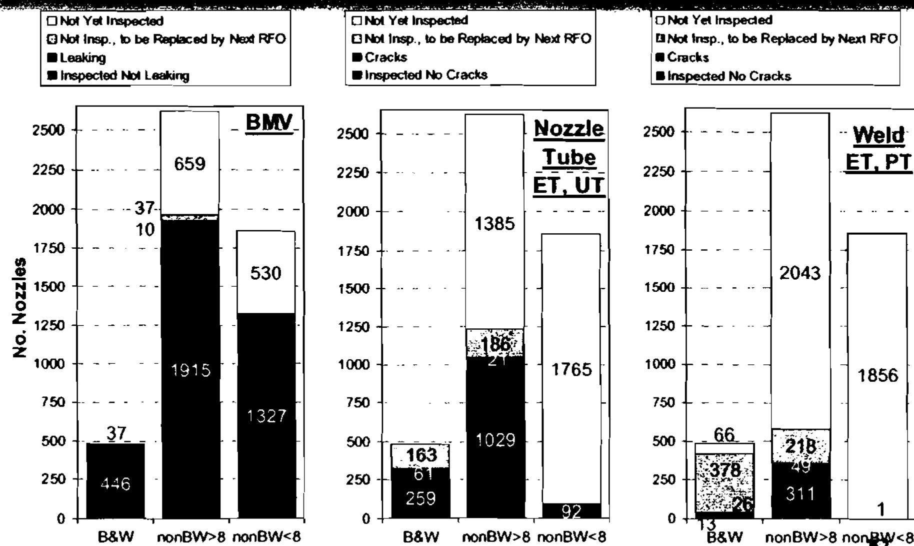
EPRI

EDY at Next RFO	No. Nozzles	Leaking Nozzles: Nozzles Leaking (Inspected)	Leaking Nozzles: % Leaking	Nozzle Tubes Cracked: Nozzles Cracked (Inspected)	Nozzle Tubes Cracked: % Cracked	Welds Cracked: Welds Cracked (Inspected)	Welds Cracked: % Cracked
>12 EDY	2069	47 (1898)	2.5%	82 (1016)	8.1%	75 (338)	22.2%
8–12 EDY	1035	0 (510)	0.0%	0 (354)	0.0%	0 (61)	0.0%
< 8 EDY	1857	0 (1327)	0.0%	0 (92)	0.0%	0 (1)	0.0%
Totals	4961	47 (3735)	1.3%	82 (1462)	5.6%	75 (400)	18.8%



NSSS Supplier / EDY at Next RFO	No. Units	BMV		Nozzle Tube ET/UT		Weld ET/PT	
		No. Units 100% Inspected	No. Nozzles Inspected	No. Units 100% Inspected	No. Nozzles Inspected	No. Units 100% Inspected	No. Welds Inspected
B&W NSSS	7	7 (100%)	483 (100%)	4 (57%)	320 (66%)	0 (0%)	39 (8%)
non-B&W > 8 EDY	38	28 (74%)	1925 (73%)	13 (34%)	1050 (40%)	3 (8%)	360 (14%)
non-B&W < 8 EDY	24	17 (71%)	1327 (71%)	0 (0%)	92 (5%)	0 (0%)	1 (0%)
Totals	69	52 (75%)	3735 (75%)	17 (25%)	1462 (29%)	3 (4%)	400 (8%)

NSSS Supplier / EDY at Next RFO	No. Nozzles	Leaking Nozzles		Nozzle Tubes Cracked		Welds Cracked	
		Nozzles Leaking (Inspected)	% Leaking	Nozzles Cracked (Inspected)	% Cracked	Welds Cracked (Inspected)	% Cracked
B&W NSSS	483	37 (483)	7.7%	61 (320)	19.1%	26 (39)	66.7%
non-B&W > 8 EDY	2621	10 (1925)	0.5%	21 (1050)	2.0%	49 (360)	13.6%
non-B&W < 8 EDY	1857	0 (1327)	0.0%	0 (92)	0.0%	0 (1)	0.0%
Totals	4961	47 (3735)	1.3%	82 (1462)	5.6%	75 (400)	18.8%



EPRI

- The total RVH nozzle population includes 3871 CRDM nozzles, 1090 CEDM nozzles, and 94 ICI nozzles at 69 units
- Bare-metal visual (BMV) and/or non-visual NDE inspections have now been performed on about 81% of the RVH nozzles
  - About 47 nozzles have been found to be leaking
- Almost 8% of the nozzles in B&W plants have leaked, but leakage in non-B&W plants is limited to North Anna 2 and Surry 1 leakage, which is primarily due to weld cracking
- Non-visual examinations have been performed on:
  - About half of the ">12 EDY" nozzles and a third of the "8-12 EDY" nozzles
  - About two-thirds of the nozzles in B&W plants and 25% of the nozzles in non-B&W plants

EPRI

- About 19% of the inspected B&W plant nozzles show base metal cracking
- Base metal cracking in non-B&W plants is limited to Millstone 2 (3 nozzles) and Cook 2 (1 nozzle), although North Anna 1 and 2 may have experienced some base-metal initiated cracking (Sandvik material)
- About 8% of the J-groove welds have been examined by ET or PT
- Weld experience ranges from no indications in a relatively high EDY plant (Robinson) to relatively extensive weld cracking in another high EDY plant (North Anna 2)
- To date, weld cracking has been limited to vessels fabricated by Rotterdam Dockyards and B&W-designed units

EDYs at Spring RFO (Note 1)	Unit Name	NSSS Vendor	Material Supplier (Note 2)	Vessel Fabricator (Note 3)	Previous Inspections (Since 11/2000)			Plans for Spring 2003 RFO (Note 4)			Current Head Replacement Plans
					Visual for Leakage	A600 Nozzle Tubes	A182 Weld Metal	Visual for Leakage	A600 Nozzle Tubes	A182 Weld Metal	
22.5	Oconee 3	BW	B	BW	BMV	UT,ET(18),PT(12)	PT(12)	Head Replacement with A690			Spring 2003
21.4	North Anna 1	W	S	RDM	BMV	ET(30),UT(8),PT(4)	PT (4)	Head Replacement with A690			Spring 2003
20.5	Surry 1	W	H	BW/RDM	BMV	UT(16)	PT(10)	Head Replacement with A690			Spring 2003
18.3	Turkey Point 3	W	H	BW	BMV	-	-	BMV	UT	-	Assessing
17.5	Farley 1	W	H/B	BW/CE	BMV	-	-	BMV	ET,UT	-	Fall 2004
15.2*	San Onofre 3	CE	SS/H	CE	BMV(34)	-	-	BMV	UT	ET	Assessing
15.2	Calvert Cliffs 2	CE	H	CE	BMV(8 ICI)	-	-	BMV	UT	-	Assessing
14.6	Cook 2	W	W	CBI	BMV	ET,UT	ET(10)	BMV	-	-	-
14.0	St. Lucie 2	CE	SS/H	CE	BMV	-	-	BMV	UT	-	Assessing
14.0	Beaver Valley 1	W	H/B	BW/CE	BMV	-	-	BMV	ET,UT	ET	Spring 2006
< 12	Kewaunee	W	H/B	BW/CE	BMV	-	-	BMV	-	-	-
11.2	Indian Point 3	W	H	CE	-	-	-	BMV	ET,UT	-	-
11.0	Palo Verde 3	CE	SS/H	CE	-	-	-	BMV(24)	UT	-	-
10.9	Diablo Canyon 2	W	H	CE	-	-	-	BMV	-	-	-
< 10	Palisades	CE	H	CE	-		-	BMV	-	-	
4.5	South Texas 1	W	H	CE	-	-	-	BMV	-	-	-
2 to 3	Catawba 2	W	H	CE	-	-	-	BMV	-	-	-
2.1*	Shearon Harris	W	B	CBI	-		-	BMV	-		-
1.7	Braidwood 1	W	B	BW	-	-	-	BMV	-	-	-
1.5	Sequoyah 1	W	S	RDM	-	-	-	BMV	-	-	-

NOTES:

1. EDYs as reported by each plant in their responses to Bulletin 2002-02. The asterisks indicate EDYs at time of the Bulletin 2002-02 response rather than the projected EDYs at the spring 2003 refueling outage (8/2002 for San Onofre 3 and 9/2002 for Shearon Harris).
2. Key for Material Suppliers. B = B&W Tubular Products. H = Huntington, S = Sandvik, SS = Standard Steel, W = Westinghouse (Huntington). CL = C.L. Imphy, A = Aubert et Duval
3. Key for Vessel Fabricators. BW = B&W, CBI = Chicago Bridge & Iron, CE = Combustion Engineering, RDM = Rotterdam Dockyard. CL = C.L. Imphy
4. The spring 2003 inspections for San Onofre 3 have already been completed with no indications of cracking or leakage. The spring 2003 inspections for Diablo Canyon 2 have already been completed with no indications of leakage.

- 20 units have refueling outages this spring:
  - Oconee 3, North Anna 1, and Surry 1 will replace their heads with new heads having Alloy 690 material
  - All 17 other units will perform 100% BMV and/or non-visual inspections
  - All the plants having greater than 12 EDYs will have performed a non-visual baseline examination by the end of the spring outage season
- The spring 2003 outage season mainly concludes the initial set of inspections following Bulletin 2001-01. After this spring:
  - All but two units (< 2 EDYs) will have completed 100% BMV and/or non-visual inspections (97% of the total nozzle population)
  - 20 of the 28 units with > 12 EDYs (as of February 2001) will have completed baseline non-visual examinations or head replacement

- After fall 2003, it is expected that:
  - All 69 units will have completed 100% BMV and/or non-visuals (or head replacement)
  - 27 of the 28 units with > 12 EDYs (as of February 2001) will have completed baseline non-visual examinations or head replacement (28^{th} unit plans such an inspection at its next RFO in spring 2004)
- Upon the conclusion of the spring outage season, the MRP will again look for correlations between cracking and factors such as EDYs, tubing material supplier, and vessel head fabricator

Process for Revising the MRP Inspection Plan

Advisory Committee on Reactor Safeguards
Materials & Metallurgy and
Plant Operations Subcommittees

Vessel Head Penetration Cracking and
RPV Head Degradation

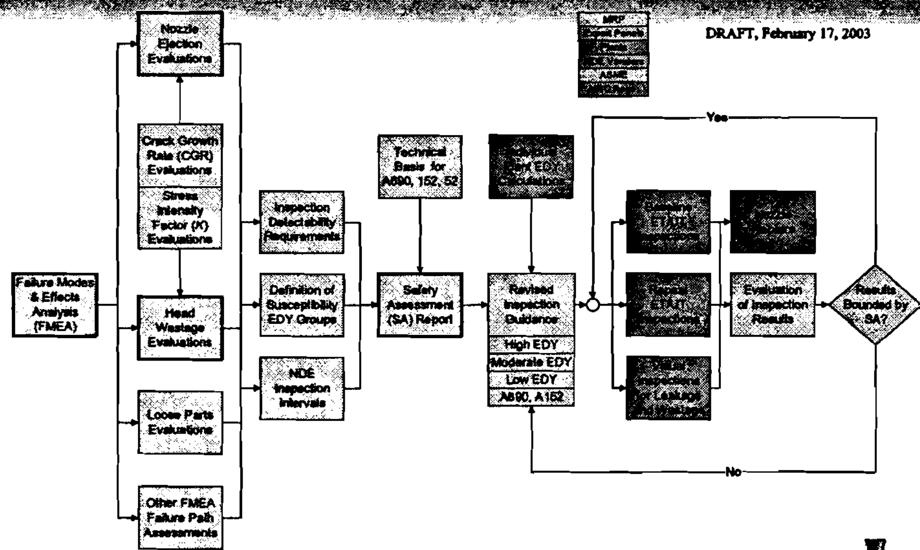
April 21, 2003
Room T-2B3
11545 Rockville Pike
Rockville, Maryland

David A. Steininger
EPRI, MRP and SGMP
Craig Harrington, TXU
MRP Alloy 600/82/182 ITG
RV Head Working Group Chairman

Topics

- Overall Safety Assessment Process
- Transition to Combination Baseline Inspections with Inspection Intervals Chosen to Ensure Safety
- Failure Modes and Effects Analysis
- Main Evaluations
  - Nozzle Ejection
  - Head Wastage
- Supporting Evaluations
  - Crack Growth Rates
  - Stress Intensity Factors
  - Proposed Additional Boric Acid Corrosion Testing
- Schedule for Issuing Revised Inspection Plan and Safety Assessment Report

Overall Process Flowchart



EPRI

Safety Assessment Process: Key Points

- The MRP approach is transitioning to ensuring safety through "combination" baseline inspections at all plants with:
  - The timing for the baseline inspection and the re-inspection interval based on the technical evaluations and
  - More frequent bare metal visual (BMV) inspections providing backup to the program of periodic combination inspections
- The revised MRP inspection plan will be formed on the basis of a comprehensive safety assessment (SA) report
- The SA report:
  - Begins with a failure modes and effects analysis (FMEA) to anticipate the possibility of failure modes that have not been observed in the field and
  - Includes the analysis tools previously developed and described in MRP-75

EPRI

Safety Assessment Process: Key Points (cont'd)

- The results of the FMEA are used to establish the required technical evaluations and ultimately the inspection detectability requirements
- Existing calculations show that non-visual inspections do not have to be performed every refueling outage to ensure safety
  - Extremely low probability of nozzle ejection and significant wastage
  - Extremely small consequential increase in core damage frequency, consistent with NRC Reg. Guide 1.174

Combination Baseline Inspections

- Subsequent to the release of the MRP-75 inspection plan and technical bases and in light of the most recent inspections results, the MRP has released a letter to the industry recommending a transition to combination baseline inspections
- Three types of combinations inspections:
  - (UT/BMV) UT of the base metal from the tube ID and bare-metal visual (BMV)
  - (UT/ET) UT of the base metal from the tube ID and ET/PT of the weld surface
  - (ET/ET) ET of the base metal ID and OD and ET/PT of the weld surface
- The timing of the baseline inspection and the inspection interval will be based on the technical evaluations to ensure safety

Combination Baseline Inspections (cont'd)

- Time at temperature (EDYs) will continue to form the basis for the susceptibility groups
- It is expected that high susceptibility plants will perform the combination baseline inspection by the next refueling outage
- It is expected that moderate susceptibility plants will perform the baseline inspection by approximately 2005 at the latest
- It is expected that low susceptibility plants will perform the baseline inspection by approximately 2007 at the latest

Failure Modes and Effects Analysis: Introduction

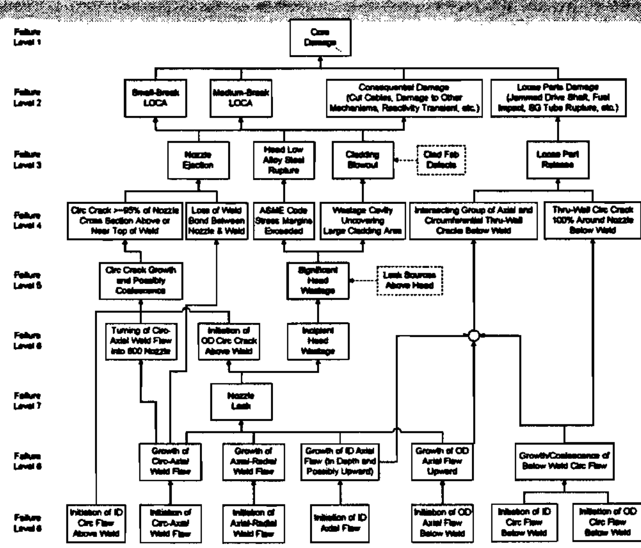
- FMEA is a technique of TQM (Total Quality Management) to ensure product reliability
- Typically, a table of the following characteristics of the possible failure modes is prepared:
  - Cause
  - Effect (consequence)
  - Detectability
  - Frequency of Occurrence
- Relationships among the failure modes are illustrated using a block diagram
- FMEA is a tool that helps anticipate new failure modes

Failure Modes and Effects Analysis: Application to RVH Nozzles

- For RVH penetrations, there are three principal failure modes:
  - Nozzle Ejection Due to Net Section Collapse
  - Cladding Blowout Due to Wastage
  - RCS Damage Due to Loose Parts Generation
- There are several levels in the failure process for these modes:
  - PWSCC initiation (nozzle ID, nozzle OD below weld, weld surface)
  - PWSCC growth (axial and circ in nozzle, axial-radial and circ-axial in weld; weld to nozzle and nozzle to weld; turn from axial to circ)
  - Leakage to annulus (new crack initiation and low-alloy steel wastage)
  - Growth to allowable size / wastage until code allowable stresses are reached
  - Growth to net section collapse or loose parts release / wastage to cladding blowout
  - Small/medium LOCA and possible consequential damage / loose parts damage
  - Effect on core damage frequency (CDF)

Failure Modes and Effects Analysis: Simplified Block Diagram

PRELIMINARY



Failure Modes and Effects Analysis: Classification of Failure Conditions

- Each failure condition will be classified as:
  - Not credible,
  - Not actionable, or
  - Actionable
- A classification as "not credible" will require a strong technical argument and thorough documentation with a high threshold
- A classification as "not actionable" requires that adequate protection be provided at a higher level in the failure process
- Conditions classified as "actionable" will be inputs to the probabilistic and deterministic evaluations and will ultimately shape the detectability requirements specified in the inspection plan

Failure Modes and Effects Analysis: Additional Higher Order Factors

- Additional factors being considered in the FMEA include:
  - Environmental fatigue
  - Fabrication practices such as nozzle straightening or nickel plating
  - Surface and imbedded flaws produced during fabrications such as welding lack of fusion and hot cracking
  - The condition of the inside surface cladding
  - Primary water chemistry factors such as resin intrusions
  - Leaks from sources above the head
  - Plant-specific differences in the air flow across the head top surface

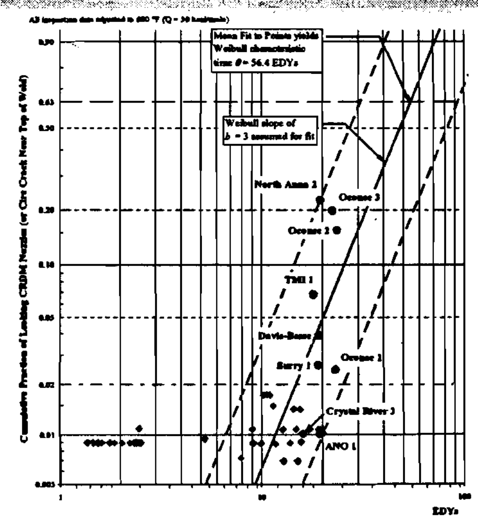
Failure Modes and Effects Analysis: Frequency of Occurrence

- Weibull reference curves based on the latest inspection results
  - Plant experience may support different curves for different nozzle material suppliers and different weld fabricators
- Crack growth rates based on MRP-55 and stress intensity factor calculations
- Existing small- and medium-break LOCA analyses
- Consequential damage assessments
- Loose parts damage assessments

EPRI

Failure Modes and Effects Analysis: Example Weibull Plot

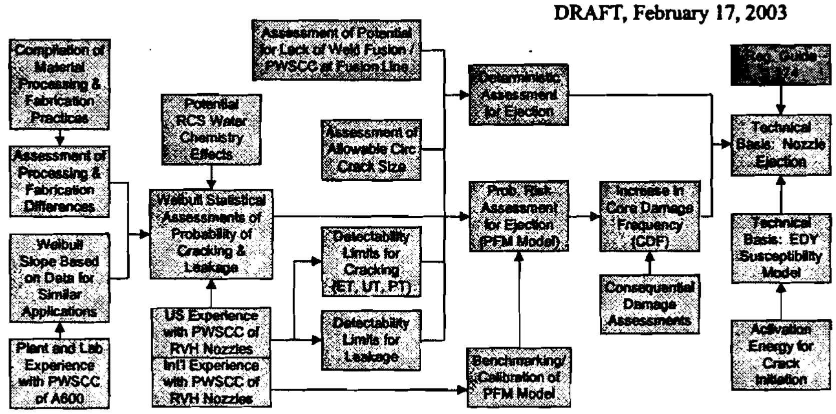
- Plot covers all plants
- Leakage (or circ crack near weld root) due to base metal and weld metal initiated cracking combined on this plot
- Diamonds conservatively represent 42 plants that did not detect any leakage during BMV inspections



EPRI

Main Evaluations: Nozzle Ejection

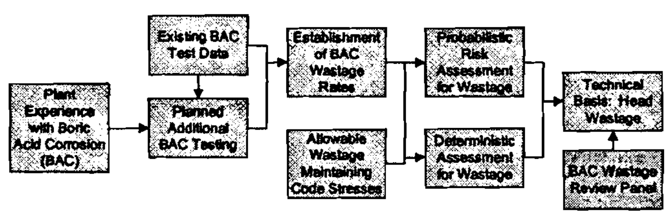
DRAFT, February 17, 2003



EPRI

Main Evaluations: Head Wastage

DRAFT, February 17, 2003



EPRI

Supporting Evaluations: Crack Growth Rates

- The MRP report addressing the crack growth rates (CGRs) of Alloy 600 base metal (MRP-55) was formally submitted to the NRC in September 2002
- The EPRI-MRP expert panel on CGRs has completed preliminary assessments of Alloy 182 and 82 weld metal
- A report addressing the weld metal will be produced after additional data is produced, collected, and evaluated
- The expert panel will meet in late March in Washington, DC around the NRC conference to discuss the weld metal evaluations

EPRI

Supporting Evaluations: Stress Intensity Factors

- Stress intensity factor calculations have been completed for several CRDM nozzle geometries
- Comparison to date with the results produced by the NRC contractor have shown good agreement
- Additional work will be used to bound the magnitude of the stress intensity factors as a function of nozzle and weld geometry and material properties (e.g., nominal nozzle tube yield strength)
- The stress intensity factors are a secondary influence behind the crack growth rates on the probability of nozzle ejection

EPRI

Supporting Evaluations: Boric Acid Corrosion (BAC) Testing

- The MRP has completed scoping work to define the types of testing that are appropriate to produce key BAC data that are not available
  - Analysis work to understand the thermal-hydraulic and chemical environments along the leak path
  - Analysis work to define the key parameters that drive the corrosion and erosion processes in the nozzle crevice
  - A probabilistic wastage model to assess the risk of producing a wastage cavity large enough to result in shell stresses exceeding the ASME code allowables (Appendices C, D, and E of MRP-75, Rev. 1)
  - An expert panel to review the probabilistic wastage model
- The MRP is in the process of requesting proposals for performing the needed testing including mock-up testing
  - BAC testing work is expected to be awarded in May 2003

Deliverables and Schedule

- A comprehensive safety assessment (SA) report will form the basis for a revised MRP inspection plan
- As appropriate, the SA report will reference other reports (e.g., the MRP report on crack growth rates of Alloy 600—MRP-55)
- Some calculations remain to be revised and extended, but much of the material to be incorporated into the SA report has already been completed in support of MRP-75
- Data developed subsequent to the initial release of the SA report will be evaluated for consistency with the SA evaluations once such data become available
- The MRP expects to be prepared to discuss the contents of the SA and the revised inspection plan summer 2003
- In the meantime, technical discussions with the NRC staff will continue

North Anna Unit 2 Reactor Vessel Head

Advisory Committee on Reactor Safeguards
Materials & Metallurgy and
Plant Operations Subcommittees

Craig Harrington TXU
Chair RPV Head Working Group
April 21, 2003

EPRI

Present Situation

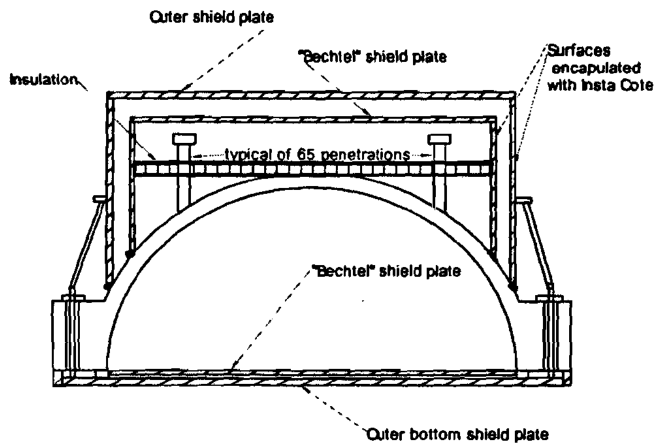
- Inspection findings drive industry response in a reactive mode
- Regulator imposes more requirements for inspection
- Inspections find unexplained and unexpected cracking at some plants
- The root cause is not known
- The inspections will ensure safety, but this is not an effective, efficient or economical strategy for the industry

EPRI

Enabling Actions to Achieve MRP Goals

- Comprehensive metallurgical examination of a failed component
- Determine root cause and generic implications
- Establish correlation between NDE indications and as found defects

Figure 2
Conceptual Shipping Arrangement
Information Only not Official



Objectives for Destructive Examination

- 1. Understand the formation of the circumferential flaws in the outer diameter of the nozzle base material and map its position relative to flaws in the J-groove weld.

- 2. Determine the most probable cause(s) of initiation and propagation of the weld flaws.

- 3. Characterize the final nozzle-annulus operating environment prior to shutdown and identify the associated corrosion mechanisms by analysis of annular deposits and local base material surface characteristics.

A 600/82/182.5

EPRI

Objectives for Destructive Examination

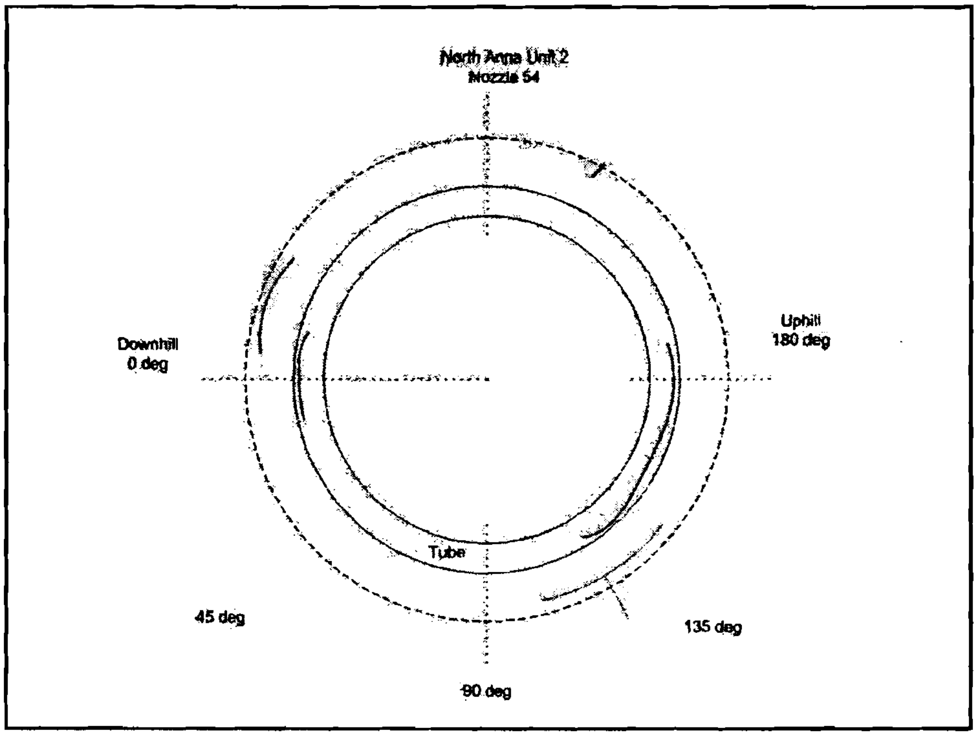
1. 4. Examine the previously repaired nozzle (#51) that exhibited visual evidence of renewed leakage to determine both the mode(s) of degradation that resulted in leakage and the leak path through the pressure boundary.

- 5. Facilitate development of a better understanding of the actual capability of current inspection techniques and technologies to detect OD circumferential cracks in the base material and axial/circumferential cracks in the weld material by conducting vendor non-destructive examinations prior to nozzle destructive examinations.

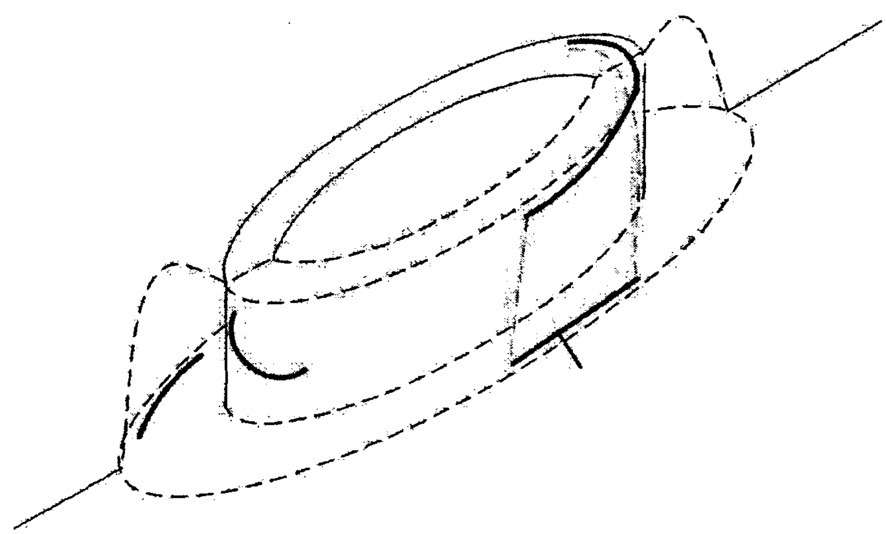
- 6. Finally, acquire samples of base material and weld metal for future PWSCC testing of Alloy 600/182 thick-walled material.

A 600/82/182 6

EPRI



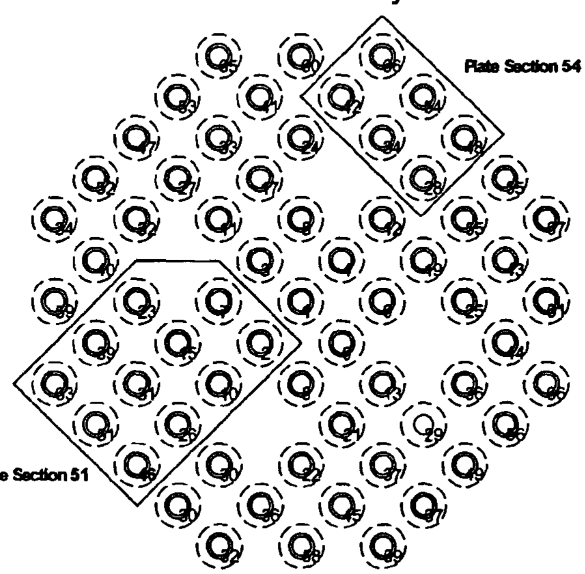
Nozzle 54 – View 2



Penetration	NDE results	Addresses Objective #(s)	Additional Information
54	Visual: Not leaking UT: ID and OD Indication in Nozzle Weld: ET circ and axial	1, 2, 5	OD Circ #1: Length 42 deg Depth 0.16" OD Circ #2: Length 80 deg Depth 0.23" Weld Circ #1: Length 1.5" Weld Circ #2: Length 1.22" Weld Axial: Length 0.32"
59	Visual: Masked UT: OD circs in Nozzle Weld: ET Circs	1, 2, 5	OD Circ #1: Length 76 deg Depth 0.15" OD Circ #2: Length 50 deg Depth 0.32" Weld Circ #1: Length 3.05" Weld Circ #2: Length 5.31"
31	Visual: Leaking UT: No detectable indications Weld: ET axials	2, 3, 5	Weld Axial #1: Length 0.08" Weld Axial #2: Length 0.16" Weld Axial #3: Length 0.20" Weld Axial #4: Length 0.20" Weld Axial #5: Length 0.24"
51 Weld repaired in 2001	Visual: Leaking UT: Weld Interface Indication (Evidence of leak path) Weld: PT linear	2, 3, 4, 5	
63 Weld repaired in 2001	Visual: Masked UT: ID Indication in Nozzle Probable Leak Path Weld: PT linear	2, 4, 5	
10	Visual: Leaking UT: Weld Interface Indication, Lack of Fusion Weld: None	NDE	
Need to determine the CRDM nozzle numbers	Sample RPV nozzle material from several different heats of material. Sample should capture the full circumference and be about 6 inches long.	6	Heats to consider: 710147, 755536, 710208, 772024, or 568011

Figure 1

Plate Section Layout



Current Actions

- Proposals due 2/24
- Finalize a sectioning plan that focuses on priority of examination of particular nozzles
- Determine if any additional NDE testing is necessary
- Determine the cost of the project by competitive bid
- Coordinate sample removal process
- Select Laboratory for DE testing

Master
8:45 - 9:40

Reactor Vessel Head Inspection Results

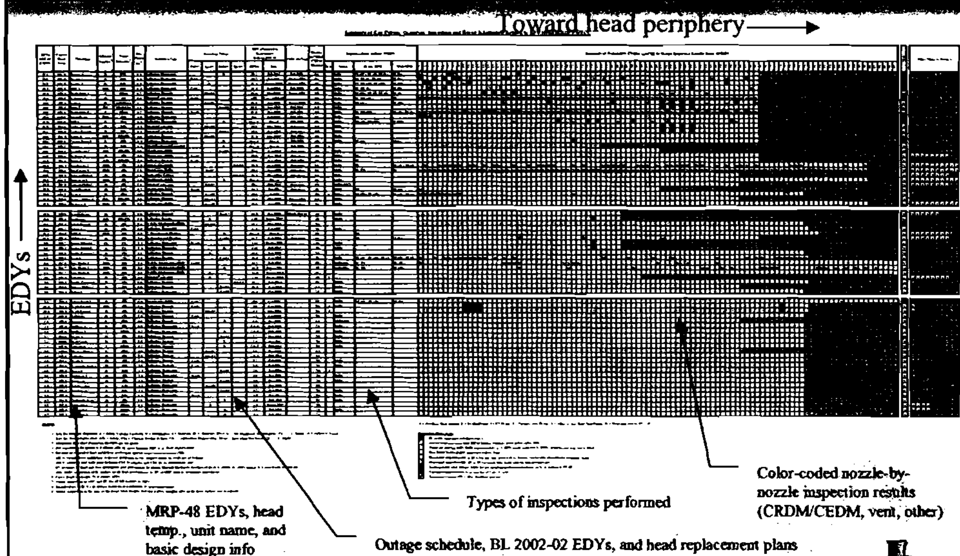
Advisory Committee on Reactor Safeguards
Materials & Metallurgy and
Plant Operations Subcommittees

Vessel Head Penetration Cracking and
RPV Head Degradation

April 21, 2003
Room T-2B3
11545 Rockville Pike
Rockville, Maryland

Larry Mathews, SNOC
MRP Alloy 600/82/182
Issue Task Group Chairman

- Overview Table of Inspection Results by Plant
- Subpopulation Summary Statistics
  - By EDY Group
  - By Head Fabricator and Tubing Supplier
  - Detected Circumferential Cracks
- Inspection Plans for Spring 2003 Outages



- The overview table graphically shows:
  - The extent to which the fleet has been inspected
  - The extent of detected cracking, leakage, and wastage correlated with effective degradation time (EDYs) and position on the head
  - Key operating and design data
  - Refueling outage schedule and current head replacement plans
- The overview table complements more detailed outage-specific and defect-specific inspection results tables that are used to generate statistical (i.e., Weibull) fits
- The MRP plans to release a revision to the table at the end of each outage season

No.	Unit	NSSS Supplier	Approx. EDYs at Inspection	Date	*Number of Nozzles on Head* CRDM	CEDM	ICI	*Total*	*Nozzles Inspected by Non-Visual* *Total*	*Total %*	*No. Leaking Nozzles/ Welds* *Leaking*	*% of Total Inspected*	*No. Cracked Nozzles/ Welds* *Cracked*	*% of Total Inspected*	*No. Nozzles with Base Metal Cracks*	*No. Nozzles with Weld Metal Cracks*	*No. Nozzles with Axial Cracks*	*No. Nozzles with Circ. Cracks*
1	ANO 1	B&W	19.6	Mar-2001	69			69	1	1.4%	1	100.0%	1	100.0%	1	0	1	1
2	ANO 1	B&W	21.1	Oct-2002	69			69	69	100.0%	1	1.4%	8	11.6%	8	8	8	0
3	Cook 2	W	13.9	Jan-2002	78			78	78	100.0%	0	0.0%	2	2.6%	2	0	2	0
4	Crystal River 3	B&W	16.2	Oct-2001	69			69	9	13.0%	1	11.1%	1	11.1%	1	1	1	1
5	Davis-Besse	B&W	19.2	Apr-2002	69			69	69	100.0%	3	4.3%	5	7.2%	5	0	5	1
6	Millstone 2	CE	11.2	Feb-2002		69	8	77	77	100.0%	0	0.0%	3	3.9%	3	1	3	2
7	North Anna 1	W	20.0	Oct-2001	65			65	30	46.2%	0	0.0%	6	20.0%	6	0	6	0
8	North Anna 2	W	19.0	Nov-2001	65			65	3	4.6%	3	100.0%	3	100.0%	3	3	3	0
9	North Anna 2	W	19.7	Sep-2002	65			65	65	100.0%	6	9.2%	42	64.6%	7	42	1	6
10	Oconee 1	B&W	21.8	Nov-2000	69			69	18	26.1%	1	5.6%	1	5.6%	1	1	1	0
11	Oconee 1	B&W	23.2	Mar-2002	69			69	5	7.2%	1	20.0%	3	60.0%	3	1	3	0
12	Oconee 2	B&W	22.2	Apr-2001	69			69	4	5.8%	4	100.0%	4	100.0%	4	4	4	1
13	Oconee 2	B&W	23.7	Oct-2002	69			69	69	100.0%	7	10.1%	15	21.7%	15	5	10	0
14	Oconee 3	B&W	21.7	Feb-2001	69			69	18	26.1%	9	50.0%	10	55.6%	10	0	10	5
15	Oconee 3	B&W	22.5	Nov-2001	69			69	52	75.4%	5	9.6%	7	13.5%	7	2	7	2
16	Surry 1	W	19.1	Oct-2001	65			65	16	24.6%	2	12.5%	6	37.5%	0	6	0	0
17	TMI 1	B&W	18.1	Oct-2001	69			69	12	17.4%	5	41.7%	7	58.3%	7	4	7	0
Totals for Inspections Since First U.S. Leakage (11/2000)					3871	1090	94	5055	1462	28.9%	47	3.2%	120	8.2%	82	75	71	19

NOTE: The table does not reflect the small-diameter thermocouple nozzles found to be cracked and leaking at Oconee 1 and TMI 1. (These are the only two plants that have this type of nozzle.)

EPRI

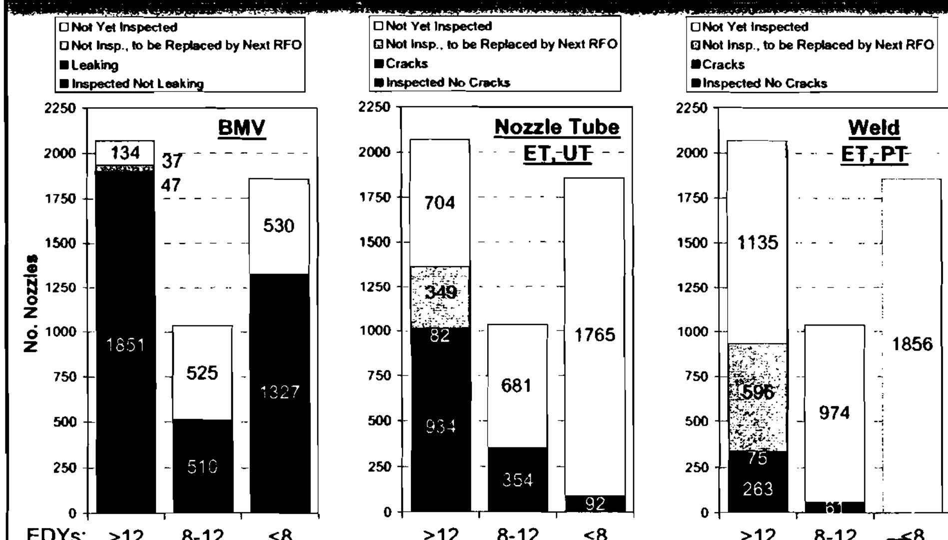
Plants w/ any cracking checked by eddycurrent or VT

EDY at Next RFO	No. Units	BMV No. Units 100% Inspected	BMV No. Nozzles Inspected	Nozzle Tube ET/UT No. Units 100% Inspected	Nozzle Tube ET/UT No. Nozzles Inspected	Weld ET/PT No. Units 100% Inspected	Weld ET/PT No. Welds Inspected
>12 EDY	30	27 (90%)	1898 (92%)	13 (43%)	1016 (49%)	3 (10%)	338 (16%)
8–12 EDY	15	8 (53%)	510 (49%)	4 (27%)	354 (34%)	0 (0%)	61 (6%)
< 8 EDY	24	17 (71%)	1327 (71%)	0 (0%)	92 (5%)	0 (0%)	1 (0%)
Totals	69	52 (75%)	3735 (75%)	17 (25%)	1462 (29%)	3 (4%)	400 (8%)

EPRI

EDY at Next RFO	No. Nozzles	Leaking Nozzles: Nozzles Leaking (Inspected)	Leaking Nozzles: % Leaking	Nozzle Tubes Cracked: Nozzles Cracked (Inspected)	Nozzle Tubes Cracked: % Cracked	Welds Cracked: Welds Cracked (Inspected)	Welds Cracked: % Cracked
>12 EDY	2069	47 (1898)	2.5%	82 (1016)	8.1%	75 (338)	22.2%
8–12 EDY	1035	0 (510)	0.0%	0 (354)	0.0%	0 (61)	0.0%
< 8 EDY	1857	0 (1327)	0.0%	0 (92)	0.0%	0 (1)	0.0%
Totals	4961	47 (3735)	1.3%	82 (1462)	5.6%	75 (400)	18.8%

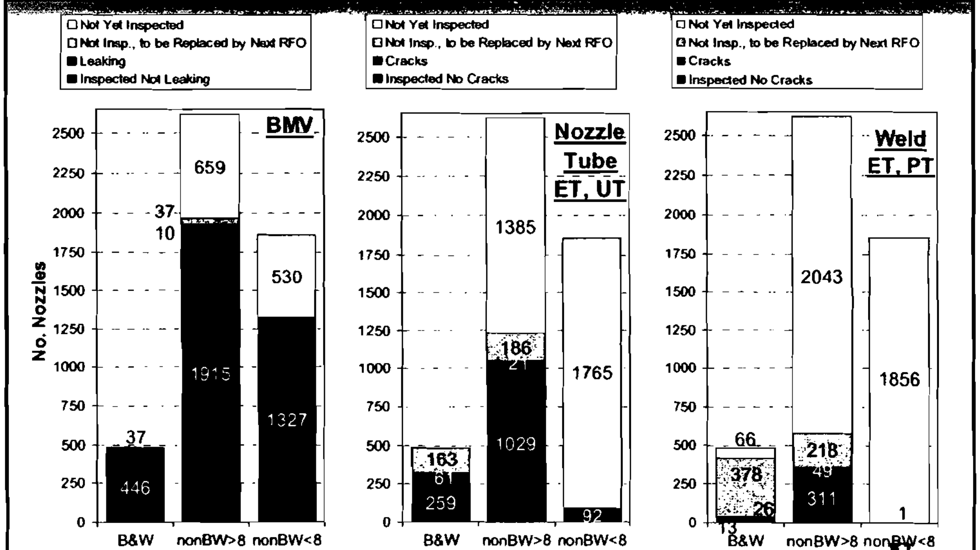
EPRI



EPRI

NSSS Supplier / EDY at Next RFO	No. Units	BMV		Nozzle Tube ET/UT		Weld ET/PT	
		No. Units 100% Inspected	No. Nozzles Inspected	No. Units 100% Inspected	No. Nozzles Inspected	No. Units 100% Inspected	No. Welds Inspected
B&W NSSS	7	7 (100%)	483 (100%)	4 (57%)	320 (66%)	0 (0%)	39 (8%)
non-B&W > 8 EDY	38	28 (74%)	1925 (73%)	13 (34%)	1050 (40%)	3 (8%)	360 (14%)
non-B&W < 8 EDY	24	17 (71%)	1327 (71%)	0 (0%)	92 (5%)	0 (0%)	1 (0%)
Totals	69	52 (75%)	3735 (75%)	17 (25%)	1462 (29%)	3 (4%)	400 (8%)

NSSS Supplier / EDY at Next RFO	No. Nozzles	Leaking Nozzles		Nozzle Tubes Cracked		Welds Cracked	
		Nozzles Leaking (Inspected)	% Leaking	Nozzles Cracked (Inspected)	% Cracked	Welds Cracked (Inspected)	% Cracked
B&W NSSS	483	37 (483)	7.7%	61 (320)	19.1%	26 (39)	66.7%
non-B&W > 8 EDY	2621	10 (1925)	0.5%	21 (1050)	2.0%	49 (360)	13.6%
non-B&W < 8 EDY	1857	0 (1327)	0.0%	0 (92)	0.0%	0 (1)	0.0%
Totals	4961	47 (3735)	1.3%	82 (1462)	5.6%	75 (400)	18.8%



- The total RVH nozzle population includes 3871 CRDM nozzles, 1090 CEDM nozzles, and 94 ICI nozzles at 69 units
- Bare-metal visual (BMV) and/or non-visual NDE inspections have now been performed on about 81% of the RVH nozzles
  - About 47 nozzles have been found to be leaking
- Almost 8% of the nozzles in B&W plants have leaked, but leakage in non-B&W plants is limited to North Anna 2 and Surry 1 leakage, which is primarily due to weld cracking
- Non-visual examinations have been performed on:
  - About half of the ">12 EDY" nozzles and a third of the "8-12 EDY" nozzles
  - About two-thirds of the nozzles in B&W plants and 25% of the nozzles in non-B&W plants

- About 19% of the inspected B&W plant nozzles show base metal cracking
- Base metal cracking in non-B&W plants is limited to Millstone 2 (3 nozzles) and Cook 2 (1 nozzle), although North Anna 1 and 2 may have experienced some base-metal initiated cracking (Sandvik material)
- About 8% of the J-groove welds have been examined by ET or PT
- Weld experience ranges from no indications in a relatively high EDY plant (Robinson) to relatively extensive weld cracking in another high EDY plant (North Anna 2)
- To date, weld cracking has been limited to vessels fabricated by Rotterdam Dockyards and B&W-designed units

EPRI

EDYs at Spring RFO (Note 1)	Unit Name	NSSS Vendor	Material Supplier (Note 2)	Vessel Fabricator (Note 3)	Previous Inspections (Since 11/2000)			Plans for Spring 2003 RFO (Note 4)			Current Head Replacement Plans
					Visual for Leakage	A600 Nozzle Tubes	A182 Weld Metal	Visual for Leakage	A600 Nozzle Tubes	A182 Weld Metal	
22.5	Oconee 3	BW	B	BW	BMV	UT,ET(18),PT(12)	PT(12)	Head Replacement with A690			Spring 2003
21.4	North Anna 1	W	S	RDM	BMV	ET(30),UT(8),PT(4)	PT (4)	Head Replacement with A690			Spring 2003
20.5	Surry 1	W	H	BW/RDM	BMV	UT(16)	PT(10)	Head Replacement with A690			Spring 2003
18.3	Turkey Point 3	W	H	BW	BMV	-	-	BMV	UT	-	Assessing
17.5	Farley 1	W	H/B	BW/CE	BMV	-	-	BMV	ET,UT	-	Fall 2004
15.2*	San Onofre 3	CE	SS/H	CE	BMV(34)	-	-	BMV	UT	ET	Assessing
15.2	Calvert Cliffs 2	CE	H	CE	BMV(8 ICI)	-	-	BMV	UT	-	Assessing
14.6	Cook 2	W	W	CBI	BMV	ET,UT	ET(10)	BMV	-	-	-
14.0	St. Lucie 2	CE	SS/H	CE	BMV	-	-	BMV	UT	-	Assessing
14.0	Beaver Valley 1	W	H/B	BW/CE	BMV	-	-	BMV	ET,UT	ET	Spring 2006
< 12	Kewaunee	W	H/B	BW/CE	BMV	-	-	BMV	-	-	-
11.2	Indian Point 3	W	H	CE	-	-	-	BMV	ET,UT	-	-
11.0	Palo Verde 3	CE	SS/H	CE	-	-	-	BMV(24)	UT	-	-
10.9	Diablo Canyon 2	W	H	CE	-	-	-	BMV	-	-	-
< 10	Palisades	CE	H	CE	-		-	BMV	-	-	
4.5	South Texas 1	W	H	CE	-	-	-	BMV	-	-	-
2 to 3	Catawba 2	W	H	CE		-	-	BMV	-	-	-
2.1*	Shearon Harris	W	B	CBI	-		-	BMV	-		-
1.7	Braidwood 1	W	B	BW	-	-	-	BMV	-	-	-
1.5	Sequoyah 1	W	S	RDM	-	-	-	BMV	-		-

NOTES:

1. EDYs as reported by each plant in their responses to Bulletin 2002-02. The asterisks indicate EDYs at time of the Bulletin 2002-02 response rather than the projected EDYs at the spring 2003 refueling outage (8/2002 for San Onofre 3 and 9/2002 for Shearon Harris)
2. Key for Material Suppliers: B = B&W Tubular Products. H = Huntington, S = Sandvik, SS = Standard Steel, W = Westinghouse (Huntington). CL = C.L. Imphy, A = Aubert et Duval
3. Key for Vessel Fabricators: BW = B&W. CBI = Chicago Bridge & Iron. CE = Combustion Engineering. RDM = Rotterdam Dockyard. CL = C.L. Imphy
4. The spring 2003 inspections for San Onofre 3 have already been completed with no indications of cracking or leakage. The spring 2003 inspections for Diablo Canyon 2 have already been completed with no indications of leakage.

EPRI

- 20 units have refueling outages this spring:
  - Oconee 3, North Anna 1, and Surry 1 will replace their heads with new heads having Alloy 690 material
  - All 17 other units will perform 100% BMV and/or non-visual inspections
  - All the plants having greater than 12 EDYs will have performed a non-visual baseline examination by the end of the spring outage season
- The spring 2003 outage season mainly concludes the initial set of inspections following Bulletin 2001-01. After this spring:
  - All but two units (< 2 EDYs) will have completed 100% BMV and/or non-visual inspections (97% of the total nozzle population)
  - 20 of the 28 units with > 12 EDYs (as of February 2001) will have completed baseline non-visual examinations or head replacement

- After fall 2003, it is expected that:
  - All 69 units will have completed 100% BMV and/or non-visuals (or head replacement)
  - 27 of the 28 units with > 12 EDYs (as of February 2001) will have completed baseline non-visual examinations or head replacement (28th unit plans such an inspection at its next RFO in spring 2004)
- Upon the conclusion of the spring outage season, the MRP will again look for correlations between cracking and factors such as EDYs, tubing material supplier, and vessel head fabricator

North Anna Unit 2 Reactor Vessel Head

Advisory Committee on Reactor Safeguards
Materials & Metallurgy and
Plant Operations Subcommittees

Craig Harrington TXU
Chair RPV Head Working Group
April 21, 2003

EPRI

Present Situation

- Inspection findings drive industry response in a reactive mode
- Regulator imposes more requirements for inspection
- Inspections find unexplained and unexpected cracking at some plants
- The root cause is not known
- The inspections will ensure safety, but this is not an effective, efficient or economical strategy for the industry

EPRI

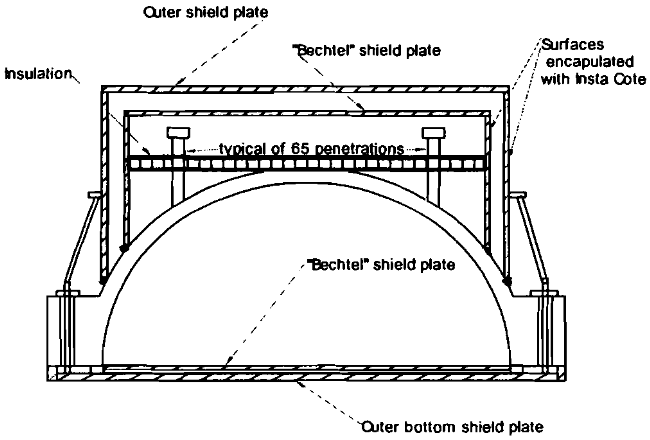
Enabling Actions to Achieve MRP Goals

- Comprehensive metallurgical examination of a failed component
- Determine root cause and generic implications
- Establish correlation between NDE indications and as found defects

A 600/82/182.3

EPRI

Figure 2
Conceptual Shipping Arrangement
Information Only not Official



Objectives for Destructive Examination

- 1. Understand the formation of the circumferential flaws in the outer diameter of the nozzle base material and map its position relative to flaws in the J-groove weld.
- 2. Determine the most probable cause(s) of initiation and propagation of the weld flaws.
- 3. Characterize the final nozzle-annulus operating environment prior to shutdown and identify the associated corrosion mechanisms by analysis of annular deposits and local base material surface characteristics.

A 600/82/182.5

EPRI

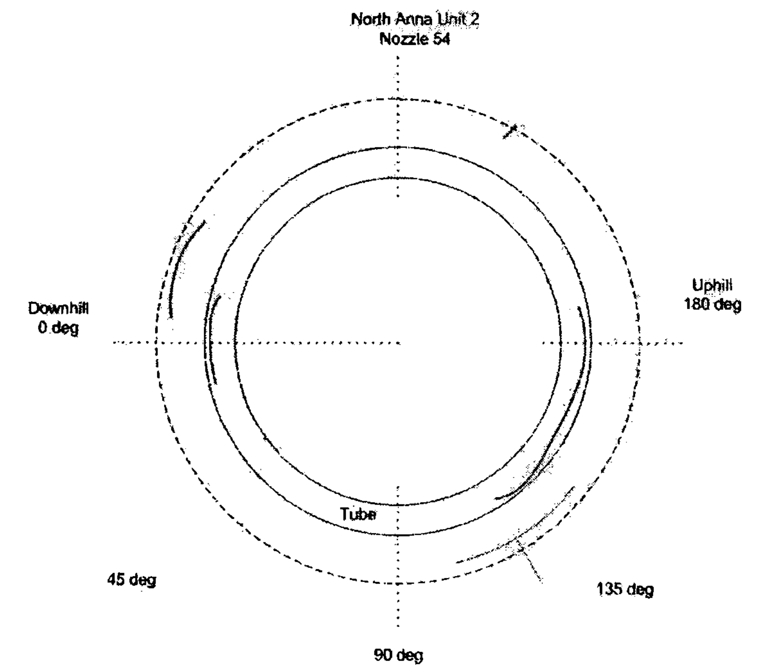
Objectives for Destructive Examination

1. 4. Examine the previously repaired nozzle (#51) that exhibited visual evidence of renewed leakage to determine both the mode(s) of degradation that resulted in leakage and the leak path through the pressure boundary.

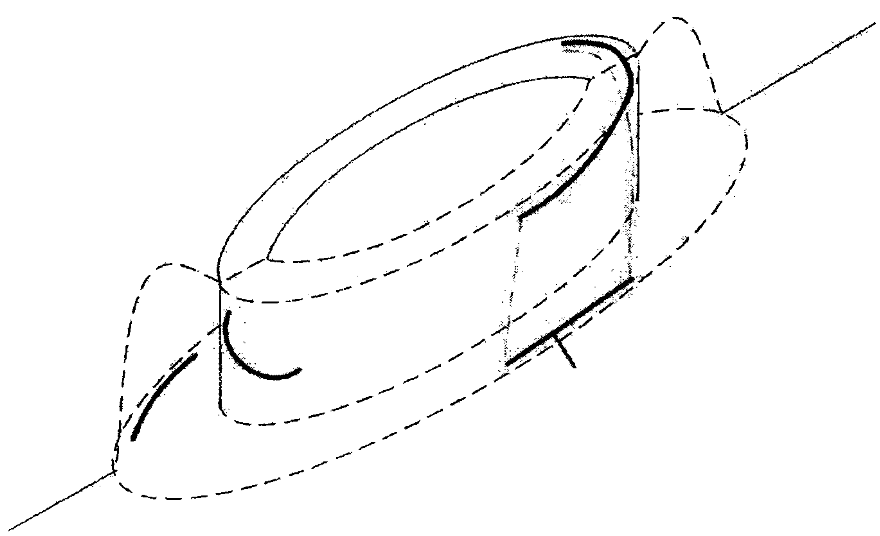
- 5. Facilitate development of a better understanding of the actual capability of current inspection techniques and technologies to detect OD circumferential cracks in the base material and axial/circumferential cracks in the weld material by conducting vendor non-destructive examinations prior to nozzle destructive examinations.
- 6. Finally, acquire samples of base material and weld metal for future PWSCC testing of Alloy 600/182 thick-walled material.

A 600/82/182.6

EPRI

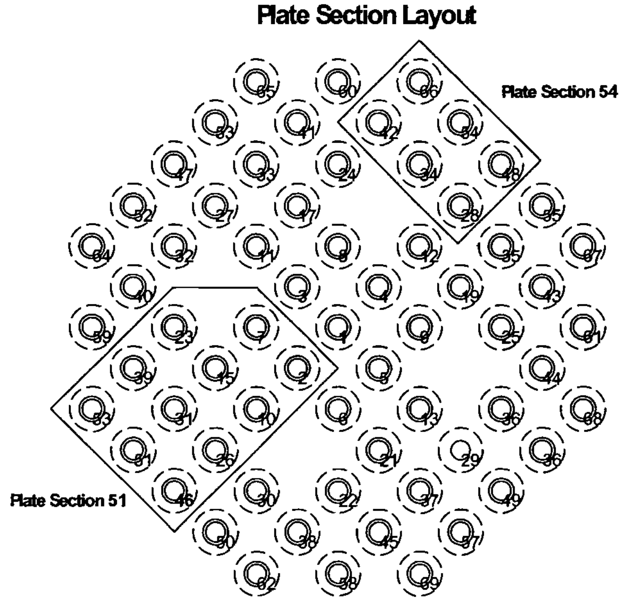


Nozzle 54 – View 2



Penetration	NDE results	Addresses Objective #(s)	Additional Information
54	Visual: Not leaking UT: ID and OD Indication in Nozzle Weld: ET circ and axial	1, 2, 5	OD Circ #1: Length 42 deg Depth 0.16" OD Circ #2: Length 80 deg Depth 0.23" Weld Circ #1: Length 1.5" Weld Circ #2: Length 1.22" Weld Axial: Length 0.32"
59	Visual: Masked UT: OD circs in Nozzle Weld: ET Circs	1, 2, 5	OD Circ #1: Length 76 deg Depth 0.15" OD Circ #2: Length 50 deg Depth 0.32" Weld Circ #1: Length 3.05" Weld Circ #2: Length 5.31"
31	Visual: Leaking UT: No detectable indications Weld: ET axials	2, 3, 5	Weld Axial #1: Length 0.08" Weld Axial #2: Length 0.16" Weld Axial #3: Length 0.20" Weld Axial #4: Length 0.20" Weld Axial #5: Length 0.24"
51 Weld repaired in 2001	Visual: Leaking UT: Weld Interface Indication (Evidence of leak path) Weld: PT linear	2, 3, 4, 5	
63 Weld repaired in 2001	Visual: Masked UT: ID Indication in Nozzle Probable Leak Path Weld: PT linear	2, 4, 5	
10	Visual: Leaking UT: Weld Interface Indication, Lack of Fusion Weld: None	NDE	
Need to determine the CRDM nozzle numbers	Sample RPV nozzle material from several different heats of material. Sample should capture the full circumference and be about 6 inches long.	6	Heats to consider: 710147, 755536, 710208, 772024, or 568011

Figure 1
Plate Section Layout



Current Actions

- Proposals due 2/24
- Finalize a sectioning plan that focuses on priority of examination of particular nozzles
- Determine if any additional NDE testing is necessary
- Determine the cost of the project by competitive bid
- Coordinate sample removal process
- Select Laboratory for DE testing

EPRI

RES/DET/MEB Programs and Activities to Address:

1. CRDM Cracking Issues
2. Davis-Besse Cavity Exams & Safety Assessment

ACRS Materials and Metallurgy, and Plant Operations Subcommittees

Meeting on
Vessel Head Penetration Cracking and RPV Head Degradation
April 22, 2003

William H. Cullen, Jr.
301-415-6754
whc@nrc.gov

RES/DET/MEB Programs and Activities to Address: CRDM Cracking Issues

A. NRC-Funded SCC Program & Products
   1. On-going EAC Program
   2. Testing of Davis-Besse Materials
   3. LLTF Rec. to Review Worldwide Experience with Alloy 600 CRDMs, Boric Acid Corrosion

B. Additional Programs with Expected, Relevant Products
   1. Japanese Coordinated Program
   2. ICG-EAC Round Robin
   3. Other Programs

C. Heat-by-Heat Analysis of Domestic Plant CRDMs

D. Stress Analysis of CRDM Penetrations

E. NRC-Industry Collaboration on CRDM Cracking Issues

F. Davis-Besse Cavity Exam Update – What it Means To NRC/RES

G. LLTF Recommendations - Barrier Integrity Action Plan - Tomorrow

RES/DET/MEB Programs and Activities to Address: Davis Besse Root Cause & Safety Assessment

A. Corrosion of RPV Boundary Materials in Boric Acid Solutions
   1. Features of Program at Argonne Nat. Lab
   2. LLTF Recommendation to Review Worldwide Experience

B. Structural Integrity Assessment
   1. Approach of Program at ORNL

C. D-B Cavity Sample Plan, and Head Disposition
   1. Documented Findings to Date
   2. Description of Last Phase of the Program
   3. Salvaging of Components from Discarded Head
   4. Additional Tasks for Future Programs

NRC's SCC Programs & Products

A. On-going EAC Program at Argonne Nat. Lab.

1. SCC Testing of Alloys 600, 182, 690 and 152 in BWR and PWR water
   a. Also evaluating strength, metallography for insight into mechanisms
2. Been testing since 1997, NUREG/CR-6717
   a. Letter report on SCC in 182 due 10/04, NUREG due 12/05

B. Testing of Davis-Besse Materials (part of BAC program at ANL)

1. Alloy 600 from Nozzle #3 (M3935), and Alloy 182 from #11 J-weld

C. LLTF Rec. to Review Int'l Experience with Alloy 600 CRDMs

1. Critique of susceptibility model [EDY = EFPY * (temp. factor)] – Done 2/28/03
2. Report on worldwide Alloy 600 cracking experience (Dec. '03)
3. Report on worldwide boric acid corrosion experience (Oct. '04)

Additional Programs

Products (CGR Data, Mechanistics) Will Contribute to Existing Databases

1. Japanese Coordinated Program
   a. Electric Joint Research Project
      - SCC and SSRT on Alloys MA600, Alloy 132, 82, TT690, Alloys 152 & 52
   b. National Nickel-Based Alloy Material Project
      - SCC on Alloys MA600, Alloy 132, 82, TT690, Alloys 152 & 52
2. ICG-EAC Round Robin
   a. Purpose: resolve factors that cause differences in stress corrosion crack growth rate response, esp. in Alloy 182 weld
   b. Status: Specimens distributed, some tests completed, reports next month
   c. Expectations:
      - Phase 1 – Collect info – Completed
      - Phase 2 – Test 30% CW A600 in '03, Compare results, Improve methods
      - Phase 3 – Test Alloy 182
3. Other Programs
   a. Tests underway in France, Spain and Sweden
4. Dialogue to Obtain Mockups from Replacement Head Fabrication

Plant-specific (heat-specific) cross-correlations starting from Davis-Besse

Heat Identification	Other Plants With Heads Containing Same Heat of Material
M3935 (3 of 5 cracked)	Oconee 3 (replace in '03), Ark. Nuclear One 1 (replace in '05)
C2649-1	Oconee 1 (replace in '03), Oconee 2 (replace in '04) Oconee 3, ANO 1
M4437	Not found in any other plant's CRDMs

So, specifics about nozzle heats from D-B are not applicable in the long-term for other licensees. However . . . .

Plant-specific (heat-specific) cross-correlations starting from North Anna 2

Heat Identification	Other Plants With Heads Containing Same Heat of Material
755534, 755535, 755536, 755537, 755538, 570892, 568011, 710209	North Anna 1, Sequoyah 1
710147	North Anna 1, Sequoyah 2
71207, 71208, 710210	North Anna 1, Sequoyah 1, Sequoyah 2
71206	North Anna 1, Surry 2, Sequoyah 1, Sequoyah 2
772024	Watts Bar-1, Watts Bar-2, Catawba-1, McGuire-2

United States Nuclear Regulatory Commission

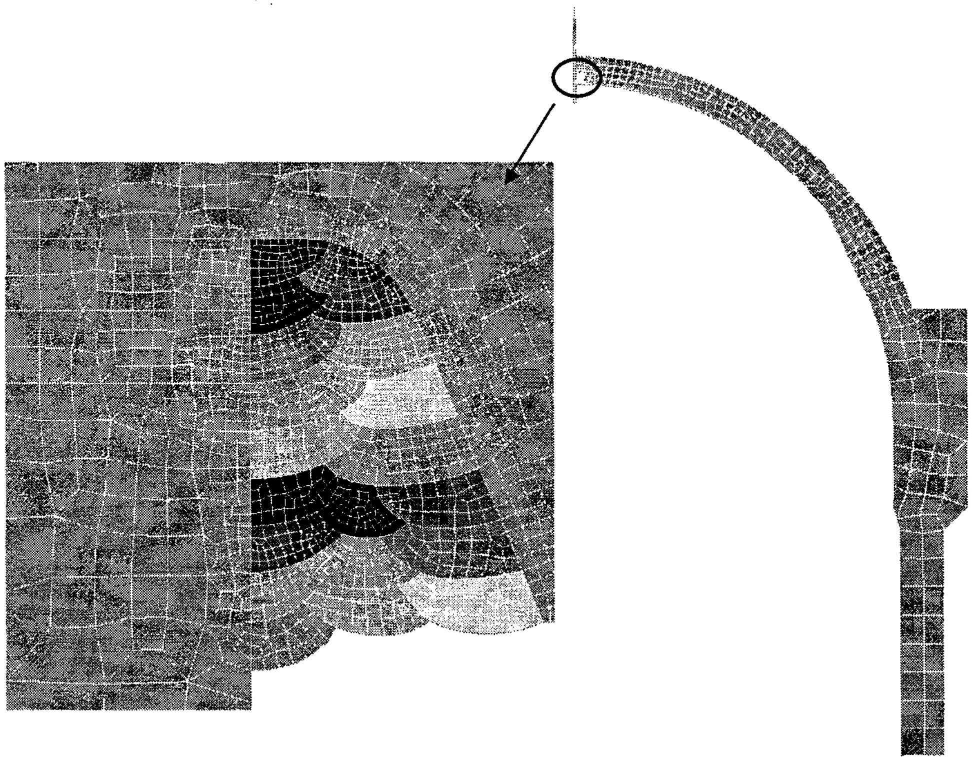
March '03 Conference on CRDM and related Issues

(Including safe ends, ICI penetrations, coolant loop repairs, etc.)

Postponed

- Five main session topics
  - Structural Analysis and Fracture Mechanics Issues (4 papers)
  - Inspection technologies, disposition & sizing of flaws, new developments (9 papers)
  - Crack growth rates for relevant nickel-base alloys & welds (8 papers)
  - Mitigation & Foreign Experience (9 papers)
  - Continued Plant Operation (8 papers)
- March 24 – 26 At Gaithersburg-Marriott
- Expected 140 or more attendees (11 countries) & participants
- Proceedings issued as CD and NUREG/CP
- To Be Rescheduled When Travel Restrictions Are Lifted

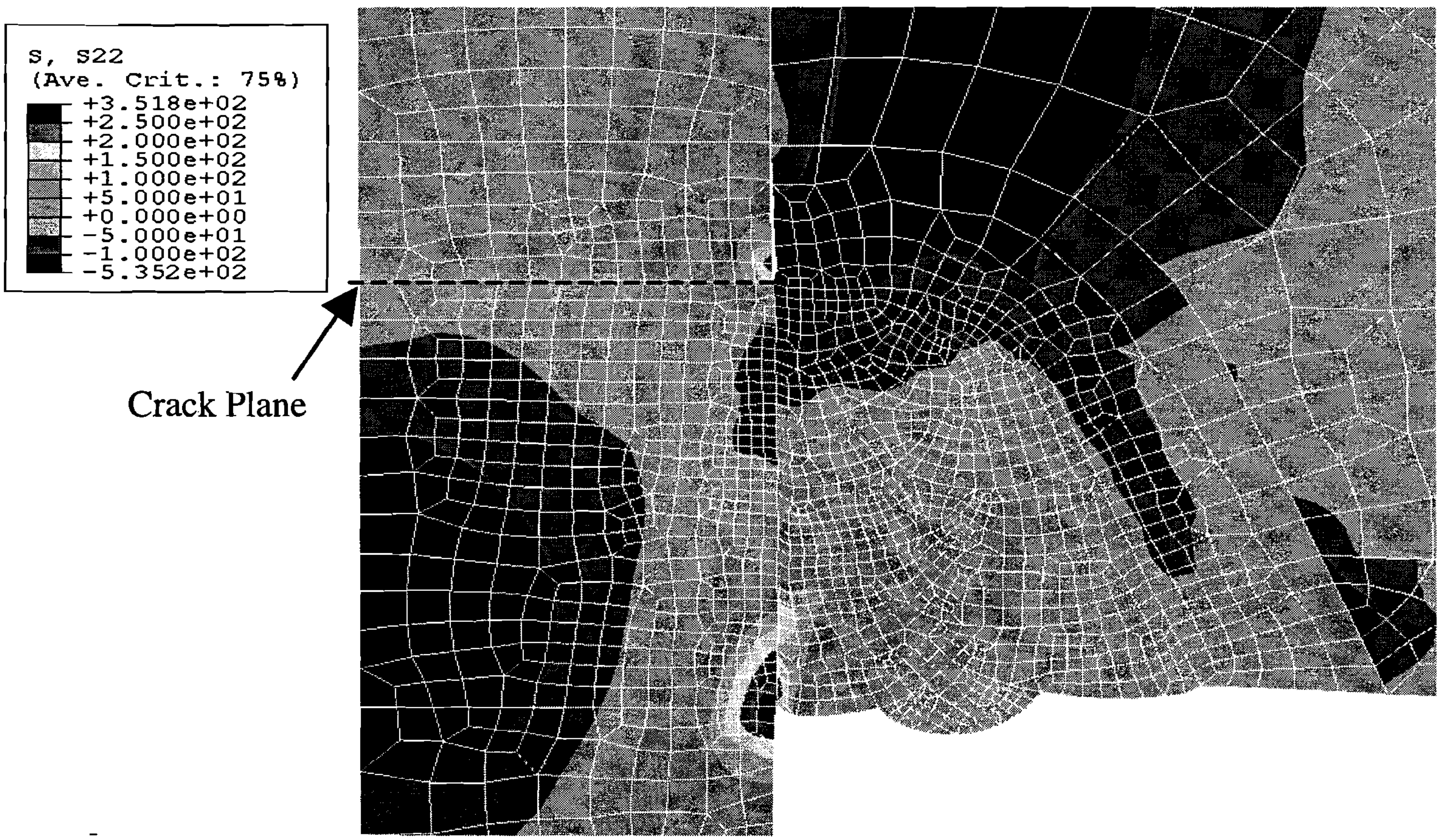
Stress Analysis of CRDM Penetrations



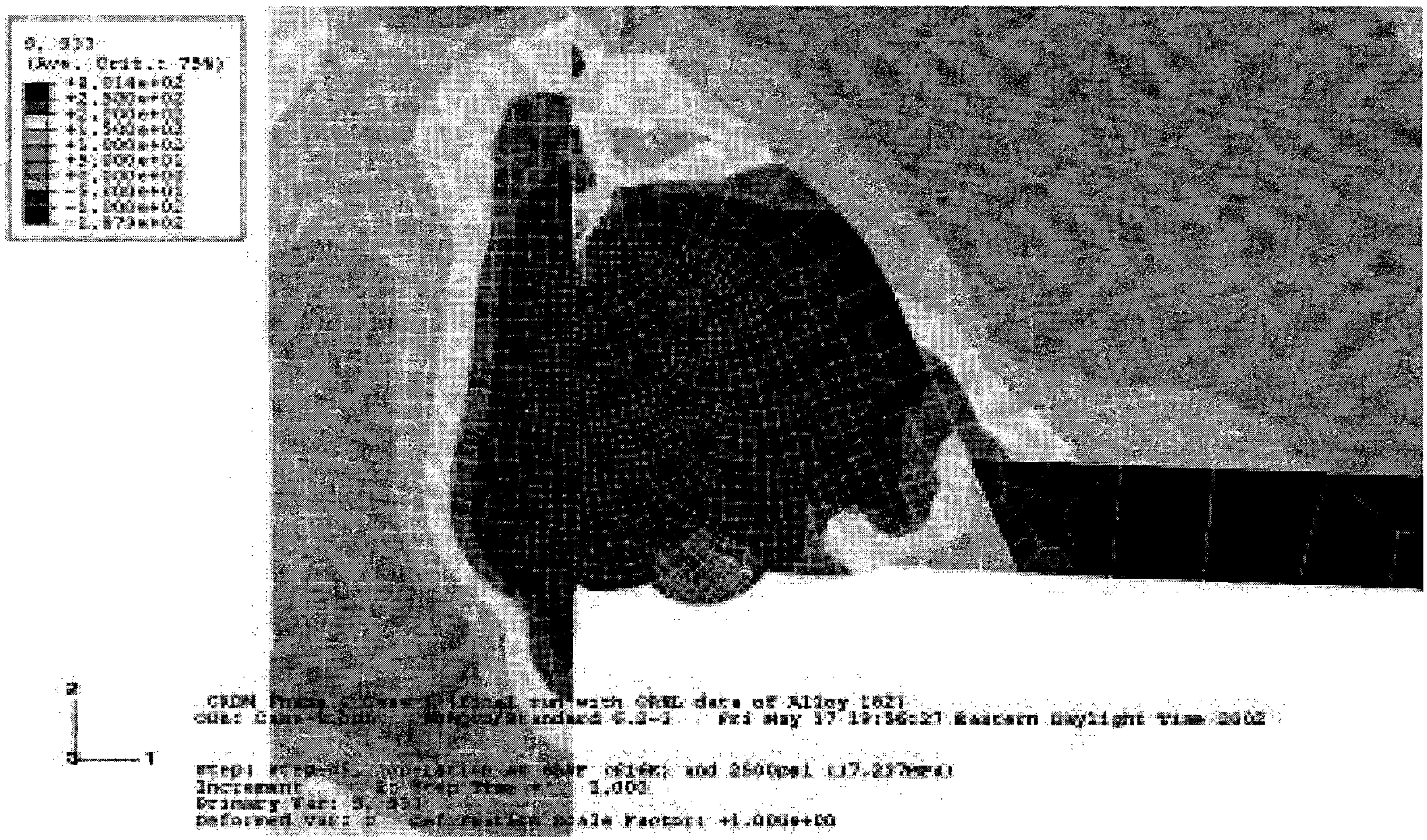
Pass-by-pass simulation of the weld, followed by calculation of the stress, proceed to the next pass, etc.

Calculate axial, radial & tangential, resolve to principal stress.

Axial Stresses at NOP/NOT

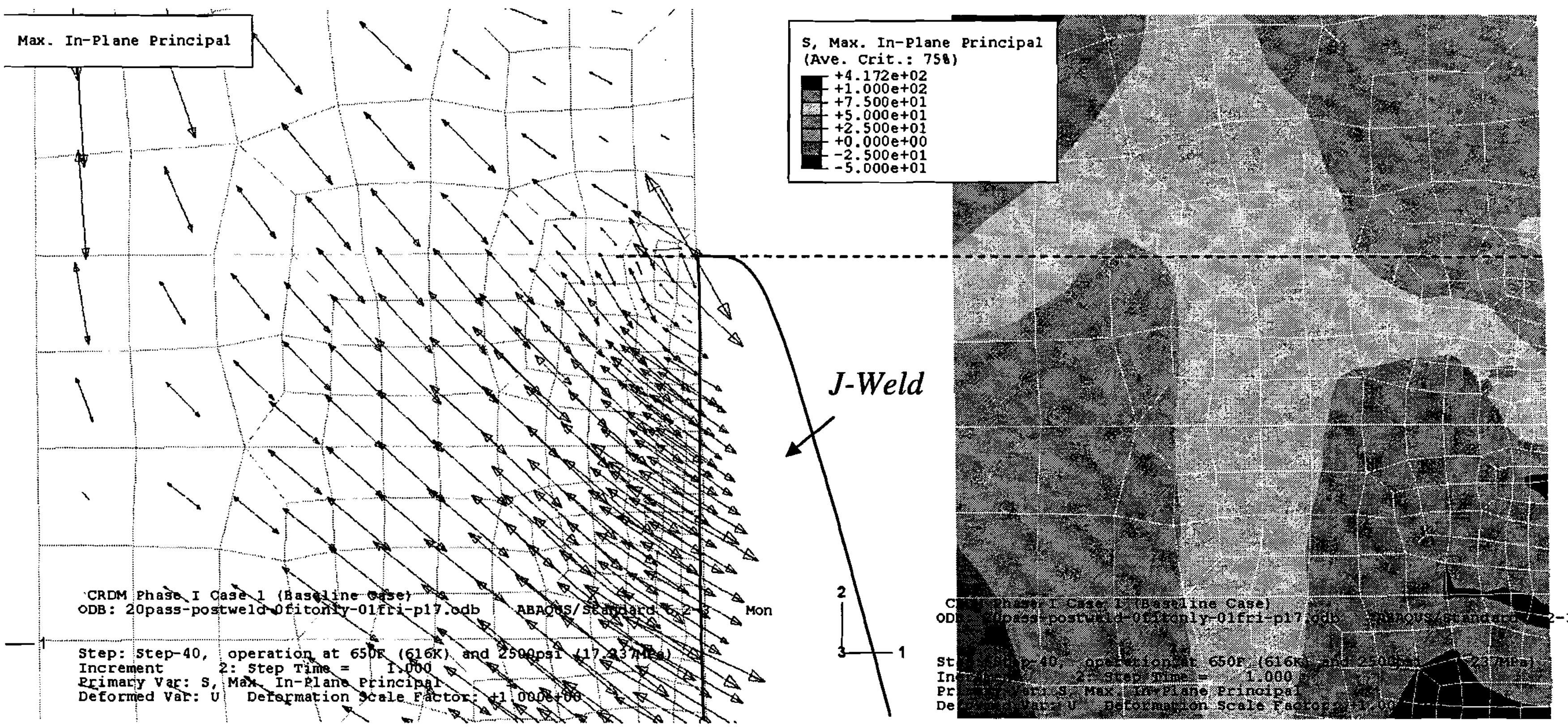


Hoop stresses at NOP/NOT



United States Nuclear Regulatory Commission

Resolution of stresses suggests inclined crack plane



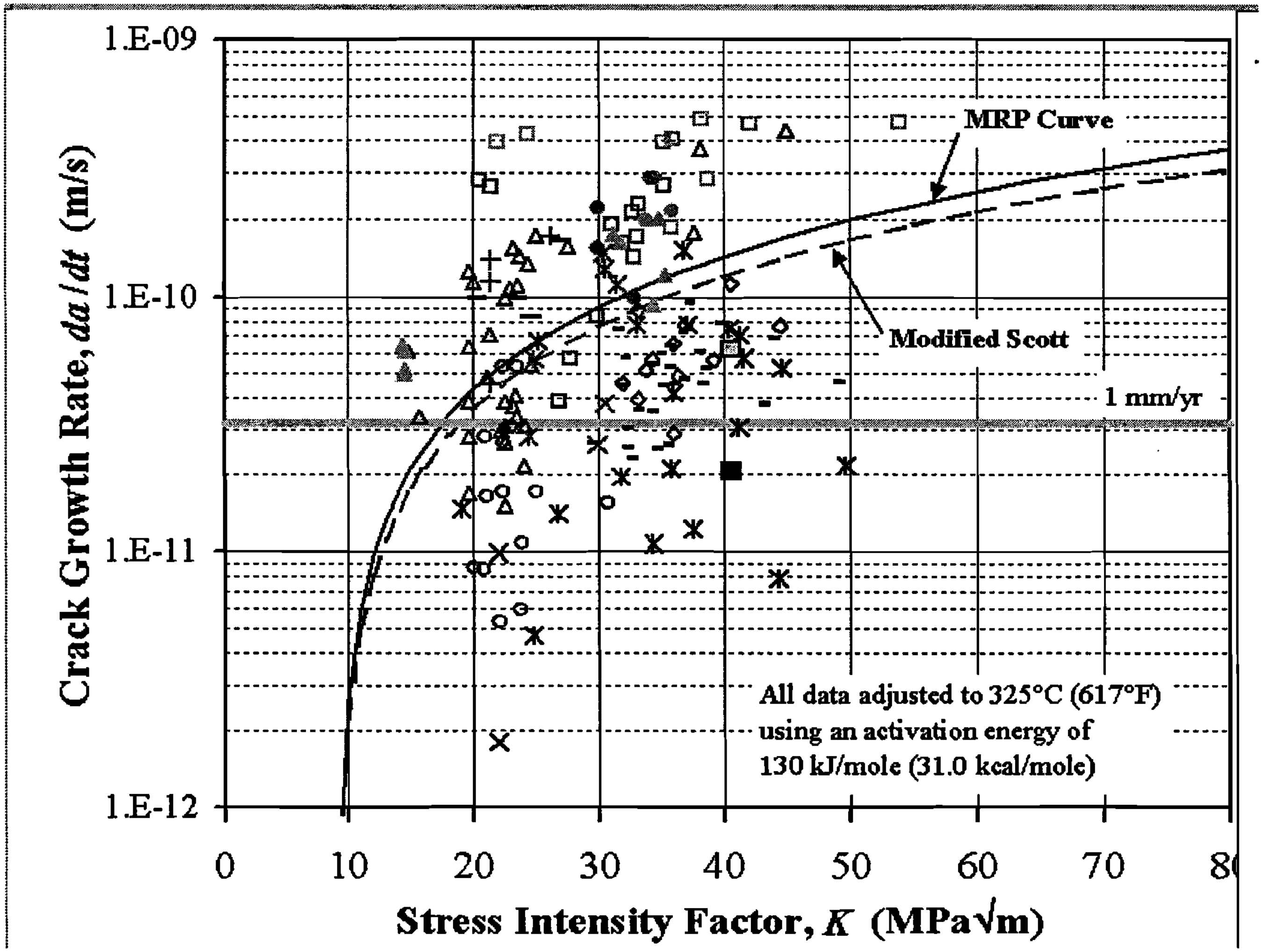
NRC-Industry Collaboration on CRDM Cracking Issues

Task Number	Task
1	Alloy 600/82/182 – (a) crack growth testing Alloy 600 and (b) Alloy 82/182
2	Alloy 690/52/152 – (a) crack growth testing Alloy 690, and (b) Alloy 52/152
3	Boric Acid Corrosion Testing – (a) Expert Panel to review the boric acid corrosion model in MRP-75, (b) Examine Nozzle #2 from Davis-Besse, (c) BAC program at ANL
4	(a) RPV Head Penetration PFM, PRA & Nozzle stress analysis by FEA, (b) Residual stresses in A600 CRDM tubing
5	Failure Analysis of North Anna RPV head – determine impact of findings on susceptibility models, visual inspection validity, and inspection and repair methods (Industry effort underway, '04 funding proposed for NRC collaborative research)
6	Nozzle 46 Davis-Besse RPV head – determine meaning of NDE signals (shadow, or "anomalous indication") and implication for future inspections
7	Mitigation Testing – determine viability and utility of mitigation options, both for Alloy 600 base material (penetrations, etc.) and Alloy 82/182 weld material (J-grooves, butt welds, etc.) (fully an industry effort at present)

Stress-corrosion crack growth rate data from MRP-55; validated by ITG on CGRs in Alloy 600.

Much more data to be added in next couple of years, mostly through international programs.

ITG now working on Alloy182 compilation – meeting next week.



NRC Research Programs Related to CRDM & Alloy 600

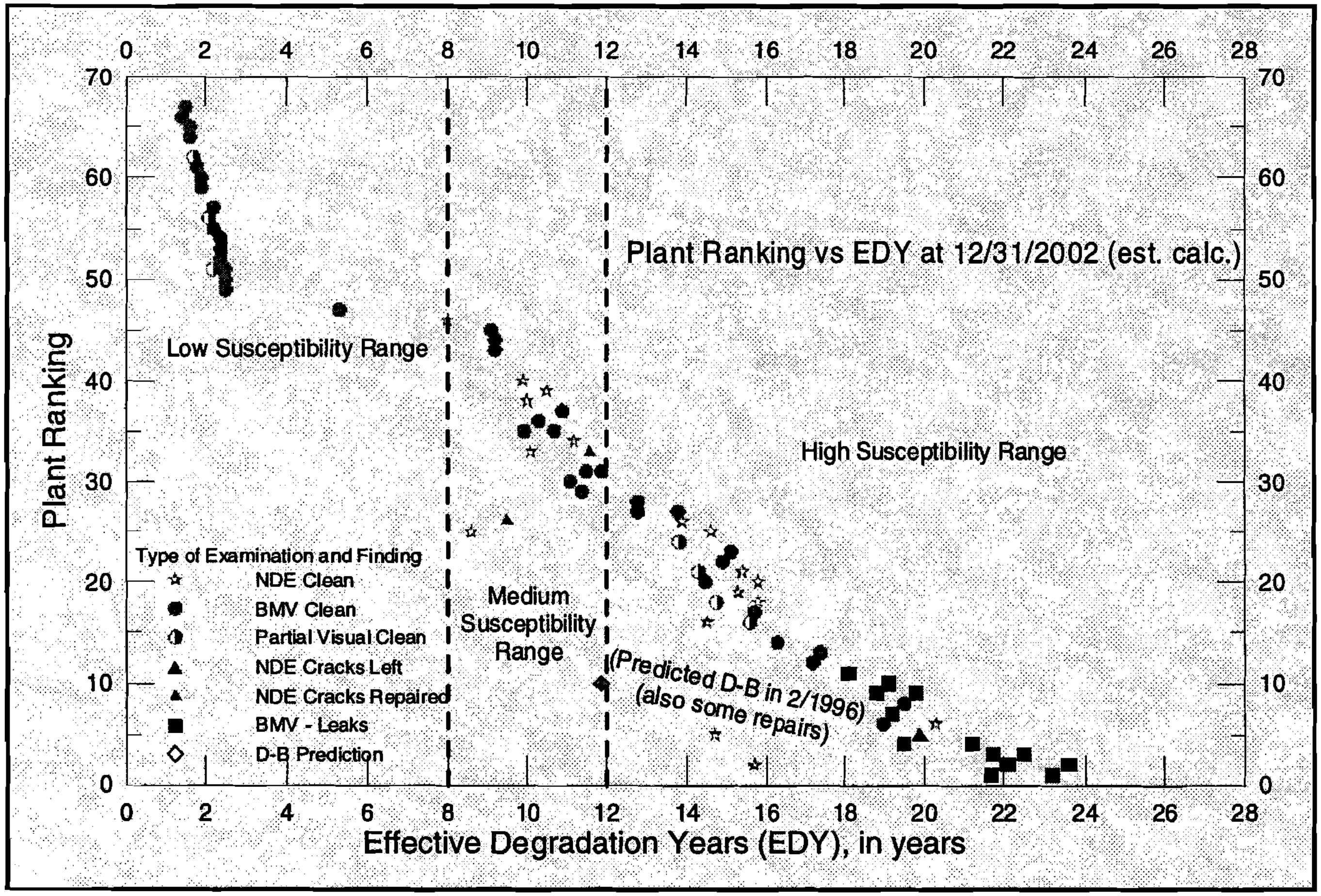
The longer term response

- Continued development of CRDM & closure weld inspection techniques
- Modeling of Residual Stresses (tube fabrication & closure weld induced)
- Improved Probabilistic Model for t_f from Leakage of Circ. Cracks
- Summary Report on Leakage from CRDMs
- Continue Testing SCC Rates of A600, A690 & Welds
    - Supplemented D-B materials (A600, A182) into on-going program

All feed into improved risk analysis models

- Development of an International Cooperative Group on PWSCC of Nickel-base Alloys, Including Inspection and Repair Techniques
- Workshop on March 24-26 to Discuss Issues of PWSCC in Nickel-Base Alloys

Plant Ranking vs. EDY



Current model depends only on time at temperature.

Other factors might be quantified well enough to warrant consideration:

- *Yield strength*
- *GB carbides*
- *Measured da/dt*

Completion of Cavity and Exposed Clad Exams

- Completion due early May, 2003 – docketed shortly after
  - Axial & circumferential cracks in J-weld sectioned, opened
    - Long axial cracks, very short circumferential cracks – both IGSCC
  - Cracks in clad were measured, opened, characterized, deposits analyzed
    - Depth is ~1 – 1.5 mm; all terminate with ~5.0 mm clad remaining
    - Possibly due to stress effect, less possibly a temperature effect
      - Temp gradient in clad was 315°C (RCS side) - ~100°C – cavity side
      - All growth by IGSCC in conc. boric acid solution, no ductile tearing
      - Elicitation of the growth rate would shed light on cavity evolution
  - Walls of the cavity examined for corrosion morphology effects

Exam of exposed clad & J-weld – sectioning scheme

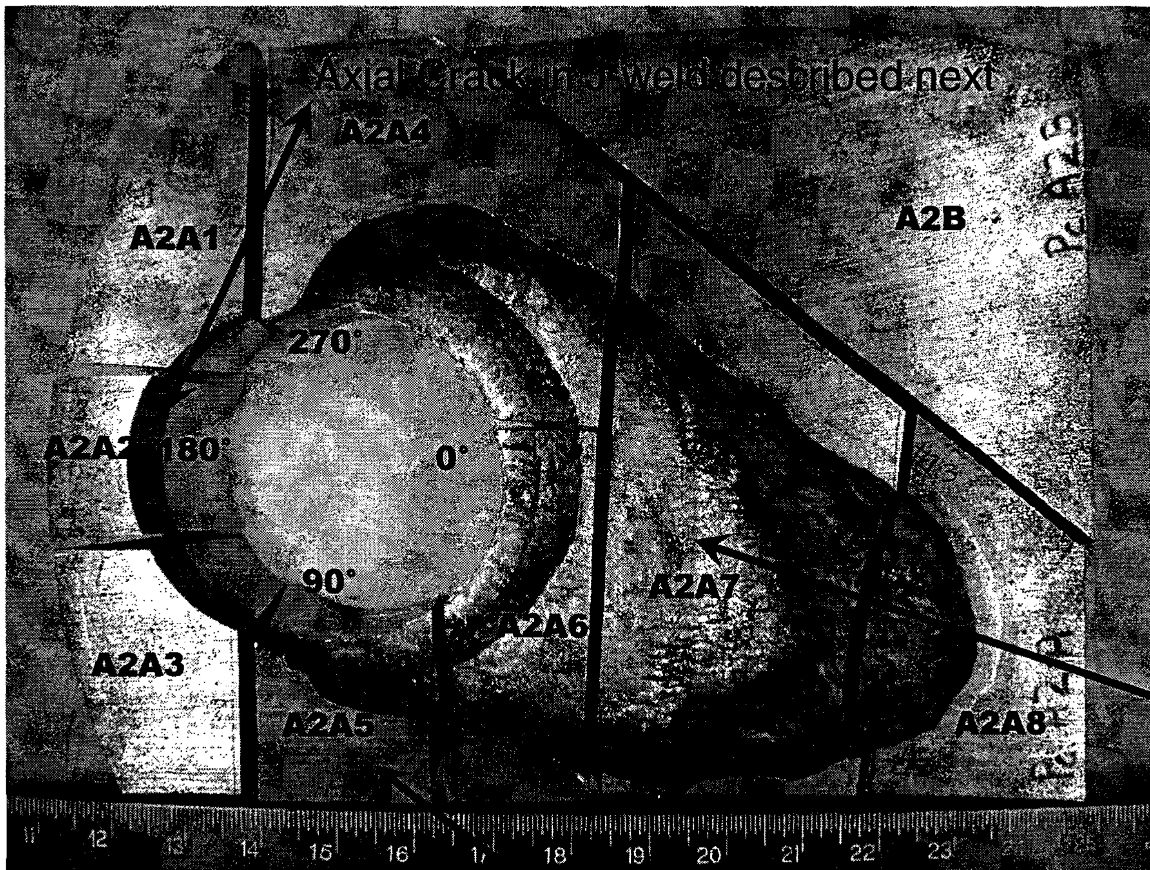


Photo shows major cuts made in preparation for cavity exam. Most sections were further reduced for metallographic and fractographic exams. Largest cracks were near ~10° (major leak) and 180° (non-leaking).

Cracks in clad described later

Piece A2A5 shown on subsequent slide

Examination of cavity characteristics near J-weld

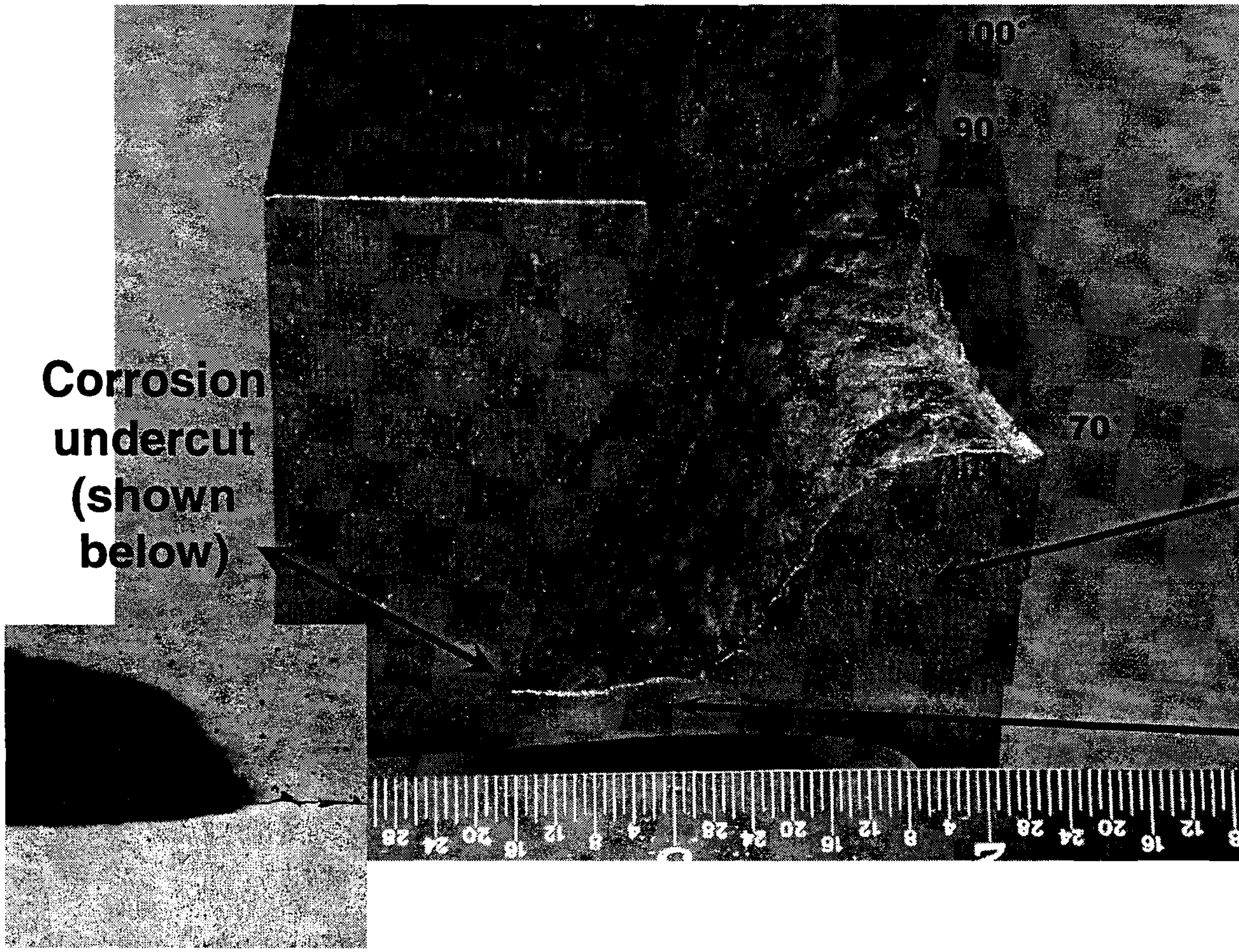


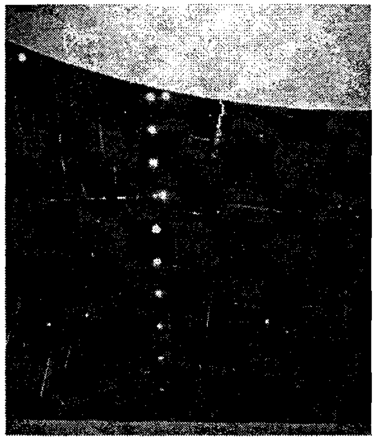
Photo shows exposed J-weld/LAS fusion surface, exposed clad, and corroded LAS near Nozzle #3.

Corrosion undercut (shown below)

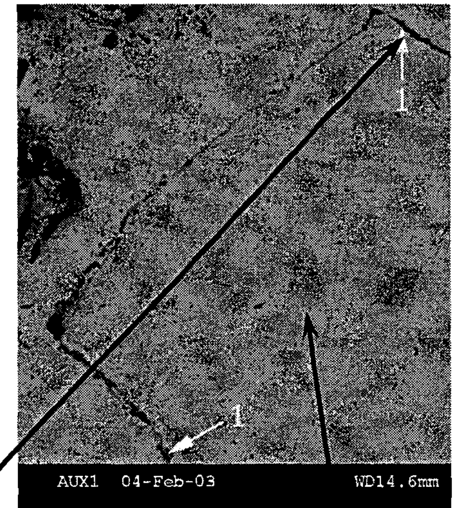
Exposed J-weld

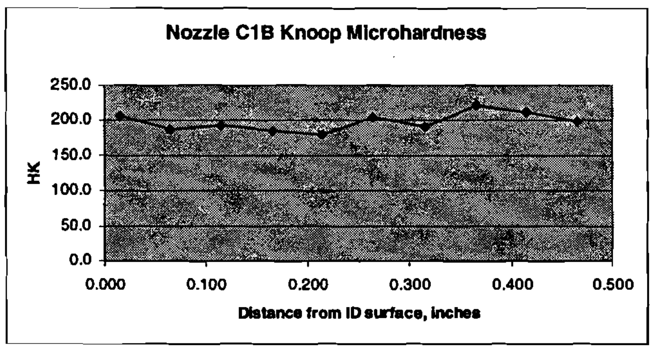
Exposed clad (thinnest location)

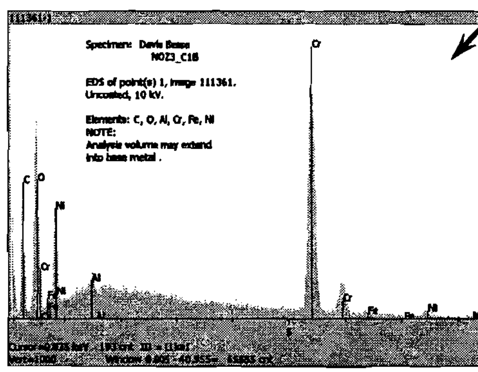
Longest crack in Nozzle #3 (on uphill side)



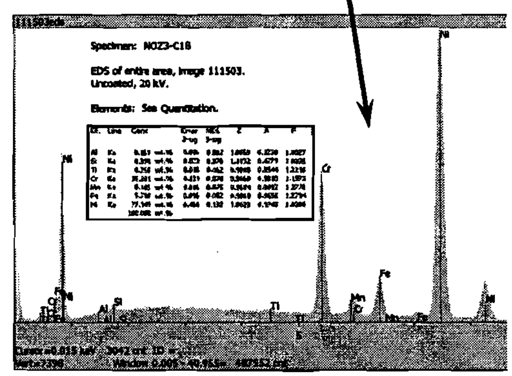
Axial crack in Nozzle #3. Crack was about 1.2 in. above J-weld, but little leakage occurred into the annulus. Hardness is uniform throughout nozzle. Grain bdy. carbide coverage is also good. Alloy is generally OK.





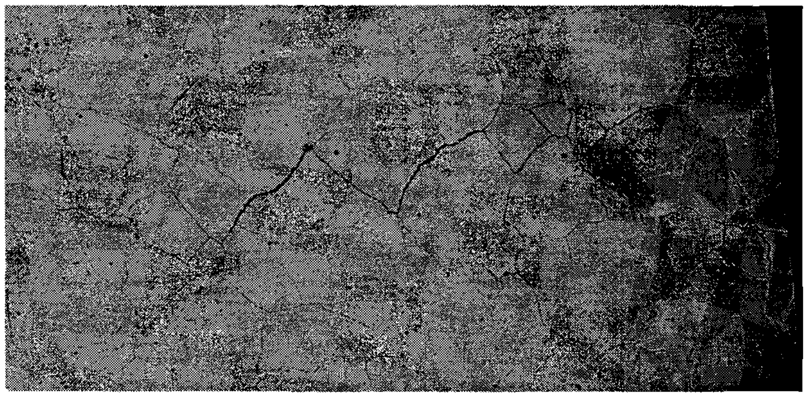


Grain boundary analysis shows high Cr, low-(Fe, Ni)

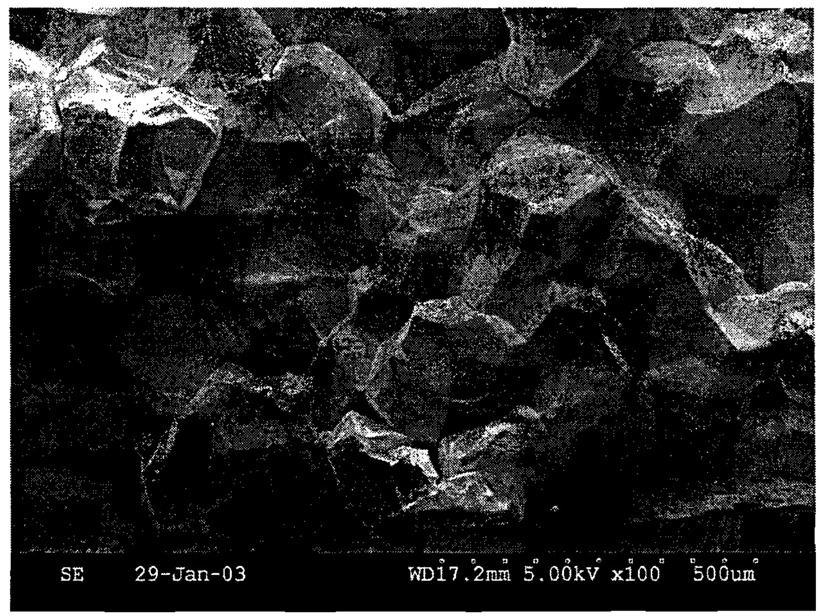


Matrix analysis shows Ni, Cr, Fe ≈ Alloy 600 composition.

IGSCC in CRDM Nozzle #3

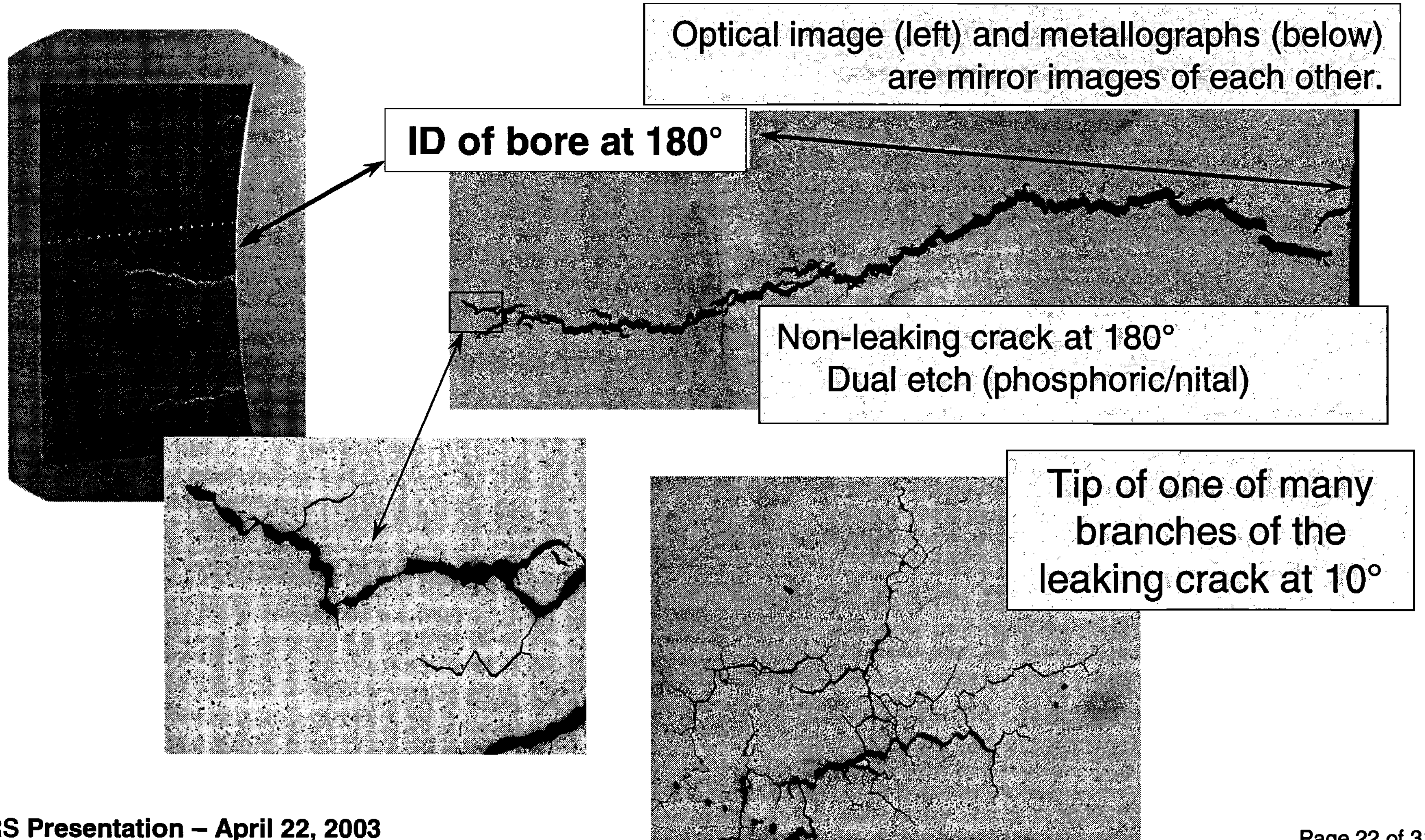


Left: IGSCC crack in Alloy 600 of Nozzle #3, 170° location, near upper end, dual, phosphoric/nital etch.

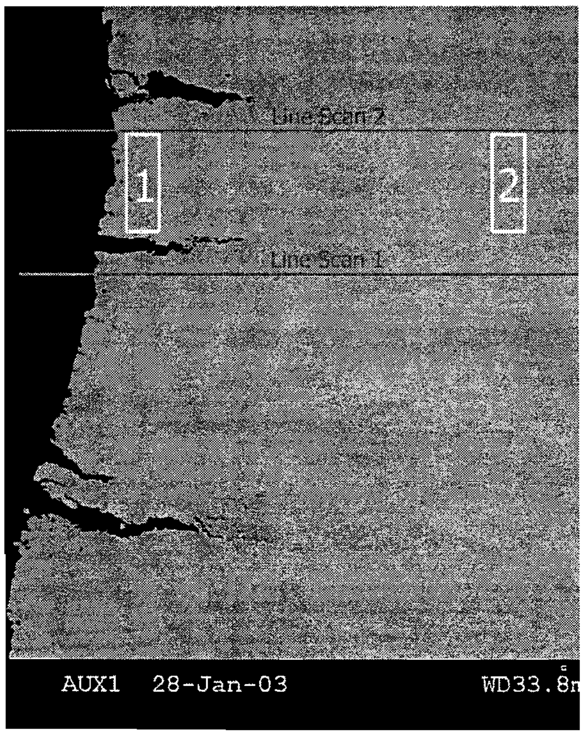


Right: IGSCC surface from Alloy 600 of Nozzle #3. Surface was 100% IGSCC, with substantial amounts of oxygen and carbon in analysis.

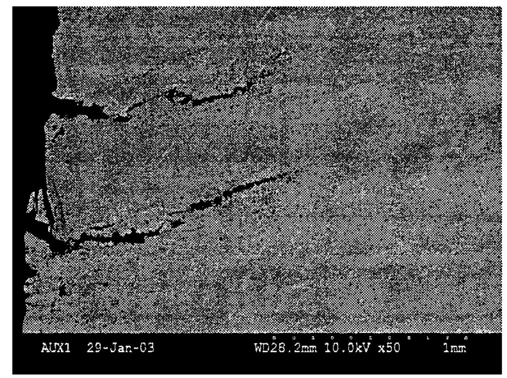
Character of IGSCC cracks in J-weld of Nozzle #3

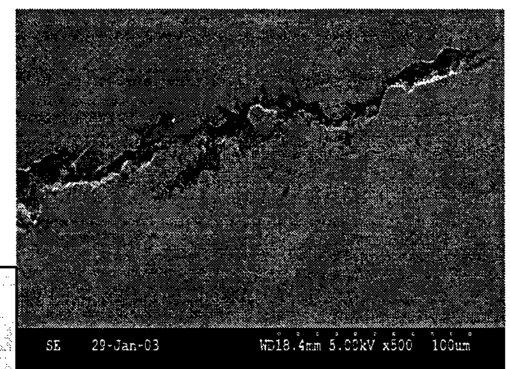


Opened crack in cladding shows interdendritic growth morphology – all IGSCC, no tearing, even near the bulge.



SEM (top) shows interdendritic crack path





SEM (right) shows preferential dissolution of ferrite creates crack path

United States Nuclear Regulatory Commission

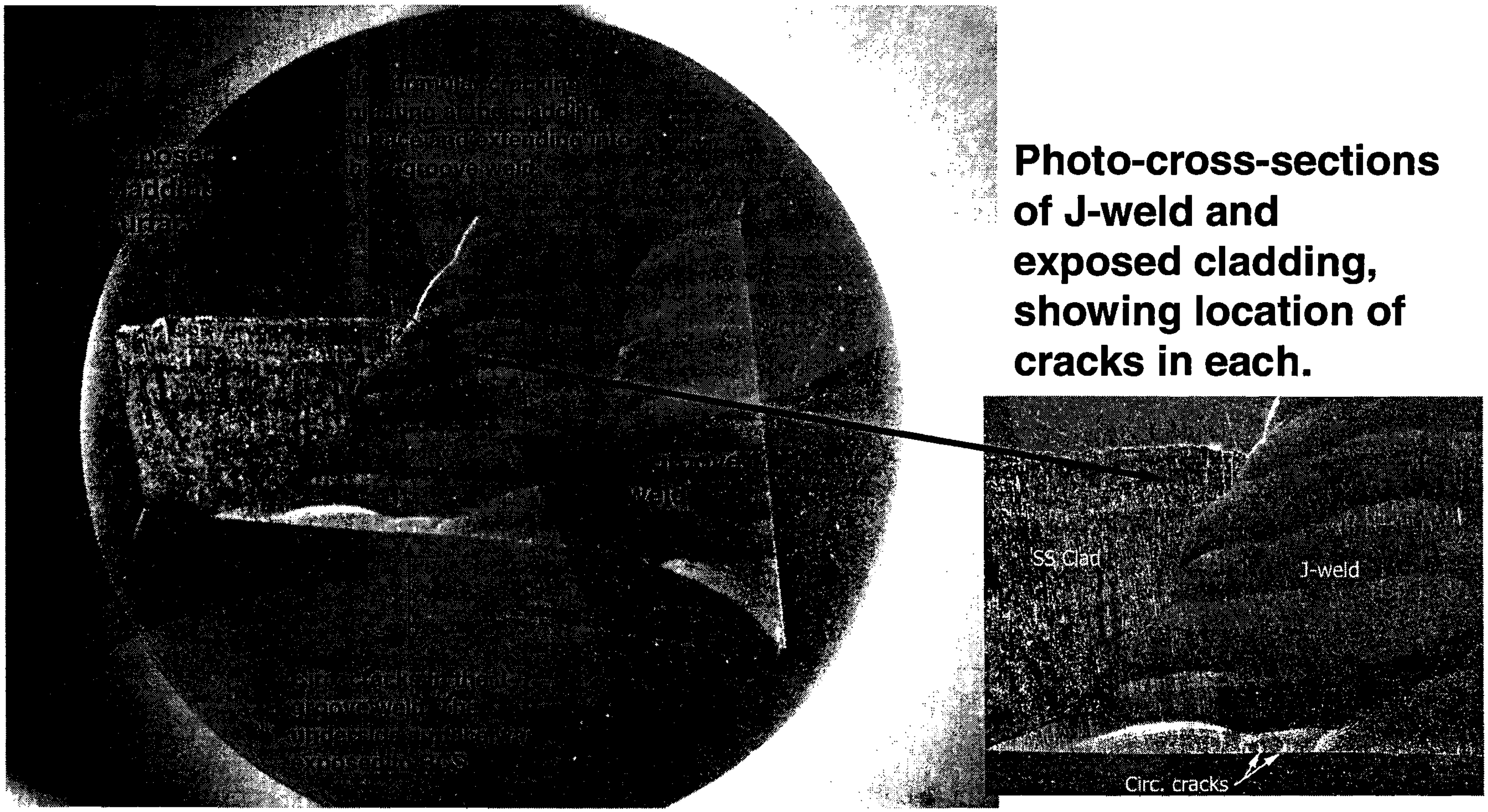
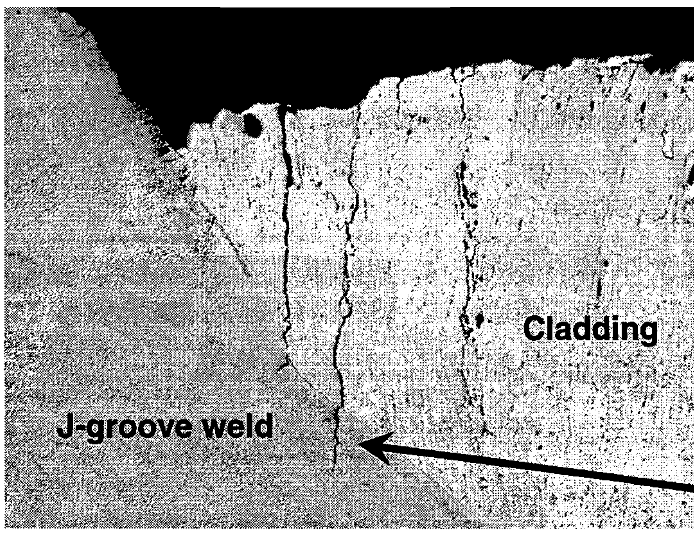
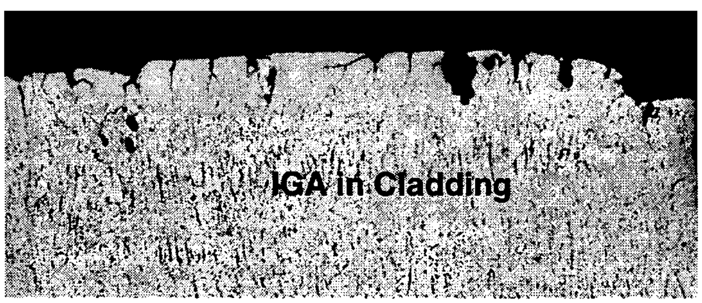
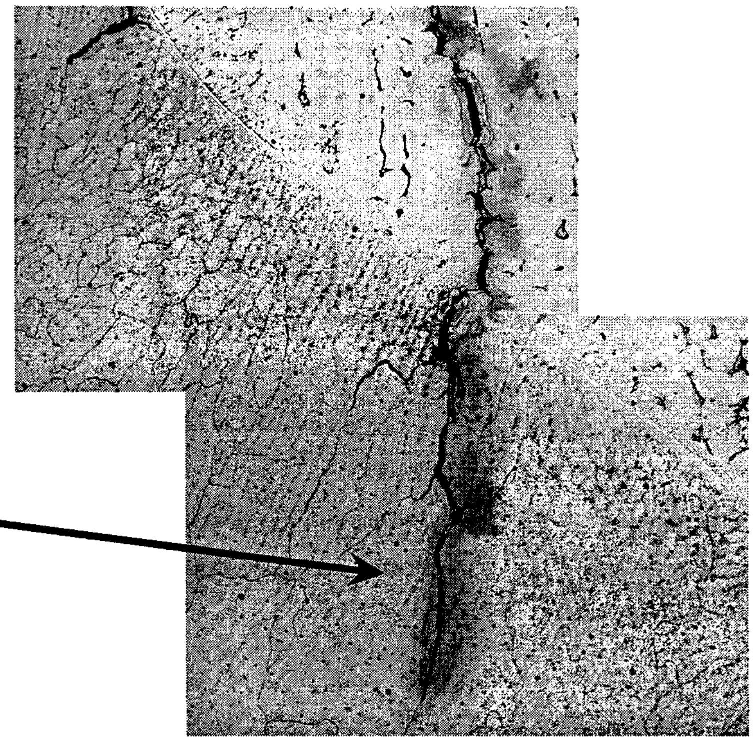


Photo-cross-sections of J-weld and exposed cladding, showing location of cracks in each.

Cracks in the exposed clad, attacked by concentrated, boric acid solutions





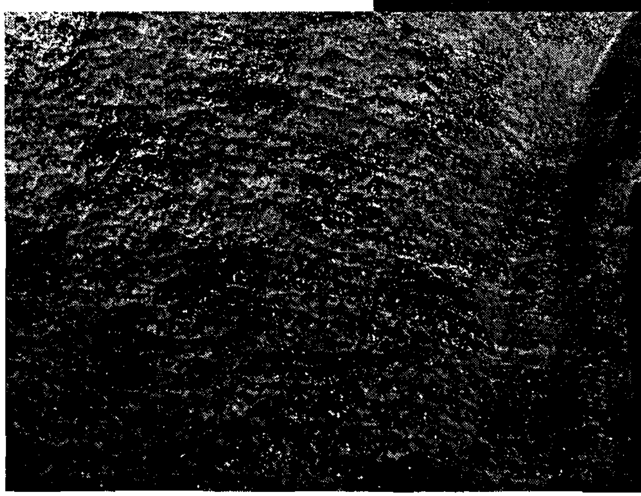


Closeup of clad crack penetrating fusion line into J-weld

Photographs of D-B Cavity Walls

Looking up near nose of the cavity

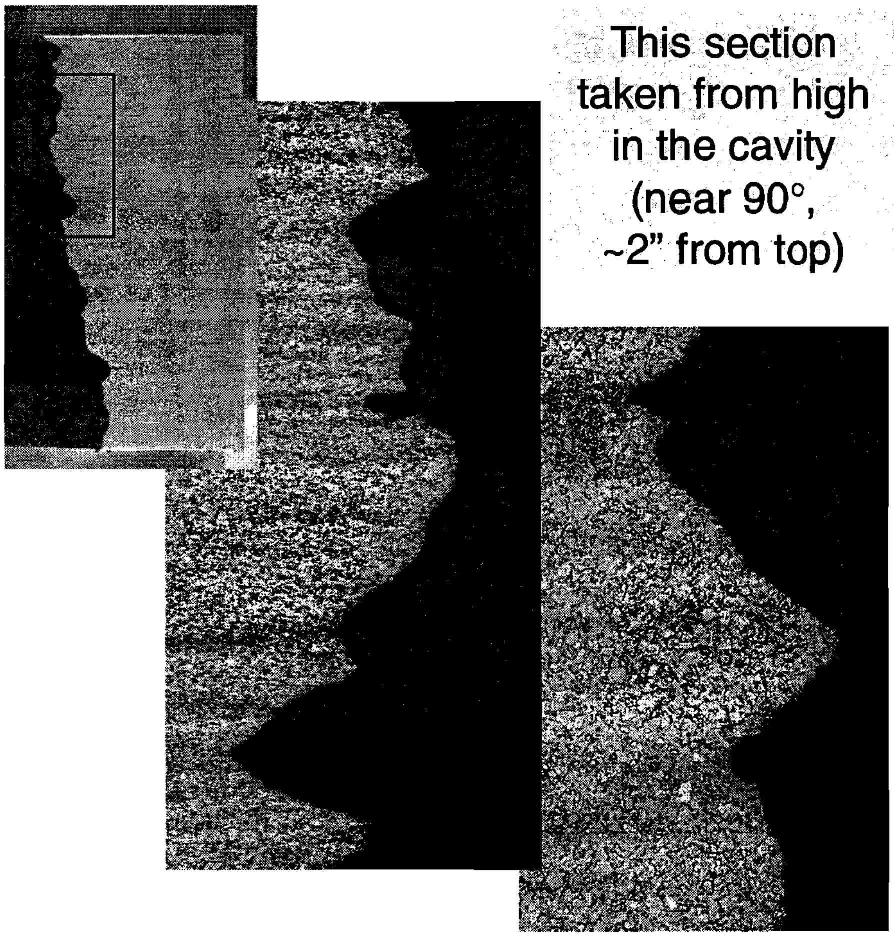
These investigations will help us to understand the corrosion timeline and process



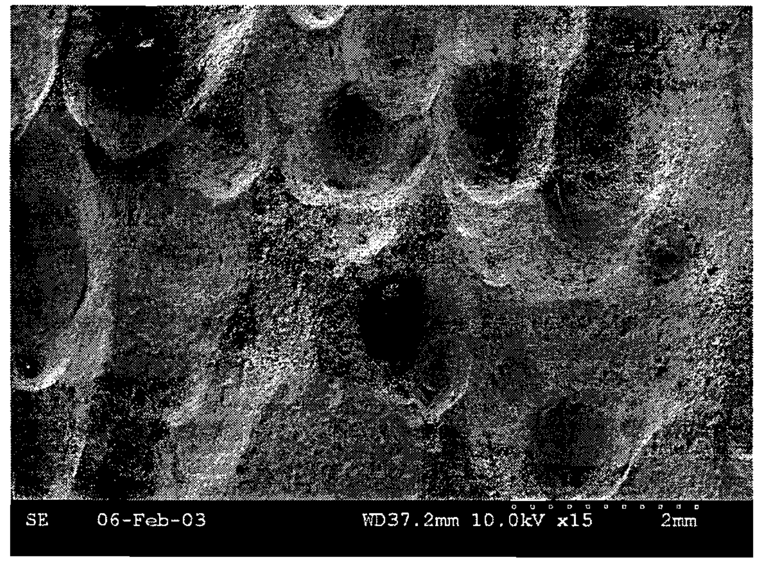
Near 90°

Near 270°

Characterization of the Walls of the Cavity



This section taken from high in the cavity (near 90°, ~2" from top)



Metallographs (stack of three at left at increasing magnification), and SEM show that cavity walls are characterized in places by ~1 mm. diam. pits, associated with banded microstructure.

Davis-Besse Root Cause and Safety Assesssment

1. **Features of Boric Acid Corrosion Program at Argonne Nat. Lab**
   - A. Crack Growth Rates of Alloys 600 & 182 from Davis-Besse Head
   - B. Computational Model, Based on Probabilistic Assessment of:
     - i. Statistics of Crack Initiation
     - ii. Probability of Detection & Accuracy of Sizing
     - iii. Crack Growth Rate Variations
     - iv. Stress Intensity Factor Gradients (Residual Stress, Interferences)
     - v. Critical Crack Sizes, Including Factor of Safety
   - C. Electrochemical Potential and Polarization Measurements of Low-Alloy Steel, Alloys 600 & 182 in Concentrated Boric Acid Solutions
     - i. Measure E_{cp} for range of solution compositions, temperatures
     - ii. Include molten boric acid species at temp. & pressure

2. **Next two slides describe MEB Program on Structural Integrity at ORNL**

Structural Integrity Assessment

Approach

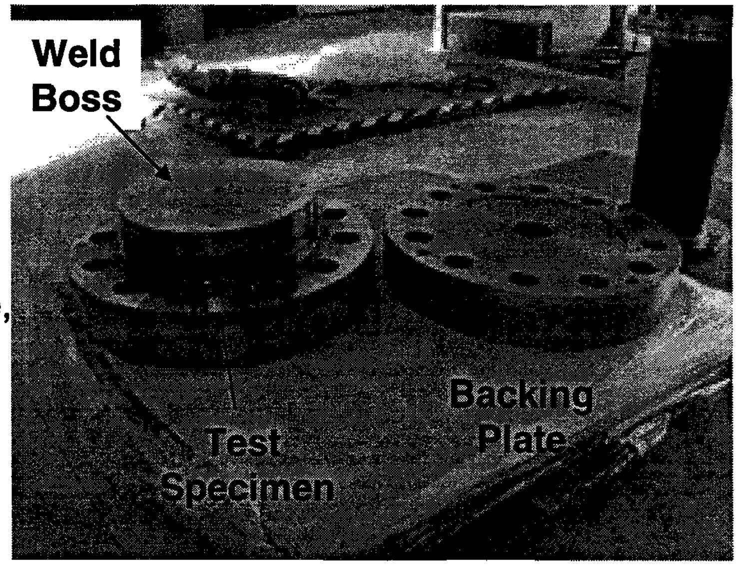
- Created detailed finite element model of the DB head, wastage cavity, and remaining unbacked cladding.
- Developed two failure models to bound expected behavior:
  1. Plastic instability model calibrated by PVRC-sponsored unflawed rupture disk results.
  2. Ductile tearing initiation model using 3-wire, 308SS quasistatic fracture toughness properties.
- Predicted best-estimate failure probability vs pressure as a function of crack depth.
- Conducted Monte Carlo analysis to determine failure probabilities with respect to the best estimate.

Variable Modeling Categories

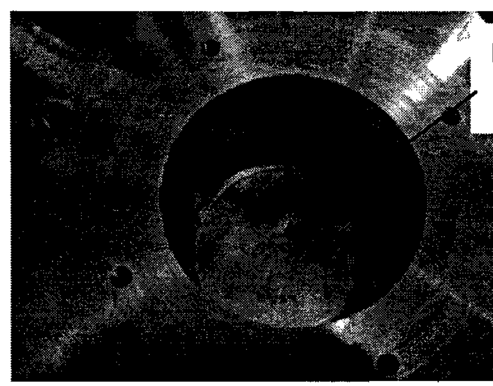
- **Probabilistic**: Crack depth, material toughness, rupture disk failure pressure.
- **Conservative Deterministic**: J-groove weld reinforcement; cladding thickness.
- **Best-Estimate Deterministic:** Cladding cavity area; low alloy steel, Alloy 600, and 308 SS constitutive behavior; vessel head geometry; operating temperature and pressure.

Ongoing Work for ASP Analysis (by 10/03)

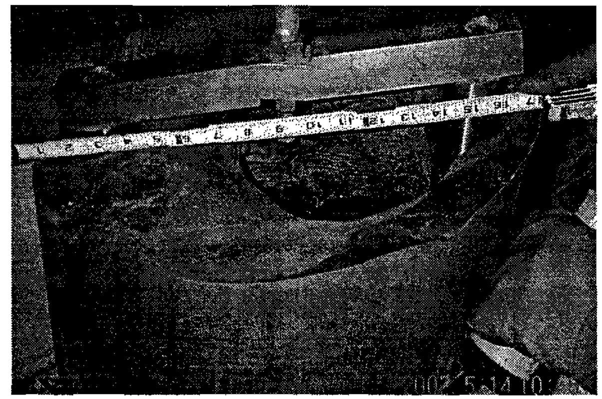
- **Analytical Program**
  - Develop tearing instability model to analyze intermediate-depth flaws.
  - Extend model to predict failure probabilities for the year preceding cavity discovery.
    - Monte Carlo Analysis
    - Probabilistic Variables: Pressure, cavity size, flaw size, wastage rate, material toughness, and burst pressure.
  - More rigorous quantification of geometric, material, and failure model uncertainties.



- **Experimental Program**
  - Conduct material property testing of surrogate cladding material (PVRUF).
  - Perform burst tests on simple, circular or elliptical cavity geometries.
    - Unflawed specimens
    - Flawed specimens
  - Assess accuracy of analytical failure models.



Harvesting of Head for Additional Research



- Nozzle #3 and surrounding low-alloy steel at BWXT-Lynchburg
  - Optical & SEM Micrography of Cavity Surface
  - Cladding Properties, Microstructure, etc.
- Nozzles #2 and #46 - removal in early 2003
  - #2 sent to Argonne for failure analysis
  - #46 sent to PNNL for research on "anomalous" UT indications
  - Additional nozzles for crack growth rate testing
- Crack Growth Rate Testing of Alloy 600 (Nozzle #3) and Alloy 182 (J-weld, from Nozzle #11) soon underway
- North Anna Unit 2 Head Being Harvested by Industry
  - Expect NRC/Industry Coordination of NA2 Research

PLANS FOR ADDRESSING THE DAVIS-BESSE LESSONS LEARNED TASK FORCE RECOMMENDATIONS

Brendan Moroney, NRR

Cayetano Santos, RES

April 23, 2003

INTRODUCTION

- NRR and RES jointly developed an overall implementing plan
- Delivered to EDO on 2/28/03
- Forwarded to Commission on 3/10/03

HIGH PRIORITY ITEMS

- Overall Plan includes 4 Action Plans for High Priority items (21 items) in Davis-Besse LLTF Review Team memo

ACTION PLANS

- Stress Corrosion Cracking

  Lead: NRR/DLPM

- Operating Experience

  Lead: NRR/DRIP

- Inspection, Assessment, and Project Management

  Lead: NRR/DIPM

- Barrier Integrity

  Lead: RES/DET

MEDIUM/LOW PRIORITY ITEMS

- **Lead Responsibility, Resource Allocation and Schedule to be established via the Planning, Budgeting and Project Management (PBPM) process**
- **Initial Screening to be completed by 8/31/03**

TRACKING & REPORTING

- Action Plan status reported quarterly to Office Directors
- Status on all LLTF recommendations reported semiannually to EDO and Commission
- First Semiannual Report 8/31/03

STRESS CORROSION CRACKING ACTION PLAN

Part I	**RPV Head Inspection Requirements**
Part II	**Boric Acid Corrosion Control Requirements**
Part III	**Inspection Program Improvements**

STRESS CORROSION CRACKING ACTION PLAN

Part I - Inspection Requirements

1. Collect world-wide information

2. Evaluate existing SCC models for use in susceptibility index

3. Evaluate results of inspections per Bulletins and Orders

4. Review and evaluate MRP and ASME efforts

5. Endorse ASME Code changes or develop alternative inspection requirements

STRESS CORROSION CRACKING ACTION PLAN

Part II - Boric Acid Corrosion Control

1. Collect world-wide information

2. Evaluate responses to Bulletin 2002-01

3. Evaluate the need for additional regulatory actions

4. Review and evaluate ASME Code revised requirements

STRESS CORROSION CRACKING ACTION PLAN

Part III - Inspection Programs

1. Guidance for periodic review of licensee ISI activities by NRC

2. Guidance for timely, periodic inspections of plant BACC programs

3. Guidance for assessing adequacy of plant BACC programs

BARRIER INTEGRITY ACTION PLAN

Part I **Leakage Detection and Monitoring Requirements**

Part II **Improved Performance Indicators**

BARRIER INTEGRITY ACTION PLAN

Part I - Leakage

1. Develop basis for new RCS leakage requirements
   - Review bases for current leakage limit
   - Review experience/capabilities of currently used leak detection systems
   - Evaluate capabilities of state-of-the-art leak detection systems
     - * Scope of Action Plan increased to include methods which may be capable of detecting degradation before leakage
   - Evaluate leak rates that lead to degradation

BARRIER INTEGRITY ACTION PLAN

Part I - Leakage (Continued)

2. Develop recommendations for improved leakage requirements
   - TS
   - Inspection Guidance
   - RG 1.45

3. Incorporate recommendations, as appropriate, into requirements
4. Examine improvements to barrier integrity requirements in addition to those which rely on leakage monitoring

BARRIER INTEGRITY ACTION PLAN

Part 2 - Performance Indicators

- **Implement improved PI based on current requirements and capabilities**
- **Develop and implement an advanced PI**
- **Re-evaluate PI based on changes to RCS leakage requirements**

REACTOR VESSEL HEAD INSPECTIONS

Presented by

Dr. Allen L. Hiser, Jr.
Materials and Chemical Engineering Branch
Office of Nuclear Reactor Regulation

ACRS Materials & Metallurgy, and Plant Operations Subcommittees

April 23, 2003

OUTLINE

- Background
- Order EA-03-009 (issued February 11, 2003)
  - Inspection requirements
  - Relaxation requests
- Recent plant experience
  - North Anna Unit 2 - fall 2002
  - ANO Unit 1 - fall 2002
  - Sequoyah 1 - fall 2002
  - North Anna Unit 1 - spring 2003
  - Sequoyah 2 - spring 2003
  - South Texas Project Unit 1 - spring 2003
- Outlook

BACKGROUND

- Fall 2000
  - Oconee Unit 1 identifies deposits - axial leak
- Spring 2001
  - Oconee Unit 2 and 3 identify circumferential cracks
  - ANO Unit 1 identifies a leaking nozzle
- **NRC issues Bulletin 2001-01 - August 2001**
  - Focus is safety issue (circumferential cracks) for high susceptibility plants
- Fall 2001
  - Circumferential cracks identified - Crystal River 3 and Oconee 3
  - Leaks and repairs at Surry 1, North Anna 2 and TMI

BACKGROUND (cont.)

- Spring 2002
  - Davis-Besse identifies RPV head wastage & circumferential cracking

- **NRC issues Bulletin 2002-01 - March 2002**
  - Focus is safety issue is RPV wastage for all plants

- Spring 2002
  - Millstone identifies part through-wall cracks

- **NRC issues Bulletin 2002-02 - August 2002**
  - Focus is adequacy of inspection programs - methods (non-visual NDE for high susceptibility) and frequency
  - Licensee responses generally vague on future program, many cite MRP-75 program

BACKGROUND (cont.)

- Fall 2002
  - North Anna 2 identifies
    - ✓ Prevalent weld cracking
    - ✓ Leak from a repaired nozzle
    - ✓ Circumferential cracking at weld root without boron deposits
  - ANO Unit 1 identifies leak from a repaired nozzle
  - Oconee Unit 2 identifies possible through-wall cracking without boron deposits on the RPV head
  - Head corrosion at Sequoyah Unit 2 - above head boron source

- **NRC issues Order EA-03-009 - February 2002**
  - Mandates inspections for all PWRs

- Spring 2003
  - Sequoyah Unit 1 - boron deposit on a low susceptibility plant
  - South Texas Project Unit 1 - boron deposits on the lower head

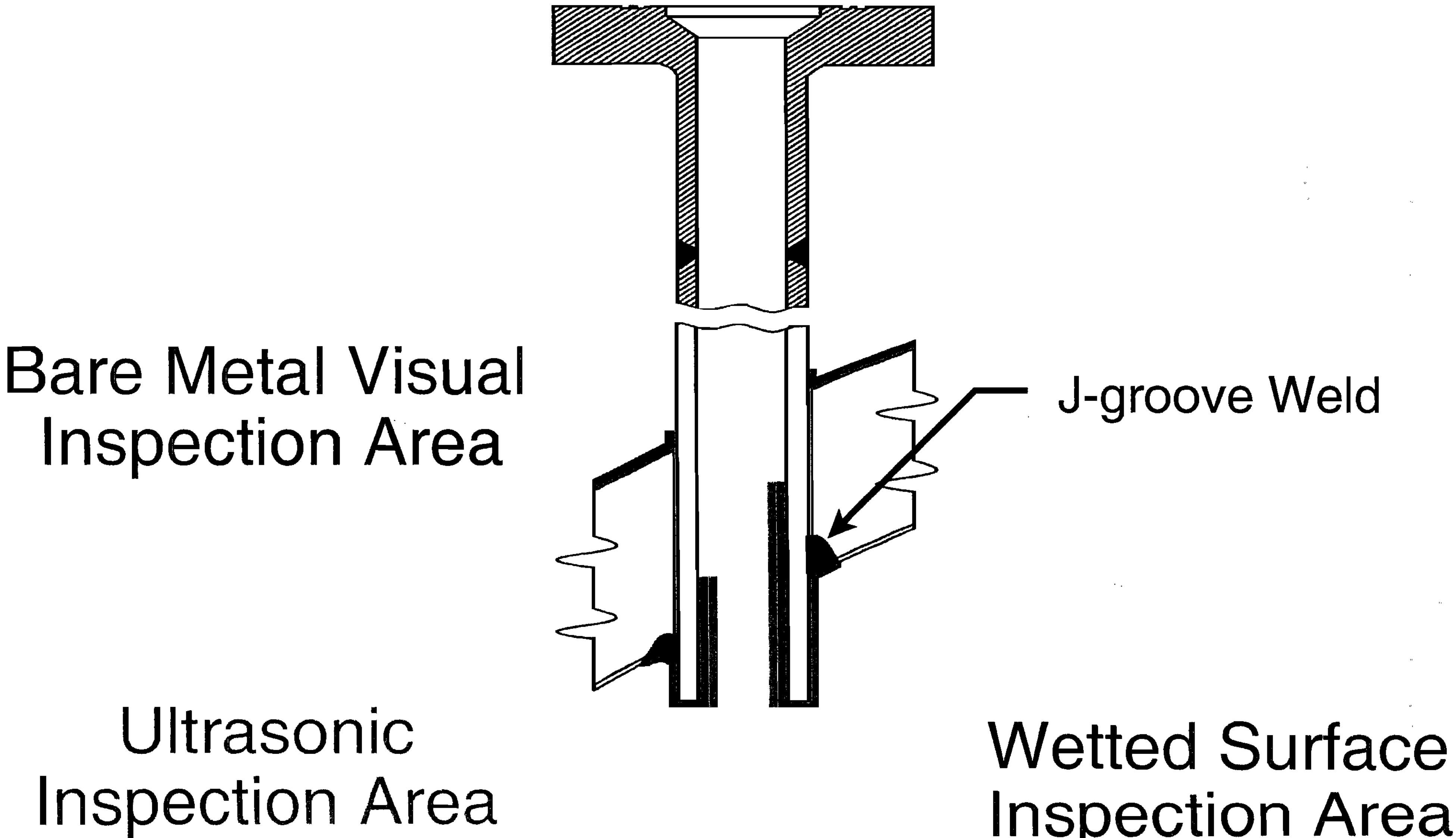
OVERVIEW OF ORDERS

- Issued February 11, 2003
- Issued to all PWRs
- Adequate protection basis
  - ASME Code inspections are inadequate
  - Revisions to inspection requirements are not imminent
  - RPV head degradation and nozzle cracking pose safety risks if not promptly identified and corrected
- Provides a clear regulatory framework pending the incorporation of revised inspection requirements into 10 CFR 50.55a

ORDER REQUIREMENTS

- Evaluate susceptibility - effective degradation years (EDY)
- High plants - bare metal visual AND non-visual NDE at EVERY RFO
- Moderate plants - BMV and non-visual NDE at alternating RFOs
- Low plants - BMV by next 2 RFOs (repeat every 3rd RFO or 5 years), non-visual by 2008 (repeat every 4th RFO or 7 years)
- Non-visual NDE is EITHER:
  - Ultrasonic with evaluation of interference fit leakage, OR
  - Wetted-surface examination

Order EA-03-009
Required Inspection Surfaces



ORDER REQUIREMENTS

- Explicit requirements and criteria to inspect repaired nozzles/welds
- Each RFO, must perform visual inspections to identify boric acid leaks from components above the RPV head - follow-up actions include inspections of potentially-affected RPV head areas and nozzles
- Flaw evaluation per NRC guidance (Strosnider letter fall 2001)
- Orders also apply to new RPV heads, either Alloy 600 (Davis-Besse) or Alloy 690 (North Anna 2 and many others)
- Post-outage report 60 days after restart

LICENSEE OPTIONS

- Must respond within 20 days
  - May request a hearing
  - May request a time extension to respond
- Request Director of NRR to relax or rescind requirements of the order
- Requests for relaxation for specific VHP nozzles will be evaluated using procedures for proposed alternatives to the ASME Code in accordance with 10 CFR 50.55a(a)(3)

NEED FOR ORDERS

- Past process of issuing Bulletins unwieldy, inconsistent, not stable, and has no regulatory weight (licensee commitments only)
- Rulemaking would take at least 1 or 2 years
- Orders can be revised or rescinded as necessary
- Although inspection plans for the next RFOs were generally acceptable, NRC wanted to provide licensees with planning time to meet order requirements
- Concerns that above RPV head leakage could result in undetected RPV head degradation

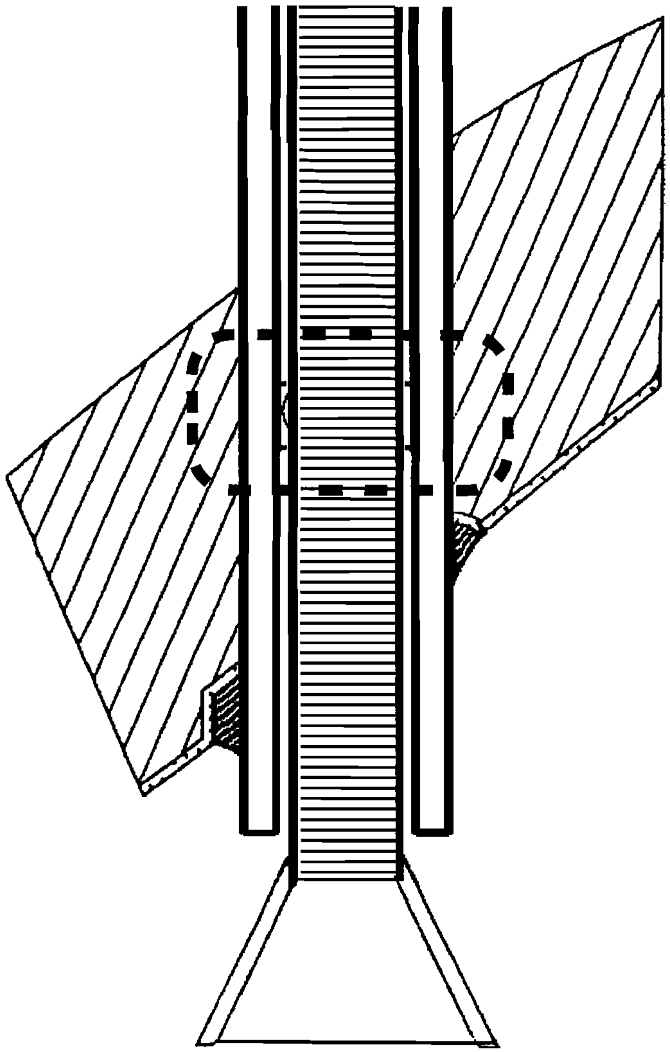
RELAXATION REQUESTS

- Limitations above the J-groove weld
  - Centering tabs & step on nozzle ID
  - Stress in non-inspected area below 28 ksi
  - Hardship - would have required guide sleeve removal and re-welding of a guide funnel onto nozzle

- Limitations below the J-groove weld
  - Guide funnel threads (ID & OD) and tapers on end of nozzles
  - Transducer coupling for time-of-flight-diffraction

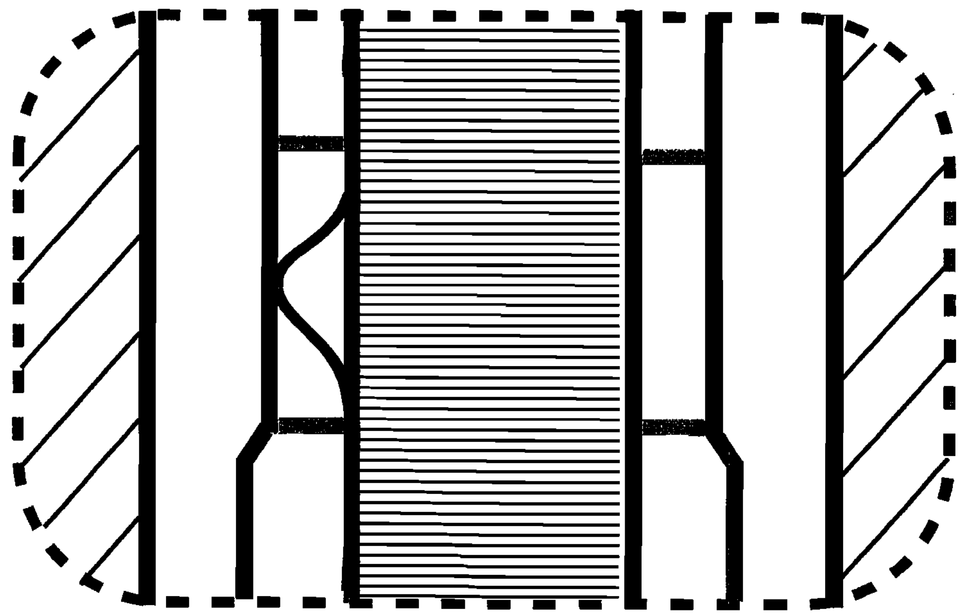
- Bare metal visual examinations
  - Localized insulation and support shroud interferences
  - Insulation prevents total access to RPV head surface
    - ✓ UT RPV head thickness measurements

Calvert Cliffs
Order Inspection Limitations

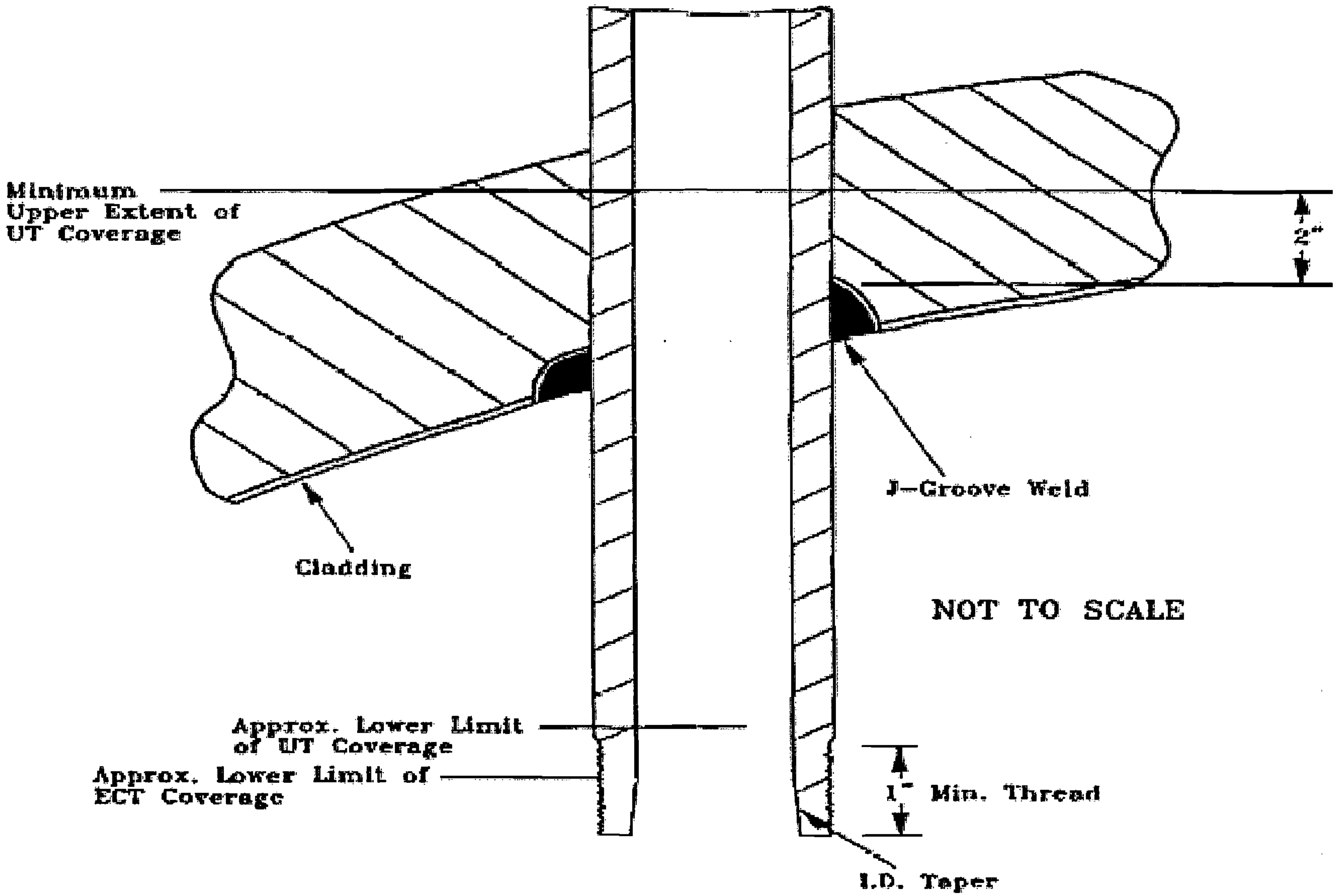


Thermal/Guide Sleeve

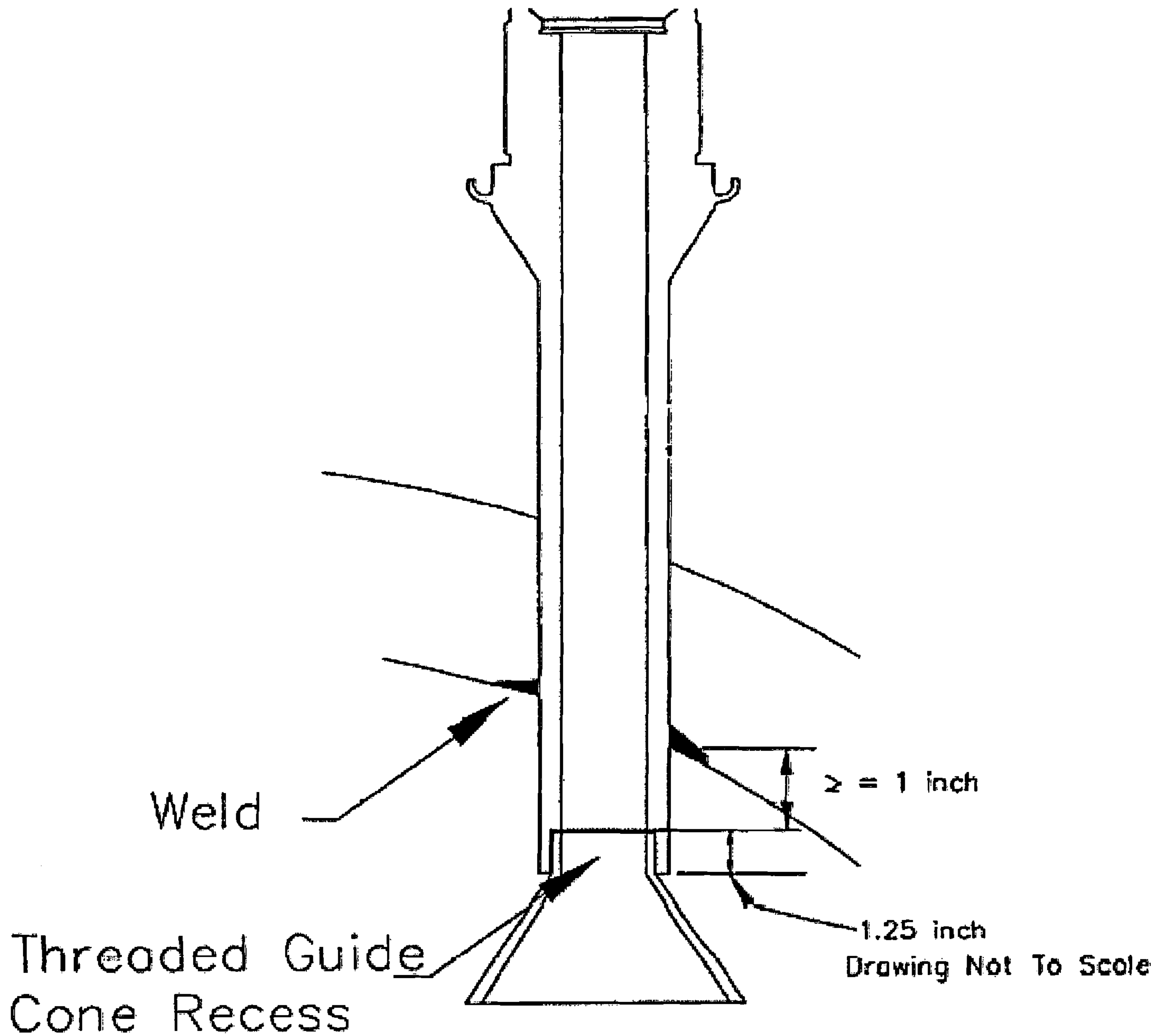
Sleeve Expansion Points



Farley Nuclear Power Plant
Cross-section of Typical 4" RPV Nozzle Penetration



St. Lucie Unit 2
Typical RPV Nozzle With Threaded Guide Funnel



INDUSTRY'S ROLE

- Complete development of and submit revised MRP-75 in a timely manner
- Continue/renew staff level interactions with NRC on the underlying analyses to support MRP-75
- Continue development of improved inspection tools to provide more effective examinations
- Continue activities to characterize RPV heads removed from service (e.g., North Anna Unit 2, Oconee Unit 2, etc.)
- Continue boric acid corrosion research to determine the conditions that can lead to accelerated corrosion rates
- Begin consideration of other RCS areas susceptible to cracking (e.g., hot leg piping, etc.)

OUTLOOK

- Goal is "permanent" requirements for inspections to ensure structural integrity of the RPV head and VHP nozzles

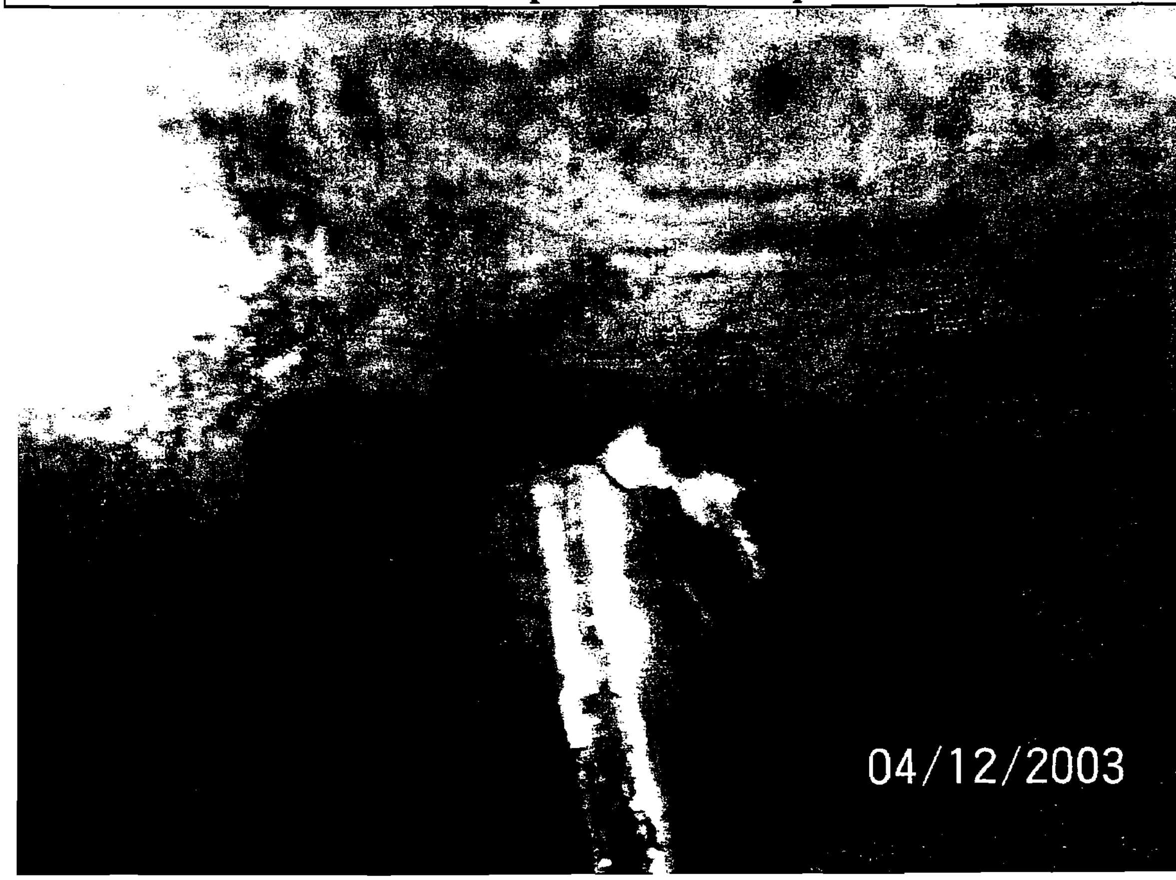
- ASME Code is working to develop inspection requirements
  - Has been based upon industry report (MRP-75)
  - NRC staff has provided comments - report is not acceptable as submitted, acceptability is not certain
  - NRC has suspended review pending revisions by the industry based on fall 2002 findings
  - ASME Code adoption of requirements may not be complete until 2004 or later

- Inspection requirements will be implemented in 10 CFR 50.55a
  - Endorse the new ASME Code requirements (if acceptable) under expedited implementation, OR
  - Codify alternative inspection requirements
  - Will take 1-2 years once acceptable requirements are identified

Unit 1 BMI Penetration 46
After Obtaining Samples

46

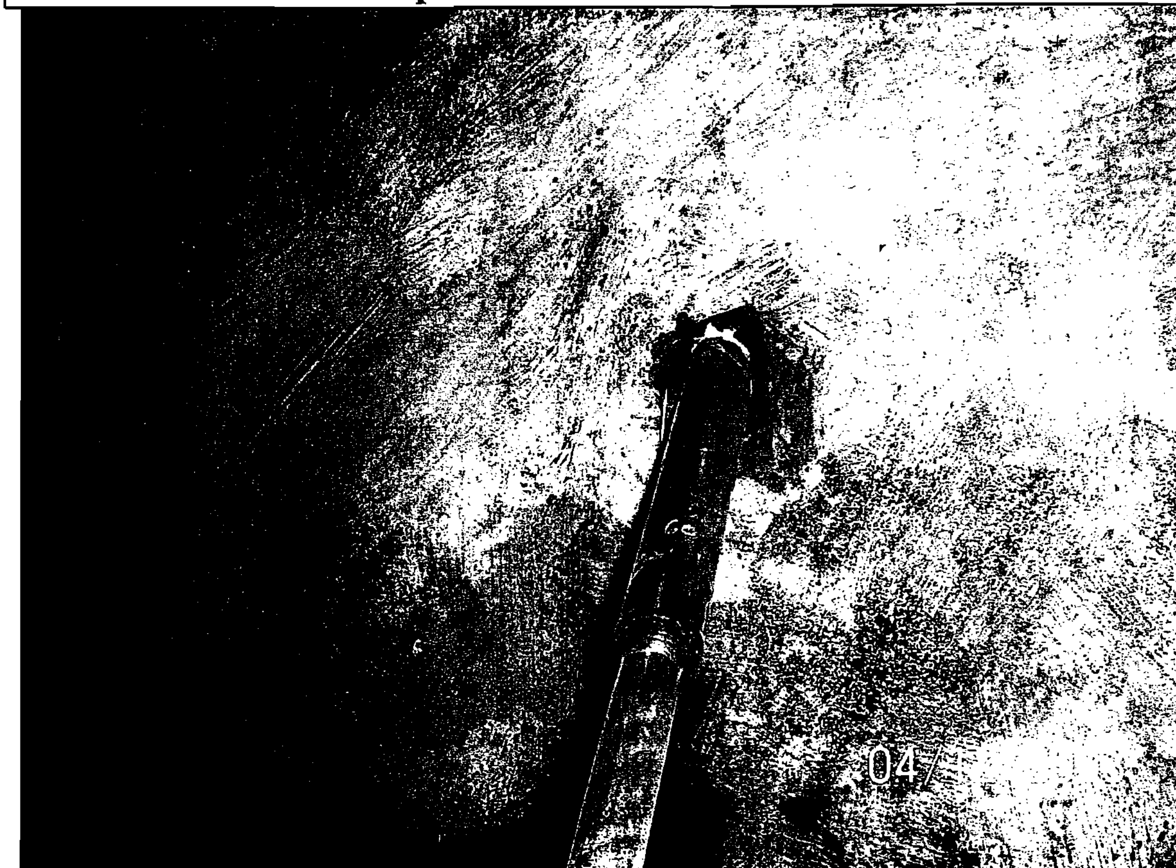
Unit 1 BMI Penetration 46
Initial Inspection – Closeups



45

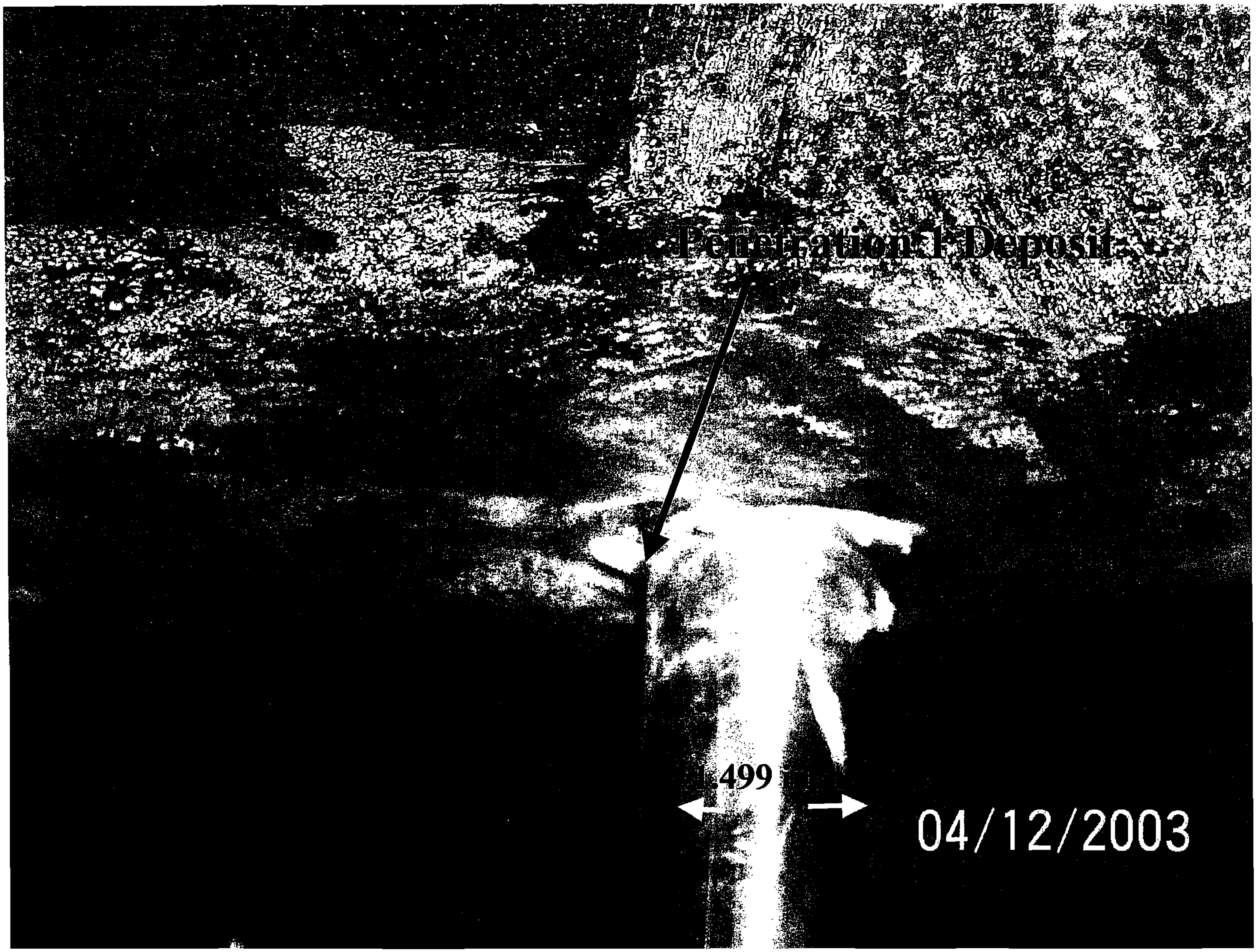
Unit 1 BMI Penetration 46
Initial Inspection – Closeups

Unit 1 BMI Penetration 46
Initial Inspection – Attachment to 03-6248

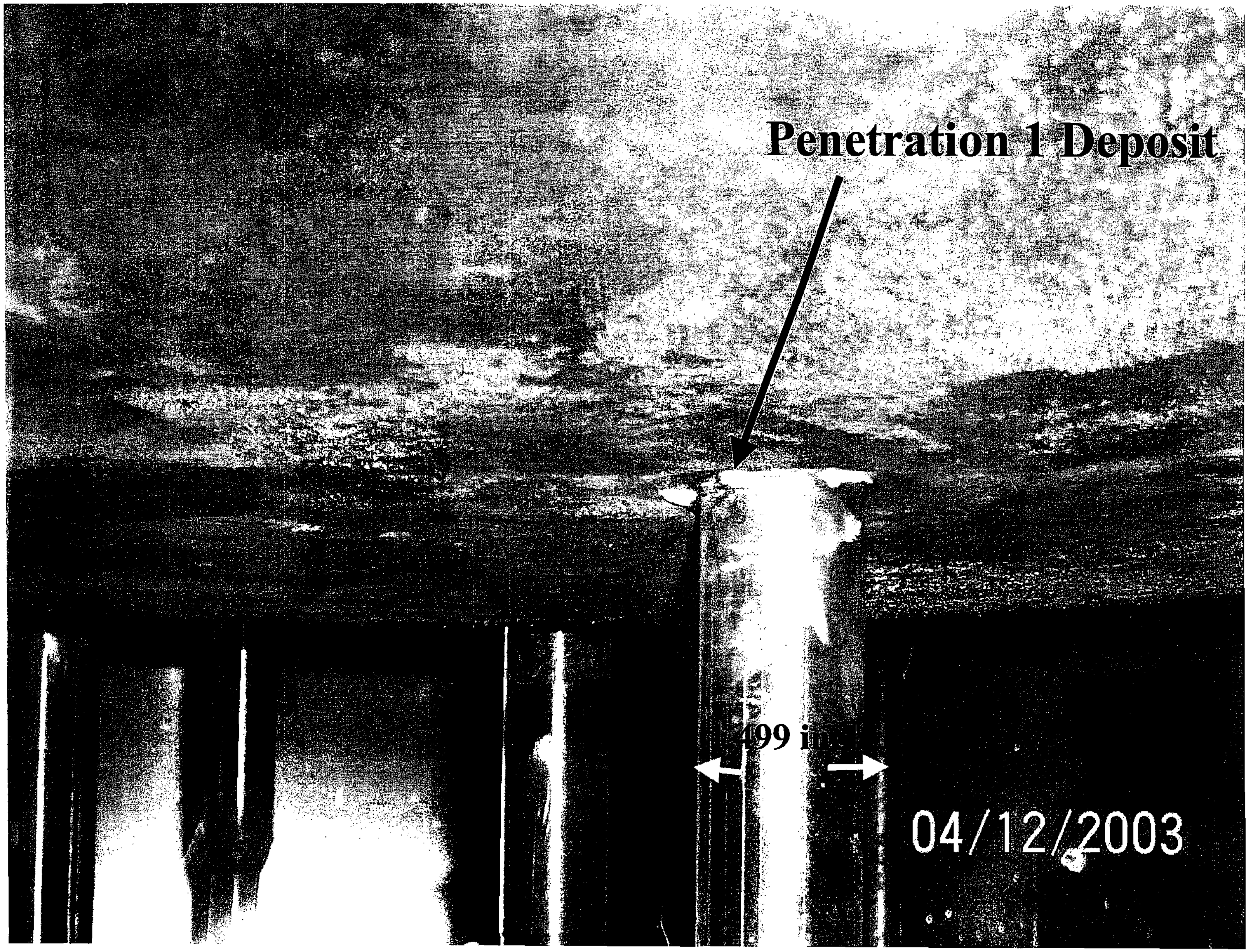


43

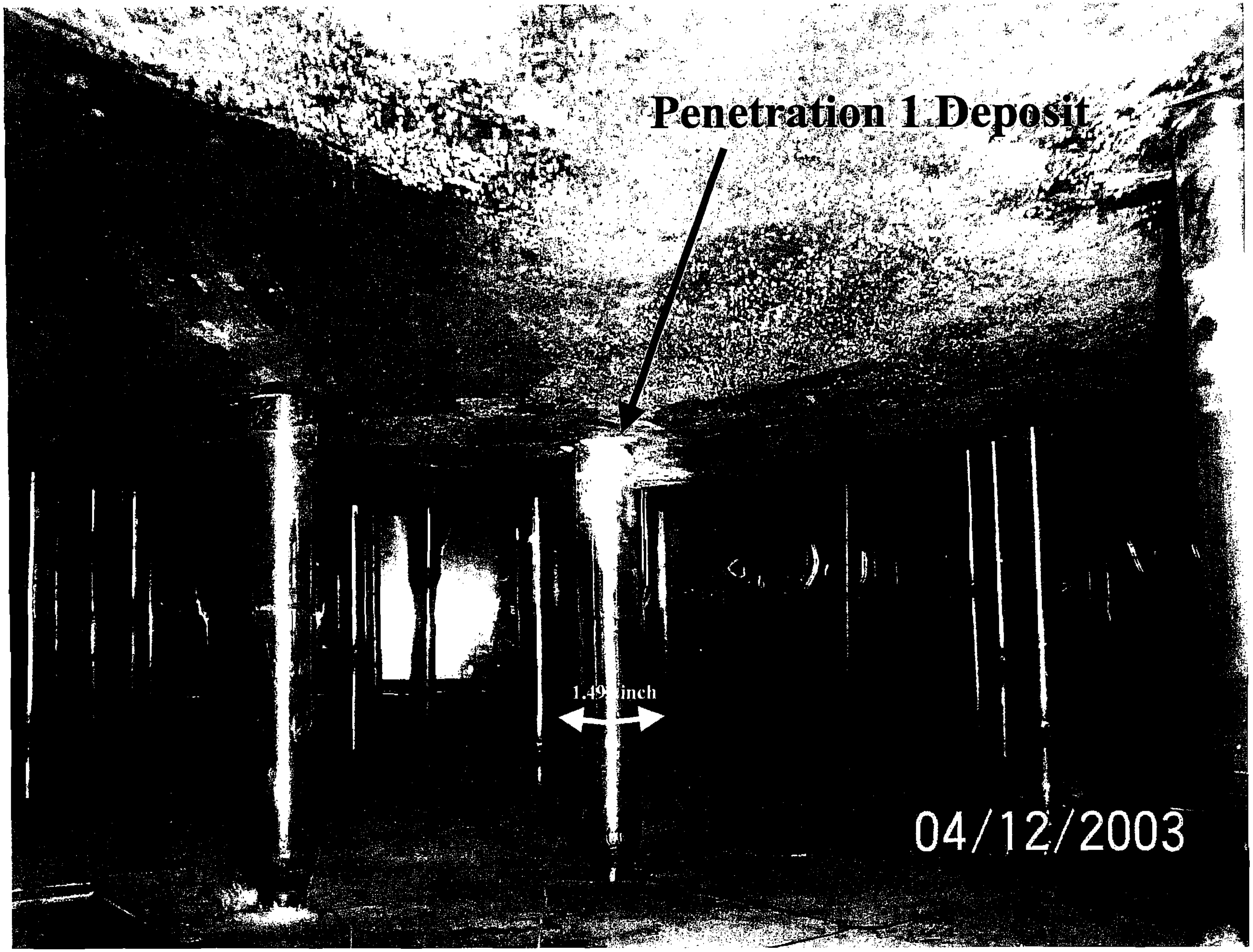
Penetration 1



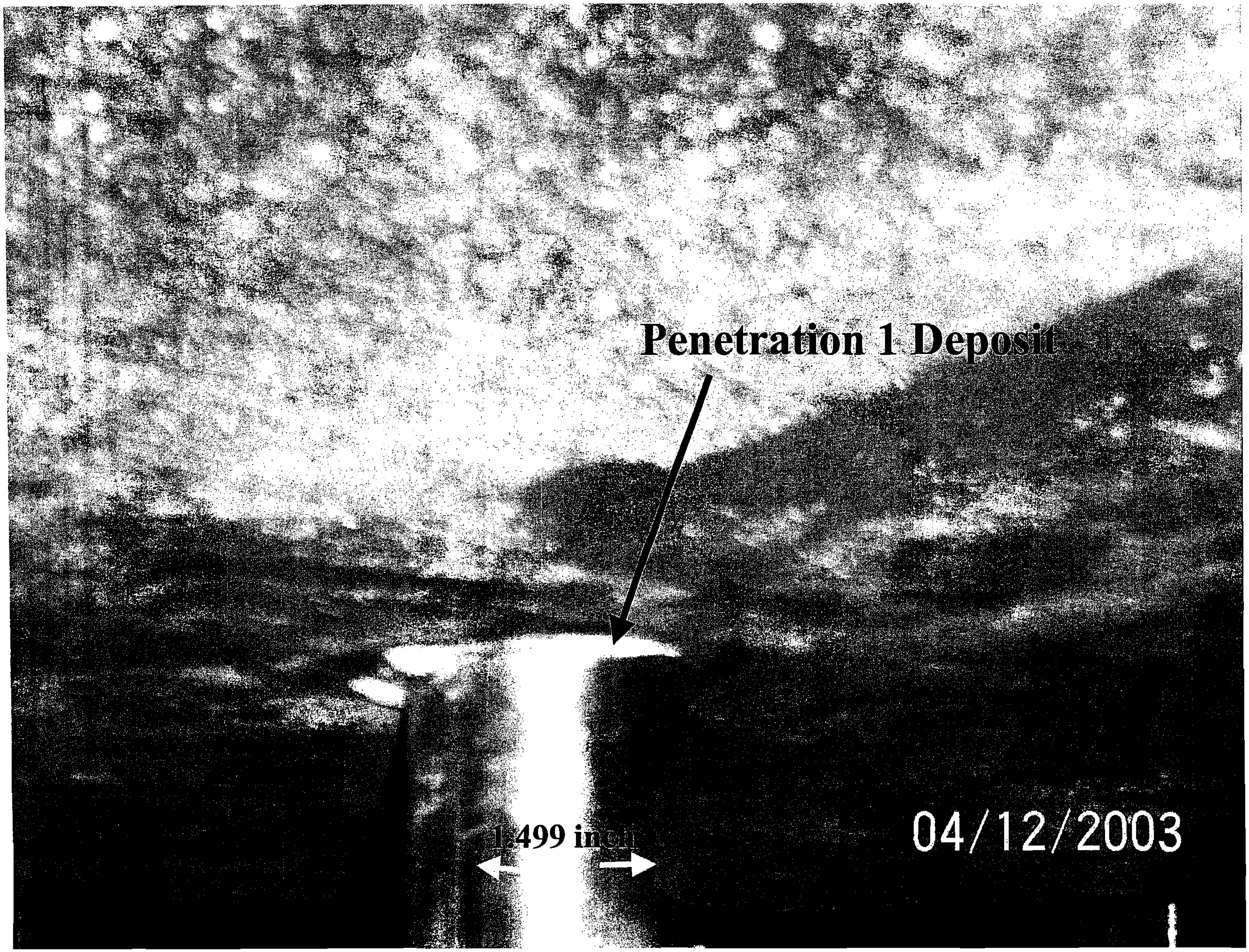
Penetration 1



Penetration 1

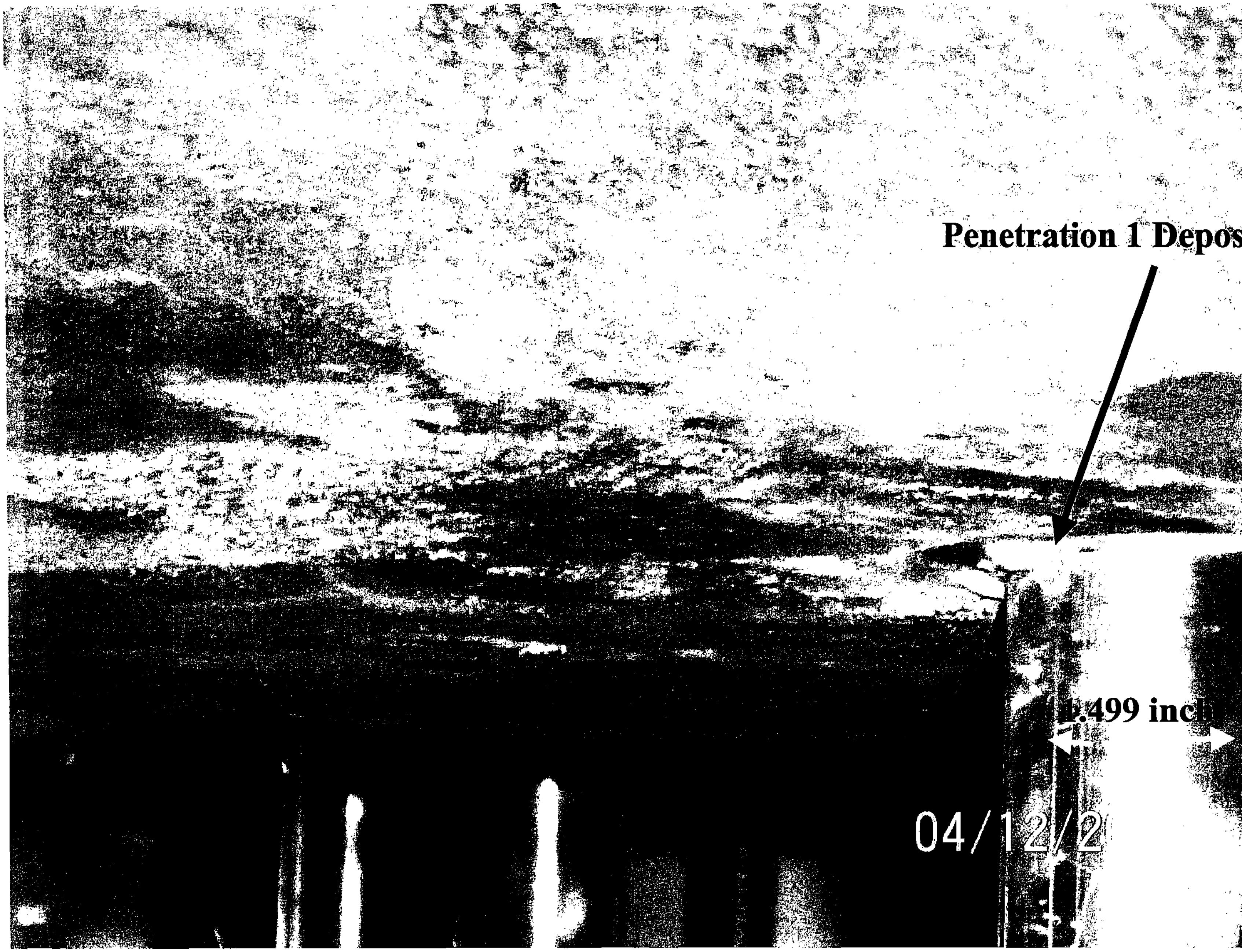


Penetration 1

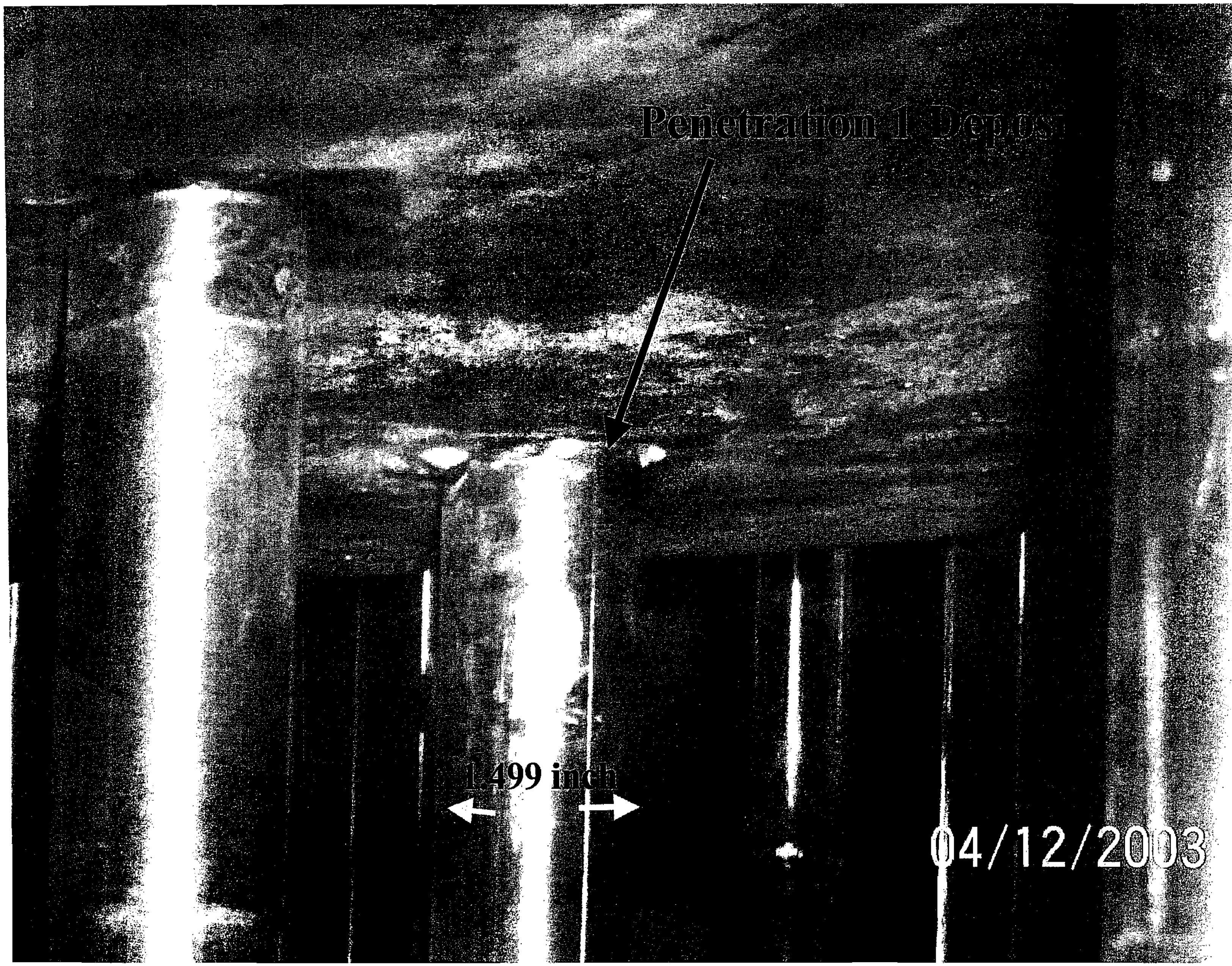


Penetration 1

38

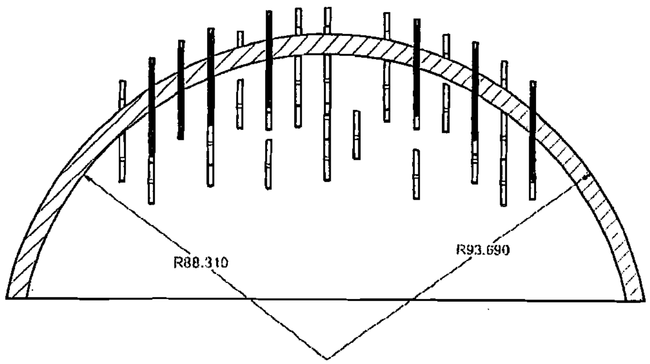


Penetration 1

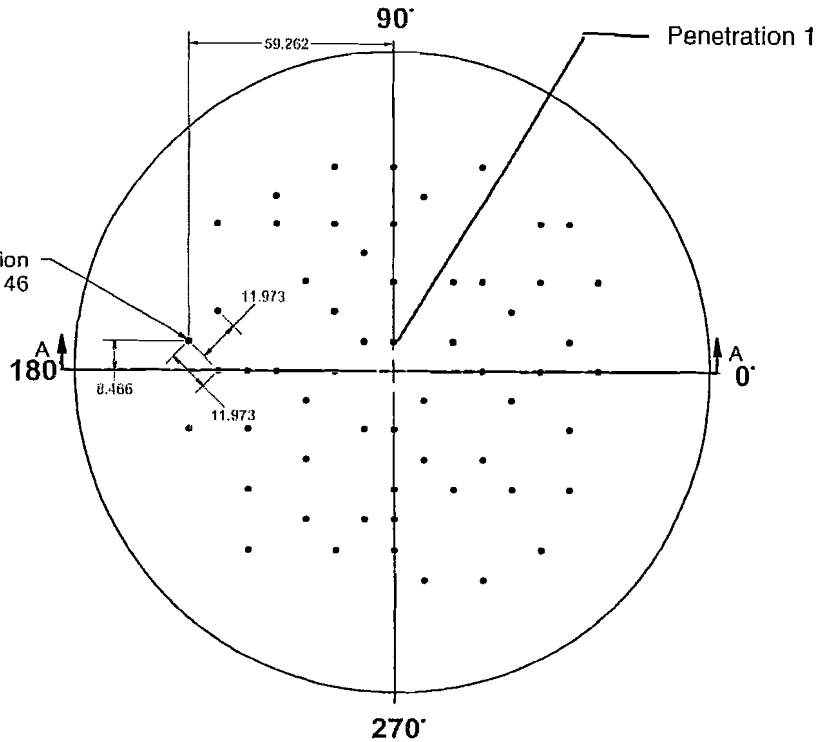


Penetration 1

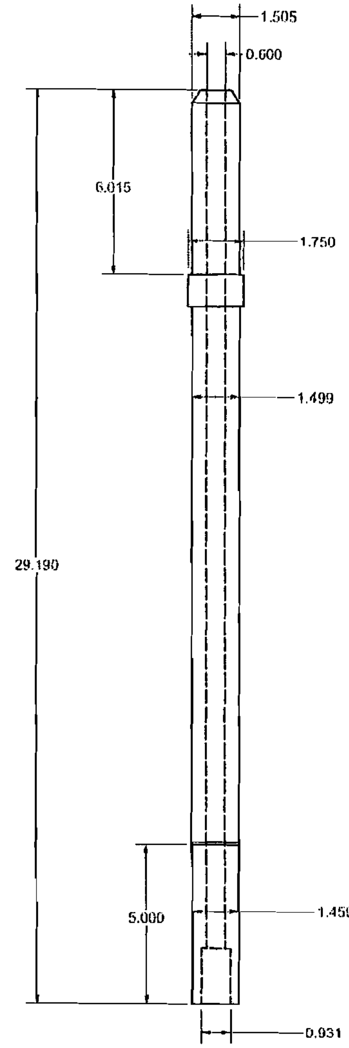
Penetration 1



SECTION A-A
SCALE 1 / 25

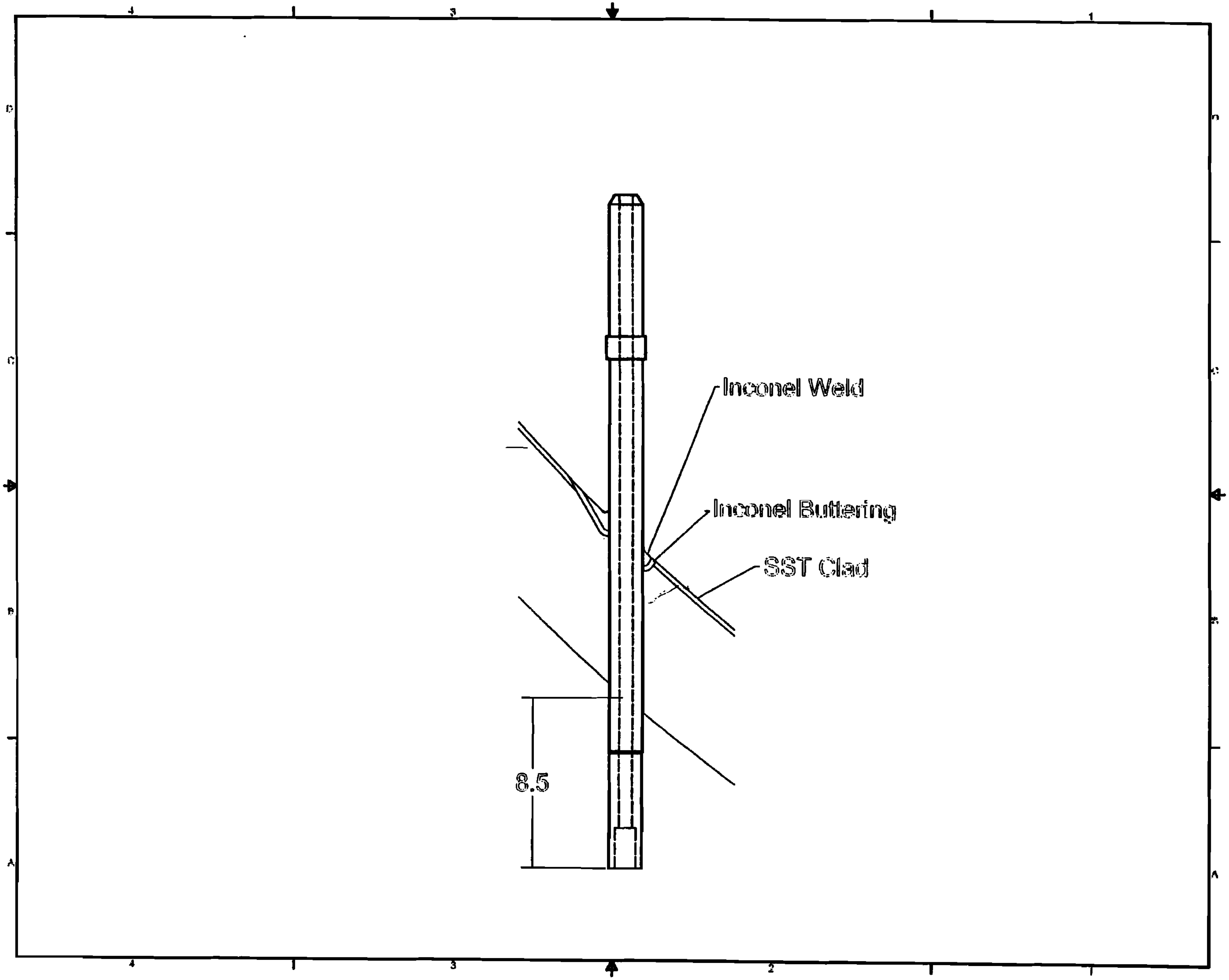


Viewed From Outside Head



Penetration 46
BMI Tube
Mtl. = SB-166

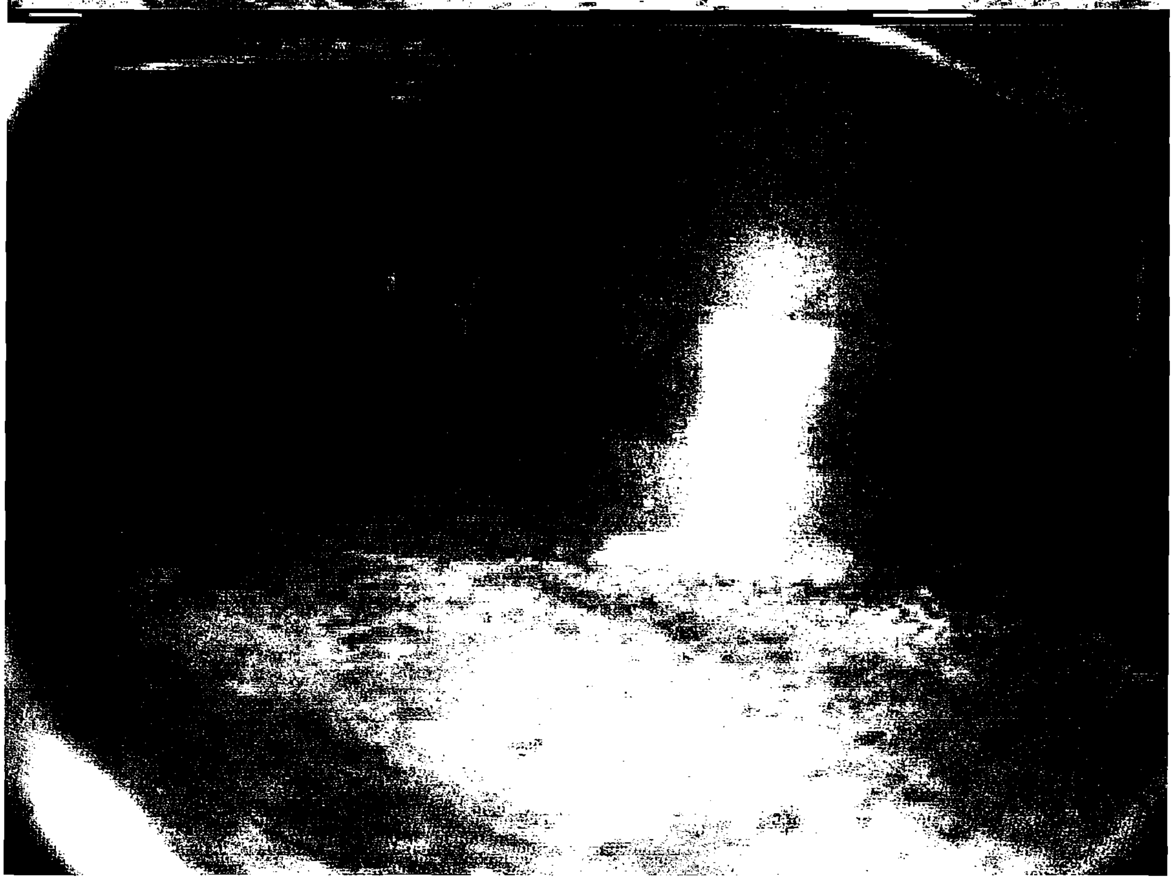
34


Inconel Weld
Inconel Buttering
SST Clad
8.5

SOUTH TEXAS PROJECT UNIT 1 - SPRING 2003

- Lower head examination identifies 2 nozzles with deposits - #1 and #46 - upper head is clean
- EDY of upper head is 4.5-6.3 (recent bypass flow conversion)
- EDY of lower head ~2.1 (operating temperature 561°F)
- Licensee planning characterization activities, including flaw identification (nozzle base material or J-groove weld?), root cause (fabrication-related, fatigue or PWSCC?) and repair - restart late summer

SEQUOYAH 1 - SPRING 2003



SEQUOYAH UNIT 1 - SPRING 2003

- Boron deposit identified at Nozzle #3

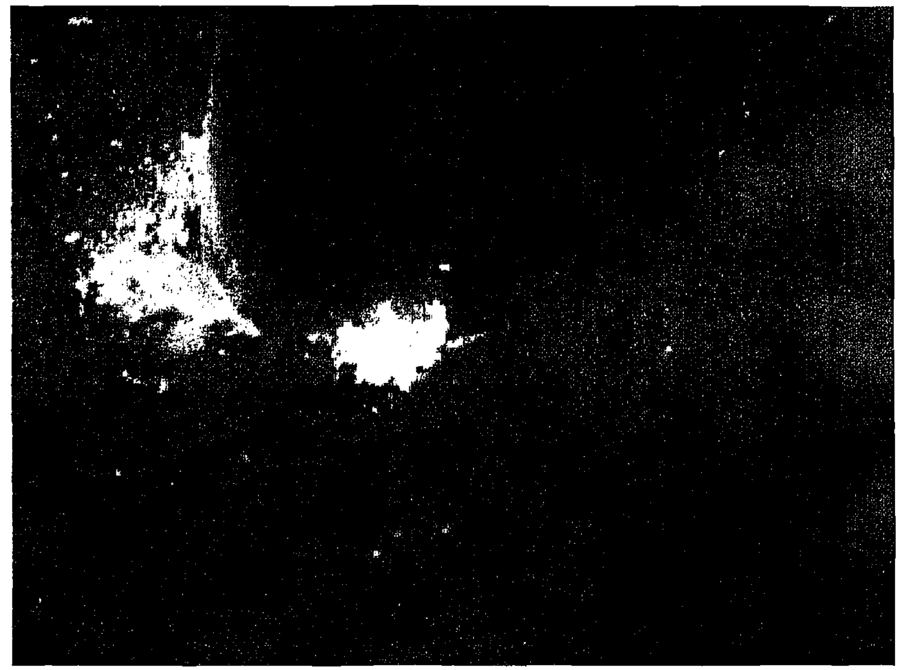
- Low susceptibility plant with lowest RPV head temperature (547°F) and EDY of ~ 1.5- first time RPV head examined

- UT of nozzle base material clean - no leak path indication

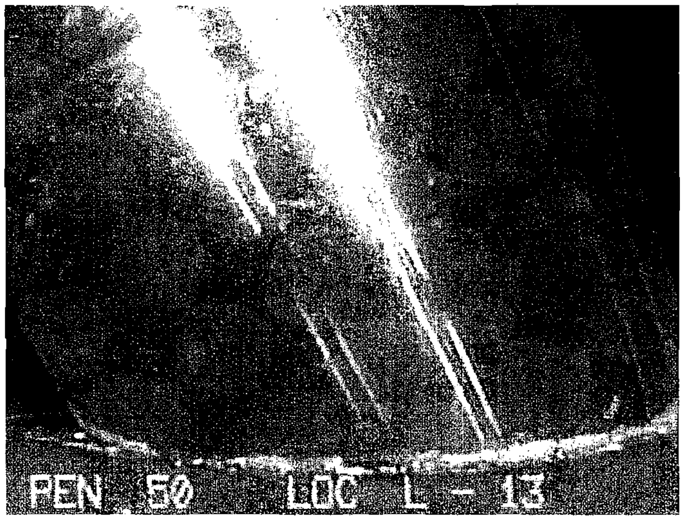
- PT of J-groove weld identified by the licensee as clean - concurred by NRC Region III and a "third-party independent assessment"

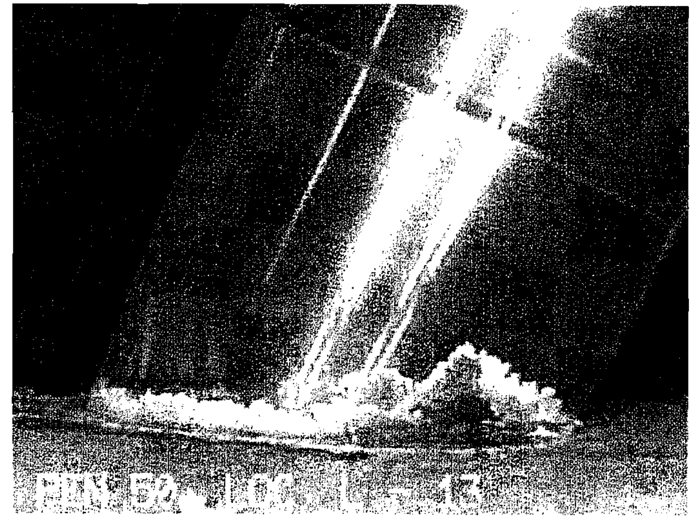
- Analysis identified boron as 5 to 10 years old based on ratio of Cesium-134 to Cesium-137

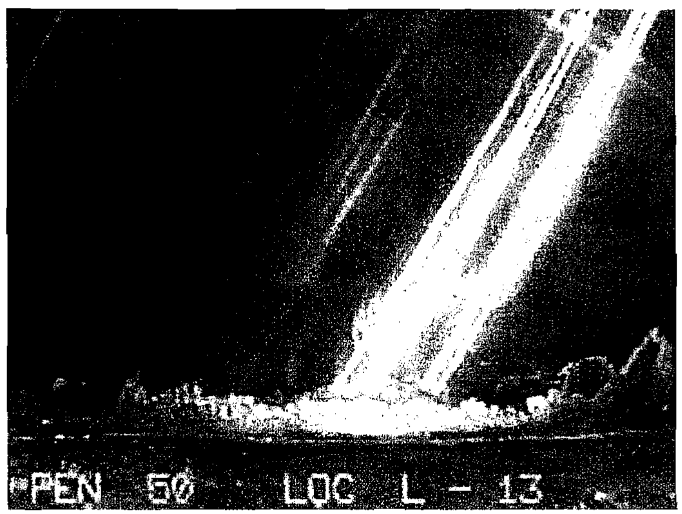
NORTH ANNA UNIT 1 - SPRING 2003
(NOZZLE #50)

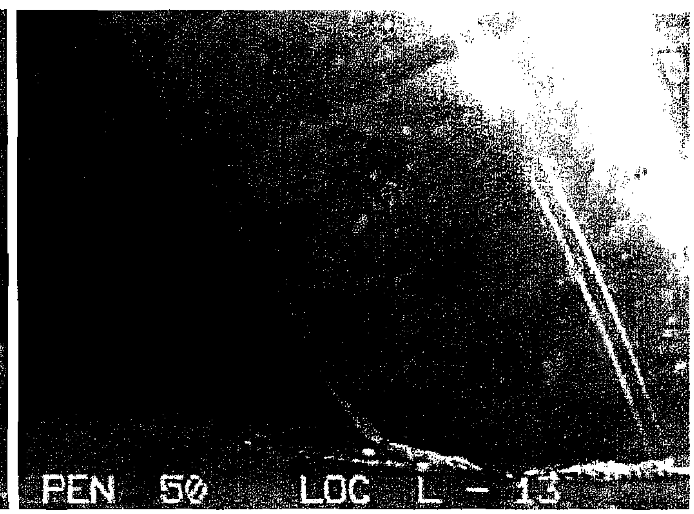


NORTH ANNA UNIT 1 - FALL 2001
(NOZZLE #50)





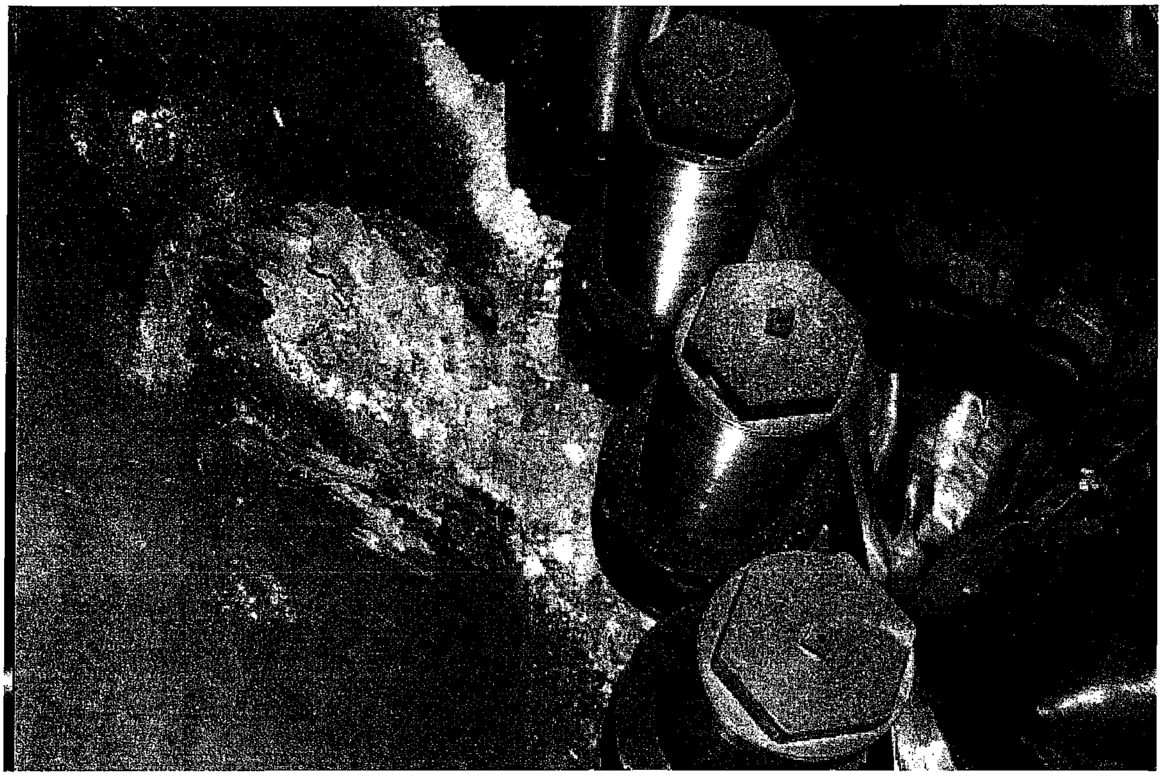


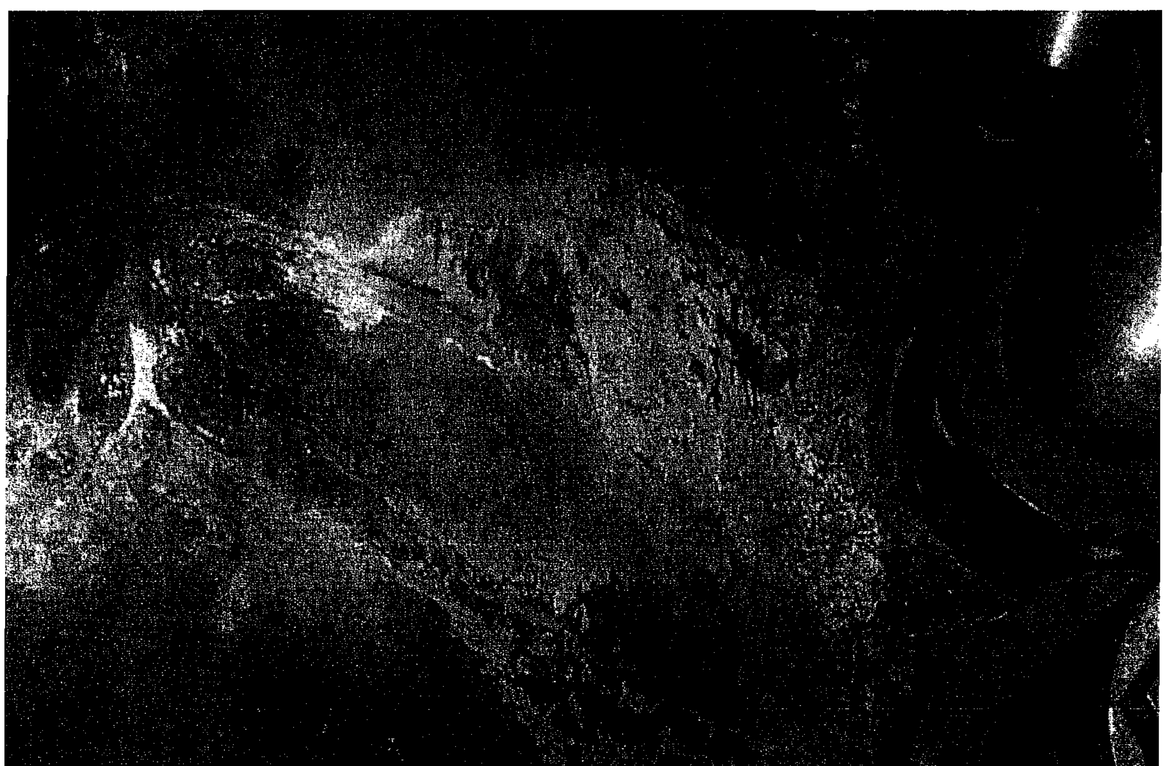


NORTH ANNA UNIT 1 - SPRING 2003

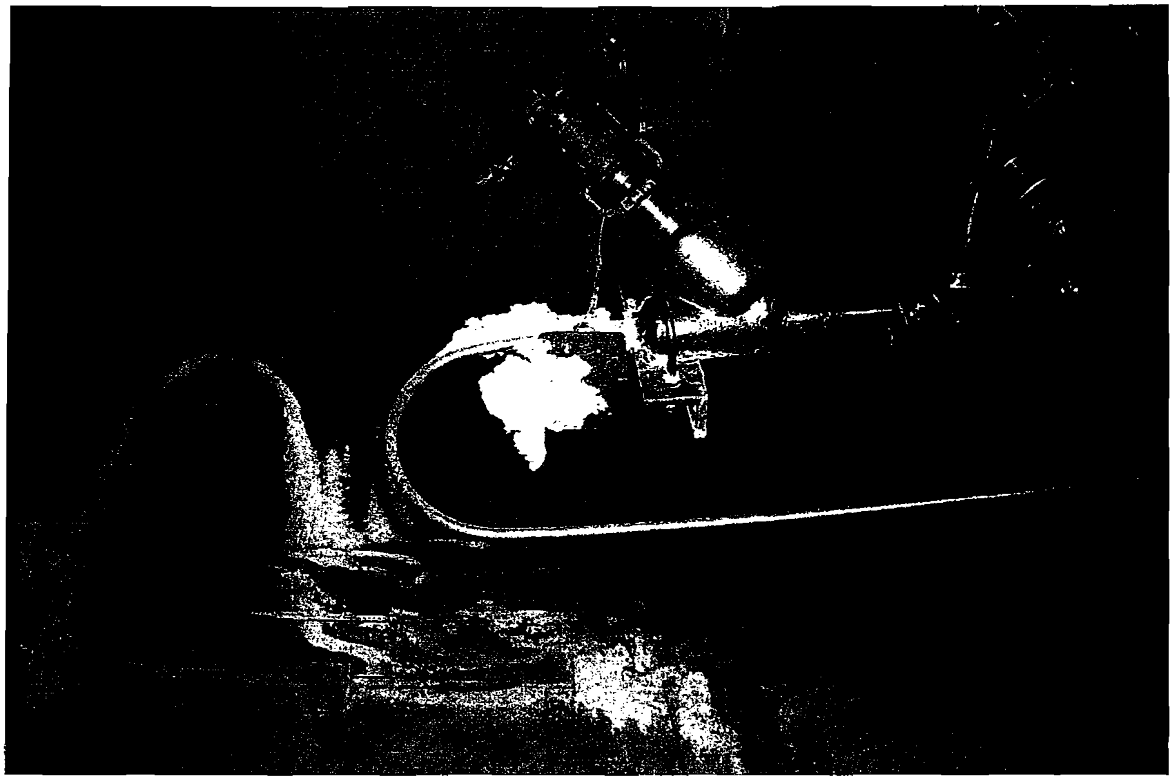
- Popcorn deposit on Nozzle #50 - only a limited bare metal visual
- Nozzle identified as suspect at fall 2001 outage - first plant inspected after issuance of Bulletin 2001-01
  - Clean ultrasonic record in fall 2001
  - PT indications "in the cladding"
- RPV head replaced

SEQUOYAH 2 - RVLIS LEAK (FALL 2002)





SEQUOYAH 2 - RVLIS LEAK (FALL 2002)

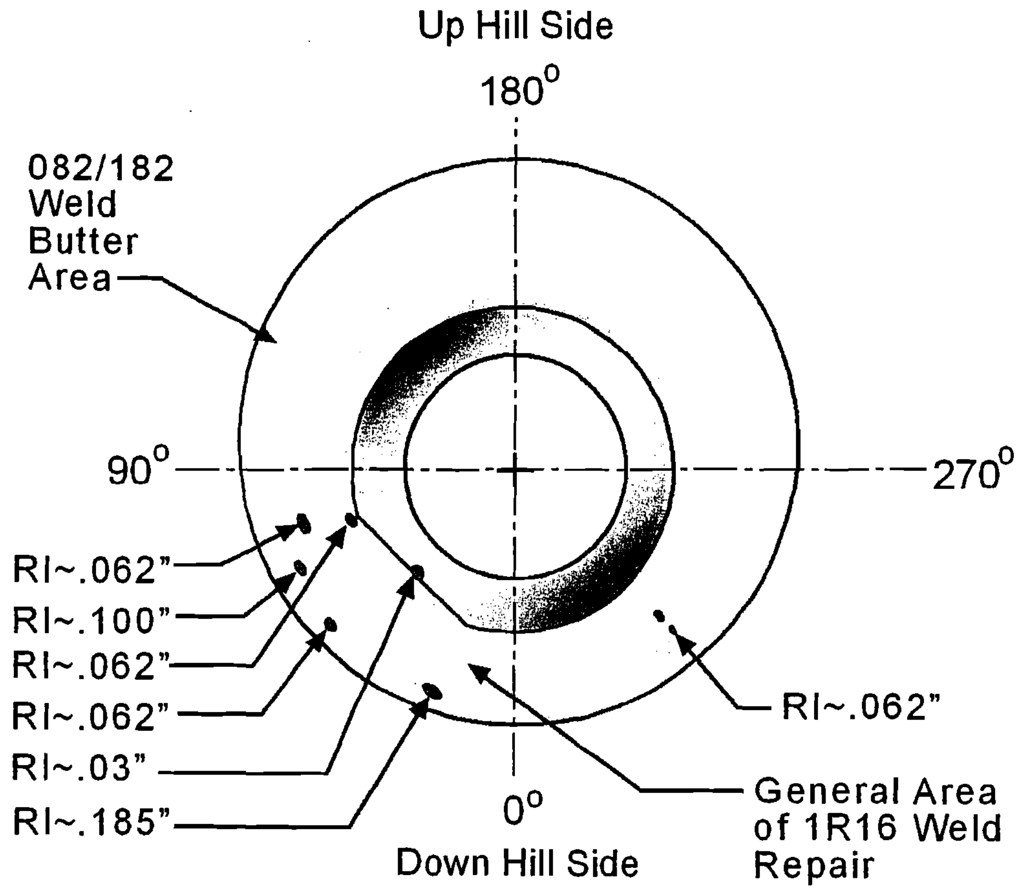


SEQUOYAH UNIT 2 - FALL 2002

- Leak from RVLIS valve
- Impacted insulation and fell through a seam and onto the RPV head
- Area cleaned up
- Corrosion area of 5 in. long x 5/16-in. wide x 1/8-in. max depth

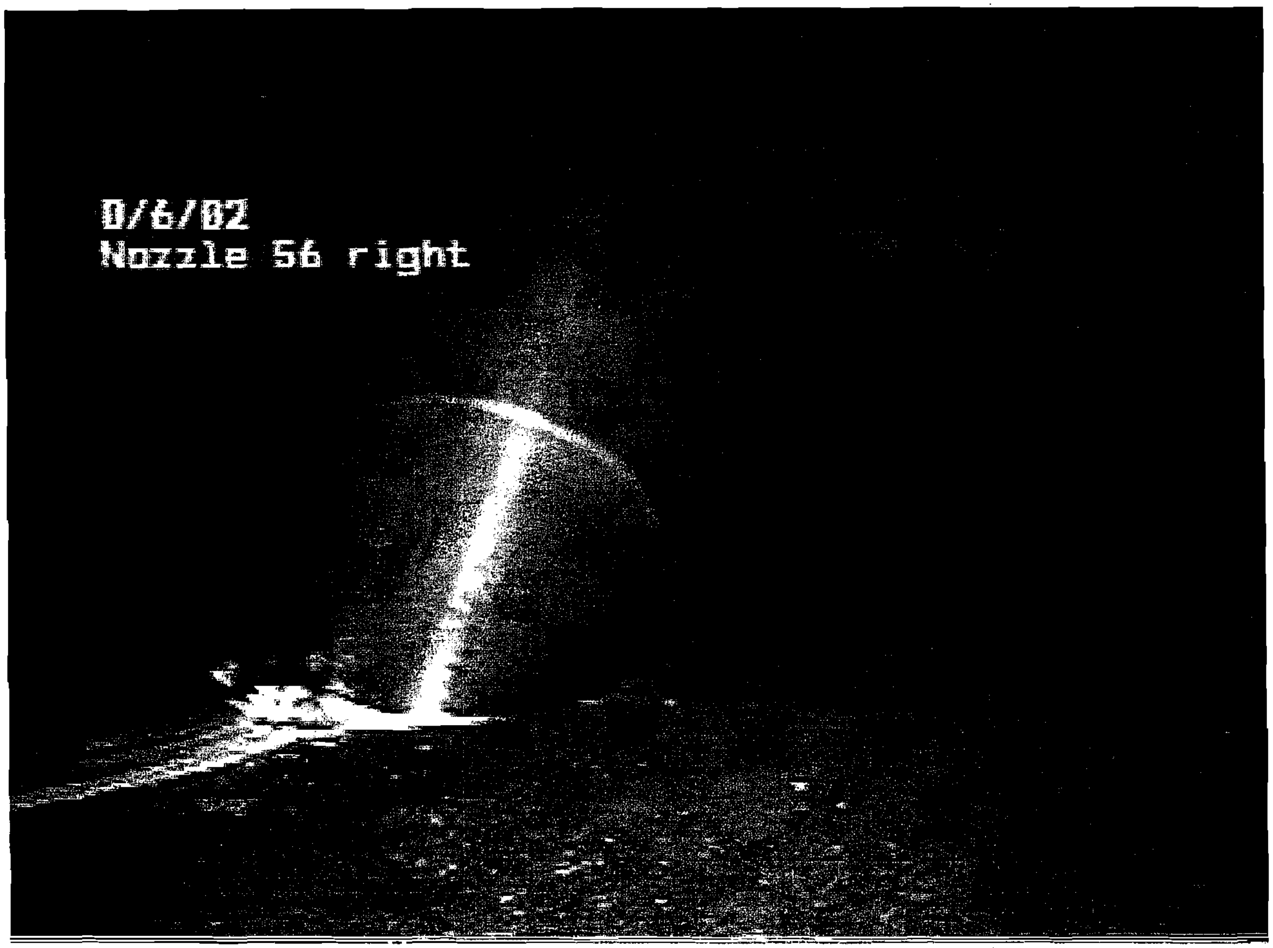
PT Layout of Nozzle 56

(General Representation)



24

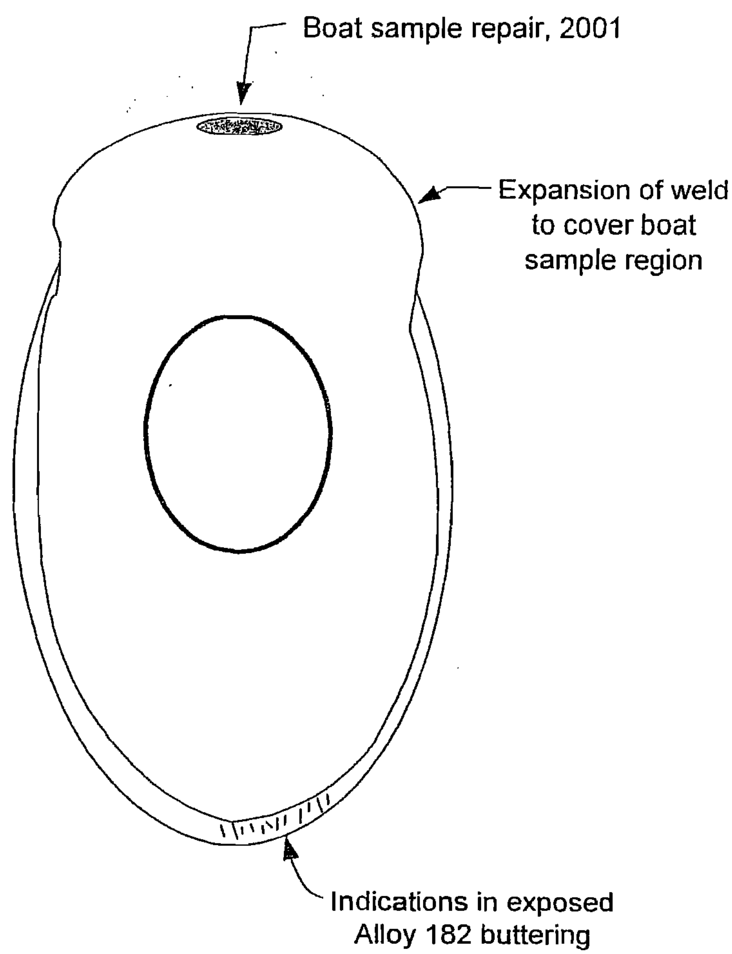
1R17 Nozzle 56 Boric Acid



ANO UNIT 1 - FALL 2002

- Leak identified on the RPV head at repaired nozzle
- Repair implemented in spring 2001 left original Alloy 182 exposed
- Revised repair implemented

Sketch of Weld Repair, Penetration 62, Shows the Extension to Cover Buttering



NORTH ANNA UNIT 2 - FALL 2002

- Several leaks identified on the RPV head
- Repairs implemented in fall 2001 did not adequately cover original Alloy 182 buttering
- Numerous welds with indications
- RPV head replaced with new head (Alloy 690 nozzles)

PLANTS WITH RELAXATION REQUESTS

- St. Lucie - High Susceptibility
  - Threaded guide cones
  - Insulation and insulation support leg interferences
- D.C. Cook Unit 1 and 2 - Moderate and High Susceptibility, resp.
  - Threaded nozzle ends
  - Transducer coupling
- Indian Point Unit 3- Moderate Susceptibility
  - External guide funnel threads
- Palo Verde- Moderate Susceptibility
  - External guide funnel threads
  - BMV of vent line

PLANTS WITH RELAXATION REQUESTS

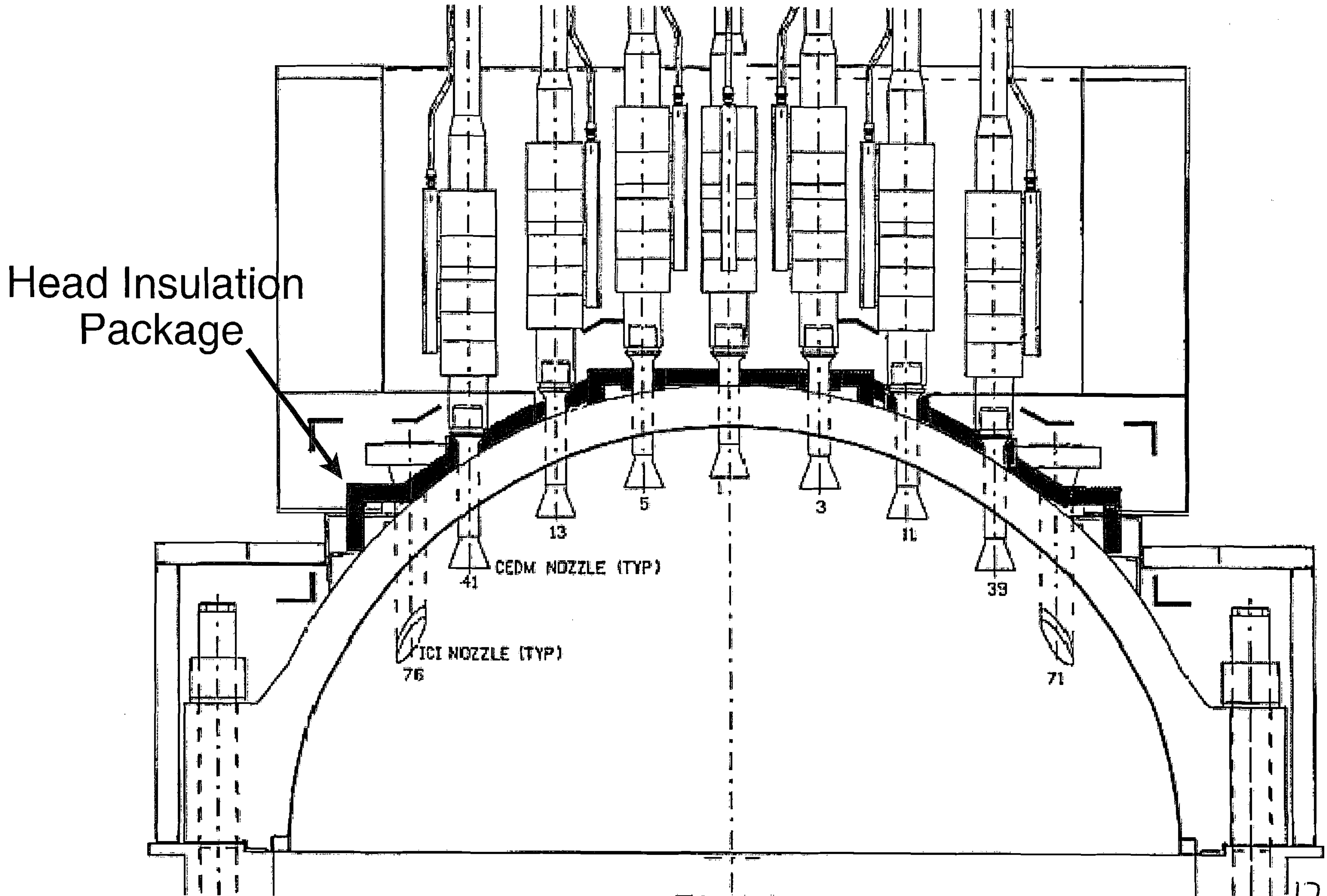
- Turkey Point - High Susceptibility
  - No ID examination of 2 RVLMS nozzles
  - Limited incomplete coverage > 1 in. below the weld

- Calvert Cliffs Unit 2 - High Susceptibility
  - Centering tab above weld
  - Transducer coupling issues

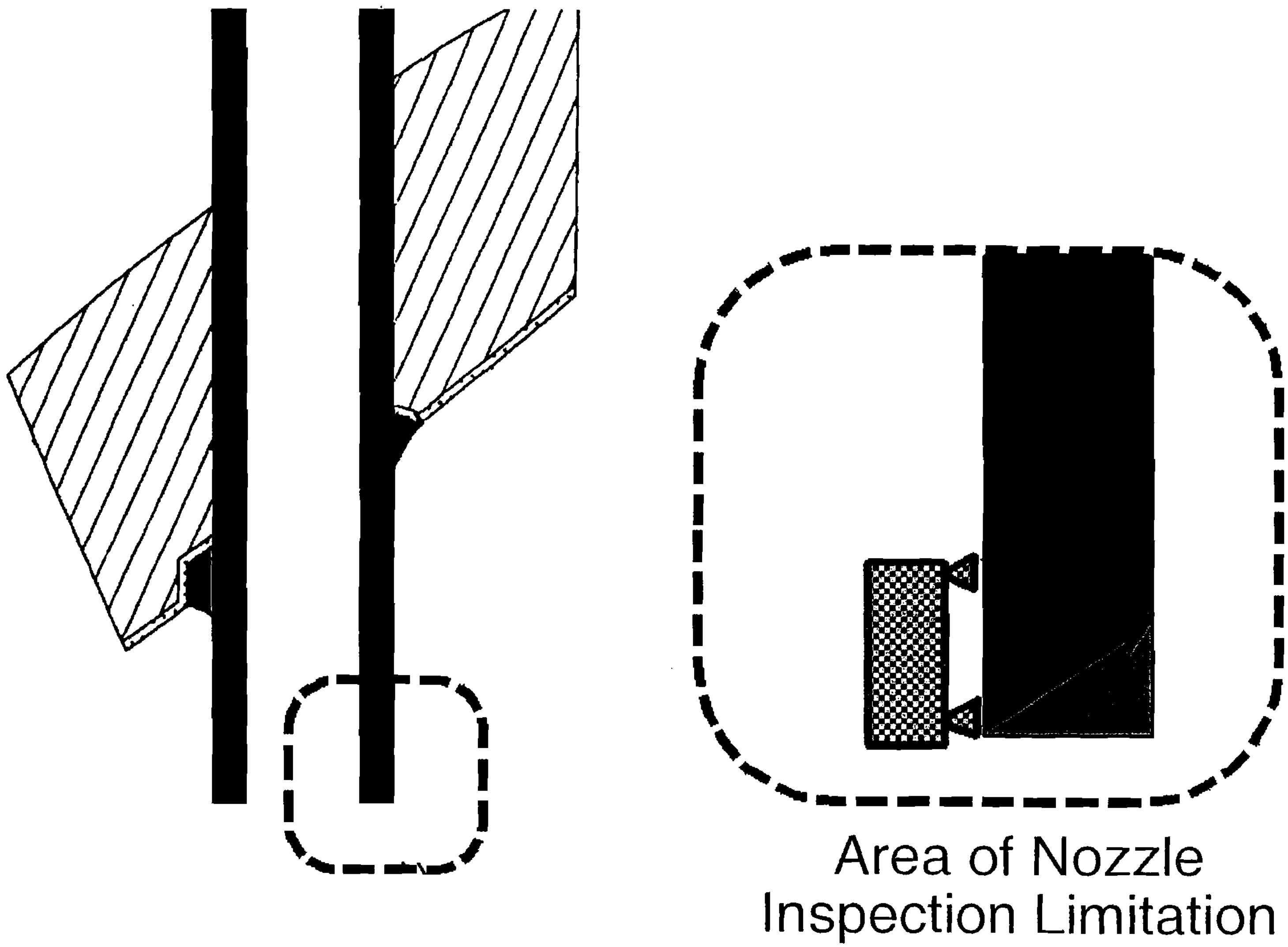
- Farley Unit 1 - High Susceptibility
  - Threads on nozzle end and taper

- Millstone Unit 2 - High Susceptibility
  - Inaccessible insulation - UT measurements of RPV head thickness

Millstone Power Station
Bare Metal Visual Inspection Restraints



TOFD Transducer Coupling Limitations



BWRVIP Lower Plenum Internal Components

- BWRVIP-47, “BWR Lower Plenum Inspection and Flaw Evaluation Guidelines,” provides a history of inspection data and inspection guidelines for the lower plenum internal components.

- BWRVIP review of field cracking data indicated that with the exception of some unusual cases, i.e., furnace-sensitized stub tubes at Oyster Creek and NMP-2, the lower plenum components have not experienced significant field cracking.

    - Stub tube cracking in the two plants with furnace sensitized stub tubes is being repaired and monitored using well-established procedures approved by the NRC (roll expansion repair method).

Inspections

- Various visual inspections are performed on the CRD guide tubes, stub tubes, and in-core housings, in accordance with ASME Code, Section XI.

- Instument penetrations are pressure tested.

- Visual inspections are performed on the dry tubes as recommended by GE SIL 409

- Additional inspections are performed in accordance with the recommendations of BWRVIP-47.

  - CRD Guide Tube Sleeve to Alignment Lug Weld

  - CRD Guide Tube Body to Sleeve Weld and CRD Guide Tube Base to Body Weld

  - Guide Tube and Fuel Support Alignment Pin-to-Core Plate Weld and Pin

  BWRVIP-47 provides recommendations of sample size, frequency, and acceptance criteria.

BWRVIP Inspection Summary Indication Results of the Lower Plenum Components 1994 - 2002

- Dresden
    - 1994: 1 dry tube was identified to be cracked and replaced.
- Oyster Creek:
    - 2000: 2 stub tubes found leaking at bottom head. UT performed of CRD housing to stub tube welds and area of housing to be rolled. No reportable indications. Roll repaired both leaking housings.
- Browns Ferry Unit 2
    - 1994: Dry tubes inspected per GE SIL 409. Cracking found. Tubes were replaced.

Safety Consequence/Inspection Experience/Susceptibility

- The cracking at the CRD and in-core housing welds does not have a significant safety consequence since it does not affect CRD insertion. Even if extensive cracking were to occur, the potential for CRD ejection is eliminated by the shoot-out steel. Thus CRD insertability is not challenged. There is additional redundancy through the availability of boron injection if failure of CRD insertion is postulated.

- If cracking is significant and leads to leakage, it would be detected immediately and appropriate corrective action can be taken.

- As plants implement moderate HWC, the actual susceptibility is expected to drop significantly.

- In view of good field history, significant inspection experience, detectability through leaks, and minimal safety implications, no additional inspections are recommended for many of the locations in the CRD housing/stub tube/guide tube/fuel support assemblies and the in-core housing/guide tube/dry tube assemblies.