ORIGINAL ACRST-1966

OFFICIAL TRANSCRIPT OF PROCEEDINGS

TR04 (ACRS)
RETURN ORIGINAL TO
B.J. WHITE, ACRS-P-315

THANKS! BARBARA JO
#27288

Agency: Nuclear Regulatory Commission
Advisory Committee on Reactor Safeguards

Title: 399th ACRS Meeting

Docket No.

LOCATION: Bethesda, Maryland

DATE: Friday, July 9, 1993 PAGES: 174 - 302

ANN RILEY & ASSOCIATES, LTD.
1612 K St. N.W., Suite 300
Washington, D.C. 20006
(202) 293-3950

ORIGINAL ACRST-1966

OFFICIAL TRANSCRIPT OF PROCEEDINGS

Agency: Nuclear Regulatory Commission
Advisory Committee on Reactor Safeguards

Title: 399th ACRS Meeting

Docket No.

LOCATION: Bethesda, Maryland

DATE: Friday, July 9, 1993 **PAGES:** 174 - 302

ANN RILEY & ASSOCIATES, LTD.
1612 K St. N.W., Suite 300
Washington, D.C. 20006
(202) 293-3950

PUBLIC NOTICE BY THE

UNITED STATES NUCLEAR REGULATORY COMMISSION

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

DATE: July 9, 1993

The contents of this transcript of the proceedings of the United States Nuclear Regulatory Commission's Advisory Committee on Reactor Safeguards, (date) July 9, 1993, as Reported herein, are a record of the discussions recorded at the meeting held on the above date.

This transcript has not been reviewed, corrected or edited, and it may contain inaccuracies.

ANN RILEY & ASSOCIATES, Ltd.
Court Reporters
1612 K. Street, N.W., Suite 300
Washington, D. C. 20006
(202) 293-3950

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

*****

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

399TH ACRS MEETING

Room P-110
7920 Norfolk Avenue
Bethesda, Maryland

Friday, July 9, 1993

The above-entitled proceedings commenced at 9:15 a.m., when were present:

PRESENT:

J. ERNEST WILKINS, JR.
JAMES C. CARROLL
CARLYLE MICHELSON
CHARLES J. WYLIE
HAROLD W. LEWIS
IVAN CATTON
THOMAS S. KRESS

ALSO PRESENT:

WILLIAM LINDBLAD

PETER R. DAVIS

ROBERT L. SEALE

WILLIAM J. SHACK

MICHAEL MAYFIELD

JOHN CAREW

RICHARD BARRETT

PETER KANG

JEROME BLAKE

DAVE LABARGE

P R O C E E D I N G S

[9:15 a.m.]

MR. MAYFIELD: We also looked at the ASME code in looking at the level -- service level C and D transients, and we have participated with them in a round-robin analysis methodology, and we did get reasonable agreement among the analysts that participated in that, just summarized in this slide.

We're within 10 percent or so, which based on other round-robin analyses we know to be pretty good. When you take three or four or five analysts, set them down with their own favorite computer codes and equations and material properties, you'll tend to see 10 percent or so variability in the numbers, just in a test case. So, we've done pretty good here.

This guy, interestingly, used Regulatory Guide 1.99, Revision 2, to determine a charpy upper shelf energy. That's a very low estimate of upper shelf energy.

He then used one of the models that's in a NUREG report, one of the statistical models that we have in a NUREG report, to estimate the J-R curve, and he came up with this 3650. So, that's about as low as you're ever going to get a number out of this guide's methodology.

MR. WILKINS: Excuse me just a moment, Mr. Mayfield.

Are you ready, young man, to start?

THE REPORTER: Yes.

MR. WILKINS: All right. Let me tell you that this is Mr. Mayfield, and he's from Research --

MR. MAYFIELD: Materials Engineering Branch.

MR. WILKINS: -- Materials Engineering Branch, and he's talking about Draft Guide 1023.

MR. MAYFIELD: Yes, sir.

MR. WILKINS: All right. I'm sorry for the interruption.

MR. MAYFIELD: That's fine.

Bill, you had a question?

MR. SHACK: What guides are you using to compute charpy energy if you're not using 1.99?

MR. MAYFIELD: Well, right now we're sort of stuck with 1.99. We don't have anything else to work from, we're pretty well stuck with 1.99. The approach taken in the statistical models is we can get around that.

If we know the chemistry of the material and the fluence, then we can estimate a J-R curve without ever having to make the argument about what the upper shelf energy is. So, in other words, we have an unirradiated upper shelf energy and the fluence.

So, we've come at this several different ways, so that we don't hang up on exactly the argument of what is the upper shelf energy. Once we decide that we need to go do this analysis, then we can get away from the argument about upper shelf energy.

MR. SHACK: Where do the 18 plants come from? Are those based on 1.99?

MR. MAYFIELD: Ed, can you answer that question? Ed, come up to the microphone, please.

MR. MALIK: Ed Malik, Materials Branch, NRR.

Those were based, Mike, as you were saying, on a couple of different methods. They were based on surveillance data. They were also based, in some cases, on Reg Guide 1.99.

MR. MAYFIELD: Okay.

So, the conclusion we reached and the reason we brought this guide to you to seek your endorsement is that we have done some extensive testing with this guide, we know the methodology works, we know it's complete, so you can take the guide and do a vessel analysis.

We have favorable comparisons with other analysts in the industry, so we believe there is not a failing in the analysis methodology. We think our equations are correct, and we think the way we do our sums agrees fairly well with the way other competent analysts do their sums.

Finally, we do have a guide that provides an alternative to the conservative approach taken in the ASME code case. It is a bit more rigorous in the analysis, but it has less inherent conservatism.

The guide provides the complete analysis methodology, where we look at the analysis formulation, the material properties, the transient selection, and the complete acceptance criteria.

MR. WILKINS: Now, if this guide had been available at the time of the Yankee-Rowe vessel evaluation, what impact would it have had on that?

MR. MAYFIELD: The only thing we were really hung up on was needing the acceptance criteria, and we got those from the code in time for the Yankee-Rowe analysis, and the basic methodology was far enough developed for the Yankee-Rowe analysis that we were able to take that the next step.

What it highlighted for us is that we were in an ad hoc situation. We really didn't have good guidance. So, we've put this together. It has followed very closely what we were doing with Yankee.

Yankee wasn't a problem on low upper shelf. It was brittle fracture problem, transition temperature problem.

MR. LINDBLAD: Mike, can you go back one slide, please?

MR. MAYFIELD: This one?

MR. LINDBLAD: Yes. Tell me again how satisfied you are with the dispersion of the results?

MR. MAYFIELD: In doing analyses some years ago, ASME, Section 11, did a round-robin analysis just to compute pressure temperature limits. So, there's none of this other complication. It's stuff that's in the ASME code. All the equations are spelled out and agreed to. They got about 10-percent variability in the computed pressure at a given temperature.

We're seeing numbers, again, for this more complicated analysis -- it's a bit more complicated -- we're running nominally within that 10-percent variability.

MR. LINDBLAD: But not on problem four.

MR. MAYFIELD: No. With this exception, we're running along here.

MR. LINDBLAD: And are you saying that any of those numbers are acceptable?

MR. MAYFIELD: Any of those numbers would satisfy the acceptance criteria. The worst of those would satisfy the acceptance criteria.

MR. LINDBLAD: But wouldn't a licensee seek out analysts, too?

MR. MAYFIELD: He might. The other thing to bear in mind is some of these problems were not defined quite as well as we'd like. There was some struggling, and one of the things we found coming out of the Section 11 exercise is that, well, if we did this again, we would be more prescriptive in certain areas and tell people more carefully how to do it.

One of the things you get caught up in is a definition of when you're on the upper shelf for the charpy. Dr. Lewis suggested that the upper shelf energy is well defined. That's generally a true statement. The difficulty is deciding when you're coming off of the upper shelf as you come down in temperature, and some of this variability gets caught up in that different analysts have different definitions for when you're coming off the upper shelf.

We've tried to fix that in the guide by saying do it this way, but there will still be a bit of variability.

MR. LINDBLAD: Thank you.

MR. LEWIS: I'm glad you added that, because I was confused. I must have misunderstood. I thought that you had said that these were the same analysts solving the same equations and getting different answers. That's not true.

MR. MAYFIELD: That's not true.

MR. LEWIS: Thank God.

MR. MAYFIELD: Interestingly, we have given -- in other exercises that I know Dr. Shack is familiar with, we gave analysts fatigue growth rate data, we have gave them crack length versus number of cycles, we gave them the equations to reduce the data completely, and the complete methodology, and when you first got the results and plotted all the results, it looked like a scatter plot.

We should have just had one line. Instead, it was just a mass of points covering the plot. So, we went back and said no, no, no, you may have Ph.D.'s, but you don't read equations very well, do it this way. We ultimately got down to where most of the analysts could do their sums correctly.

MR. LEWIS: Well, I've given Ph.D.'s to people who couldn't do equations correctly.

Just out of curiosity, how much capability do you have to do these kinds of analyses in-house, compared to giving them out to contractors?

MR. MAYFIELD: We can and have done -- in fact, most of the -- all of the work done here was done in-house by Dr. Malik. This is something that was developed completely in-house, with the exception of the statistical treatment of the material properties. We had that done under contract.

MR. LEWIS: Okay. Very good. Thank you.

MR. MAYFIELD: Anything else?

MR. LINDBLAD: That was a very good presentation.

MR. SHACK: I believe the proposed draft guide fills a real need for providing guidance so that we do come up with a more consistent set of results.

Again, if everybody agrees on the ways to do the analyses, the material models that you're going to be using, you're going to come up with a more consistent set of results.

The results seem conservative but not overly conservative -- conservative enough to handle the uncertainties that you really have in the basic data procedures.

MR. LEWIS: One of my pitches, not just in this field, is to try to quantify uncertainties as you try to apply things like this to regulatory processes -- and people have a tendency to say they're doing conservative calculations but to shy away from the kind of question that Mayfield was happy to answer, how do conservative do you think it is, and you characterized it as conservative but not too conservative.

MR. SEALE: They are complex problems. We'd be hard pressed to come up with rigorous investigations in the uncertainties here.

MR. LEWIS: Some people who are not all that experienced have a tendency to think that the results of conservative calculations constitute the truth instead of conservative calculations, and then you begin to get the substitution and you begin to escalate down the stairway, and that's unfortunate.

MR. MAYFIELD: The second part deals with calculational and dosimetry methods for determining pressure vessel neutron fluence.

The approach we intend to take this morning is I will introduce to you the background for the guide and why we think we need it, how we went about developing it, then we'll call on John Carew from Brookhaven National Laboratory to go through some of the details.

MR. WILKINS: The original schedule called for 40 minutes for this portion of the presentation, and I observe that, 40 minutes from now, we will be late.

MR. SEALE: The original schedule called for 25 minutes for this portion. They were reversed in order.

MR. WILKINS: In any case, we're behind schedule.

MR. MAYFIELD: We're a bit behind schedule, and I will go very quickly through this.

MR. WILKINS: Thank you.

[Slide.]

MR. MAYFIELD: The objective for this guide is to provide a state-of-the-art method for fluence determination. Our intent was to reflect present-day practice, as we see it in licensee submittals from the surveillance report.

The guide specifically is not intended to replace methods that have already been accepted by the staff. To use one of OGC's terms, this guide is prospective in nature.

We needed to codify existing staff practices, and our hope is to eliminate unnecessary work both by the licensees and by the staff, and finally, we want to provide a consistent set of guidelines for estimating neutron fluence for the pressure vessel.

What we have right now is a situation where there is a lot of difference in the different submittals, and we need to try and provide a consistent set of guidelines for how to do these complicated analyses.

[Slide.]

MR. MAYFIELD: The name for the guide stems principally from a request from NRR, as early as 1987, from Harold Denton and, more recently, in '92, from Tom Murley.

The current methods submitted by licensees vary widely. They have varying reliability, varying accuracy, and varying conservatism buried in these analysis.

Occasionally the staff feels obliged to include bias factors in some of the analyses, because we're not satisfied they are adequately conservative.

Recent reviews continue to identify some questions in the various analyses.

We have identified some errors in the cross section libraries. This was identified in the industry, and they are going about correcting those, but we need to be a bit clearer on what cross section libraries we think are acceptable.

Finally, we think there is a great need for an uncertainty analysis to be included in these fluence estimates.

Another need for the guidance is that the submittal-specific reviews are labor-intensive both for the licensing staff and for the licensees.

[Slide.]

MR. MAYFIELD: I mentioned that we occasionally have had to include some bias factors, or multipliers if you will, on the fluence estimates, because we're not quite sure things have been done adequately or with a sufficient degree of conservatism.

However, there is a concern about adding unnecessary levels of conservatism. That can result in some operational problems.

For unnecessary conservatism, it does produce more restrictive pressure/temperature limits and LTOP set-points than would otherwise be necessary, and particularly for the more restrictive LTOP set-points, that can produce a potentially adverse impact on safety.

Specifically, if you're running a very tight LTOP set-point, the operator now has a very narrow pressure region through which he must navigate the plant during start-up.

If he violates that, he's going to lift one of the -- will lift the LTOP valve, whether it's a PORV or one of the RHR safeties, and now there is the potential that that valve will not reseat. So, you have unnecessarily challenged a system simply because of conservatism buried in some other analysis.

We think that it's more appropriate to come back to a consistent analysis methodology, where we have hopefully been able to define the level of conservatism in that methodology, and that it's no more than is necessary.

Another consideration in this is that we would be unnecessarily approaching some of the criteria, specifically the pressurized thermal shock screening criteria or the charpy low upper shelf energy criteria to this 50-foot-pound limit that we talked about.

This actually could force some unnecessary annealing operations, potentially could result in an unnecessary plant shutdown.

One of the final things that -- reasons we think we need this guide is to serve as a reference guide for the future.

Some of the people that have been doing these analyses for many years are getting set to retire, and we're needing some form of documentation on the books as to how these complex analyses are done and the basis for some of the analyses.

[Slide.]

MR. MAYFIELD: Very quickly, there are three regulations that are impacted by the fluence estimates.

It's Appendix G to 10 CFR Part 50, which is the fracture toughness requirements -- that regulation was issued in '83; 10 CFR 50.61, which is the pressurized thermal shock rule; and finally, Appendix H, which is the reactor vessel surveillance program. You have to do fluence analyses to make sense out of the surveillance results.

MR. MICHELSON: A question on Part 50: That covers the entire reactor coolant pressure boundary, doesn't it?

MR. MAYFIELD: That is correct.

MR. MICHELSON: Not just the vessel.

MR. MAYFIELD: That is correct. The fluence estimates are focused on, of course, the belt-line.

MR. MICHELSON: Yes, but you can get -- you know, if you didn't have adequately tough piping, for instance, on the reactor vessel, you might rupture the piping instead of the vessel.

MR. MAYFIELD: That's correct.

MR. MICHELSON: Now it doesn't have the fluence problem, but it has --

MR. MAYFIELD: Correct.

MR. MICHELSON: It isn't built to quite the same standards, either.

MR. MAYFIELD: The big pipe is basically a pressure vessel.

MR. MICHELSON: Now, we're talking about in the older plants, and we're talking about re-circ loops, that sort of thing.

MR. MAYFIELD: Yes.

MR. MICHELSON: What do you think the material is for a re-circ loop? Do you know?

MR. MAYFIELD: Mostly A106. For the carbon steels, it's A106.

MR. MICHELSON: A106 doesn't have a particularly powerful charpy test requirement, and therefore, I don't know how good it is, even though it's well-designed and is constructed to the code. It doesn't have the same kind of impact --

MR. MAYFIELD: That's correct.

MR. MICHELSON: -- requirements as the vessel did. So I must bust a pipe instead of busting the vessel, which we have designed for, except I'm not sure we've designed for the conditions existing at these lower -- you know, like on shutdown and whatever.

It's something we've really never looked at, as to what happens if you get a rupture of a pipe while you're in the shutdown mode.

MR. SEALE: In any event, I think the fluence level calculation is --

MR. MICHELSON: Well, it's not a fluence problem at all.

MR. SEALE: That's what we're talking about here.

MR. MICHELSON: I realize. I just was asking for some additional information. I'll bring the subject up later.

MR. MAYFIELD: We don't have data or information dealing with the brittle rupture of piping. Our focus has been on failure of piping during some operational occurrence, and that tends to be a higher temperature problem, a ductile fracture problem.

MR. MICHELSON: Right.

MR. MAYFIELD: When you're in a shutdown operation, you're vented, for the most -- well, I shouldn't say that too conclusively -- you will often be vented, and the loads on the piping from the earthquake, for example, that's where you get the bigger --

MR. MICHELSON: Temperature over pressurization.

MR. MAYFIELD: So, even there, you're going to be fairly ductile on the A106's, unless you have a real bad piece of pipe.

MR. MICHELSON: Yes, and that's the question. Do we know how bad some of this can be? I looked into a little bit several years ago for a reactor water cleanup piping problem, and yes, it's not necessarily that good.

MR. MAYFIELD: That's right.

[Slide.]

MR. MAYFIELD: The way we approached developing this guide was to pull together the combined expertise from folks on the staff, as well as the experts at Brookhaven, Oak Ridge, and the National Institute of Standards Technology, formerly NBS for those of us that are still having trouble in this.

The guide also reflects the learning and understanding obtained from the LWR pressure vessel surveillance dosimetry improvement program. That was a multi-national program, brought together folks from the U.S. as well as other countries, UK, Germany, Belgium, and Italy. We looked at participation from vendors, from AE's, as well from EPRI and the ASTM. The program provided benchmarks and round-robin programs to qualify the analysis techniques.

The guide also reflects more recent staff and Brookhaven experience in performing independent calculations of reactor vessel fluence.

Finally, we have included information from updated cross-section libraries, in particular ENDF/B-VI.

At the subcommittee meeting, we had a presentation on the work that the NRC has funded to put together the cross-section libraries. We did not bring that presentation along this morning, because we didn't think it was particularly a driving consideration for the guide, but the NRC did take over and fund a particularly piece of work to develop the ENDF/B-VI cross-section libraries into something that was usable, because DOE had fallen a bit behind the schedule we thought we could live with.

With that, Mr. Chairman, I'd like to turn it over to John Carew from Brookhaven to give you a brief update on the information on the technical content of the guide, and we will try and finish by 10 o'clock.

[Slide.]

MR. CAREW: I'm John Carew from the Advanced Technology Division, Department of Advanced Technology, at Brookhaven National Laboratory, and I'll be discussing the regulatory guides for the calculation and measurement of pressure vessel fluence.

I'd like to first give some background and motivation for the regulatory guide.

The pressure vessel fluence is required for the determination of the vessel embrittlement and lifetime. The vessel fluence is used to determine the mill ductility transition temperature, the RTNDT, and also the PTS rule requires the fluence in order to determine the reference temperature for pressurized thermal shock, RTPTS.

[Slide.]

MR. CAREW: The fundamental problem of determination of the vessel fluence stems from the fact that neutron fluence undergoes several decades of attenuation between the core and the vessel.

[Slide.]

MR. CAREW: On this slide, we have a radial profile from the core out to the vessel cavity of the neutron fluence.

Here, you can see, as the fluence propagates from the core out to the -- through the valve, through the thermal shield, and to the inner wall of the vessel, it undergoes a reduction by about a factor of 4,000.

MR. CARROLL: That's fluence defined as what?

MR. CAREW: This is basically the flux above 1 MEV.

MR. CARROLL: Okay.

[Slide.]

MR. CAREW: As a result of the strong exponential attenuation or decay of the neutron fluence, the calculation of the fluence is extremely sensitive to the material and geometry representation of the core and vessel internals, to the space energy neutron source, to the transfer calculation and numerical schemes used to calculate it, and as a result, an accurate estimate of neutron fluence requires a detailed, multi-group, multi-dimensional analysis of the fluence.

[Slide.]

MR. CAREW: These analyses are presently performed in the industry using a wide range of fluence methods, including cross-section sets, physics approximations, and computer codes.

The limited number and uncertainty of the capsule benchmark ca makes validating and benchmarking these calculations extremely difficult.

This is further complicated by the fact that, for certain vessels, there's only a limited margin to the end-of-life reference temperature PTS limits.

[Slide.]

MR. CAREW: In the following presentation, I will provide a overview of the general approach and applicability of the regulatory guide, the calculational methods developed and described in the regulatory guide for the calculation of fluence, and the expected licensing impact of the guide.

[Slide.]

MR. CAREW: The overall approach taken in developing the guide was to focus on those critical areas where there was a substantial degree of uncertainty.

The guide recommends state-of-the-art computer codes, state-of-the-art methods that are well-validated and makes specific requirements. The guide assumes good engineering judgement and does not over-prescribe in detail.

Alternate fluence methods other than that described in the guide are also allowed but will be reviewed on an individual basis.

[Slide.]

MR. CAREW: The guide provides fluence input for the Appendix G and Reg Guide 1.99 and applies to present BWR and PWR core vessel geometries and fuel designs.

It's also applicable to vessel fluence reduction designs, including partial length shield assemblies, low leakage core designs, and life extension calculations, and it calculates the fluence spectrum above .1 MEV.

It also includes guidance for the use of cavity dosimetry and measurements.

[Slide.]

MR. CAREW: The regulatory guide provides a best estimate rather than a bounding or conservative approach. It provides a capability to determine the neutron fluence of the vessel in a wall to within the order of about 20 percent 1 sigma.

It covers the energy range from .1 MEV up to 15 MEV, and the guide employs an absolute fluence calculation rather than an extrapolation of measurements. It requires qualification of the methods by benchmarking and ununcertainty analysis.

[Slide.]

MR. CAREW: In the following, in the interest of time, I will go through the basic features of the fluence calculational methodology, but I will not discuss every item in the handout. If there's any questions on any specific item, I will be glad to answer the question at the end of the presentation.

There are three basic tasks in calculating the vessel fluence: first, the determination of the geometric and material composition input data; second, the determination of the core neutron source; and finally, the transport and propagation of that source out from the core to the vessel inner wall.

[Slide.]

MR. CAREW: The geometry looks as follows: We have a core, the bypass region, the barrel, the intervening water region, the thermal shield, and the vessel.

There's typically surveillance capsules on the inner wall of the vessel or in the back of the thermal shield at peak fluence locations, and the problem we're confronted with is to propagate the neutron source originating in the core out to the bypass barrel thermal shield to the vessel, out into the cavity.

[Slide.]

MR. CAREW: These calculations are typically performed using a discrete ordinance transport code like the DOT code. This DOT transport code gets three basic inputs.

First of all, it requires the core internals, vessels, and geometry, which it gets from this box here. It requires nuclear cross-section data, material data, which it gets from over here, into the DOT calculation, and finally, the DOT calculation requires neutron source from the core, which it gets from these two items here.

This is the isotopic fission spectrum of the source in the core, and this is the cycle-dependent assembly, pin-wise, its powers and exposures that determine the source to the -- for the -- in the core.

The DOT calculation then determines -- propagates this source of neutrons out to the vessel, and a 3-D vessel fluence calculation estimate is made.

[Slide.]

MR. CAREW: With respect to material composition and data, the geometry data, the regulatory guide requires an accurate pressure vessel diameter and eccentricity.

This is because the calculation -- there's a very steep gradient in the downcomer, and displacement of the vessel one inch towards the core will result in a 50-percent increase in the fluence. So, we require very accurate vessel ID's.

MR. LEWIS: When you say eccentricity, you mean departure from circular flow?

MR. CAREW: Yes, exactly.

MR. WILKINS: You might also worry about tilting.

MR. CAREW: All sorts of things.

MR. LEWIS: You don't mean by eccentricity that it's elliptical. You just mean it's distorted.

MR. CAREW: Any deviation from a constant radiation.

MR. LEWIS: I understand, but eccentricity is a term that's usually used for an ellipse.

MR. CAREW: Right.

MR. LEWIS: But you mean any distortion.

MR. CAREW: Exactly.

MR. LEWIS: So, a dent would describe concerns of an eccentricity.

MR. CAREW: Right.

MR. LEWIS: But that might fool you. If you have a circle with a dent in it, it's actually a bad approximation to describe it as an elliptical --

MR. CAREW: Exactly. Right.

MR. LEWIS: Since you've made such a big to-do about the --

MR. CAREW: Right.

MR. LEWIS: I see. Okay. How well do you know the shape? You know the outside shape.

MR. CAREW: Well, a typical -- from as-built drawings -- from measurements made after fabrication of the vessel, you're looking at, say, 12 different azimuths. There might be a deviation of like a quarter of an inch.

MR. LEWIS: Okay. But with 12 different azimuths, you don't get all that -- that's 30 degrees apart.

MR. CAREW: That's not that great a sample.

MR. LEWIS: You can't tell a dent from an ellipse.

MR. CAREW: Exactly. Precisely.

MR. CARROLL: Do those change in service as a result of stress relaxation?

MR. CAREW: I don't know of any change with the -- we concern ourselves with the thermal expansion, but we don't -- I don't know of any -- I don't have any measurements as to what the deviation is with lifetime.

MR. CARROLL: I know you don't, but has anybody thought about that possibility?

MR. CAREW: As far as I know, that's not a large effect, but I don't really know the answer to that.

MR. MAYFIELD: This is Mike Mayfield from Research. I would think that the thermal growth would swamp any variation you'd get from any sort of stress relaxation. There is an appreciable thermal growth to these vessels.

[Slide.]

MR. CAREW: Also, the guides requires documented as-built plant-specific data on the geometry. When plant-specific data is not available and generic data is used, the deviations, uncertainties should be included in the uncertainty analysis.

[Slide.]

MR. CAREW: With respect to the nuclear data, the regulatory guide recommends the use of the latest ENDF nuclear data files.

This is important, because we know that, depending upon what cross-section sets you use, there is some significant variation or variability, up to 18 to 20 percent, depending upon which cross-section library you would use.

[Slide.]

MR. CAREW: In addition, the regulatory guide requires a P-3 angular decomposition on scattering cross-sections. This is important, because --

MR. LEWIS: Am I the only one who doesn't know what a P-3 is?

MR. CAREW: P-3 is when you represent the angular dependence of the cross-section using a third P-3 only on an angle.

MR. LEWIS: I suppose I should have understood what you said.

MR. WILKINS: Let me try, Hal. You expand the scattering cross-section into a series of --

MR. LEWIS: I understand. I've even written papers about it.

[Slide.]

MR. CAREW: Here's an example where we see that in the forward direction corresponding to the -- equal to zero degrees, the forward direction, the P-3 decomposition is much more forward peaked and therefore gives you much more penetration and dose to the vessel. So, that's an important effect, and the regulatory guide identifies that.

[Slide.]

MR. CAREW: With respect to the neutron source, the regulatory guide recommends that a pin-wise power distribution in the peripheral assemblies be used.

This is important because the peripheral assemblies of the core provide -- the first two rows on the periphery of the core provide about 85 percent of the dose to the vessel, and the guide recommends that -- in the center assemblies, you can use a flat power distribution on each assembly, but on the periphery, you must put a pin-wise power distribution in there, and this will, in effect, actually reduce the dose to the vessel, because it accounts for the gradient on the periphery, but this is something that the guide recommends.

[Slide.]

MR. CAREW: As a matter of fact, on the next slide, you see the effect of this pin-wise power distribution reduces the vessel inner wall fluence by about 10 percent.

Neglecting this effect, of course, therefore, would be conservative, but for a best estimate calculation, you want to include it.

Another important feature that the guide recognizes is the following. With burn-up, initially, at the beginning-of-life fuel assembly, 92 percent of the fissions are produced in U-35, but at higher burn-ups, at 30,000 mega-watt days per ton, for example, 50 percent of the fissions are produced in plutonium-239.

Now, plutonium-239 is of concern because the neutrons born in fission from plutonium-239 are faster and harder and provide a larger dose to the vessel.

In addition, per energy produced, there are more neutrons born in a plutonium-239 fission than in a U-35 fission. These both tend to reduce the -- increase the dose to the vessel, and the guide requires that you account for this.

[Slide.]

MR. CAREW: Another important feature of the guide is that it recommends specifically that a fairly dense angular distribution be used, and this is because the calculations are typically done in R-theta geometry, but the core peripheral geometry is rectangular, and we know that a one-inch displacement of this nose out here which is closer to the vessel will result in a significant increase in the vessel dose, and therefore, we must take a lot of angular mesh near this corner to make sure we get a valid, reliable representation of that corner.

So, the guide makes specific recommendations with respect to the geometry of the model. It also recognizes the seep attenuation of the fluence as it propagates in the core to the vessel and makes very specific requirements with respect to the radial mesh density.

MR. WILKINS: You didn't say anything about the third point. I was going to ask you about that.

MR. CAREW: I was trying to make this fairly quick.

MR. WILKINS: Can you say something in 30 seconds or so about Z?

MR. CAREW: Sure. The calculations are typically done in R-theta geometry, because the fluence -- the axial power shape has a peaking of about 1.2 in the core and it tends to flatten as it goes out to the vessel, but the flattening or annealing of the power shape is relatively small, so therefore -- and you can sort of neglect it as long as you're close to the belt-line.

Typically, propagation from the core to the vessel results in a flattening of about 1 percent. So, typically you would neglect that and use the axial power shape, but if there are more peaked axial power shapes, the flattening may be significant and the shifting may be significant. In that case, you would do a calculation in the vertical dimension, as well.

MR. WILKINS: Thank you.

[Slide.]

MR. CAREW: The guide makes specific recommendations -- well, the guide makes very specific recommendations as to the mesh and numerical procedures and what have you, but in any case -- which we believe are adequate for most applications, but in any case, the kind recommends that whatever spatial mesh and angular quadrature group convergence, group-wise description, what have you, it should be tested for every application. So, the licensee or the analyst must test his knowledge with respect to these prescriptions.

[Slide.]

MR. CAREW: The guide recommends that the calculational methodology be qualified and validated. It specifically recommends that a two-step qualification procedure be carried out.

In the first place, we require an analytical uncertainty analysis, and in the second step, we require specific comparisons of the methodology with benchmark data.

MR. KRESS: What do you mean when you say an analytic uncertainty analysis?

[Slide.]

MR. CAREW: On my next slide, I'll discuss that in some detail. What this means is the following, that you look at your calculation and ask the question, where are my uncertainties coming from, and typically the guide lists a fairly -- includes a fairly extensive list of where they're coming from, typically nuclear data, the geometry, the vessel ID, isotopic compositions, how much iron you have in your thermal shield, the neutron source, the numerics. These are the typical sources of uncertainty.

The next question is what are my estimates of how big those uncertainties are? How much variability do I have in my vessel ID? And you have to make some judgement based on whatever measurement data and what have you is available.

MR. WILKINS: Do we assume a distribution for that?

MR. CAREW: Typically, you would assume that it's a normal distribution, but if you have other information that indicates that it's not, you would make some -- include that distribution, as well.

You would make an estimate of what the uncertainties were. You'd determine the sensitivity of the fluence to those deviations. Then, finally, you would --

MR. WILKINS: Is that done by a sensitivity analysis of your transport code?

MR. CAREW: Right. You would take the transport code and you would increase the vessel ID by some delta-X or delta-R and you record the delta-F, the delta fluence.

MR. KRESS: You do it all over again.

MR. CAREW: Exactly. You don't try to use any of the fancy methods of differential calculus that would give derivatives.

MR. CAREW: Well, the guide does not specify -- well, it suggests that you do a perturbation, individual discrete perturbation delta for each calculation, but it certainly does not prohibit using some other more elaborate method.

MR. KRESS: You don't map the whole output space on that. You just do the uncertainty of each individual parameter around a standard one at a time.

MR. CAREW: Nominal value, right.

[Slide.]

MR. CAREW: The next part of the benchmarking is comparisons to benchmark data, and this is important because it provides an independent assessment of the estimate of the fluence calculation of uncertainty, and this is recommended in the guide.

[Slide.]

MR. CAREW: The expected impact of the dosimetry guide will be, first, to reduce the calculation of uncertainty to of the order of 20 percent.

This would result from improved nuclear modeling and data, basically the use of in-depth cross-sections and better vessel geometry data, improved modeling assumptions -- for example, the P-3 cross-sections, the pin-wise power distribution -- and also the execution of the benchmark comparisons in the uncertainty analysis.

MR. KRESS: Excuse me. When you say you reduce the fluence calculation of uncertainty to less than 20 percent, what precisely does that mean? Does that mean the mean value you'd calculate at 95-percent confidence is 20 percent lower than it would be if you didn't do all this?

MR. CAREW: It would mean that, if you used this methodology and you did a calculation, you would have a 68-percent probability of being within 20 percent of the correct, true answer.

MR. LEWIS: I wonder whether the sigma model is appropriate Taussian distribution.

MR. CAREW: Well, the guide doesn't address that. Presumably, you would use -- their usual situation is you assume that it's a very complicated calculation and that the distribution -- the resultant of all these uncertainties results in a normal distribution of the error.

MR. LEWIS: If it's additive, it is; if it's multiplicative, it isn't.

MR. CAREW: Yes.

MR. LEWIS: I just responded to your 68 percent for 1 sigma, which is a Taussian assumption.

MR. CAREW: Right. Yes. Exactly. That's what I meant, right.

MR. WILKINS: The first order is additive. That's the point. We'd better go ahead.

MR. CAREW: Finally, the regulatory guide is expected to reduce the measurement of uncertainty by of the order of 20 percent due to the improved dosimetry response interpretation in the guide, the improved quality assurance, and the periodic calibration uncertainty analysis.

Also, we expect the guide will standardize the vessel fluence methods in that the guide includes acceptable and documented methods and ensures the benchmarking uncertainty analysis. We expect, also, the guide will also simplify the licensing reviews.

That's all I have to say, and I'll answer any questions anybody has.

MR. SEALE: There are some comparisons with specific measurements and so on in the last page of the second set of charts you gave us which I think address some --

MR. WILKINS: I waited very patiently, because I thought you were going to, at some point, talk about the time dependence of the flux, which you have to integrate in order to get the fluence, and it's the fluence that counts.

At least as I understand the metallurgy, it's the fluence that counts, and so, you need to compute the flux at various times and integrate in order to get the fluence, and you didn't say those words at any time. Was that because you assumed we knew it already?

MR. CAREW: Yes, but let me go back a step. You're right, I really didn't go into detail on that, but what that means is the following, that the time dependence really just enters into the calculation of the source.

MR. WILKINS: I agree.

MR. CAREW: When you construct the source -- and that's in this box here -- if you look in this box here, you can see that we require, in determining the source, the cycle-dependent power and explosion distribution.

MR. WILKINS: I saw that slide, I saw that box, and I didn't see the word "cycle-dependent."

MR. KRESS: You ignore start-ups and shutdowns and just assume constant power on those?

MR. CAREW: Well, it depends. What you do is, in a particular application, you would actually get the power history throughout the whole cycle, including start-up, shutdown, and so on.

MR. KRESS: But you don't use the flat parts of the curve.

MR. CAREW: It's presented as a histogram over time intervals, and you sum those up.

MR. KRESS: Okay.

MR. SEALE: The big change is in the isotopic composition.

MR. CAREW: Exactly.

MR. SHACK: Combining this fluence calculation and going directly from your reg guide using the J flux calculations so that you bypass Reg Guide 1.99, you're going to get quite a different distribution of fracture toughness through the vessel wall.

MR. MAYFIELD: That's correct.

MR. SHACK: And it will be less conservative, presumably, than the Reg Guide 1.99 answer.

MR. MAYFIELD: No, you have to be careful, because this calculation doesn't address -- the way we would use the fluence calculation is to take the fluence calculated at the inner surface and attenuate that through-wall based on the Reg Guide 1.99 parallel.

MR. SHACK: You wouldn't take this distribution and go straight to a J flux curve?

MR. MAYFIELD: Not at this stage. That's one of the things we're looking at in the revision to Regulatory Guide 1.99, is the way we attenuate fluence through-wall, but right now, we would take the inner surface and attenuate it.

MR. SHACK: Is there a footnote in the Reg Guide somewhere that says you can't do that? If I remember the Reg Guide, it says you can use that J flux curve.

MR. MAYFIELD: Yes.

MR. SHACK: That's Reg Guide 1.99.

MR. MAYFIELD: You've asked me a question I guess I can't answer, because I haven't thought it through. The intent was that you'd use --

MR. SHACK: You didn't make Art Lowe very happy, right?

MR. MAYFIELD: We didn't make Art Lowe very happy. I'm not sure that it would be warranted that it would make Art Lowe very happy.

MR. SHACK: And my answer is would you accept it?

MR. MAYFIELD: I think the answer right now is I don't know. You've raised an issue that I hadn't thought about, and maybe we need to add a footnote to address it one way or the other.

MR. SEALE: Thank you, Bill. Any other questions?

MR. WILKINS: Bob, are you going to prepare a letter?

MR. SEALE: We have.

MR. WILKINS: You've already prepared it, and so, we can discuss it this afternoon. You will have it available for us to discuss this afternoon.

MR. SEALE: Yes.

MR. WILKINS: The issue, as I understand it, is whether the ACRS feels that this is ready to go out for public comment.

MR. SEALE: Yes.

MR. WILKINS: Thank you.

We are, I believe, ready for our first break. Let me look at this just to make sure, and we're only about four minutes behind. Let's try to pick up that four minutes. Let's get back by quarter after 10, please.

[Recess.]

MR. WILKINS: Will the members please take their seats? We will resume our meeting. There is a little ministerial matter I'd like to take care of just before we get started with the formal business.

We have with us today Mr. Johnny Mathis, from Region II. He has a BS in physics from Mississippi Valley State and an MS in nuclear engineering from Howard

University.

He started working with the NRC, I gather, immediately thereafter, for about eight months in Emergency Preparedness and then transferred to Region II in Atlanta.

He was a Resident Inspector at Grand Gulf in 1987, a Senior Resident Inspector down there a little bit later, and then he transferred back to Region II as a project engineer for Brown's Ferry and Sequoyah. He's presently here on a six-month rotational assignment to ACRS.

MR. KRESS: Is it out of order to ask if he can sing?

MR. WILKINS: I resisted that. It was a strong temptation.

MR. CARROLL: I was going to point out that his alma mater produces very fine wide receivers, like my 49ers' Jerry Rice. I assume they do the same with physics majors.

MR. WILKINS: It is a fact, Mr. Mathis, that I was at Howard University -- I left Howard in 1977. Were you there that early?

MR. MATHIS: In the summer of 1977.

MR. WILKINS: Then we overlapped just that much.

The next item on our agenda deals with debris plugging of emergency core cooling suction line strainers, and this will be introduced by Jay Carroll.

MR. CARROLL: We earlier had a briefing on the event in Sweden, and I guess the staff had promised they would update that when they had more information.

More recently, Perry had an interesting problem involving strainer plugging, and we're going to also hear about that today.

MR. DENNING: Good morning. My name is Bob Denning. I'm the Section Chief in the Events Assessments Branch of the Division of Operating Reactors Support. I'm here today acting instead of Al Chaffee, who couldn't be with us.

Also here from DORS is our Division Director, Brian Grimes, at the table to my left.

We'll be pleased to respond to the ACRS request for a briefing on two subjects today. The first, of course, will be the potential for debris plugging of ECCS suction lines, and then, later, we'll be talking about the extraction steam line break at Sequoyah 2.

With that bit of introduction, let me turn things over to Marty Virgilio, the Deputy Director of the Division of Systems Safety and Analysis in NRR, who will lead us into the discussion of the ECCS suction line strainer issue.

MR. WILKINS: The first of your items is our agenda item 12, and the second one is our agenda item 13, and I only introduced 12, but you're going to treat them as a coherent whole?

MR. DENNING: No. We'll certainly break after the first discussion. I was just trying to bracket the whole events presentation this morning.

MR. WILKINS: All right. Thank you.

MR. VIRGILIO: Thank you, Bob.

Good morning. My name is Marty Virgilio. With me today I have Rich Barrett, who is the Chief of our Containment and Severe Accident Analysis Branch; John Hickman and Bob Stranski from our Division of Reactor Projects; and Roger Woodruff, a technical expert in our Containment and Severe Accident Branch.

The purpose of today's briefing is to provide you an update -- we were last here in January -- an update of operational experience, NRC activities, and our findings related to the potential for fibrous thermal insulation in containment to degrade safety system performance.

USI A43 was resolved in the mid-'80s. It was focused on containment emergency sump performance and addressed concerns for performance of safety-related pumps in containment during an emergency.

As part of that effort, Reg Guide 1.82, Sumps for Emergency Core Cooling and Containment Spray, was revised to provide additional assurance that debris from thermal insulation would not interfere with the operability of safety-related pumps.

This revision was based on engineering and analysis and testing, and based on our cost-benefit analysis back at that time, a decision was made not to backfit the Reg Guide but only use it on a forward-fit basis.

Because of the event that occurred at Barsebeck 2 in July of 1992, the resolution of A43 is being reevaluated from two perspectives.

The first perspective is the potential for strainers and filters to become clogged by debris and therefore decrease the necessary pump suction head, and the second potential is for the debris to actually be ingested by the pumps and thereby degrade the pump performance by having an effect on a seal or a bearing.

Large break LOCAs are low-probability events. Nevertheless, this new information does raise concerns that, if such an event were to occur, ECCS strainers and screens could become clogged with fibrous insulating material and thus degrade safety system performance.

Because of these concerns, we have initiated a very structured program to go back and evaluate this new information and ensure the conclusions supporting the resolution of A43 remain valid; that is, that safety system designs are, in fact, adequate to ensure public health and safety.

Immediately following our assessment of the

Barsebeck event, we issued an information notice and developed a program plan for conducting our evaluation.

More recently, our assessment of U.S. operating experience resulted in the promulgation of a bulletin on this subject, Bulletin 93-02.

We're in the process of implementing our program plan. That plan calls for our re-review of regulatory requirements, the collection of specific data, and the conduct of some scoping analysis -- if necessary, plant-specific analysis -- to be performed, and based on all that, we intend to evaluate the results and, if warranted, promulgate new requirements, corrective actions.

John Hickman and Rich Barrett will now provide the additional details from our operating experience assessment and the implementation of the program I just outlined.

John?

MR. HICKMAN: I have two events that I'm going to provide some background information on, Grand Gulf and Perry, and then I'll provide some information on the bulletin the staff issued in response to the implications of those two events.

The first event occurred at Grand Gulf. In 1988, during an ECCS pump flow test, reduced suction pressure was observed. An investigation by the licensee determined that the strainers in the suppression pool were clogged with sediment.

The licensee subsequently cleaned the strainers and initiated plans to provide regular cleaning of the suppression pool. However, the plans to clean the suppression pool were not fully implemented.

In 1989, another pump test also indicated reduced suction pressure, and the strainer was again found to be clogged. Following this second occurrence, the strainer was cleaned again, and this time the pool was vacuumed to remove debris, and the walls and floor of the suppression pool were hydrolyzed.

The licensee also established a requirement for vacuum cleaning of the suppression pool at the end of every refueling outage, and since that time, no further problems have been observed.

MR. CARROLL: What was the nature of the debris that was causing it?

MR. HICKMAN: It was mostly just normal operational debris, dust and silt and other small material. Grand Gulf has a Mark III containment. So, basically the suppression pool is open to activities inside the containment.

There wasn't any particular stand-out item at Grand Gulf. It was just general debris.

MR. MICHELSON: What mesh size on the strainer did they have?

MR. HICKMAN: Pardon me?

MR. MICHELSON: What was the mesh size?

MR. HICKMAN: I'm not sure exactly what the size was at Grand Gulf.

MR. MICHELSON: That has a great bearing on the significance of the debris.

MR. BARRETT: I'm Richard Barrett. I can't exactly answer the question for Grand Gulf, but what we've found typically is the mesh sizes -- the hole sizes for BWRs of this vintage ranges from about 70 mils to maybe 125 mils. At Perry, I believe, it was 70 mils.

MR. LINDBLAD: And what determines that mesh size?

MR. BARRETT: The mesh size is determined primarily by the need to protect downstream components from material getting through the strainers.

MR. LINDBLAD: I understand that, but which downstream component is determinative?

MR. BARRETT: I believe that the limiting component for Mark III, BWR-6, is the core spray or containment spray spargers.

MR. MICHELSON: The nozzle itself.

MR. BARRETT: The nozzles, yes.

MR. MICHELSON: But that's a pretty large throat, of course. They're not small, by any means. There's always an argument as to what size it should be.

The real component of significance in the case of some boilers was the bearing seal cyclone separator, which had an eighth-inch throat in it, and you wanted to make sure that you didn't let larger debris get in and clog the throat. That kind of set the kind of sizes people were using, and it depends on whose separator you've got.

MR. CARROLL: This design is just the single strainer. There's not a coarser strainer ahead of it.

MR. HICKMAN: No. There's just the one strainer.

MR. MICHELSON: Is it a round-hole plate, you know, a plate with round holes in it, or is it meshed wire?

MR. HICKMAN: When we get to Perry, we have some drawings and some videotape we can show you.

MR. MICHELSON: Good.

MR. HICKMAN: Okay. Basically, what the events at Grand Gulf demonstrated was that just normal operational debris can cause some clogging of the strainers.

MR. MICHELSON: Now, normal operational debris has got to be pretty big. It isn't rust and so forth. It's got to be people dropping things into the pool.

MR. SEALE: "Some" is a fuzzy word. You say "some clogging" and reduced suction pressure. To what extent was the capability of the -- well, to what extent was the water essentially choked off?

MR. HICKMAN: Well, in the case of Grand Gulf, there was adequate NPSH for the pumps. In the case of Perry, as I'll get to, they did some measurements, and their tests indicated a loss of up to 6 psi over a 9-hour period.

The next event occurred at Perry. In May of 1992, at the end of an outage, debris was identified on the pool floor and strainers during an inspection of the suppression pool and the suction strainers. This was done by remote camera, and we'll show a little videotape on that in just a second.

The debris, again, consisted of general maintenance type material and fine dirt, and at the time, the licensee simply generate a maintenance work request to have the strainer cleaned subsequently.

Following the vacuum cleaning of the pool and strainers, which was done in January of '93, the strainers were recognized as being physically deformed and cracked. Basically, the flow restriction caused by the debris had deformed the surface of the strainers. At this point in time, the licensee replaced the strainers.

Subsequently, in March of 1993, an event occurred during which several safety relief valves were manually lifted. An RHR was then used for suppression pool cooling. When the strainers were inspected after use, they were again found to be coated with debris.

Tests of this as-found condition of the strainers indicated a significant drop in pressure -- as I indicated, up to 6 psi over a 9-hour test period -- but they found no change in system flow rates or pump motor amperage. So, they didn't have a flow restriction to the point that it bothered the pump's operation.

Prior to restart from the corrective actions this time, the corrective actions Perry took, including replacing the strainers with strainers of a larger size, the pool was thoroughly cleaned, procedures for a manual back-flush of the strainers were implemented, and trend monitoring of MPSH during pump test was initiated.

MR. MICHELSON: Are you going to show us the drawings on that --

MR. HICKMAN: Yes.

MR. MICHELSON: -- that larger size?

MR. DAVIS: That's not a larger mesh size.

MR. HICKMAN: No, no. It's a physically larger strainer.

MR. DAVIS: Thank you.

MR. HICKMAN: Okay. We have some drawings here I'd like to pass around of the fibrous material that was found in the pool and the debris that was on the surface of the strainer and a picture of the strainer, as well as some samples of the fibrous material that was on the strainer.

MR. MICHELSON: Can you tell us the source of the fibrous material?

MR. HICKMAN: Okay. The fibrous material was part of normal air filters that were used inside Perry. Basically what they had installed inside their containment were roughing filters on the intake side of their air-handling units. There's a picture of the filters in there. Basically, these were not much more than the kind of filters you'll see in your home HVAC units, covered with a wire mesh.

Apparently, one of these filter segments -- I believe they eventually came to the conclusion it was a one-foot-by-one-foot piece -- somehow was dropped or ended up in the suppression pool -- they don't really know how -- and to a certain extent, it came apart in the pool, and that filter on the surface of the strainer then caused the significant problem of acting as a filter for the debris in the pool and then clogging the strainer.

I guess, at this point in time, we could go ahead and run the videotape real quick to show what the strainer looked like.

[Videotape presentation.]

MR. HICKMAN: This is an inspection that was done at Perry when they initially found the clogged strainers in May of '92. They're using a remote underwater submarinetype camera. The picture quality isn't great, but you can see some of the debris floating in the pool there.

[Videotape presentation continues.]

MR. MICHELSON: Now, that's a lot more than from one square foot.

MR. HICKMAN: What you're seeing in the pool now is basically the general operational debris that's floating in the pool. That's not the one square foot of filter material.

MR. LINDBLAD: When you say "floating," you mean suspended?

MR. HICKMAN: Suspended, yes.

One of the pictures gives a good viewing of how damaged and deformed the strainer is, but this is probably the best view of the general coating that was observed on the surface of the strainer.

MR. MICHELSON: That's a flat plate strainer with holes. Is that correct?

MR. HICKMAN: Well, it's a cone strainer.

MR. MICHELSON: Oh, it is a cone.

MR. HICKMAN: Yes, it's a cone.

MR. MICHELSON: Then it's a wire mesh strainer.

MR. HICKMAN: Well, it's a metal fabricated cone with holes perforated in it.

MR. MICHELSON: Okay.

MR. HICKMAN: There was a significant amount of debris you noticed on the strainer, and as you can see, there's general debris floating.

MR. LINDBLAD: What's the dimension of the suction pipe, roughly? One foot, two foot?

MR. MICHELSON: I assume the licensee analyzed that cone for the hydrodynamic forces during blowdown in the reactor, because that's quite a water resistant design. It's got a lot of drag to it when you start getting your blowdowns. I assume that was designed -- it's got to survive the blowdowns.

MR. CARROLL: Is the pump running while all this is going on?

MR. HICKMAN: No. They were doing the inspection without the pump running at all. There was no suction through the strainer when they were doing this.

MR. GRIMES: But the debris is probably not usually in the water. It's being churned up by the --

MR. HICKMAN: Yes, to a certain extent.

MR. GRIMES: -- the remote camera.

MR. HICKMAN: The sub itself is churning it up.

MR. GRIMES: You can see what might happen if you churned that whole --

MR. HICKMAN: Obviously, if have a discharge, it's going to do the same thing, only more so.

[End of videotape presentation.]

MR. HICKMAN: The licensee analysis of the debris found in the strainer indicated that it consisted of fibers from the air filter material that had been introduced in the suppression pool and corrosion products that had been filtered from the pool by the fibers adhering to the surface of the strainers, and the fibers, as I stated, were intended as roughing filters for the air-handling units.

This filtering effect of fibrous material in the strainers was a previously unrecognized mechanism for increasing the flow restriction on the strainers.

MR. MICHELSON: Not recognized by whom?

MR. HICKMAN: By the staff.

MR. MICHELSON: We talked about it ad infinitum when we went through the resolution of that generic issue, when Al Serkis was down here. We talked about it for months. We talked about the cyclone separator problem, the whole bit.

MR. GRIMES: I think what John was referring to is the special filtering effect of this fibrous material to capture very small debris that would have otherwise passed through.

MR. MICHELSON: That's part of the problem, no doubt. No doubt that's part of the problem.

That's what he talked about and also talked about what hole size it took to make sure the material didn't get to the cyclones, because it could get plugged the same way, because it was a very small diameter, and this is a typical BWR, and I think GE put in the same type of design on the seal at every plant.

MR. GRIMES: I think maybe another way of saying it is that, in calculating the head loss due to this kind of caking on the strainers, this filtering phenomenon was not included in the correlations. It was not anticipated that this would be a phenomenon.

So, all the experiments, for instance, that were done were done with homogenous material, fibrous material, without the presence, for instance, of any other kind of debris and sediment.

MR. MICHELSON: There are two problems on the strainers. One was the vortex formation, and the other was the clogging. In this design here, I'm not sure -- I don't recall they ever tested a clone intake when they determined the vortex effects.

Remember, you set up a whole experiment and everything, did all that vortex work to make sure that the vortex wasn't interfering with the MPSH, and I'm not sure this was ever even tested, that configuration. So, it's another problem.

MR. CARROLL: When all was said and done at these two plants, they still kept the same basic strainer design.

MR. HICKMAN: Yes.

MR. CARROLL: Okay.

MR. HICKMAN: Perry did increase the size of their strainers and the other corrective actions, but it's basically the same strainer.

MR. LINDBLAD: What do you mean by the size? The area?

MR. HICKMAN: The total area of the strainer.

MR. LINDBLAD: Of the same mesh size.

MR. HICKMAN: Yes.

MR. MICHELSON: A longer cone. Is that the idea?

MR. HICKMAN: Yes.

MR. CARROLL: So, I guess, to continue with what Carl started, has anybody looked at what the hydrodynamic loads from blowdown do to these rather large protrusions out into the pool?

MR. HICKMAN: I can't say that I'm aware.

MR. MICHELSON: That's why the early BWRs, of course, when to a flat plate steel configuration with holes drilled through it, because it took that much to make sure you didn't blow it apart.

Now, since then we've learned more about hydrodynamic loads and so forth. I don't know if that's helped or hurt, but somehow you have to check these kinds of devices sticking out in an area that's under severe disruption.

MR. CATTON: The strainer is submerged, isn't it?

MR. MICHELSON: It's down near the bottom. It's probably down at about at the level of --

MR. CATTON: It's down near the bottom, Carl. The hydrodynamic loads on the strainer are probably negligible.

MR. MICHELSON: Well, in the Mark I, it was --

MR. CATTON: Mark I is different.

MR. MICHELSON: Yes, it was different, and as I say, you've got to look at it to see. I was kind of thinking backwards in terms of, okay, this is a smart idea, we'll go back to the Mark I's and put these big long cones and make sure we don't plug. Mark I is a serious problem. I don't know in the others.

MR. BARRETT: We'll certainly look into the question of whether the loads were considered, but I recall that, when the new strainers were being designed for Perry, I remember being told that one of the main expenses was to qualify them for the loads, both the seismic loads and the hydrodynamic loads, and the hydrodynamic loads were limiting.

MR. MICHELSON: Now that they're changing the design, you'd expect to see a new qualification.

MR. BARRETT: That was my point. The

qualification of the new strainers was the pacing item.

MR. MICHELSON: Oh, okay.

MR. HICKMAN: Okay.

Based on this event at Perry, which demonstrated that filtering of corrosion products, dust, and other debris may cause an unexpectedly rapidly loss of net positive suction head for the ECCS pumps, the staff issued Bulletin 93-02.

Bulletin 93-02 requested licensees to identify fibrous air filters or other temporary sources of fibrous material not designed to withstand a LOCA which were installed or stored in the primary containment, take any needed compensatory actions necessary to assure the functional capability of the ECCS, and promptly remove any identified material.

In response to Bulletin 93-02, most licensees indicated that no removal of material was required. For the most part, this conclusion was supported by a discussion of what fibrous filters and other fibrous materials were in use, which fibrous materials were able to withstand a LOCA environment, including susceptibility to jet impingement, and for the material postulated to transport to the sump or suppression pool, reference to analyses which demonstrated adequate NPSH still being available for the ECCS pumps.

MR. MICHELSON: Now, the case of the boilers, the upper drywell region on all of the boilers contains all of the cooling equipment for inside a containment. It's a very massive thing. You've undoubtedly seen them. Are they all made out of non-fibrous materials. You know, the air-handling units, the whole bit, is that all non-fibrous?

MR. HICKMAN: No. What multiple licensees indicated was they have fibrous filters in those air-handling units, but they're fully enclosed in the air-handling units.

MR. MICHELSON: I was thinking more of the duct-work and so forth. There's no fibrous insulation being used in any of that equipment.

MR. HICKMAN: For these licensees, they indicated that, where fibrous insulation was used, either on piping or on duct-work, it was metal-jacketed or in some way restricted from being dislodged or the amount that was postulated to be dislodged was of an amount that the strainers could handle that and still provide NPSH.

MR. MICHELSON: But I guess I don't know what amount it takes -- in the case of the filter, I don't know whether one square foot is all it took or what.

MR. HICKMAN: Well, although the case of that one square foot of filter material at Perry did provide a noticeable loss of suction pressure, it wasn't a loss of suction pressure that it caused the pump to have inadequate

NPSH.

MR. MICHELSON: Of course, one square foot is not very much.

MR. BARRETT: In the case of Perry, the filtering material that was -- there was quite a large amount of filtering material. It was only required for outage situations. However, Perry's practice was to replace the filters after the outage and leave them in there during operation.

MR. MICHELSON: Yes.

MR. BARRETT: So, they've changed that practice, because they don't these filters during normal operation. That may well be the case for some of the filters you're thinking about.

MR. MICHELSON: Well, during normal operation, of course, that air-handling equipment is what's keeping the containment cool inside. That's what protecting containment during normal operation, and you've got to keep it running.

Containment cooling equipment is essential on a boiler. It's running all the time, particularl, the upper part of the drywell, where it gets terribly hot otherwise, and if that containment cooling equipment fails, you're in deep trouble, from the economic viewpoint at least.

MR. DAVIS: But I thought he said those filters are all enclosed.

MR. MICHELSON: It isn't the filters I'm really worried about. Do people really know what else they've built all of that air-handling equipment out of, because they're handling -- heating and ventilating engineers use different materials than steel.

MR. HICKMAN: That was the point of the bulletin, was to get licensees to identify that fibrous and other filter material that was in use.

MR. MICHELSON: You keep using the word "filter material."

MR. HICKMAN: The bulletin asked for filters and other fibrous material.

MR. MICHELSON: It's the fibrous material that I would be worried about, not just the filters.

MR. CATTON: When this fibrous material is jacketed, what's the gate of the jacketing material?

MR. HICKMAN: I am sure that varies from plant to plant. I don't know specifically what it would be.

MR. BARRETT: You're referring to the insulation?

MR. CATTON: Yes.

MR. BARRETT: Yes. We actually have a sample of the insulation.

MR. CATTON: Probably, if you had a line break in the room or something, you would just rip it off.

MR. MICHELSON: This stuff is going to be in every direction. I don't think you've asked the right question of the licensee.

MR. CATTON: This is somebody's patio furniture?

MR. BARRETT: No, that's second base. That's a sample of fiberglass insulation used in typical operations in U.S. plants. It's jacketed with a woven fiberglass kind of cover.

That's wrapped around pipes, typically, and in turn is jacketed with a metallic cover which has a snap-on/snap-off type of apparatus. That would be a typical insulation.

MR. MICHELSON: I think the Germans found that that type of insulation was -- they had it in some of their testing, and it came unzipped, of course, when they got the de-pressurizations inside a containment.

MR. BARRETT: From the perspective of this particular issue, having it come unzipped and flying away from the break is actually better than having it stay there and get pulverized.

MR. MICHELSON: Well, what they found is the break stripped it for a number of feet on each side of where the break was --

MR. BARRETT: That's correct.

MR. MICHELSON: Once the jacket is stripped, then the insulation is quite --

MR. HICKMAN: In most cases where a licensee addressed insulation, such as that on pipes or duct-work, they also addressed the susceptibility to LOCA impingement.

Where there was no high-energy lines, they would tend to presume that it was not going to transport. Where there were high-energy lines available, they assumed a certain quantity was going to transport to the sump or suppression pool.

MR. MICHELSON: Depending on how you do your analysis, you've got to recognize that we're not looking for using usual jet impingement rules like line of sight.

The jet can go around a corner and strip this stuff very easily, because it doesn't take much force to do it. So, you can't count on using the pipe break rules of jet impingement.

MR. CATTON: Downstream of doorways and things like that, the gusting gets quite vigorous. It can shred things.

MR. MICHELSON: Jetting around any obstruction would just tear this stuff off if it was close to the break.

MR. CATTON: The photographs from inside the HDR containment really are enlightening.

MR. MICHELSON: Yes. We went through this when we discussed the regulatory guide -- I mean the resolution. There was a regulatory guide, also, but the guide went through, and that's why we're here.

So, you're rethinking the guide, and I guess we'd like to see how you're rethinking it.

MR. HICKMAN: Okay. As I started, several licensees indicated no removal of material was required.

Several other licensees identified and removed material which was determined to be within the scope of the bulletin. For any fibrous material that assumed is remaining in containment, they provided an analysis similar to the first group.

Two licensees responded to say that they required to do further analysis to determine the acceptability of certain material, and they're going to provide further information later.

Several licensees also provided a discussion supporting acceptability for use of certain material which, upon initial staff review, has raised some questions, and these items will require further staff review, and we'll be in contact with the licensee on those.

MR. CARROLL: Give us some examples.

MR. HICKMAN: They postulated peculiar transport, or they postulated that a section of insulation was in a location in containment where they felt it couldn't transport to the pool, and maybe, based on the design of that containment, that's an accurate assessment, but at this point we haven't had a chance to assess accuracy of that.

Finally, several licensees provided insufficient information in their response to the bulletin, and we're going to have to contact them to get further information.

We also plan on preparing a temporary instruction to do some type of audit inspection of their response to verify the accuracy of what they told us.

If there's no further questions on these events or the bulletin, Rich Barrett --

MR. MICHELSON: Let me ask you, in another area -- of course, I assume, on looking at this, they were looking at such common things as the chilled water piping inside of containment that's going off to the air-handling units.

That's typically handled, of course, as non-safety, because it isn't required for safety purposes, and traditionally, you like to just simply insulate cold water piping with what is essentially fibrous insulation, and it is particularly good, because it does sweat so much, and it's a real problem inside a containment, and now they're assuring you that they either don't have that kind of insulation or that they have adequately tied it down such that LOCA will not disrupt it.

MR. HICKMAN: Or they're postulated that a given quantity will transport and the strainers can handle that quantity.

MR. MICHELSON: That's where it begins to get a little flakey, showing that, but I'm just trying to figure out what the position is.

MR. BARRETT: We don't mean to imply that, as a result of this bulletin, there is no fibrous material in the containment that could transport to the pool in the event of a LOCA. I mean we recognize that, based on Reg Guide 1.82, that no matter how it's protected, it will transport.

What we were trying to get out with this bulletin was that there were some filtering materials, other types of fibrous materials that were either installed in a totally unprotected manner and had been totally un-analyzed previously for this kind of effect or, in some cases, were even stored sitting on the floors within the drywells. That was the purpose of the bulletin.

MR. MICHELSON: But having decided that it didn't affect the filter, you also decided it didn't affect the pump seal cooling system, as well. Is that correct?

MR. BARRETT: Perhaps it's time for me to start my presentation.

MR. MICHELSON: Was your inquiry to the licensee in the form of a bulletin?

MR. BARRETT: Yes, it was a bulletin.

MR. MICHELSON: And what was the number on that bulletin?

MR. BARRETT: 93-03, I believe.

MR. GRIMES: 93-02.

MR. BARRETT: 93-02.

MR. MICHELSON: Oh, it is in our book?

MR. WILKINS: It's on page four of tab 12, I believe.

MR. BARRETT: Okay. Again, I'm Richard Barrett. I'm the Chief of the Containment Systems and Severe Accidents Branch in NRR.

The last time we briefed you on this subject was on January 7th of this year. We gave you an idea of what our plans were at that time, and I'd like to say that a lot has happened since then, and a good bit of what we planned to do has gone through some rethinking, primarily as a result of the Perry and Grand Gulf information, but also because of some information we've gotten regarding tests that have been done in Sweden. We've visited Sweden in the meantime.

However, let me just start by giving you a little bit of update on what we had talked about in January. At that time, the principle activity that we were looking into was a survey of the industry conducted by the resident inspector staff.

We wanted to find out -- get a cross-section of the characteristics of U.S. BWRs to see to what extent they were susceptible to the same kind of problem that had been experienced at Barsebeck.

The first important question that we asked was the types and amounts of insulating materials that exist in U.S. BWRs, and what we found out was that, unlike the Barsebeck reactor, the reactor vessels in our country are, by and large, insulated with metallic insulation or so-called reflective metallic insulation, which is an advantage. The vessel at Barsebeck is insulated with calcium silicate, which has a tendency to cake the strainers.

MR. MICHELSON: When you said "by and large," you mean there are some that do not use metallic insulation?

MR. BARRETT: I said "by and large" because I'm not sure that every single one -- but I believe every single --

MR. MICHELSON: So, as far as you know, every single one --

MR. BARRETT: As far as I know, every single one has metallic insulation.

The situation with regard to large piping, however, is different. Large piping in this country -- there's a minority of the plants that have metallic insulation.

The vast majority of the plants -- in fact, I think all but one -- well, there are about seven plants that have metallic. The vast majority of the rest have a fiberglass type of insulation, which is basically what's encased in the sample we gave out earlier.

I'm going to pass around a sample of that and a sample of a typical mineral wool. This is the type of insulation, not the same brand of insulation, that was used at Barsebeck.

MR. MICHELSON: As a matter of history, I think, earlier, a larger number of plants had metallic insulation. They started taking this stuff out and putting in fiber, taking the metal out and putting the fiber in, and the staff proceeded to allow them to do that.

MR. BARRETT: That's what I've been told, but you know, I've never been able to verify that, that that was, indeed, the case 10 years ago.

MR. MICHELSON: You lose a lot of heat through -- metal insulation isn't that good.

MR. BARRETT: Exactly.

MR. SHACK: I think they were doing that with the BWRs that had the pipe cracking, too.

MR. BARRETT: That's correct.

MR. MICHELSON: I think even Brown's Ferry junked their metal.

MR. CARROLL: Well, it wasn't very good, the early insulation, in terms of durability and handling.

MR. BARRETT: You're absolutely right. There are two reasons. One is the better insulating capability. The other is the accessibility.

In fact, when I said that seven of the plants have reflective metal on large piping, even those have this type of insulation at the ISI wells, yes, for easy removal.

A couple of things now. This is that fibrous insulation that we have in the majority of our plants, but there are two differences between our fibrous insulation and the mineral wool that was at Barsebeck.

One is there is quite a large density difference, something like a factor of five or six. The fiberglass is less dense by a factor of five or six, and that's good. For the same amount of material or volume that's displaced, there is a lot less mass.

Secondly, for the same amount of mass, the indications are that you get less head loss on a coated strainer than you would with the mineral wool.

MR. MICHELSON: More important is the strength of this material, the ability to hang together and go down into the drywell as large pieces, which is far more plugging than the finely divided fibers. So, which is stronger, what Barsebeck was using or this kind of stuff?

MR. BARRETT: Well, let me take issue with what you said about which is worse.

It turns out that the experimental evidence is that the worse situation you can have is to completely pulverize the material, because if you get a jet that impinges on the insulation and totally pulverizes it, that very, very fine material transports to the pool more readily, it stays suspended in the pool longer, and once it's on the strainer, it tends to produce a higher head loss than --

MR. MICHELSON: I was simply thinking of, typically, a Mark I, for instance, wherein when you get the LOCA, everything is blowing down to those four vent tubes to the downcomers, and that's a cyclone blowing down there --

MR. BARRETT: That's correct.

MR. MICHELSON: -- and this will be carried as large sheets, I'm afraid, and that might even be worse, because it will go down nicely, go right down through the downcomers, and end up in the water.

MR. BARRETT: There have been some experiments on that. So, let me describe a little bit about that, but let me go on here.

The second important thing, besides the insulation, is that the -- is the size of the strainers. Obviously, a larger strainer will take more insulation without losing head.

The strainers in this country, by and large again, are of the same rough size in terms of area as what they have at Barsebeck.

There are a minority of plants, maybe five or six, that have actually gone through a Reg Guide 1.87 Rev 1 analysis, even though it's not required for them, and as a result of that have backfit larger strainers on their ECCS and containment spray inlet pipes.

MR. LINDBLAD: What's a typical cleanliness factor applied in the design of the strainer?

MR. BARRETT: Cleanliness factor. I'm not sure I know what you mean.

MR. LINDBLAD: Clogging factor, the inverse of the clog.

MR. BARRETT: Oh, I see. Well, most of these plants are designed to Reg Guide 1.82, the original Reg Guide 1.82, and there you were supposed to design the strainer such that you could take 50-percent plugging.

MR. LINDBLAD: Fifty percent. Thank you.

MR. BARRETT: Yes.

So, the strainers are roughly of the same size for most of our plants as was at Barsebeck.

The third important parameter is the flow rate. The higher the flow rate through the strainer, the more head loss you have, and the flow rate or, perhaps more importantly, the approach velocities tend to be rather high for BWR strainers.

They're one to four feet per second, which tends to give you relatively high head losses. Some of the plants are down around .1 feet per second.

MR. MICHELSON: So, that will give you a good vortex, also, and the vortex is important in the design of the configuration of that strainer, and we recognized that long ago and did all those vortex tests in the '70s and early '80s, and I just wondered if we still know what we've got.

MR. BARRETT: We have not reopened the question of vortexes here.

MR. MICHELSON: It may be a non-problem. I'm just saying if you're going to change the design from what you tested, you need to do something to confirm they're still okay.

MR. BARRETT: You're absolutely right about that.

MR. LINDBLAD: I also remember that the reg guide had a non-thermodynamic NPSH. The NPSH did not really consider vapor pressure.

MR. BARRETT: I don't know. I really don't know about that.

MR. LINDBLAD: I think it was conservative in that regard.

MR. BARRETT: I see. The reg guide only deals with NPSH loss. It doesn't actually -- you have to separately assess available NPSH.

The other characteristic we looked at was whether there were alternate water sources available for the situation in which the pool were to become unavailable for RHR or for containment sprays, and what we found is that essentially all -- with perhaps one or two exceptions, all of the plants in this country have the ability to inject with alternate water sources, such as the service water system or fire water system.

There are variations, however, with how available these systems are, how well they're piped, how much action is required to get them on-line, and whether or not procedures exist.

MR. MICHELSON: That depends upon how soon the clogging occurs, whether they're even effective or not.

MR. BARRETT: That's correct. We don't consider alternate water sources as a design-basis solution to this problem. We simply think of it as an interim accident-management type of strategy that might be available if a LOCA were to occur before we completely have resolved this question.

We have actually done some head loss calculations for these plants based on the data that we have. To actually do a head loss calculation, you would have to really have much more information about the geometry of the plant than we have.

For instance, we had to make very crude estimates of how much insulation might be knocked off in a LOCA, and we also had to make some rather simplifying assumptions, but if you use Reg Guide 1.82 Rev 1 assumptions and you take an amount of insulation that would be equivalent in volume to what was knocked off at the Barsebeck event, for instance, you can calculate head losses that are in excess of the available NPSH.

The thing you have to keep in mind, however, with that kind of calculation is that one of the conservative assumptions in Reg Guide 1.82 is that all of the insulation that is dislodged makes it directly to the strainer; there's no transport effects. So, you must keep that in mind.

But what I want to tell you, as a result of this survey, we were wondering if perhaps we could say that U.S. plants were not susceptible to this problem. That's not the case.

Based on what we see, this is a problem that we really have to pursue, and we have to continue working on this problem for U.S. BWRs.

The other issue we talked about in January was a concern that was raised by you, namely the inverse of this question for BWRs, and that is what about the material that's not captured on the strainers and can be ingested on components down the line in the system? Primarily, the concern was for pumps.

I have to say that, because of all the happenings at Perry and the followup on that, we haven't done as much work in this area as I would have liked, but there are -- but it doesn't appear that, for BWRs, this particular issue is nearly as significant as the inverse issue, which is the clogging of the strainers.

For BWRs, you would have a very, very large volume of water, and the amount of insulation that can cause a strainer head loss problem in a BWR is perhaps 100 pounds of insulation or less.

So, you've got 100 pounds of insulation and about 10 million pounds of water, and most of that insulation is either sedimented or is trapped on the strainers.

MR. MICHELSON: Again, when we discussed the regulatory guide and the issue a long time ago, I think I made some simple-minded calculations pointing out, of course, that each time you have a transfer through the seal of the pump, which is a very fine -- what is happening is the debris, whatever concentration you name, it's just a question of how many hours before that will totally clog the seal of the pump, because it's a perfect filter. So, the dirty water gets into the seal.

Now, the cyclone was supposed to clean up the dirty water, but this type of debris is not necessarily heavy enough for the cyclone to work. The fact is it's about the same density as water --

MR. BARRETT: It's far less dense than water.

MR. MICHELSON: -- and a result, it doesn't even work, the cyclone won't even separate it, and it ends up in the seal, and it clogs it up, and it only takes a little bit.

Just do your calculations, because it keeps passing the water continuously, about three or four gallons a minute, through the seal. The seal just filters it all, and eventually, the seal is clogged.

MR. DAVIS: It might even concentrate it.

MR. MICHELSON: Well, it does, yes, precisely what I was trying to say. It becomes the clog in the system. If you don't get the cyclone first with a larger piece of debris, you'd go through the seals and catch it there.

MR. DAVIS: You said it was less dense than the water?

MR. BARRETT: I'm sorry. That was a mistake. I'm glad you asked that question. The gross insulation, as it's put together, is less dense than water. The individual fibers, I believe, are -- I'd better ask if Roger knows. I think they're twice the density of water.

MR. DAVIS: Okay. I was going to say, if it floats on the pool, you're okay.

MR. BARRETT: It does not float on the pool.

MR. DAVIS: It does if it stays intact.

MR. BARRETT: Actually, it doesn't if it stays intact.

MR. DAVIS: It gets water-logged.

MR. CATTON: Slowly gets water-logged.

MR. DAVIS: That takes time.

MR. BARRETT: At the temperatures that this would experience, it turns out it doesn't -- it rapidly sinks or becomes neutrally buoyant.

MR. MICHELSON: The cyclone won't work, because it's passing water. It's trying to take sand -- cyclones are designed to take sand out of water. They aren't designed to take fiberglass out of water.

MR. BARRETT: What we expect is that, when we get around to looking at the PWRs, this will be a more serious problem, because for one thing, there's far less water in the sump than there is in the suppression pool. So, you're going to have higher densities of insulation.

The straining capacity or the sizes of the holes in the PWRs will pass more of this material. So, I think this is an issue that we want to focus on when we get to PWRs.

Now, we are really focusing on BWRs, and this seems to be a lower-priority issue than the strainer clogging issue.

MR. MICHELSON: On a PWR, Westinghouse got smart and didn't use a cyclone, didn't use the processed water to use the bearings. It was a separate water system.

However, B&W used the processed water to cool the bearings. So, on B&W plants, again, you've got the same problem but not on the Westinghouse.

The B&W -- their pumps, at least the ones I'm familiar with, use the cyclone separators, generated the same problem.

MR. CATTON: Mr. Linblad asked about clogging factor, and you said 52 percent or something. What is a clogging factor?

MR. BARRETT: Well, the original Reg Guide 1.82 simply said, equivalently, that you have to make the strainer twice as big as the pipe. That's basically it. It didn't really get into mechanistic questions of how could 50 percent of it get clogged or is 50 percent enough.

MR. CATTON: These strainers are submerged, aren't they?

MR. BARRETT: That's correct.

MR. CATTON: So, what's you're going to get is a fairly uniform distribution of whatever the stuff is over the whole screen.

MR. BARRETT: That's correct.

MR. MICHELSON: Most of the small stuff is going to go right through the strainer.

MR. CATTON: It will become uniformly distributed.

MR. MICHELSON: You're talking about two to three millimeter holes. This fine stuff goes right through. What happened in the case of Perry is that it fooled us a little bit, because the fine stuff kind of got stuck to the edges instead of going through the hole.

It was small enough to go through the hole, but it got stuck to the edges and built up that way, and that is a new mechanism that I don't think was considered.

MR. BARRETT: We're finding out that the simple model of the hole being larger than the fiber doesn't seem to work.

MR. CATTON: That's not enough.

MR. BARRETT: It tends to bridge the hole, and there is also a synergistic effect between the larger particles that come in and the smaller particles, which tend to get trapped in the larger particles. So, a lot of it gets trapped on the filter.

MR. CATTON: Next time you clean your swimming pool filter, just watch what happens.

MR. BARRETT: I'll take your word on that.

I'm afraid I don't have very much time left, and I do want to just roughly run through what we learned when we were in Sweden regarding some experimental tests that they've done which we think are indicative but not necessarily typical of what we're going to see in real accidents, and so, we're evaluating these tests.

With regard to Perry, I think we have already discussed the new phenomena -- or at least new to us -- that we found there, mainly the importance of sediment in the pool as a clogging mechanism and also the importance of this synergistic filtering phenomenon of fibers trapping -- either large fibers trapping smaller fibers or fibers trapping corrosion products and other sediment.

The Swedish authorities have sponsored a whole bunch of tests that look at essentially every aspect of this problem, and I'm going to put up a slide here that maybe would help me to walk through this very rapidly.

[Slide.]

MR. BARRETT: If you picture this as a very simple representation of a BWR over/under design, what you have here is a pipe in the drywell that's undergoing a LOCA and generating debris.

The important questions then become how much debris is generated, how well does that debris transport into the pool through this very violent blowdown phase, but also later, when the sprays are operating, how much of it gets washed into the pool?

Once it's in the pool, how much of it floats, how much of it sediments, how much of it deposits on this conical strainer here, and then, of course, for a given amount of deposition, what kind of head losses do you get?

All of these, with the exception of the transport mechanisms, are modeled in Reg Guide 1.82, and Swedish data bring into question some of the results in Reg Guide 1.82.

For instance, the Swedes believe that their experimental results indicate that there is greater debris generation than one would calculate using Reg Guide 1.82 assumptions.

Secondly, although Reg Guide 1.82 assumes that all the debris is deposited directly on the strainers, we have always taken a great deal of comfort in the belief that the transport mechanisms are very inefficient, that perhaps only 10 percent of the insulation is transported to the pool and that a fair bit of that ends up being sedimented.

The Swedish results and the results of the Barsebeck event, as a matter of fact, indicate that the transport to the pool is more efficient than we might have thought, at least for Swedish design plants.

Now, they may not be as efficient for U.S. design plants, but we have to make an assessment of that.

MR. MICHELSON: That's essentially a Mark II containment there.

MR. BARRETT: Yes.

MR. MICHELSON: And that one does have the drag force problem on the cone, very definitely, just like a Mark I does. A Mark III may not, but for Ivan's benefit, that configuration is pretty tough on drag forces, too.

MR. BARRETT: I hope you're not taking this too literally. This is a drawing I made this morning.

MR. MICHELSON: I think you would be interested in finding out where the closest downcomers are to the cones.

MR. BARRETT: Yes, but there is nothing about this drawing that's typical of a real reactor in terms of its geometry. This is purely schematic.

MR. CATTON: Aren't there some rules, though, on the location of things like that?

MR. MICHELSON: No. The rule was keep it as far away as you can, which was about six feet in the case of the Mark I.

MR. CATTON: I thought it said things like five diameters and stuff like that.

MR. MICHELSON: No. That was on the SRB. This is the downcomer.

MR. BARRETT: Let me say this, Ivan. My belief is that, in the United States and in Sweden, the strainers are specifically designed with all of the applicable loads in mind. I don't believe there is a specific separation criterion.

In fact, at Barsebeck, if I remember my mental image of that picture, the downcomer was quite close to the strainer.

MR. MICHELSON: It almost has to be.

MR. BARRETT: It turns out that the insulation does not tend to float at all, whereas earlier we thought it did float.

Sedimentation mechanisms don't appear to be as efficient as we earlier thought, partly because there's a lot of churning here, partly because the Swedes believe that the particle sizes are much, much smaller than earlier thought, and their data tend to indicate that, for a given amount of insulation deposited, the head losses can be significantly higher -- in fact, in some of their experiments, an order of magnitude higher -- than were observed in the experiments that were used as the basis for Reg Guide 1.82.

I don't want to just give these results as gospel. We feel that we have to evaluate how applicable these data are to a real accident in a U.S. reactor, and so, as a result of that, we have reoriented our program to do basically two things, and I'll try to wrap up here quickly.

We have initiated a cooperative project with our own Office of Research and with the Olin Labs, primarily, as the contractor, to look at -- first of all, to take a real U.S. reactor and, using the actual as-built configuration, calculate the amount of material, the insulation debris, for a large number of break locations and sizes, so we can get a spectrum of breaks and see what kinds of insulation is generated.

Those of you who are familiar with the resolution of A43, this is essentially the same study that was done for Salem. If you recall, A43 tended to look more at the PWRs than the BWRs.

The other part of this study and, I think, maybe the more important part of the study is that we want to take the experimental data that we have from Reg Guide 1.82 Rev 1, the new experimental data that came out from the Swedes, some experiments that have been done by the Swiss that we've recently found out about, and some experimental work that's actually being sponsored and has been sponsored in the United States by the vendors of insulation, and based on all of that, we wanted to come up with a model that we feel comfortable with as a regulatory model for the debris generation, the transport to the pool, sedimentation, deposition, and the head loss characteristics, and this is a study that we feel will take about six months to do, and at the end of that study, we feel we'll be technically ready to make a decision as to whether or not back-fits are in order for U.S. BWRs.

MR. MICHELSON: Let me ask -- I've been trying to find it and I didn't. I looked at Bulletin 93-02. Bulletin 93-02 asked the licensees only to identify fibrous air filters or other temporary sources of fibrous material.

Did you put out something else that says tell me about your insulation? So, you -- all your statements about insulation are without foundation in terms of what the licensee, at least, reported from the bulletin, unless he just, by happenstance --

MR. GRIMES: I think we got some gratuitous information, but the idea of the bulletin was to get us back to where we thought we were before the Perry event.

MR. MICHELSON: If you re-solicited with a bulletin that says tell me about your fibrous insulation, you might get some more information.

MR. GRIMES: That may be one of the steps that has to be done as we go through.

MR. MICHELSON: Clearly, if they had a bad case, they probably didn't tell you, because it wasn't required.

MR. BARRETT: That's correct. It was not the intent of that bulletin to look at --

MR. MICHELSON: You only asked have you left something in there temporarily or have you used any air filters.

MR. BARRETT: That's correct.

MR. MICHELSON: That's a small part of the problem.

MR. BARRETT: That's exactly right.

Basically, we discussed what would be the scope of this bulletin, and one of the considerations is what aspect of this problem was urgent enough to put out an emergency bulletin which bypasses most of the process that we go through, including informing the public, including review by the ACRS, and on the other hand, what aspects of these problems do we want to go through a full systematic review, and the only part that really passed that test was to get the filters and the other temporary fibrous materials out of the containment.

MR. LINDBLAD: When you asked for the temporary fibrous, did most licensees recognize that, during outages and maintenance, that workers bring in extraneous materials, from handkerchiefs to film?

MR. BARRETT: My presumption is that that's the case. We described -- you know, we put out Information Notice 93-34, which described the problems at Perry and the type of materials that can be dropped in there, but we did not explicitly call out that information.

MR. KRESS: Does your new program call for any experimental work, or is that all analytical?

MR. BARRETT: It's all analytical.

MR. WILKINS: Jay, are we about finished with this portion of the presentation?

MR. CARROLL: Are there anymore questions?

MR. MICHELSON: I guess we're going to hear a lot more later, after the staff decides what's next.

MR. BARRETT: We intend to keep you fully informed.

MR. CARROLL: Good job.

MR. WILKINS: All right.

MR. CARROLL: This next presentation is the Sequoyah event which involved wall thinning.

MR. DENNING: That's correct. This is Bob Denning again.

Just to introduce things, we're going to talk about extraction steam head rupture at Sequoyah Unit 2 some months ago, and in this presentation, we have a number of speakers, and we're appreciative of the support from Region II, and we have as our first speaker the Team Leader of the AIT inspection associated with this event, and we have Dave LaBarge, the Senior Project Manager, will talk about licensee actions, and then that will be followed by Tom Koshy from Events Assessments Branch talking about NRR actions.

MR. CARROLL: My presumption of the committee's interest is more on the effects of this steam release, as opposed to the erosion/corrosion aspects of it.

MR. MICHELSON: Potentially safety-related effects.

MR. CARROLL: Safety-related effects, yes.

MR. GRIMES: Let me also note that we have Jim Wiggins with us, who is the Acting Director of the Division of Engineering now that Jim Richardson has taken another assignment. So, he will be providing us whatever he needs to in terms of the review.

MR. CARROLL: And where is Jim Richardson temporarily assigned?

MR. GRIMES: Jim Richardson has taken an assignment in Vienna.

MR. WILKINS: Tough duty.

MR. BLAKE: I'm Jerome Blake. I was the Team Leader for the AIT. Team members included Billy Crowley, who is a member of my staff, who is a materials specialist; Dave LaBarge, the Senior Project Manager for NRR, who did the interviews with the operators and looked at the operations side of it; Peter Kang from Electrical Engineering, NRR, who looked at the electrical problems associated with this event; and Chris Parczewski from the

Materials and Chemical Engineering Branch, who is the erosion/corrosion specialist.

The event involved the rupture of -- it was a four-inch-by-six-inch rupture in a piece of pipe. I've got a photograph made with a digital camera that I'll pass around that you can look at.

Because of the location of the piping in the turbine building, the steam involved the voltage regulation system of the turbine generator, which had approximately a 19-percent increase in voltage at the safeguards bus.

Depending on where you were in the electrical system, the voltages were higher by anywhere from 10 to 20 percent. We'll get into that later.

MR. DAVIS: Excuse me. I may have missed it, but what was the condition of the steam at the time of the rupture, the pressure and temperature?

MR. BLAKE: Pressure and temperature -- I'll have to dig that out. It's the extraction steam line --

MR. DAVIS: I understand.

MR. BLAKE: -- off the -- hang on. I've got it somewhere in the reference material here.

MR. DAVIS: I can wait if you want to go on.

MR. BLAKE: Okay. Let me see if I can find that, and I'll get back to you on that one.

The safety significance was the fact that we did have potential degradation of electrical equipment or safety-related equipment because of the over-voltage, and of course, we always have the personnel hazard with steam.

MR. MICHELSON: Now, that was an over-voltage on all safety-related equipment that was operating off the emergency boards, I assume.

MR. BLAKE: The over-voltage was upon everything that was being -- that was coming off the generator output, the main generator output.

MR. MICHELSON: All the emergency boards come off that transformer for normal supply.

MR. BLAKE: Right.

MR. MICHELSON: There's no alternate transformer for an alternate line from outside, is there?

MR. BLAKE: No. They're all supplied by that.

I'm kind of walking you through this event with this overview. As you can see, there's a lot of activity involved affecting the operators of the plant.

During a surveillance, they had a failure of a containment valve, failed the surveillance. They sent an operator to the area off the control room to pull the fuse to electrically isolate the containment valve that had failed the surveillance.

The fuses at this particular plant are in a long strip, went from floor to ceiling. The fuse in question was at about knee-high. The man reached down at an angle, put the fuse holder on the fuse, moved the fuse to make sure he was on the right fuse, and then he bent down and realized he was on the wrong fuse, he was on an adjacent fuse.

So, he took the fuse holder off, put it on the right fuse, pulled the fuse, walked back in the control room, and the operators were in the middle of trying to control a feedwater steam flow mismatch, because his latching onto a fuse and moving it had been enough to cause a trip signal to the flow control valve feeding the number three steam generator.

MR. LINDBLAD: I have trouble understanding that number three steam generator level control valve going closed.

MR. BLAKE: That's a flow control valve on the main feedwater.

MR. LINDBLAD: It's just the main feedwater?

MR. BLAKE: Main feedwater control valve.

MR. LINDBLAD: Okay.

MR. LEWIS: Forgive me. I came in a bit late, so you may have said this. The steam rupture isn't what caused the over-voltage. It's the sequence of events that caused the steam rupture?

MR. BLAKE: No. The steam itself -- the point of the rupture was in the turbine building, one floor below where there is a cabinet that is the turbine generator voltage control cabinet.

MR. LEWIS: Okay. Fine. So, the operator who put the pulling tool on the wrong fuse is an irrelevancy.

MR. BLAKE: It's the trigger on the event that happened.

MR. LEWIS: I'm trying to understand.

MR. BLAKE: Okay. Let me walk you through it, and we'll get there.

MR. LEWIS: It was the moisture from the rupture on a cabinet that contained a voltage controller of some kind that caused the over-voltage --

MR. BLAKE: Right. That's correct.

MR. LEWIS: -- because the voltage controller was not -- was environmentally sensitive to the steam.

MR. BLAKE: That's correct. Right.

MR. LEWIS: Okay. Then all I have to do is understand why the operator putting the pulling tool on the wrong fuse is --

MR. BLAKE: Okay. What happened was he moved a fuse that sent a trip signal to the solenoid. The trip solenoid on the flow control valve caused the valve to go closed.

The operators attempted to manually correct the steam flow/feed flow mismatch. While they were doing that, they started getting alarms associated with the main generator.

They got a power loss, they got a insulation resistance low -- these are all alarms coming into control -- generator volts per cycle high, generator voltage regulator tripped to manual, and they were starting to get an over-voltage on the 6.9-KV board.

MR. LEWIS: I guess the best way -- I mean I'm probably the slowest person in the room, but the best way for me to understand is will I, in the end, understand what would have happened if the operator had not put the fuse puller on the wrong fuse but everything else had happened as it did?

MR. LINDBLAD: Yes, sooner or later. It will happen some other day. It will happen some day or other.

MR. BLAKE: The reason that that caused the event on that particular day is because of the closing of the feedwater reg valve, and in the manual reopening of it, they ended up with a water hammer in that system.

That water hammer sent a pressure spike back through the feedwater system, which increased the pressure on the extraction steam line enough to blow the hole in it.

The hole was a spontaneous event because of a water hammer caused by the man putting his fuse puller on the wrong fuse.

MR. LEWIS: Okay. Fine.

MR. BLAKE: It could have happened on another day. They could have had a demand for a change in power level, which would have changed the pressure enough on the extraction steam on another day.

MR. LEWIS: I understand now.

MR. WILKINS: Okay.

MR. GRIMES: I think what we're going through here is what the operators saw and did until they finally recognized that they had a steam rupture, but the steam rupture, indeed, is what caused the over-voltage, but they got signals for the over-voltage before they realized they had the steam rupture, and that's what this sequence describes.

MR. DAVIS: What we need is an event tree. That will explain it perfectly.

MR. LEWIS: I'm sorry?

MR. DAVIS: An event tree is what we need.

MR. LEWIS: An event tree is certainly what we need, but if we don't have an event tree, I have to ask it in different ways.

MR. CARROLL: He could have approached another way, Hal, but what he's trying to do is tell you what the operators saw.

MR. LEWIS: I understand that, but I'm interested in the root cause.

MR. CARROLL: The operators will finally figure out what it is at the bottom of the next page.

MR. MICHELSON: We don't draw event trees that follow steam through to what effect it has on non-safety equipment reflecting back to safety equipment. That's not in our event trees. That's the unwanted action syndrome.

MR. CARROLL: Okay. Moving on.

MR. LEWIS: We're getting too complicated. There are two initiating events here. One was the steam and the other was the fuse puller. Which is the initiating event?

MR. GRIMES: The fuse puller was the proximate cause of a lot of the things which ended up with a water hammer, which ended up with a steam rupture, and the steam rupture caused the over-voltage.

MR. LEWIS: Let me try to paraphrase what I think you've just said.

So, the fuse puller, which caused the water hammer, which in the end caused the steam rupture, was the initiating event, but it need not have been the fuse puller. It could have been some other --

MR. GRIMES: Right.

MR. LEWIS: -- that caused the water hammer.

MR. GRIMES: It was going to happen someday soon.

MR. LEWIS: It's just that I'm trying to separate the could have from the what did. Okay. So, the fuse puller was, in this case, the initiating event.

MR. BLAKE: I could have sworn that's what I thought I said.

MR. WILKINS: Let's continue.

MR. BLAKE: Keeping in mind, we've got operators in the control room trying to control a steam flow/feed flow mismatch, and suddenly, they've got a main generator voltage control that goes to manual, because it's going hot, and now they have to try to control turbine generator voltage at the same time they're doing that.

They find that they cannot manually reduce voltage, and just about the time they get informed verbally from the turbine building that they have a steam line break in the turbine building, they decide we can't do anything about it, and they trip the plant and brought the units down.

MR. MICHELSON: How high could the voltage have gone, or was it full up?

MR. BLAKE: As close as we can tell by looking at the saturation curves for the generator, it had just about reached saturation. Peter Kang has got saturation curves.

MR. MICHELSON: I don't need to see the curves. I just wanted to get an approximate idea.

MR. BLAKE: It was 27 KV. We're about 20 percent above normal output.

The event lasted -- based on instrumentation, the event lasted for -- I kept referring to three to three-and-a-half minutes, and Peter, who did the electrical review, kept insisting it was 3 minutes and 38 seconds, based on the best instrumentation they had to review.

So, that's the length of time that the generator was -- and the output to the generator was going about 20 percent above. The saturation characteristics limited it.

One of the things that was a saving thing with this particular plant is TVA has had electrical equipment specifications that required 25 percent over-voltage.

MR. MICHELSON: Did you actually look at the specs yourself to see what was required of the manufacturer.

MR. KANG: During inspections, we did look at all the equipment, components and buses, and what was their limiting over-voltage conditions.

MR. MICHELSON: How about the loads on the buses? Did you look at the limitations on the equipment that were being powered at the time?

MR. KANG: Yes.

MR. MICHELSON: I'm surprised at the 25 percent, but if TVA assures you everything in that train, all the way down to the motor-operated valves, is 25 percent --

MR. KANG: Well, some of the equipment was relays, and solid-state equipment was rated -- some of them rated 33 percent, some of them is at 25 percent.

MR. MICHELSON: I was interested in the load, the attached loads that could have been damaged, for instance.

MR. KANG: Yes.

MR. MICHELSON: Motor-operated valves.

MR. KANG: Yes, MOVs, yes.

MR. MICHELSON: Are they rated for 25 percent over-voltage?

MR. KANG: Well, yes, some of them did. Most of them did.

MR. MICHELSON: All of them are attached.

MR. KANG: Right. That's right, and there was pumps, and we did review --

MR. MICHELSON: They go out to 25-percent over-voltage.

MR. KANG: Right.

MR. WYLIE: How did you determine that that was the case?

MR. KANG: We reviewed each equipment, its ratings.

MR. WYLIE: You mean the specs?

MR. KANG: Yes.

MR. WYLIE: You looked at the specs.

MR. KANG: COT sheets.

MR. WYLIE: Beg pardon?

MR. KANG: COT sheets, yes. We call it the COT sheets, which is specification sheets.

MR. BLAKE: The individual data sheets for each piece of equipment that was attached. We primarily looked at -- Peter looked at the pieces of equipment that were operating or that would have been called upon to operate.

MR. WYLIE: Was that an original design document you looked at?

MR. BLAKE: Procurement documents for the pieces of equipment.

MR. KANG: Yes. All of them -- original summary of characteristic sheets, yes.

MR. MICHELSON: Whose summary? TVA's?

MR. KANG: TVA's, yes.

MR. MICHELSON: You did not spot check any of these numbers to verify that, indeed, it was 25 percent.

MR. KANG: Call each manufacturer? No.

MR. MICHELSON: No, just two or three of them, just to see if that's what the spec really called for.

MR. KANG: Well, we just looked at the specification sheets that were provided by the licensee.

MR. MICHELSON: You looked at TVA's summary of the specification.

MR. KANG: Not summary, individual, all the components involved that we thought was running and that we thought maybe was operating at the time.

MR. MICHELSON: The procurement spec on that item to see what the voltage rating was that the manufacturer was told to design to.

MR. KANG: Right.

MR. MICHELSON: Okay.

MR. BLAKE: Okay. From the op yard, this unit power goes to a 161-KV switchyard, and the load dispatcher off-site noted that the voltage on that line went up to 181 KV. It had been at 166 KV.

MR. MICHELSON: The grid was apparently still stable, even though Sequoyah was trying to carry a lion's share of the load.

MR. BLAKE: Right.

MR. MICHELSON: You could bring the voltage on down, and it could still handle it.

MR. BLAKE: They didn't get anything other than a comment from the load dispatcher.

During the event, people noted that the diesel generator panels registered 8.1, between 8.1 and 8.2 KV, which is on a 6.9-KV board.

They had a digital meter, but it went to default value, because it would only go up to about 7.8, I believe, and after that, it just went to default value. So, we know it went above that.

MR. CARROLL: Is that a good design?

MR. BLAKE: Pardon me?

MR. CARROLL: Is that a good design? How would the operator know, if he was relying on that meter, that he had a high-voltage condition?

MR. BLAKE: That was one of the many lessons learned in this. The digital meter --

MR. LINDBLAD: That was one piece of electrical equipment that was not designed for plus 25 percent.

MR. BLAKE: That's right.

MR. MICHELSON: All the meters apparently went to default, because there's one on each board.

MR. BLAKE: They had a digital one that went to default.

MR. MICHELSON: On each board, they had a digital one.

MR. BLAKE: Correct.

MR. MICHELSON: Okay. And they've got a number of boards, more than one.

MR. LINDBLAD: Did its equipment specification sheet indicate it was designed for 25 percent?

MR. BLAKE: When we were looking at what Peter was talking about, we were looking at major equipment, the motors, relays, and things like that.

We didn't look at meters, and as far as we recognized, that particular meter didn't make it, but we did have meters on the boards that did show where the voltage went to.

During all the testing that they did after the fact, they didn't find any examples where there had been any problems in any safety-related electrical equipment.

MR. MICHELSON: What kind of testing did they do to verify that?

MR. BLAKE: The testing that's specified was -- hang on -- part of the report.

They did calibration checks on all the relays, the tech spec relays that they had regular surveillance data for, checked for change in calibration, did an inspection of all the battery chargers and inverters to ensure that there were no problems on it.

MR. MICHELSON: By "inspection," did they do such things as insulation checks?

MR. BLAKE: They did Megger checks on motors that had been running during the event, and they were going back and doing signature checks with MOVATs units on everything that they had MOVATs data on to make sure that there were no changes in the signature.

MR. LINDBLAD: Was the Megger test a power factor absorption test?

MR. KANG: Just a Megger test to see whether there was any insulation damages.

MR. LINDBLAD: So, you just measured resistance or did you --

MR. KANG: Yes.

MR. LINDBLAD: -- do the absorption power factor?

MR. KANG: Yes.

MR. CARROLL: Back to my digital meter, is it designed so that the operator knows that it's gone to its default position? Does a light come on or something?

MR. BLAKE: No. It's flashing with 8-8-8-8 showing on the dial, so that -- it doesn't go to zero. It just goes to four 8's and flashes, and all that says is that it exceeded 7,400 volts.

MR. CARROLL: When you said "default" earlier, I thought it went to 5 volts.

MR. BLAKE: No, no, no. It went to a signal that said we went over voltage.

One of the major problems we found as a result of this inspection was that the erosion/corrosion program was very fragmented, had not gotten very much management attention, very low resources, and a lot of people doing different parts of it.

Key problems on this particular line was that the people that did the modeling for the EPRI Checkmate program ignored six lines that were called operating vents that tied in upstream of where the erosion took place.

MR. MICHELSON: Was that modeling done under a QA program?

MR. BLAKE: No, it was not. It was done by the corporate materials engineering staff, independent of anybody doing any QA check.

MR. MICHELSON: Clearly, it should have been under a QA program.

MR. BLAKE: That was out in the balance of plant.

There are some concerns about whether it should have been a QA program or not, but our big concern was that it should have been done in conjunction with the operation staff and the chemistry staff on the site who knew what was happening in the lines.

If you look at an FSAR drawing of the particular line, if you look at the steam numbers and the water numbers going through that line, you would say that it was about 94 to 96 percent steam, but that ignores the six vents.

When you put the water input from these operating vents in, it drops the steam quality to the neighborhood of 72 to 74 percent steam. Excess moisture with that large a flow changes the wear rate on the pipe significantly.

They also had even ignored the computer programs that are available today for doing that kind of modeling.

In 1985, they did a replacement, because everybody was replacing feedwater heaters that have copper tubes to get away from copper in the feedwater.

During the replacement of feedwater heaters, they noted that the elbows immediately entering the feedwater heater were severely eroded. So, they changed those, replaced them with stainless steel.

If you saw that picture I passed around, where that smaller pipe joins the larger pipe, there is a metal collar. The way that it is fabricated, there is a weep-hole on the metal collar. They got steam coming out of some of those, and so, in 1991, they put Fermanite in there.

Then, in '92, they opened up the end-cap of a 20-inch line and put a welder inside, and he weld-repaired those connections from the inside.

There was an inspection point on the repair order that told them to do a visual inspection, and they skipped that step for some reason.

They did some ultrasonic inspections on one of the 10-inch lines at about the same place where it was extremely thin, and the numbers got taken to somebody, an engineering person, who looked at it and said that exceeded the minimum wall, it's okay, we don't have to replace it.

There were some long-term plans to replace some of these lines with stainless. They just hadn't gotten around to it yet.

The other thing that we had -- just a month earlier than the event that -- the major line that failed, the resident got concerned because there were a lot of little lines that failed.

One of them was a three-inch diameter target-T, and so, I sent an inspector up there, and he reviewed it, and when he tried to track down how many problems like this they had had in the past, nobody seemed to know, until he got the maintenance foreman and the Fermanite people, and they got down some drawings, and they went back through all the back-orders and started marking up some drawings and realized that they had some significant areas of degradation, and not only that, but you could almost predict, based on what was happening in one unit, when the next failure was going to be in the other unit, and that was when we really got an indication that they weren't putting a lot of attention on these, and management was -- you kn , there wasn't anybody taking an overview of the whole steam plant system and trying to get a handle on how badly it was coming apart.

MR. CARROLL: If I recall, either Taylor or Selin wrote a very strongly-worded letter to NUMARC on this subject. That was the last I heard. Has NUMARC responded?

MR. LaBARGE: That response is part of the restart plan for Sequoyah, and NUMARC has responded and informed the industry of the problem, and other than that, they are still evaluating what they're going to do with it, but they are aware of it, and they have responded to that letter.

MR. CARROLL: In the sense that they have informed the industry that this happened?

MR. LaBARGE: Yes, sir.

MR. CARROLL: And that's it.

MR. LaBARGE: Well, they may do more, but they have not specified what that will be yet.

MR. CARROLL: Okay.

MR. CATTON: Is this coupled with Checkmate, its application?

MR. BLAKE: The problem was with the application.

MR. CATTON: Checkmate, if applied appropriately, this would not have happened.

MR. BLAKE: That's correct. Part of the corrective action was they brought in -- TVA brought in an independent contractor and the EPRI people to look at it.

They sat down and remodeled the plan based on Sequoyah's operating data and the actual piping configurations, and once they ran the model with all the information that should be in the model, the model predicted that where this pipe failed was the number one area that they should be inspecting.

MR. CATTON: Is it difficult to develop a Checkmate model for a plant?

MR. BLAKE: It's very difficult.

MR. CATTON: Conceptually, there's no problem.

MR. BLAKE: Conceptually, there's no problem, but there is an awful lot of data that needs to go into it.

MR. CATTON: I understand that.

MR. BLAKE: The fatal flaw here was the fact that there were not -- TVA did field run on piping four inches and below. So, somebody at the corporate level made the decision that they would not model anything four inches and below.

So, the engineer who was doing the modeling for Sequoyah got to the point where these three-inch lines were coming into it and said I don't have to model those, failing to recognize the fact that the input from those lines to the big lines needed to be included in the big lines.

MR. SEALE: You said that this particular break was the number one -- let's say the first -- the lead culprit or the lead failure in the proper Checkmate analysis.

MR. BLAKE: That's correct.

MR. SEALE: Were these other failures, these other cases that you have listed here, on the previous slide and this slide, that they have experienced in the past also identified in that Checkmate analysis?

MR. BLAKE: Yes. One of the other lines that we talked about was just downstream.

MR. SEALE: Yes.

MR. BLAKE: Where this break is, if you go downstream, there is a valve and then there is an elbow that goes into the feedwater heater. That elbow into the feedwater heater and this T off the 20-inch header get about the same rating on the EPRI Checkmate.

MR. SEALE: Okay.

MR. BLAKE: So, they would have been looking at both those areas.

The other areas -- these target T's in a lot of the smaller pipes that we found earlier -- would not have been modeled, because they were too small, but there were a lot of things --

MR. SEALE: They were less than the two-inch.

MR. BLAKE: They were less than two-inch, yes. We said there was a three-inch-diameter pipe break earlier, but that's a target T, which is an expansion area -- it's a three-inch-diameter expander at the end of a three-quarter-inch or one-inch line.

So, it's a short segment of three-inch pipe. It probably wouldn't have been modeled anyway.

MR. CARROLL: Gentlemen, we are running out of time. Carl is the one who asked for this presentation. So, I'd like to let him get on to the electrical aspects of it.

Do you have some questions you haven't asked?

MR. MICHELSON: I don't think mine will take 15 minutes, anyway.

MR. BLAKE: The causes -- the pressure perturbation on extraction steam caused by the valve closure. The over-voltage was caused by the electrical cabinet with the turbine voltage control one floor above where the pipe happened, which is an open-grate floor.

It was within 30 feet of where the steam rupture was, and like any other electrical cabinet in a fairly warm area, it's got a circulating fan that pulls air in and blows it across the equipment to try to maintain some kind of low temperature level, and suddenly, it was pulling steam through the cabinet, and they got all kinds of indications that the insulati. was going bad, and it just tripped to manual.

MR. MICHELSON: Now, by "all kinds of indications," what exactly do you mean?

MR. BLAKE: Well, back on the list of indications that the people were getting in the control room, back on the earlier slide --

MR. MICHELSON: Yes. Those are not indications that insulation was going bad.

MR. BLAKE: Those indications were coming from that same cabinet.

MR. MICHELSON: They were coming from that cabinet.

MR. BLAKE: That's a voltage control cabinet.

MR. MICHELSON: Yes.

MR. BLAKE: That's where all the instrumentation -- that controls the turbine and also sends the signals to the control room, all coming from that one cabinet.

This is what the regulator thought it saw, and the regulator started seeing all these things, and it was also reading that the field was dropping, so it started calling for more voltage, because the instrumentation was telling it that the voltage was dropping.

MR. MICHELSON: Now, when this was all over with and the event was finished, I guess they tried to recover the cabinet for further use. What did they find the shape of the cabinet to be itself? What really happened to the cabinet that caused this to occur?

MR. KANG: Basically, they find that water was -- steam was just circulating around and that -- they seemed to think that there was -- some sneak circuit was established which demanded the higher voltages.

MR. MICHELSON: What I'm really asking is, after you got it all -- after the event was all over but before people cleaned it up --

MR. KANG: Yes.

MR. MICHELSON: -- did they go in and do some testing to see what the condition of the circuitry might have been then?

MR. KANG: Okay. When the water was all dried up --

MR. MICHELSON: Before the water dried. When the event was over -- an hour later, let's say, or whenever they got ready to do testing -- did they do any testing to see what the condition of the cabinet might have been?

MR. KANG: No. Once the unit was off and the power was transferred to the off-site line, I don't believe they ever tested it.

MR. MICHELSON: They must have eventually cleaned up the equipment --

MR. KANG: Yes, they did.

MR. MICHELSON: -- dried it out and everything. When it was all dried up, did they have to do any maintenance on it, any replacement?

MR. KANG: Well, as far as the functionality of the voltage regulator, they didn't find anything wrong with it.

MR. MICHELSON: So, what the voltage regulator was doing was temporarily reacting to the environmental condition that it was exposed to, but it wasn't necessarily at damaging conditions.

MR. KANG: Yes. That was the Westinghouse conclusion.

MR. MICHELSON: So, they were getting unwanted actions from this equipment during the event, but the equipment itself was not necessarily even being damaged.

MR. KANG: Right.

MR. MICHELSON: I think that's understandable.

MR. LEWIS: The regulator itself, presumably, wasn't in a sealed case.

MR. KANG: It's wide open in a cabinet.

MR. LEWIS: It's wide open.

MR. KANG: Yes. And it is all solid-state.

MR. LEWIS: It's a solid-state regulator.

MR. KANG: Yes.

MR. LEWIS: But that still doesn't tell me how it functions. I'm surprised that it's that sensitive to the humidity or to the steam.

MR BLAKE: It's the control circuitry.

MR. MICHELSON: Can you tell us in 30 seconds what the regulator consisted of? Maybe that would help.

MR. KANG: First of all, it was in a cabinet which has a fan in the bottom, and the top has two air holes to be able to circulate the air, and inside of it, it has a stack of cards, solid-state cards, and that's just about it.

MR. LEWIS: Components on cards are usually hermetically sealed.

MR. KANG: The individual card was sealed, each of them, but they were stacked in the cabinet fashion. So, once steam gets in the bottom side, it was susceptible to steam and could establish some kind of sneak circuits.

MR. LEWIS: We're talking in a different dimension. I'm trying to understand how the steam got into the circuit, into the electrical circuit. Bathing a card in steam doesn't necessarily disable it.

MR. KANG: Probably condensation could establish circuits in between these.

MR. LEWIS: It depends on how the wiring is laid and whether it's been painted over. Usually they're painted over, one way or another.

MR. KANG: Some section was and some section was not.

MR. MICHELSON: Let's stop just a moment. What kind of plug-in cards do they have?

MR. KANG: It was just a --

MR. MICHELSON: Just a mechanical plug-in.

MR. KANG: Right.

MR. MICHELSON: And those are not bathed in anything, nor are they coated. They are just plugged in.

MR. KANG: Right.

MR. MICHELSON: You can do such things as to coat them and everything. I don't think they do, but --

MR. LEWIS: Usually, they shouldn't react to steam condensation, because that's pretty good water, usually.

Can I ask a slightly different question? The pipe that popped under the water hammer was corroded, apparently. If that particular section of pipe had not been corroded, if for some magic reason it had just been replaced, where else would the rupture have occurred?

I'm trying to find out how big the water hammer over-pressure was and whether it would inevitably have popped a pipe or whether the corrosion of that particular pipe was --

MR. BLAKE: It probably would not have popped anything that was anywhere design wall thickness.

MR. LEWIS: Okay.

MR. BLAKE: It was very, very minor pressure perturbation, but it was enough of a pressure perturbation that it went through an area -- was able to burst an area that was essentially ready to go.

MR. LEWIS: So, your judgement is that the over-pressure was not sufficient to pop a healthy pipe.

MR. BLAKE: That's correct.

MR. LEWIS: Thank you.

MR. MICHELSON: I thought I heard that these were hermetically-sealed cards. Is that a fact?

MR. KANG: Some of them was, and some of them was not.

MR. MICHELSON: By hermetically sealed, do you mean they were coated cards, having an epoxy or --

MR. KANG: Yes, some of them was, but some of them not. Apparently --

MR. MICHELSON: In that application, it's kind of unusual to buy those real expensive coated systems. Often times, they are un-coated cards, no coatings.

MR. KANG: Usually, at the placing of the voltage regulator, they were not expecting any steam.

MR. MICHELSON: It's a non-safety piece of equipment.

MR. KANG: That's right.

MR. MICHELSON: Commercial-grade.

MR. KANG: Right.

MR. BLAKE: That's correct.

MR. MICHELSON: But you can buy coatings, but hermetically sealing those cards, which means further encompassing them inside of a can and protecting the junctions --

MR. BLAKE: Westinghouse did replace a number of cards and pieces in the voltage regulators, but the damage that was -- that they were replacing them for was normal aging.

These cards were -- based on construction time -- close to 20 years old, and so, they replaced them; they were in the cabinet, we might as well refurbish them anyway.

MR. MICHELSON: Do you think those were the original cards?

MR. BLAKE: Westinghouse's report on this concluded that it was no more than a routine maintenance that they do on a lot of these regulators.

Because of the nature of the event, we did have an AIT. We issued a confirmation of action letter, which has the requirement that we have to give them an approval before they can start up again, from the original office, and we have established a restart panel.

I think Dave LaBarge is going to talk to you a little bit about licensee's actions.

MR. MICHELSON: Before he does that, could you tell me what tests were done on the transformers?

MR. BLAKE: The main transformer?

MR. MICHELSON: The transformers on the boards, feeding the boards. Those were experiencing the over-voltage as well.

MR. BLAKE: The only tests that they were doing on transformers that I was aware of -- they were going to give them time for any gases that you can build up by excess heat, and then they were taking oil samples and having them run for gas content.

MR. MICHELSON: On the boards, they've got a bunch of 460-volt transformers coming off the 6,900-volt boards.

MR. KANG: Yes, you're correct. This is the first transformer I've seen. This was not the dry type of transformers.

MR. MICHELSON: These were liquid transformers.

MR. KANG: It was liquid transformers, and what they said was the over-voltage wouldn't have too much problem with it. So, they didn't do anything on that, the transformer side.

MR. MICHELSON: Didn't do any testing.

MR. KANG: No.

MR. LINDBLAD: There is a limit for transformers on volts per cycle, as I recall, Charlie. That's mainly on large transformers, rather than smaller.

MR. MICHELSON: These are large transformers.

MR. BLAKE: The justification was that the damage to the transformer would be by heat, and based on the extent of the over-voltage for 3 minutes 38 seconds, there was just no reason to believe that there had been any heat damage, and testing of all the circuitry and everything held that up.

MR. WILKINS: If we're going to have another presentation, we'd better get it started.

MR. LaBARGE: This is Dave LaBarge. What I was going to discuss a little bit was the installed shutdown board voltage recorders that they have installed. They had some recorders before, but they had them disabled. So, they upgraded the system.

They upgraded and modified their -- upgraded their trip system. It was not very effective on Unit 2.

Then we talked about the electrical equipment checkouts that they did, and like we've been talking, they took a real close look at their erosion/corrosion program, and prior to the event, the new site vice president had determined that there were some areas in this erosion/corrosion program that were not being addressed very well from a management standpoint.

He was in the process of upgrading that program to be better managed. Before he had a chance to become effective in that area, this steam leak developed.

He has carried on with that program, and there have been no program assignments, responsibilities initiated, and EPRI has been used to upgrade the erosion/corrosion software and the program procedures, and they have replaced approximately 3,000 feet of small-bore and 300 feet of large-bore piping or are in the process of replacing that much piping for each one of the units.

MR. MICHELSON: Could we go back to the second bullet for a moment, and can you tell me what voltage they're monitoring in determining their trip?

MR. LaBARGE: The set-point?

MR. MICHELSON: Not the set-point so much as what are they monitoring when they decide they've got too high volts per hertz.

MR. KANG: Most of the plants, they have -- volts per hertz relays were installed to provide alarms for the over-voltage conditions.

MR. MICHELSON: Yes.

MR. KANG: This Unit 2 had only one set of volts-per hertz relay they just used for monitoring over-voltages. It sends alarms for anything above 7 percent of over-voltage.

MR. MICHELSON: But that doesn't tell me anything.

MR. KANG: Okay. So, what it does it just send an alarm, but by having a second volts per hertz relay installed, this will have a capability to automatically trip the unit.

MR. MICHELSON: They're going to put a high-voltage trip on it.

MR. KANG: Yes, sir, set at 15 percent. So, if they had this one installed, they wouldn't have this problem, over-voltage conditions.

Strangely enough, Unit 1, Sequoyah Unit 1 had installed this second volts per hertz relay, but what they told us was priorities in the plant -- Unit 1 and Unit 2 have different priorities. So, they just didn't install this one.

MR. MICHELSON: Did you inquire as to why they had put it on Unit 1?

MR. KANG: That's all they told me, because of priorities.

MR. MICHELSON: It's not something you normally do. It's not generally utility practice, I think, to put over-voltage trips. They worry about under-voltage, not over-voltage. I'm just wondering if they had some other experiences that maybe we are not --

MR. KANG: I just read a LER not long ago where North Anna had a similar problem, but they did have a second volts per hertz relay, and they tripped the unit right off the grid.

MR. MICHELSON: They tripped it on the relay --

MR. KANG: Yes.

MR. MICHELSON: -- not on manual action.

MR. KANG: Not manual action. It's done automatically.

MR. MICHELSON: Yes.

MR. LINDBLAD: Is there a time delay on the --
MR. KANG: Yes.
MR. LINDBLAD: -- relay?
MR. KANG: Yes.
MR. LINDBLAD: And what's the time delay?
MR. KANG: This is just the planning stage. They didn't tell us, but they did tell me what the set level was.
MR. CARROLL: On the need to improve the erosion/corrosion program at Sequoyah, has the region looked at what the situation is at the sister plant, Brown's Ferry?
MR. BLAKE: Yes, we have, and it's the same -- essentially the same corporate group that did Sequoyah that has done Brown's Ferry, but they have taken the lessons learned from the Sequoyah event.
During this recent outage at Brown's Ferry, they have completely overhauled their Checkmate program, and they have expanded the sample of pipe locations that they inspected to more than double what they had before, what they had planned to do.
So, they've done an extensive erosion/corrosion check at Brown's Ferry during the last outage.
MR. MICHELSON: Do you know what they found out?
MR. BLAKE: They found some areas -- expected areas of wear, but they didn't find any surprises. They didn't find anything that Checkmate didn't predict.

Of course, through the lessons learned at Sequoyah, they did a very careful check of their model before they selected the sample locations.

MR. MICHELSON: Have they done any pipe replacement as a consequence?

MR. BLAKE: Not that I'm aware of.

MR. CARROLL: What are you going to tell us in the two minutes you have remaining?

MR. LaBARGE: Unless there are some questions, I was going to let it lie there.

MR. KOSHY: My name is Thomas Koshy. I am from the Events Assessment Branch.

Slide number 13 addresses the three events and other actions, starting from the earliest, even, in 1986, at Surry. That's when the NRC issued Bulletin No. 87-01, and the experiences after that was communicated through NUREG 1344.

Soon after that, we did a sample audit at about 10 stations, and we found that the licensees have put in a program, but events continued to happen, and we have now a total of about eight to nine information notices addressing events that have actually happened.

Later, we issued Generic Letter 89-08, and that is the letter that required a program to prevent failures from erosion and corrosion. The recent events I have listed in the Information Notice 91-18, and one foreign, even those are included there.

Subsequent to the event that happened at Millstone Unit 3, we used a draft TI to look at the licensee program again to see what the licensees have done, and the general consensus was that all the licensees have put in a program, but they lacked an administrative commitment to make this program continue to happen.

That is beyond the one time looking at program to trend and see what areas are having the most problems and also to schedule these actions such that these weaker areas or weaker pipe sections could be identified ahead of time and proper solutions can be done at the time.

Now, subsequent to the event, slide number 14, as was earlier mentioned, EDO wrote a letter to NUMARC highlighting the recent events and requested additional guidance to the industry.

What we recognized is that there had been oversights in the use of these state-of-the-art programs.

We have such omissions, like in the case of Sequoyah, the moisture content that was coming in from the drain lines were not factored in, and also, the limited attention from the licensee management to avoid such oversights.

Electrical issues we discussed in some level of detail. In this case, what we recognize is that most of the safety-related equipment remained unconnected to the system.

Therefore, they were not subjected to this high-voltage conditions, and those buses were very lightly loaded, and equipment such as motor-operated valves and the ECCS pumps, they were all unconnected at the time. So, they remained free from the damage.

The generic implications are still being looked at by the vendors, and we are trying to collect the related matters of an applicable nature and put it in an information notice to convey the electrical lessons learned and also, from the metallurgical part, the omissions that we had noticed in the Sequoyah program, and we intend to issue an information notice on that subject.

MR. MICHELSON: What do you think the staff has so far learned about the exposure of electronic equipment to steam environments?

MR. KOSHY: Okay. The electronic equipment that are used generally in the reactor protection systems at Sequoyah are usually supplied by power supply units which are capable of withstanding voltages up to 20 percent.

MR. MICHELSON: I'm not thinking of the over-voltage aspect but rather --

MR. KOSHY: In a steam environment?

MR. MICHELSON: -- exposure to the environment itself.

MR. KOSHY: These areas are generally free from such steam line breaks, and they are in a protected area, also. In the EQ program, we have been through these areas and located these equipment in mild environments, such that it will be free from such damage.

MR. MICHELSON: Well, you might want to rethink that a little more carefully to make sure you're looking at all of the equipment inside a secondary containment, for instance, in a typical boiling-water reactor, which is the bulk of the electronic control system.

Some of it, admittedly, is in the control room, but a great deal of it is out at the instruments, including the instruments themselves, which use solid-state --

MR. KOSHY: If I may, in those cases, what we have done is this instrumentation tubing that comes from the primary containment area are taken to a different area.

MR. MICHELSON: They're capable of taking out the secondary containment.

MR. KOSHY: Right. In those areas, we did qualification for instruments such as Rosemont transmitters and trip units and pressure switches. We have put them through a rigorous qualification process, and we hope that it will withstand that environment.

MR. MICHELSON: That same area has a large amount of so-called non-safety-related equipment, because it doesn't perform directly a safety function.

Do you think we've learned some lessons that perhaps we need to look at non-safety-related equipment a little more carefully from the viewpoint of how it interacts with safety-related equipment?

That's the kind of lesson learned I was wondering if you were even going to pursue, the problem of the unwanted actions resulting from these breaks on equipment which aren't even qualified for the breaks, because it's thought to be non-safety and not affecting safety.

It this case, it was the turbine, but how about inside a secondary containment, where we have large number of these pieces of equipment?

MR. KANG: In conjunction with this issue, I did look at -- searched through some LERs, which has a similar event and all of that, and there was about -- we searched about two years, and there was about 26 events relating to over-voltages, but --

MR. MICHELSON: I wasn't thinking of over-voltage now. I was thinking of steam environment.

MR. KANG: You have to start with a search of the LERs. You have to give key words such as over-voltages.

So, in the past two years, there's 28 events, but we looked through each one of them, and none of them had --

except at Sequoyah, none of them was related with a steam environment, like what you're implying.

MR. MICHELSON: Let's just go to the Surry pipe break, wherein the steam entered the auxiliary building after it passed through the turbine building, entered into the fire protection system, got into the controls of it, set off the halon system and the CO-2 system, which then sprayed on the safety-related electronics.

That's the kind of thing that I'm talking about. Are we learning any lessons from this that says maybe we need to think a little more carefully about the effect of non-safety-related equipment on safety-related equipment, not just whether it falls on it or not.

MR. BLAKE: In the area of erosion/corrosion and the steam type of problems, that was pretty much the message that Mr. Russell gave to the industry in January when they held a seminar on erosion/corrosion up there, invited representatives from all the industry, and pointed out the problems with the erosion/corrosion, the problems that are coming from it, and pointing towards the maintenance rule implementation that they were going to have to have a handle on these kind of interactions, what the consequences of an erosion/corrosion pipe failure would be on their plant when that maintenance rule comes into effect.

So, I think we've pretty much given the message to industry from that standpoint. We do have to look at some specific areas to see if there is something more urgent that we need to address.

MR. MICHELSON: The next pipe break may not be erosion/corrosion. It may be a pipe inside a secondary containment.

MR. BLAKE: I understand that.

MR. MICHELSON: There are lots of high-energetic pipes in there to do the job.

MR. CARROLL: Okay. We're going to have to wrap this up. I'd like to thank the presenters this morning. Good job.

MR. WILKINS: Lunch is here. So, we'll declare a five-minute recess to let the lunch get brought in here, and we're going to work while we eat.

I have two things that I really want to get done before Hal disappears, and one is this letter, if we can hopefully get this letter finished, and then there's agenda item 5, which we really didn't address yesterday, which is reconciliation of ACRS comments and recommendations, and there are six subjects, six letters from the EDO, and we have to decide whether we like them or wish to take further action, and two of those -- have HWL initials on them.

[Whereupon, at 12:25 p.m., the meeting was concluded.]

REPORTER'S CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

NAME OF PROCEEDING: 399th ACRS Meeting

DOCKET NUMBER:

PLACE OF PROCEEDING: Bethesda, MD

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

Jon Hundley

Official Reporter
Ann Riley & Associates, Ltd.

INTRODUCTORY STATEMENT BY THE ACRS CHAIRMAN
399TH ACRS MEETING, JUlY 8-10, 1993

THE MEETING WILL NOW COME TO ORDER. THIS IS THE <u>SECOND DAY</u> OF THE 399TH MEETING OF THE ADVISORY COMMITTEE ON REACTOR SAFEGUARDS. DURING TODAY'S MEETING, THE COMMITTEE WILL DISCUSS AND/OR HEAR REPORTS ON THE FOLLOWING:

(1) DRAFT REGULATORY GUIDE DG-1025, CALCULATIONAL AND DOSIMETRY METHODS FOR DETERMINING PRESSURE VESSEL NEUTRON FLUENCE
(2) DRAFT REGULATORY GUIDE DG-1023, EVALUATION OF REACTOR PRESSURE VESSELS WITH CHARPY UPPER-SHELF ENERGY LESS THAN 50 FT.LB.
(3) DEBRIS PLUGGING OF EMERGENCY CORE COOLING SUCTION LINE STRAINERS AND RELATED MATTERS
(4) RECENT EVENT AT THE SEQUOYAH NUCLEAR POWER PLANT, UNIT 2 INVOLVING A RUPTURE OF AN EXTRACTION STEAM HEADER LINE.
(5) PREPARATION OF ACRS REPORTS

THIS MEETING IS BEING CONDUCTED IN ACCORDANCE WITH THE PROVISIONS OF THE FEDERAL ADVISORY COMMITTEE ACT.

MR. ELPIDIO ~~INGE~~ IGNE IS THE DESIGNATED FEDERAL OFFICIAL FOR THE INITIAL PORTION OF THE MEETING.

WE HAVE RECEIVED NO WRITTEN STATEMENTS OR REQUESTS FOR TIME TO MAKE ORAL STATEMENTS FROM MEMBERS OF THE PUBLIC REGARDING TODAY'S SESSIONS. A TRANSCRIPT OF PORTIONS OF THE MEETING IS BEING KEPT, AND IT IS REQUESTED THAT EACH SPEAKER USE ONE OF THE MICROPHONES, IDENTIFY HIMSELF OR HERSELF AND SPEAK WITH SUFFICIENT CLARITY AND VOLUME SO THAT HE OR SHE CAN BE READILY HEARD.

NRR STAFF PRESENTATION TO THE

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBJECT:	STRAINERS USED IN EMERGENCY CORE COOLING SYSTEMS		
DATE:	JULY 9, 1993		
PRESENTERS:	MARTIN VIRGILIO,	NRR/DSSA	504-3226
	JOHN HICKMAN,	NRR/PDIII-2	504-3017
	RICHARD BARRETT,	NRR/SCSB	504-3627

STRAINERS USED IN EMERGENCY CORE COOLING SYSTEMS

INTRODUCTION	M. VIRGILIO
RECENT EVENT INFORMATION	J. HICKMAN
DOMESTIC BWR MARK III EVENTS	
BULLETIN ISSUED	
LICENSEE RESPONSES	
NEW STRAINER INFORMATION	R. BARRETT
SWEDISH TESTS, DESIGN, AND MODIFICATIONS	
SURVEY OF U.S. PLANTS	
RESOLUTION OF THE PROBLEM	

INTRODUCTION

- BARSEBECK EVENT
  - CONTAINMENT SPRAY STRAINERS CLOGGED BY INSULATION DEBRIS
- EARLY STAFF RESPONSE
  - INFORMATION NOTICE 92-71
  - CONTACT WITH BWR OWNERS GROUP
  - SURVEY BY NRC RESIDENT INSPECTORS
- ACRS BRIEF: JANUARY 7, 1993
  - ACRS CONCERN REGARDING PUMP DAMAGE
- TODAY'S PRESENTATION
  - MARK III EVENTS: JOHN HICKMAN
  - STRAINER ISSUE UPDATE: RICHARD BARRETT

GRAND GULF

- STRAINERS WERE CLOGGED WITH SEDIMENT IN 1988.
- THE STRAINERS WERE CLEANED.
- POOL CLEANLINESS WAS NOT FULLY IMPLEMENTED.
- THE STRAINERS WERE AGAIN FOUND TO BE CLOGGED IN 1989.
- THE STRAINERS WERE AGAIN CLEANED.
- SUPPRESSION POOL CLEANLINESS REQUIREMENTS WERE ESTABLISHED.

PERRY

- DEBRIS WAS IDENTIFIED ON THE POOL FLOOR AND STRAINERS IN MAY OF 1992.

- FOLLOWING CLEANING IN JANUARY 1993, THE STRAINERS WERE RECOGNIZED AS BEING PHYSICALLY DEFORMED AND CRACKED.

- THE STRAINERS WERE REPLACED.

- IN MARCH OF 1993, SUPPRESSION POOL COOLING WAS USED.

- THE STRAINERS WERE AGAIN FOUND COATED WITH DEBRIS.

- TESTS INDICATED SIGNIFICANT DROP IN SUCTION PRESSURE.

- THE STRAINERS WERE REPLACED WITH A LARGER SIZE, THE POOL WAS CLEANED, BACKFLUSH WAS PROVIDED, AND NPSH MONITORING WAS INITIATED.

BULLETIN 93-02

- THE DEBRIS CONSISTED OF FIBERS FROM AIR FILTER MATERIAL AND CORROSION PRODUCTS THAT HAD BEEN FILTERED FROM THE POOL.

- THIS FILTERING OF DEBRIS WAS A PREVIOUSLY UNRECOGNIZED CONTRIBUTOR.

- THE STAFF ISSUED BULLETIN 93-02.

- B 93-02 REQUESTED LICENSEES TO:

  - IDENTIFY FIBROUS AIR FILTERS OR OTHER TEMPORARY SOURCES OF FIBROUS MATERIAL.

  - TAKE ANY NECESSARY COMPENSATORY ACTIONS.

  - PROMPTLY REMOVE ANY IDENTIFIED MATERIAL.

LICENSEE RESPONSES

- LICENSEE RESPONSES WERE:

	BWRS	PWRS
NO REMOVAL OF MATERIAL WAS REQUIRED:	19	26
MATERIAL HAS BEEN OR WILL BE REMOVED:	3	6
FURTHER ANALYSIS BY LICENSEE:	0	2
NRC STAFF REVIEW REQUIRED:	2	4
FURTHER INFORMATION WILL BE REQUIRED:	1	11

NEW STRAINER INFORMATION

- SURVEY BY THE STAFF
  - TYPES OF INSULATION
  - SURFACE AREAS OF STRAINERS
  - FLOW RATES
  - ALTERNATE SOURCES OF WATER
  - HEAD LOSSES
- PUMPS, NOZZLES, AND CORE CHANNELS
  - BLOCKAGE

NEW STRAINER INFORMATION

- PERRY
  - SEDIMENT
  - FILTERING
- SWEDISH TESTS
  - DEBRIS GENERATION
  - TRANSPORT
  - FLOTATION AND SEDIMENTATION
  - HEAD LOSS
- SWEDISH MODIFICATIONS
  - LARGER STRAINERS
  - AUTOMATIC BACKFLUSHING
  - METALLIC OR FIBERGLASS INSULATION

NEW STRAINER INFORMATION

- RESOLUTION OF THE PROBLEM
  - APPLY REG GUIDE 1.82, REV 1, TO A REFERENCE BWR
  - CONSIDER REVISION OF REG GUIDE 1.82, REV 1

    DEVELOP TRANSPORT MODEL

    CONSIDER FILTERING

    CHECK HEAD LOSS CORRELATION

    CLEANLINESS
  - CONSIDER BACKFITTING

RES STAFF PRESENTATION
TO THE
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

PROPOSED DRAFT REGULATORY GUIDE, DG-1025

CALCULATIONAL AND DOSIMETRY METHODS

FOR DETERMINING PRESSURE VESSEL NEUTRON FLUENCE

July 9, 1993

Michael Mayfield
Section Leader
Fracture and Irradiation Section
Materials Engineering Branch
Division of Engineering

(301) 492-3844

Subcommittee: Materials and Metallurgy

PROPOSED DRAFT GUIDE OBJECTIVES

- o Provide acceptable state-of-the-art method for fluence determination
  - Reflect present day experience and surveillance report submittals
  - DOES NOT REPLACE METHODS ACCEPTED IN PREVIOUS REVIEWS
- o Codify existing staff practices and eliminate unnecessary work by licensees and staff
- o Provide consistent set of guidelines for estimating neutron fluence exposures to reactor vessels

NEED FOR GUIDE

- o Requested by NRR (Denton in 1987 and Murley in 1992)

- o Current methods submitted by licensees vary widely

  - varying reliability, accuracy and conservatism
  - bias factors mandated by staff in some cases
  - recent reviews continue to identify questions
  - errors found in cross-section libraries could give non-conservative result for cavity dosimetry
  - need for uncertainty analysis

- o Submittal-specific reviews are labor intensive for licensee and staff

<u>NEED FOR GUIDE</u> (cont.)

- o Unnecessary conservatisms may result in operational problems
  - restrictive P-T limits and LTOP set points -- potentially adverse impact on safety
  - unnecessarily appraoching PTS screening criteria and Charpy upper shelf energy criteria
  - could force unnecessary annealing or plant closure

- o Serves as reference guide for the future

REGULATIONS IMPACTED BY THE GUIDE

- Appendix G, 10 CFR Part 50, "Fracture Toughness Requirements" issued 1983

- 10 CFR 50.61, " Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock" issued 1991

- Appendix H, 10 CFR Part 50, Reactor Vessel Surveillance Program Requirements" issued 1983

DEVELOPMENT OF GUIDE

- o Combined expertise from staff, BNL, ORNL and NIST

- o Reflects results of the LWR Pressure Vessel Surveillance Dosimetry Improvement Program

  - multi-national (UK, Germany, Belgium, Italy) cooperative effort that included U.S. vendors, architect/engineers, EPRI, and ASTM
  - provided benchmarks and round robin programs to qualify techniques

- o Reflects staff and BNL experience in performing independent calculations of reactor vessel fluences

- o References updated cross-sections

  - NRC funded development of ENDF/B-VI cross-section libraries to meet overall schedules

REGULATORY GUIDE FOR THE CALCULATION AND MEASUREMENT OF PRESSURE VESSEL FLUENCE

J.F. CAREW

JULY 9, 1993

ADVANCED TECHNOLOGIES DIVISION

DEPARTMENT OF ADVANCED TECHNOLOGY

BROOKHAVEN NATIONAL LABORATORY

BACKGROUND

- REACTOR PRESSURE VESSEL FLUENCE IS REQUIRED FOR DETERMINATION OF THE VESSEL EMBRITTLEMENT AND LIFETIME

- VESSEL FLUENCE IS USED TO DETERMINE THE ADJUSTED REFERENCE TEMPERATURE FOR THE NIL-DUCTILITY TRANSITION RT_{NDT}

- THE "PTS RULE", 10 CFR PART 50.61, REQUIRES THE DETERMINATION OF THE VESSEL FLUENCE FOR RT_{PTS}

BACKGROUND (Cont'd)

- NEUTRON FLUENCE UNDERGOES SEVERAL DECADES OF ATTENUATION TO THE VESSEL

- VESSEL FLUENCE CALCULATION IS THEREFORE VERY SENSITIVE TO

    - MATERIAL AND GEOMETRY REPRESENTATION OF THE CORE AND VESSEL INTERNALS

    - SPACE/ENERGY NEUTRON SOURCE

    - TRANSPORT CALCULATION NUMERICAL SCHEMES

- DETAILED MULTIGROUP/MULTIDIMENSIONAL ANALYSIS IS REQUIRED FOR AN ACCURATE FLUENCE ESTIMATE

BACKGROUND (Cont'd.)

- WIDE RANGE OF FLUENCE METHODS ARE USED: CROSS SECTION SETS, PHYSICS APPROXIMATIONS (SOURCE AND AXIAL TREATMENT) AND CODES

- LIMITED NUMBER AND UNCERTAINTY OF CAPSULE BENCHMARK DATA

- FOR CERTAIN VESSELS LIMITED EOL MARGIN TO RT_{PTS} LIMITS

PRESENTATION OVERVIEW

- OVERALL APPROACH AND APPLICABILITY
- CALCULATION OF VESSEL FLUENCE
- EXPECTED LICENSING IMPACT

OVERALL APPROACH

- FOCUSES ON CRITICAL AREAS HAVING SUBSTANTIAL UNCERTAINTY

- RECOMMENDS STATE-OF-THE-ART METHODS THAT ARE WELL VALIDATED

- MAKES SPECIFIC REQUIREMENTS

- ASSUMES GOOD ENGINEERING JUDGEMENT - DOES NOT OVER PRESCRIBE

- ALTERNATE FLUENCE DETERMINATION METHODS ARE ALLOWED BUT WILL BE REVIEWED ON AN INDIVIDUAL BASIS

SCOPE AND APPLICABILITY

- FLUENCE INPUT FOR APPENDIX-G AND REG. GUIDE 1.99
- PRESENT PWR AND BWR CORE/VESSEL GEOMETRIES AND FUEL DESIGNS
- VESSEL FLUENCE REDUCTION DESIGNS (PLSAs, LOW LEAKAGE CORES, etc.,) AND LIFE EXTENSION CALCULATIONS
- FLUENCE SPECTRUM >0.1 MeV
- CAVITY DOSIMETRY MEASUREMENTS

CALCULATION OF VESSEL FLUENCE

- FLUENCE CALCULATIONAL METHODS
  - BEST-ESTIMATE RATHER THAN BOUNDING APPROACH
  - PROVIDES ~20% (1-σ) ACCURACY
  - ENERGY RANGE FROM 15 MeV TO 0.1 MeV
- EMPLOYS AN ABSOLUTE FLUENCE CALCULATION RATHER THAN THE EXTRAPOLATION OF MEASUREMENT
- QUALIFICATION VIA BENCHMARKING AND UNCERTAINTY ANALYSIS

PRIMARY CALCULATIONAL TASKS

- DETERMINATION OF GEOMETRICAL AND MATERIAL COMPOSITION INPUT DATA

- DETERMINATION OF THE CORE NEUTRON SOURCE

- TRANSPORT THEORY CALCULATION OF THE NEUTRON FLUX FROM CORE TO VESSEL AND CAVITY

MATERIAL COMPOSITION AND GEOMETRY DATA

- ACCURATE PRESSURE VESSEL DIAMETER AND ECCENTRICITY REQUIRED

- DIMENSIONS AND LOCATIONS OF THE FUEL ASSEMBLIES DETERMINE THE LOCATION OF THE SOURCE

- DIMENSIONS AND COMPOSITION OF THE REACTOR INTERNALS (BAFFLE, BARREL, THERMAL SHIELD AND NEUTRON PADS) AFFECT FLUENCE ATTENUATION

- LOCATIONS OF CIRCUMFERENTIAL AND LONGITUDINAL WELDS ARE REQUIRED FOR THE ΔRT_{PTS} EVALUATION

MATERIAL COMPOSITION AND GEOMETRY DATA (Cont'd)

- CAVITY DATA INCLUDING SUPPORT STRUCTURES AND CONCRETE SHIELDING AFFECT THE INTERPRETATION OF THE CAVITY SURVEILLANCE CAPSULES

- AXIAL VARIATIONS IN WATER DENSITY MAY HAVE A SIGNIFICANT EFFECT ON THE FLUENCE ATTENUATION

- DOCUMENTED AS-BUILT PLANT-SPECIFIC DATA ARE REQUIRED

- IF GENERIC DATA IS USED, PLANT-SPECIFIC DEVIATIONS SHOULD BE INCLUDED IN THE UNCERTAINTY ANALYSIS

NUCLEAR DATA

- LATEST VERSION OF THE EVALUATED NUCLEAR DATA FILE (ENDF/B) GENERALLY INCLUDES THE MOST ACCURATE AND ACCEPTABLE DATA AND IS RECOMMENDED

- EARLIER CROSS SECTION SETS ARE ALSO ACCEPTABLE PROVIDED THEY ARE THOROUGHLY BENCHMARKED

- FLUENCE ESTIMATES MUST BE UPDATED WHEN DEFICIENCIES IN THE NUCLEAR DATA ARE IDENTIFIED

- MASTER LIBRARY OF 100-200 GROUPS IS COLLAPSED TO A JOB LIBRARY OF $\lesssim$ 50 GROUPS

- COLLAPSED LIBRARIES SHOULD PRESERVE FLUENCE ATTENUATION AND THRESHOLD DETECTOR REACTION RATES

- A P-3 ANGULAR DECOMPOSITION OF THE SCATTERING CROSS SECTIONS (AT A MINIMUM) IS REQUIRED

CORE NEUTRON SOURCE

- SOURCE SPATIAL DEPENDENCE IS DETERMINED BY THE DETAILED CYCLE-DEPENDENT PIN AND ASSEMBLY POWERS/ EXPOSURE DISTRIBUTIONS

- VESSEL END-OF-LIFE FLUENCE ESTIMATES MUST BE UPDATED WHEN FUEL MANAGEMENT PROJECTIONS ARE NON-CONSERVATIVE (e. g., WHEN GENERIC POWER DISTRIBUTIONS ARE USED)

- THE PIN-WISE POWER DISTRIBUTION OF THE PERIPHERAL ASSEMBLIES SHOULD BE REPRESENTED IN DETAIL FOR BEST-ESTIMATE FLUENCE (NEGLECT IS CONSERVATIVE)

- HIGH EXPOSURE FUEL ASSEMBLIES PRODUCE MORE PENETRATING AND A LARGER NUMBER OF NEUTRONS PER MEGAWATT (NEGLECT IS NON-CONSERVATIVE)

- ACCURATE SOURCE REPRESENTATION TYPICALLY REQUIRES 40-80 ANGULAR INTERVALS

NEUTRON TRANSPORT CALCULATION

- HORIZONTAL SPATIAL FLUENCE DEPENDENCE DETERMINED IN (r,θ) GEOMETRY USING 40-80 ANGULAR INTERVALS

- RADIAL MESH DENSITY

  ~ 2 INTERVALS/INCH IN PERIPHERAL ASSEMBLIES

  ~ 3 INTERVALS/INCH IN WATER

  ~ 1.5 INTERVALS/INCH IN STEEL

- FLUENCE AXIAL DEPENDENCE MAY BE DETERMINED USING AN (r,z) MODEL OR USING THE CORE AXIAL POWER DISTRIBUTION (WHICH IS CONSERVATIVE FOR BELTLINE LOCATIONS)

NEUTRON TRANSPORT CALCULATION (Cont'd)

- SYMMETRIC S_8 ANGULAR QUADRATURE IS ADEQUATE FOR IN-VESSEL CALCULATIONS - OFF BELTLINE/NARROW-CAVITY CALCULATIONS MAY REQUIRE A HIGHER ORDER S_n QUADRATURE

- ADEQUACY OF SPATIAL MESH, QUADRATURE AND GROUP-WISE CONVERGENCE MUST BE DEMONSTRATED BY TIGHTENING THE NUMERICS

- LARGE DETAILED (r,θ) GEOMETRIES MAY BE CALCULATED USING A "BOOTSTRAP" APPROACH

QUALIFICATION OF METHODS

- FLUENCE CALCULATIONAL METHODS MUST BE QUALIFIED, AND FLUENCE UNCERTAINTIES AND BIASES DETERMINED

- TWO-STEP QUALIFICATION

    - ANALYTIC UNCERTAINTY ANALYSIS

    - COMPARISON WITH BENCHMARK AND PLANT DATA

QUALIFICATION OF METHODS (Cont'd)

- ANALYTIC UNCERTAINTY ANALYSIS

  - IDENTIFICATION OF MODEL INPUT UNCERTAINTIES: NUCLEAR DATA, GEOMETRY, ISOTOPIC COMPOSITIONS, NEUTRON SOURCE, NUMERICS

  - ESTIMATE UNCERTAINTY IN MODEL INPUT

  - DETERMINE FLUENCE SENSITIVITY TO CHANGES IN MODEL INPUT PARAMETERS

  - COMBINE INPUT UNCERTAINTY ESTIMATES WITH FLUENCE SENSITIVITIES TO DETERMINE FLUENCE UNCERTAINTY

QUALIFICATION OF METHODS (Cont'd)

- COMPARISONS TO BENCHMARK AND PLANT-SPECIFIC DATA
  - POWER REACTOR SURVEILLANCE CAPSULE DOSIMETRY
  - PRESSURE VESSEL SIMULATOR BENCHMARKS (e. g., PCA EXPERIMENT)
  - CALCULATIONAL BENCHMARKS
- COMPARISONS TO DATA PROVIDE AN INDEPENDENT ESTIMATE OF FLUENCE CALCULATION UNCERTAINTY
- WHEN SUFFICIENT HIGH QUALITY BENCHMARK COMPARISONS ARE AVAILABLE, A BIAS MAY BE DETERMINED AND APPLIED TO THE CALCULATED FLUENCE ESTIMATE
- OVERALL FLUENCE CALCULATION UNCERTAINTY IS DETERMINED BY AN APPROPRIATE COMBINATION OF (1) THE ANALYTIC UNCERTAINTY ANALYSIS AND (2) THE UNCERTAINTY ESTIMATE BASED ON THE BENCHMARK COMPARISONS

EXPECTED IMPACT OF THE DOSIMETRY GUIDE

- REDUCE FLUENCE CALCULATIONAL UNCERTAINTY TO <20% BY

  - IMPROVED NUCLEAR AND MODELING DATA
  - IMPROVED MODELING ASSUMPTIONS AND APPROXIMATIONS
  - BENCHMARK COMPARISONS
  - CALCULATION UNCERTAINTY ANALYSES

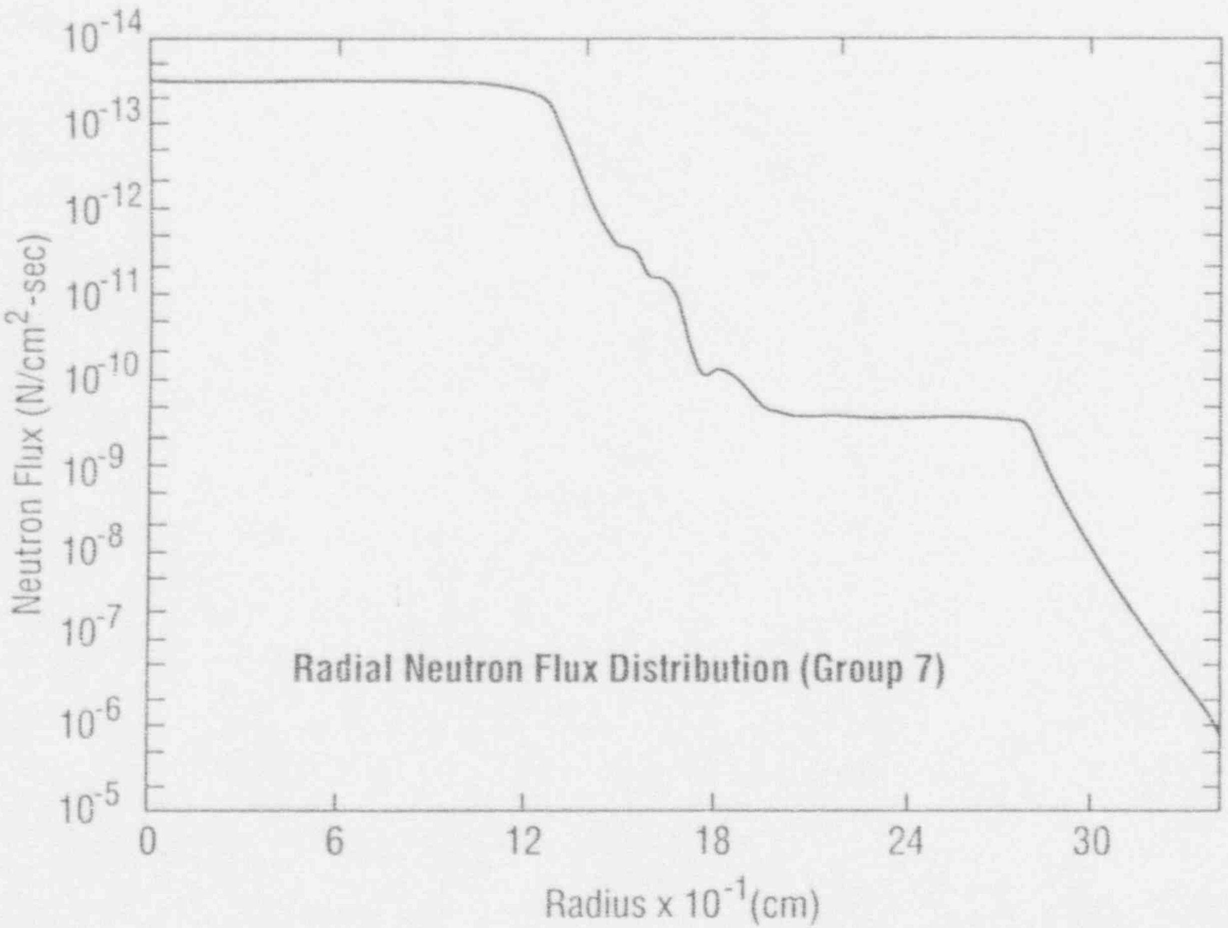
- REDUCE FLUENCE MEASUREMENT UNCERTAINTY TO <20% BY

  - IMPROVED DOSIMETER RESPONSE INTERPRETATION
  - IMPROVED QUALITY CONTROL
  - PERIODIC CALIBRATION
  - MEASUREMENT UNCERTAINTY ANALYSIS

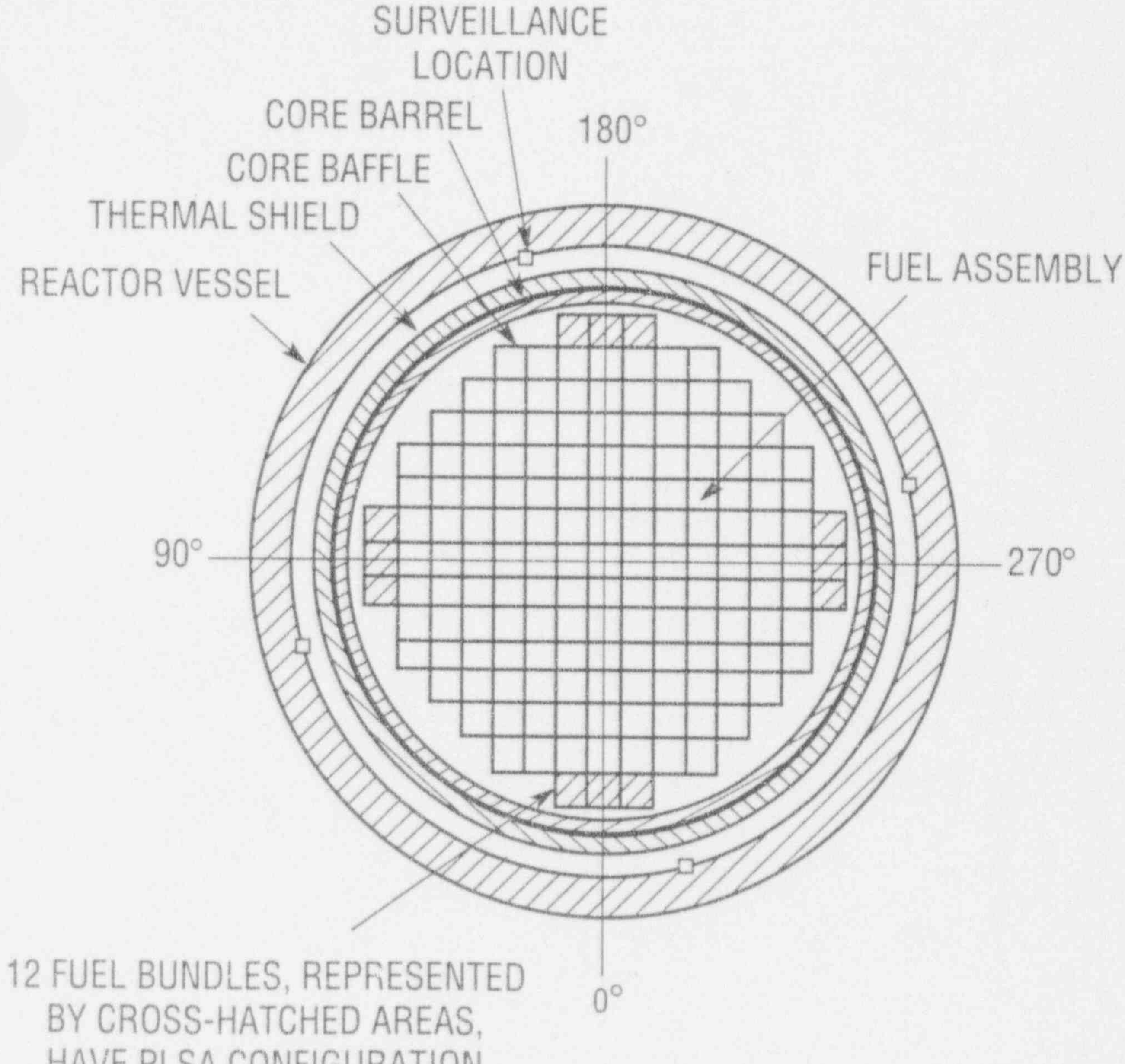
EXPECTED IMPACT OF THE DOSIMETRY GUIDE (Cont'd.)

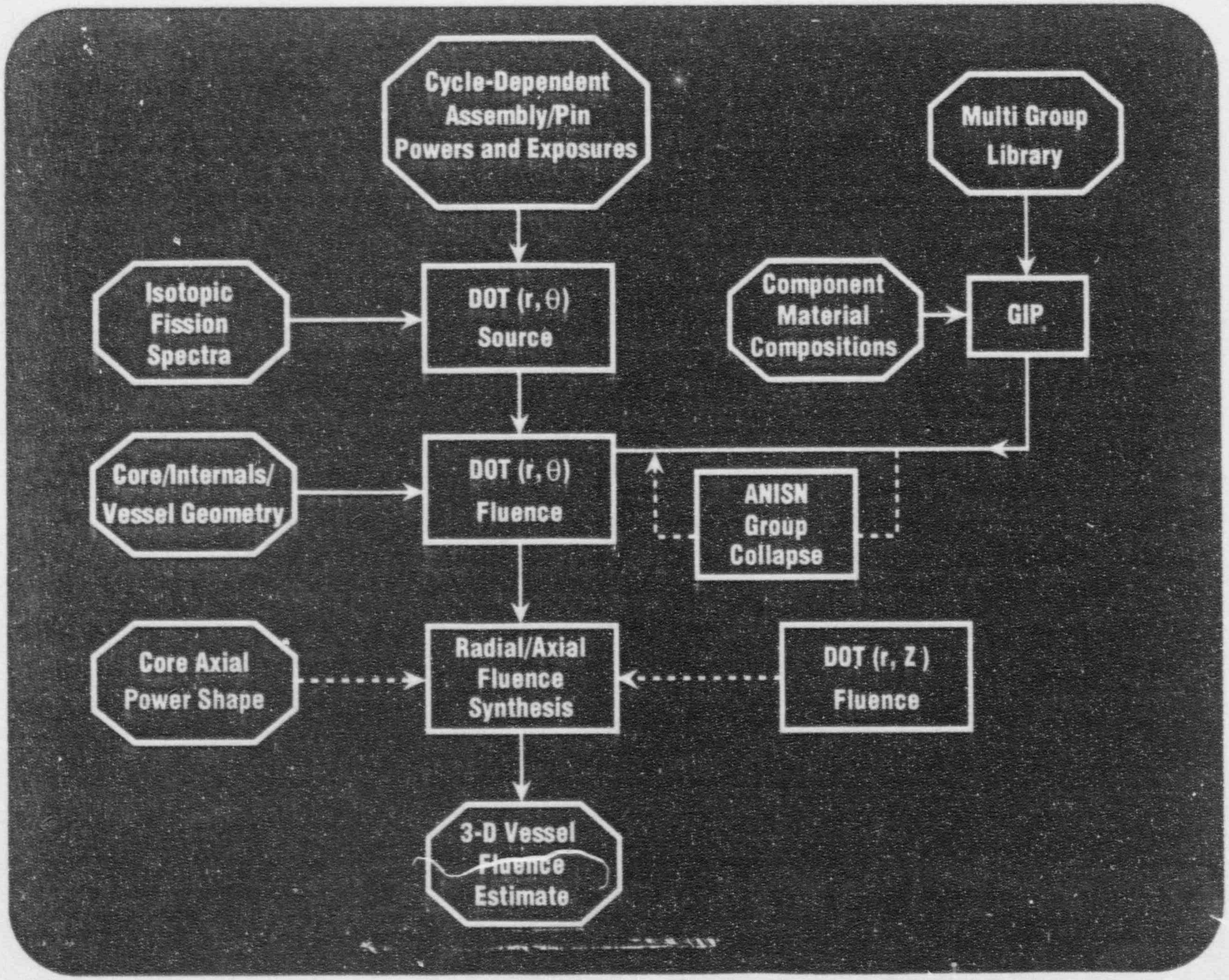
- STANDARDIZATION OF VESSEL FLUENCE METHODS
  - ACCEPTABLE AND DOCUMENTED METHODS
  - REQUIRED BENCHMARKING
  - QUANTIFIED UNCERTAINTY

- SIMPLIFY LICENSING REVIEWS



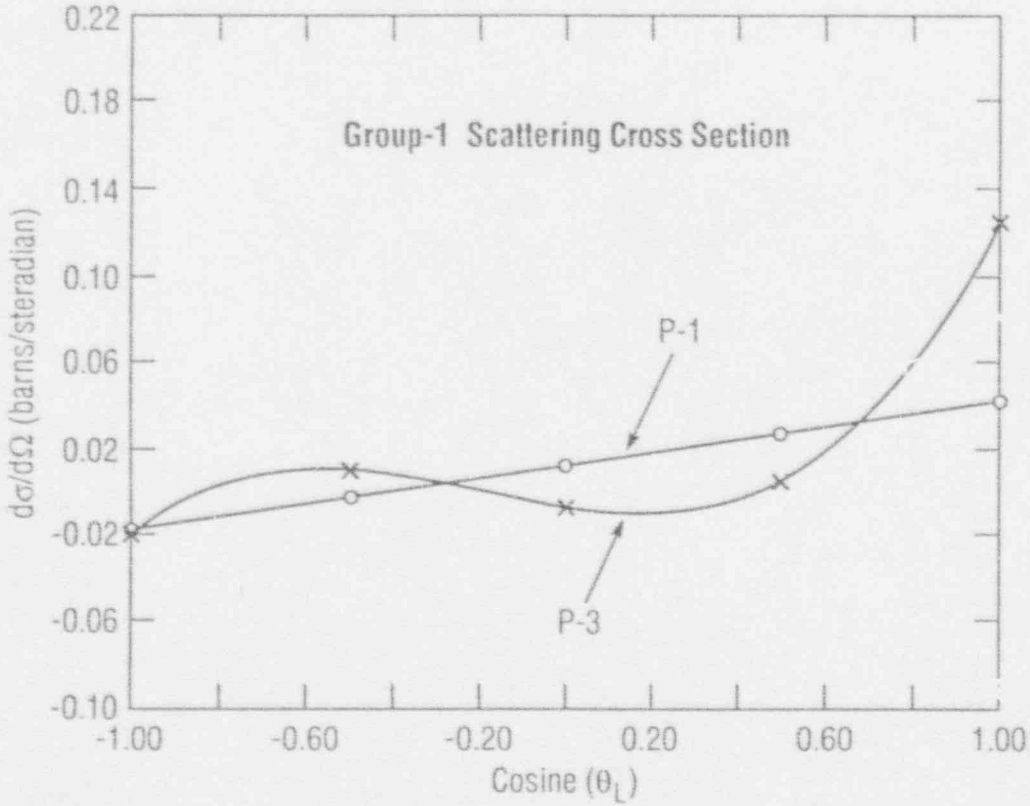
Carew 6a 3/93 judy


SURVEILLANCE
LOCATION
CORE BARREL
180°
CORE BAFFLE
THERMAL SHIELD
REACTOR VESSEL
FUEL ASSEMBLY
90°
270°
0°
12 FUEL BUNDLES, REPRESENTED
BY CROSS-HATCHED AREAS,
HAVE PLSA CONFIGURATION


Cycle-Dependent Assembly/Pin Powers and Exposures
Multi Group Library
Isotopic Fission Spectra
DOT (r, θ) Source
Component Material Compositions
GIP
Core/Internals/ Vessel Geometry
DOT (r, θ) Fluence
ANISN Group Collapse
Core Axial Power Shape
Radial/Axial Fluence Synthesis
DOT (r, Z) Fluence
3-D Vessel Fluence Estimate

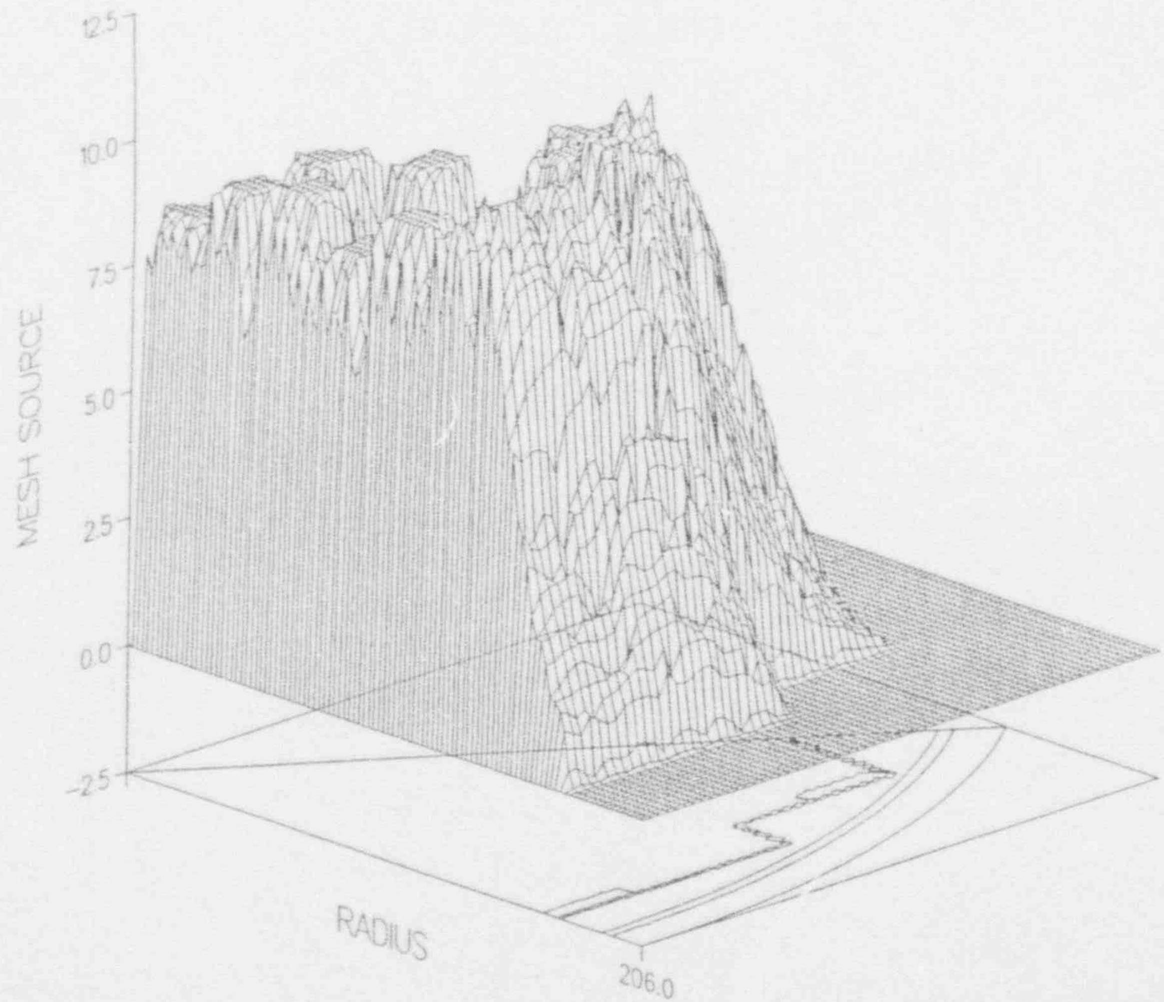
COMPARISON OF FAST NEUTRON FLUXES AT INNER SURFACE OF PRESSURE VESSEL

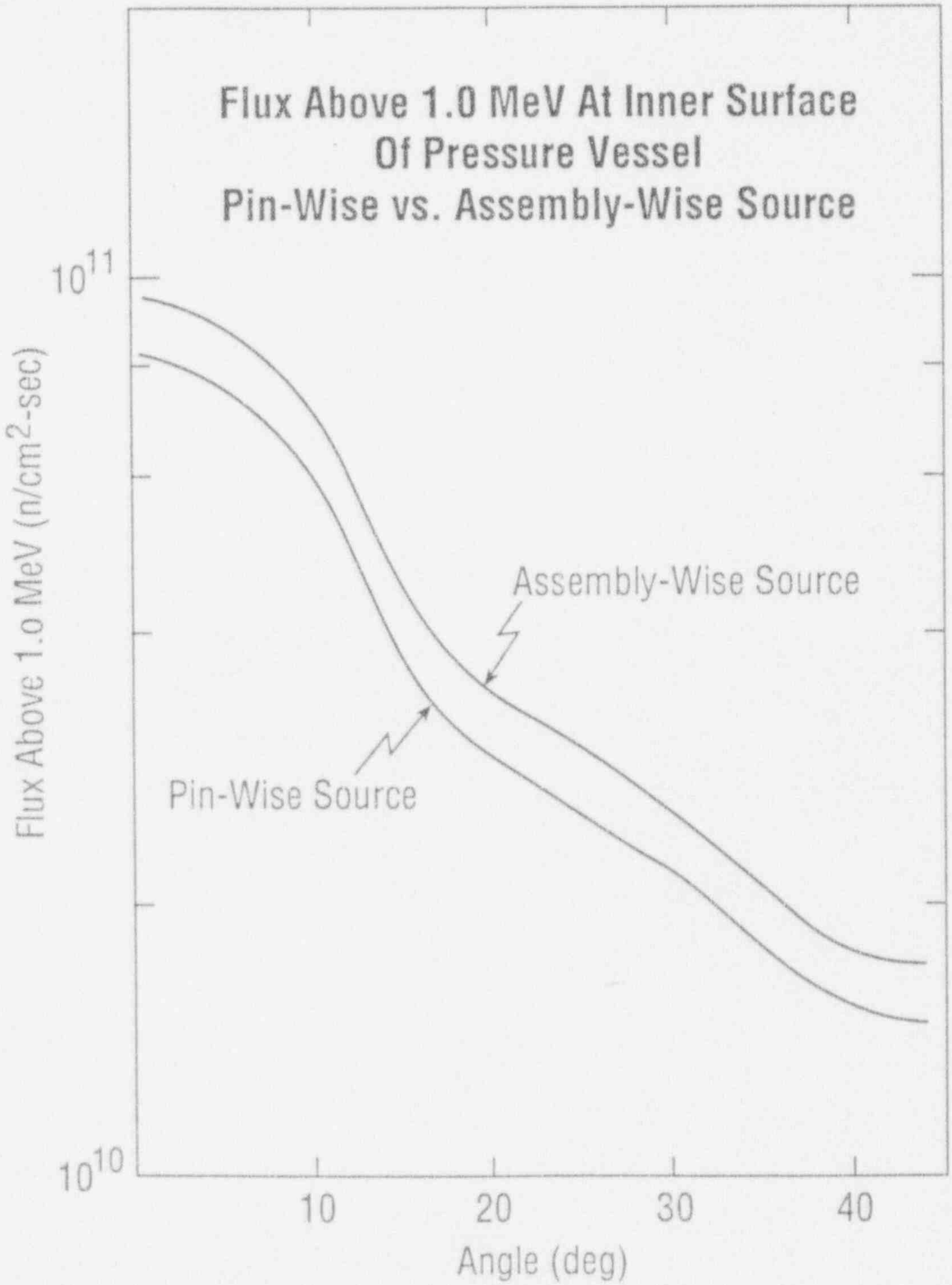
LIBRARY	PERCENT DIFFERENCE Φ (E>1 MeV)	Φ (E>0.1 MeV)
VITAMIN-C	-	-
EPR	0.6	-0.7
BUGLE-80	2.0	1.5
CASK	17.8	15.1
ENDF/B-VI	7.0	6.5



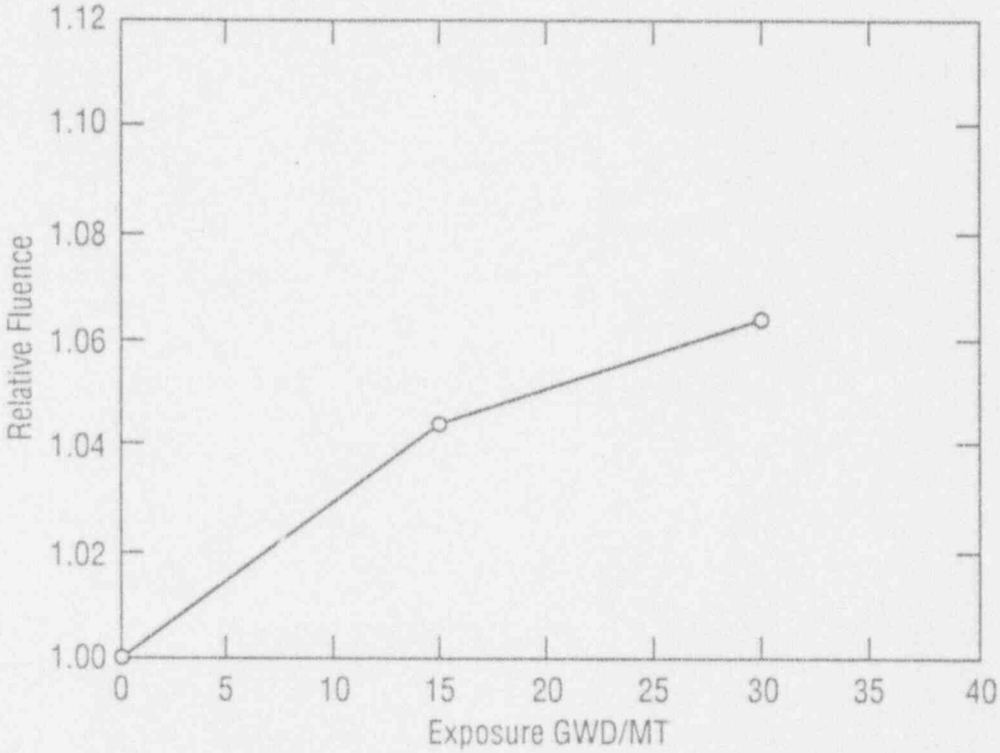
Carew 5a 6/93 judy

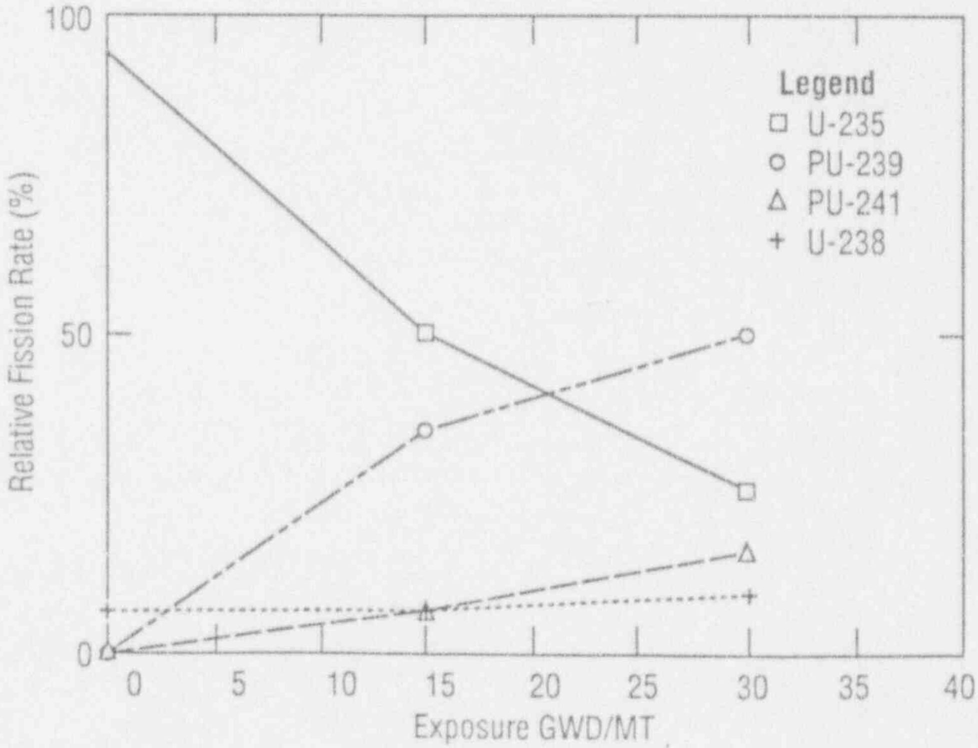
CY 9   INNER REGION SOURCE



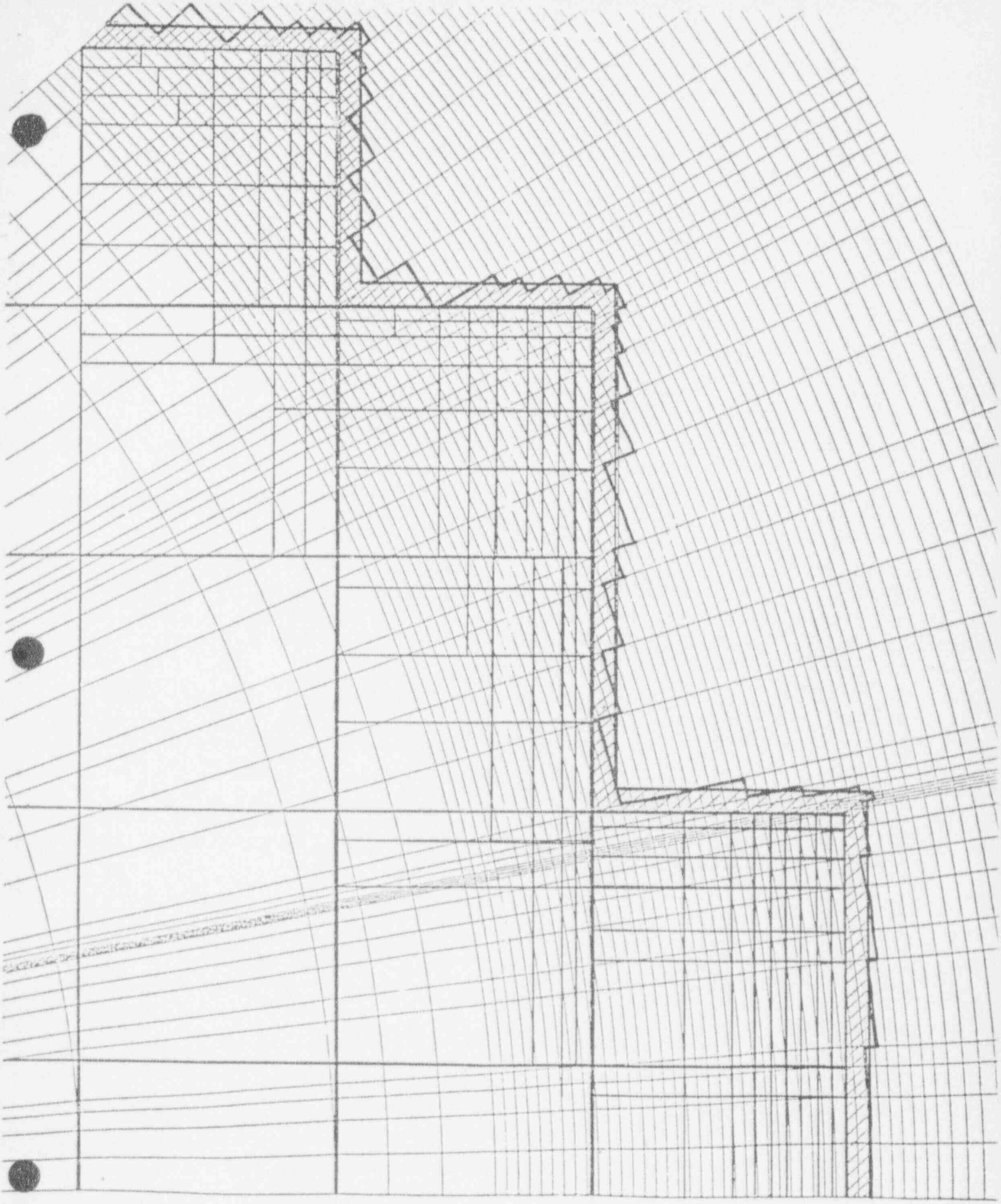


Carew 1a 6/93 judy





Carew 4a 6/93 judy



Core Boundary Representation

COMPARISON OF CALCULATED AND MEASURED (> 1-MeV) FLUENCES

Measurement	BNL Calculated Fluence ($n/cm^2 \times 10^{18}$)	Measured Fluence ($n/cm^2 \times 10^{18}$)	Calculation/Measurement Difference (%)
Maine Yankee 263 Capsule (HEDL)	5.77	5.67	+2
Ft. Calhoun-1 W-225 Capsule (HEDL)	4.9	5.83	−15
ANO-1 ANI-E Capsule	.75	.73	+3
ANO-1	2.30+	2.61+	−12
ORNL/PCA	.9*	1.0*	−10

+Fluxes in units of $10^8 \times n/cm^2$-sec.
*Vessel flux based on the A4, A5, and A6 reactions with thresholds ≥ 1-MeV for both the 8/7 and 12/13 configurations (in arbitrary units).

RES STAFF PRESENTATION
TO THE
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

PROPOSED DRAFT REGULATORY GUIDE, DG-1023

EVALUATION OF REACTOR PRESSURE VESSELS WITH CHARPY UPPER-SHELF ENERGY LESS THAN 50 FT-LB

July 9, 1993

Michael Mayfield
Section Leader
Fracture and Irradiation Section
Materials Engineering Branch
Division of Engineering

(301) 492-3844

Subcommittee: Materials and Metallurgy

DRAFT REGULATORY GUIDE 1-023
"EVALUATION OF REACTOR PRESSURE VESSELS WITH CHARPY UPPER-SHELF ENERGY LESS THAN 50 FT-LB"

Need for Regulatory Guidance

- Appendix G to 10 CFR Part 50 requires:
  - Unirradiated Charpy USE > 75 ft-lb
  - Charpy USE > 50 ft-lb throughout life

    OR

  - Analysis to demonstrate margins of safety equivalent to Section III, Appendix G

- Unresolved Safety Issue (USI) A-11 addressed vessels with USE below 50 ft-lb
  - USI resolved with publication of NUREG-0744 in 1982
  - Staff asked ASME Section XI to develop acceptance criteria

Need for Regulatory Guidance (cont.)

- Members of ASME Committee provided technical opinion concerning acceptance criteria -- 1991
  - Section XI undertook development of Code Case addressing Service Levels A and B

- Yankee Rowe evaluation highlighted need for guidance

- Staff's evaluation of responses to GL 92-01 identified 15 plants below 50 ft-lb based on staff's methods
  - 3 more predicted below 50 ft-lb before EOL
  - SECY-93-048

- Code Case N-512 developed by ASME Section XI not sufficient

- Staff developed Draft Guide DG-1023 to provide complete analysis methodology

Similarities and Differences with ASME Code Case N-512

- Draft Guide and Code Case N-512 identical concerning
  - Acceptance criteria
  - Service load levels
  - Flaw shape/size/orientations
  - Margins

- Code Case N-512 has conservative analysis only for Level A & B
  - Draft Guide includes more rigorous transient analysis
  - Transient analysis method will allow lower USE values
  - Example calculation for A/B transient shows 41 ft-lb for transient analysis vs 47 ft-lb for Code Case

- Code Case N-512 does not provide guidance on specific material properties or transient selection
  - Draft Guide provides guidance on both issues

<u>Outline of Draft Regulatory Guide on LUSE Issue</u>

Proposed draft regulatory guide describes:

- Acceptance criteria for different vessel operating conditions
- Analysis method for Service Levels A, B, C, and D
- Selection of material properties and loading transients
- Example cases
- Details of a method for including cladding effects

Acceptance Criteria:

1. "Initiation" of ductile crack growth:

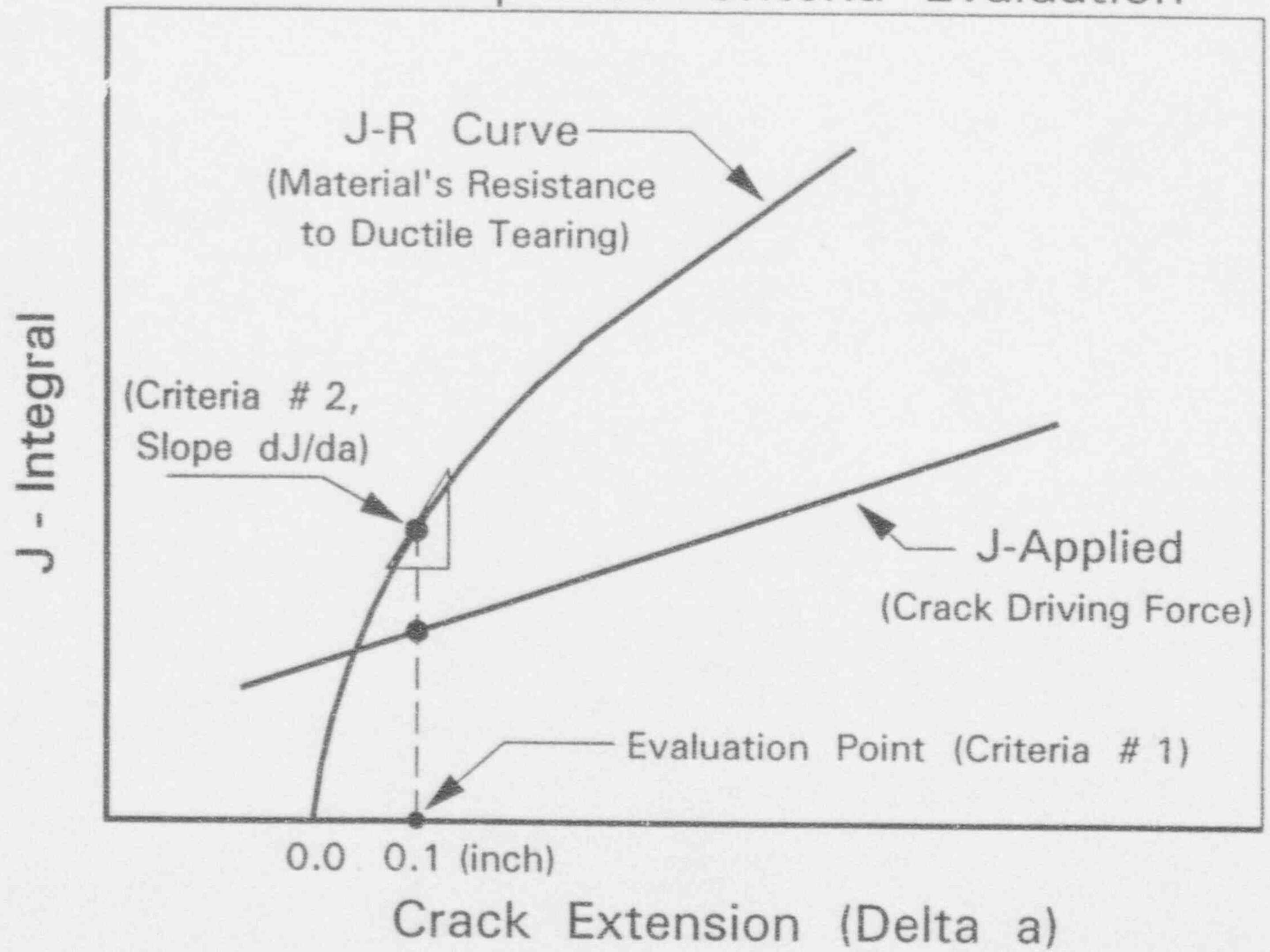
$$J_{applied} \leq J_{material} \quad \text{(at } \Delta a = 0.1 \text{ inch)}$$

2. "Stability" of ductile crack growth:

$$\frac{dJ_{applied}}{da} \leq \frac{dJ_{material}}{da} \quad \text{(at } J_{applied} = J_{material}\text{)}$$

Service Level	Safety Factor on Accumulation Pressure	Crack Depth (in.)	J-R Curve Bounds
A	For Crit. 1: SF = 1.15 For Crit. 2: SF = 1.25	0.25t+0.1	Mean - 2σ
B	For Crit. 1: SF = 1.15 For Crit. 2: SF = 1.25	0.25t+0.1	Mean - 2σ
C	For Crit. 1&2: SF = 1.0	0.1t+0.1 $\leq$ 1.0	Mean - 2σ
D	For Crit. 1&2: SF = 1.0	0.1t+0.1 $\leq$ 1.0	Mean

LUSE Acceptance Criteria Evaluation

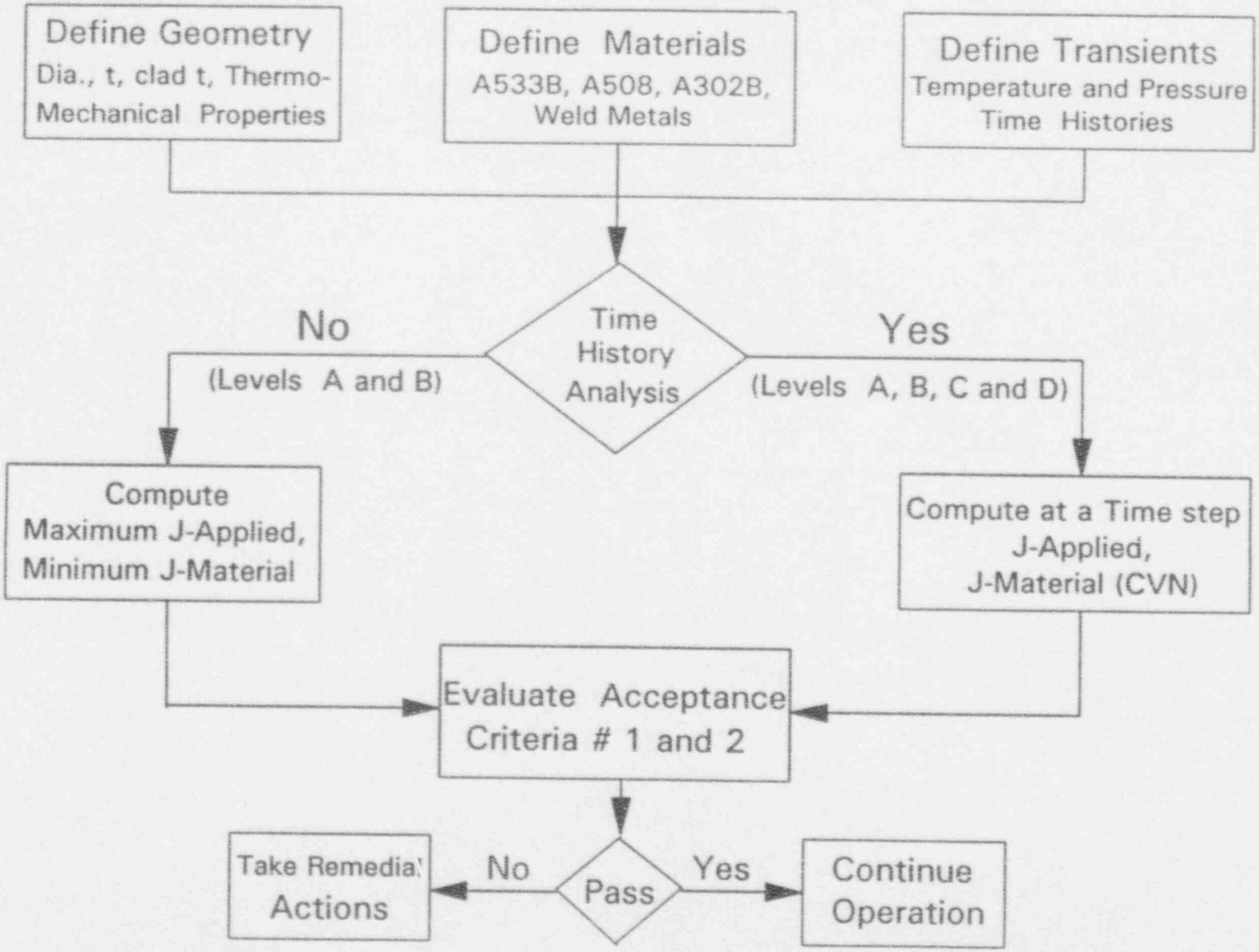


SERVICE LOAD CONDITIONS:

Service load levels defined in ASME Code, and Standard Review Plan, Section 3.9.3

- Levels A and B (Normal and Upset) Conditions
  - -- Normal and system operating transients
  - -- OBE (operating basis earthquake)
- Level C (Emergency) Conditions
  - -- Design basis pipe break
  - -- Small LOCA
  - -- Small steam line break
  - -- ATWS (anticipated transient without scram)
- Level D (Faulted) Conditions
  - -- Large LOCA and SLB
  - -- Main steam and feed water pipe breaks

LUSE Analysis Method



Materials' J-R Curve:

- For A533B, A508, Welds

  - Based on statistical analysis of test data

  - Unirradiated and irradiated conditions

  - Typical materials (plate, forgings, welds)

  - Test conditions typical of service

- For A302B Plate Material

  - Limited data base
    - One plate -- identified as V-50
    - One orientation (transverse) tested
    - One test temperature (180°F)

Materials' J-R Curve (cont.)

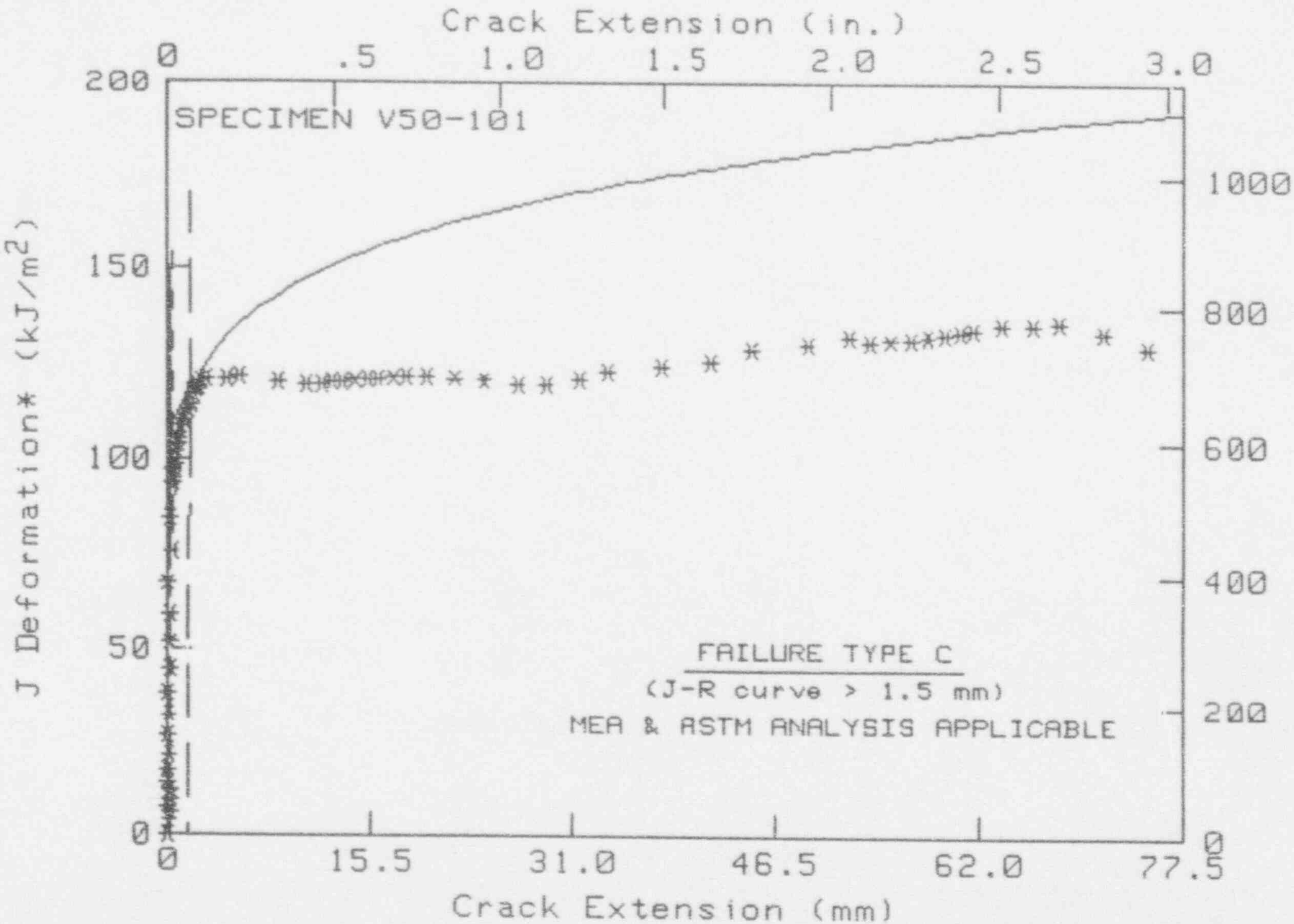
- Plate V-50 may be atypical

    * Minimum cross-rolling to obtain 50 ft-lb USE value

- Conservative approach taken in proposed draft guide

- Additional testing of typical plates underway

- Guidance will be revised as appropriate after analyzing the test data



Crack Extension (in.)
0
.5
1.0
1.5
2.0
2.5
3.0
200
150
100
50
0
SPECIMEN V50-101
1000
800
600
400
200
0
J Deformation* (kJ/m²)
J Deformation* (in-lb/in²)
FAILURE TYPE C
(J-R curve > 1.5 mm)
MEA & ASTM ANALYSIS APPLICABLE
0
15.5
31.0
46.5
62.0
77.5
Crack Extension (mm)

Transient Selection:

- Builds on Design Basis Transients

- No requirement to perform system-level analyses

- If appropriate transients not included in Design Basis or list is incomplete, use generic transients from similar, later vintage plants

- If no plant-specific transients available, use conservative **"bounding"** pressure-temperature-time history

    * 100°F/hr cooldown rate for Service levels A and B
    * 400°F/hr cooldown rate for Service level C
    * 600°F/hr cooldown rate for Service level D

Experience With Draft Guide Methodology:

- Gained considerable experience using the methods proposed in the draft guide

- Generic Bounding Analyses

  - Show USE below 50 ft-lb will satisfy the acceptance criteria

    * PWR and BWR
    * Service Levels A, B, C and D
    * CVN and Cu-ϕt models for J-R curves
    * A533B plate, Linde 80 weld, generic weld, and A302B plate

- ASME, Section XI, Round-Robin Analysis

  - Round-robin analyses for Service Level C and D showed reasonable agreement among the results by several analysts

Generic Bounding Analyses for LUSE Evaluations

Bounding Charpy V-Notch (CVN) Upper-Shelf Energy				
RPV Type	Material Type	Service Level	USE (ft-lb)	ASME Flaw Designation
PWR	A-533B Plate	A and B	33 (Axial) 22 (Circ.)	Longitudinal Transverse
PWR	A-302B Plate Material	A and B	25 (Circ.)	Transverse
PWR	A-302B Plate Material	C and D	29 (Circ.)	Transverse
PWR	Linde 80 Weld * Material	A and B	41*(Axial) 22*(Circ.)	Longitudinal Transverse
PWR	Linde 80 Weld * Material	C and D	33*(Axial) 22 (Circ.)	Longitudinal Transverse
PWR	Generic Weld	A and B	41 (Axial)	Longitudinal
BWR	A-533B Plate	A and B	33 (Axial) 22 (Circ.)	Longitudinal Transverse
BWR	A-302B Plate Material	A and B	25 (Circ.)	Transverse
BWR	A-302B Plate Material	C and D	25 (Circ.)	Transverse
BWR	Linde 80 Weld Material	A and B	33 (Axial) 22 (Circ.)	Longitudinal Transverse
BWR	Linde 80 Weld Material	C and D	33 (Axial)	Longitudinal
BWR	Generic Weld Material	A and B	33 (Axial)	Longitudinal
BWR	Generic Weld Material	C and D	33 (Axial)	Longitudinal

(*): The Cu-ϕt Model applied to Linde 80 welds in PWRs gave, at 0.35 wt% Cu, ϕt value of $1.6 \cdot 10^{19} n/cm^2$ (Level A&B, Axial Crack) or $3.5 \cdot 10^{19} n/cm^2$ (Level C and D, Axial Crack).

ASME, Section-XI, USE Service Levels C and D Bench Marking Results

Analysts	Internal Pressure that Satisfies 0.1 inch Crack Extension Criteria #1 in Plate Material with Axial Crack		
	Prob. # 2[A]	Prob. # 4[B]	Prob. #5[C]
Analyst 1	--	4950 psi	--
Analyst 2	7320 psi	5180 psi	2850 psi
NRC Staff (Draft Guide)	6850 psi	4550 psi	3300 psi
Analyst 3	--	3650* psi	--

(A): Level C loading on a typical PWR vessel and CVN_P Model for J-R Curve

(B): Level C loading on a typical BWR vessel and CVN_P Model for J-R Curve

(C): Level C loading on a typical PWR vessel and A302B (low-toughness) Plate J-R Curve

(*): Used Reg. Guide 1.99, Rev. 2, to Predict Irradiated Upper-Shelf Energy, and Charpy Model for J-R Curve

Conclusions:

- Extensive generic bounding analyses were performed during development of the proposed draft regulatory guide

- Draft regulatory guide results on ASME Section-XI bench marking problems match with results of other analysts.

- Compared to ASME Code Case N-512, the proposed draft guide

  * Provides additional analysis method for Service Levels A and B -- more rigorous analysis but less inherent conservatism

  * Provides complete analysis methodology -- analysis formulation; material properties; transient selection; acceptance criteria

ACRS PRESENTATION ON EXTRACTION STEAM HEADER RUPTURE AT SEQUOYAH UNIT 2

JULY 9, 1993

INTRODUCTION	**ALFRED E. CHAFFEE** BRANCH CHIEF, EAB
AIT INSPECTION	**JEROME J. BLAKE** SC, MATERIALS & PROC, DRS, RII
LICENSEE ACTIONS	**DAVE LABARGE** SR. PROJECT MANAGER, SEQUOYAH
NRR ACTIONS	**THOMAS KOSHY** SR. REACTOR SYS. ENG., EAB

SEQUOYAH UNIT 2

EXTRACTION STEAM HEADER RUPTURE

ACRS BRIEFING - JULY 9, 1993

AIT INSPECTION REPORT 50-327,328/93-10

AIT TEAM LEADER: JEROME J. BLAKE, RII

AIT TEAM MEMBERS: BILLY CROWLEY, SR. ENG. INSPECTOR, MATERIALS & PROCESSES SECTION, RII

DAVE LABARGE, NRR SR. PROJECT MANAGER, SEQUOYAH

PETER KANG, ELECTRICAL ENGINEERING BRANCH, NRR

KRZYSZTOF PARCZEWSKI, MATERIALS & CHEMICAL ENGINEERING BRANCH, NRR

PROBLEM

- A 10 CM (4") WIDE AND 15 CM (6") LONG RUPTURE OCCURRED ON A 25 CM (10") DIAMETER EXTRACTION STEAM LINE PROVIDING STEAM TO FEEDWATER HEATER NO. B2.

- EXTRACTION STEAM HEADER RUPTURE RESULTED IN APPROX. 19% INCREASE IN VOLTAGE AT THE SAFEGUARDS BUSES.

SAFETY SIGNIFICANCE

- POTENTIAL DEGRADATION OF SAFETY-RELATED EQUIPMENT WHEN SUBJECTED TO OVERVOLTAGE.

- PERSONNEL HAZARD.

OVERVIEW

- AT 14:20 HRS. AN OPERATOR PLACED A FUSE PULLING TOOL ON THE WRONG FUSE. MOVEMENT OF FUSE RESULTED IN NO. 3 STEAM GENERATOR LEVEL CONTROL VALVE GOING CLOSED.

- WHILE OPERATORS WERE ATTEMPTING TO MANUALLY CORRECT STEAM FLOW/FEED FLOW MISMATCH, AN OVERVOLTAGE CONDITION WAS OBSERVED IN THE CONTROL ROOM.

- THE OPERATORS RECEIVED THE FOLLOWING ALARMS ASSOCIATED WITH THE MAIN GENERATOR:
  - EXCITER RECTIFIER POWER LOSS;
  - EXCITER INSULATION RESISTANCE LOW;
  - GENERATOR EXCITER FIELD OVERCURRENT;
  - GENERATOR VOLTS PER CYCLE HIGH;
  - GENERATOR VOLTAGE REGULATOR TRIP TO MANUAL;
  - 6.9 KV BOARD 2B-B & 2A-A OVERVOLTAGE.

OVERVIEW (CONT.)

- THE GENERATOR VOLTAGE REGULATOR APPEARS TO HAVE SENSED A LOW VOLTAGE AND TRIPPED TO MANUAL FROM EXCESSIVE HEAT AND MOISTURE CIRCULATED BY THE CABINET'S VENTILATING FAN.

- MANUAL CONTROL OF MAIN GENERATOR VOLTAGE GAVE THE OPERATORS A SECOND PROBLEM (ALONG WITH THE STEAM FLOW/FEED FLOW MISMATCH.)

- THE OPERATORS TRIPPED THE PLANT SINCE THE VOLTAGE COULD NOT BE MANUALLY REDUCED. THE VOLTAGE BECAME NORMAL AFTER THE TRIP WHEN POWER TRANSFERRED TO OFFSITE SOURCE.

- THE CONTROL ROOM WAS INFORMED OF THE STEAM LINE BREAK DURING MANUAL CONTROL OF FEEDWATER AND MAIN GENERATOR VOLTAGE.

DISCUSSION

- THE INCREASE IN VOLTAGE APPEARED TO HAVE BEEN NO MORE THAN 20% AND PLANT DATA INDICATED THAT IT LASTED FOR ABOUT 3 MIN. 38 SEC. (BOTH VOLTAGE CHART RECORDERS WERE OUT OF SERVICE.)

- VOLTAGE RISE LIMITED BY INTRINSIC EXCITER SATURATION CHARACTERISTIC.

- TVA SPECIFIES ELECTRICAL EQUIPMENT FOR 25% OVERVOLTAGE.

- THE 161 KV SWITCHYARD VOLTAGE WENT FROM ABOUT 166 KV TO ABOUT 181 KV ACCORDING TO THE LOAD DISPATCHER.

DISCUSSION (CONT.)

- THE ANALOG METERS ON THE EDG PANELS REGISTERED BETWEEN 8.1 AND 8.2 KV (19% ABOVE THE NORMAL OF 6.9 KV).

- NO SAFETY-RELATED ELECTRICAL EQUIPMENT DEGRADATION WAS IDENTIFIED.

- THE FAILED PIPING WAS ALLOWED TO ERODE WITHOUT DETECTION BECAUSE THE SEQUOYAH EROSION/CORROSION PROGRAM LACKED MANAGEMENT ATTENTION IN PROVIDING RESOURCES AND DIRECTING RESPONSIBILITY.

- THE CHECMATE PROGRAM MODELING FOR THE RUPTURED SECTION DID NOT CONSIDER 6 VENT LINES FEEDING HIGHER MOISTURE CONTENT INTO THE EXTRACTION STEAM LINES.

DISCUSSION (CONT.)

- THE CHECMATE MODEL WAS ASSEMBLED BY AN ENGINEER FROM THE LICENSEE'S CORPORATE OFFICE AND THEN TURNED OVER TO THE SITE.

- THERE WERE THREE EARLIER INSTANCES THAT REVEALED PROGRAM WEAKNESS:

  - ♦ 1985 REPLACEMENT OF 25 CM (10") FEEDWATER HEATER ELBOWS BECAUSE OF SEVERE EROSION.

  - ♦ SEPTEMBER 1991 REPAIR OF A WEEP-HOLE AT THE JUNCTION OF 25 CM (10") AND 50 CM (20") LINE AT HEATER 2C.

  - ♦ A VISUAL INSPECTION DURING THE PLANNED WELD REPAIR IN 1992 OUTAGE AT THE JUNCTION OF 25 CM (10") AND 50 CM (20") PIPING COULD HAVE DETECTED THE DETERIORATION.

DISCUSSION (CONT.)

- REGION II IDENTIFIED PROGRAM DEFICIENCIES WHEN A REACTIVE INSPECTION WAS CONDUCTED IN EARLY FEBRUARY DUE TO A 7.5 CM (3") DIAMETER PIPE BREAK. {THE LICENSEE'S PROGRAM MODELED ONLY DOWN TO 10 CM (4") DIAMETER UNLIKE THE EPRI RECOMMENDATION OF PIPES DOWN TO 5 CM (2") DIAMETER.}

CAUSES

- THE INITIATING EVENT APPEARED TO HAVE BEEN A PRESSURE PERTURBATION ON THE EXTRACTION STEAM HEADER POSSIBLY CAUSED BY A LEVEL CONTROL VALVE CLOSURE FOR STEAM GENERATOR NO. 3.

- THE OVERVOLTAGE CONDITION WAS CAUSED BY THE VENTILATION FAN CIRCULATING STEAM INTO THE MAIN GENERATOR VOLTAGE REGULATOR CABINET.

- THE RUPTURE OCCURRED AT DEGRADED PIPING UNDETECTED BY THE LICENSEE'S DEFICIENT EROSION AND CORROSION MONITORING PROGRAM.

FOLLOWUP

- REGION II CONDUCTED AN AIT INSPECTION FROM MARCH 3 THRU 11, 1993 CONCLUDING WITH AN EXIT AND A PRESS CONFERENCE.
- A CAL WAS ISSUED ON MARCH 4, 1993.
- BASED ON THIS EVENT AND OTHER CONCERNS EVOLVED DURING THE NRC REVIEW, A RESTART PANEL WAS ESTABLISHED TO COORDINATE STAFF ACTIVITIES AND MONITOR LICENSEE'S RESTART ACTIONS.

LICENSEE ACTIONS

- INSTALLED SHUTDOWN BOARD VOLTAGE RECORDERS.
- A SECOND VOLTS/HERTZ RELAY WILL BE INSTALLED TO AUTOMATICALLY TRIP THE PLANT AT APPROX. 15% OVERVOLTAGE.
- SATISFACTORILY CHECKED OUT AFFECTED ELECTRICAL EQUIPMENT.
- EROSION/CORROSION PROGRAM IMPROVEMENTS:
  - ♦ PROGRAM RESPONSIBILITIES ASSIGNED.
  - ♦ REVISED APPLICABLE PROCEDURES.
  - ♦ UTILIZED EPRI ASSISTANCE FOR REVIEW.
  - ♦ 3000 FT. SMALL BORE & 300 FT. LARGE BORE PIPE PLANNED TO BE REPLACED IN EACH UNIT.
- LESSONS LEARNED APPLIED TO OTHER PROGRAMS.
- PERFORMED SECONDARY PLANT DESIGN STUDY.

NRR ACTIONS

PRE-EVENT

- BULLETIN 87-01: MONITOR PIPES IN HIGH ENERGY CARBON STEEL PIPING SYSTEMS (JULY 9, 1987).
- NUREG 1344: EROSION/CORROSION INDUCED PIPE WALL THINNING IN US NUCLEAR PLANTS (MARCH 1989).
- GENERIC LETTER 89-08: REQUIRED A PROGRAM TO PREVENT FAILURES FROM EROSION/CORROSION (MAY 4, 1989).
- INFORMATION NOTICES:
  - ♦ 91-18 MOISTURE SEPARATOR REHEATER LINE RUPTURE AT MILLSTONE UNIT 3, FEEDWATER LINE WALL THINNING AT SAN ONOFRE UNIT 2 AND LOVIISA (MARCH 12, 1991).
  - ♦ FEEDWATER LINE EROSION INFORMATION NOTICES 87-36, 86-106, ETC.
- AUDITED (USING A DRAFT TI) LICENSEES' EROSION/CORROSION PROGRAM AS A REGIONAL INITIATIVE AFTER MILLSTONE 3 EVENT.

NRR ACTIONS (CONT.)

POST-EVENT

- EDO LETTER TO NUMARC: HIGHLIGHTED RECENT EVENTS AND REQUESTED ADDITIONAL GUIDANCE TO THE INDUSTRY (MARCH 15, 1993).

- ELECTRICAL ISSUES
  - ♦ MAXIMUM VOLTAGE AND THE DURATION OF THE OVERVOLTAGE CONDITION WAS WITHIN EQUIPMENT RATING FOR SEQUOYAH.
  - ♦ GENERIC IMPLICATIONS ARE BEING REVIEWED.

- INFORMATION NOTICE IS PLANNED TO INCLUDE RECENT EVENTS.

- PARTICIPATION IN RESTART PANEL.

SEQUOYAH NUCLEAR PLANT UNIT 2

EXTRACTION STEAM LINE RUPTURE