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UNITED STATES NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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JOINT MEETING OF THE SUBCOMMITTEES ON

DECAY HEAT REMOVAL AND

THERMAL HYDRAULIC PHENOMENA

The Westbrook Inn

The Yellowstone Room

475 River Parkway

Idaho Falls, Idaho

Wednesday, August 29, 1990

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D. WARD, ACRS Subcommittee Chairman

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PROCEEDINGS

[8:30 a.m.]

MR. WARD: The meeting will now come to order.

This is a joint meeting of the Advisory Committee on Reactor Safeguards Subcommittees on Decay Heat Removal and Thermal Hydraulic Phenomena.

I'm David Ward, Chairman of the Decay Heat Removal Systems Subcommittee, and I will chair the session today.

Other ACRS members in attendance are: Mr. Catton, Mr. Carroll, Mr. Kerr, Mr. Michelson. We're also privileged to have ACRS consultants, Mr. Davis and Mr. Schrock.

The purpose of the meeting is to explore the use of feed-and-bleed for decay heat removal in pressurized water reactors.

Paul Boehnert is the cognizant ACRS staff member for the meeting.

The rules for participation were announced as part of the notice of the meeting published in the Federal Register on August 9, 1990. A transcript is being kept and will be made available, as stated in that notice.

I will request that each speaker identify himself or herself and speak with sufficient clarity and volume so that he or she can be readily heard by both the attendees and the recorder.

We have received no written statements nor requests to make oral statements from members of the public.

Let me make a few comments, primarily to the Subcommittee, before we begin, or as a part of our beginning.

As I stated, our purpose is to review what we have called feed-and-bleed or bleed and feed in pressurized water reactors. We want to consider the status of the technical understanding of feed-and-bleed as a process. We also want to consider the status of regulatory and industry postures with regard to feed-and-bleed, and I'd like to see us come to some sort of conclusion whether we're satisfied with either or both of these, both the technical understanding of the process and the regulatory and industry postures, and if not, we may want, I think we will want to consider developing some ACRS advise on what should be done differently.

Just to remind you, the feed-and-bleed is a bit of an odd duck. It's now generally recognized that feed-and-bleed can be a significant last-ditch means to cool a core, given certain circumstances where more usually-used systems are not available. This wasn't always so. It wasn't always recognized as an appropriate means to cool a core, and in fact, PWRs are really not explicitly designed to feed-and-bleed.

The risk analyses that have been done are a bit ambiguous about the magnitude of benefit that comes from use of feed-and-bleed. In fact, in some cases, they are even ambiguous about the direction of the benefit, whether there is a net benefit or not. And as with so many things, there are indications that the benefits, if there are any, are very highly plant-specific. The NRC has, so far, taken no actual regulatory position with regard to feed-and-bleed.

There are several aspects of this package of things we call "feed-and-bleed" that are important.

First are the thermal hydraulic heat transfer phenomena. For the primary system, the path for steam generated in a core, to remove the heat, to pass through the hot leg, the surge line, and the pressurizer, and out the PORV is a complex path that isn't always simply available by opening valving or turning on pumps. The equipment that's required, the valves and the injection pumps, don't necessarily all have the appropriate flow and pressure ratings to do the job.

Another issue is the reliability of the equipment. In general, the equipment that would be called on to feed-and-bleed isn't safety-grade. The degree of redundancy available is not always clear; certainly, it varies from plant to plant. And the capacity in a given plant to successfully feed-and-bleed with some of this equipment in a partially degraded state is a complex question.

Then, another aspect is the instrumentation. Feed-and-bleed is fairly -- as I said, is fairly complex. It's not clear that, in all plants, there is adequate indications to the control room of what's going on during the process.

Also important is the status of our procedures that are provided. This isn't an action that's taken every day, certainly, and so, good procedures are probably essentially to successful cooling of the core.

The operator training, including the extent of what available simulators can actually simulate accurately the feed-and-bleed process, is another question.

Most of the discussion in the past has been about what we call "primary" feed-and-bleed, bleed directly from the reactor vessel. But there is also sort of a parallel process, a secondary feed-and-bleed, that can have a safety role, and some of the same issues are important there, and for that reason, we have asked, on today's agenda, that the role and description of what is sometimes called "secondary" feed-and-bleed should be discussed.

About 2 years ago, there was a report issued by EG&G/Idaho on decay heat removal using feed-and-bleed in U.S. PWRs. That's NUREG/CR-5072. It, I think, pretty effectively presents the status of what's known, the understanding of feed-and-bleed, and it comes to the conclusion, which I think is a reasonable conclusion, that what it calls "operating considerations" are paramount in assuring whether or not the process of feed-and-bleed can contribute to successfully cooling a core.

So, I think what we're going to want to listen to today and consider is whether the operating considerations are getting appropriate consideration in today's -- from licensees and from the regulators.

Let me make a couple of comments on the agenda.

First, we have moved item D. Mr. Blumberg of the NRC has suggested that we move item D to the end of the agenda, and I think that's probably appropriate. I put it up earlier on the agenda, originally, because I wanted to emphasize the point that there are no regulations, and I think we can simply stipulate that.

There are no regulations, but the NRC does have some activities underway, and Mr. Blumberg suggested it may be easier for him to describe those activities after we've heard everything else than before, and so, we have moved that to the end.

Let's see -- one other comment: On items A and B, particularly with item B -- Mr. Condie?

MR. CONDIE: Wherever Condie is, Larson should be in, and wherever Larson is, Condie should be

MR. WARD: Oh, okay. Okay.

I had stuck in item B a summary description of the feed-and-bleed processes early on the agenda, and that's kind of redundant wi'.ı the technical description, which comes later. But my purpose there was just to give a brief -- as I say, a summary description early on, before we started talking about the topic, so that we all, especially here at the table, understood what was being discussed, and it may or may not be necessary to do that, depending on what Lou Shotkin says in his discussion.

Anyway, with item B, Mr. Larson can just make that pretty brief and just kind of a technical description of the processes, to get us all on a level playing field at the start of our discussion, so everybody knows what we're talking about. Is that okay?

All right. That's what you had planned all along, right? Okay. Good.

Okay. Does anyone else at the table have something they'd like to say before we go to Mr. Shotkin?

[No response.]

MR. WARD: Okay. Lou, it's yours.

MR. SHOTKIN: I'd like to thank the people at Idaho, particularly Sam Naff, and other individuals, who have put together a large effort, going down memory lane in many cases, to get ready for this meeting, and we do want to express appreciation for that.

What I would like to cover are two items on the agenda: item A, which I call preliminary discussion, or introductory remarks, and item N, which is entitled "Documentation." I think the two of them would be best done together. You will hear about documentation in several of the Idaho talks, as well, and I believe you already have copies of the handout.

[Slide.]

MR. SHOTKIN: I'll try to answer many of the questions that were asked in the material that we received.

First, NRC currently has no specific projects going on, either in research or regulatory, that are directly concerned with feed-and-bleed. I would like to, on this view-graph, go through three projects that -- or two projects that we did have.

First, several years ago -- and this was back in the early 1980s -- NRR had a project on shutdown decay heat removal, which involved Sandia Labs doing PRAs and Los Alamos doing TRAC calculations. You will hear many of the results from that study today, and also, many of the results of that study are also in this NUREG report on feed-and-bleed that the Chairman mentioned.

The NRR contacts for this project are Thad Marsh and Chu Liang, and if you want to contact anyone, the correct person is Mr. Liang, who is still cognizant of this.

Mr. Marsh moved away to other areas several years ago.

For this project, a LANL effort was -- and it was hard to make this estimate, but the LANL effort was bout \$750K. The contact is Brent Boyack. He would still be the contact today.

The Sandia effort was also about \$750K, and that is really a ballpark estimate, and the contact there is Alan Camp, even though his name is not mentioned, I believe, in any of the documents.

That was an important study, and you'll hear more about that today.

Second, the Office of Research sponsored a synthesis report on research related to primary feed-and-bleed. It was our first synthesis report, this NUREG that the Chairman mentioned. We did it on feed-and-bleed, primary feed-and-bleed.

We have a second synthesis report that is being worked on on natural circulation, which -- natural circulation under -- not severe accident but under normal operating conditions -- I mean abnormal operating conditions.

The cost for this synthesis report, which came out in June of '88, was about \$50K. The contacts for NRC are Don Solberg and, for Idaho, Mr. Loomis.

This synthesis report contains 57 references to previous analytic and experimental results. You will hear many of them today. However, there has been work going on since that report was written, and the material that is not covered in that report are primarily analyses of data from two experimental facilities: the MIST facility, which was B&W geometry, and the ROSA IV facility in Japan. And that leads me to my next view-graph.

MR. CARROLL: Lou, the Los Alamos work is documented in this?

MR. SHOTKIN: The Los Alamos work is referenced in this work and is summarized; a good part of this report is a summary of the Los Alamos work.

MR. WARD: He's got another -- an earlier, 1985 report, I think. That's the Boyack report.

MR. CARROLL: So, that's the Los Alamos report.

MR. SHOTKIN: Yes, I believe so. There were other reports. That seems to be the summary report, though. But there are other reports referenced.

In this synthesis report are many of the answers to the questions that the Subcommittee asked us to present to you during this meeting, and I hope we will be able to answer them.

[Slide.]

MR. SHOTKIN: As I say, many -- later work, since 1988, is not covered in the synthesis report, and on this next view-graph, I will just give you a sampling of documents that are not ted in the synthesis report.

First is the MIST test results. There were two test series that covered feed-and-bleed. The reference is NUREG/CR-5395. Volume 5 of that MIST data, final data reference is the test group 33, which contained 4 tests on HIP-PORV cooling; that's what it was called. Today we're called it "primary feed-and-bleed."

In addition, test 4 of test group 36 in Volume 8 was a test that was also HPI-PORV cooling but involved it with the pump going, primary pumps going, whereas the test group 33 had the pumps coasting down.

There was a Los Alamos report on a post-test analysis of one of these MIST tests from test group 33. The reference is given there, and I assume Los Alamos is going to cover that today.

Next, there was a regulatory and backfit analysis that came out in November 1988 on the unresolved safety issue A-45, which was the feed-and bleed unresolved safety issue. I will have more to say about that in my concluding remarks, but effectively, what I will say is that A-45 has been subsumed in the IPE process.

Finally, the question of feed-and-bleed has a special relevance for Combustion Engineering plants that do not have PORVs. There was an early report, in 1984, that evaluated this need for rapid depressurization capability in Combustion Engineering plants, and more recently, this year, SECY-90-232 came out with a resolution of this Generic Issue 84, which was the generic issue involving Combustion Engineering plants, which effectively said that we could not -- NRC could not justify the backfit of PORVs on these Combustion Engineering plants. And the NRC contact for that issue is Roy Woods.

That's all I had planned to say now, and I plan to cover more in my concluding remarks. But I'd be glad to answer any questions, if there are any.

MR. WARD: Okay. Any questions for Lou?

[No response.]

MR. WARD: Thank you very much.

Mr. Larson?

[Slide.]

MR. LARSON: Good morning.

Contrary to the schedule, which we have already discussed, my name is not Condie; it's Larson.

This presentation, as Mr. Ward already alluded to, is really in two parts, the first part of which will be a very brief summary of the feed-and-bleed processes for both primary and secondary feed-and-bleed, or more appropriately, feed-and-steam, and later on in the morning, I will get into some of the more appropriate technical details that deal primarily with primary feed-and-bleed.

[Slide.]

MR. LARSON: In terms of an outline, as we have already discussed, I intend to cover a summary description, talk a little bit about plant states that may require feed-and-bleed cooling of one or the other of the two, primary or secondary. With respect to primary feed-and-bleed, in particular, I will address some of the key factors, the phenomena that have been shown to be of importance in determining the viability of feed-and-bleed, and lastly, provide some conclusions.

What the first two bullets constitute, really, is part 1 of this presentation; the second two are really for later on this morning.

[Slide.]

MR. LARSON: In the most general sense, to me anyway, primary feed-and-bleed -- both feed-and-bleeds are relatively simplistic processes, although when you get into the details, obviously there are a lot of complicating factors.

For primary feed-and-bleed, assuming that you've got ECS capability, make-up plus HPI, your objective is to pump cold water into the system, let that cold water heat up, if you will, absorb decay heat, flash, and then discharge that heated up liquid -- it will probably be vapor at that point in time -- through the PORV thereby effecting a mass and energy balance on the system.

[Slide.]

MR. LARSON: The next slide is simply a cartoon that displays these basics. There are some other assumptions that normally are associated with primary feed-and-bleed.

You wouldn't be in primary feed-and-bleed unless you had a loss of steam generator cooling capability and those kinds of things. But for the time being, we assume that some HPI capability is available; push that into the system, where it mixes, gets heated up. You open the PORV, at least in the feed-and-bleed sense, which then discharges something out through the PORV.

Now, what that "something" is is also a question, as we will see later on in the morning. It can make a big difference on the feed-and-bleed process, on the window for feed-and-bleed process operation, what you're actually discharging out through that PORV, whether it's saturated steam, a two-phase mixture, or liquid. And I think Keith Condie has got some slides from experiments that have been conducted in facilities that have run feed-and-bleed-type experiments to show what the difference in the energy and mass transfer rates is, given those different conditions upstream in the pressurizer.

MR. MICHELSON: Do you also consider it might be intermittent vapor and liquid?

MR. LARSON: Quite possibly.

MR. MICHELSON: That's a part of your analysis?

MR. LARSON: That's not part of an analysis; that's difficult to do. You can make assumptions, and actually, I have done that, assume a quality and then see what difference that makes in the feed-and-bleed map. The codes, however, presumably calculate the occurrence of this, or the mixture, thermodynamic state upstream of the PORV and, hence, the energy discharge rate.

[Slide.]

MR. LARSON: Secondary feed-and-bleed -- I guess, more appropriately, that should be feed-and-steam, because generally, you're steaming out through the steam valve and providing auxiliary feedwater or main feedwater to the generators to provide make-up water.

Steam generator feed-and-steam is really one of the normal operating modes at steady state. Okay? I kind of lost track of that when I was preparing this presentation, but it was pointed out to me that steam generators operate that way in the normal mode.

So, basically, all you're doing is pumping water into the generator. Presumably, there is energy transfer from the primary to the secondary, either -- well, conduction, obviously, and convection on both sides, hopefully, unless there is a -- if the pumps are tripped, then maybe it's natural circulation; so, the energy transfer regimes may change.

I guess there is also -- we could talk a bit about the once-through steam generator design, which has some somewhat different considerations for secondary feed-and-steam. What I've shown here is a cartoon of a U-tube steam generator.

So, basically, feedwater comes in and goes down the downcomer, maintains some kind of level, presumably a mixture level in the steam generator, steam goes out through the steam line to the condenser, except under normal operating modes, of course, it's going to the turbine.

The B&W plant, with the once-through steam generator, is a bit different. The aux feedwater is generally introduced way up high on the secondary, so there are additional concerns, like feedwater wetting and spreading, what is the effective area for energy transfer, and I suspect Jim Steiner, this afternoon, will talk more about his analyses of the MIST facility and some of the complications of that different geometry.

[Slide.]

MR. LARSON: Plant states that might require feed-and bleed, aside from the normal operating sense at steady state full power conditions when you're generating electricity, assume that there's a case where there's a loss of main feedwater. That's one potential state where you might use feed-and-steam or feed-and-bleed.

Certainly you wouldn't be using primary feed-and-bleed in this case, because you still got aux feed to the secondaries. It's far preferable to use secondary feed-and-steam or feed-and-bleed than it is to primary; it's a cleaner operation.

By the way, these states over here to not reflect any official state. It's just my way of keeping track of state one versus the state two. It's not a -- not a state definition that's on the books anywhere. And also note that these states are listed in terms of increasing operational demand. Not to imply that that's -- the implication there -- it's an increasing hardship on the plant as you go downward or the states increase. It's a more severe situation.

State 2 then, for example, assume that there's a loss of main feedwater, but you've still got aux feed water available to all the steam generators, another potential circumstance.

MR. MICHELSON: When you say main feedwater, do you mean high pressure main feedwater, or do you consider the possibility of dropping down to even lower pressures on the secondary side. And you don't have to have the main turbines -- the main feedwater turbines?

MR. LARSON: Oh, true. Some plants have electric motors, or --

MR. MICHELSON: No, no. You don't need the high pressure stage to feedwater to the generator if you want to drop the pressure on the generator.

MR. LARSON: Sure.

MR. MICHELSON: And so, as long as you can get any kind of feedwater in, you might have the possibility of cooling that way.

MR. LARSON: Oh, certainly. Certainly.

MR. MICHELSON: So, I didn't know what you meant by main feedwater. I'll keep in mind. The procedures ought to tell the operators how to maneuver with the loss of the main feedwater pump, but not loss of the condensate pump. Because you can feed even with a condensate pump, if you drop the pressure on the secondary.

MR. LARSON: Oh, sure -- shut off to get water in it, yes.

MR. MICHELSON: Just clarification.

MR. DAVIS: You said in state 2, with all aux -- available to all steam generators -- your slide says one steam generator. Is the slide correct?

MR. LARSON: Both statements are correct. Like I said, this is just the way to think about this potential state where I could have loss of what I consider main feedwater with aux available to all generators. And the second state could be aux feed available to at last one, like TMI.

And that's fairly important because I think, like Mr. Ward already said, plants weren't necessary designed with feed-and-bleed in mind. But if you look at the current design, it's my understanding that all plants, if aux feed is available to one steam generator, they can remove decay heat.

A third state might be -- states 1 and 2 assume no break in the primary. State 3 might be a situation where I do have a small break LOCA, aux feed into only one steam generator. But it might be such a small small break that the energy flow out the break is insufficient to provide any amount of cooling above and beyond the decay heat plus the pumping power input.

State 4 -- perhaps a total loss of steam generator secondary cooling: No main feed, no aux feed, no condensate pumps; but we could have a small break LOCA in the primary. Now, again, depending on the break size, range, maybe the small break itself is enough to -- to remove sufficient energy from the system to affect a cool-down, maybe it's not.

The last case might be no small break LOCA and no secondary cooling. That might be a case where you'd --

MR. MICHELSON: Ultimately, you've got the -- the safety valves themselves on a primary system will start opening if you don't take the energy out, so you always have --

MR. LARSON: Yes, sure.

MR. MICHELSON: -- a small break LOCA of some sort on the primary side.

MR. LARSON: Eventually you could always get one of the pressure -- sure.

MR. MICHELSON: Yes. It just comes whether you want it or not.

MR. LARSON: All right, the important point here -- this -- these are increasing operational demand, hardware demand availability, etcetera on the system hardware.

[Slide.]

MR. LARSON: In terms of operational priority, I think I've already said basically what this slide says, the secondary feed-and-steam, that's really a normal operating mode. Everything is fully operational, the plant is up and running.

A second possible operational priority is when all the steam generators are available with aux feed. That's not necessarily a normal operating state, but again, it's still a case where secondary feed-and-bleed could be effected -- would be most likely effected.

A third -- third --

MR. CARROLL: This is a normal operating state on the start-up of a plant that has steam-driven main feed pumps.

MR. LARSON: That's true -- that's true.

The third operational priority might be one steam generator with aux feed available. Again, that's -- that's a situation where secondary feed-and-steam work.

The last operational priority might be a case where I have to use primary feed-and-bleed. Now, we're all familiar with the complications associated with primary feed-and-bleed. You've got to take water, you've got to dirty up the containment perhaps, radway storage tanks are of limited supply.

Operational priorities really means that -- the bottom one is probably my last resort, certainly not my first resort, if I've got secondary cooling.

[Slide.]

MR. LARSON: The next two slides -- I want to make perfectly clear that these are what I call functional requirements for the operability of secondary or primary feed-and-bleed. It doesn't mean that plants were designed to satisfy these operational requirements.

If you look at secondary feed-and-bleed, as I mentioned earlier, a requirement for secondary feed-and-bleed is that secondary operation is possible with some sort of injection capability. As Mr. Michelson pointed out, that could be aux feed, could be main feed, could be other -- some other source of water. As long as I can get some water in and there's the potential to use secondary feed-and-bleed, it is my understanding that the design capability of all current plants is such that with aux feed in one generator, decay heat can be removed.

[Slide.]

MR. LARSON: There is a similar slide for primary feed-and-bleed. Again, the functional requirement is that -- if we limit our discussions to PORV flows, anyway -- it's also been pointed out that safety's on a primary system may also, given a high enough head in the HPI pumps so you can get mass back into the system, the safety's may also be used in the primary feed-and-bleed sense.

The requirement here is really that the energy flow out of the system, whether it be the PORV or the safety's or whatever, the energy flow has to be greater than or equal to the decay heat plus pumping power, if the pumps are still running. In other words, the energy in is equal to the energy out -- First Law.

Design capability; again, it's my understanding that most plants with one PORV satisfy that requirement. There are a few plants -- I think Millstone is one -- that may or may not meet this requirement. I assume we'll hear more about that later today.

MR. MICHELSON: Now, did you look at the systems from the viewpoint of the operability of the valves that are required to function, since you have the lead valves?

MR. LARSON: Do you mean from a risk standpoint?

MR. MICHELSON: Well, not necessarily for risk; just from strictly a mechanistic standpoint. In other words, if you lose all plant air, how much of the feed-and-bleed capability is gone? Perhaps all of it, depending on the plant. I don't know.

MR. LARSON: Do you lose the PORV capability?

MR. MICHELSON: Would you have the capability to depressurize on the secondary and on the primary, except for the spring-loaded release. Do you look at things like that, or does somebody else do that?

MR. LARSON: I'd assume that the John will address that.

MR. MICHELSON: John will tell us about that; okay, thank you.

[Slide.]

MR. LARSON: It's also my understanding that plants with only one of two PORVs operating may have some complications. In other words, it may take them a certain amount of time to get depressurized to a point where their HPI pumps come on. Now, as we'll see later, there are a lot of interconnected factors here like the HPI headflow curves, the assumptions on how many trains are available, what the actual decay heat level is, et cetera, et cetera. There are a lot of factors that feed into the feed-and-bleed operating map window.

Nevertheless, there are some plants that may take a certain amount of time before you can depressurize them with only one of two PORVs to get down to the HPI shutoff so that you can actually start putting HPI water in.

[Slide.]

MR. LARSON: This next slide is really bit of a summary and will lead into what I will discuss in the next presentation; that is, what kinds of things influence feed-and-bleed feasibility? We've already, in a roundabout way, discussed a lot of them.

Obviously the governing parameter linked to mass and energy balances are a key factor. The equipment availability is a key factor. The range of initial conditions that the plant is in, also is an important consideration. Can I get from wherever I am down to a state where a feed-and-bleed is a viable option.

That's something that feed-and-bleed maps will not tell us. A feed-and-bleed map will tell you where the window of steady state operation for feed-and-bleed is, but it doesn't tell you exactly -- it doesn't give you much help on whether I can or can't get there. That's where the large codes come in.

Geometry effects and system scale; as I said earlier, Keith will talk a bit about comparisons between LOFT Semiscale and I'm aware of some of the MIST experiments. They all seem to imply that feed-and-bleed is a viable decay heat removal mechanism.

The details of each of the transients in each of the experimental facilities are a bit different, but the general phenomenon is, indeed, the same. I will, in a later presentation, talk a bit about geometry effects, including search line orientation, flooding and that sort of thing.

[Slide.]

MR. LARSON: The last slide in your first handout contains something that Lou has already alluded to. It's just a partial laundry list of information sources. I think any one of these reports has at least 10 or 15 symbolic links to other reports that will detail a lot of the presentations that you're probably going to see later this morning.

MR. MICHELSON: I have a question. Back on your slide where you said on the primary feed-and-bleed, on PORV

satisfied the requirement, is that true if the PORV is
passing liquid, for instance?

MR. LARSON: In some case, yes. It depends,
again, on what the decay heat level is.

MR. MICHELSON: This seemed to be a general
statement that says every plant could -- one PORV could
handle it. Pardon me, you said most plants, okay.

So there are some plants where that may be true if
you're passing steam, but not necessarily passing liquid.

MR. LARSON: That's true. The complicating factor
there is, if you're only passing liquid, then there's a
crossover between the mass and energy removal rates, and you
have to have a balance of mass and a balance of energy and
there's a window where that occurs which I will show you
later. You've probably already seen these maps.

MR. MICHELSON: The point is; if you're trying to
avoid further pressurization, I guess you've got to get
another PORV open or you will go on up to the safety's.

MR. LARSON: Yes, that may be the same thing, but
the higher you go, the harder it is to get water into the
system on most of these.

MR. MICHELSON: Now, these statements all pertain
to a B&W as well as GE and Westinghouse?

MR. LARSON: Well, assuming that it's not a System
80 without a PORV.

MR. MICHELSON: Clearly.

MR. CARROLL: One clarification: you said that the mechanism was feedwater in and steam flow to the condenser, but sometimes it could be the pressure relief valve.

MR. LARSON: It could be ADVs or SRVs.

MR. CARROLL: Okay.

MR. LARSON: Again, in Semiscale, we ran some tube rupture experiments, okay, coincident with loss of feedwater in that affected steam generator, if you will. Part of the recovery procedure there was t determine if you can use secondary feed-and-bleed on the unaffected generator or primary feed-and-bleed to get the system pres ure down so that the pressure in that affected generator is such that you don't have to push stuff out the ADV, because it could be dirty water and it makes a mess.

But you're quite right; this is just another hole that energy and mass can flow out.

MR. MICHELSON: I have one more question. In on of your previous slides, again, you pointed out that it may take one and a half hours before you reach the point where you can use HPI injection. During that time, you're depleting the inventory, I assume, since there's no other way to make it up.

Is somebody going to tell us later about the calculations that assure you can ride through that dry period?

MR. LARSON: Los Alamos has done numerous calculations on those kinds of things. H.B. Robinson, I think, is a plant like that. It's got low head HPIs. I can't attest to wh-t Jim is going to say specifically.

MR. STEINER: I think we have some information on that.

MR. MICHELSON: Jim, please pick up a microphone and identify yourself.

MR. STEINER: Jim Steiner from Los Alamos. The answer to that question is, yes, we will be talking about that in our presentations later today.

MR. MICHELSON: Thank you.

MR. WARD: Okay, thank you, Mr. Larson. I see John Bickel is next.

[Slide.]

MR. BICKEL: Gooa m-rning. I'm John Bickel, the Manager of the NRC Risk Analysis Organization at the Idaho National Engineering Laboratory.

MR. CARROLL: What is the risk of the NRC at your plant?

MR. BICKEL: It depends on the day that you pulse it. Basically, our organization performs risk analysis work for the U.S. NRC.

I'd like to discuss three items.

MR. CARROLL: You will agree that it's risky?

MR. BICKEL: We're a risky operation, I agree.

MR. CARROLL: He analyzes the risk of the NRC.

MR. BICKEL: That was not intended. I understand the tapes are running.

Today, I'd like to discuss three items, the first one being the role of feed-and-bleed cooling in decay heat removal. Second, I'd like to talk about the key factors that impact the reliability of feed-and-bleed as a decay heat removal mechanism. Finally, I'd like to discuss insights which have been gained from recent PRAs which were conducted on pressurized water reactors involving transients in which you lost main feedwater, auxillary feedwater and the operators relied on feed-and-bleed cooling as an ultimate decay heat removal mechanism.

We'll discuss basically how it's been modeled and what some of the results show. First of all, feed-and-bleed cooling is an important backup decay heat removal mode in pressurized water reactors.

If you look at operating experience, you look at LERs and data like that, you identify the fact that decay heat removal is frequently demanded on an operational basis, maybe once to 15 times a year, based on actual data. Each time the reactor trips, you have got to provide some mechanism of removing core decay heat.

The primary mechanism that is utilized in pressurized water reactors is, of course, steaming through the steam generators. The main mechanisms considered would be using main feedwater, pumping it into the steam generators, boiling it and then sending it to the condenser.

Alternate mechanisms -- and I think they were discussed in by the previous presenter -- include the use of auxillary feedwater and use of steam dump valves. In some plants, they've got emergency procedures that allow things like, when you've maybe depleted your entire demineralized water storage tank, even going to things as exotic as fire water or service water as an ultimate water source.

Should steam generator cooling --

MR. WARD: Those sources would require depressurization?

MR. BICKEL: That is correct. Typically, you would not get to a point of needing things like fire water until you've completely exhausted all of the water in your DWST and that's usually many hours into an event. You would be, in fact, depressurized.

Should steam generator cooling fail, emergency procedures implemented on basically all of your pressurized water reactors provide mechanisms and they show the operator how to recover coolant. That is your first priority. If you don't have steam generator cooling, try and get it back somehow.

If you can't get the main feedwater pumps -- I think that Mr. Michelson brought up the point that, yes, you can -- they do have procedures instructing them to basically dump through the steam lines, get the pressure way down and you can use a condensate pump. That is explicitly documented in typical power plant emergency procedures.

However, if all of these mechanisms fail and you're basically down to the fact that you've got no way of removing decay heat, feed-and-bleed will then be attempted and is proceduralized in emergency operating procedures in plants.

MR. MICHELSON: This suggestion that the operator is told to do everything he can with whatever source is available before he falls back to primary side --

MR. BICKEL: That is correct.

MR. MICHELSON: Does that mean he would also go to firewater before he fell back to the primary side?

MR. BICKEL: On some plants, they might, and I think that as an example, I think in the combustion engineering plants, they will do anything to try and use the steam generators.

MR. MICHELSON: I'm thinking of the ones that have pretty good bleed.

MR. BICKEL: Yes, that's correct.

MR. MICHELSON: They may not go -- they may not put fire water in before they try the feed-and-bleed.

MR. BICKEL: That's correct -- ah, well, it depends on what the plant has.

MR. MICHELSON: I take it that the staff has no viewpoint one way or the other on the acceptability of doing that.

MR. BICKEL: Well, I think that somebody from the NRC could better comment on that, but the main thing is that there were requirements in the post-TMI era to put out owners group related procedures that were symptom oriented and basically incorporated the use of more types of systems.

MR. MICHELSON: I guess I never appreciated that that use of fire water would use the primary side feed-and-bleed.

MR. BICKEL: It would depend on the specific plant. They'd have to have the capability to do it.

MR. DAVIS: I have a related question.

MR. BICKEL: Yes, Pete.

MR. DAVIS: It seems to me one of the concerns here is that -- is the timing.

MR. BICKEL: That's correct.

MR. DAVIS: If operators spend too much time trying to recover secondary water, they've lost the window of time available for feed-and-bleed on the primary.

MR. BICKEL: You're exactly correct.

MR. DAVIS: I'm wondering if that's accounted for in these procedures, because as you say, there are many options to try to get water in the secondary.

MR. BICKEL: I would say that's something that warrants a lot of further look. I agree with the comment. If you waste a lot of time, you won't work. You know, you basically uncover before you get to the mode.

MR. MICHELSON: Is the window identified in the emergency procedures?

MR. BICKEL: Typically, no.

MR. MICHELSON: How do they know how much time to take, then?

MR. BICKEL: It would basically be based on plant-specific analysis.

MR. MICHELSON: No, but I mean -- I'm talking about plant-specific emergency operating procedures now, of course.

MR. BICKEL: Yes.

MR. MICHELSON: Clearly, if there is a window, it ought to be in there.

MR. BICKEL: The procedures are not typically written in nuclear power plants based on timing. They are based on operator recognition of falling levels in generators and rising pressure and rising core exit temperatures.

MR. MICHELSON: Those are related to the window.

MR. BICKEL: They are related to the window; that's correct.

MR. MICHELSON: So, it says if it gets below a certain point and you haven't got secondary water, go --

MR. BICKEL: Go to feed-and-bleed, yes.

MR. MICHELSON: Okay. This accomplishes the same purpose.

MR. BICKEL: As I was saying, if you get down to that path, your basic option is feed-and-bleed cooling on the primary side. It is accomplished via use of some source of high-pressure make-up. That could be either the charging pumps, in some plants, or the HPI pumps. The mechanism for bleeding off is the PORVs.

Now, first of all, another thing that has to be recognized is that if you go into feed-and-bleed cooling, over the long term, you're going to have to cool the water you've discharged to the containment. So, you've got to additional consider -- once you've opened up a hole, you've basically created a LOCA, like a small LOCA. You've got to then consider areas of things like high-pressure recirculation cooling, and additionally, in some plants, you need to consider containment cooling.

On certain plants, if the back-pressure builds up in the containment, the rising air pressure, pressure in the containment will cause the PORVs to go closed, and that's the end of feed-and-bleed cooling. That is a plant-specific item, and I identify that on my overhead, that that's not all plants, but some PWRs need to consider containment cooling.

MR. MICHELSON: Now, that's only true, though, for low-pressure injection, isn't it?

MR. BICKEL: No. What I'm referring to is the PORVs. You know, like if you've got an AC-operated PORV, it basically, you know, has a solenoid that fires on an air-line, and then the pressure difference in the air system between the -- you know, the air line and the containment air that the air is vented to, if the pressure rises in the containment to a certain level, the PORVs -- some PORVs will go closed.

MR. MICHELSON: The diaphragm no longer has enough --

MR. BICKEL: Yes, exactly.

MR. SHOTKIN: Excuse me. Can I answer Mr. Michelson's question?

MR. WARD: Yes, Lou.

MR. SHOTKIN: The USI-A45 has been around for several years in decay heat removal, and I'll repeat, this has been subsumed within the IPE process. So, there is no staff position on any details of this. It's going to be relied upon to industry to examine their vulnerabilities, submit their capabilities for decay heat removal, and the staff will then review what the industry submits on a plant-specific basis.

MR. WARD: Thank you, Lou.

MR. CARROLL: On your previous slide --

MR. BICKEL: Yes, sir.

MR. CARROLL: -- you used some terminology that I am not sure I understand. What is "high-pressure recirculation"?

MR. BICKEL: I'll show you that in one minute; it's on this slide.

[Slide.]

MR. BICKEL: What I've shown here is a simplified schematic showing what a feed-and-bleed cooling loop in a pressurized water reactor ultimately looks like.

Initially, you would have this recirculation valve of some type closed, and you've got either charging or HPI, which is your high-pressure make-up source, taking suction on borated water from the refueling water storage tank, injects it into the reactor, where it cools the core, and it boils or whatnot, is discharged through one of the hot legs into the pressurizer and out the PORVs. I have shown this plant having two PORVs. There are, in fact, some plants that only have one PORV. There is a lot of variability out there. The bulk of them --

MR. CARROLL: Some of them have three.

MR. BICKEL: Yes, some of them have three. The bulk of them, typically, have about two of them, redundant.

The steam flow, water flow, two-phase flow, whatever you want to call it, will go through the discharge lines of the PORVs, through the block valves, and ultimately, into either what's called a pressurizer relief tank, in some plants; some plants called it a pressurizer quench tank.

When the water in here basically can't take any more of the heat and energy, typically that occurs at about -- in a lot of the plants, maybe at about 200 psig, rupture disk on the quench tank or relief tank pops open, and you get a discharge now onto the containment floor and into the sumps.

If you cannot restore anything and you have to stay on feed-and-bleed cooling indefinitely, this is basically like the recirculation phase in a small LOCA. You will eventually take suction from the containment sump through a low-pressure pump, put it through a heat exchanger, which you cool either with service water or component cooling water, and then recirculate it back in here. You've now got basically a closed loop, and you can basically, in procedure, stay on this as an indefinite source of decay heat removal.

There is nothing tremendously different in this than from a small LOCA in the way you're using high-pressure recirculation, and again, yes, you would depressurize -- the system will depressurize as the decay heat eventually goes away, and it would amount to nothing more than a low-pressure recirculation, eventually.

MR. WARD: Typically, that pressurizer relief tank quench thing doesn't have any cooling capacity, other than the --

MR. BICKEL: It has a very small cooling capacity, but the amount of energy being discharged from an open PORV over the long term, will overwhelm it. As an example, I think that if you look at the design like they had at TMI where there was a lot of documentation, I think the design, typically, of the cooling is handled like a single popping; that it's not really designed for just the full core decay heat being dumped into that tank.

MR. CARROLL: There is a cooling coil on the bottom of that.

MR. BICKEL: Yes.

MR. SCHROCK: What is the status of the block valves? Are they kept open fully?

MR. BICKEL. No. Hot topic.

MR. MICHELSON: PORVs are not necessarily safety grade circuitry, either.

MR. BICKEL: PORVs are --

MR. CARROLL: A mixed bag.

MR. BICKEL: It's a mixed bag. I won't make a comment on it.

MR. MICHELSON: Having two there does not necessarily mean they're redundant.

MR. BICKEL: I have shown the block valves are typically open. Typically, yes, the utility would want to have them open because it does give them pressure protection, but if you had a leaking PORV, I think operationally they close the block.

MR. SCHROCK: Then you don't have that path.

MR. BICKEL: Well, you don't have that path until you unblock it.

MR. SCHROCK: You can open it.

[Slide.]

MR. BICKEL: What I'm showing in my next viewgraph is a simplified event tree of a transient in which the reactor trips. I call on the various levels of, you know, contingencies of decay heat removal systems, the first one, of course, being the use of the main feedwater and condenser system.

That would be the preferred way, if I have a transient, to shut the plant down. It's using normally operating equipment. The operators are very intimately familiar with how the two of them behave from normal operation, and it is, in fact, you know, a very reliable way of removing decay heat.

Should the main feed system fail, we can now revert to the use of auxillary feedwater. Again, this is a fairly reliable redundant system and the operators have typically an awful lot of experience in using the auxillary feedwater, primarily at things like plant startup to remove decay heat.

They have an awful lot of hours logged in doing things like maintaining generator water levels using the aux feed system so they, again, are familiar with it and it's a fairly reliable way of removing decay heat. Should you now get into a point where main feedwater is not working, auxillary feedwater is not working, the main thing that you're going to get into at that point is trying to recover one of the above.

There's a number of options, depending on the plant type; what you're going to attempt to recover. At some plants, they're going to instruct the guy to open up the ADVs and use a condensate pump to get water into the steam generators. On some plants, they have the capability of cross tying the auxillary feedwater flow from one unit to an adjacent unit, so they will look for auxillary feedwater coming from an adjacent unit as a recovery action.

That's typical. As an example, that capability exists on the Surry units which were studied in NUREG 1150. If all of these items fail, you get down to the path --

MR. WARD: In there is where you might have the fire water option, for example.

MR. BICKEL: If you could depressurize low enough, yes, you could use fire water. That's a very, very low pressure source.

If all of these items -- taking these failure paths on the event tree -- you eventually get down to a point of feed-and-bleed cooling. If that is successful, you still have a couple of other things that must additionally occur to successfully cool the core; in other words, to get up to this Path No. 4, which is, everything is okay.

If you initially get feed-and-bleed cooling working, but subsequently fail to provide some way or recirculation at the point when you drain out the reactor water storage tank, again, you can end up in a long term or a late core melt situation. Again, I've also mentioned that on some plants, it may be a necessity to provide containment cooling to assure that the PORVs don't go closed as a result of pressure buildup.

As we now, from a PRA perspective, try and look at the different types of plants out there and the system considerations that would be modeled in trying to assess risk, there are a number of considerations. I've summarized the following slides:

[Slide.]

MR. BICKEL: First of all, main feedwater and condenser are typically available online all the time on your B&W reactors, your Combustion Engineering reactors and your older Westinghouse reactor designs. The implication then is that you're going to have fewer challenges of auxillary feedwater and then even fewer challenges of feed-and-bleed.

On the newer Westinghouse reactors --

MR. CARROLL: That is as long as the trip doesn't result in --

MR. BICKEL: As long as there was not a loss of feedwater trip; that is correct.

MR. CARROLL: Or loss of power.

MR. BICKEL: Or a loss of power. Those would be less frequent transients than the ones that you get one to ten times a year. Typically, a loss of feedwater vent is, you know, is not that frequent. It's much less than once a year.

On a newer Westinghouse --

MR. CARROLL: I disagree with what you said. Feedwater trips are about 50 percent of the plant trips that we see.

MR. BICKEL: I don't know. I worked in a utility for 9 years and we tried to avoid loss of feedwater trips like the dickens.

MR. CARROLL: I worked in a utility for 35 years --

MR. BICKEL: I know you did. You outrank me by 20 some years. Different utilities, I think, have had different experience. I would say that, based on my experience, loss of feed was not the most prevalent type. The most prevalent type we got in pressurized water reactors was water level problems in steam generators that caused trips.

The feed system was available. You know, some people said, well, that was a feedwater related trip, but that wasn't a loss of feedwater. Do you agree with that?

MR. CARROLL: Yes, that's correct.

MR. BICKEL: When you look at new Westinghouse reactors, there is kind of an interesting nuance and that is the fact that main feedwater is isolated by safety grade equipment, post-trip on all reactor trips. So, if you have a reactor trip, the drop in T average will typically close safety related main feedwater isolation valves.

You do not have the use of your main feed system then post-trip. That's a significant change between the new Westinghouse and the older Westinghouse plants.

MR. KERR: These can be reopened?

MR. BICKEL: They could be reopened, but it requires a procedure involving jumpering out the logic that caused the isolation. This was installed basically in plants starting in the early 80's and it was primarily protection against pressurized thermal shock.

Yes, I was in a utility and I thought it was dumb, too, but that's the way the system is designed. You can open them, but you do have to go in with alligator clips and jumper out the logic. It's not as clean as if you just open a valve or something like that.

A clearer indication of this is that on a newer Westinghouse Plant, you are going to have many many more challenges of auxiliary feedwater than you do in the older plants, where the main feed system stayed online. Obviously, then there's additionally more reliance on recovery actions.

An additional item to be considered is that some of the multi-unit sites, where you've got multiple reactors of the same design and they're all right next to each other, they have the capability of cross-tying the auxiliary feedwater. The implication is that given a loss of main feedwater and additionally, a loss of auxiliary feedwater, they can draw on an auxiliary feedwater source from an adjacent unit, and use that in lieu of going to primary feed-and-bleed. And I say, as a good example, that the Surry Plant is one of the plants that has that has that capability.

MR. MICHELSON: By having that capability, you mean it's already hard piped?

MR. BICKEL: It is hard piped and can be accessed from the control room. That is correct.

MR. WARD: John, on the first item.

MR. BICKEL: Yes, sir?

MR. WARD: I guess I had the idea that, in many cases, the main feedwater pumps have trouble following the decr[illegible]mand and often trip off anyway. But apparently that's not a big --

[illegible]KEL: I'm looking at the older plants pr[illegible]

MR. WARD: Yes.

MR. BICKEL: Remember, in the older plants, they were typically of a smaller size. They had electric steam -- they typically had electric feedwater pumps. When they went to the newer larger plants, they had the steam-driven pumps. And your comment is correct. The steam -- steam pumps, you know, on the larger -- the larger, typically newer units have a -- they do have a tendency, you know, to lose them.

The older plants -- typically the vintage of the 60's and 70's, they were less than 900 megawatts, they had electric-driven feed pumps, they can be sustained following the trip and the loss of the steam and all that.

MR. WARD: Okay.

[Slide.]

MR. BICKEL: Continuing on. Older combustion engineering reactors. If you look at the PORV charging pumps and HPI systems, you would reach the conclusion that they have what would be termed as marginal capability to support feed-and-bleed. It's not to say that they are physically impossible, it means to say that the window for using feed-and-bleed in some of these plants is tight and the requirements on the operators to get to feed-and-bleed on those type of plants is very -- you've got very little time, to put it mildly.

The implication of this then would be an increased reliance on main feedwater, auxiliary feedwater and recovery actions. And I've listed here primarily, the use of secondary bleed and feed. In other words, trying to -- if you've lost your main feed pumps, depressurize the secondary side and use condensate pumps.

Those type of procedures, they typically are given higher priority. If all of those things fail in the CE reactor, yes, they are also instructed to a feed-and-bleed type activity, but they have to augment it with other equipment.

The emergency operating procedures on the combustion plants, typically also have in them things like using the pressurizers, sprays, and also trying to dump the steam simultaneously. They basically try and crash the pressure. And they put all that in there to give the operators the best chance they can.

The newer CE reactors do not have PORV's. And the obvious implication there is that they are obviously going to be much more reliant on main feedwater, auxiliary recovery and secondary bleed-and-feed.

MR. KERR: What about their high pressure injection pumps? Can they inject against a pressure that will open the --

MR. BICKEL: Open the safeties?

MR. KERR: Yes?

MR. BICKEL: My recollection is that they use positive displacement pumps. Do you know what -- Dana Kelly, from my staff -- do you have the numbers on that, Dana? Better go get a little microphone.

MR. KELLY: Dana Kelly from INEL.

Typically, the newer CE plants will have, as John was saying, positive displacement charging pumps, separate from the high pressure safety injection pumps. The positive displacement charging pumps could inject about -- with all three running, about 132 gallons a minute against the PORV set pressure. The high pressure injection pumps are lower head, so they could not inject against the PORV set pressure.

MR. CARROLL: You don't mean PORV?

MR. KELLY: I'm sorry, safeties.

MR. WARD: And I gather that the 132 gpm isn't enough to sustain decay heat removal?

MR. KELLY: Not with just acting against the safeties -- I don't believe it is, no. I'm sure that there have been calculations done on that.

MR. BICKEL: I don't think anybody tried.

MR. WARD: Well, wait a minute. If they're a positive displacement pump, it doesn't matter whether they're acting against the safeties or not; does it?

MR. KELLY: The problem being, I think, that the safety may not go full open, it may sit there and chatter against the positive displacement pump.

MR. BICKEL: You can't latch it open.

MR. CARROLL: If you cycle it enough times, then it will probably stay open.

MR. BICKEL: We haven't run that test yet.

MR. CARROLL: But, what we are leaving out of the picture is the -- is the safety grade experiences.

MR. KELLY: Correct. They do have the auxiliary depressurizer spray that operates off the charging pumps. And that will act to bring down pressure somewhat.

MR. MICHELSON: Somewhat.

MR. KELLY: But I don't think they could get it down low enough with that to do with the high pressure injection pumps, or definitely not enough to get down on shut-down cooling.

MR. DAVIS: Excuse me. I thought plants were required now to have a vent on the reactor vessel. They -- they are. Is it possible to use that as a mechanism to depressurize?

MR. KELLY: That's one of the questions I've had. And I've tried to find calculations --

MR. BICKEL: I don't anybody has done the calculation yet.

MR. KELLY: I haven't found any calculations that look it. For example, on ANO-2, using the reactor vent valves for this. Maybe some of the other people, like Mr. Steiner, could leave us that.

MR. MICHELSON: But they're pretty small.

MR. WARD: They are small.

MR. BICKEL: They're just designed for passing gas on top of it.

MR. WARD: Yes. But I think it -- as a matter of fact, at Palo Verde, those are credited along with the pressurizer spray, in combination -- for managing the steam generator 2 brush -- rupture event.

MR. BICKEL: Yes, I can see that. But if you've got a tube rupture, you've also got another source of energy leaking out of the primary.

MR. WARD: No, no that's right. It's another issue. But they are -- they do have some small capacity.

MR. SHOTKIN: He is going to discuss this later. We have the Westinghouse Owners Group Emergency Response Guidelines, not the procedures, the guidelines, and one of them is that if you -- one of the options is to open all the high-point vents, but then it's plant-specific. You have to enter a plant-specific list.

MR. CARROLL: This is Westinghouse or Combustion?

MR. SHOTKIN: Westinghouse.

MR. MICHELSON: You open all the high-point vents? Are you talking about piping vents, as well?

MR. SHOTKIN: Reactor coolant system high-point vents.

MR. MICHELSON: Well, there are some vents on the piping system; there are some on the vessel.

MR. BLUMBERG: I'm Norm Blumberg, NRC.

This is a general guideline, and it says open all high-point vents, and then it says enter plant-specific list. So, you depend on the plant. So, that answers your question: Whatever the plant has is what they would do. And then we'd have to look at it from a plant-specific point of view.

MR. MICHELSON: I think you'd have to look at that very carefully.

MR. CATTON: Have calculations been done for the specific plants to see how effective it would be?

MR. BLUMBERG: I can't answer your question. I don't know the answer to that.

MR. SHOTKIN: I don't think they've been done.

MR. CATTON: I don't think so, either.

MR. MICHELSON: I'm not sure the valving on those vents is designed to be cycled. They are designed for low-pressure venting. The one on the vessel is not, but these others I don't think are designed for operation to full pressure and so forth. Check into it and see. I'd be surprised if they are, because they don't need to be, normally. And you might not want to open them, as a matter of fact.

MR. SHOTKIN: That is a good point.

MR. BICKEL: Okay.

I guess the final comment on this slide which I'd like to emphasize a little bit is that when the feed-and-bleed path is initiated in the primary circuit of the reactor, we've got to point out that multiple operator actions are required. This is not just an automatic thing where you push a button and you just walk away. There are a continuing number of things that the operator will be called on to do, lots of different systems.

This is not a simple decay heat removal mechanism like turning on the auxiliary feedwater system. We've got PORVS. You've got water flowing in a lot of different paths. You've got cooling in the high-pressure recirculation system on some plants. On some plants, you may have to take actions to control containment pressure, as well.

The implication, very clearly, when you make those kind of considerations, is that feed-and-bleed, as a decay heat removal mechanism, will not be as reliable as many of the other types of decay heat removal mechanisms that are your front-line approaches.

MR. MICHELSON: Before you leave that slide, I wanted to ask, did you consider, in looking at this risk evaluation, what the possibilities of the loss of non-essential air might have or even the loss of essential air, depending on how this is all rigged together and how well it's isolated and so forth?

MR. BICKEL: Okay. Carl, typically, in many of the PRAs, they treat issues like loss of air as an initiating event, and the frequency of that event might be something in the range of -- you might see it once in a particular plant lifetime, like maybe once in 40 years. It's clearly a much more complicated event than just a regular reactor scram, the reason being, typically, is that the air system is not only used for the PORVs on plants; it's also typically used to regulate main feed.

So, when you -- like, say, if you dump the air supply, you get a loss of feedwater, and on some plants, it maybe complicated. You know, you may impact the PORVs. However, a lot of plants separate their air systems between the ones they use in the secondary plant and the air system they use in containment, the reason being because of, you know, contamination and things like that.

So, it would typically be a secondary air system. But on some plants, you're correct. You could lose the whole thing in one shot.

MR. MICHELSON: I think you need to look more carefully a safety injection and a number of other systems. They use air-operated valves, also, but they usually have an accumulator valve or something.

MR. BICKEL: Yes.

MR. MICHELSON: But now, keep in mind, that accumulator valve, the check valves, which are all standing now between you and the barrier, have to close, and there may be a bleed down, not a fast loss.

So, how do you know the accumulator -- what's the probability that accumulators are not even going to be able to function properly for the particular scenarios you might name?

MR. BICKEL: Typically, what you're trying to do in feed-and-bleed with the air is to get the PORV and get the cool-down commenced, but your point is well taken, that if you lost air, you could defeat the feed-and-bleed process subsequently, later on.

MR. MICHELSON: Not only that, but you've lost the water injection capability, you've lost the ability to open the PORVs. All that stands between you and real problems is eventually the safety opens, but you don't make up the water.

MR. BICKEL: Yes.

MR. MICHELSON: It's a question of time in which to hopefully do something about what's happening.

MR. BICKEL: Correct.

MR. MICHELSON: But I'm wondering if this is going to be in the safety analysis you're going to tell us about.

MR. BICKEL: I'll tell you a little bit about that in a minute, yes.

MR. MICHELSON: Keep in mind, those PORVs are not too good if you even get degraded air pressure.

MR. BICKEL: Yes.

MR. MICHELSON: You don't have to lose the air; you've just have to degrade it a little bit. You have to have slowly leaking check valves. It doesn't have to be fail to close. And they're not tested, to my knowledge.

MR. CARROLL: Just a comment: I would add to your implication on your last bullet something that the human factors people call the operator reluctance factor.

MR. BICKEL: You are correct.

MR. CARROLL: Your operators can be extremely well-trained in a simulator to go through all of this, they know it's a similar and they do it, but if they are confronted with the real-world problem of initiating feed-and-bleed and propping up the containment --

MR. BICKEL: And having to explain to the boss what they did.

MR. CARROLL: That's bad news.

MR. BICKEL: I agree with you. That is a factor that is considered in the -- like in the human factors assessment, and one of the points I will make, and I'll show that a little bit later, is that the human factor dominates all the equipment issues in the thing. It's the likelihood that the operator will not do it in time that will bag you.

[Slide.]

MR. BICKEL: What I have shown you is the same slide I showed you a little earlier, but added I've added some numbers in now, reflecting the -- reflecting the -- how one would go to quantify accident sequences that involve feed-and-bleed cooling.

And what I'd like to show there is that some of the main transients of interest, which are the normal operating transients that occur most frequently. If I want to -- or if I become concerned about things like losing a DC battery bus or losing the air system, and getting a more complicated transient, the frequency of those type of transients would be a lot less than just a simple plant trip. But they are considered in PRA's that are done today.

MR. MICHELSON: And now, the frequency is less but the consequence could be far greater, because it involves so much. In fact, it involves the entire plant.

MR. BICKEL: It can mess up equipment all across the board.

MR. MICHELSON: And so, you really --

MR. BICKEL: Yes.

MR. MICHELSON: -- can't say it out of hand. You really have to do the PRA --

MR. BICKEL: You have to do the detailed analysis.

MR. MICHELSON: -- correctly and find out.

MR. BICKEL: That' correct.

The main feedwater numbers I'm showing here, typically, I've broken them down into a high range and a low range. For the -- the new Westinghouse Plants that isolate the main feed, well the probability of main feed failing is 1. For the older Westinghouse, the combustion engineering and the B&W reactors, which are designed to try and keep the main feed system running, post-scram. In other words, all they do is they -- they use control grade equipment to run back the feed flow.

Typical experience indicates that about 95 percent of the time, the feed system will be able to continue running. So it would be roughly about a five percent chance of -- of an additional loss of the feed, given that it was not a loss of feedwater trip.

Auxiliary feedwater systems are different in the various plants. You've got some plants that have shared auxiliary feedwater systems. You have some plants that have a combination of one electric and one steam. You've got some plants that include two steam-driven pumps. You've got -- I guess maybe the Cadillac variety, is two electric driven and one steam-driven, and you've basically got like better than triple redundancy.

You can end up with a -- with a fairly wide range of auxiliary feedwater system reliabilities. And the staff in the years right following Three Mile Island, evaluated the reliability of a lot of the existing and operating auxiliary feed systems. And I've shown a range of somewhere between one in a thousand, one and ten-thousand, as the typical results that you would get for the failure probability of auxiliary feedwater.

Recovery actions are, again, very --

MR. CARROLL: On the --

MR. BICKEL: Yes, sir?

MR. CARROLL: -- on the path review of auxiliary feedwater systems, I'm not sure you are the right one to answer the question. But I guess I was a little concerned to learn, a year or so ago, that one very sophisticated utility had a real glitch in their auxiliary feedwater system that was sort of by chance discovered, which suggested to me that the review wasn't as thorough as it might have been.

MR. BICKEL: Hopefully, the IPE process will catch all the other glitches out there, hopefully.

There's a range that in -- the -- what the failure probability --

MR. CARROLL: Can you comment, Lou, on the extent of that review?

MR. SHOTKIN: We are not relying only on the IPE's. As Mr. Blumberg would say, we do send inspection teams out to the plants and do routine inspections, not only on simulator capabilities, but also there are exercises that are run at the utilities where, presumable if -- I don't know what this glitch was, but presumably during those exercises, such a glitch might be uncovered.

MR. CARROLL: It was a control system problem that would have defeated auxiliary feedwater under certain circumstances.

MR. DAVIS: Excuse me, John. It might be a minor point, but, this will not apply for all transients, obviously?

MR. BICKEL: Oh yes, that's correct.

MR. DAVIS: A loss of off-site power transient?

MR. BICKEL: It's completely different.

MR. DAVIS: Completely different. So, it might be --

MR. BICKEL: You lose the main feed in one shot.

MR. DAVIS: -- useful to qualify what you mean by transient.

MR. BICKEL: Okay. The transients I'm talking about are the -- you know, the typical ones that you know, you read about that are more -- the most frequent category. The ones that occur one or more times per year in a typical operating pressurized water reactor.

One of the more prevalent types is the -- is when you get a trip on -- feed steam mis-match in one of the generators. You get a low-level in one generator. It can be caused by something like an INC tech doing a calibration and he hasn't properly jumpered something out, and you get a "boop," and the reactor trips, or you get a flow imbalance, That will trip a pressurized water reactor.

These events are very frequent, but the main characteristic is that the main feed system is -- is not effected. If you're talking a loss of feed water event, you're talking something that occurs less than once per year. It's maybe once every three years in some plants, some plants, maybe even lower.

I agree, there may be a plant that has a loss of feedwater once a year. I would bet though that the regional inspectors would be -- be on them like a ton of bricks about having that high a frequency though.

I was discussing the various numbers that kind of go into a risk assessment of the feed-and-bleed process. The next step in there would be the recovery -- consideration of recovery options that are available on a particular plant.

They range, and I think I've mentioned earlier -- there's a lot of plant-specific type issues here. Some of the plants have the capability to cross-tie and get aux feedwater from an adjacent unit. That would be considered.

Some plants have procedures that direct them to use the dumps, crash the pressure and put in -- use a condensate pump to refill the steam generators. There are a whole series of things that they would attempt.

On the newer Westinghouse reactors, it is not untypical to find a procedure instructing the operators that if you've lost main, or it's been isolated and the auxiliary feedwater is -- is failed, they have a procedure that will instruct them to take, basically, alligator clips and jumper out the logic on the main feedwater isolation valve, so that they can reopen them. Because typically, they will have the pumps running. That's not uncommon. It's -- it's complicated, but it is a -- it is a viable recovery way of getting secondary cooling.

Now, if all of those things fail, you're now down to the node --

MR. WARD: Your number one-tenth there refers to the --

MR. BICKEL: One-tenth.

MR. WARD: -- failure?

MR. BICKEL: The probability of failure -- one-tenth, typically.

When you get to feed-and-bleed cooling, depending on the plant type, the new combustion engineering reactors, I think one might say it doesn't look like you're going to be able to do it. There is a range of values between about 1 in 100 and 1 in 10, for the other types of reactors. And I will show you in a subsequent slide, some actual numbers from recently completed PRA's, where they assessed the failure probability of feed-and-bleed cooling.

And, again, if you are successful in entering the feed-and-bleed cooling path, you still have a couple of other things that you've got to do which, by the way, are also typically operator-dependent. And they would be entering the high-pressure recirculation cooling at the point the RWST water level is too low, and containment cooling, if you need it.

What I've shown under --

MR. MICHELSON: On your --

MR. BICKEL: Yes, sir?

MR. MICHELSON: -- on your CE plant, where you showed one --

MR. BICKEL: Yes.

MR. MICHELSON: -- possibility --

MR. BICKEL: What I'm saying is it's failed.

MR. MICHELSON: Yes. It failed because you don't have it; is that what you meant?

MR. BICKEL: Yes. The likelihood of -- on a System 80 reactor of getting to feed-and-bleed and having it work, given the fact that --

MR. MICHELSON: Well, you don't have a feed-and-bleed capability, you don't --

MR. BICKEL: It doesn't work, it's failed.

MR. MICHELSON: Wait a minute. I'm trying to -- are you talking about a plant without PORV's?

MR. BICKEL: Yes, the System 80's don't have PORV's.

MR. MICHELSON: Right, okay. So, instead of PORV's though, don't they have the capability of lifting the safety with the high pressure injection?

MR. BICKEL: I'm not aware of analysis showing how well that would work, Carl.

MR. WARD: Well, we're back to this question of whether the 132 gpm is enough, and my impression is is that it is not enough.

MR. MICHELSON: Well, first of all, I was wondering -- I thought the HPI's could lift the safeties? I don't know what flow it has by the time it lifts the safety.

MR. WARD: He said 132.

MR. MICHELSON: 132.

MR. CARROLL: But that's charging -- that's positive displacement charging.

MR. BICKEL: The HPI, I think, has a shut-off head that's considerably lower -- it's --

MR. MICHELSON: I'm not that sure of that.

MR. KELLY: The typical shutoff head on the HPI, with Maine Yankee being the oddball here -- Maine Yankee has high-pressure shutoff head; the others are typically in the range of about 1,200 to 1,500 psig.

MR. MICHELSON: What is the charging head?

MR. KELLY: I'm not sure what the full charging head or the rated head of the pump is, but it will go against the safeties.

MR. MICHELSON: It will with the safeties, but you don't know what flow you would get when you --

MR. KELLY: Well, you should get 132 gallons a minute for positive displacement.

MR. MICHELSON: With all three working.

MR. KELLY: With all three running.

MR. KERR: You would have to remove decay heat early on.

MR. MICHELSON: Yes. So, what happens is the reactor continues to pressurize.

MR. KELLY: The reactor itself would lift the safeties, and then the positive displacement pumps are just kind of helping things along, putting a little bit of water in, but like I said, I haven't seen any analysis to show that that small amount of water would really do you any good.

MR. MICHELSON: When you said one here, you meant don't count on that.

MR. BICKEL: It's failed. Don't count on it. Exactly.

MR. WARD: Well, of course, the 130 gpm is going to delay things, give them more time to recover heat exchangers. Do you have any idea whether EOPs take credit for that?

MR. BICKEL: EOPS will always try and put the plant in a safer condition. The problem is that PRAs are a mechanism of estimating risk, and they basically use paths.

MR. WARD: I understand that. I'm sort of asking a question on the side. Do you have any idea whether the System 80 plants have EOPs that would call on trying to use the charging pumps?

MR. BICKEL: I am not 100-percent familiar about what the procedures would be in a System 80 plant.

MR. CARROLL: You would expect they will, wouldn't you?

MR. BICKEL: I'd expect they will try and put it in a safer mode, but I don't know exactly what the steps are.

What I've shown at the bottom, under the event tree, is the type of range of core-melt frequencies; in other words, the probability of getting to state or sequence number 7 for the various classes and vintages of plants, and what you see there is that the older plants that were designed with main feed staying on line and having feed-and-bleed capability and all the positive things, not too surprisingly, have a lower range of core melt frequencies.

The newer Westinghouse plants and the newer Combustion Engineering plants, as we see, would be a little bit higher than the old Westinghouse and B&W numbers.

I have put these numbers here with an emphasis that their intent is for illustrative purposes only. What I would now like to show you is the results that have come about in actual PRA studies. There are now about maybe 20 full-scale PRAs that have been performed on pressurized water reactors in the United States.

MR. MICHELSON: Before you leave that, why do you think the probability of success for B&W and Westinghouse for primary feed-and-bleed were so small?

MR. BICKEL: The value of .1 came from the Oconee PRA.

MR. MICHELSON: That's the probability of success, isn't it?

MR. BICKEL: No, it's the probability of failure. It's a 1-percent probability of failure.

MR. WARD: I think you've probably still got the question, though, Carl. It looks pretty high to me.

MR. MICHELSON: I must be reading the drawing wrong then.

MR. WARD: All the numbers he has shown there are the probability of failure.

MR. MICHELSON: Since I was on the success line, I thought that was --

MR. WARD: No. Those are the ranges.

MR. BICKEL: They're all failure probabilities.

MR. WARD: But those 99 and 90 percent chance of success seem pretty high.

MR. MICHELSON: That's pretty high.

MR. CARROLL: I guess your other footnote on that figure is that the one real-world data point we have is TMI in a feed-and-bleed mode that didn't work right.

MR. BICKEL: They have had a couple of plants that approached modes similar to feed-and-bleed -- Davis-Besse and North Anna, after that event, Crystal River, several of them.

MR. SHOTKIN: They're discussed in the synthesis report, pages 14 to 15.

[Slide.]

MR. BICKEL: They key insights that you gain out of current PRAs, when you look at them, is that the human factors issues dominate the feed-and-bleed failure probability, and the type of issues that are most important -- I put them roughly in the order that they've got there --

is the timing. How big a window of time do the operators have to successfully, you know, reach the conclusion: Gosh, I don't want to go into this mode, but heck, I'd better. The longer that window is, obviously the better the chances of success.

If you have a plant where they have a very, very short time window, where he must be into a feed-and-bleed cooling mode or he is beyond all hope, the probability of failing feed-and-bleed is, of course, going to be much, much higher.

Training plays an important role. If you were to assess a facility that had poor procedures and training and things like that, that impacts the likelihood that they are going to know how to do this in the heat of some kind of an accident that they were in.

MR. WARD: Do you know anything about the status of simulators for training and the capability of simulators to accurately reproduce feed-and-bleed?

MR. BICKEL: I trained on a Westinghouse simulator that was circa mid-'80s, and they do have the capability of simulating feed-and-bleed.

Now, the one proviso I would point out is that they are not like running RELAP/SCDAP or something like that, and they are not like nuclear plant analyzers. They do not model core heat-up and things like that.

What they do simulate is water levels, flashing of steam, and operation of the PORVs, and the operators do get the handle of running their hands over the controls and watching the process.

So, they do -- current-day simulators that are the ones that people really are using nowadays, they do, in fact, have the capability of drilling guys on feed-and-bleed cooling, as well as things like secondary feed-and-bleed, where they dump the pressure and use condensate pumps. Those capabilities are there right now, but they don't do the high-detailed stuff like you get with a RELAP simulation.

MR. CARROLL: Do you have any sense of how many of the pressurized water reactors in the country have simulators that can do that?

MR. BICKEL: No, I do not.

MR. MICHELSON: In the case of B&W plants, correct me if I'm wrong but I got the impression that the Staff kind of let them use hot-leg level indicators and lieu of vessel level indicators, is that correct?

MR. BICKEL: I don't know the answer to that.

MR. SHOTKIN: I don't know the answer either.

MR. MICHELSON: I think you let them off the hook on vessels and let them use hot-legs. I'm wondering how hot-leg works for guiding some of these feed-and-bleed processes, particular if you begin to lose large amounts of water and once it's out of the hot-let you don't know where you're at anymore, but I wanted a verification.

I am pretty sure you let them use hot-leg in lieu of vessel because it was easier for them and everybody said, gee, that's great, that's all we need!

I think for feed-and-bleed if you are talking about prolonged events you may be out of indication and then I wonder what you do.

Check into it. Maybe you could give Paul a clarification on how many B&W plants have true reactor vessel level indication, not just hot-leg.

MR. BICKEL: I've mentioned that the human factors issue tend to be the dominant issue in determining the reliability of the feed-and-bleed process and then the ultimate going on to recirculation cooling.

Based on PRAs that have been completed the equipment reliability issues are typically of secondary importance. The items that would be, you know, major interest in that area would be the PORV capacity -- is it such that you have a one out of two reliability or do you in fact need two out of two if you are using high pressure injection pumps versus centrifugal charging pumps.

Another question is then the -- now many pumps do you have potentially available that could provide the high pressure make-up source. If you are going to include charging as well as HPI you may be looking at questions of do I have a one out of four redundancy versus a two out of four.

The main point I would make is that when you are looking at the probability of feed-and-bleed failing the area to concentrate on is what are the operators going to do. The equipment is important but it is a secondary consideration.

MR. MICHELSON: In looking at the reliability of equipment did you look at the reliability of the PORVs in terms of the possibility that they may be passing slug flow and what their capability is of passing slug flow?

Or do you think you never pass slug flow during the feed-and-bleed?

MR. BICKEL: Oh, I think they pass almost everything in various phases.

MR. MICHELSON: I think that's correct. Now do we know how reliable the PORVs are for slug flow?

See, feed-and-bleed you know you may stick them open.

MR. BICKEL: Yes.

MR. MICHELSON: You may get them cycled once and not be able to reopen them, I don't know but slug flow has always been a real tough problem for those valves to handle.

MR. BICKEL: Yes, well, the main thing we would be interested is opening them and keeping them open for quite a period of time.

MR. MICHELSON: We may be lucky and bend the stem on the way open and it does fail and we may be unlucky and have it reclose and not be able to reopen again.

MR. BICKEL: Not to reopen forever, yes.

MR. CARROLL: Why would it reclose, Carl?

MR. MICHELSON: Well, you're going through cycles. The operator is going through cycles.

MR. BICKEL: When they go into the mode they latch it open, they want it open.

MR. MICHELSON: You mean you open them just once, one cycle?

MR. BICKEL: That's correct. You open them up, leave them open so that you have it continued.

MR. MICHELSON: When you get slug flow and you never try to cycle the valve again, you're probably right.

[Slide.]

MR. BICKEL: What I'd like to show now are some active results from recently completed PRAs. I have taken a spectrum and one thing we are hindered by is that there is no recently completed PRA in a combustion engineering reactor.

I have shown the results from the Surry plant. My chart here shows the plant, what the total core melt frequency was -- it was assessed in the PRA -- the percentage of the core melt frequency that involved accident sequences in which feed-and-bleed cooling was a mechanism that was used in the PRA and that failed and it resulted in core melt.

Additionally, I am showing what the PRA study assessed the failure probability of feed-and-bleed cooling to be and I have put in my final column some comments about the relative importance of feed-and-bleed in the risk of particular facilities.

On the Surry plant, it was studied very recently as part of the NUREG 1150 process. It had a 4 times 10 to the minus 5 core melt frequency.

Accident sequences involving failure of feed-and-bleed only were about 1.1 percent of the total. The feed-and-bleed failure probability was about 7 percent.

The reason why it was, I would characterize it is that on the Surry plant feed-and-bleed cooling is not very important. The primary reason is because Surry utilizes cross-tie capability between the two units so that they can swap aux feedwater and in fact several other vital services in the plant.

Now the lines are typically closed. In other words the two plants are separated via valves but in the course of an accident, if it wasn't working out so well you could open the valves and draw auxiliary feedwater from an adjacent unit.

Sequoyah was one of the other plants studied in the NUREG-1150 process. The core melt frequency there was a little bit higher, about 5 times 10 to the minus 5. The percent of the core melt involving feed-and-bleed there is about 4.6.

It had a little bit lower failure probability but again it's only two percent versus seven percent --

MR. CARROLL: Do you have any sense of why this range between one and seven percent?

MR. BICKEL: It had to do with the human factors assessment.

MR. CARROLL: And it was because of different approaches used in human factors assessment?

MR. BICKEL: It has to do -- no. The same approaches were used. It's differences in procedures, training, timing and all those type of things -- going into the numbers.

MR. WARD: The same approaches were used in the first two anyway.

MR. BICKEL: That is correct. That is correct. There was a common methodology used in those two PRAs.

I think the differences of how important it is, it's a little bit more important at Sequoyah. One of the reasons is they did not model cross-tie. I do not believe they have the cross-tie capability at Sequoyah.

MR. SCHROCK: A minor point, but none of these numbers are better than one significant figure; are they?

MR. BICKEL: You've got me. You're probably correct that it's one significant figure. I'm just quoting the results that were published, but you're probably correct.

On Millstone-3, what you have there is a new, large, Westinghouse reactor that's designed to isolate main feed following all scrams. Although it's the third unit on a multi-unit site, it does not have any crosstie capability. The core melt frequency there is a little bit higher, 7.7 times 10 to the minus 5. The percent of the core melt frequency involving loss of feed-and-bleed is about 18.4 percent, very important in that facility.

It has the same, basically 7 percent failure probability as you saw in Surry. You'd find about the same results if you looked at the Seabrook PRA. It's a little higher total core melt number, but again, the amount involving feed-and-bleed on Seabrook and Millstone is a bunch more.

The Oconee PRA, which is --

MR. WARD: Could I ask you something about the

Millstone one?

MR. BICKEL: Yes.

MR. WARD: Is this thing of defeating the main feed isolation with the alligator clips; is that an important success path? I'm trying to get a feel for this.

MR. BICKEL: It's the recovery path they would use if they failed aux feed first.

MR. WARD: But when you did the PRA for that?

MR. BICKEL: They used .1 -- as about the number.

MR. WARD: Point one?

MR. BICKEL: Failure probability.

MR. WARD: So you assume that doing that with the alligator clips was going to be successful 90 percent of the time?

MR. BICKEL: Yes. If you had feedwater running, it's basically just opening up the isolation valves. They've got this problem and what it is, is they are designed to trip closed on a sense drop in the reactor T average and on the size of that plants, the rods go in, the T av is going to hit that setpoint in 100 out of 100 times. It's basically guaranteed.

On the Oconee Unit 3 was the subject of a PRA performed by the NSAC operation. It is a B&W reactor, a Duke. The core melt frequency is a bit higher. It's 2.5 times 10 to the minus 4. The amount of the core melt frequency involving feed-and-bleed failure sequences is 10 percent.

It's very important at that facility and I think the primary reason is the -- has to do with the auxillary feedwater system reliability. It is a -- I think at the time it was studied -- that study was done, I believe it is a shared auxillary feedwater system where one -- where -- three pumps shared by three units, as I understand it.

The feed-and-bleed was very important in that facility. We do not have comparable numbers right now from a Combustion Engineering PRA. None of them have been released yet. You have to wait till the IPE process.

MR. WARD: That Oconee number is pretty interesting. It's ten percent or 10.7 percent and that's with a very low estimate of failure of the feed-and-bleed function. It's going to be successful 90 percent of the time?

MR. BICKEL: That's correct.

MR. WARD: Is it a notably simpler human factors operation?

MR. BICKEL: Yes. I looked at the PRA just last week and one of the items in there is that PRA models the HPI system being actuated automatically and that all they had to do then was to -- the main thing that they're modeling is latching open the PORV. It's not like they've got to start pumps and realign the charging pumps to the RWST, start them manually and then open the PORV.

They gave it a better number because there were less actions that had to be taken. I think that that's a reasonable argument. There's less that the operator has to do. But I would agree that it is a low number. They've got a one percent number there.

MR. CARROLL: I think the reluctance factor may be bigger.

MR. BICKEL: Even bigger than they have assessed.

MR. WARD: Maybe, unless they look at the 10.7 percent.

MR. MICHELSON: This slide now; these are real accident scenarios?

MR. BICKEL: That is correct.

MR. MICHELSON: As opposed to your earlier one which was sort of hypothetical.

MR. BICKEL: That was to show you roughly the range, yes.

MR. MICHELSON: Now, these then must have looked at a full spectrum of accident scenarios.

MR. BICKEL: That is correct. As an example, they looked at loss of DC, loss of air, loss of vital AC.

MR. MICHELSON: That was what I was going to lead up to. In the case of loss of air then, all these plants have some kind of auxillary air system for all of the essential functions, I assume?

MR. BICKEL: No. Let me clarify that. The feed-and-bleed failure probability numbers that are quoted here reflect all support equipment working. If you got to a situation where, say, you had a plant that was dependent on DC to open the PORV -- you know, to actuate the solenoid and the event you were looking at was a loss of DC, it might be failed. The answer might be, you know, the probability of failure in that particular case would be one.

MR. MICHELSON: In the case of loss of air, then they didn't look at that case, you're saying?

MR. BICKEL: They did look at loss of air, yes. All of these have looked at air, DC, vital AC and things like that.

MR. MICHELSON: In the case of loss of air, I think nearly all plants will lose their feedwater system because all that I'm aware of use air control. It's non-essential air control unless they've added some little wrinkle to it.

The safety injection and so forth, if it required air, had to put in an accumulator system or an auxillary air supply system of some sort, as an example. So these numbers then reflect the probability of these auxillary systems working properly as well?

MR. BICKEL: That is correct.

MR. MICHELSON: That was included in the analysis?

MR. BICKEL: Yes, but the point I would make is this; this is a summary just of those cases where you had all your auxiliaries working. The PRAs do consider -- they do, in fact, consider the case you're talking about where you don't have --

MR. MICHELSON: These numbers don't reflect loss of air?

MR. BICKEL: That is correct.

MR. MICHELSON: Okay. That's an important caveat.

MR. BICKEL: Oh, yes.

MR. MICHELSON: It should have said it somewhere on the slide that all auxiliaries were working.

MR. BICKEL: I agree.

MR. MICHELSON: Another interesting thing is what effect the auxiliaries have since some of them are rather high air.

MR. KERR: I don't think you and John are communicating.

MR. MICHELSON: Maybe not.

MR. KERR: John is saying that -- I believe -- that your concern is taken care by that part of the treatment which includes the failure of the auxiliaries. This is only that part of the situation in which they were working.

MR. BICKEL: Yes.

MR. MICHELSON: These answers, these probabilities only reflect all auxiliaries working properly.

MR. BICKEL: Yes. These parts are dominated by the people. If you cut off your vital auxiliaries to the equipment, yes, the numbers could be one, and they're independent. No matter how good the operator is that day, if he doesn't have what he needs to open the PORVs or to run or cool the pumps, they aren't going to work.

MR. MICHELSON: There is a set of numbers existing somewhere that shows me what effect loss of air will have.

MR. BICKEL: Yes. If you dig into one of these PRAs today like Millstone or on of the Surry ones or Oconee, you will, in fact, find different numbers used for feed-and-bleed failure probabilities.

MR. MICHELSON: In that case?

MR. BICKEL: Yes.

MR. MICHELSON: Okay, so that would be the interesting thing to do; to see how sensitive these are to the loss of auxillary functions, some of which have widespread effects on the plant.

MR. BICKEL: That's true. PRAs do account for that and basically the deal is that the initiating event frequency for something like the loss of a DC bus or a loss of air is not something that's going be a once a year affair.

MR. MICHELSON: That's right. It's widespread when it happens. Also, the failure probabilities may not have been done really well for loss of air. For instance, particularly the degraded air cases, you didn't just -- the system just didn't fit, but you started a hole in a non-safety system, for instance, during the event because you never considered non-safety when you considered your break analysis.

Then the air starts bleeding down and when it does, these systems don't work right. Some of them won't work at all.

MR. BICKEL: Yes.

MR. MICHELSON: Some instruments go crazy. A lot of interest things happen. And I'm wondering of the PRA has really gone through loss of air in a rigorous fashion?

MR. BICKEL: That, in -- to the extent you're talking about, no. I would say they probably don't.

MR. MICHELSON: But that's why we're going to pursue it some mo

MR. KERR ay I go back to the earlier slide, just to make su nderstand the numbers? The Millstone and Oconee, th and 10.7 percent?

MR. BICKEL: Yes.

MR. KERR: That means that had feed-and-bleed not worked, there would have been an increase in core melt frequency that is roughly 18 and 10 percent of what one sees?

MR. BICKEL: No. Let me clarify that. Those percentage amount to, if I take the total core melt frequency, and I take the sequences that involved failures of feed-and-bleed, what percentage were those sequences. You know, how much did they contribute to core melt frequency, versus the total?

What -- let me give you one implication. On Oconee, as an example, they assumed a one percent failure probability.

MR. KERR: Yes.

MR. BICKEL: If I assume that it was not one percent, but was 10 percent, what it's saying is that I would get an increase of 2.5 time 10 to the minus 4 or something like that -- I would basically double the core melt frequency, if I got an increase of 10.

MR. SCHROCK: Could you say that again? The percent of core melt frequency involving feed-and-bleed failure --

MR. BICKEL: Feed-and-bleed failure --

MR. SCHROCK: -- or success? Failure.

MR. BICKEL: Accident sequences involved in feed-and-bleed failure.

MR. SCHROCK: Thank you.

MR. KERR: Now, if -- if the feed-and-bleed failure were 10, using that same logic, then the core melt frequency would have been about 2.5 times 10 to the minus 3?

MR. WARD: No, five times 10 to the minus 4. It doubled.

MR. BICKEL: What I'm saying is that right now, roughly about 2.5 times 10 to the minus 5 is the amount of the core melt frequency that is associated decay heat -- feed-and-bleed failure.

If I increased the probability of failing feed-and-bleed by a factor of 10, that number would go from 2.5 times 10 to the minus 5 up to 2.5 times 10 to the minus 4, which would basically double the existing core melt frequency at that plant.

MR. MICHELSON: And it would double again if you went to 100?

MR. BICKEL: It would go more, it's geometric at that point.

MR. KERR: Okay, what I'm trying to understand is if one did not have feed-and-bleed, didn't use it, or it didn't work, what would be the core melt frequency for Oconee?

MR. BICKEL: Okay, what you're saying then is, if

I change the feed-and-bleed failure probability from 1 in 100 to one --

MR. KERR: Yes.

MR. BICKEL: -- so I increase it by a factor of 100. You would be talking some number in the range of 10 to the minus 3, that's correct.

MR. KERR: This puzzles me a little bit -- these numbers -- because it's my impression, I don't have the numbers very well in my head, that station blackout is a significant contributor, in almost all PWR's, it's not in Oconee, because you have a outdoor station.

MR. BICKEL: The dam.

MR. KERR: In station blackout, feed-and-bleed won't work, I think.

MR. BICKEL: Yes.

MR. KERR: Because you've got to have all these pumps running.

MR. BICKEL: That's correct. You need electric power in a station blackout.

MR. KERR: And I'm puzzled by the big contribution of feed-and-bleed to the efficacy of core melt frequency in a situation in which, electric power being unavailable, is already a significant contributor to core melt frequency. But, I'll puzzle about that.

MR. BICKEL: Over dinner, I guess?

Let me summarize.

MR. WARD: Yes, well I think -- can I just go on, because I think this is an important point. I think, you know, one way of looking at this is -- you know, as I started out, I said, are we happy with the status of feed-and-bleed reliability or a contribution that capacity plants to feed-and-bleed make to safety. And one way to look at would be, well, if the NRC came up with some regulations that assured perfection of the feed-and-bleed process, we'd only be reducing core melt frequency by the percentages, and that's --

MR. BICKEL: That's correct.

MR. WARD: Okay. But on the other hand, these percentages are small, particularly in the case of Oconee, because we're already assuming, in the risk estimates, that PRA is -- I mean that feed-and-bleed is nearly perfect. I mean, you're already assuming that -- that when it's called on, it will work 99 percent of the time. So, that -- that kind of give you two different perspectives on it -- that --

MR. BICKEL: It's basically saying you're not going to get a whole lot more. You could not get a whole lot more on a human driven system.

MR. WARD: Yes. Well, you're not going to get a whole lot more, but in the case of Oconee, that's because you're already getting a whole lot.

MR. CARROLL: And you have to question whether -- whether the -- problems --

MR. BICKEL: I think the main point I'm trying to draw here is that the range of feed-and-bleed failure probabilities fall in the range of one percent, up to maybe 10 percent. That's roughly the range it seems to span.

[Slide.]

MR. BICKEL: My summary. Complete cooling is an important back-up mode for decay heat removal in pressurized water reactors.

Recent PRA's tend to show feed-and-bleed failure probably, as I mentioned, in the 1 in 100 to 1 in 10 range. Currently, the analysis that has been performed in several PRA's, indicates that the failure probability is dominated by human factors issues and that equipment issues are of secondary importance. They are important, but the real problem right now is the -- the people, doing it in time and doing it correctly.

The degree of safety importance of feed-and-bleed on a particular -- you know, if you look at a particular facility, will be related to the reactor type; is it a combustion or a Westinghouse reactor? It will be related to the vintage; is it a vintage of Westinghouse plant that keeps the feed online, versus one that isolate it?

It will also be related to the reliability built-in to the auxiliary feedwater system. How many pumps? What is their capacity? And in additionally, what type of capability do you have for getting an additional source of water at that particular facility.

That concludes my presentation.

MR. MICHELSON: Question.

MR. BICKEL: Yes.

MR. MICHELSON: I was a little surprised to have you tell me that the intent is to just open the relief valves once and leave them open thereafter. It would appear then that for many feed and bleed situations, we're going to have to cycle the pumps on and off or something, to control levels at desired locations in the system. Usually you don't like to turn a big pump on and off to control the small flow, but it could be done.

MR. BICKEL: The charging pumps have always have some degree of throttle capability.

MR. MICHELSON: For charging pumps, that's true. It depends on the system at the plant, as to whether the charging pumps work. I mean, it's -- they may or may not even be safety grade, depending upon the plant.

Clearly, the lower pressure pumps are all big pumps. Isn't there some intention, after you get down to lower pressures, to cycle, or is it always intended just to open once and leave it there?

MR. BICKEL: Dana Kelly from my staff can answer that question.

MR. MICHELSON: Or maybe I just misunderstood before.

MR. KELLY: The HPI pumps, once you go down low enough in pressure and you're wanting to control the level, you can throttle the pumps. The basic intent is to eventually get down low enough in pressure so that you can go on shutdown cooling using the shutdown cooling heat exchangers.

So, eventually, you're right, you would get to a point where you want to close the PORVs and go on to shutdown cooling.

MR. MICHELSON: But the instructions right now, then, are apparently open them up, leave them open until you want to go into shutdown cooling?

MR. KELLY: I believe that's correct. I'm not 100-percent familiar with all of the procedures that are out there, but I believe that's correct. I know, initially, they do latch open the PORV.

MR. MICHELSON: Those high-pressure injection pumps running on dead-ended with just mini-flow is not a good idea, and you're talking about essentially that. If you're not going to control, how else are you going to control the water input and maintain a level?

MR. KELLY: Well, you're not talking about throttling it all the way back to where the throttle valve is completely closed.

MR. MICHELSON: We are talking about how many gallons a minute, a couple of hundred at that point?

MR. KELLY: Probably more than that.

MR. MICHELSON: I was surprised. I thought you were going to cycle the valves to control the levels.

MR. WARD: Okay. Thank you very much, John.

MR. KERR: John, it occurs to me, in reading the descriptions of the analyses in the PRAs, that apparently what is done in the PRAs is to not worry much about a time sequence but to assume, in the lack-of-success path that gets you to feed-and-bleed, that this happens without any particular delay after the transient.

Is that the case, or is it assumed that there is a significant delay after the transient initiates before?

MR. BICKEL: Let me see if I understand the question. You're asking me do PRAs model the time factors involved in the various sequential steps?

MR. KERR: Yes.

MR. BICKEL: Yes, they do. Various PRAs, obviously, do it better than others, but if you're doing a good PRA, what you should do is a lot of thermal hydraulic analysis to delineate what happens when and how much time is available, and when you have the time windows available, the time windows, then, become an integral piece of the assessment of the probability that an operator does the job right or wrong.

MR. KERR: I guess I'm not making myself very clear.

Let's suppose, for example, that one has a situation in which auxiliary feedwater or some other source of feedwater is initially available, maybe for 30 minutes or 40 minutes, and then one has to start making decisions.

The reason I ask this is because it strikes me that this is maybe as likely or more likely than a situation in which all the stuff becomes unavailable right away.

MR. BICKEL: Okay. Your question, then, is if I get partial success of, like, say, main feedwater or auxiliary feedwater, they subsequently fail and I can't get them back, and now I go on to aux feedwater.

MR. KERR: Yes. Now, it seems to me, the windows for success are different.

MR. BICKEL: The windows are going to be much larger, and the PRA analysis would be very conservative to model those things.

MR. KERR: And since we're presumably talking about unusual events, I would wonder how much emphasis we should put on tactics, which I would identify as the detailed procedures, and how much should be put on strategy, which is sort of laying out the possible things that one could do. I don't know the answer to that, but it's hard for me to believe that something that leads to feed-and-bleed is going to be something which has been well anticipated initially. It's likely to be a series of events that hasn't been thought about very much.

MR. BICKEL: I think that some procedures show things like "use any one of the following pumps," and it gives them a list. It puts them in a priority, but the guy will step through what he can get on the quickest.

MR. KERR: Now, another part of this deciding on a window assumes that, I think, if you get down below the top of the core, you're in serious trouble --

MR. BICKEL: Yep.

MR. KERR: -- which I don't think is necessarily so. I would guess you could get down halfway without causing -- well, you'd maybe not be able to use that fuel anymore, but you probably wouldn't have a molten core on your hands.

MR. BICKEL: Yes. One of the -- I think one of the considerations is that the operators that have to carry those things out are typically not RELAP5 analysts. They write those procedures with a lot of fat in them, and I remember I never liked the feeling that I couldn't tell when

I read an emergency procedure, does this mean absolute, guaranteed success 100 percent of the time, or is this like, well, if I'm going to jump out of a window of an airplane and I haven't got a parachute, opening an umbrella wouldn't hurt?

Procedures do not clearly show you that if you just get this pump running, you are home-free, you can go home. It basically tells a guy to put on as much stuff as you can, given the limitations of available water.

So, the procedures tend to push the guy in a more favorable direction, but it doesn't give him clear guidance that, okay, you know, if you're at this point here, you must get on one source of water with at least 50 gpm, and then you're free, and you've hit success. Procedures don't tend to do that. They just tell him to put on as much as you can, as quick as you can. And I'd say the PRAs that analyze that, obviously we can't take that kind of process well into consideration as to how that impacts risk.

I think the way the PRAs treat it right now tends to be conservative. We assume if it's going to fail, it fails right off, at the beginning. If it's going to recover, he is going to recover it immediately; either that or he goes on to the next step.

MR. KERR: I don't quarrel with that treatment of the PRA, but if you're now looking for what an operator should do in a given situation, it seems to me that one does have to look in more detail at possibilities that can exist.

MR. BICKEL: Yes.

MR. WARD: Okay. Thank you.

Let's take a break now until 10:50.

[Brief recess.]

MR. WARD: Mr. Larson. We are ready for your second part.

(Slide.)

MR. LARSON: Tom Larson again -- as Chairman Ward said, this is Part 2.

Part 2 of my presentation is basically to continue on where I left off earlier and address with more specifics mainly primary feed-and-bleed.

The ultimate goal here is to get to a concept that I think most of you have already seen before but it is the feed-and-bleed map. It's a convenient way on basically the back of an envelope to look for a window that describes where a plant with given specifics can potentially operate in the feed-and-bleed mode under steady operating conditions.

Of course, lastly to provide some summary and concluding statements.

(Slide.)

MR. LARSON: For the purpose of this discussion and the back of the envelope type calculations we made some assumptions about the state of the system during this start or the search for the window for primary feed-and-bleed.

That includes, first, the complete loss of secondary heat sink. The reason for doing that really is to effectively eliminate some of the other sources of energy removal or energy addition as in some of these other cases here to simplify the analysis.

Now a person would not have to do this but it certainly simplifies the construction of a map.

We also assume that the core stripped or scrammed and we're at decay heat levels.

Some sort of pump DCC system was available. That doesn't mean it's all available but one can trade off the availability of one train of charging pumps if the plant under consideration has them plus a train of ECC HPI pumps or HPI only or multiple trains.

We also assume that the PORV is operative. We have heard some discussion earlier this morning about whether that means being able to open it and latch it or being able to cycle it many times without a failure in either one state or the other, open or closed.

The assumptions here are basically that it can be opened and it stays opened because what we are looking for in terms of construction of a map is what is the mass and energy efflux on an average basis.

We also assume the pressurizer heaters are off again to eliminate that additional source of uncertainty as far as energy input to the system -- wouldn't have to do that.

MR. WARD: What about the sprays? Does that make any difference?

MR. LARSON: It would in terms of this analysis because that's a potential way to add a little bit of mass and remove some energy of condensation but we have ignored the sprays -- so they are basically off.

MR. WARD: So they are off, yes.

MR. CARROLL: Why are the primary pumps necessarily off?

MR. LARSON: Oh, they're not. We just assumed that they were so we don't have to worry about the pump heat addition. Now one could certainly say, all right, the pumps are on therefore there's X megawatts per pump that's added into the system, above and beyond core decay heat, so that's not a necessary assumption.

MR. MICHELSON: What do the operating procedures normally state? Do you trip the pumps or do you leave them running as you start to work into the scenarios?

MR. LARSON: My assumption is that they are already tripped at this point but I am not the right person to ask.

MR. MICHELSON: I don't know. Anybody know?

[No response.]

MR. LARSON: I think some of the experiments that have been run -- somebody mentioned the MIST experiments earlier -- they have been done with pumps on and pumps off and we have done likewise in Semiscale, so obviously there are probably circumstances where the pumps could be on or they could be off.

MR. WARD: So let me see if I understand. With a different set of assumptions, you would have a different, somewhat different window but conceptually it is the same thing, is that the idea?

MR. LARSON: It's the same -- the map looks the same but the lines on the map may shift around. In fact I will show you how they shift around for a different set of circumstances for a particular plant, just to show what happens to the window or how it shrinks or grows.

(Slide.)

MR. LARSON: As I mentioned earlier this morning, just from a simplistic viewpoint you draw a control volume around something and write the first law -- it's energy and mass balances that influence the phenomena of interest -- i.e., what's the pressure in the system and can I get mass in and take energy out in the significant -- in sufficient proportions to run the station, so one would reason then that they key factors influencing primary feed-and-bleed are just those things that affect the mass and energy balances on this control volume, the system.

Hence that means core decay heat or other sources of energy -- if the pumps are on then you would have to account for that as an energy input.

The pump DCC injection capability used loosely here to perhaps define the subset including makeups and HPI of various number of trains depends on your assumptions for generating the map.

Of course the PORV -- what is its energy relief capability and what is its mass relief capability?

Well, those two parameters depend on a lot of things as I mentioned earlier, like what are the thermodynamic conditions in the pressurizer and as Carl mentioned earlier, how do those conditions vary? Do you get slug flow or is it always single phase steam or can it be water and still make feed-and-bleed work?

The feed-and-bleed map is capable of addressing some of those questions but again I want to emphasize that the maps that you are about to see only define what the window is given a specific set of circumstances. It does not tell you whether a plant in some state at some high pressure can ever get to that window. That is something that requires a more detailed analysis and addresses some of the things like two-phase flow through the PORV, et cetera.

MR. SCHROCK: You don't consider the initial mass inventory a key factor? I mean you get some benefit from the initial inventory which is discharged at high --

MR. LARSON: You mean the initial inventory that is in the system?

MR. SCHROCK: It makes a difference whether you have a bubble in the upper head or not.

MR. LARSON: Oh, sure, yes, but the experiments we have run, Virgil, show that -- well, TMI shows it. You open the PORV and you get steam flow for a bit and then suddenly the pressurizer has a tendency to fill up so there is a period of two-phase flow and then there may a period of single-phase flow and then depending on what is happening in the surge line, whether it is flooding or maybe not flooding. Ultimately you may get back to a point where you can discharge pretty much vapor through the PORV and then effectively reduce the pressure.

To answer your question, those kinds of things are factored into, inherently into the code analysis but for this simplistic analysis, no. We do not assume that there is X cubic meters of vapor space above or in the upper plenum for example that then moves to the pressurizer and is exhausted.

We don't get into that detail with these maps.

[Slide.]

MR. LARSON: Again, based on energy and mass balance, one can reason that there is perhaps a lower bou. , speaking in terms of pressure, and an upper bound defined by these energy and mass balances that define an operating window for steady-state operation of a feed-and-bleed. The two factors that factor into the lower bound are the energy input and output.

The factors that affect the positioning of the upper bound, of course, are the mass input and output. It is possible to bleed without feeding, as long as the inventory of the system remains such that the core doesn't uncover. In fact, experiments have been run where the core does uncover during feed-and bleed, but it recovers about five times, as I recall, just because of mass inventory shifting around.

It was still a successful feed-and-bleed, but the core did uncover momentarily several times. That was not what you would consider a steady-state operation, so we don't factor those kinds of details in, either. Mainly what we're looking at here are steady-state energy and mass balances, plant-specific capabilities of the equipment.

We heard John say earlier that really it's probably the operator that's the key element, not necessarily the equipment reliability or availability. I think that's correct.

However, for some plants, the equipment capabilities are a factor. We will see that on the maps.

[Slide.]

MR. LARSON: This map has no scales. It's just a dummy map with set pressure scales along the bottom. This typifies a typical feed-and-bleed map where you plot energy on one scale, mass flow rate on the other and what we're essentially looking for is the intersection of the energy eflux and the energy influx, if you will, to define one of the boundaries, the lower boundary.

That intersection on this particular map happens to be at 6 megaPascals. Again, this is just a dummy map, but nonetheless, the numbers are realistic. The decay heat here is something like 2 percent. We're talking a timeframe into one of these accidents on the order of 20 minutes or maybe a half hour with decay heat on the order of 2 percent to 1 and a half percent.

PORV energy removal was plotted here. The other boundary is defined by the intersection of the ECC injection curve, the HQ curve with some estimate of the average mass flow rate out the PORV. Now, there's two ways to get at some estimate of the average mass flow rate out of the PORV. You can go look at the valve specs and use vendor quotes for the capacity of that valve to pass saturated steam at some pressure; that's one way to do it.

Another way to do it to simply say, well, I've got a big control going here. I'm putting in cold water through the ECC, presumably. It's got an entropy of maybe 100. I'm going to assume for the purposes of the map, at least the first maps, that the PORV will pass saturated steam, therefore, the mass flow rate that has to go through that PORV is simply Q, decay heat, divided by that entropy change. It's really an effective vapor generation rate.

That can then define another point here, this intersection which is really an upper bound, so this really defines a point at which I can maintain a positive or a zero change in the mass inventory of the system and likewise for the energy inventory. The space in between defines what I've referred to on several occasions, this space here, as the window.

Okay, so, presumably with the ability to either throttle the HPI if necessary or modulate the PORV -- whether that's a good idea or not, I can't say, but presumably with those abilities to alter your mass and energy eflux rates within this window, you can maintain a steady feed-and-bleed operation.

MR. WARD: Okay, but that's assuming -- well, that's sort of an idealized case, if you the level down below the hot leg and the surge line was clear and you just had saturated steam coming out of the core and going up through the depressurizer and out?

MR. LARSON: Exactly. That's a key point. One of the biggest -- I'm getting a little bit ahead of myself, but one of the biggest uncertainties, I guess, if you will, is what might that number be as a function of time during this process.

As Carl said, what happens when it starts to be slug flow. Well, it might pound the valve up quite a bit, but also it changes the flow characteristics and the flow rate will either increase or decrease and the energy removal rate will either increase or decrease which changes what happens to that window.

MR. SCHROCK: I realize this is just schematic, but I don't understand the small slope on that PORV average mass flow rate and curve. Is that saturated steam?

MR. LARSON: That's because hg changes a bit as they come down.

MR. SCHROCK: It's because of what?

MR. LARSON: hg, saturated vapor entropy.

MR. SCHROCK: I'm looking at mass flow rate.

MR. LARSON: This mass flow rate here is really the vapor generation rate. The PORV has to pass that. That's Q over hg minus HECC, if you will.

MR. CATTON: That's required.

MR. LARSON: Yes.

MR. WARD: I thought was what the valve --

MR. LARSON: The other way to do this is to say, what is the valve capacity at some pressure. Usually it's quoted at one point. Another way to do it is to use the critical flow model or some of your correlations to define what this line might be as a function of the pressure, assuming some upstream --

One of the problems with that -- it's not a problem, but it becomes again another plant-specific because I think most plants have different PORVs. Their characteristics are different, the discharge coefficients are different. In a lot of cases, the downstream piping can have some effect on the valve flow rate, choking and unchoking.

MR. SCHROCK: Usually the manufacturers have test data for steam but not for liquid.

MR. LARSON: Right.

MR. SCHROCK: Has that situation been pretty well corrected so that we know pretty well what the characteristics are with saturated liquids against the valves?

MR. LARSON: I am aware of the EPRI work that was done to look specifically at several different valve manufacturers of valve types under different flow conditions like that. I couldn't roust up a copy of the report, but I know there are tables in that report that define the different discharge coefficients for the different valve types.

MR. SCHROCK: Sort of generic valves, but really, the question is: Is the database for valves in general that are in use in the actual plants now good enough for this assessment?

MR. LARSON: I can't answer that.

MR. MICHELSON: It's a little bit of a problem when you start talking about taking the very large pressure drops that you'd have to have across the PORV. It's still a pretty high pressure. It's atmospheric, almost, downstream.

MR. LARSON: The valve forces.

MR. MICHELSON: Yes. The problem is trying to take that extremely large pressure drop across the valve is going to be -- it's going to be a very unstable situation. The valve wasn't designed for that sort of thing to begin with, and the thing to worry about is you shake it for a while, and it will be shaking, you break off the instrument line, for instance, and that's the PORV's signal to close. I think these are all fail closed. And so, you break the instrument line because you're shaking the valve, and instrument lines do break. There's lots of LERs about vibration breaking instrument lines, and it doesn't take many cycles, if it's a severe vibration, to do it.

MR. LARSON: That's a reliability point.

MR. MICHELSON: There are a lot of things you've got to worry about if you don't pass pure steam through the valve, because manufacturers, I don't think, like to pass water with that kind of pressure drop across it, or a two-phase sub-flow is the worst of all. They just hate to see that.

MR. CATTON: I think a response to your question, Virgil, I recollect an article in the magazine called "Power" that said that the EPRI study was inadequate, and then I heard EPRI had written some kind of rebuttal, but I never saw it.

So, I don't think they fully tested the range that would be of interest for these kinds of applications. So, we don't know. And there was a paper given at a meeting in Santa Barbara a few years ago that showed how just subtle changes within the valve changed the mass flux by a factor of 2 with two-phase flow. It has something to do with the re-attachment point for the sonic line within the valve.

MR. MICHELSON: I don't think EPRI really looked at the vibration problems in some of these flow regimes.

MR. CATTON: They didn't do that at all. They did not look at the vibration problem.

MR. MICHELSON: And what effect it has on the air supply to the valves.

MR. CATTON: Well, the flow was only partially looked at.

MR. MICHELSON: Yes.

MR. CATTON: I think they stuck pretty close to what the design conditions for the valve were, rather than looking at these off designs.

MR. LARSON: I intend to get the report.

MR. CATTON: They were criticized severely for it.

MR. CARROLL: How do we get the current status of valve capabilities?

MR. CATTON: I think you have to test them.

MR. WARD: How do we get some information on it?

MR. CATTON: A phone call to EPRI probably would do it.

MR. WARD: Well, maybe that's some followup we need to do after this meeting.

MR. LARSON: I will look into it, just as part of my own curiosity.

MR. MICHELSON: You will ask them about the attachments to the valve under the circumstances that we're talking about here, normal operations.

MR. CATTON: I don't see Duffey here, but he was at EPRI when that work was done. He would know.

MR. LARSON: He is the one that mentioned this the other day. He couldn't find his own report. He has more information than I do. So, we'll provide some information.

I agree with everything that's been said. But for the purposes of these maps, indeed, if you want to get more detailed and, I guess, more accurate, then certainly we need to worry about all those effects.

[Slide.]

MR. LARSON: The next slide is really a re-hash of what I already said. Obviously, what affects the two bands that I have pointed out on there are the mass and energy removal rates. So, I won't belabor that point anymore.

[Slide.]

MR. LARSON: The next slide shows a feed-and-bleed map that was generated some years ago for Zion under assumptions of a 2-percent decay heat. That's about 20 minutes into a transient. Again, with all of the assumptions listed on the previous slides, like complete loss of feedwater, etcetera.

Now, as I said, this is information that was generated several years ago, and I know for a fact that the FSAR that some of the information came out of was not exactly accurate at that point in time. So, therefore, this map is not necessarily specifically accurate for these conditions. However, it is sufficient to show what my intent is here today, and that is what happens on the map when things like decay heat assumptions regarding the HPI capability and so on change. So, I think it's okay for these purposes here.

I've normalized the two Y scales to unity, not with any desire to try to confuse you. It has nothing to do with the physics. It's simply an aid to make the plot look better.

MR. MICHELSON: You call this a window yet, I assume, on this drawing, as well.

MR. LARSON: Yes, here.

MR. MICHELSON: Now, a window, to me, means that something -- in the pressure range that you show, I must do something. Is that the interpretation?

[Slide.]

MR. LARSON: What this map means is that if I can get myself into this range of pressures, then I can feed-and-bleed, primary feed-and-bleed, and operate under steady conditions. Okay?

If I try to operate beyond this point, there is a net mass imbalance.

MR. MICHELSON: It infers that the operator is supposed to realize if it gets over nearly 1,300 there that he should back off on the pressure. Is that right? How does he do that?

MR. LARSON: He's got to have some ability, in my opinion, to throttle or modulate the PORV, as required.

MR. MICHELSON: We kind of, I thought, agreed earlier the procedure just said open PORV and leave it there, and I think we verified that, and the guidelines even says that. So, I don't think you've got the PORV to diddle with. I thought you did, too, but apparently we don't. So, how do you get yourself into this range?

MR. CATTON: Throttle, I guess.

MR. MICHELSON: The throttle only changes the rate of make-up of water. That's all it does.

MR. LARSON: What this map says --

MR. MICHELSON: It can very slightly affect pressure.

MR. LARSON: Let's assume I'm way up here at some higher pressure, and I've made the decision that I've got to try to get to a point where I can feed-and-bleed the primary. So, if I were looking at this map as an operator, I would say I've got to get over here so that there is a net mass gain in the system, which means the HPI can put in more than the PORV has taken out. If the PORV is locked open, okay. Then, hopefully, I've got HPI capability that can make up that loss and more. So, I have to maybe throttle the HPI. But to get over here, then, I've got to bleed, perhaps without feed until I get in there.

MR. MICHELSON: I'm doing all the bleeding I can; I opened by PORVs.

MR. LARSON: Right. But I didn't necessarily start from a point with the PORV open. So, I've just lost feedwater. The PORV is likely now open.

MR. MICHELSON: I guess maybe you never get into this regime if you're already opened your PORVs. The only thing to worry about then is can I close the PORVs, because my pressure is getting too low?

MR. LARSON: Yes. Can I prevent myself from going lower?

MR. MICHELSON: So, if you don't want to fiddle with the PORVs, what do you do when the pressure gets too low?

MR. LARSON: When I get down here?

MR. MICHELSON: Yes.

MR. LARSON: Well, in my opinion, you've got to be able to close the holes in the system and make the pressure go back up or bite the bullet and say can I get down to a point where there's still inventory in the system and I can get on RHR?

MR. MICHELSON: The procedures say just keep them open, and when you get down to shutdown cooling, then you start doing other things. I believe that's what the procedures say.

MR. LARSON: But the question there if I'm continually bleeding, by the time I get down to 1.4 mega-Pascals, where I can get RHR going, is there enough inventory in the system to maintain the pump levels?

MR. MICHELSON: Has anybody studied -- run the numbers? Because that's what the procedures seem to be saying to do.

MR. LARSON: The numbers have been run.

MR. MICHELSON: I hope it's backed by a study somewhere that says yes, that's the right thing to do.

MR. CATTON: I think the Los Alamos study did do that for a number of plants.

MR. LARSON: Yes. They looked at three different generic plants. Jim Steiner will probably talk about this.

MR. MICHELSON: I don't care about generic. Each utility has to be assured that his operating procedure will carry him through properly.

MR. LARSON: This all depends very much on plant specifics and valve PORV specifics and what's available and what isn't.

MR. MICHELSON: But having the window concept -- I thought we had windows, too, but I don't believe that's purely a window. The instructions say open the valves and leave them open. So, windows don't mean too much.

MR. LARSON: That's if there isn't one.

MR. WARD: I think the window has to be considered by the people writing the procedures, not by the operators.

MR. MICHELSON: Okay.

MR. LARSON: Yes. I don't expect an operator would ever be sitting at the console looking at something like this.

MR. MICHELSON: He is not even aware of the window. He is just aware that the procedures say open the valves.

MR. CARROLL: He is aware of another kind of window.

MR. LARSON: Yes, like do I have to start feed-and-bleed as soon as the --

MR. CARROLL: That is the window the operator has to be locked in on.

MR. LARSON: Let me point one more thing out about the scales here. This is no intent to confuse you, but unity up here simply means that's 200 megawatts, okay? Unity over here simply means that's 120 kilograms per second. So that the two scales have been normalized differently for amounts of energy.

And this scale will change on the subsequent maps, just for convenience in blowing the map up so, also don't let that be a confusion factor.

MR. MICHELSON: I think you said typically, decay heat removal is around 120 on your X axis.

MR. LARSON: Oh, this number here?

MR. MICHELSON: No, no, no. Decay heat removal. What is the pressure at the point of initiation? I can't convert the mega-Pascals.

MR. LARSON: I think it's about 250 psi's..

MR. MICHELSON: Yes, 250/300. And that's how many mega-Pascals? That's about one and a half here, I guess.

MR. MICHELSON: All right. That's all I wanted to know. Thank you.

MR. WARD: It was way down in the corner.

MR. MICHELSON: You scientists can figure out these megapascals, I can't. I don't even want to, I'll leave it at that.

MR. LARSON: Multiply these numbers by roughly 7, to get the psi.

MR. MICHELSON: That's the -- that's the magic number? Yes, I learned something.

MR. LARSON: What I failed to mention here is that this HPI -- this HQ curve for inductive flow rate is the combination of make-up and HPI, as we heard this morning. The make-ups are probably a positive displacement, and they can pump a reasonably small flow rate, but at -- at a -- over a wide range of pressure, and the HQ curve for the HPI pump, of course, is a --

MR. DAVIS: Such a conversion is a 150 psi curve mega-Pascal?

MR. LARSON: It's 6 -- multiply by 6.894 to get 145 per mega-Pascal.

MR. DAVIS: So that 15 mega-Pascals is about operating pressure?

MR. LARSON: 16 is 23 psi.

MR. DAVIS: So the conversion is not 7 it's 145, or whatever? Okay.

MR. LARSON: Did I say multiply? Divide mega-Pascal.

[Slide.]

MR. LARSON: The next slide shows basically the same set of conditions, except we no longer have charging flow. Now, I should point one other thing here, is that I have some concerns about this HQ curve for Zion, because it's my understanding that Zion has a high head HPI. It can pump at a pressure near set point for the -- or safety set point for the plant, which is 16 or 17 mega-Pascals.

This curve here shows that it's got a dead head at 10.3 mega-Pascals, I think that's an H.B. Robinson HQ curve.

Nevertheless, the point here is, given a different set of circumstances, pretend like this is not Zion, for example, the window for steady state operation in feed-and-bleed goes away at 2 percent decay heat, because now the upper bounds is actually less than the lower bounds, so that means there's no window there, it's a non-physical circumstance.

MR. MICHELSON: Did you say the HPIS can lift the safeties, or not even quite make it on the PORV set point to lift?

MR. LARSON: It's my understanding that Zion has high head HPI pumps.

MR. MICHELSON: Okay. All the way to the safeties?

MR. LARSON: That's my understanding.

MR. MICHELSON: High head can mean various things to various people.

MR. LARSON: Yes. It can -- can --

MR. MICHELSON: It can lift and not go fast enough through --

MR. LARSON: -- can bump the safeties.

MR. MICHELSON: -- the safeties to remove -- pass the amount of --

MR. LARSON: I don't know about passing the amount of energy, because I don't know what the safety relief breaks are.

MR. CATTON: You're hitting the zero ac 1500 psi, on the mass flows -- no, move over. On your HPI flow rate. It's coming down, it hits zero at a little over 1500 PSI.

MR. KERR: He didn't think this was valid.

MR. LARSON: I really think this HPI curve should shift over.

MR. KERR: He said earlier, he didn't want to confuse us, but it's clear he's trying to confuse us.

MR. CATTON: That's all right. We probably deserve it.

MR. LARSON: My apologies.

This is not necessarily to represent -- well we thought it represented an accurate map for Zion at one time. I no longer think it does, but the principals are the same.

MR. CARROLL: Your -- your report, in fact -- on describing Zion says, oh no, it doesn't. It says "two safety grade centrifugal charging pumps deliver 20.59 kilograms per second at PORV set point of 16.1 mega-Pascals, while two safety injection pumps provide additional injection capability on intermediate pressures." Okay.

MR. LARSON: Yes. So, I think what I've said is consistent with this -- but is not necessarily correct here.

MR. CARROLL: Yes, but the centrifugal charging pumps are -- have a fair flow.

MR. LARSON: Yes. Like 50, wasn't it? 50 kilograms a second?

MR. CARROLL: 20 each. A total of 20.

MR. MICHELSON: What would they have at this pressure?

MR. LARSON: I have a chart that says 15.6 for Zion on the centrifugal charging pumps.

MR. MICHELSON: What flow, 15.6?

MR. LARSON: That was the flow.

MR. MICHELSON: What is the pressure on that flow?

MR. LARSON: That was 16 mega-Pascals.

[Slide.]

MR. LARSON: I don't want to get too tangled up in the details, I just wanted to show you the concept. One of these can be done for each plant, but in order to do it properly, you need up-to-date information on all the pump capabilities and the PORV and so forth.

The next slide shows basically the same curve, except that we've now gone another ten minutes into this transient so the decay heat has dropped. We're now down to 1 and a half percent decay heat. The same assumptions on the HQ curve, no charging.

Core power here is down to about 50 megawatts. The PORV mass removal required has moved down again also because that's Q over hg minus HECC. The window has now appeared again, so, again, it's a subtlety in the point in time, rather than anything to do with the plant-specifics. It's simply that the decay heat has dropped off so now the window appears again.

That is also something that probably would factor into the preparation of a procedure, because it's certainly not something an operator would know and be looking for.

[Slide.]

MR. LARSON: Several times in discussions this morning, Carl and several other members have mentioned what the PORV characteristics really are. What are some of the other things that influence the PORV flow and energy eflux. Well, I've listed here what I think are some of the factors. This is not necessarily all-encompassing.

A lot of them are addressed in the reports that you're looking at. Clearly, upstream conditions are a factor; upstream meaning what conditions are in the pressurizer. Is it full? Is there a vapor bubble in it? Are droplets being entrained so that it's a two-phase mixture going into the PORV?

What is the primary inventory? Where are the levels? The effect of where are the levels depends on the plant. If it's a B&W plant with the pressurizer surge line stuck in the vertical about halfways up the hot leg, then that's a different consideration than it is for a Westinghouse plant where the pressurizer has a horizontal connection, for example, in a horizontal pipe and the surge line geometry is different.

So, that inventory is a factor in determining when you get flooding in the surge line, when you get uncovering of the surge line connection so that I can potentially get vapor back to the pressurizer to vent through the PORV, rather than liquid or a two-phase. Other geometry considerations that we already talked about include the valve characteristics and its reliability, discharge coefficients and discharge piping.

What is the open area of this valve? What is its quoted open area versus what it will really open up to when I've been pounding it with steam and two-phase mixture? The pressurizer itself can have some impact, L over D, phase separation. I've already mentioned the surge line orientation.

MR. MICHELSON: Another one that you didn't mention, unless it's incorporated somewhere else is the diffuser screen in the pressurizer at the end of the surge line. That has a significant effect upon whether the water remains up in there and the steam is passing through the surge line and out through a body of water and out. Did you look at that?

MR. LARSON: Yes, flooding considerations at the diffuser screen.

MR. MICHELSON: Well, yes, the diffuser screen is very instrumental in what the level is in the pressurizer, irrespective of what the level is in the vessel.

MR. LARSON: I agree. Again, this whole concept is very plant-specific.

[Slide.]

MR. LARSON: One of the things that we did examine in a simplistic way was what happens if the quality mixture is exiting the PORV? One way to get a handle on that is just to assume a pressure and use a critical flow model, HEM or your druthers and ask, as a function of quality, what are the energy and mass removal rates through that PORV, again, assuming some quoted manufacturer's open area.

What you see here is that as a function of quality, the flow rate in kilograms per second and the energy removal in megawatts, again, using the quality to establish what the entropy is of whatever that mixture might be. Constant pressure; what I did on the next slide is --

MR. MICHELSON: This is not steam, but fluid quality. Fluid quality means all liquid?

MR. LARSON: All liquid.

MR. MICHELSON: Is that all steam at that end?

MR. LARSON: That's a misnomer, quality.

MR. MICHELSON: Quality, I understand; fluid quality, I was not sure what you meant.

MR. LARSON: Thermodynamic quality in the traditional sense where one is vapor. hg up here and --

[Slide.]

MR. LARSON: For no good reason, really, other than to illustrate what happens on the map, quality is 75 percent and constant conditions with a flow rate of 75 percent quality and again, construct this map with one and a half percent decay heat with this HQ curve. What you see again is that the two bounds, the upper and lower, basically are right on top of each other.

Now, obviously, if I would have picked a different quality or a range of qualities, then this window would switch around. In some cases, the upper bound would be below the lower bound and in other cases, it would be a viable window. All this serves to illustrate is, that given unknowns in what the real fluid conditions delivered to the PORV are, it affects the map somewhat drastically.

It affects whether or not there is a window on the map. Of course, what that really points to is that in order to incorporate things like time, at what point do I have to something in this transient and at what point is it too late to do anything like feed-and-bleed, or given a set of initial conditions, can I get to a window or is there even a window for this plant? It requires some more sophisticated analyses.

MR. CARROLL: Ivan and Virgil, does that energy removal rate curve for the PORV look right to you?

MR. LARSON: There's a tail on the end that's an artist's misconception.

MR. SCHROCK: You're talking about the previous slide?

MR. CARROLL: Yes.

MR. SCHROCK: I was just looking at the one in the reference document, Figure 2 on page 3. The numbers are quite different, but it's qualitatively similar. It struck me that, just from the homogeneous equilibrium model, a factor on the order of 3 between saturated vapor and saturated liquid seems large for 10 megaPascals.

In fact, if you compare that with the numbers in the document, at pure steam, you have about 62 -- excuse me, I'm looking at the wrong scale.

At pure steam, you've got about 30 on your mass scale and for pure liquid, only 50 on the mass scale, less than a factor of 2 increase.

MR. LARSON: You're questioning this slide?

MR. SCHROCK: Yes.

[Slide.]

MR. LARSON: I have it.

MR. SCHROCK: On the flow curve the range that you are showing here is much larger than the range shown in the document. Is there some reason for that?

MR. LARSON: Not that I know of. I'll check into it and get back with you, Virgil. I don't know the answer to that.

MR. CATTON: The shape of the curve looks exactly the same.

MR. SCHROCK: The shape looks similar. It's just the scale.

MR. CARROLL: Where are you looking?

MR. SCHROCK: Well, it's figure 2 on page 3 in the NUREG 5072. It has a range on the flow which is less than a factor of two and what he's got on the board here, it's nearly a factor of three and a half.

MR. LARSON: On the flow?

MR. SCHROCK: Excuse me, more than a factor of two.

MR. LARSON: Just a tad over the factor of two. Let me check into that and see. This scale could be incorrect. That is in kilograms, is it not?

MR. SCHROCK: Yes.

MR. LARSON: Shouldn't make a difference.

MR. KERR: You observed that he switched the scale from left to right.

MR. SCHROCK: Yes. But otherwise is your question is it realistic to have a minimum?

MR. CARROLL: Yes.

MR. SCHROCK: Yes, there is a minimum.

MR. LARSON: You'd probably also agree that HEM is not the thing to use for this situation.

MR. SCHROCK: It is not as bad for the pure steam cases as it is for the pure liquid cases.

MR. WARD: Do you have choke flow in this?

MR. SCHROCK: Choke flow, yes.

MR. LARSON: Downstream of the PORV is atmospheric basically.

MR. SCHROCK: There is a long section of pipe there.

MR. LARSON: Yes, there is probably considerable pressure drop.

MR. SCHROCK: The actual location of choking, the pressure, if the upstream pressure is 10 MPA, the pressure at the point of choking is probably like 6.

MR. CARROLL: The only other comment I have is megawatts are a unit of power, not energy.

MR. LARSON: Touche!

MR. SCHROCK: Oh, yes.

[Slide.]

MR. LARSON: The next slide is a culmination of something we have heard many times this morning and that is about the plant differences. All the plants are different. This is just a plant-by-plant summary for each of the vendor types that shows some of the differences including the operating power ranging from 25 to 80 in Oconee and the Zion which is 3500 plus.

Secondary inventories also factor into this feed-and-bleed question. We are all familiar with the small secondary inventory in the B&W plants, the once through generator. It's got about three seconds' worth of -- three minutes' worth of boil-off -- 35 minutes' worth of boil-off whereas the Westinghouse plants and the Combustion have much larger steam generators -- 30 minutes to an hour's worth of heat removal at decay heat conditions.

The number of PORVs -- some plants have one. Some have none. Some have two. Some even have three -- I cannot name a plant that has got three but I know there are some.

MR. CARROLL: Try Diablo.

MR. LARSON: Yes. The PORV capacities, again there is a range of nearly four here just across plants, B&W being the lowest in the ones that I have selected.

MR. WARD: And that's not for valve. That's total capacity, I guess, is that right?

MR. LARSON: Yes.

MR. WARD: Okay.

MR. LARSON: For example, the Zion and number here represents roughly 26 kilograms per second per valve.

ECC flow capabilities, there are high head systems. Some people refer also to the intermediate head system on the HPI with different pressure ranges, 10 to 16 mega-Pascals and 15 up to the PORV lift point and some plants like Calvert Cliffs have 8.3 mega-Pascal shutoff.

[Slide.]

MR. LARSON: That summarizes what I wish to cover on the maps and the summary and conclusions here like the other -- John said earlier this morning, what we looked at to date shows that feed-and-bleed is a viable decay heat removal mechanism in many circumstances. In order to establish the details of those circumstances, when it will work and when it is ultimately successful, like John said, obviously additional calculations have to be done, sophisticated calculations.

That is not to imply that these have not been done or at least a dozen reports that document various applications of different codes to plant specifics and it is also my understanding that plant owners have also done calculations of a similar type for the preparation of operating guidelines.

We have seen that the simplistic approach of looking at a feed-and-bleed map I think is useful I think for examination of the existence of a window for a given set of plant characteristics.

We can also use that map to show when the window may disappear and when it may reappear -- not when in terms of timing statistics but when in terms of relationships between the capabilities of the equipment that's being used.

MR. SCHROCK: Tom, in that regard, wouldn't it be useful to have a map that shows time on the abscissa and then the zones of window? It would converge closing out an area if you start with a window but the window disappears and then how long is it before a window reappears.

Knowing that information would enable you to do some additional analysis to see if you can make it on inventory through that gap.

MR. LARSON: I think that's a good idea, Virgil. It would be nice to see -- here's a window, it's this big and how long does it last?

MR. SCHROCK: Yes.

MR. CATTON: Didn't Las Alamos do some of that kind of stuff? They took four plants and they initiated things at several points that the operator might observe.

MR. LARSON: Yes.

MR. CATTON: Then they came to a go/no go conclusion.

MR. LARSON: Right.

MR. CATTON: So they have sort of done that.

MR. LARSON: I don't know if it's quite as convenient as Virgil suggests but --

MR. CATTON: No, but they took as best they could the four plants, picked several points. I might have liked to see them pick a few more. It's a good start.

You reference it in your report.

MR. LARSON: Yes.

MR. CATTON: In fact, some of the figures are directly out of the Las Alamos work.

MR. LARSON: No, my figures aren't.

MR. CATTON: Not your figures here but the figures in one of these reports.

MR. LARSON: Oh, yes, right. The reports that you speak of, I think, are even more detailed than the Las Alamos summary report. They did it for each plant and then there is a map, something or other --

MR. CATTON: That's right. They then incorporated a few of those into the summary report.

MR. LARSON: That concludes my presentation.

MR. MICHELSON: Question. I have kind of been led to believe that the capability of bleeding down the system is pretty important and that there are certain windows existing as to when it can be done and so forth. What bothers me a little bit though is that I haven't really heard about the design of the system in terms of which plants have safety-related, real redundancy when there are two and clearly with one plant with one at least, maybe more.

I also haven't heard about the likelihood of the valves even being available since I am not sure whether tech specs allow you to valve these out permanently during operation, in which case what do you do when you get into the event?

How do tech specs play into this idea and how do the redundancy of the equipment in terms of real redundancy? In other words, are they safety grade designs or one power supply doesn't take out both valves and so forth?

It's a mixed bag. Could you generalize at all? Also the tech spec question -- can you generalize on it?

MR. LARSON: I can't. Here's John Bickel.

MR. BICKEL: I can't, Carl, but I'm sure Phillip Donnelly or one of his people can address that.

Mr. Blumberg, can you address some of those questions when you --

MR. BLUMBERG: On the tech spec issue the answer is no. As he pointed out, a tech spec is a mixed bag. Some PORVs address the tech spec as far as set point goes. They are allowed to blocked, if that is your question.

MR. MICHELSON: Indefinitely, I think. Therefore, I don't know what happens.

MR. BLUMBERG: Indefinitely, so --

MR. MICHELSON: Therefore you could say -- I don't know if I derive any comfort from feed-and-bleed -- what happens on, you know, if you say, gee, what probability I am going to block them off? Some people have been blocking them off a fair amount of time.

MR. KERR: Does blocked mean they can't be unblocked?

MR. BLUMBERG: They could be unblocked.

MR. MICHELSON: It depends on the reason for blocking them to begin with.

MR. BLUMBERG: They would normally be blocked because there is some kind of leakage problem, so therefore if you have to open them obviously you can unblock them and the procedure to do that --

MR. MICHELSON: Well, that's when it isn't quite so obvious because we discovered the gate valves, if you've got this leakage with your pressurizers you may not be able to open the gate valve. It's a new problem, so I was just trying to get some comfort, though.

I just wonder why we don't cover the PORVs as a part of the tech spec. The reason they don't is because people say they are not safety-related and therefore if they are not safety-related I can't count on them. I have to hear a different story than I have heard here because the probability of them being available is extremely low perhaps.

MR. CARROLL: That's right. In the good old days they were put in simply for the reason of operational convenience. You didn't lift safety valves. That was not a safety-related function.

MR. MICHELSON: The study I would like to see is the safety valve study showing I can go ahead, I've got the capability of lifting the safeties and doing all my good things without ever worrying about the PORVs.

MR. BLUMBERG: The only thing you would find in the tech spec concerning the PROVs, if my memory sets me correct, would be set point validation. In other words, you check the set point every so often, that's so if the valves are not activated, to my knowledge, or tested, the safety relief valves have to be periodically either tested in place or pulled off and sent back to the manufacturer or locally tested and put back in.

So there's more extensive criteria on the safety relief valves and they are operated. There is no criteria that I recall that requires you to operate the PORVs that the set points can be checked, as far as that goes, as far as calibrating goes.

MR. CARROLL: Well, the later plants' tech specs do have requirements on the PORVs from the point of view of low temperature of a pressurization.

MR. BLUMBERG: It's a mixed bag out there, obviously.

MR. CARROLL: Yes.

MR. MICHELSON: Has any study been done to show the ability of these plants to bleed through the safety valves, which is the only device I think I can call on that. It is a code device. It is presumably safety related because it has to keep the thing from overpressurizing. That's the one I think I'd be wanting to see. If that one shows I'm in high cotton, I wouldn't worry about the PORV. Nobody showed me that I can lose the PORVs and still get through.

MR. CATTON: I don't think you can.

MR. MICHELSON: Well, I don't know, I haven't seen what the safety valves can do for me.

MR. CARROLL: Well, it even gets crazier than that. Diablo has got three PORVs, two are safety grade, one is not, but they're identical valves, it's just the paperwork on the damn things. But that stemmed from pressurized thermal shock considerations, I think, and tube rupture.

MR. MICHELSON: Well, we know we have highly reliable PORVs and if we know we're controlled by tech specs, then I wouldn't worry about the study showing I can fall back to the safetys and make it, but I'm not sure either of those is true.

MR. WARD: I don't think there's many plants that probably can feed-and-bleed with safety valves.

MR. MICHELSON: I don't know.

MR. WARD: Well, I don't think there are.

MR. MICHELSON: Well, if there aren't any, then I say that the PORVs -- then you've got a real situation on your hands.

MR. WARD: That's right.

MR. MICHELSON: I've heard people say, oh, wait, the safetys are. Well, I haven't seen the studies on the safetys.

MR. CARROLL: The answer, at least in part to your questions, is going to come out of the IPE, which subsumed this whole issue, provided the staff does a reasonable job of reviewing feed-and-bleed as part of that process.

MR. MICHELSON: Looking at the safetys as part of the IPE?

MR. CARROLL: Well, it's whatever the utility thinks makes sense, or the owners' group or whatever.

MR. WARD: I think some of these things we need to discuss at the end of the meeting. This is sort of the purpose of the meeting, to bring out these things. We're running significantly behind.

I think what I'd like to do is to leave the next three items, (f), (g), and (h), until the end of the day. I don't know if all our speakers are here. I think right now we're probably more interested in the plant calculations and things like instrumentation and operator training than we are in the experimental data base and analytical methods.

So, if our speakers are here, I'd like now to jump to item (i). Is Mr. Steiner here?

MR. STEINER: Yes.

MR. WARD: Could you go ahead now?

MR. STEINER: Yes, that would be fine.

MR. WARD: And I'm sorry to inconvenience the other speakers, but this is -- well, I see Mr. Steiner as one of the other speakers, but Mr. Condie and Mr. Riemke, we'll call on you later in the afternoon. Mr. Steiner, this will be your presentation (i) now on plant calculations, right?

MR. STEINER: Right.

MR. WARD: All right, good.

[SLIDE.]

MR. STEINER: Good morning, my name is Jim Steiner from Los Alamos, and I'd like to talk about some feed-and-bleed calculations that we did about 6 or 7 years ago. These were done in the 1984-1985 timeframe. This work was done by Brent Boyack, Rudy Henninger and Jim Lime, and at that time, they were in the energy division at Los Alamos.

[SLIDE.]

MR. STEINER: The objectives of the feed-and-bleed study were basically to evaluate the success or failure in specific plant calculations and to provide some plant specific insights and also to use the i:.sides to predict the feasibility of feed-and-bleed for PWRs for which detailed plant calculations have not been performed, basically to provide some extension statements to other plants.

The scope of the study was basically to perform four detailed plant calculations basically covering the range of the three PWR vendors and also to provide two plant calculations for Westinghouse plants, one for Zion, a four-loop PWR, and one for H.B. Robinson, a three-loop PWR. And then also to use the results of the plant calculations to provide extension statements for similar plants of each vendor type.

[Slide.]

MR. STEINER: I think at the beginning we need to provide some definitions. Feed-and-bleed, that has already been discussed. But for the purposes of our study, we have defined -- provided a definition of the success of feed-and-bleed -- the first success criteria that we used in our study was the success of being able to transition to a hot pressurized holding condition. And this is an intermediate condition that -- that would require further operator actions to get to the final goal, being entry conditions to HRH heat removal.

Let's see. The -- the two criteria we have for successful transition to pressurized -- hot pressurized holding condition are that the final system vessel and mass inventories are either stable or increasing and also that the top of the core remains covered by the liquid level throughout the transition.

I guess that covers the definitions that I wanted to talk about.

[Slide.]

MR. STEINER: The approach, as I've already referred to a little bit, was to use basically QA input models of the -- the four specific plant types that we looked at. These were -- Calvert Cliffs was a CE plant, the B&W plant we looked at was Oconee, and two Westinghouse plants: Zion and H.B. Robinson.

We used the -- these plant models to simulate the plant response, to review the results for as much insight as we could obtain from running these plant calculations, and also to provide extension statements for similar plants.

[Slide.]

MR. STEINER: For our study, we made the following assumptions. First, we assumed, in all of our plant calculations, that the plant equipment needed for feed-and-bleed was available and operable throughout the calculation of the feed-and-bleed procedure. We didn't look at any equipment failures during -- during the middle of the transient. I think we ran some calculations with various HPI assumptions of HPI train availability -- full HPI versus partial HPI being available; assuming that at the beginning of the calculation, and running the entire plant analysis calculation with that assumption.

Let's see, for Calvert Cliffs, the calculations we ran are shown on the slide. We assumed that both PORV's were available, all three charging pumps were available, and I think we ran a sensitivity calculation, an additional calculation with two out of the three HPI pumps being available.

For Oconee, we assumed that the single PORV was available and two out of the three HPI pumps were available.

And Item four is the degraded equipment study calculations that we ran for the four plants, shown on the slide.

[Slide.]

MR. STEINER: The next slide.

MR. MICHELSON: Excuse me. The degraded equipment studies, they were only in cases wherein one of the trains or more -- one of the trains were unavailable, but you didn't do other kinds of studies, like degraded air and so forth?

MR. STEINER: No. No, we did not. So basically item 4 covers all of the degraded equipment study calculations that we did.

MR. CATTON: Are those included in your report -- your summary report?

MR. STEINER: Yes.

The next slide provides a quick comparison of key plant characteristics. I won't read off all the numbers. Basically, what we've done is -- is divided the -- the relief and the PORV relief capacity and ECC flow capacity by the thermal power for each plant, to provide a little bit more meaningful comparison.

MR. DAVIS: Excuse me. You also have charging pumps, but you did not consider those ECC flow pumps, or do you?

MR. STEINER: I think this is just the ECC flow.

MR. DAVIS: Either HPI or SI?

MR. STEINER: Right. But I don't --

MR. DAVIS: Not charging?

MR. STEINER: Right. But I don't think that the charging flow capacity is included in these numbers.

MR. CARROLL: Wouldn't that be whatever you described as nominal equipment?

MR. DAVIS: That is what I'm wondering.

MR. CARROLL: On the proceeding page?

MR. DAVIS: It is so low, I think charging may have just been left out.

[Slide.]

MR. STEINER: The results of our study, in summary, are that, first of all, that feed-and-bleed is a potentially useful alternative method of decay heat removal. The previous presentations have basically said that same thing. That basically just says that the window -- it does exist. And HPI, or feed-and-bleed cooling is -- is potentially a viable heat removal mechanism.

MR. KERR: Is potentially useful different from useful?

MR. LARSON: I guess my answer to that would be --

MR. KERR: I am trying to understand whether there is a meaning here that I am missing.

MR. LARSON: Well, I think what we mean by "potentially useful" is that it could be used to -- following a loss-of-feed accident to bring about a transition to entry conditions for RHR.

MR. KERR: So, I wouldn't be doing a grave injustice to that by just describing it as "useful."

MR. LARSON: That's correct.

Secondly, the availability of the HPI -- of SI delivery capacity greatly enhances the effectiveness of the procedure. Basically, for plants that have high-pressure HPI capacity, what we found in our calculations was that the operators have much more time to initiate the feed-and-bleed procedure and still be successful in transitioning to entry conditions for RHR heat removal.

MR. WARD: And those are which plants?

MR. LARSON: Most of the B&W plants have that capability; I think some of the Westinghouse plants. That would probably be on the previous slide. Actually, it's on the last two slides, looking ahead in the handout. I think there is a table that indicates which plants have low-pressure, intermediate-pressure, and high-pressure SI capability.

MR. WARD: Okay. Thank you.

MR. MICHELSON: Which category was Davis-Besse in?

MR. LARSON: Well, that's a B&W plant.

MR. MICHELSON: I thought they just had low-pressure. During the Davis-Besse event of 1985, where the steam generators ran out of water for several minutes, I don't recall that they started a feed-and-bleed process, but maybe they did.

MR. LARSON: No.

MR. BOEHNERT: They delayed.

MR. MICHELSON: So, they at least didn't start at the time they lost secondary heat sink. I think it was 12 minutes before they got the auxiliary feedwater restarted.

MR. KERR: This says that had they started at 12 minutes, it wouldn't have worked. If it was going to be successful, it had to be started at the time when they lost it.

MR. MICHELSON: In other words, they'd waited too long already, and they were lucky they got auxiliary feedwater back.

MR. KERR: I would say they were skillful.

MR. WARD: I don't know that that's right. You say Davis-Besse doesn't have high-pressure SI?

MR. MICHELSON: It's low-pressure.

MR. WARD: They're an exception to the B&W rule?

MR. MICHELSON: Yes.

MR. STEINER: I don't think we considered Davis-Besse.

MR. MICHELSON: In 1985, you were in the middle of this study. I thought it was a very interesting event to have been thinking about, if I understood when you did the calculations.

MR. STEINER: I think Davis-Besse occurred just after we completed this study.

MR. MICHELSON: I see.

MR. STEINER: I think we were probably in the final stages of documenting results.

MR. CATTON: Well, you could have included it by extension, as you did a lot of the other finds.

MR. STEINER: That's right, and I'm not sure why we didn't.

MR. CARROLL: You made no extension statements for Davis-Besse. In addition to the raised-loop design, the HPI characteristics differ markedly from those of the other B&W plants. We believe and recommend that a model of Davis-Besse should be developed and used to analyze feed-and-bleed for the plant.

MR. STEINER: Davis-Besse is kind of a hybrid plant. It's a 177 plant, but it has the raised-loop design, and I think maybe some of the other parameters are a little bit different for Davis-Besse.

MR. MICHELSON: So, we're really worse off than one might think from reading the write-ups.

MR. WARD: I am not sure that's right.

MR. MICHELSON: Maybe not.

MR. WARD: They're different, but I don't recall that the evidence was they would have been unsuccessful if they had started the feed-and-bleed. I don't know -- I guess they could --

MR. MICHELSON: I thought that was the inference here, though, that the window had already passed.

MR. WARD: No. I think he said it's more difficult.

MR. CATTON: They couldn't extend the analysis that was done.

MR. ST[illegible]NER: The current study really was inconclusive in terms of being able to make any statements about Davis-Besse.

MR. SCHROCK: Was this recommendation ever carried out, do you know, that there be a model of Davis-Besse?

MR. SHOTKIN: Yes. After the Davis-Besse event, there were several what-if studies calculated. I'm finding out right now whether Schultz is going to have that in his presentation.

MR. MICHELSON: I was under the impression that feed-and-bleed would work.

MR. STEINER: I think there was a study that showed that feed-and-bleed could have been used in Davis-Besse, but I'm not -- I'll have to get back with you on that later.

Moving along, item 3 on our summary results says that the PORV capacity is important during the transition to hot shutdown if only safety-grade water supplies are considered. Basically, plants with lower PORV capacity would require a longer period of transition to hot shutdown, and that would be that more safety-grade water would be required, and then there is the potential that these plants would run out of water before that transition has been completed.

Finally, we found that simple inspection is a useful technique for extending detailed calculations to a broader set of plants, and I'll talk more about that later.

[Slide.]

MR. STEINER: I would like to talk a little bit about an example to provide sort of a typical example of the calculations, the plant calculations that we performed for our feed-and-bleed study. We chose Calvert Cliffs as a reference plant to demonstrate the technique that we used in this study.

I'll be talking about two calculations, one in which the transition to RHR heat removal was successful and the second calculation assumed a delayed time of initiation of feed-and-bleed which proved to be unsuccessful in being able to transition to RHR heat removal without any core heatup.

[Slide.]

MR. STEINER: In the first calculation, we assume that feed-and-bleed was initiated at the time of the loss of secondary heat sync, at the time basically that the steam generators boiled dry. The next slide shows the calculated primary system pressure. Some of the major events shown on that slide are the initial rapid depressurization as a result of the PORV opening, followed by turnaround in the pressure at the time the vapor generation rate in the core exceeds the PORV relief capacity.

At that time, the pressure starts to increase, oscillates a little bit until it increases beyond the SI shutoff pressure and continues to increase until the time when the primary system inventory is depleted to the point that the two-phase flow is reestablished through the PORV.

MR. MICHELSON: Why is it oscillating?

MR. STEINER: I think those pressure oscillations correspond to oscillations in the primary system flow rate, causing mixing and periods of depressurization followed by stagnant periods when the pressure increases a little bit at the beginning.

MR. MICHELSON: Cycling the PORVs; they were all open and remained open?

MR. STEINER: Right, right.

MR. CATTON: Could it be intermittent two-phase flow through the PORVs?

MR. MICHELSON: You think they modeled that?

MR. STEINER: Oh, yes.

MR. DAVIS: It's probably just chugging in the core; isn't it?

MR. STEINER: Yes, I think so, basically.

MR. CARROLL: The pumps are tripped in this case?

MR. STEINER: Right.

MR. CATTON: I suspect it's intermittent two-phase flow.

MR. STEINER: Through the PORV.

MR. CARROLL: Now what happens?

MR. WARD: Go ahead.

MR. STEINER: There is a brief, rapid depressurization at the time the loop seal clears. Basically, when that happens, HPI injection into the cold legs is going into a vapor space and you get some condensation of steam on the HPI, causing the depressurization that corresponds to the loop seal clearing.

MR. CARROLL: Hold it. You're above the shutoff pressure of the SI. How are you getting SI into cross condensation?

MR. STEINER: That's right. I think it must -- okay, there's probably a plug of liquid, maybe in the downcomer and part of the cold legs left over from the previous period of SI injection. When the loop seal clears then that fluid gets mixed with the hotter fluid which is basically what pressurizes the primary system, basically pressurized by the hottest -- the vapor pressure of the hottest fluid in the system and a thermal mixing resulting from --

MR. WARD: This bulge above the SI shutoff pressure is just the loop seal clearing. That's really what it amounts to.

MR. STEINER: Right.

MR. WARD: I mean, you wouldn't --

MR. CATTON: It shifts some cold water to the core.

MR. STEINER: You're right, it's not, as I said incorrectly -- it's not condensation on the HPI. I think it's just thermal mixing that results from the loop seal clearing.

MR. CATTON: When you clear the loop seal, you've burped some fluid through the core. That increases the amount of steam generation and the pressure falls.

MR. STEINER: Right.

[Slide.]

MR. STEINER: The next slide shows the vessel liquid mass for this particular calculation, the Calvert Cliffs calculation. Basically, in this calculation, the core was not uncovered and prior to the -- when the system pressure fell below the shutoff head for the SI flow and HPI was reestablished --

MR. DAVIS: What vessel mass would correspond to the top of the core?

MR. STEINER: I'm not sure exactly.

MR. CARROLL: I bet you get pretty close.

MR. STEINER: I don't know the answer to that exactly, but I do recall --

MR. WARD: Two slides later it shows a case where apparently it did uncover, right?

MR. STEINER: That's right.

[Slide.]

MR. STEINER: The next slide shows the depressurization for the calculation where feed-and-bleed was basically initiated at primary system saturation, several hundred seconds after the steam generator and secondaries had boiled dry. Basically, this is sort of similar to the first calculation, with a little bit more pressurization.

The pressure starts to decrease when the PORVs are opened and decreases further when the HPI flow is established, when the pressure drops below the shutoff head for HPI flow.

[Slide.]

MR. STEINER: The vessel liquid mass inventory for this calculation is shown on the next slide. And in this calculation the core is uncovered before the HPI flow was reestablished.

MR. KERR: That means the top of the core was uncovered, I assume, not the whole core?

MR. STEINER: Right. The liquid level in our calculation, fell within the -- the active length of the core. I'm not sure exactly how far down that penetration was.

MR. WARD: So the answer to Pete's earlier question is somewhere between 40,000 and 25,000; is that right?

MR. CATTON: Right.

MR. SCHROCK: What you're saying is the collapsed liquid level, not a two-phase?

MR. STEINER: Right.

MR. WARD: Probably.

[Slide.]

MR. CATTON: This is not a core melt is it, even though you classify it as a failure, you -- this is not, by no means, a core meltdown?

MR. STEINER: Right. In fact, that's shown on the next slide.

MR. CATTON: Shown in the slide you've got right here?

MR. STEINER: Right, right. But, based on our definition that we used for -- to define success of feed-and-bleed, for the purposes of our study, this calculation was not successful.

MR. WARD: All right.

MR. STEINER: Not successful, to the extent there was some core uncovering in the heat up, not to melting temperature.

MR. CATTON: This is a far cry from a core melt.

MR. WARD: We saw Bickel's number before, which said it was 99 percent of 90 percent -- what did the 1150 PRAs assume for this sort of thing? Bill, do you have any idea? Would they say this was a failure of a success?

MR. KERR: I have no idea.

MR. CATTON: I suspect they would say this was a failure, because they don't --

MR. CARROLL: The 1150 definition for PWR's is core uncover, if I remember correctly.

MR. CATTON: It looks to me like you could have pushed a little further.

MR. WARD: Don't push too much because I'm not very comfortable with those 99 percent and 90 percent numbers.

MR. SCHROCK: Core uncovery neglects level swell, and you're boiling in the core, there has to be a level swell. So --

MR. MICHELSON: I assume -- it's when they're talking about level, it's a collapsible level.

MR. CATTON: You can collapse the core -- down to the core if you think there's no problem.

MR. CATTON: Basically this slide.

MR. STEINER: Core cladding temperatures, elevated above the saturation temperature.

[Slide.]

MR. STEINER: After we performed our plant calculations, we looked at methods for extending the results of the calculations that we had to similar plant types. And basically, our study identifies the following four methods of making extension statements for similar plants, plants with similar HPI and PORV system parameters, similar to the plants -- for which feed-and-bleed calculations have been performed.

The first and the most straightforward method of extending the results, is to just use simple exception. And basically, that involves comparing the parameters on the previous slide. I think it was about the third or fourth slide that we had, summarizing the SI and PORV flow -- flow system capacities normalized to core power.

The next method that was considered for extension was -- was what we called enhanced inspection. Basically, that was the same as simple inspection. And we looked at whether or not the feed-and-bleed operating maps could be used in conjunction with simple inspection to provide an enhanced statement -- extension statement to -- to other plants.

And basically, we found that that was not possible, mainly because the feed-and-bleed maps, while they're useful for understanding the phenomena, are not really predictive, and therefore cannot really be used to extend the results of existing plant calculations to other plants.

The fourth -- the third method of extension, which would require significantly more effort, would be to -- to develop simplified plant models, and run some simplified plant calculations and using that method to extend the results of the detailed plant calculations that have already been performed.

And finally, the fourth method, which would be very costly an time consuming, would be to develop detailed models for each specific plant. In fact, this really wouldn't be an extension.

[Slide.]

MR. STEINER: The next slide provides a simple example of the method we used in this study for extension, the inspection method. Basically, this method involves comparing parameters for similar plants for which a feed-and-bleed calculation has already been performed.

On this slide, the reference plant that we ran our calculation for was Calvert Cliffs, and the parameters for the other CE plants are provided on this slide.

[Slide.]

MR. STEINER: The next slide shows the results of the extension statements that can be made by comparison of the parameters on the previous slide.

MR. CATTON: Did you run one other set of calculations, e.g., something based on containment pressure or something as an initiation point for the HPI? I could find it if you don't remember.

MR. STEINER: I think there are some additional calculations in the NUREG report, results of calculations that we ran assuming that feed-and-bleed was started at the time of containment overpressure, I think?

MR. CATTON: Right.

MR. STEINER: I think there are some additional results in the NUREG.

MR. CATTON: I can understand why you would do the two calculations you have up there, but why did you do the other set? What would cause the pressure to go up in the containment?

MR. STEINER: I would say containment heating from the PORV flow.

MR. CATTON: Okay.

MR. STEINER: As I said, the next slide provides the results of extension statements that can be made just by simple inspection of the parameters on the preceding slide. For example, if we go back to the preceding slide and look at Fort Calhoun, we see that the HPI shutoff head for Fort Calhoun is higher than that of Calvert Cliffs, while the -- and the PORV capacity is also higher. So, it's pretty easy, just by looking at those numbers, to say that the results that we obtained for Calvert Cliffs, the same statement of feed-and-bleed success could also be made for Fort Calhoun, and similarly, for the other plants, CE plants.

There is one exception in this list, and that's Maine Yankee. What we have shown for Maine Yankee is that we feel that feed-and-bleed would be successful for the Maine Yankee plant if the operators waited until the time of primary system saturation, and the reason that we say that is that Maine Yankee is really more like a B&W plant in some ways than a CE plant. It has some similarities to the B&W plant.

So, this one exception statement that we've made for Maine Yankee is based on its similarity to some of the other PWR types, but the others in the list are just basically straightforward application of the inspection method.

MR. WARD: Okay. Now, for ANO-2, you say "NC," which means what?

MR. STEINER: No conclusion.

MR. WARD: And that's because you don't know what the vent valve is compared with the PORV or what? I mean the numbers look about the same as Calvert.

MR. STEINER: Right.

MR. CATTON: No PORVs?

MR. STEINER: Right. That plant does not have PORV; it has vent valves.

MR. WARD: It's got a pretty big vent valve, but I guess that wasn't looked at or something.

MR. STEINER: I think, at the time of the study, we were not able to obtain the flow characteristics of the vent valve.

MR. WARD: I understand.

MR. KERR: This is a conclusion you reached by simple inspection, not a calculation.

MR. WARD: Yes. I understand. I thought maybe it was known that the vent valve had as big a throat as -- I mean it's just a globe valve, as I understand.

You've got a couple on this list -- Millstone 2 and Palisades are in this list, and they aren't on the previous list. But apparently, they had characteristics that were similar to Calvert Cliffs, also?

MR. STEINER: That's correct. This is sort of the summary results.

MR. WARD: Okay. This is just a more complete list.

MR. CARROLL: For the record, ANO-2 is equipped with a vent valve, but its relief capacity is not known to us. It's sufficiently large. It should also be able to feed-and-bleed.

MR. MICHELSON: Did it say how large, though?

MR. WARD: No.

MR. CARROLL: In the same ballpark as the ones that are successful.

MR. MICHELSON: How do we know that?

MR. CARROLL: From the table.

MR. STEINER: That concludes what I had to say about our PWR feed-and-bleed calculations.

MR. WARD: Okay. Anymore questions?

[No response.]

MR. WARD: Okay. Thank you very much, Jim. I appreciate it.

Let's break for lunch now and return at 1:30, and we'll go with Mr. Schultz. I hope he'll be here at that time.

[Whereupon, at 12:30 p.m., the meeting recessed for lunch, to reconvene this same day at 1:30 p.m.]

AFTERNOON SESSION

[1:34 p.m.]

MR. WARD: We are reconvening the meeting here. Okay, is next speaker is Mr. Schultz who will talk about power plant calculations. This is Item J on the agenda. We will proceed with Items J, K, L and M and then go back to F, G and H, if we have time this afternoon.

[Slide.]

MR. SCHULTZ: Good afternoon. My name is Richard Schultz and I'm from the Idaho National Engineering Laboratory. I'm in the Energy and Systems Technology Group.

This presentation will cover feed-and-bleed studies on the PWR plants. We have not, I don't believe, done as many PWR plant calculations as Los Alamos, so there will be fewer that will be covered here.

[Slide.]

MR. SCHULTZ: The presentation will cover key parameters, uncertainties and INEL feed-and-bleed analyses. The order that will be taken is: first of all, key parameters that affected feed-and-bleed sequences, analysis limitations and uncertainties, including modeling practices for plant calculations and then finally there will be a summary of the INEL feed-and-bleed analyses.

The topics that will be covered are: we have one or two slides that give a short description of the plant.

There will be some analysis results, a discussion of feed-and-bleed operational envelope and finally, a discussion of candidate procedure equipment improvements. I'll close with conclusions.

[Slide.]

MR. SCHULTZ: Key parameters can strongly affect the outcome of the feed-and-bleed in a plant type. The key parameters are the ones that I've listed here. First of all, there's the system state at the start of the feed-and-bleed transient; in particular, the reactor coolant system temperature.

The core power; that is, how long after scram does feed-and-bleed begin, so that will determine their core power level. Also, the external energy losses and that becomes an important factor if the decay heat and the decay power is rather low. The lower it gets, the more influential the losses to the environment are.

There is the makeup and high pressure injection flow rates and finally the flow rates through the PORV. The question there, in particular, is the flow of water two-phase.

[Slide.]

MR. SCHULTZ: The reactor coolant system temperature is a key parameter and I'm going go through them here briefly just to underline whey they're key parameters.

It's important because, first of all, it's representative of the system's state; that is, the initial energy level. Even more importantly, it factors into the operator guidelines.

Sometimes I'm told the operator guidelines are written such that they take a particular action, depending on the RCS temperature.

[Slide.]

MR. SCHULTZ: The core power level is important because that, of course, is a system energy addition. I don't think I need to go into that. Likewise, the PORV and ECCS flow. The net result there is that you're replacing higher energy flow with lower energy flows.

[Slide.]

MR. SCHULTZ: Limitations and uncertainties of analytical methods are strongly linked to the key parameters in calculational tools. I've listed the various factors here. First, the initial and boundary conditions; for the purpose of an analyst is asked to make a plant calculation -- the uncertainties are significantly greater for plants than they are for experimental facilities.

For example, he's not really sure how much inventory is in the secondary, because if a lot of fouling has taken place, then there can be less secondary inventory present. For the code, that also represents an uncertainty, but since the thermal hydraulic phenomena characteristics that are present generally in a feed-and-bleed transient are rather mild, there are well within the capability of an advanced thermal hydraulic code so this really isn't a big factor.

Finally, the input model; here two factors are of concern. That is the nodalization fidelity and the nodalization adequacy. Fidelity is -- I've used that word to describe whether or not the analyst faithfully represented everything as it should be represented. Are all of the areas, as they ought to be, entered? Are all the volumes there and so on.

Adequacy, on the other hand, has to do with -- faced with a number of ways of nodalizing it, has he nodalized it in the best way for the particular kind of transient that's being examined here? That's the distinction between the two of them.

[Slide.]

MR. SCHULTZ: These uncertainties and key parameters anyway, are caused by unknowns concerning the plant's state at the time of the transient. For example, at core power, the largest uncertainty there is associated with post-trip fission power. Feedwater availability in the state of the steam --

MR. CARROLL: Why is -- why is that uncertain?

MR. SCHULTZ: Because the quantity of actinides, for example, that are present. Exactly how is that core power going to behave immediately after scram? If we don't know what the true state of the core is, and often we're not told when we're asked to do an analysis, then we have to put an uncertainty bound on it.

I think in time, somebody could go to the actual core map and figure it out, but usually when we do an analysis, we're not told that.

MR. CARROLL: I think I see what you're saying.

MR. SCHULTZ: Feedwater availability and state of the steam generator. Whether the feedwater will be available and the degree of the steam generator tube fouling, for example, have an impact. And if these are unknowns, then we have to do sensitivity studies to bracket the bands that these parameters are believed to be in.

The PORV mass flow conditions. And here again, we have the two-phase.

MR. CARROLL: I guess I have a -- I believe tube fouling, at least the number of tubes plugged certainly has an influence, but you -- you don't really reduce the quantity of secondary inventory by any significant amount with -- with corrosion or deposits in the real world. If you did, you couldn't run the plant.

MR. SCHULTZ: I think -- well the way it shows up in our uncertainty numbers is, our engineering judgment, I'll show you the slide in just a few minutes. It shows up as an uncertainty. And, yes, it has to do with, I guess, primarily the tube plugging.

MR. WARD: Tube plugging wouldn't effect the secondary side?

MR. CARROLL: Well, the number of tubes that are plugged, Dave.

MR. SCHULTZ: We don't exactly know how much inventory is in the secondary, I guess that's what it boils down to. We're given a nominal number, but we don't know how accurate it is and I don't think they do either.

MR. WARD: Yes. Well I can see that, but I don't see how fouling has much to do with it. But that's all right. We're making too much of this probably.

MR. DAVIS: Excuse me. Do you take account of the rundown of the water pumps and the additional inventory that that runs into the steam generators?

MR. SCHULTZ: Yes.

MR. DAVIS: Is that a well-known parameter for these?

MR. SCHULTZ: That also is estimated. We will have a characteristic. Well, usually when we run -- run a calculation, we just ramp the feedwater down some sort of a straight line approximation, unless we're given some known information on it. If we are, then we'll put that in. But usually, it's just a straight line approximation, because we don't have the particulars.

MR. KERR: I need to re-ask a question that you already answered. Why is the post-trip fission power so uncertain?

MR. SCHULTZ: Because we're not really sure of their core map; how long various bundles have been in there and, consequently, what the fission products are throughout the core.

MR. WARD: Somebody knows that.

MR. SCHULTZ: Somebody knows.

MR. KERR: I don't see that the number of fission products has anything to do with the post-trip fission power. Do you really mean fission power, or do you mean --

MR. SCHULTZ: The post-trip fission --

MR. WARD: The decay heat power, you mean?

MR. SCHULTZ: Well, the decay heat and also the -- the power contributed by the actinides.

MR. KERR: But is that -- do you mean contributed by actinides fissioning? Because that says post-trip fission power. To me, that means power produced by fission; it doesn't mean that to you?

MR. SCHULTZ: Well, there is fission --

MR. SCHROCK: You mean you don't know the reactivity on shut-down or what? Calculation of the decay of fission power is very uncertain?

MR. SCHULTZ: Let me put the -- let me try to answer your question by moving ahead to this slide.

[Slide.]

MR. SCHULTZ: We have broken down the uncertainty on the core power, in terms of what is known about the initial power, the post-trip fission power and the decay heat in this fashion. And the post-trip fission power, I believe, is the power which is contributed by the actinide contribution in the -- somebody may correct me, but I think -- believe that's true.

MR. SCHROCK: I think you're saying that don't know the negative reactivity insertion. That's the only way I can interpret it. For about 10 seconds after trip, the fission power may still be larger than decay power; but you can calculate it. I mean you're --

MR. SCHULTZ: Oh yes, you can calculate it. And the point I'm making is -- is that we don't know what the characteristic of the core that we're being asked to analyze is.

So generally, we'll receive a request to analyze --

MR. SCHROCK: So you really don't know the negative reactivity insertion on trip, I guess that's the point? Yes, the schedule of negative reactivity.

MR. SCHULTZ: Isn't that the contribution which comes from the presents of the actinides in the --

MR. SCHROCK: Yes, but that's very small. I mean it's about -- about one-third of the decay power from fission products at the time of shut-down.

MR. KERR: But that's not due to fission reaction.

MR. SCHROCK: No, it has nothing to do with fission power, that's a part of the decay power.

MR. WARD: Do you mean the power that is generated between the time a trip signal occurs and between the time the reactor is actually shut down? Is that what's the question here?

MR. SCHULTZ: Well, it's a contribution over and above the presence of decay heat. Now, it's the sum of that.

MR. WARD: Maybe, you know, if you're assuming an instantaneous large break LOCA or something, and you assume there is some fission power between that instant and -- I don't know if that's what they're thinking of or not.

MR. KERR: You don't assume -- you don't assume that the core is voided instantaneously. I think it just has to do with the --

MR. WARD: But there's a delay in the -- the scram delay, is that what --

MR. KERR: It must be.

MR. CARROLL: Once the rods are in, although there are a few fissions occurring for a variety of reasons, that's a very insignificant amount of power coming from fission.

MR. SCHROCK: It takes about 10 seconds for the fission power to drop to the level of decay power in a typical scram.

MR. CARROLL: Right. But once that's happened, that's it.

MR. SCHROCK: That's it. Right.

MR. CATTON: It would be zero at 10 seconds.

MR. SCHROCK: At 20 seconds it would absolutely be zero unless it is an energy deposition.

MR. MICHELSON: Is there any accommodation for return to power, for dropping the temperature. The rods are in all right but haven't got enough boron in yet.

MR. SCHULTZ: Usually these kinds of calculations are done not with neutronics -- it will simply put in a power profile that would be calculated based on --

MR. MICHELSON: It wasn't built into the --

MR. SCHULTZ: We can use neutronics if we wish but usually these calculations are not done in that fashion.

The reason I am unsure about how to answer your question is I have never found the various contributions to the power level. When we do these kinds of analyses we receive or we generate a power profile for the core, which is representative and you are asking a question about a particular part of it and exactly what the contribution of that is.

MR. WARD: It looks like this 35 percent is large but it isn't necessarily. That's just 35 percent of some small number so maybe we're spending too much time with this point.

MR. SCHULTZ: I guess your question is really what effect does that have on the calculation, and to be frank, I can't tell you that at this point but these various factors were taken from that brown-covered report which is over there on the table.

MR. SHOTKIN: It's discussed in Appendix C of this report.

MR. WARD: Let's move ahead.

MR. SCHULTZ: These are the various uncertainties which come into play.

MR. WARD: Go ahead, please.

(Slide.)

MR. SCHULTZ: Typical model regions, now moving on to uncertainties associated with the model, typical model regions that may require study during such a transient and by that I mean people if they are doing a feed-and-bleed analysis, unless they are certain about how each portion of the model should be nodalized, then they will do some sensitivity studies.

That is what will be our standard procedure.

For the steam generator secondary inventory level and this determines in part when primary feed-and-bleed must begin.

The pressure vessel upper head and upper plenum modelling and that is of concern with regard to where is the pressure vessel inventory. If we don't model it quite properly then it will not drain in a representative way into the core region, for example.

The heat structures -- the reactor coolant system heat-up rate is affected by the heat structures.

(Slide.)

MR. SCHULTZ: The hot leg nodalization -- that is modelling the connection of the pressurizer surge line to the hot leg for example is of concern and it is of concern because the time at which the surge line uncovers is significant in terms of when you will begin to get level swell in the pressurizer.

Finally, the RCP, the Reactor Coolant Pump, geometry and loop seal liquid levels -- this is a point that's made specifically in the report you just received. B&W plants have a Weir and exactly where it is will determine the amount of inventory that's in the loop seal itself. If it is in the loop seal, then it's not inside the pressure vessel.

(Slide.)

MR. SCHULTZ: INEL has performed I think several feed-and-bleed analyses on the four plants listed on the title. I haven't put this up here with any expectation of you reading the very small print that's in the table, but the purpose of giving you that is when an analysis is done on the Oconee-1 plant for example it means that for the second item you can use some of the results in an extensive way for, say, the Oconee-2 and -3 and the ANO-1 plant, the Crystal River 3 plant and so on.

Of course you have to take into account specifics for the geometry and the equipment that may be a little bit different there but these plants are supposedly very similar.

MR. SCHROCK: Is this the same information that we learned from Las Alamos? Are you describing parallel computations? It's the same.

MR. SCHULTZ: I think it's the same. The analysis I'll show will be INEL analyses. I assume that Las Alamos just showed theirs.

MR. WARD: Yes. It shows a similar table. I mean yes and no mean that --

MR. SCHULTZ: It's in the legend at the bottom, so that means --

MR. WARD: Y means yes; N means no --

MR. SCHULTZ: Right.

MR. WARD: But going beyond that --

MR. SCHULTZ: Okay, this SGSD is Steam Generator Secondary Dryout, so Y is yes, it occurred and for example when saturation occurred, no for the first example.

This table came from this reference and I didn't give you that reference. We can get you that reference though if you so desire.

This reference is a summary of studies done to evaluate the feed-and-bleed in the Oconee-1 plant and to compare those results to a similar transient in a typical Westinghouse and a typical Combustion Engineering plant.

MR. WARD: This is 4966?

MR. SCHULTZ: Yes, 4966.

MR. WARD: Let me understand the table.

This looks an awful lot like the table Mr. Steiner showed. In that case yes and no mean feed-and-bleed would be successful if initiated by the time of steam generator -- SGSD.

MR. SCHULTZ: SGSD is Steam Generator Secondary Dryout.

MR. WARD: Secondary dryout or saturation. I mean does this table have the same meaning as what Mr. Steiner showed?

MR. SCHULTZ: I suppose. I guess it is. Yes. He is shaking his head yes.

MR. CATTON: This is his table, isn't it?

MR. SCHULTZ: I believe this table came out of the reference I just put on the overhead.

MR. CATTON: But that particular reference is to Las Alamos.

MR. SCHULTZ: Well, I don't -- to be truthful --

MR. STEINER: No, it does not.

MR. CATTON: INEL did these calculations too?

MR. SCHULTZ: No, we didn't do the same calculations Las Alamos did.

MR. WARD: It looks like a pretty similar list.

MR. CATTON: The table is identical.

MR. SCHULTZ: Just because it has the same plants doesn't mean we did the same calculations.

MR. CATTON: You even used the same symbols? The only thing that is different is the SGSD. They called it something else.

MR. WARD: I guess -- are the results the same? This is wonderful if they did two different --

MR. SCHULTZ: I don't believe we did the same analysis that Las Alamos did. I believe we did different analyses.

MR. BEELMAN: If you would like to understand it, I think I can shed some light.

I am Ron Beelman. I am one of the authors of the PD Weekly Report referenced.

A lot of these calculations were done in parallel on RELAP and TRAC. Some of them were only done on RELAP or TRAC. The table is a compilation of all the feed-and-bleed calculations that have been done, I believe.

MR. CARROLL: By both?

MR. BEELMAN: By both Las Alamos and by INEL. It's a compilation.

But a number of them were done in parallel. For instance, on Calvert Cliffs there was a parallel TRAC calculation to the RELAP 5 calculation. I cannot tell you specifically which ones are which but that is at the base of that table.

MR. WARD: Okay. Thank you.

MR. SCHULTZ: That work is in the report.

[Slide.]

MR. SCHULTZ: The next table I'll show, which is from the same report, incidentally, lists nominal key parameters for typical plants that were used for feed-and-bleed analyses. The reason for putting this up is just to put the various plants into perspective with one another.

The core power is listed in the first row. Of special note, though, is the second item, the total steam generator secondary inventory. You will note that there is quite a bit less inventory in the B&W plant, which is Oconee; Calvert Cliffs is a CE; and these two are Westinghouse.

Also of note is, for example, the total rate of PORV flow versus the total ECC flow, and here you'll note that Oconee has a much greater ECC flow than PORV flow, and it's just exactly the opposite for Calvert Cliffs, a glaring difference, I think. The same is true for Zion, but there is not as great of a gap between the PORV and ECC flow.

[Slide.]

MR. SCHULTZ: There was a study done to approximate the uncertainty on the various parameters of interest, the key parameters, and incidentally, this was done in this reference, done by Cliff Davis, the Davis-Besse uncertainty study, of which you have a copy. These uncertainties were based, for the most part, on engineering judgement, and this gives you some idea of the order of magnitude.

MR. KERR: I can't for the life of me see how post-trip feedwater uncertainty could be 100 percent.

MR. SCHULTZ: Well, that's just if it works or doesn't work.

MR. KERR: But I mean you have to make an assumption about it one way or the other, and once you make the assumption, there is no uncertainty.

MR. SCHULTZ: Yes, but if you're asked -- you have to, perhaps, do two studies, one with and one without; that's all.

Am I correct in saying that, Ron?

MR. KERR: It's a funny way to describe two boundary conditions, to show that the uncertainty is 100 percent, it would seem to me.

MR. DAVIS: If the feedwater stays on, then you don't need the feed-and-bleed.

MR. SCHULTZ: That's true.

MR. DAVIS: So, maybe you're talking here about the assumptions on coast-down, which I what I asked about earlier, whether you get some additional input from coast-down or whether you assume that all flow stops at time zero. That assumption is made occasionally.

MR. SCHULTZ: The contribution of feedwater to -- in other words, the coast-down --

MR. DAVIS: The coast-down of the feedwater pumps, yes.

MR. SCHULTZ: I would have to check that. I'm not an author. I didn't do this work. I'm presenting this work, but I did not do this work.

MR. MICHELSON: If you have feedwater, you still have to have bleed.

MR. SCHULTZ: That's correct.

MR. MICHELSON: Okay. I thought you said if you had feedwater, you didn't need to worry about feed-and-bleed.

MR. SCHULTZ: Well, I meant -- that's an incomplete sentence. You don't have to worry about primary feed-and-bleed. That was where I was going with that statement.

MR. MICHELSON: Feedwater is on the secondary side.

[Slide.]

MR. SCHULTZ: The plant models which were used to develop -- using our standard practices at that time, and I don't want to cause confusion on this. By saying "standard practices," I am not telling you that we have a document somewhere that says, okay, the following are standard practices for producing a model for feed-and-bleed.

The standard practices that we had were to use the experience base that we have in building a plant model to do operational transients of this sort. We've had a great deal of experience in terms of nodalizing the pressurizer and the other portions of the plant, and if there is a question on a particular part or even all of it, we will convene a committee to discuss that and to settle on exactly how the model should be nodalized in its final form. If questions exist after the committee has convened, then that will mean that sensitivity studies will be done to examine the importance of those parameters, and that's what is meant by "standard practices."

The B&W plant decks developed and used for these studies -- and by "these studies" I'm speaking of the one that I have referenced so far, the one by Cliff Davis and the one by Wheatley et al. -- were all developed and used to analyze feed-and-bleed transients prior to the assessment done using the OTIS facility, and that's simply because the OTIS facility data was not available early enough.

These models were developed, in large measure, to analyze the pressurized thermal shock problems. So, a great deal of experience had been obtained in using these models and in analyzing the way they behave. Since feed-and-bleed transients are mild, a relatively coarse nodalization was used.

[Slide.]

MR. SCHULTZ: Feed-and-bleed analyses were performed to study the Davis-Besse-1 and also a portion of the operator action envelope for Oconee-1. The studies that were done are shown on this slide.

First, the Oconee-1 sensitivity bullet: This was a study that was done to determine the latest time that you could initiate primary feed-and-bleed prior to having -- to prevent core heat-up, and to provide a basis of comparison, similar studies were done together with it on the H.B. Robinson plant and also the Calvert Cliffs plant.

The Davis-Besse-1 feed-and-bleed analysis was performed to determine plant behavior if feed-and-bleed had been required following the loss-of-feedwater plant that that plant experienced in June of 1985, and the reason for the uncertainty table that I gave you -- and that's present in Appendix C -- was we used the best available information we had at the time, Mr. Davis did; there were uncertainties on the various numbers, and he had to factor that in to give a representative answer.

MR. CARROLL: Was there a conflict of interest? Mr. Davis looked at Davis-Besse?

MR. SCHULTZ: No relation.

[SLIDE.]

MR. SCHULTZ: First of all, before these studies, and I'm speaking now of the Oconee I, benchmark calculations were performed to determine the time before heat-up, assuming no feed-and-bleed procedures were undertaken. The assumptions were that there was a loss of feed water and no HPI available, and the time the core heat up was calculated and for the three plants, these were the times that were calculated in months. Of course, the Oconee I number was what was expected because of its much lower secondary inventory and the others are proportionately greater.

[SLIDE.]

MR. SCHULTZ: Following that, calculations were performed to determine the latest time that primary feed-and-bleed could be initiated to prevent core heat-up. And for these same classes, these are the times. And Calvert Cliffs ends up in a position of which you had to initiate feed-and-bleed prior to 31 minutes in order to prevent core heat-up. And that is, I believe, because of its ratio between the ECC and the PORV flows capacities. Oconee falls midway between Robinson and Calver Cliffs.

The conclusion was in this study that primary feed-and-bleed is an effective means of removing decay heat. But there's other factors that we have considered, as I'm sure you know and I'll talk about that briefly in a few minutes.

[SLIDE.]

MR. SCHULTZ: The Davis-Besse I feed-and-bleed calculations were done and showed that if procedures were initiated within 20 minutes of the loss of feedwater and full make-up flow was available, then the primary system will be depressurized and the core will remain covered. That was the primary conclusion of that.

[SLIDE.]

MR. SCHULTZ: I'm now going to move on to a short description of the synthesis report, which is the blue report that I have stacked up there on the table. This report synthesizes the calculations done at Los Alamos, it syntehsizes also the various assessment work done and the calculations done at INEL. And that's contained in this document.

[SLIDE.]

MR. SCHULTZ: The question that was faced by the authors was, is primary feed-and-bleed a viable method for removing core decay heat? And the answer to that is, yes. But the equipment characteristics of U.S. PWRs differ considerably from plant to plant. And, therefore, the window that Tom Larson spoke about earlier is different from plant to plant, and consequently the procedures must be different.

The presence of high-head ECCS greatly increases the range of conditions for which feed-and-bleed is feasible and for which procedures will be successful. And larger PORV capacities also increases the range.

[SLIDE.]

MR. SCHULTZ: Operational considerations also exert a lot of influence on the certainty of successful recovery. Operational considerations include instrumentation, and the first two bullets that deal with instrumentation. First of all, the capabilities. It's important because the operator has to rely on that kind of data to determine the need, first of all, and then secondly, to monitor the progress.

In general, the instrumentation has been found to be adequate to identify the need for feed-and-bleed. And following the NRC requirement for plants to install primary vessel liquid level measurements, this limitation should be sufficient to monitor feed-and-bleed. However, the report recommends that plant specific evaluations are needed to confirm that.

MR. WARD: Let me understand if you're making some subtle or difference between the second and third bullet there. You say you've concluded that the instrumentation to identify the need for feed-and-bleed is adequate, but the third one then talks about the instrumentation needed to follow the progress of feed-and-bleed. And are you saying that's not adequate, or that will be adequate when something gets installed, or what is being said?

MR. MICHELSON: I believe that there was a -- I'm not sure what they're called -- and edict, perhaps, that the plants will install some vessel liquid level measurements, which the primary purpose behind that was to allow the operator to monitor the quanity.

MR. KERR: I do not believe that that definition was an unambiguous interpretation among the people who considered it.

MR. CARROLL: Well, I added a confusing point. Actually, it's when you go dry. I guess no expectation of restoration of auxiliary feedwater was what Davis Besse really did. They -- but they violated the guideline that said, Hey, when you go dry, you ought to start feed and bleed.

MR. KERR: Okay. In your view, should they have started feed and bleed?

MR. CARROLL: I guess I have never had a question totally answered: Could they have started feed and bleed if they had waited as long as they did? If they couldn't have gotten feedwater back, could they have started feed and bleed?

MR. WARD: He just said in an earlier slide that they could have. That's the calculation showed.

MR. CARROLL: Yes, but how long were they --

MR. WARD: Twelve minutes.

MR. CARROLL: Oh, only twelve minutes.

MR. WARD: No. They were -- well, loss of feedwater. I guess that means -- but that is still not the same as loss of heat sink. They were twelve minutes from loss of feedwater.

MR. SCHROCK: What would the operators be instructed to do if they had no feedwater source whatsoever, but they were outside the pressure window that was talked about earlier?

MR. CARROLL: I think they could give it a shot and see what happens. Kick the console.

MR. CATTON: The instructions say nothing about that.

MR. SCHULTZ: I do not know myself. But I guess the point of this bullet is that unless the operator has clear black and white definition, the person probably will not do it, and then you run the risk of him waiting until it's too late, and then he may have an even worse situation. So, that's the meaning of the bullet.

System conditions at which feed and bleed operations should begin regardless must be clearly defined. I mean, this bullet really relates to perhaps there can be a ranking in the procedures. He should begin them at this time; however, if not, if this other situation exists, then finally there's the ultimate time. If you don't begin now, then that's it, you know?

For plants where important system information is limited or missing, procedures must be developed to reduce the likelihood of unsuccessful feed and bleed operations, and this bullet was written because there were some plants or are some plants that don't have all the information that they ought to. So, they should have a special procedure which takes that into account until their equipment is upgraded.

Alternative courses of action should be formulated for situations in which first-line equipment is unavailable. In other words, all these scenarios should be considered and direction given to the operator so he knows what to do and he doesn't have to plunder.

MR. SCHROCK: These seem to be recommendations sort of, but who are they made to? NRC doesn't require the use of feed and bleed, and so are these intended to be for the benefit of the owners?

MR. SCHULTZ: Well, this report was written for the NRC at their request to answer their question of is feed and bleed viable, and if not, then what are the holes that are in the procedures and the various factors involved? I'm not sure how the report's being used -- who, aside from the NRC, it's gone to is what I'm saying. It was in answer to their question, anyway.

[Slide.]

MR. SCHULTZ: So, in conclusion, feed and bleed procedures can be a useful alternative method of decay heat removal in many PWR plants, but the influence of operational factors must be considered for operational plants.

MR. WARD: Okay. Thank you very much, Mr.

Schultz.

Our next speaker, on instrumentation, is Mr. Berta. Do we have your slides, sir?

MR. BERTA: Yes, you do.

[Slide.]

MR. BERTA: My name is Vic Berta. I'm with the Energy and Systems Technology Group of EG&G Idaho. The subject of this presentation is plant instrumentation used for feed and bleed, and the nature of this presentation will be to consider the PWRs as a group and to provide you with a summary, a status type of rundown of what instrumentation is used and whether or not that instrumentation is safety grade currently or not.

[Slide.]

MR. BERTA: The outline for this talk is shown here. The first three items listed there -- instrument categories, their principal use, and the operator experience with those instruments -- are mainly to provide you with a brief overview of the kinds of background information that is needed to address the actual instruments that are used in feed and bleed operations, and that is the list that is Item 4 there.

[Slide.]

MR. BERTA: Functionally and also for ease of discussion, we can separate the instruments into three groups or categories. There are those instruments that are located in the primary coolant system which would be used by the operators for either primary or secondary feed and bleed. Then there are two other categories of instruments which are used either for secondary or primary feed and bleeu.

[Slide.]

MR. BERTA: The principal use of these instrument categories is shown here. The primary coolant system instruments are used for pressure temperature and mass inventory tracking, and they provide the operators with the ability to assess the effectiveness of the feed and bleed mode that's in operation.

The other two categories of instruments provide principally operational verification of the particular feed and bleed mode. They are indicators of valve positions, whether or not valves are open, the line-ups, the status of the water sources, etcetera.

[Slide.]

MR. BERTA: I would then like to touch briefly on what we call the operator experience with instrument behavior, with these same instruments.

The first group, the primary cooling system instruments, you will have to be able to correlate instrument read-out and have a fairly good familiarity with plant responses indicated by those instruments, through reactor normal operations, through start-up operations, as well as shut-down. You'll also be able to understand the plant performance and what those instruments should be re ding rough reactor simulator training.

The same is true for the instruments that are located on the secondary coolant system, which is the category 2 instruments. Those are also used the same way, and experience is gained the same way as the primary coolant system instruments.

[Slide.]

MR. BERTA: If you look at those instruments now that are associated with primary feed and bleed -- directly with that process, we see that we now have PCS pressure and coolant charging pump associated instruments. Experience with that can be gained from normal reactor operations. However, those instruments that are associated with PORV and -- and downstream of PORV, as well as HPI instruments, reactor normal operation will only give status indication to the operators of those instruments. However, he can gain some insight into their performance and plant performance through reactor simulator training.

So with that in mind, I'd like to move now to the actual instruments that are used for feed-and-bleed.

[Slide.]

MR. BERTA: This slide shows the instruments that are used on the primary cooling system for either mode of feed-and-bleed, either primary or secondary. Also listed is whether or not these instruments are currently safety grade instruments.

The first three licted there: The core exit T/C's and RTD's, reactor vessel level and the subcooling meter, all came from NUREG-0737 and Reg. Guide 1.97. The --

MR. CARROLL: Not the -- not RTD's.

MR. BERTA: Not the RTD's.

However, the RTD's are listed as a safety grade instrument. Those three are the primary ones an operator would use to access the effectiveness of a feed and bleed operation, whichever one is in process.

MR. WARD: Now, everybody doesn't have a RVLIS, right?

MR. BERTA: I believe everyone is supposed to have one, if they follow the Reg. Guide.

MR. WARD: Oh, is that right? Well, no, I thought a RVLIS meant a fairly specific system would -- I mean, for example, some plants have heated junction thermocouples.

MR. CARROLL: That's a RVLIS.

MR. WARD: Oh, you're calling that a RVLIS?

MR. BERTA: Yes, whatever is needed -- whatever is needed by -- to detect or measure the reactor vessel level.

MR. WARD: Okay. What about this comment we had earlier that there may be some plants, perhaps some B&W units that have only hot leg measurement -- down to the hot leg?

MR. BERTA: I believe that's a problem, because the Reg. Guide states that the range of this instrument has to be from the bottom of the hot leg to the top of the reactor vessel.

MR. WARD: So you think it's unlikely that there are plants that have measurements only down to the hot leg, is what you're saying?

MR. BERTA: I can't -- it's -- well it's unlikely, if --

MR. MICHELSON: That's what we're going to find out.

MR. BERTA: That's what we want to find out. But the Reg. Guide is written stating that they have to have it over that certain range.

The reactor coolant pump run indication is not a safety grade instrument as yet. It's -- had its origins as a process measurement. The safety injection indication and the source of safety injection, which is the refueling water storage tank, are both safety grade instruments.

And lastly, the make-up let-down indication and the pressurizer heater indication are -- are not safety grade instruments at this time. Because they are -- they would have to be upgraded from a process rep to a safety type of instrument.

MR. CARROLL: What do you mean by reactor coolant pump run indication? You mean the rad energize light on the control switch?

MR. BERTA: Yes, yes.

MR. CARROLL: Okay.

MR. MICHELSON: When this question on B&W came up, and it's been several years ago. At that time it was argued that that hot leg -- that vertical riser was sort of like an extension of the vessel, if you measured from the bottom from the vertical riser on up, and you had no level, your water must be somewhere in the vessel, and you'll act as if you bring on everything you own, until the water starts rising back up in the hot leg again. These are vertical hot legs.

Now whether or not that argument ever finally resulted in people being allowed to get by with that, I don't know. That's what we're going to find out. But that was the argument at the time. That was a vessel extension and we could -- we -- if you lost the water there, what good does it do to have a vessel indication? You can pour out -- in all the water you own; if you don't own anything, what's the difference, you're on your way.

That was kind of the subjective argument. Now, whether or not they got by with that argument in today's plants, I'm not sure. That's what we'll have to find out.

MR. BERTA: I would think that they would have to show that they could recover a corresponding level in the reactor vessel. You know, you could have a steam bubble, or a noncondensable bubble in that reactor vessel.

MR. MICHELSON: Well, presumably, it couldn't be a bubble such that you would search -- and not avoid the vertical hot let then right away then too, because of the elevation.

MR. CATTON: They could have a bubble just in the top of the head and you'd never know it.

MR. BOEHNERT: Wasn't the argument about the check valves?

MR. MICHELSON: Yes. Part of the argument was the flapper valves. That was part of the argument too. But whether that argument ever won, I do not know. I'd be curious to find out.

MR. CARROLL: Do you add system pressure to your list?

MR. BERTA: I think that is tied up into the subcooling area. Once they have the thermocouple indication, at the temperature indication, whether or not it's subcooled or not. It's a steam table relationship.

MR. CARROLL: But I also want to know pressure separately to understand where I am with respect to pressurizing safety valves and a whole bunch of things.

MR. MICHELSON: This item you have a feedwater line up indication. Now that suggests to me that these are the indicating lights on the operator valves. Is that indicating light surface safety grade? This is just a suggestion.

MR. BERTA: These are instruments now that are used for secondary system feed-and-bleed and they're on the secondary side. The question you have is --

MR. MICHELSON: But they're auxiliary feed line indications?

MR. BERTA: Yes.

MR. MICHELSON: Is that safety grade? It says yes.

MR. BERTA: Yes, it is.

MR. MICHELSON: So the surface light circuits are safety grade, you're saying? You're sure of that?

MR. BERTA: Well, I'm not absolutely positive, but my understanding, the auxiliary feed system itself is considered a safety system.

MR. MICHELSON: Oh, yes, but that doesn't mean everything on it is safety grade, only the things required to make it function are, like opening the valves and so forth. And I'm not sure these kinds of indications would perform those control functions or safety grade, I don't know, I'm asking.

MR. BERTA: The people here, particularly Ron Beelman, says that they are safety grade, and I believe also -- he's also not here, but the next speaker supposedly, John Steinke of operator training, says that they also are safety grade.

Now the instruments associated with the main feed are not safety grade. That's, again, a process, but those that are associated with auxiliary feed are considered a safety grade.

Again, the pressure and level on the steam generator is secondary, with wide range and narrow range are also safety grade instruments.

[SLIDE]

MR. BERTA: The second slide shows the rest of the instruments that are used on the secondary side. They are listed here, and none of these are safety grade. The main feed pump as well as the auxiliary feed pump, discharge pressure are considered as back-up instruments at this point in time, and to the run and speed indication and, therefore, they are not considered or have not been raised to safety grade requirement.

The last item there is applied only to the B&W

once-through steam generator, and it's there because of the constraints, stress constraints between the tube sheet.

MR. CARROLL: What's a condenser/reservoir feed level? Is that condenser have a level?

MR. BERTA: I believe it is, but I -- I think that's what that is.

MR. CARROLL: Okay.

[SLIDE.]

MR. BERTA: The next two slides show the instruments now that are used for primary system feed-and-bleed in conjunction with the category 1 instruments. The high pressure injection pump, coolant charging pump, run indication is safety grade on the HPIP side. The valve line up position indication as well as the HPIP injection flow meters are safety grade. The HPIP discharge pressure is safety grade. The coolant charging pump discharge pressure is not safety grade.

The rest of those items listed there, the PORV open indication, tail pipe T/Cs, balanced stream ultrasonic flow indication and quench tank pressure and level are not safety grade instruments. I think based upon what I heard previously, in order to raise the PORV instruments to safety grade, it's going to take a considerable effort. First, in determining what the environmental qualification standards are going to have to be for those instruments and then the design of the instruments themselves to withstand that environment, which is probably going to very severe.

MR. WARD: Is that any more severe than what's required for instruments in containment?

MR. BERTA: Yes, because I think of the vibration requirements.

MR. WARD: Okay, there's more than just the containment pressure temperature that you're thinking about.

MR. BERTA: I'm thinking of structural.

MR. WARD: Structural, okay.

MR. CARROLL: Well, there are a number of plants that do that safety grade PORVs, a number of the later ones.

MR. MICHELSON: Is there a requirement of the PORV open indication to be directly open to stem the PORV? Or are you relying on particular about the air set?

MR. BERTA: I can't answer that.

MR. MICHELSON: Direct valve position indication? That's was one of the problems. I don't know which way it got settled because air set indication is not always to be. I know it's not safety grade. Along the lines of the question asked, Lou, would you find out for us if indeed valve position indication is safety grade? Keeping in mind, that means physical separation of the lettering on the position indication. At one time that was not required. It was bundled together and when you had a bad fire, you got a lot of interesting problems

MR. SHOTKIN: Which --

MR. MICHELSON: Well, these are the valves associated with the ones he said are safety grade. Probably auxiliary feedwater is a good one to chose. You might well ask about high pressure injection. It may be that now that's a requirement. Safety grade normally means the physical separation.

[SLIDE.]

MR. BERTA: The last two instruments, the sump level and the containment pressure, are safety grade instruments and they would come into play sometime during the primary system feed-and-bleed when the quench tank was overwhelmed and the rupture disk opened, and we now involve the containment system as well.

[SLIDE.]

MR. BERTA: To summarize, the operators will have awareness and will build experience of instruments that are associated with feed-and-bleed, primarily those which are located on the primary coolant system and those which are associated directly with secondary feed-and-bleed systems. They'll do that through normal reactor operations and simulator training. And that is the basis or the experience source that they will use to determine the effectiveness of feed-and-bleed operations.

Building experience with instruments that are associated directly with systems involving primary feed-and-bleed can be attained through simulator training, but as you go through those types of operations, you do not have that source of experience in normal plant operations.

The principal instruments for primary and secondary feed-and-bleed operations will measure parameter magnitudes and currently they are safety grade. Instruments associated directly with systems used in either primary or secondary operations provide both parameters as well as status information. Those instruments are primarily used to evaluate the operational status of those systems for either primary or secondary feed-and-bleed. And the principal instruments there are also safety grade at this time.

MR. WARD: Any questions for Mr. Berta.

MR. DAVIA: I have one. It seemed to me like maybe the operator would like to know the status of the containment sprays also. If the tank fails, the containment pressure will go up, and the spray should come on automatically.

MR. BERTA: Okay.

MR. DAVIA: And they draw fluid from the same source that he's trying to get fluid from for his HPIS, the refueling water storage tank, and there may be a need for him to try to conserve that inventory if he no longer needs the sprays, or can operate them intermittently or something.

That's a complexity, maybe, that we don't want to address here, but --

MR. CARROLL: And another one is monitoring the performance of the RHR system, if you have to put that in, or when you put that into service, to gain inventory.

MR. DAVIA: There can be some alterations of these scenarios that would require the operator to likely have more information.

MR. BERTA: I think these are the ones, though, that if you get into a feed and bleed -- get started a feed and bleed process, that these are the ones that would guarantee that you could assess how you're progressing through, and as you would have to bring in other systems later, like the RHR, then those instruments would now come into play.

MR. CARROLL: Although you didn't say it in your summary, I gather your conclusion is that there is adequate instrumentation typically available to handle the feed and bleed operation. You have no recommendations for additional instrumental, or --

MR. BERTA: Well, I've been through the LOFT program, so we came from a situation where we had many more instruments than we needed. When we started out on looking at what was needed for plants to acquire or upgrade their instrument systems, you know, the RVLIS and the core exit T/Cs came out of that, and that ended up in the Reg Guide.

Now, when it started out, the RVLIS system was not -- as I understand it, it was not all that reliable or interpretable, but now I believe they say that it is. There are smart processors on the indicators.

So that system, I think, is fairly good, but I personally still have some problems with the core exit T/Cs.

MR. CATTON: Some others do, as well.

MR. DAVIA: I guess a related question is it's not clear to me what the implication is of some of these instruments not being safety graded. If there's an environmental concern, their not being safety graded could be very important. If there's not an environmental concern, the reliabilities might be the same whether they're safety graded or not.

MR. CARROLL: Or better.

MR. DAVIA: Or even better.

MR. MICHELSON: The problem is the power supply. For instance, that instrument may also be the power supply that failed and got the whole transient started, that sort of thing.

MR. DAVIA: Or it may not.

MR. MICHELSON: Or it may not. I don't know. That's why you make a safety grade -- then you do know.

MR. KERR: Wait a minute. Do you mean if you have a safety graded power supply, it can't fail?

MR. MICHELSON: No, no, no, no. Safety grade means it's two-trained, and even on its failure, there's an alternate train that can accomplish the function. Non-safety grade means it may not be two-trained. Even though the instrument is great, maybe the power supply is where the pinch point was, not in the instrument at all. If it's a safety grade instrument, presumably it's powered by a safety grade power supply, I hope. It wouldn't do much good if it weren't.

MR. BERTA: The safety grade also means it has to be environmentally qualified, and that goes into the design of the instrument, then, for survivability. On the core exit T/Cs, they have, you know -- what? -- 15 to 20 of them, or something, I believe, and they take an average of the five hottest as being the core exit temperature. So there, redundancy plays a part in the availability of that measurement.

MR. WARD: Thank you very much, Mr. Berta.

Our next speaker, Mr. Steinke, will discuss operator training. Is Mr. Steinke --

MR. NAFF: Oh, I'm sorry, I just called him in the middle of Vic Berta's talk and told him to get here, left word for him to get over. He's not here at the moment.

MR. WARD: Okay. We are ahead of schedule. How about Mr. Naff. Is he here?

MR. NAFF: That's me.

MR. WARD: Oh. You're here.

MR. KERR: Mr. Chairman, I hate to bring this up, of course, but I think it's time for a break.

MR. WARD: Let's come back at three o'clock.

[Recess.]

MR. WARD: Our next speaker is Mr. Steinke, who will talk about operator training.

(Slide.)

MR. STEINKE: Good afternoon. My name is William Steinke. I am here today as a member of the Examiners' Group from EG&G who currently work under contract with the NRC licensing branch, administering operating licenses to the various utilities.

MR. CARROLL: Have you ever had an operating license?

MR. STEINKE: Yes, sir. Just a word on my background here.

Two years I was working at the Zion Generating Station in which capacity I had Senior Operating License at that station on Units 1 and 2. During that time I also spent approximately 1400 hours on the simulator working with the station operators as far as requal programs and verifying procedures.

Subsequent to that I went to work for Pacific Gas and Electric at Diablo Canyon facility, where in that position I held a senior operator's license for eight years.

MR. CATTON: That just disqualified you.

[Laughter.]

MR. STEINKE: I was also qualified as reactor engineer at that station and did hold the position of assistant reactor engineer during that time period.

(Slide.)

MR. STEINKE: I would like to address the topic of operator training here in two parts today.

First of all, I would like to look at the training that is currently being provided to the PWR operators for feed-and-bleed operation and secondly, to look at the evaluation process of that training as it is being administered to the operators.

(Slide.)

MR. STEINKE: As we are well aware here, there are several events that can lead to conditions in the plant which require feed-and-bleed operations by the operators, one of those being namely the loss of all feedwater, which has been discussed during the process today.

I would like to bring it up once again just to re-emphasize that in order to achieve this goal in a training sense requires multiple casualties or equipment operability malfunctions within the plant systems.

It can be a very complex training exercise to achieve the end state here of getting the operators into the condition where feed-and-bleed has to be initiated.

MR. CATTON: Is that Condition A?

MR. STEINKE: Condition A, yes. I am referring to a complete loss of feedwater and as we have discussed previously, a loss of main feedwater -- I am speaking now of Westinghouse plants in particular, where my experience base is -- on a reactor trip or a safety injection condition your main feedwater is isolated due to automatic signals.

The valves are closed and the capability is no longer there without operator action.

MR. CATTON: Do you straight-away start the feed-and-bleed?

MR. STEINKE: No, we do not, sir. As I get a little bit more into the discussion here, I'll show you more of a sequence here and looking at the actions that the operator has to perform between the initiation and the event and actually getting to the feed-and-bleed process.

Of course to complete the scenario a loss of auxiliary feedwater is necessary and there was discussion earlier about the fact that this is an engineered safety feature of the plant and has vital power supplies usually backed up by diesel generators.

It is also powered by turbine-driven pumps which have the capability of drawing steam from one or two steam generators, depending on the plant design.

In order to achieve this goal here, complete loss then requires again a problem, usually within the electrical system, and/or a problem with steam generators, faulty steam generators such that a steam supply is not readily available to that turbine-driven pump.

The other event that readily comes to mind is the small break LOCA where eventually as inventory is lost we would get into the inadequate core cooling situation.

Now depending on plant design will determine how complex this training exercise has to be. As has been previously discussed, some plants have high pressure injection capability that is only in a medium range, say 1500 psig, whereas some Westinghouse plants have high pressure injection capability that goes all the way up to and including 2500 psig which at least will reach the safety valves on the reactor vessel, reach their set points.

In addition to removing their high pressure injection capability then for this type of scenario, we also -- there is a time factor in there where a loss of inventory is needed on the primary side or loss of inventory also on the secondary side of the steam generator such that heat transfer capability is reduced if not gone completely.

This probably, from an operations standpoint and an operator's stance, this is probably the worst scenario because the procedure, as we'll see here in a little bit, for the inadequate core cooling would drive the operator into running reactor coolant pumps and opening the PORVs, making a hole in the primary system to provide some sort of cooling.

[Slide.]

MR. STEINKE: In order to mitigate these particular events, the operators have, at their disposal, a fairly extensive supporting network of procedures.

Now, I'm addressing, using an example here of the Westinghouse Network, where two main categories -- category A, as I have depicted it up here -- the emergency operating procedures, or the EOP's, principally, event-related type procedure, dealing with loss of primary coolant, loss of secondary coolant, steam generator tube rupture, and also possibly dealing with electrical problems.

Now, this network has an entry procedure. And I want to state up front, that this network is assuming that we're in an at power condition -- a mode one or two, with the reactor, where we're producing thermal power. We do have a substantial decay heat problem to deal with.

As we enter this procedure, the EO, which is the very first one in this series, it will take the operator through an extensive verification, assessment, evaluation, diagnostic process. And I've included in your hand-out, on the next page, a list -- a brief description of those steps as we go down through this procedure. Now, I'm not going to cover the entire list here today, but I want to use this list just to show you the path that -- of diagnostics and so forth that this operator has to accomplish in order to get him -- get himself down into the network for a feed-and-bleed operation.

In looking first at this sequence, you see that, number one, he has to verify the reactor is tripped, and secondly, looking at the turbine to make sure that the turbine has tripped here. His third item of interest in this series is the electrical status. Does he, in fact, have power available to his vital busses, which means that he has his ECCS pumps available, namely, high pressure injection, medium and low head injection?

Now, once you get down into this, the sequence may vary a little bit, from utility to utility. What is presented here was a recommended sequence at Westinghouse, or the owner's group came up with when they developed this network.

Now, as you follow down through, there are some steps here, namely step 4, 5, 6 and 7 -- well going on all the way through step 11, where he is verifying that his ESF equipment has, in fact, gone to the state that he wants it in for the condition that the plant is in.

MR. KERR: What does "not required" mean?

MR. STEINKE: All right. The "not required" is a check for the operator. He looks at his instrument channels, to look to see if the logic is made up for that actuation, whether it ought to be a 2 our of 3 or a 2 out of 4 trip logic. And he has in front of him, on the control board, indication of the bistables for the protection channels. And he verifies, by his bistabled network that, in fact, automatic action is not required.

MR. WARD: Look at step number 4. Does "check" mean something different from "verify."

MR. STEINKE: "Check" here is in the same sense that I just mentioned, to look at his bistables associated with the input signals for a safety injection, to ensure that he did not have a logic made up for that particular actuation. He looks up at his enunciation to see whether or not a safety injection has been initiated, and he can also look at his bistables as a back-up indication, to see whether or not one is needed for the -- for what the plant parameters are at that time.

MR. MICHELSON: Step number 22 says "to check reactor coolant system to see if it's intact;" can you tell me what that mean?

MR. STEINKE: Okay. This is getting down into a -- the diagnostic section. What he's looking there is to see whether or not he has a LOCA present in the primary coolant system.

MR. MICHELSON: What does he do if he determines he has one?

MR. STEINKE: Looking -- with the -- he has a detailed list of instrumentation to verify there. If he -- and he does verify that he has radiation problems, loss of pressure, all the things indicative of a LOCA, then there will be an exit command for him to leave this diagnostic procedure and for him to enter in the other event related procedure which deals specifically with a primary LOCA.

MR. MICHELSON: And having gotten into that procedure, is there any instruction to try to isolate this LOCA?

MR. STEINKE: Yes. Once you get into the LOCA procedure itself, then it deals with the problem, to make attempts, if possible, to isolate it, yes.

MR. MICHELSON: Now, we're sure that whenever he determines that he has the LOCA and he knows where it is and he can isolate and he does isolate it, that it's still okay. How do we know it isn't already too late to isolate the

LOCA? Because feed-and-bleed doesn't work too well, if you start out with a small inventory to begin with.

MR. STEINKE: True. Let me back up just a second here on the list. The step that you are referring to is down here -- it's step 22. If I go back up the list, and I look at step number 13 -- step number 13 says "verify the aux feedwater status." When he does down this list, and I want to point out, that he is going step by step, in this sequence here. This is a very regimented process. The training says you will do step 1, step 2, so forth. We don't do steps out of order.

MR. MICHELSON: Even if he has LOCA, you don't do a modified --

MR. STEINKE: That is correct. There is only one instance right now, from my experience, where I could ever cite that steps are allowed to be done out of order, and that is in the case of a steam generator tube rupture, and you know you have a known release to the environment. In that case, it is authorized with usually the utility administration that's in there, procedures specifically, that they can take a procedure and go ahead and isolate a steam generator for instance.

MR. MICHELSON: Now 13 is to verify the AFW status. Now, if I verify it isn't running, what difference does that make?

MR. STEINKE: That immediate will kick -- that's an exit step 4. I mean, immediately he will exit this procedure and he will go to, if I might back up --

MR. MICHELSON: Something eventually leads him though to what to do about the LOCA, doesn't it, even though the auxiliary feedwater failed to start on the LOCA, which may make no difference whatsoever, depending upon the LOCA, he -- he certainly is kicked into to a procedure to tell him what to do about the LOCA?

MR. STEINKE: Eventually. Eventually.

Now, let me just follow through here just a minute on the aux feedwater process.

[Slide.]

MR. STEINKE: He verifies that the aux feedwater flow is less than the minimum required in order to maintain an adequate heat sink. That number is established for each individual utility. And that will direct him to exit that procedure and then enter this next network that I've indicated here, the functional restoration procedure.

Now, these procedures are slightly different than these event-related type that we are dealing with in category A. These -- this, for instance, he would go into the loss of heat sink restoration procedure. It's single goal is to reestablish that heat sink.

Now, I've made a couple of items under that category that I wanted to bring up about this network. Number one, it's -- they are not immediately in effect. And I was alluding to this a little bit earlier when I said that even if the operator immediately identified the fact that he had no aux feedwater or no feedwater at all at the very onset of the event, he still has to follow through these verification steps to get down to this exit and allow him to enter this procedure here.

MR. MICHELSON: Where is the exit?

MR. STEINKE: That exit would be contained in the verbiage under step 13, where it says "verify aux feedwater status."

MR. MICHELSON: That's where he would exit though, this E-0?

MR. STEINKE: Right. That's correct. The instruction would be to verify X number of gallons per minute flow rate to the steam generators. If he cannot verify that flow, then the response not obtained would be to exit this procedure and go to the H-1, for instance, which is loss of heat sink.

MR. MICHELSON: Yes, but now -- because that's what you thought you were into. But now -- now, what do you do about these indications of the LOCA then?

MR. STEINKE: We address he problems here one at a time, and on this -- in this instance here, these restoration procedures, take precedence over the LOCA. So he's locked in, for the moment, he is locked into this procedure, to deal with the loss of heat sink.

MR. CARROLL: And he may have exited earlier than -- than that too, depending upon what else is going on.

MR. STEINKE: That's right. Now, an important point here to cover this other situation. Let's say, for instance, that when he did first verify aux feedwater, that, in fact, he had sufficient flow, he met the requirement and the proceeds on down the list. You will notice, as you get farther down the list here, for instance, step 25, there is an information item to the operator there, and this is just in the form of a note within the procedure. It tells him to "initiate monitoring of these critical safety function statestries," which he's looking at conditions, and one of them being aux feedwater flow. This is a constant monitoring process.

If at any time now after he reaches that point, feedwater would drop below 5 -- say 500 gallons per minute, he would immediately exit the procedure that he's in and he would implement his loss of heat sink procedure.

So, even though on the first cut, or the first diagnostic he was okay, now these procedures are active and they are instructed to, as I said, exit these event-related procedures and go immediately to the symptom-base --

MR. MICHELSON: We'll look into this at another time, but it seems strange to me that when you have a LOCA, you worry about auxiliary feedwater, a big LOCA, that is.

MR. STEINKE: True. Well, on a -- on a big LOCA then the energy removal capability is such there that you have -- you should have core cooling.

MR. MICHELSON: Yes, unless you isolate it later.

MR. STEINKE: Exactly.

MR. MICHELSON: Then you've got to get back to doing something about that.

MR. STEINKE: True.

MR. MICHELSON: That's a -- that's accounted for in the procedures too? Since you have accounted for shutting off the break, do you account for how to recover after you've shut off the break?

MR. STEINKE: If you are able to terminate the leak, then, yes. You now are looking at regaining subcooling, and then as you regain subcooling, then to start terminating your emergency core cooling equipment.

MR. MICHELSON: If, indeed, all this works, it depends on how much inventory you've already lost before you isolate --

MR. STEINKE: That is true.

MR. MICHELSON: I'm not sure the operator will know that.

MR. STEINKE: But with this instrumentation there and the way the procedures are directed, he operates strictly on degree subcooling and reactor vessel inventory.

MR. MICHELSON: If that instrumentation is working for the larger break.

MR. STEINKE: Correct.

MR. MICHELSON: It may give you strange results of what's going on in the core.

MR. STEINKE: At this time, we've established how the operator is going to initially react to the situation, what his first diagnostics and assessments are, and we're down now to his functional restoration procedure.

I've commented on when they're in effect here. The fact that once he's in it, he must complete the procedure, unless there is an exit step explicitly stating that he can leave it and go back either to the procedure previously in effect or to some subsequent procedure for recovery.

Eventually within this restoration procedure, he's going to get to the steps that contain the feed and bleed operations. I have a transparency.

[Slide.]

MR. STEINKE: What I'm showing you here, like I did with E-0, I'm showing you a sequence of events or sequence of steps that the operator is dealing with trying to get down ultimately to this feed and bleed proce s. Once he has established that he is, in fact, in this los of heat sink procedure, you can see, as you look at these first steps on this particular slide, that his first objective is to look at his alternative sources.

Can he regain the auxiliary feedwater system. Those are the initial attempts. Trying to initiate work repair activities, whatever the initiating problem was. There are some other functions that are accomplished in between, but as we follow down to Step No. 5 here, we also bring up the idea of trying to use a main feedwater system, whether it be the condensate pumps, the main feedwater pumps themselves, to try and initiate flow back to the steam generators.

If he is unsuccessful in these attempts at using these other systems, the procedure then down on Step No. 11 contains the items that he needs to check and initiate very quickly in order to get the primary feed and bleed in process prior to losing his inventory on the secondary side of the steam generators.

[Slide.]

MR. STEINKE: I want to bring out a point here. At the very beginning of this procedure, if you look at the next page of your handout, the very first information that this operator encounters when he opens his procedure is this caution right up front. The caution directs him very explicitly as to when he has to initiate feed and bleed.

With the Westinghouse plants, we're dealing with a bleed and feed because our directions are always to open the PORVs here. So our terminology there within the Westinghouse realm was always bleed and feed.

But as you see, his instrumentation that he is using here is this wide range steam generator level indication. When he gets down to a point, a predetermined level by each utility for their particular type of steam generator and their instrument ranges, he will cease to try to establish flow with these condensate and aux feedwater systems and immediately go to execute the feed and bleed steps.

Now, this is what is called continuous knowledge. You read this as you start the procedure and it's something that is in effect at all times within that procedure. As he's working his way down through Steps 1 through 10, in a training sense, we refer to it as constant knowledge; that at any time that he reaches this criteria, these steam generator wide range levels, he will immediately drop what he's doing and go to Step 11.

MR. DAVIS: When does he trip the coolant pumps?

MR. STEINKE: The reactor coolant pumps consideration there is strictly on the energy input and we're adding to the problem from that sense.

MR. DAVIS: One other question. On the previous slide there was an item, try to establish main feedwater flow. How long does he stay in that? There are some conditions which will prevent him from ever establishing feedwater. He may not know that exists and he will keep trying until he comes to some conclusion about not being able to do it.

Is there a way he could tell when he is supposed to --

MR. STEINKE: The directions that he has is to continue to try to reestablish flow through one of those systems, either the auxiliary system or the main feedwater system, until his inventory level meets that criteria within the caution. If it takes 45 minutes or 30 minutes, depending on the plant conditions at the onset, he stays within those restoration efforts until that criteria is met.

MR. DAVIS: I see.

MR. CARROLL: I think what you're thinking about, for example, is if somebody goes out and finds that one of the main feed pump turbines is blown up and destroyed the other one. You obviously don't keep trying to start it.

MR. STEINKE: It's no longer a viable option.

MR. DAVIS: Or loss of off-site power.

MR. STEINKE: I might make a comment on the loss of all off-site power, for instance, and also loss of station electrical AC. Going all the way back through this network to that Step 3 on the entry condition, E-0, if he does not satisfy the condition that he has a vital bus energized there, he is no longer in this network right here.

There is a contingency set of procedures that are used, and they deal specifically with restoring electrical power to the bus. In parallel with that, if core condition -- the concern here is the reactor coolant pump seals and if there is steam generator inventory available to start an immediate depressurization on the secondary to bring the reactor coolant system down to temperature, and try to inject accumulators as a cooling source.

MR. MICHELSON: I am still puzzled by the E-0 procedure. Item 4 is check the SI. Do I get brought back into this procedure again at Step 5 after I've fixed whatever the SI problem was?

MR. STEINKE: On this question of SI, it says what you're doing is verifying whether or not an SI did, in fact, happen. If it did, the operator stays in this path and goes on down. If he has no SI actuated, it is considered a, if I will, normal reactor trip and he will exit this procedure and go to a subset. It's a 0.1 and it deals with just a normal recovery from a reactor trip.

MR. MICHELSON: But certainly after residing in that procedure for a while, realizing that wasn't really the problem, he's got to somehow get back on track.

MR. STEINKE: Right. Well, in his recovery procedure, he goes through and verifies the same important parameters, such as does he have auxiliary feedwater flow. If he runs into a roadblock there, in effect, that he's lost his auxiliary feedwater, he will exit that. There will be an exit step there and he will ultimately end up down here in the H-1 loss of heat sink procedure.

MR. MICHELSON: But he never goes back to E-0 again.

MR. STEINKE: Not unless he has an SI that's actuated. That is correct.

MR. MICHELSON: So the SI procedure will lead him to the logical correct end, even though SI hadn't actuated yet, because it depends on the scenario.

MR. STEINKE: That is correct.

MR. MICHELSON: That's all accounted for in these other branches, never returning to E-0.

MR. STEINKE: That's correct.

MR. MICHELSON: Thank you.

MR. STEINKE: If at some time in the future -- now, initially he did not have an SI actuated, but let's say 15 minutes later we lose pressure and an SI is actuated on low reactor coolant system pressure. Then the operator would immediately drop where he's at and he will come back to this E-0 procedure and verify that and go through the process again.

MR. MICHELSON: So if I ask for the procedure on what I do if I had a loss of reactor coolant system integrity, that's the only procedure I will need to look at and it will lead me all the way to the end.

MR. STEINKE: That's correct.

MR. MICHELSON: Good. I would like to get a copy of that procedure, Paul. Could you put that on your list?

MR. STEINKE: One thing this process does is the entry point is always the same. The only thing that will kick him out immediately is a loss of all electrical power at the station, all AC electrical power. Then he will enter this procedure that deals with the station blackout, trying to restore power to a vital electrical bus.

MR. CARROLL: While you are between frames, could you contrast for us these Westinghouse procedures that you're using or running this through and Combustion Engineering B&W procedures? Are they all about the same in approach?

MR. STEINKE: I can say that the Combustion Engineering procedure network is fairly similar to this. Their terminology is a little bit different and they deal with these critical safety functions slightly differently, but the end result is very close.

I'm really not familiar enough with the B&W procedures to comment on their network.

MR. CARROLL: Okay.

[Slide.]

MR. STEINKE: My objective here on this H-1 overhead was just to show you the alternatives that the operator has, that he's directed to and the order that they show up, and also the idea that he is constantly aware that if he reaches this criteria, that he should move ahead into the procedure to the step specifically on the primary feed and bleed.

Once initiated, we can follow down through there, but once the PORVs are opened, they remain open until the operators are successful in reestablishing a heat sink in the steam generators. So we stay in this mode until that heat sink is recovered, and then based on subcooling, we go through a turbination process.

MR. CARROLL: Or until you get down so you can put RHR in service.

MR. STEINKE: Correct.

MR. CARROLL: So the valves stay open and to the extent there's a need to change ECCS flow, it's done by starting and stopping pumps.

MR. STEINKE: That is correct. But in the procedure, the pumps are left running until the heat sink is reestablished. Then based on an actual subcooling within the reactor coolant system, then the pumps are taken off in a controlled sequence, and the PORVs are consequently shut at that point.

MR. CARROLL: Even though you know that you're spilling water out of the PORVs.

MR. STEINKE: Yes.

[Slide.]

MR. STEINKE: In order to conduct the training on this particular evolution that we've been discussing here, simulator exercises are developed by the utility and also the examiner's group as we go into look at the candidates for licensing or relicensing.

What I have here on this overhead is a typical objective, very broad scoped objective for a particular scenario, given a loss of all feedwater here with the inability to feed at least one steam generator, initiate a primary feed and bleed prior to drying out steam generators.

The dry-out here, again I'm referring to specifically that level that has been determined by the utility where inadequate heat transfer is occurring from the primary side to the secondary side in the steam generator.

Some of the advantages that I'd like to discuss with this form of training here is that it's using plant-specific simulators at most utilities today, which provides the operator with an exact duplicate of the controls and the instrumentation that he would normally have in front of him to conduct this procedure.

Secondly, the real-time response issue here. The benefit of being able to do this on a simulator today versus doing it on a tabletop discussion, it's immeasurable. This real-time response, you get a feeling for how long does it take to go through these steps and when you should be getting the response, are things going correct. The simulator does provide an experience base along those lines.

Some advantages to the way the training is being conducted today, too, for the new license candidates. I can point them out. They have a very accelerated program when they're trying to ready a candidate for licensing and he will perform these procedure exercises multiple times within his short training frame. It might be a two or three month timeframe as he's preparing for his examination.

So he gets a lot of exposure and a lot of practice with these. So we try to build up the confidence factor in the new people or it is there, the opportunity is there to try and establish that confidence factor before the person is licensed and sets foot in the control room as a licensed individual.

MR. CARROLL: Just so you don't confuse people, the total training time is much more than three months.

MR. STEINKE: Yes.

MR. CARROLL: You're talking about the last three months before --

MR. STEINKE: A typical training program for a license candidate is about twelve months in duration, of which he will spend normally two to three months on the simulator in six to eight hour training sessions, say typically 40 hours a week.

Some of the disadvantages, from my perspective, is that once licensed now, they fall into a new regime here where their training requirements now only fall on a biannual basis, which biannual in most cases here is 18 months. The programs typically take about 18 months from start to finish.

The operator is only required to perform that one time during that 18-month period. From a utility standpoint, too, the emphasis it not always on feed and bleed because when we looked at that procedure sequence, we saw that there were alternatives presented to him first in the procedures, such as restoring AFW and, secondly, trying to reestablish the main feedwater system.

The main feedwater system, that evolution of trying to feed those generators in that plant situation can be very sensitive or very difficult to control. So training time sometimes is devoted to that aspect of the procedure. The emphasis is not always exactly on the feed and bleed.

The scenarios, as I've indicated here, are often terminated early. What I mean by that is by plant design here, we know that it takes sometimes 30 to 45 minutes just to reach that initiation criteria of low steam generator level, or even longer.

The scenarios that are run on the operators are typically one hour in duration, sometimes two hours. But if you're working within a one hour timeframe, your ability to go much beyond the initiation step is somewhat limited. You can get the operator up to that first step of ensuring that he has a high pressure injection available, and then opening the PORVs, and then that is considered satisfactory. The training session is terminated after that point.

So it's only under these expanded training sessions that the operator would be allowed to go well into the feed and bleed process to look at it say a half-hour to an hour down the road after the initiation.

MR. KERR: Do the simulators have the capability to do that?

MR. STEINKE: That is what I was leading up to with this last item, the simulator capabilities. Depending on the simulator itself, when it was built, some of the models are not as capable. The newer models are very good, the ones that I have had exp·rience with. Some of the older ones that they were upgrading .ow, they were very limited in being able to simulate these complex evolutions when I started gettinc a dynamic situation within the RCS and the pressurizer.

MR. CARROLL: So what you're saying is that if we were to ask you this question five years from now, you think everybody's simulator would be pretty good in terms of being able to do feed and bleed.

MR. STEINKE: Yes. My feeling on that is yes. The commitments of the utilities to ensure fidelity in their simulator models and the capabilities of them now is ongoing and they're upgrading constantly. So I say definitely yes on that.

MR. CARROLL: And the driving force for that is principally requal exam or initial exams?

MR. STEINKE: Well, it's a commitment that they have, as well as a desire on their own to be able to do training that is very accurate and reflects the plant response.

[Slide.]

MR. STEINKE: Going hand in hand with conducting these simulator scenarios goes the evaluation or the assessment side of it. The operators are looked at or evaluated by several groups throughout their operating careers here. Constantly the utility, in the form of their biannual requal program, is addressing this issue of feed and bleed.

There is a commitment that they must at least cover the procedure and the basis so that the operator continually has a refreshed knowledge on what is required for this procedure and the reasons for, for instance, the alternatives here.

Going along with that, the written exam, as they have these classroom discussions on the procedures, they are objective-driven and they will form or write exam questions and follow up on that for evaluation purposes.

The simulator scenarios I was talking about, if they're administered by the utility, then each operator has an evaluation that's completed on him by the simulator instructor. Now, these evaluations are very detailed, identifying critical tasks and operations and his response throughout this scenario.

The evaluation form is written up specifically, for instance, for this feed and bleed operation and has what are considered the critical steps identified here.

So there is constant feedback to the operators themselves as to how well they are performing from their own people, the utility instructors. Now, the NRC licensing process also brings us on-site occasionally, depending on their need for initial exams and also at least once every six years, the Licensing Branch has to go and administer a requal exam to every operator. That's on a minimum six year basis that they see every operator.

That is not to say that on every visit that they will run a feed and bleed scenario. I would say right now that if we were to look at the scenarios that were being conducted, that about 20 to 25 percent of the scenarios involve getting the operator into, for instance, this loss of heat sink condition and end up with a feed and bleed operation.

But, again, here, as I discussed earlier, time constraints really keep us from going and evaluating the process beyond the initiation point. It generally takes an hour to get through the initiation, and it's terminated as soon as he opens the PORVs and meets that requirement.

The last item here, the INPO Accreditation Team, which is on a regular time schedule with the utilities, not only do they go in and evaluate the operators on these operational exercises, but they're also evaluating the instructors themselves.

So this brings in another element; not only how well the operators are performing within this atmosphere, but how well are the instructors doing. And they're comparing them with the rest of the training groups within the industry. So the training departments themselves get some feedback here.

[Slide.]

MR. STEINKE: This next overhead, I'd like to take a few minutes and just go into, as I've stated, criteria for success here. I've heard the term of reluctance of the operators to act in concerns in this area.

When this training is conducted, we're trying to establish this familiarity, this confidence level in that procedure network. By repetition here, going through the exercise multiple times, we're developing a very detailed knowledge of the procedure. There are no surprises, hopefully.

When this man who has this procedure in front of him under this situation with a lot of stress on him, he will clearly read this step, make the decision, and move on to the next item of business.

It follows down that if he knows the plant response or he has an experience base to draw from here which he obtained on the simulator, then that plant response is not going to be anything to pose a problem to him. He can anticipate what's going on.

Also under this category I want to bring out the idea of team work. Here recently, within the last few years, in the realm of training, especially for these operators, team work has become a very, very big issue. Every person is evaluated individually, but they are also evaluated as a team.

When they go through these exercises, there is only one man that usually has this procedure in front of him and he's reading it. But with all of the group being very knowledgeable on the procedure, then every team member can participate here and try to stop the whole evolution if he sees a bad decision being made and keep the team on the track and going to the right end point here. So team work is very important.

Item B, knowledge of instrumentation. This is very critical here to how well the operator can perform in Section A. All these procedures, as you get into them and you look at them, they're nothing more than defining instrumentation, interpretation the instrumentation, going back to the written page and then making a decision based on the information that he's just gathered.

So his knowledge both on the primary side and second side feed and bleed, what parameters are important, his ability to locate them quickly, to interpret where they are at, what he expects, is it normal, and to make a decision and move on is very important.

Then the final goal here, of course, is did he initiate the evolution before dryout. In other words, is it even going to be successful here. A very clearcut measuring point, if you will.

MR. CARROLL: Did he initiate it in the simulator scenario.

MR. STEINKE: True.

MR. CARROLL: You are going to talk about your views as to whether in the real world he would do that.

MR. STEINKE: Well, I haven't had the opportunity, thank God, of being in a control room when we needed to do this, but I have been there when we have reached some other decision points which were very critical to equipment and personnel safety.

One example that I can cite from experience was an electrical problem on a reactor coolant pump. At the Diablo Canyon plant, for instance, it's a 12 KB system and we were arcing to ground. A very serious situation. The operator showed no hesitation there to immediately trip the reactor, trip the reactor coolant pump, and get us into the E-0 procedure network.

There was no hesitation. It was look at the instrumentation, interpret what you see, look for a backup indication, and in this case we were looking for problems over in the electrical section of the instrumentation. I saw no hesitation there.

All I can do is I can tell you that based on what events we've had to date is that I don't think there is going to be that hesitation factor, and I think the team work effort here is also going to keep us on track. If there is one person who does hesitate in there, there are other team members who are going to reinforce what has to be done.

I think that the ultimate goal is going to be reached and within the required timeframe.

MR. CARROLL: Yes, but tripping a reactor coolant pump is a heck of a lot different than cracking up a containment.

MR. STEINKE: Right. Now, if you had asked me that question five years ago about making a hole in the reactor coolant system and initiating a primary LOCA, I probably would have had to answer yes, that I wasn't that confident that they would exercise that step or complete it.

But from my personal experience over the last few years and going through and seeing the confidence level, we have worked these procedures on the simulator and watched the response, and I think there is a very high confidence level. Also, good or bad, there is the idea of procedure compliance and the operators say as long as I'm in this procedure, I'm okay.

That's sort of the mindset that I see out there right now. You may not have a person who is intimately familiar with all the thermal hydraulic processes that are going to go on when he opens that valve, but they have established that thought process that I'm okay as long as I'm in this procedure.

MR. KERR: Teams generally don't make decisions. They contribute to them. Who actually makes a decision of this kind as to whether one goes into feed and bleed? Is that the SRO or shift supervisor?

MR. STEINKE: It would be the SRO, which could be one and the same here, depending on the makeup of the control room. But ultimately, if there is a shift manager, he's usually -- depending on the utility and the way they distribute their responsibilities, but the SRO is typically the procedure reader there and when that procedure step is in effect, he executes the step.

There is not a decision process necessarily that because this step is more important than any of the others that they come to a halt and have a little conference on it.

MR. CARROLL: But I bet they would be in the real world.

MR. KERR: As something as unlikely, as we hope this is, it occurs to me that there may be situations that aren't exactly described by the procedures. So there may have to be some decisions that aren't as clearcut as if one followed these lists step by step.

MR. STEINKE: That's true. I think the procedure networks as they are put together today are very complete and they follow now with these function restoration guidelines. It covered the very extreme conditions within the core or different parameters of the plant.

We haven't really discussed the fact that when these events do get in motion, that technical support centers are being manned up and that operator, if he does get off into a gray area, something that he's not quite sure of, he does have resources that he can confer with to try and do some other evaluations for him. That's in the form of the plant staff engineers out there with usually the availability of all the safety monitoring devices.

MR. CARROLL: How do you answer this question? If I went and talked to any licensed RO, would he understand the idea of a time window and why there is a time window in the classic feed and bleed situation or loss of all feedwater? Would he understand that if he goes too far, it's all over?

MR. STEINKE: My feeling on that is yes. It is covered in the basis. We not only go through the procedures to cover specifically what the direction of the step is, but the bases are always brought into play on this and there is time spent on that area trying to make him very comfortable with why he's doing that action or the consequences of not doing it.

MR. SCHROCK: I have a question in the same general area. We learned from these detailed studies that one plant, the window closes in 31 minutes and in another it's 49 minutes. Is there any risk here that it takes too long to get through all of this procedure in certain plants?

MR. STEINKE: I think the answer to that is that it falls back to that caution statement and the knowledge here that there is a time window, but as we saw in that caution, we don't specifically put any time factor on it.

It's all driven by that one parameter of steam generator inventory. Now, how fast or how slow he loses that inventory is going to then trigger his response.

MR. SCHROCK: I thought I heard you mention 45 minutes a little earlier. Was that --

MR. STEINKE: What I was bringing in there was by design, that following a trip, a reactor trip from full power, that the inventory that is in the generator, be it a Westinghouse or a Combustion Engineering type of steam generator, there is sufficient mass then to provide heat removal for about 30 to 45 minutes before dryout --

MR. SCHROCK: That didn't refer to the time for these procedures at all.

MR. STEINKE: Maybe I --

MR. SCHROCK: I'm sorry. I associated that with your discussion of how long it took to carry out these procedures.

MR. CARROLL: Wherever you are in the procedure, if you hit the words in the caution, you start feed and bleed.

MR. STEINKE: The thing that I was getting to, repetition now, because of the way this network is built, every time that the plant trips, he goes into that same procedure, that E-0, as I took us through earlier. So he performs the same actions there and these are immediate actions.

The timeframe to go through that and reach that exit step can be very quick, should be very quick.

MR. WARD: If the SRO and the other control room people are ticking through these procedures and he's come to the point where he's going to need to open the PORV, he hasn't yet bucked up against this caution statement requirement, so he knows he has some time.

You suggested he has other resources; the technical support centers, for example; but that probably -- well, depending on the scenario, that may very well not be manned. But if it isn't, at this point, is that SRO likely to be on the telephone to some operations management at their homes, for example?

MR. STEINKE: There is definitely within there notification scheme, yes, as soon as they start into a serious event. Now, notification duties are delegated to control room clerks or whatever to initiate the notification process. There are also other members of the control room staff, such as the shift technical advisor, which would be on the phone trying to establish some kind of technical conversation with other plant management.

But the SRO, for instance, though, his primary purpose is direction of the plant activities and implementing these procedures.

MR. WARD: Notification is one thing and the consultation with the operations management over the telephone is something different.

MR. STEINKE: Yes.

MR. WARD: I guess what I am asking, is he likely to engage in some consultation at that point as opposed to just having the person notified.

MR. STEINKE: My feeling on that is no. We have had problems, from my experience at the plant, on back-shifts and things when we had gotten ourselves into situations. The notification process and telephone calls were a problem at one time, but I think that's pretty well sorted out.

The utilities, the operators have a -- the situation now is that they will not get distracted. They will bring in extra people to get on the phone and discuss the issues, but not to distract them from the problem at hand.

MR. CARROLL: The technical consultation, you said, would more typically be between the STA and somebody else.

MR. STEINKE: Correct.

[Slide.]

MR. STEINKE: I'd like to summarize here and go over what I see here as some of the strengths with this type of training. Very importantly, the plant-specific simulator here has to be mentioned. Providing the tool which we can evaluate them with on a real-time basis. Of course, we're dealing here with an issue that is time sensitive, as we've clearly identified.

A second strength, as I see it, the operators receive procedure training with their knowledge and confidence level based on actual plant response. It's like a continuous procedure verification process. They are using their own procedures. They are using them on their plant controls. They're manipulating system controls and they're seeing the response of that. They're developing that experience base to work from.

Now, from an evaluation standpoint, I think here in Item C that both the examiners and the utility instructors, we have developed now some evaluation forms with, as I have pointed out, critical tasks clearly delineated. What it results in is very consistent evaluation here and gives the operator good consistent feedback. I think that, within this process, is a very important element.

[Slide.]

MR. STEINKE: Last, but not least, some of the weaknesses I think should be brought out. These scenarios, in order to build a good training exercise, they do really require multiple failures of safety grade equipment, power supply, so forth.

At one time, I would say that developing this credible scenario is difficult, but I think here that it's important to add that as our operating experience base gets larger, that we're seeing more problems out in the industry that we can use to implement into these training exercises and make them believable for the operators.

The operators' reaction sometimes to these events is, ah, it could never happen here.

MR. CARROLL: Right.

MR. STEINKE: But I think that because of the fact that they're being taught industry events and they're very aware of what's happening at other plants, that this problem is being overcome.

Item B here goes back to plant design, where there is sufficient inventory on that steam generator that the window, the window can be up to say 30 to 45 minutes before action is required here. From an evaluation standpoint, this can be a drawback because of the time that is required to evaluate the entire process.

The training departments have a lot of commitments, a lot of areas that they have to cover within the given requal program. So what I'm saying is that sometimes it is deemed satisfactory just to get to the initiation step, see that the operator does, in fact, open the valves, and then terminate the exercise at that point.

MR. CARROLL: Does every operator in his initial training get to see one of these through to getting to a safe condition?

MR. STEINKE: I think that I can answer that yes, because there is more time available within that program and they have more time on the simulator. The scenarios can be taken out to two and three hours in duration, where, as opposed to the requal format, usually they're working under a much more constrained time.

Last here, but not least, addresses the fact that once licensed as part of that requal program, that he may only enter this procedure once every year to year-and-a-half as part of his training, and then not necessarily always reach the end point here.

Also, he may not be the procedure reader during this event. He may be just another operator, say the SRO. He may be filling the RO position within the training team and he may not always be the man behind the desk, if you will. So sometimes credit is given for positions which are not really, as you want to call it, in the hot seat. So I think that is definitely a weakness.

That really concludes what I had to say on the operator training issue.

MR. WARD: Any questions?

[No response.]

MR. WARD: It was very interesting, Mr. Steinke. Thank you. Now we're ready to turn to Mr. Naff.

[Slide.]

MR. NAFF: I am Sam Naff. I work for EG&G. The original topic of the talk as listed in the agenda was Foreign Plant Feed and Bleed. You'll notice the title of my talk is called Feed and Bleed Features of PWRs in the Federal Republic of Germany. That's for two reasons.

Out of the 18 years that I have worked for EG&G, I've spent eight of them in Germany. But that's not the only reason. I also, while I was over there, participated quite a bit in OECD activities, CSNI activities for the NRC. During a number of those discussions, there were discussions by the different countries about what they're doing to address accident management and things like that.

It became quite clear that Germany had decided that their main accident management tool, let me say, was primary and secondary feed and bleed. So they've bent over backwards to do everything that they possibly can to make that as likely to be successful as they can.

I will talk about what they've done as I go through this a little bit.

MR. WARD: Sam, that's kind of interesting because I know particularly with the Germans, if we go back eight years ago, they talked a lot about secondary feed and bleed. But they regarded primary feed and bleed as something they didn't want to have anything to do with.

MR. NAFF: Much like in this country.

MR. WARD: But they seemed to almost have a more extreme position back then. Is that consistent with your observations?

MR. NAFF: Yes, I think so. I'll talk about the risk studies a little bit, too. But that had a lot to do with it.

[Slide.]

MR. NAFF: Now that I've told you what I'm going to talk about, I'll tell you again. I've got an introduction in which I'm going to tell you just a little bit about what kind of plants they have in Germany, a little bit about the basic safety features related to feed and bleed, and I will talk about the German risk studies.

It is a matter for this talk because a lot of the changes they've made in their plants relative to feed and bleed came from what they learned from their risk studies. Then I will talk about recent improvements that they've made in the plants because of the risk studies and because of attention being paid to accident management and severe accidents. Then I will give you a short summary.

[Slide.]

MR. NAFF: I can make the introduction brief. I don't know how much you want to know about what there is in Germany. This tells you that there are 14 PWRs in the range of 340 to 1300 megawatts electric; seven BWRs in the range there; one LMFBR which will never be operational, I'm told. So they've got a total of 21 plants on-line, producing 22,000 megawatts electric.

Just a little history, their first plant went on-line in 1969 and their most recent one went on-line in 1989. They bragged to me that it took them 66 months to get on-line, too, by the way. A little better than we've been doing.

MR. CARROLL: Sixty-six months from --

MR. NAFF: From signing the contract.

[Slide.]

MR. NAFF: Their plants, for quite some time -- they brag about their combined injection systems; not related to feed and bleed, primarily related to large break LOCA or any kind of LOCA, I guess. Originally, they had all eight legs, all four hot legs, all four cold legs in their PWRs at all systems, high pressure injection, accumulator, and LPIS, ECC systems.

As an after thought, and I don't remember what year this happened in, they decided, gee, one of the ways we can minimize pressurized thermal shock problems is by putting our makeup water, our HPIS only in the hot leg and we don't have cold water flowing to the cold leg junction of the downcomer and we minimize the risk for PTS.

So the plants that had their HPI systems in both hot and cold legs, they always had valves in them so they could valve out either side they chose to. They have valved out the cold leg side on their HPISs, and I think some cases totally removed that path.

The newer plants, their standardized convoy plants, don't even have installed that line. When the next bubble came in time, again I'm not real sure, but at the moment they have decided, and they've emphasized this in the risk studies later, something that I think John Bickel mentioned in his talk, the problem is the operator, not the equipment.

So they said one of the ways we can minimize our risk is let's forbid the operator to touch the system for the first half-hour of accidents. We can automate it all. So their plants do 100 kelvin per hour, 180 degrees fahrenheit per hour.

The convoy plants are all of the newest generation of plants, standardized plants in Germany are all of the 100 per hour. Some of the ones slightly before that, the older plants are slightly less than that for various reasons; I think metallurgical, I'm not sure; something in the 80K per hour region.

So they consider that an important feature and it does have a significant effect on the risk. Valve testing, I mentioned here. They have a large facility at Karlstadt near Frankfort, and they do claim to test every safety-relate at least, and some other valves in every reactor in real size, the actual valves.

This testing is in either single-phase steam or single-phase water or two-phase flow, depending on what the valve could be subjected to; not only what it's intended to be used for, but what it's subjected to. They think that's pretty important and they've learned a lot, and I will talk a little bit more about that later when I get into improvements.

[Slide.]

MR. NAFF: I mentioned earlier the risk studies. They chose a referenced plant. I believe it was the last plant built in Germany before the so-called convoy plants. The difference between it and the convoys is almost nothing. But the convoy plants are a standardized plant now and that's what they do there.

As you can see, it's a 1240 megawatt electric plant, 3750 megawatt thermal, four-loop PWR built by Siemens KWU. It started up in January 1977. Their risk studies, they say they're two studies. They call them Phases A and B. The first study was completed in 1979, not long, you'll notice, after the commercial start of this plant.

Now, both studies were for this plant. Risk studies and PRAs on plants since then have been a delta on the one they did for this plant. The first study was virtually a copy of the Rasmussen study, WASH-1400. Phase B, then, was completed just June 1989.

The NRC has an English translation of the Phase B risk study. Do you know whether that's available to everybody, Lou? I don't see why not. I got a copy from Joe Murphy. Of course, I've got a copy of the one in German.

If you do get that and read it, I might point out that the translation leaves something to be desired. Pressure vessel and pressurizer become the same word, for instance. I kind of wondered about the PORV they described on top of the pressure vessel when they were going through this.

What I say here is there are more triggering events considered in Phase B and there were some other things different that they did, too, that I believe I include on the next slide. The resulting core damage risk in Phase A was nine-times-ten-to-the-minus-fifth per year; Phase B, three-times-ten-to-the-minus-fifth per year.

Now, it would have reduced a whole lot more -- I don't remember the numbers. I had them in an earlier talk that's more complete than this one or lengthier than this one. But if they had not added additional triggering events, the difference in these two would have been at least twice as much between the results of Phase A and Phase B.

[Slide.]

MR. NAFF: Here I talk a little bit more about the differences in the two studies. More triggering events considered, as I mentioned. They claimed to have used more sophisticated safety risk analysis techniques in Phase B.

They claimed to have used much better mathematics. I haven't studied it in detail. I talked to John Bickel about this the other day. I guess personally I don't see the increased sophistication. Certainly, they had a lot more plant data. Remember I pointed out to you the first one was finished two years after the plant they were studying went on-line.

So for Phase B, they had more plant-specific data for the B iblis B plant, a lot more. They also had a lot more plant data from other places, too; other very similar plants in Germany.

They had done a lot to the plants based on the Phase A risk study. They hadn't ignored the results of that. This is when they begin their improvements in the plant, although they went on -- they're still going on, for that matter.

They brag about their safety research results. The Germans are doing a lot of experimental work. They were one of the participants in the 2D/3D program, as most of you know; the UPTF facility full-size results. They've got a very active PKL program. They were the major funder of the LOBI program in Italy. They haven't ignored our experimental results. They use our codes.

They think that was valuable also in helping them understand better what the real risks were.

MR. DAVIS: Excuse me, Sam. Is triggering event the same as initiating event?

MR. NAFF: Right.

MR. DAVIS: Or is there some distinction here that I --

MR. NAFF: No, there isn't. None at all. That happens to be what the translator chose to call it from the German study and that's what I use on this slide.

MR. DAVIS: Thank you.

MR. NAFF: It's identical.

MR. WARD: So the reason for core damage the number went down in Phase B, even though there were more initiating events considered, is what, the more --

MR. NAFF Virtually all the reasons I said in the differences. They think the mathematics were better and they were able to get -- where you try to bound the safety number of probability of an event, you have to admit sooner or later -- typically what you're doing is saying I know it is no worse than this.

Basically, by each of these steps that I mentioned, the further research data, the better plant data, the better mathematics, and so forth, they took some conservatives. They think they have a better handle on what the exact number really is.

MR. KERR: Are you implying that Bickel gets his numbers by saying I know it's not any worse than this?

MR. NAFF: I will let John speak to that.

MR. BICKEL: No comment.

MR. MICHELSON: How do they treat external events?

MR. NAFF: Somebody else asked me that and I'm sorry. I've read through their study, but I don't remember. I remember it is not a large contributor to their overall risk. They have done that. Their containments, for instance, the design of their containments is very beefy.

MR. MICHELSON: I'm only saying that if they haven't treated external events --

MR. NAFF: No. They have.

MR. MICHELSON: -- the conclusion that they have and they come to the conclusion they're a small contributor, that's great.

MR. NAFF: They've got a certain size airplane crashing at a certain speed into the containment. They've got fire, they've got flood, they've got all the standard external events. But I don't remember the number associated with that risk-wise, except that it is small compared to the --

MR. MICHELSON: What is their largest risk?

MR. NAFF: What is the largest?

MR. MICHELSON: Yes.

MR. NAFF: By memory, I'm sorry. I'd have to get out some other slides and show you that.

MR. MICHELSON: We'll get it on the next page.

MR. NAFF: No. I don't think you will. I wish you would, but this is only related to feed and bleed. I didn't make a nice table like John had in his talk that showed the percentage of accidents that were related to feed and bleed. I probably could get that out of the German risk study.

MR. KERR: One of your slides says the main contributions to risk were the transient 69 percent, and small leaks 25 percent.

MR. NAFF: I thought you wanted a narrower answer than that; what kin.. of transients specifically.

MR. KERR: I wasn't the one that asked the question, but I was just trying to --

MR. NAFF: If that's the answer to the question, that's fine.

MR. MICHELSON: I was just wondering what the contribution of, for instance, fire was or the contribution of certain transients.

[Slide.]

MR. MICHELSON: How do they treat human performance?

MR. NAFF: I can't answer for you exactly how they treat it. I know they did judge that it was one of the major contributors to risk, and in the risk study Phase B, they took a lot of credit for having automated the secondary feed and bleed system.

MR. MICHELSON: So they attempted to model it into the --

MR. NAFF: Right. They said we've taken the operator out by automating it and, therefore, we can take that risk out. They did that not without good reason. It was a significant contributor.

MR. MICHELSON: Do you know if they included omissions as well as --

MR. NAFF: Yes, they did. I mentioned they made some improvement in their plants related to feed and bleed. They've made some not related to feed and bleed, too. There's a much longer list than this that I used in another talk that described all the safety features in Germany.

They've improved their pressurizer valves, their PORVs. They've said they are now designed for both liquid and gas, and by both liquid and gas I also include two-phase flow. They've got beefier, better valves at that level than they had before.

MR. CARROLL: And designed for means that they can be opened and closed with those kind of flows going through them?

MR. NAFF: That's right, so they claim. In addition to that, relative to open and closed, they've put additional battery backup control valves on all those so that they can be opened under total loss of power conditions, open or closed.

They claim that they can think of no way that they could not open or close a PORV. Of course, they can break like anybody else's

MR. CATTON: I thought they could open the safeties, too.

MR. NAFF: Also the safeties. I'm sorry. I meant to -- that's the reason I said control valves, which is probably not the best word. Pressurizer valves; I did use the right word. They can. You're right.

MR. CATTON: They can open the safeties.

MR. NAFF: That's right. That's my understanding. It's my understanding they can open or close every valve that sits on top of the pressurizer.

MR. WARD: Well, they don't have ASME codes.

MR. NAFF: They don't have an ASME code, but they have similar codes.

MR. WARD: But their safety valves really can't be used -- are of the type they can't be used in the U.S., as I understand.

MR. NAFF: Cannot be used in their U.S., the Germany U.S.?

MR. WARD: The United States. We couldn't use, in the U.S., these safety valves that can be manually opened.

MR. NAFF: That may be. I'm not an ASME code -- John Bickel is shaking his head yes.

MR. BICKEL: The Germans have in their codes the -

- they have the ability to block and operate their safeties, which is different from ours.

MR. CARROLL: So it's a question of whether there is a block valve.

MR. BICKEL: They allow block valves in their codes that are very, very different.

MR. NAFF: Right. Different rules. Which is best, you decide. They call this second bubble grid return switching. I've forgotten what that got translated from German. Basically, they claim they're hooked up to a completely separate grid. If they lose off-site power or the diesels come on first, and then they claim they've got a cable going somewhere to some completely separate grid in Germany that allows them to try one more time to get on a different grid to regain off-site power.

MR. CATTON: Maybe it's French.

MR. NAFF: Very likely is, as a matter of fact. In maintaining their secondary feed and bleed, they've done a number of things. One of them is they pressurize their feedwater storage tank with steam. They can, therefore --

MR. CATTON: One of the steam generators.

MR. NAFF: Right. They can put a lot of water in with complete loss of power and steam-driven pumps and what have you, even from this also. Use of non-safety grade water sources, external connection. They've got on all their plants, outside of containment, a big pipe that they can hook a pumper truck up to.

They also have the capability of hooking up to their city water or whatever water source they have at the plant. That goes for both the primary side and the secondary side. I'm sure there's a number of other things that they've done in their improvements, but this is a list I made for this talk.

MR. CATTON: They've got pieces everywhere, so they can drag in pieces.

MR. NAFF: That's right.

[Slide.]

MR. NAFF: So my brief summary. The Germans think feed and bleed is very important for their accident management procedures. They do have accident management procedures written for most cases. They are still writing them. They also do think that an accident management procedure is no good whatsoever if they have not done a believable code calculation and/or experiment showing that accident management procedure.

The main thrust for their PKL activities in these days, in fact, is doing the accident management procedures that are written up by KWU. They also use RELAP 5/MOD 2 and RELAP 5/MOD 3 as their principal licensing code and as their principal code to look at their accident management procedures to see if they think they're okay.

MR. KERR: Have they improved it as much as they've improved their reactors?

MR. NAFF: Have they improved the procedures as much as the reactors?

MR. KERR: RELAP 5/MOD 3.

MR. NAFF: Have they improved it? No. They're using our version, the same version we're using. There is a guy from KWU that was here yesterday that's up at ANF, and ANF has been bought, you know, by KWU some time ago, and they are looking at potential improvements in RELAP 5/MOD 2. Within Siemens, they're debating about whether they want to use an ANF improved MOD 2 or whether they want to use our MOD 3. They haven't made that decision yet.

In fact, they've got two groups within Siemens who feel more strongly about that than anybody at Idaho does, I think.

As I've talked about a number of times, the risk studies are useful tools for improving the plant safety, the minimized operator error through automation, all those things I've said before.

That concludes my talk. If I can answer any questions?

MR. WARD: Any questions?

[No response.]

MR. WARD: Thank you very much, Mr. Naff. Mr. Blumberg, how long do you think --

MR. BLUMBERG: This will go very quickly, I think.

MR. WARD: Is Mr. Condie here?

MR. CONDIE: Yes.

MR. WARD: I would like to hear about the experimental database. Is about 20 minutes right for that?

MR. CONDIE: It would be closer to 30. i was going to discuss LOFT and semiscale experiments in limited detail.

MR. WARD: Let me ask the Subcommittee what they'd like to hear. I think that's all we're going to be able to get in, is about 20 minutes on the experimental database.

MR. KERR: The LOFT data ought to be more meaningful, shouldn't it?

MR. CATTON: Let's hear about the LOFT.

MR. WARD: Can you do that, just talk about the LOFT data?

MR. CONDIE: Sure.

MR. WARD: Then we'll come back to Mr. Blumberg after that. Thank you.

MR. SCHROCK: Did we choose the right one?

MR. CONDIE: Yes, because in the Loomis and Cozzuol report, that NUREG has the semiscale, but I will be discussing the OECD LOFT experiment, LF-1.

[Slide.]

MR. CONDIE: Mr. Larson and I drew straws last week to see who would do which discussion today. For a moment there, I thought that he had drawn the short straw.

I'm just going to start in with the LOFT experiment FW-1. This was really the first experiment done under the LOFT OECD program, and I'm sure the reason that this data was not included in the summary report on feed and bleed is because the data hadn't really been released for overall use at that time.

Since then we've been told that the data can be discussed openly and so we can talk about it. The experiment FW-1 was performed specifically to address the concerns of primary feed and bleed. It was a complete and unrestored loss of feedwater. It was initiated from typical PWR operating conditions at full power for pressure and temperature.

The HPIS was scaled to one of the three HPIS trains in the PWR. So there could have been additional HPIS capability had they so desired. The primary feed and bleed was the means of recovering the plant.

So I will start right in by looking at the early part.

[Slide.]

MR. CONDIE: I apologize a little bit in the first part. The experiment data that I show here, many of the figures come from various sources and the time scale, they're not all the same by any means. So you need to be cognizant of the time scale on this. But this looks at the first 300 seconds of the primary system pressure response.

The initiating event, as I indicated, was the feedwater termination. At that point, the pressure started to go up slightly as the steam generator started to boil dry. The pressurizer sprays did come on, came on at this point right here. It turned the pressure curve down a little bit.

The sprays terminated, the pressure went back up, and the sprays went back on at that time, and that second spray initiation really didn't do anything as far as slowing down the pressure increase.

At about 50 seconds, then the reactor scrammed on a high pressure signal automatically, and the PORV was also latched open at that time. That would be right here, and you can see then the pressure started to drop rapidly. At t his point in time, at about 100 seconds, the steam generator level reached the bottom of the indicating position.

Remember now LOFT only has one steam generator and that simulates the volume in three steam generators in a PWR. The pressure continued to decline to about 250 seconds, which is a pressure-related signal, pressure of

1270 psi. The primary coolant pumps were tripped and the HPIS was initiated.

MR. DAVIS: I find it a little strange that you didn't get scram on loss of feedwater. Wouldn't that be more typical, instead of 50 seconds later?

MR. CONDIE: I guess I couldn't tell you exactly why they didn't allow scram at the loss of feedwater. The plant may be configured one way or the other. But in this case, the operating specification for the test allowed it to go until the pressure had reached a high pressure trip.

MR. CATTON: They probably wanted to get the pressure up.

MR. CONDIE: I can't give you all the background on the decisions that went into the various setpoints that were tripped.

MR. DAVIS: Tha[illegible]u.

MR. CARROLL: The PORV opening was not due to reaching the setpoint of the PORV. It was manually opened at the time of scram.

MR. CONDIE: That's right.

[Slide.]

MR. CONDIE: The next slide just shows a continuation of that same pressure curve, from zero down to 8,000 seconds to the termination of the experiment and delineates the termination criteria, at what point it occurred, the initiation of the residual heat removal system. It reached the point at which that system was capable of handling the decay heat removal.

But you can see that the decrease in pressure over that period of time was very uniform.

[Slide.]

MR. CONDIE: Now let's take a look at the steam generator liquid level. Again, this slide, at the initiation and the loss of -- closed the main feedwater valve and, of course, the aux feed was not available. So it continued to -- it started to decrease in level with boil-off.

The reactor scrammed, as I mentioned earlier, at about 50 seconds. So there was still some heat removal capability in the secondary side after scram, but not very much. The way the instrumentation on the LOFT steam generator is positioned, we lose the ability to tell the level while there is still some liquid in it.

So when we're about at this point in time, we lose the ability to indicate, to know just exactly what the level is. So that's the only reference point we had. But that occurs at about 100 seconds out in time.

The steam valve takes a few seconds to close. The steam valve was also starting to close at the time that scram was initiated and the PORV was latched open. So that also had some effect on the pressure decline and the loss of inventory because of the about 20 seconds it takes to close the main steam control valve.

[Slide.]

MR. CONDIE: In the primary system, of course, the pressure is dropping and the primary coolant is heating up. You see this curve shows a saturation temperature based on the pressure in the upper plenum and the temperature of the fluid in the upper plenum.

Before scram, as the secondary heat removal capability was degrading, the primary system temperature went up, dropped at the opening of the PORV, some cooling, but it really dropped because of scram, some cooling, and then it stayed fairly constant as the pressure decreased until about 250 seconds, and that was then when we started to get some voiding in the primary system.

You don't see near as much evidence of the effects of the primary system voiding in LOFT as you do in the smaller system like semiscale, but as you will see here in a minute, we can see some of the effects of that generation of steam in the primary system.

[Slide.]

MR. CONDIE: Just to take a look at the pressurizer level, the pressurizer level rose as we had the initial degrading of the heat transfer. Then at scram it dropped, and then as the PORV opened, of course, it flushed out all the liquid and the level basically indicated full for the rest of the transient.

We have kind of an interesting situation where we measure the density of fluid upstream of the PORV.

[Slide.]

MR. CONDIE: The piping arrangement from the outlet of the pressurizer goes out the top and it goes horizontal for a ways and then it goes vertically downward for a ways, then it goes horizontal again.

That's where the PORV is, quite a ways away. Our measurement is slightly upstream of that. So while the pressurizer may be indicating full, you would think liquid would be measured as not necessarily the case the way it's set up. So this is a slide of the density that we measured upstream of the PORV.

While it appears to be low in the consideration of the full PORV or the full pressurizer, we can see quite a change in the density and, thus, the flow rate that goes out the PORV. Initially, we have a slug of liquid that's in that line from the outlet of the pressurizer to the PORV. So that's flushed out. So we're measuring that liquid and a density of approximately -- well, a specific volume of one.

As that is flushed out, then right in here we get a much lower density as that steam has exited through the

PORV. Then that next big spike is at the time where the upper plenum -- at about 250 seconds, it flashed. As that expanded, then the volume in the primary system then pushed a big slug of fluid into the pressurizer and you got a bigger mass, higher density mass outlet at the pressurizer.

Then it drops and oscillates and the density fluctuates then in response to the primary system and the other events that are occurring in the primary system.

MR. WARD: Let's see, Keith. I don't understand what's going on there. The previous figure shows the pressurizer is full of liquid after about a couple hundred seconds or something, right? Is that what that shows?

MR. CONDIE: That's what it shows, yes. The indication is that the pressurizer is full at that point.

MR. WARD: It's full of liquid.

MR. CONDIE: Full of liquid.

MR. WARD: But going out the PORV then is a two-phase mixture.

MR. CONDIE: That's right.

MR. WARD: Is that steam coming up through the liquid?

MR. CONDIE: What I tried to explain is that we have a pipe. The location of the PORV. The PORV is not located right on top of the pressurizer. There's a piece of pipe that goes up, goes horizontal, then goes vertically downward for quite a ways, and then it turns horizontal, and that's where the PORV is.

These density measurements are taken in the vertical portion just before it turns horizontal. So there's perhaps some flashing that occurs in that that lowers the density. So what we're measuring upstream of the PORV is really a two-phase mixture, even though our indication on the pressurizer in the vessel itself is that it's full.

That may be well be an anomaly as far as the interpretation, but you're not going to have --

MR. CARROLL: So pressure is dropping as it transits that pipe.

MR. CONDIE: Right.

MR. WARD: So you've just got flashing flow going through there.

MR. CONDIE: Flashing flow going through there, and that's why you end up with a lower density fluid in the two-phase mixture, and that two-phase mixture then controls the mass flow rate.

MR. WARD: So the pressure at the inlet of the PORV is probably -- is that halfway down the atmospheric or something?

MR. CONDIE: It wouldn't be that far, because your main flashing occurs or choking occurs across the PORV. But you do get some choking and flashing in that line.

MR. WARD: But there must be a lot of it if --

MR. CONDIE: A lot of it, that's right. But that's the reason for that, of why you -- it's a good question. And I don't have enough experience on large plants to know. It does show one of the things that was brought out before in the other discussions. It shows the importance of knowing what that density of that fluid going out of the pressurizer is, because it does -- the energy removal rate, as well as the mass removal rate is dependent upon whether that's a single or two-phase mixture going out of there.

You can see that reflected throughout the system. The fact that our system may not represent exactly how that would occur is --

MR. CARROLL: At a big plant, it would just be a nozzle on the top of the pressurizer.

MR. CONDIE: Top of the pressurizer, right. We needed to get space in there where we could put a densitometer and we didn't want to have it where we had a horizontal leg where we'd get some stratified flow. Then we'd really have a heck of a time determining what the actual density was. So it's a tradeoff in the experiment.

[Slide.]

MR. CONDIE: This next slide then shows the mass flow rate of both through the PORV and the HPIS. The HPIS starting at zero and at the 200 seconds going up, dropping back, just a little spike in there and then increasing steadily as a function of the system pressure, basically.

The PORV flow rate starts high, drops down, and it's hard to see which goes up if you look at the circle there, but right here, this is the PORV flow rate that went up in response, again, to that flashing in the upper plenum that increased the pressure and pushed more of the higher density fluid out the PORV.

MR. KERR: What should I conclude from this graph? That things are behaving just the way they were expected to behave or there were surprises?

MR. CONDIE No. I don't think there were any surprises. It is showing that there can be a significant period of mass loss, a mass imbalance, a net mass loss for a significant period of time without any consequences to the core.

During this period of time we're removing a lot of energy that is necessary to bring the pressure down.

MR. SCHROCK: Where was the flow rate measurement made in this?

MR. CONDIE: The PORV flow rate was then --

MR. SCHROCK: Downstream or --

MR. CONDIE: Well, it was downstream of the PORV, brought into a condensing coil and measured. Of course, the HPI was a single-phase flow.

MR. SCHROCK: It was the PORV that I was concerned about. Did you also measure the pressure at that location where the densitometer was?

MR. CONDIE: I'm sure that's part of the density measurement. I don't have that information right here.

MR. KERR: You would refer to this as confirmatory research because you sort of knew the answer ahead of time.

MR. CONDIE: We, of course, did a lot of the code analysis. And, of course, the subject of this talk was to take and compare the data to what we previously predicted would occur. There is an entire analysis report available on this particular experiment that is now available.

It's called OECD LOFT T-3105, if you want to write that down. Probably to request those through the NRC would be best. That gives the pretest predictions, the expected performance, the data, as well as improvements that were made in the code.

MR. DAVIS: Keith, the only thing that is of interest to me, at least, is it looks like the operator didn't do anything. He turned on the HPI, opened the PORV, and that was all he did.

MR. CONDIE: That's right. The pump trip was all activated automatically as a result of pressure response.

MR. DAVIS: We keep hearing about how much operator action is required for these things, but in this case there was essentially none. He didn't have to throttle anything or he didn't have to cycle the PORV or do any of those things.

MR. CONDIE: That's true. On the previous LOFT test, we used secondary feed and bleed on a lot of occasions and tried to approach pre-selected cool-down rates. In those cases, there was operator intervention all along. As far as secondary feed and bleed, we used that in a -- I think I listed all those tests in there.

There are a number of tests in which secondary feed and bleed was used, but you're right. In this case, the primary feed and bleed was just -- you ended up with a significant net mass inventory that was negative; that is, we lot initially. Still that allowed us to bring the pressure down so the HPI could come on, and it didn't take long to -- the net loss was overcome.

In fact, we show that on the next slide.

[Slide.]

MR. CONDIE: It is really just an arithmetic sum of the previous slide and it shows that the minimum mass occurred at about 2500 seconds and then started to increase. At that 2500 seconds, the inventory was 4600 kilograms. That inventory is sufficient to cover the entire core and the hot legs if it's all collapsed into the vessel.

There is no indication from any of the thermal responses, of course, that it did anything other than that in the LOFT experiment. In the semiscale experiments, on the other hand, we had significant mass redistribution within the primary system during feed and bleed, such that even though we had the proper total mass inventory, we did have some core heatup.

You can see that in some of those slides I've shown for that semiscale test PL-3, and it's also in that NUREG report. So I don't think it's necessary to -- and there's quite a discussion on the mass redistribution into the steam generators during that period of time.

MR. DAVIS: Were the primary coolant pumps shut off?

MR. CONDIE: In LOFT, the primary coolant pumps were shut off at HPI initiation at 1270 psi. I think it's delineated on that pressure plot, the first pressure plot.

MR. CATTON: How well can these observations be predicted?

MR. CONDIE: That was to be the subject of the other two talks I didn't get to present, one by Jim Steiner and the other INEL person on benchmarking the codes against experimental data.

MR. KERR: Do you mean before or after the experiment?

MR. CONDIE: We've had the whole series of standard problem analysis, both blind, double-blind and eyes wide open. There's a wh le body of reports that address that.

MR. CATTON: Is there a synthesis report dealing with the analytic capability?

MR. CONDIE: For just the feed and bleed?

MR. CATTON: Yes.

MR. CONDIE: Well, that one you have there by Loomis and Cozzuol addresses it some. I wouldn't say you'd call that a synthesis report. There's a pile of them right there, if you don't have them, by the water.

MR. CATTON: I'll check on the way out.

MR. CONDIE: They address that. They're also addressed, like I said, in semiscale PL-3 experiment, which talks about the primary system inventory imbalance. We call it liquid hold-up in the steam generators and the effect of that. That's been an issue that's been discussed quite a bit.

But I'd have to say that as far as the LOFT primary feed and bleed, it behaved basically like we expected. It showed that you can recover, even with a net mass differential that's negative over quite a significant period of time.

Even if that level had dropped into the top of the core, our experience from semiscale and others indicates you could cool it for quite a period of time. That deficient mass balance could have continued for quite a while and you would still say that you had a successful decay heat removal mechanism.

I guess that's about all the time I've got.

MR. WARD: Okay. Thank you very much. We appreciate that. Let's go right now to Mr. Blumberg. Lou, did you have anything you wanted to say?

MR. SHOTKIN: Just a couple of short se[illegible]ces.

MR. WARD: All right.

[Slide.]

MR. BLUMBERG: I am Norman Blumberg. I'm normally with NRC Region I, and I'm on a temporary rotational assignment for three months in the Office of Research and I'm working for Lou Shotkin.

MR. CARROLL: What do you do in Region I?

MR. BLUMBERG: I am sorry. I'm the Chief of the Operational Programs Section, which is in the Inspections Section up there. I've been with the NRC 12 years and an inspector supervisor all during that time.

[Slide.]

MR. BLUMBERG: Like I said, I think this is going to be short. I wanted this last because I think as you see in looking at the slide, a lot of the things that I have on my slide, working independently from the people here, it was hard to coordinate this, but it turns out that as you can see a lot of it was already covered.

I felt it was a good idea to do this last so that -- I think most of the questions in some of these areas can be answered. The question that we got was regulatory requirements related to feed and bleed.

The answer to that is there aren't any. That was the short answer and we stipulated that this morning. I probably could go home right now, but I think we need to elaborate on the NRC's involvement in the feed and bleed process, even beyond what the regulations say.

MR. KERR: When you say there aren't any and then you say that the feed and bleed process is part of the emergency operation procedures, then you say that NRC reviews the emergency operating procedures, there's a contradiction in logic here somewhere. Help me.

MR. BLUMBERG: I'm going to try, to the extent that I can. Let me get down to the part where we're reviewing emergency procedures. Basically, there weren't any -- there weren't and aren't any regulations concerning bleed and feed. They assume multiple failures.

Feed and bleed presumes a situation where you're in multiple failures. The original emergency operating procedures -- and I say the original, the ones -- the event-oriented procedures required by Regulatory Guide 133, which, by the way, is still in effect, did not cover the process that would even address bleed and feed.

The evolution, as I understand it, was after TMI and the owners' groups, there were a number of discussions between the NRC and the various owners' groups, and as a result of NUREG 737 and other things, that the emergency operating procedures needed to be improved.

Out of this came the current emergency operating procedures, the system-oriented procedures, the package that Bill Steinke talked about earlier. That, in fact, was not levied upon the licensees or the owners as a result of any regulation or result of any changes to the regulation, but was as a result of the owners' groups and various people over a period of time reviewing the emergency procedures and coming to the decision that the emergency procedures needed improvement, there needed to be a new direction.

Among that, included in there was the decision by the owners' group, maybe with discussions with the NRC, that a feed and bleed procedure would be included in and be part of the emergency operating procedures.

Again, as I understand it, that is a voluntary decision by the owners' group and not a requirement.

MR. CARROLL: But once a licensee has made that voluntary decision --

MR. BLUMBERG: Then they're stuck with it.

MR. CARROLL: It really is part of their tech specs.

MR. BLUMBERG: Not the tech -- yes. It's part of their tech specs indirectly, in that the tech spec says you'll have emergency operating procedures and once you establish those procedures, then you're obligated to live by whatever rules you've established. The answer is yes.

MR. CARROLL: This is a de facto regulation.

MR. BLUMBERG: Yes. I can go in or an inspector can go in and pick up that emergency operating procedure, and including feed and bleed, the feed and bleed procedure, and say if it's incorrect or it has some deficiency, that they were not allowed to work.

I could, in fact, write a violation or something against that procedure, with the current existing rules, saying your procedures have to be established and be correctly established.

MR. KERR: Even though the tech specs only require that they have procedures, the NRC has decided what correct procedures are and what incorrect procedures are.

MR. BLUMBERG: The answer to your question is the tech spec itself says that you will establish, implement and maintain procedures as specified in Regulatory Guide 1.33, lists of categories and procedures. Among those are the emergency operating procedures.

Inherent in establishing a procedure is that procedure has to be technically correct. If there is a technical deficiency, that's a citable violation and a violation of regulatory requirements. Simply just putting a procedure on the street and saying here it is, guys; I have a title that says feed and bleed or loss of coolant or whatever is not sufficient.

MR. KERR: I'm just trying to understand the situation in which you tell me that you do not require any procedure, and then I'm learning that you review them in detail and you are able to decide whether they are correct or not. And if they are not correct, they have to correct them and could even be cited for violating them.

I've also read Alice in Wonderland and I don't really understand it.

MR. BLUMBERG: There are two parts to this process. One is a regulatory part and the other is a review part. If you notice in here, I have primary feed and bleed procedures are established by owners' group emergency procedure guidelines. I showed Dr. Michelson one of those guidelines this morning. I think Bill Steinke talked about them.

Those guidelines were submitted to the NRC and reviewed and approved by the NRC and NRR specifically. This was a one-time review, to the best of my knowledge, and if there are any changes, we would review the changes. They have been established and have been in effect for some time.

In addition to that, the licensees have established what we call a procedure generation package, which is what they tell us the mechanism by which they intend to establish emergency operating procedures. In fact, those were reviewed by the NRC/NRR.

Those have been established. I can't tell you whether that's Alice in Wonderland or what. I am telling you that was the process that happened between the NRC and the licensees. That is not a regulatory process.

MR. KERR: You now have processes rather than regulations. NRC is not regulating by process.

MR. BLUMBERG: I think some of this is --

MR. SHOTKIN: Let me try to help out, if I can. The first sentence in Mr. Blumberg's slide is what he's talking about. 10 CFR 50 is the Code of Federal Regulations related to power reactors. It does not specifically address primary or secondary feed and bleed. That's what Mr. Blumberg is saying; that there's nothing in the regulations. He's referring to that Code of Federal Regulations.

There are, in addition to that, if you want to call it a process by which the NRC interacts with the licensees, and one of that main process that Mr. Blumberg is very familiar with is the inspection process.

We have in each region inspectors that go and inspect what goes on at the plant. That's what he's talking about.

MR. BLUMBERG: I'm trying to get to the inspection process. Before we can do the inspection process, something should be on the street that establishes some guidelines for the licensee that they've accepted and that they're going to go to, and then that establishes something, a criteria for the inspector to look at.

In addition to that, the NRC establishes -- and I'm sorry I didn't make a copy of this for you -- a temporary instruction 25, 15, 92, and I don't know whether I can give these later, if you're interested in them.

Emergency operating procedures team inspections. This is specifically the guidelines that the NRC inspectors are using. If you're interested, I'll see that, after this, that copies are made.

MR. KERR: I have already asked for a copy.

MR. BLUMBERG: These are the questions now. I'm reading from the front of these so you can see what the inspector is asked to do. It says are these procedures technically correct; subset, do they generally conform to the vendor generic guidelines; have they provided technical justification for safety significant deviations for vendor guidelines.

These are the questions that the inspectors are expected to answer. Can the procedures be physically carried out; are referenced procedures and controls present and accessible; is there a proper operations environment; will plant personnel be prevented from taking designated actions due to time constraints; are necessary tools, personnel, aids and equipment available; can the staff correctly perform procedures; do plant staff understand the procedures; are functions appropriately allocated; are there enough staff to perform the functions; and, can procedures be read under adverse environmental conditions.

These are the questions that the inspector, either all or in part, is expected to address. These are guidelines to the inspector. If any of those areas are deficient, they can be commented on and we can encourage the plant to fix them. If some of those areas are deficient, they are, in fact, violations.

MR. CATTON: What if nowhere at a given plant is the word feed and bleed even mentioned? Then what do you do?

MR. BLUMBERG: You mean the word itself or the procedure?

MR. CATTON: If it just does not exist in the plant.

MR. CARROLL: But physically could?

MR. PLUMBERG: You mean the procedures don't address even the process that would do it. That's your question.

MR. CATTON: They decided that they weren't going to do it. So it's nowhere in any of their procedures, even though they physically could do it.

MR. MICHELSON: But it's in the industry guidelines, though, isn't it?

MR. BLUMBERG: They are not under obligation to follow the industry guidelines. The best we could do is to note it, write a report on it or whatever. We could not force them to do it. The answer to your question --

MR. CATTON: Would you inspect them more often and give them a poor SALP rating or something?

MR. BLUMBERG: There's probably a lot of things that could be done, including to have various levels of meetings and discussions and try to find out why. But in terms of a regulatory requirement to say you were violating something, in my opinion, the answer is we have no justification, no legal justification, if that answers your question.

MR. MICHELSON: What is the stature of the emergency guidelines, then?

MR. BLUMBERG: They are just that.

MR. MICHELSON: For the particular utility. Just for information only.

MR. BLUMBERG: They're guidelines --

MR. WARD: No, no. You say that the utility has to give adequate technical justification --

MR. BLUMBERG: We would expect adequate technical justification for deviation, but --

MR. MICHELSON: So he doesn't have feed and bleed in his plant. There must be a documented --

MR. BLUMBERG: We would expect to see that. If they don't have it, I'm not sure that we could cite for a violation. In fact, normally we get that. If there is a deviation or whatever, we get some sort of a technical justification. Whether it's adequate or not, I don't know.

MR. MICHELSON: But he does at least have to document it.

MR. BLUMBERG: Doesn't have to. Reality is, I think, that most of the places are doing it just --

MR. CATTON: To make life easier.

MR. BLUMBERG: To make life easier. I agree with you. To make life easier on them. For them, it's not worth the fight, I don't think. I think it's just a matter of, hey, these are out there. If we do this, we get it done.

MR. KERR: From what you have read, the individual inspector has a great deal of discretion in determining whether the procedures meet those requirements.

MR. BLUMBERG: Yes. And I think there are other people involved. The individual inspector can make an initial judgment. He's part of a team and ultimately part of a management process that will review this. But I would say the inspection process has a fair amount of discretion.

MR. KERR: Even though a utility has no particular guidance ahead of time as to what is expected of them.

MR. BLUMBERG: I disagree that they don't have any particular guidance. They have the emergency response guidelines, and they also have their procedure generation package which gives them guidelines.

MR. KERR: There are no NRC requirements, you told me.

MR. BLUMBERG: You said requirements and then you said guidelines. If we're talking guidelines, I think there are plenty guidelines out there.

MR. KERR: I said guidance as to what the NRC is going to require. You told me the NRC doesn't require anything.

MR. BLUMBERG: Beyond the very basic regulations on procedures, the answer to that is true. And my answer to you is that they have been asked and have established procedure generation packages where they've been allowed to establish the guidelines, and then we expect them to observe those guidelines. Does that answer your question? I'm not sure that it does.

MR. KERR: If they don't observe them in the way you think they should observe them, so it's not as simple as they're establishing them and you're expecting them to observe them. You have a pretty good idea of what you want them to do and you insist that they do that.

MR. BLUMBERG: Yes. That's true.

MR. KERR: But there are no requirements.

MR. BLUMBERG: That's true. Beyond some of the very basis regulatory requirements concerning procedures and adherence to them and establishing them, that's true.

This inspection procedure goes through a lot of that. If you go through and a procedure requires equipment to be staged, certainly the inspector, jumpers or whatever, the inspector would walk through and see that that stuff is staged. If it isn't, do you have a violation or not? The answer is you do.

If it's staged in such a way that it may not be there when you need it, the inspector has a fair amount of comment on that.

MR. KERR: I am not opposed -- indeed, I am in favor of requirements made by the NRC when they are needed to enhance safety. The reason I like regulations is because the present procedure for formulating regulations requires that the NRC say they are going to formulate a regulation, it goes out for public comment, it is discussed by various groups, it may be changed, and everybody knows what it is.

The sort of thing you are doing is sort of Cella Rosa. There is no regulation. There is no set procedure for formulating it. There is no public comment period. There is no review process. It just sort of happens.

MR. CARROLL: There is a lot of inspector discretion.

MR. BLUMBERG: There certainly is.

MR. KERR: I personally don't think it's conducive to safety, because I don't think you get nearly as good regulations this way, and I think it's certainly not --

MR. BLUMBERG: I'm not sure I agree with you about saying it's not conducive to safety. I think that every one of these processes, call them what you want, fall into a mechanism that most people who deal with it understand it and understand it fairly well.

And I think in terms of having procedures out there that we expect to work and are going to be inherent to safety, then have people go look at them, whether they're part of a "regulation" or not is conducive to safety and it makes a safer process.

MR. KERR: I recognize that you think that, and

I'm trying to make an impression on you to convince you that the method of formulating regulations which has been used in the past gives a much broader spectrum of opinion and comment on the regulations that finally exist than your existing scheme which is sort of an inhouse thing and can be very much ad hoc.

MR. BLUMBERG: Up to a point, I would agree with you that's true. But the inspector, if you understand, that's what he has to work with. So the best bet is to give the inspector the best guidelines that you can and let them work with it. They're tasked to working with that, and I think within the scope of that, in terms of walking down these procedures, in going over these procedures, in running these procedures on the simulator -- I'm separating this from the operator licensing process -- I think is conducive to safety and is better system than just ignoring it.

I think that's what we do. I think we have a safer process doing that, whether you agree with the methodology of how we got there or not.

MR. WARD: Norm, I think that's been very helpful. There's an issue here and I don't think you're going to be in a position to solve it. But I think that your discussion has been valuable, though. Appreciate it.

MR. BLUMBERG: I just don't want to walk away from here feeling that this somehow is an unsafe process. I think it is conducive to safety.

MR. WARD: Thank you very much, Norm. Lou, you've got about five minutes and then we have to end the recorded part of the meeting. At that time, we will go into an Executive Session or just an unrecorded session.

MR. SHOTKIN: You spent the day talking about the feed and bleed process for decay heat removal, and using PORVs and HPI. This is a process that is useful for reactors at or near operating power.

Our codes have been assessed against data. We feel that we understand the phenomena. We have enough test data, that we understand the phenomena for feed and bleed at power and that our codes, even though you didn't hear it, that our codes are accurate enough and give reasonable enough results that we can analyze what is expected to happen.

What is the NRC going to be concentrating on? As I said at the very beginning, we have very little or nothing going on on feed and bleed for decay heat removal, other than what is going to come in through the IPE process. However, what we are looking at and will be spending a lot of time on in the next year or two will be decay heat removal at shutdown or near shutdown conditions.

What we have going before the Vogtle event, some of this is related to the Vogtle event. Before the Vogtle event, we were developing PRAs to assess the risk of lower power on shutdown. After the Vogtle event, which was a loss of RHR cooling, which is a form of decay heat removal at low power or shutdown, we are looking at various ways to remove decay heat when you lose this capability.

The process is not necessarily feed and bleed and it certainly isn't using a PORV. One process is to use gravity drained from the RWST and have that go through. But the main process that we will be looking at is more of a natural circulation reflux cooling process, because at low power or shutdown conditions the system is available and the plant condition is very different than at power.

I would just like to leave you with that. I think we understand the feed and bleed, which is full power, and what we will be spending most of our time on in the next year or so will be the low power or the shutdown.

The only other point has to do with the advanced reactors, the 600 megawatt reactors, and they have come in with the AP-600 SBWR with long-term decay heat removal systems that operate, that are quite different than current plants, operate on gravity, and are supposed to work quite well.

We will be evaluating our code's capabilities to analyze these new systems.

MR. WARD: Thank you. Does anybody want to say anything to Lou?

MR. CARROLL: I guess I just hope that when the IPE evaluations are done, that some emphasis is placed on looking at what kind of a job the licensees do on evaluating feed and bleed and the credit they take for it.

MR. WARD: Thank you very much. We won't end the meeting, but we'll go off the record at this point.

[Whereupon, at 5:10 p.m., the Subcommittee was adjourned.]

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: Joint Decay Heat Thermal Hydraulic

DOCKET NUMBER:

PLACE OF PROCEEDING: Idaho Falls, Idaho

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.

Lynn Estep

Lynn Estep
Official Reporter
Ann Riley & Associates, Ltd.

FEED AND BLEED:

PRELIMINARY DISCUSSION DOCUMENTATION

Louis M. Shotkin, NRC

ACRS T/H AND DHR SUBCOMMITTEES

INEL, AUGUST 29, 1990

NRC CURRENTLY HAS NO SPECIFIC PROJECTS CONCERNING FEED AND BLEED

NRR HAD A PROJECT ON SHUTDOWN DECAY HEAT REMOVAL INVOLVING SNL (PRA) AND LANL (TRAC CALCULATIONS). NRR CONTACTS ARE L. MARSH AND C. LIANG

THE LANL EFFORT WAS ABOUT $750K AND THE CONTACT IS B. BOYACK

THE SNL EFFORT WAS ABOUT $750K AND THE CONTACT IS A.CAMP

RES SPONSORED A SYNTHESIS REPORT ON RESEARCH RELATED TO PRIMARY FEED AND BLEED (NUREG/CR-5072, 6/88). THE COST WAS ABOUT $50K AND THE CONTACTS ARE: NRC, D. SOLBERG, INEL, G. LOOMIS.

THIS SYNTHESIS REPORT CONTAINS 57 REFERENCES TO PREVIOUS ANALYTIC AND EXPERIMENTAL RESULTS.

A SAMPLING OF DOCUMENTS NOT LISTED IN THE 1988 SYNTHESIS REPORT INCLUDE:

- MIST TEST RESULTS:

  NUREG/CR-5395, VOL. 5 TEST GROUP 33, HPI-PORV COOLING

  VOL. 8 TEST GROUP 36 PUMP OPERATION (TEST 4)

  LA-UR-88-1937, "POST-TEST ANALYSIS OF MIST TEST 330302 (HPI-PORV COOLING) USING TRAC-PF1/MOD1"

- NUREG-1289 "REGULATORY AND BACKFIT ANALYSIS: USI A-45", NOVEMBER, 1988.

- CE PLANTS w/o PORV:

  NUREG-1044, "EVALUATION OF THE NEED FOR A RAPID DEPRESSURIZATION CAPABILITY FOR CE PLANTS", DECEMBER, 1984, L. MARSH AND C. LIANG

  SECY-90-232, RESOLUTION OF GI-84, CAN'T JUSTIFY BACKFIT OF PORV'S. NRC CONTACT: R. WOODS

PWR Feed and Bleed Processes
(Part 1)

Presented by

T. K. Larson

ACRS Meeting

Idaho Falls, ID

August 29, 1990

INEL

Objectives

- Review Feed and Bleed (F&B) process
  - Primary feed and bleed
  - Secondary feed and steam
- Plant states requiring F&B operation
- Capabilities and limitations of F&B cooling

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Outline

- Summary description of F&B in PWRs
  - Primary
  - Secondary
- Plant states requiring F&B operation
- PWR F&B process description
  - Key factors
  - Phenomena of importance
  - F&B maps
- Summary/Conclusion

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PWR Primary Feed and Bleed

- ECC pumped into primary
- Primary fluid is heated/vaporized
- Energy removed by controlled discharge through PORV

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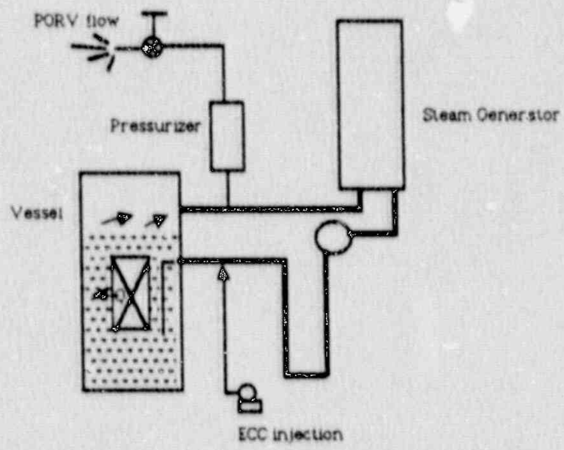
Primary F&B



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PWR Secondary Feed and Bleed

- Feedwater pumped into secondary
- Energy conducted/convected from primary to secondary
- Energy removed from secondary via steaming to condenser (or ADV,SRV)

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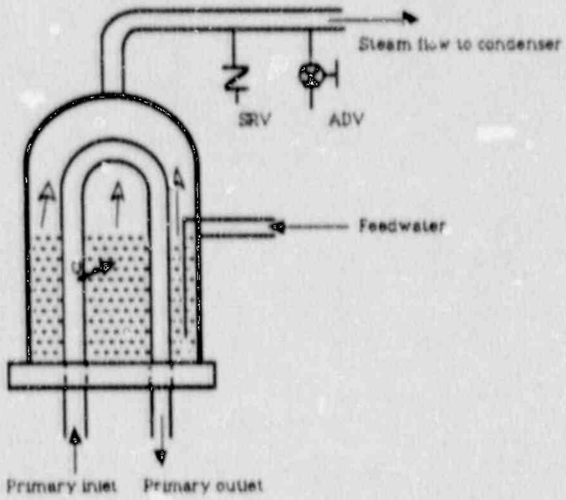
Secondary F&B



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Plant States Requiring F&B

Plant State	Definition
1	Loss of main feedwater, AFW available
2	Loss of main feedwater, AFW available to one steam generator
3	Loss of MFW, AFW available to one steam generator, SBLOCA in primary with energy input > losses
4	Total loss of secondary cooling with primary SBLOCA
5	Total loss of secondary cooling without SBLOCA

Note: States listed in order of increasing operational demand

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Operational Priority

Secondary F&B	Normal operation, secondary fully operational
Secondary F&B	All steam generators available with AFW only
Secondary F&B	Single steam generator available with AFW only
Primary F&B	Complete loss of secondary heat removal

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Plant Functional Requirements and Design Capability for F&B

Secondary F&B

- Requirement - Secondary operation with AFW sufficient to remove decay heat
- Design capability - One steam generator with AFW can remove decay heat (all plants)

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Plant Functional Requirements and Design Capability for F&B (cont'd)

Primary F&B

- Requirement
  - PORV energy flow > decay heat plus pump energy
  - HPI capacity > PORV mass loss
- Design capability
  - Most plants with one PORV satisfy requirement
  - Plants with one of two PORV operational may require 1.5 hrs to reach HPI shutoff head

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Feed and Bleed Feasibility

- Governing parameters for steady-state conditions
- Range of initial conditions from which F&B is possible
- Geometry effects
- System scale (experimental systems)

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Information Sources

D. J. Shimeck, et al. "Analysis of Primary Feed and Bleed in PWR Systems,"EGG-SEMI-6022, September 1982.

Y. S. Chen, et al. "A Feasibility Study on Feed and bleed for Pressurized Water Reactors,"ASME paper 83-HT-16, June, 1983.

G. G. Loomis and J. M. Cozzuol, "Decay Heat Removal Using Feed and Bleed for U.S. Pressurized Water Reactors," NUREG/CR-5072, June 1988.

B. E. Boyack, et al., "Los Alamos PWR Decay-Heat-Removal Studies Summary Results and Conclusions," NUREG/CR-4471, March 1986.

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Idaho
National
Engineering
Laboratory

Risk Assessment Insights on "Feed and Bleed Cooling"

presentation to:

Advisory Committee on Reactor Safeguards
U. S. Nuclear Regulatory Commission
August 29, 1990

by:

Dr. John H. Bickel, Manager
NRC Risk Analysis

Discussion Items

- Role of feed and bleed in decay heat removal
- Key factors impacting feed and bleed reliability
- Insights gained from recent PRAs

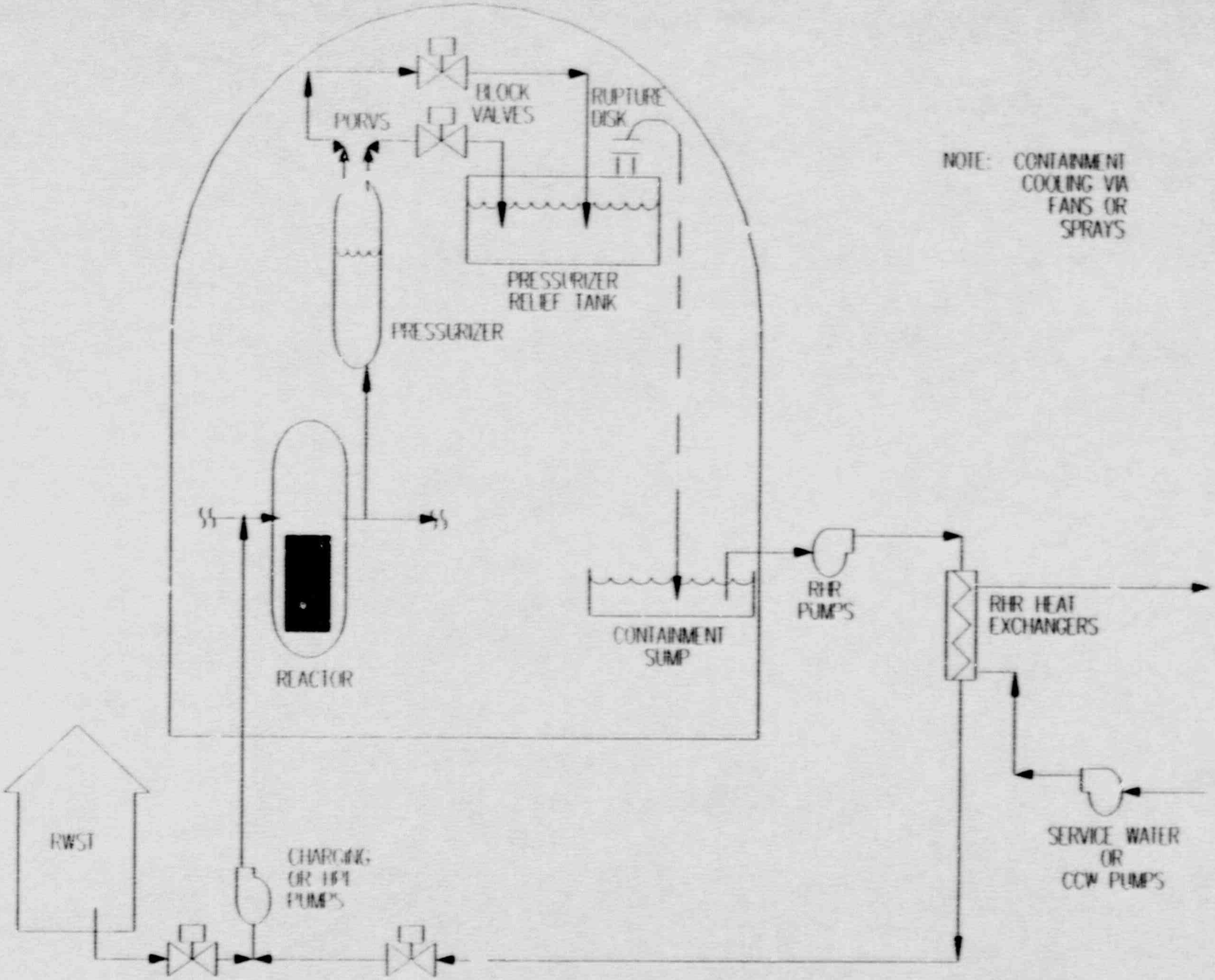
M132 JHB-0890-002

Feed and Bleed Cooling is Important Backup Deay Heat Removal (DHR) Mode

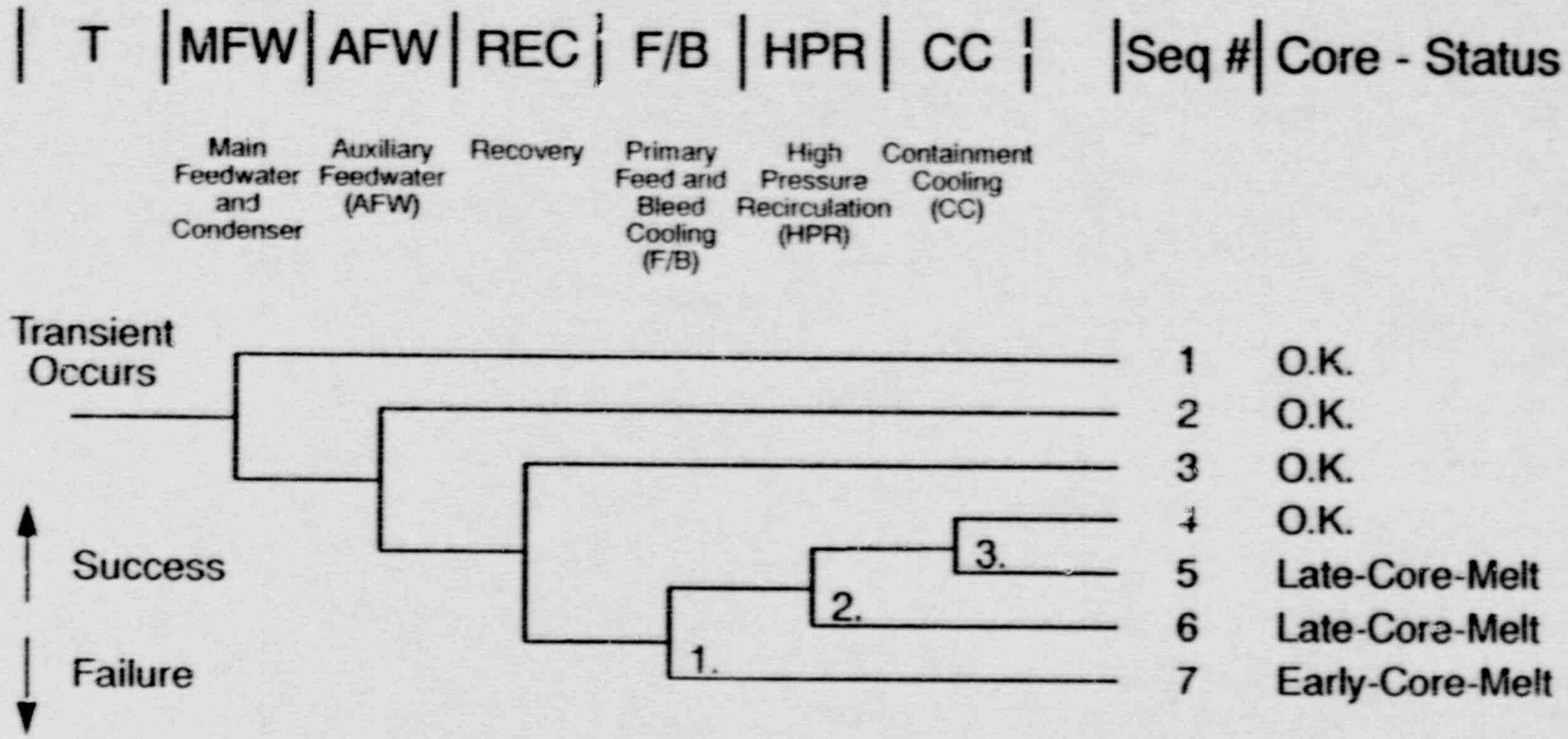
- Decay heat removal frequently demanded (1-15 events/yr)
- Steam generator cooling is primary decay heat removal mode
  - Main feedwater and condenser or
  - Auxiliary feedwater (AFW) and steam dump valves (secondary feed and bleed)
- Should steam generator cooling fail, operators will attempt recovery
- Should recovery fail, feed and bleed cooling will be attempted
  - (HPI or Charging) and PORVs and
  - High pressure recirculation and
  - Containment cooling*

*Plant Specific

M132 JHB-0890-003



FEED AND BLEED COOLING



Notes:

1. Loss of secondary cooling causes net inventory loss from PORVs/safety valves
2. Feed and bleed will deplete R.W.S.T. - recirculation necessary
3. Steam pressure in containment may cause PORVs to close - containment cooling may be necessary

M132 JHB-0890-004

Items to be Considered in Feed and Bleed (F/B) Risk Evaluation

- Main feedwater and condenser available post-trip on B&W, CE, older Westinghouse reactors
  - Implication: Fewer AFW challenges

- Main feedwater isolated post-trip on new Westinghouse reactors
  - Implication: More AFW challenges, more reliance on recovery action, F/B

- Some multi-unit sites have AFW cross-tie capability
  - Implication: Given loss of main feedwater, AFW failure, less reliance on F/B

M132-JHB-0890-005

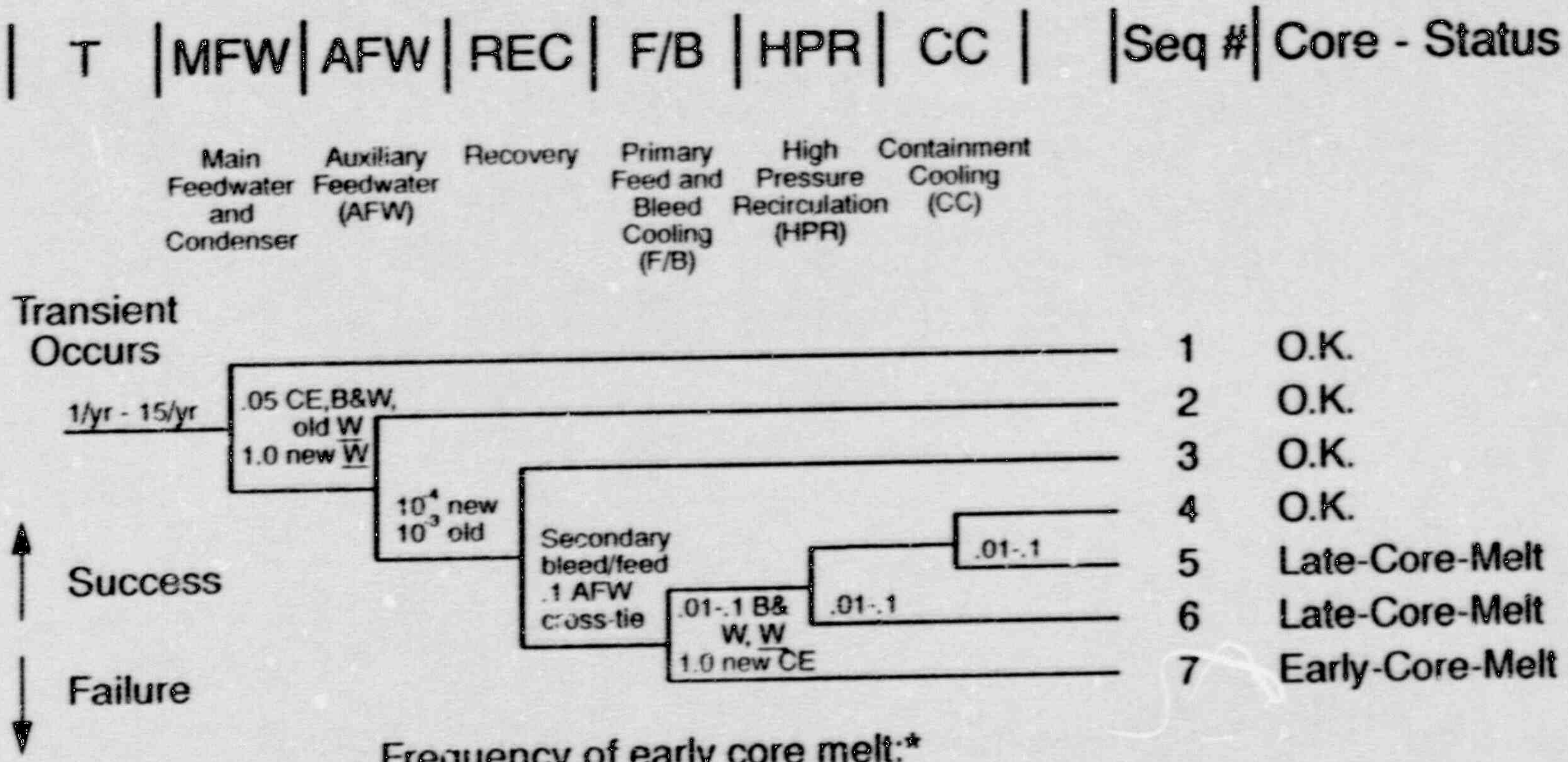
Items to be Considered in Feed and Bleed (F/B) Risk Evaluation (continued)

- Older CE reactors have marginal PORV/charging pump/HPI capacity to support F/B
  - Implication: More reliance on main feedwater, AFW, recovery actions (secondary bleed and feed). F/B must be augmented by other equipment in relatively short time frames.

- Newer CE reactors do not have PORVs
  - Implication: More reliance on main feedwater, AFW, recovery actions (secondary bleed and feed)

- When F/B path initiated, multiple operator actions, and systems required
  - Implication: F/B not as reliable as other DHR modes

M132-JHB-0890-006



Frequency of early core melt:*

Old W, B&W	: 3.75×10^{-6}	-	2.5×10^{-7}
Old CE	: 7.5×10^{-6}	-	5.0×10^{-7}
New W	: 7.5×10^{-6}	-	5.0×10^{-7}
New CE	: 7.5×10^{-6}	-	5.0×10^{-7}

* For illustrative purposes only

M132 JHB-0890-007

Feed and Bleed Reliability Insights

- Human factors issues dominate F/B failure probability
  - Timing
  - Training
  - Procedures
  - Instrumentation
- Equipment reliability typically of secondary importance
  - PORV capacity (1/2 vs 2/2)
  - Charging/HPI capacity (1/4 vs 2/4)

M132 JHB-0890-008

Feed and Bleed Results from Recent PRAs

Plant	CMF	%CMF Involving F/B	F/B Failure Probability	Relative Importance
Surry (NUREG-1150)	4.0×10^{-5}	1.1	7.1×10^{-2}	Not very important (AFW cross-ties)
Sequoyah (NUREG-1150)	5.72×10^{-5}	4.6	2.2×10^{-2}	More important (no AFW cross-ties)
Millstone-3	7.7×10^{-5}	18.4	7.0×10^{-2}	Very important (feedwater isolates post trip, no AFW cross-ties)
Oconee-3	2.5×10^{-4}	10.7	1.0×10^{-2}	Very important (shared AFW cross-ties)

Accident scenarios involving feed and bleed are in 10^{-5}/yr - 10^{-7}/yr range

M132 JHB-0890-09

Summary

- Feed and bleed cooling is an important backup mode of decay heat removal in PWRs
- Recent PRAs show feed and bleed failure probability to be in 10^{-2} - 10^{-1} range
  - Dominated by human factors issues
  - Equipment issues are secondary
- Degree of safety importance is related to:
  - Reactor type/vintage
  - AFW reliability/cross-tie capability

M132 JHB-069C-010

PWR Feed and Bleed Processes (Part 2)

Presented by
T. K. Larson

ACRS Meeting
Idaho Falls, ID
August 29, 1990

INEL

Purpose

- PWR F&B process description
  - Key factors
  - Phenomena of importance
  - F&B maps
- Summary/Conclusion

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Primary F&B Assumptions

- Complete loss of secondary heat sink
- Core at decay heat levels
- Pumped ECC systems available
- PORV operative
- Pressurizer heaters off
- Primary pumps off

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Kev Factors Influencing Effectiveness

- Core decay heat
- ECC injection capacity
- PORV
  - Energy removal capacity
  - Mass removal capacity

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F&B Operational Bounds

- Lower bound - energy balance
  - Core decay heat
  - PORV energy removal rate
- Upper bound - mass balance
  - Injection capacity
  - PORV mass removal rate
- Steady-state conditions
  - Cycle PORV to maintain pressure (bleed and feed)
  - Throttle injection to maintain mass balance (feed and bleed)

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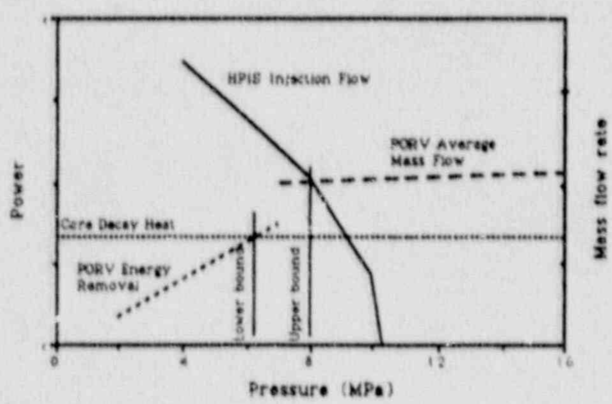
Feed and Bleed Map



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Factors Influencing F&B Bands

- PORV mass removal rate
- PORV energy removal rate
- Actual heat load
- Pumped injection rate

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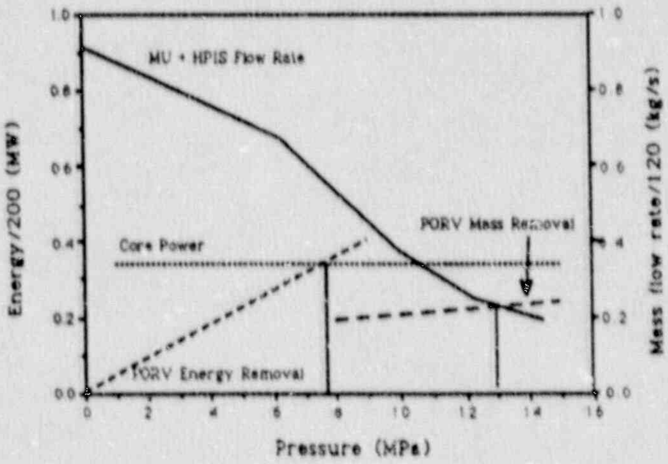
Zion F&B Map - 2% Decay Heat



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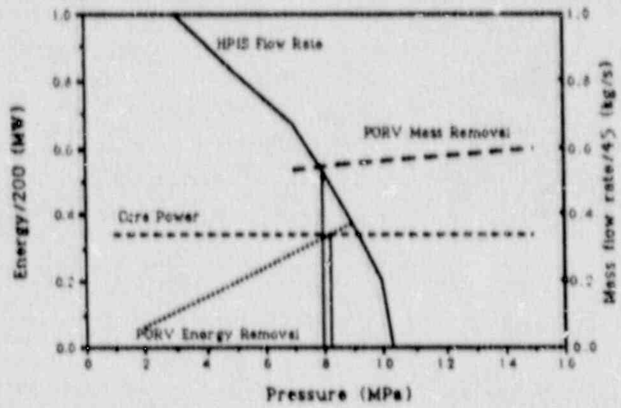
Zion F&B Map w/o Charging Flow 2% Decay Heat



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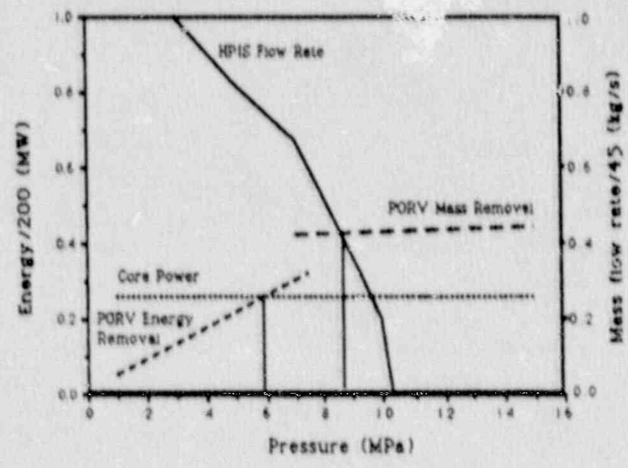
Zion F&B Map w/o Charging Flow 1.5% Decay Heat



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Factors Influencing PORV Flow

- **Upstream conditions**
  - **Pressurizer coolant**
  - **Primary Inventory**
- **Geometry**
  - **Valve characteristics and discharge piping**
  - **Surge line**
  - **Pressurizer vessel**
- **Surge line orientation**

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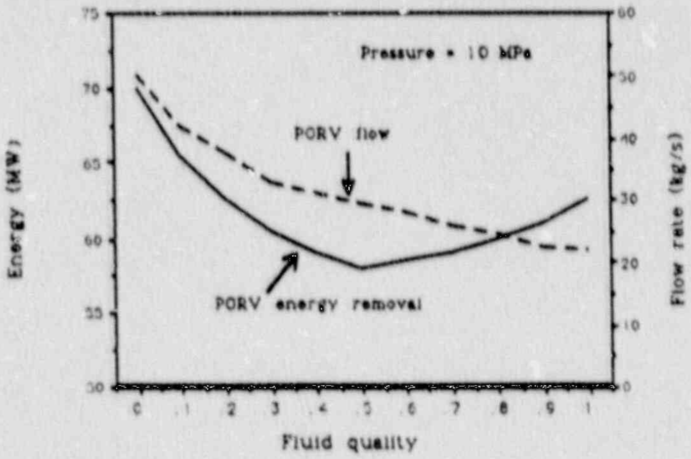
PORV Flow Versus Quality (10 MPa)



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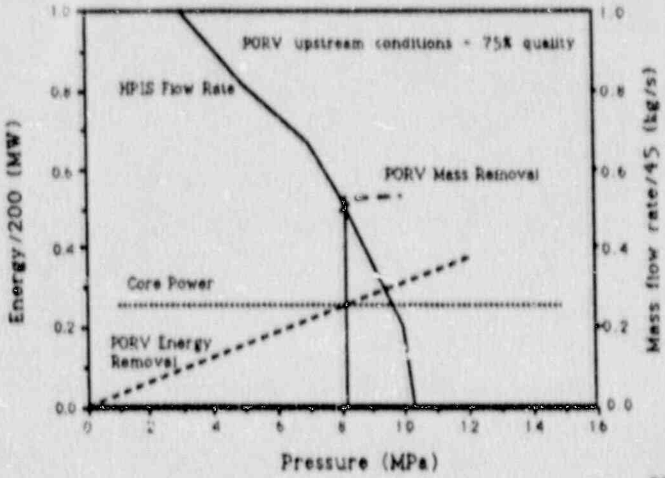
Zion F&B Map with PORV Quality 1.5% Decay Heat



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Plant-to-Plant Differences

	Oconee	CalvertCliffs-1	Zion	H.B.Robinson
Power(MW)	2584	2700	3250	2300
Sec. Inventory (kg)	34970	124588	173684	126792
No. PORVs	1	2	2	2
PORV ca.,-. (kg/s)	11.88	38.65	52.93	52.93
ECC flow (kg/s)	27.17	8.3	15.6	11.7

Note: ECC flow at PORV setpoint

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Summary/Conclusions

- Secondary and primary feed & bleed viable for decay heat removal
- Feed & bleed map useful for examining F&B feasibility
- F&B "window" depends on plant specifics
- Some combinations of key parameters result in elimination of F&B window
- Code analyses used to examine plant specifics

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LOS ALAMOS FEED-AND-BLEED STUDIES
SUMMARY RESULTS AND CONCLUSIONS

by

B. E. Boyack, R. J. Henninger, and J. F. Lime

Energy Division

Los Alamos National Laboratory

presented at

ACRS Joint Subcommittee Meeting
August 29, 1990
Idaho Falls, Idaho

OBJECTIVES

1. EVALUATE SUCCESS OR FAILURE OF FEED AND BLEED (F&B) IN SPECIFIC REACTORS BY DETAILED CALCULATION
2. IDENTIFY PLANT-SPECIFIC AND GENERIC INSIGHTS
3. USE INSIGHTS TO PREDICT FEASIBILITY OF F&B FOR PWRs FOR WHICH DETAILED ANALYSES NOT PERFORMED

SCOPE

1. DETAILED CALCULATIONS PERFORMED FOR COMBUSTION ENGINEERING (C-E), BABCOCK & WILCOX (B&W), AND WESTINGHOUSE (W) PLANTS
2. EXTENSION STATEMENTS MADE FOR AN ADDITIONAL 7 C-E PLANTS, 7 B&W PLANTS, AND 26 W PLANTS

DEFINITIONS

1. FEED AND BLEED – AN EMERGENCY CORE-COOLING PROCEDURE EFFECTED BY MANUALLY ACTIVATING THE HPI SYSTEM AND OPENING THE PORVs TO RELEASE CORE DECAY ENERGY

2. SUCCESS CRITERION 1 – THE FAB PROCEDURE IS SUCCESSFUL IN TRANSITIONING THE PLANT FROM REACTOR TRIP TO A HOT, PRESSURIZED HOLDING CONDITION IF:

   A. PRIMARY SYSTEM AND VESSEL MASS INVENTORIES ARE STABLE OR INCREASING,
   B. THE TOP OF THE CORE REMAINED COVERED THROUGHOUT THE TRANSIENT.

3. SUCCESS CRITERION 2 – FROM REACTOR TRIP TO HOT SHUTDOWN IF THE CONDITIONS OF 2. SATISFIED AND PRIMARY PRESSURE AND TEMPERATURE ARE REDUCED TO LPIS ENTRY CONDITIONS.

APPROACH

1. USE AUDITED MODELS OF SPECIFIC PLANTS

0 CALVERT CLIFFS-1	(C-E)	2 X 4 LOOPS
0 OCONEE-1	(B&W)	2 X 4 LOOPS
0 ZION-1	(W)	FOUR LOOPS
0 H. B. ROBINSON	(W)	THREE LOOPS

2. SIMULATE PLANT RESPONSE USING TRAC

3. REVIEW RESULTS FOR INSIGHTS

4. EXTENSION TO PLANTS FOR WHICH DETAILED CALCULATIONS NOT PERFORMED

5. REVIEW OF RESULTS BY NRC AND ITS SUB-CONTRACTORS

STUDY ASSUMPTIONS

1. PLANT EQUIPMENT USED TO FAB IS AVAILABLE AND OPERABLE THROUGHOUT THE TRANSIENT

2. BOTH NOMINAL AND DEGRADED EQUIPMENT STUDIES

3. NOMINAL EQUIPMENT STUDIES

   0 CALVERT CLIFFS-1 (2/2 PORVs, 3/3 CHARGING PUMPS (CPs), 2/3 HPI PUMPS)
   0 OCONEE-1 (1 PORV, 2/3 HPI PUMPS)
   0 ZION-1 (2/2 PORVs, 2/2 CPs, 2/2 SI PUMPS)

4. DEGRADED EQUIPMENT STUDIES

   0 CALVERT (1/2 PORVs, 1/3 HPI PUMPS)
   0 OCONEE-1 (1/3 HPI PUMPS)
   0 ZION-1 (1/2 PORVs, 1/2 SI PUMPS)
   0 H. B. ROBINSON (2/2 PORVs, 0/3 CPs, 2/3 SI PUMPS)

COMPARISON OF KEY PLANT CHARACTERISTICS

	CALVERT	OCONEE	ZION	ROBINSON
STEADY-STATE POWER (MWt)	2700	2584	3250	2300
TOTAL SG SEC INVENTORY (lb/MWt)	101.7	29.8	117.8	121.5
TOTAL PORV CAPACITY (lb/hr/MWt)	115.2	36.0	129.6	163.6
TOTAL ECC FLOW AT PORV SETPOINT (lb/hr/MWt)	24.1	82.8	39.6	39.6

SUMMARY RESULTS

1. FEED AND BLEED IS A POTENTIALLY USEFUL ALTERNATIVE METHOD OF DECAY HEAT REMOVAL

2. AVAILABILITY OF HIGH-PRESSURE SI DELIVERY CAPACITY GREATLY ENHANCES EFFECTIVENESS OF THE PROCEDURE

   A. PLANTS WITH LP OR IP SI SYSTEMS MUST INITIATE FEED AND BLEED NO LATER THAN LOSS OF SECONDARY HEAT SINK

   B. PLANTS WITH HP SI SYSTEMS CAN INITIATE FEED AND BLEED AS LATE AS THE TIME OF PRIMARY SYSTEM SATURATION

3. PORV CAPACITY BECOMES IMPORTANT DURING THE TRANSITION FROM REACTOR TRIP TO HOT SHUTDOWN IF ONLY SAFETY-GRADE WATER SUPPLIES ARE CONSIDERED

4. SIMPLE INSPECTION IS A USEFUL TECHNIQUE FOR EXTENDING DETAILED CALCULATIONS TO A BROADER SET OF PLANTS

EXAMPLES OF DETAILED RESULTS

1. CALVERT CLIFFS – FEED AND BLEED AT LOSHS (1250 s)

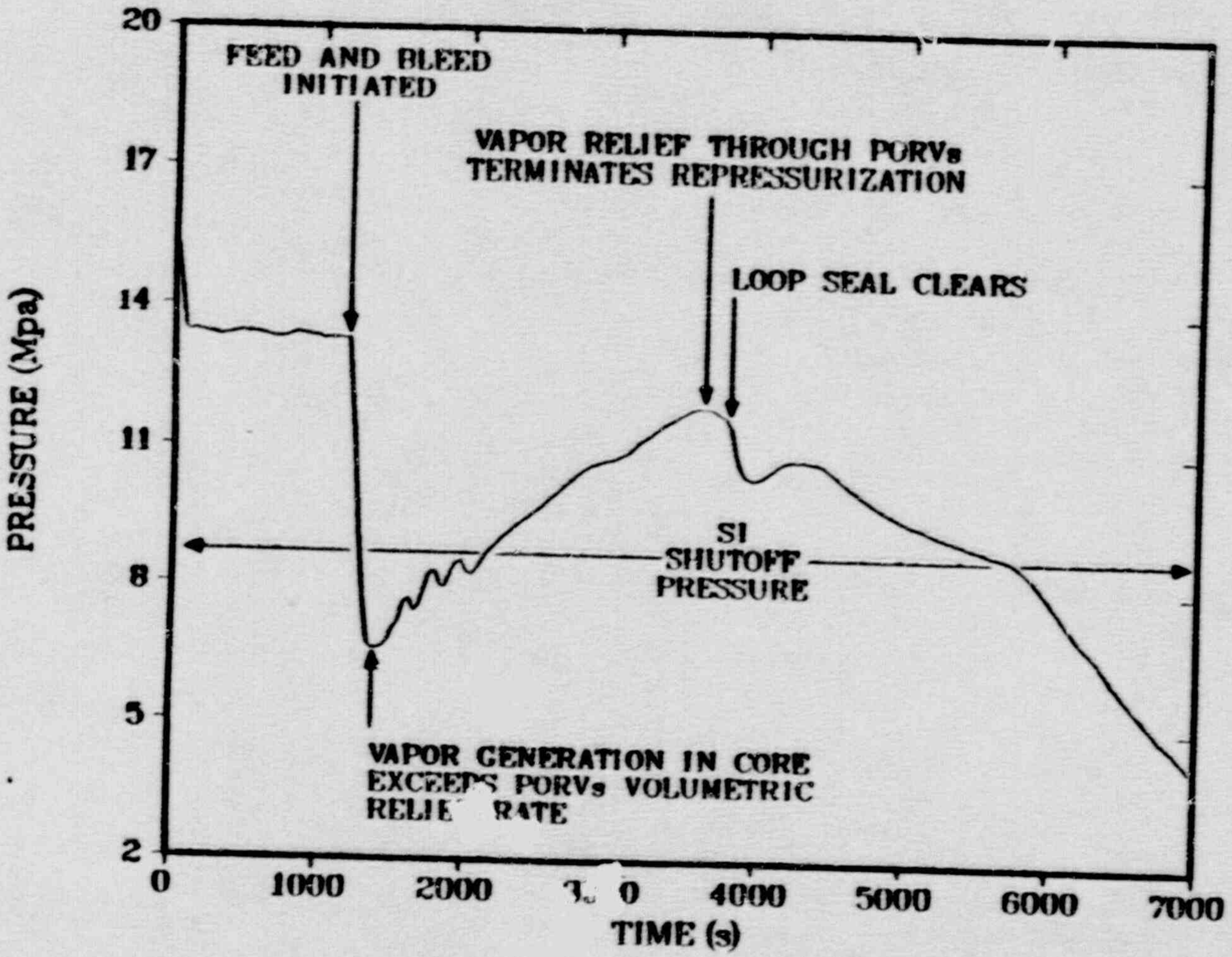
   A. PRIMARY PRESSURE
   B. VESSEL LIQUID MASS INVENTORY

   SUCCESS

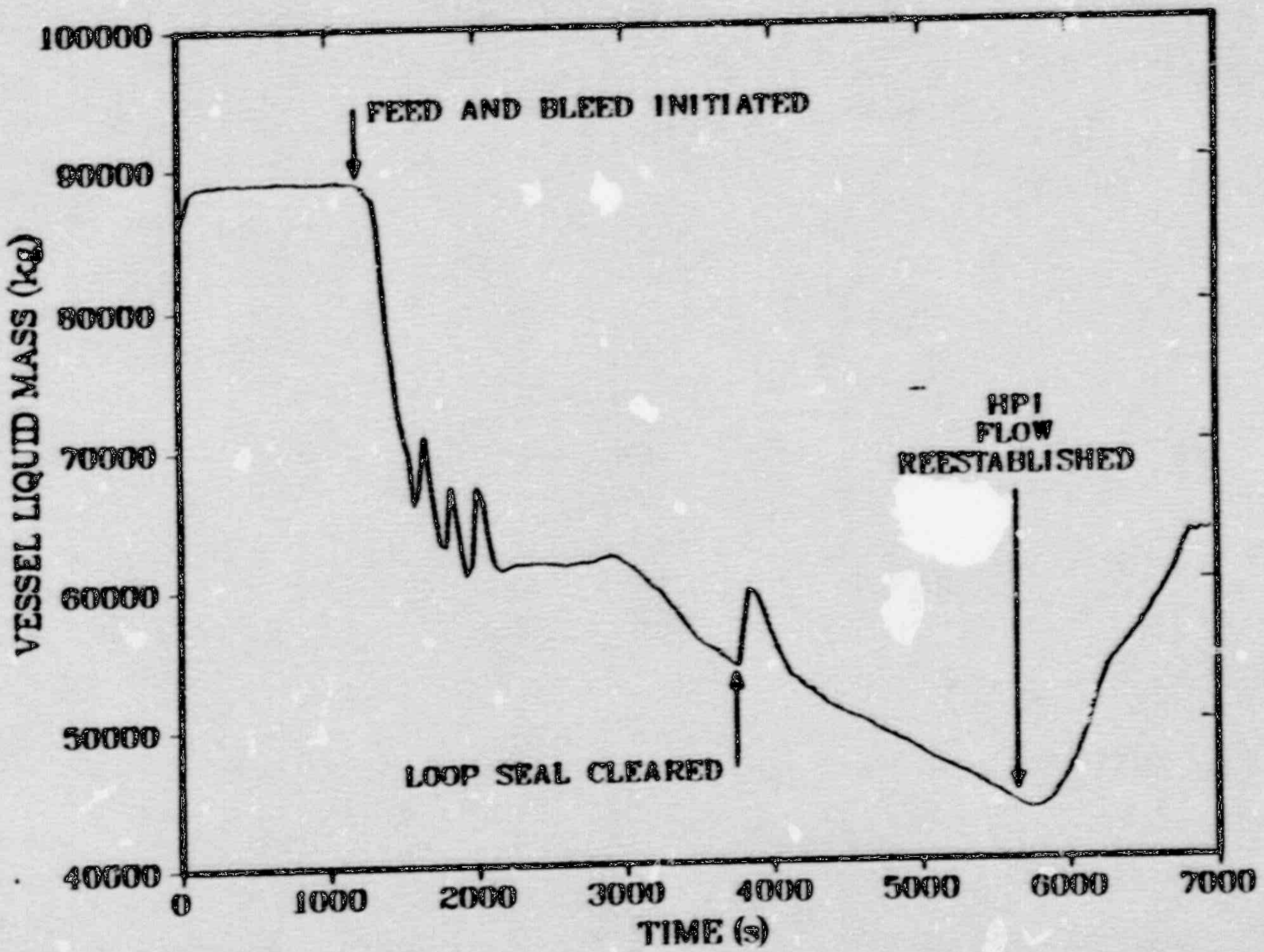
2. CALVERT CLIFFS – FEED AND BLEED AND PRIMARY SYSTEM SATURATION (2900 s)

   A. PRIMARY PRESSURE
   B. VESSEL LIQUID MASS INVENTORY
   C. CLADDING TEMPERATURE

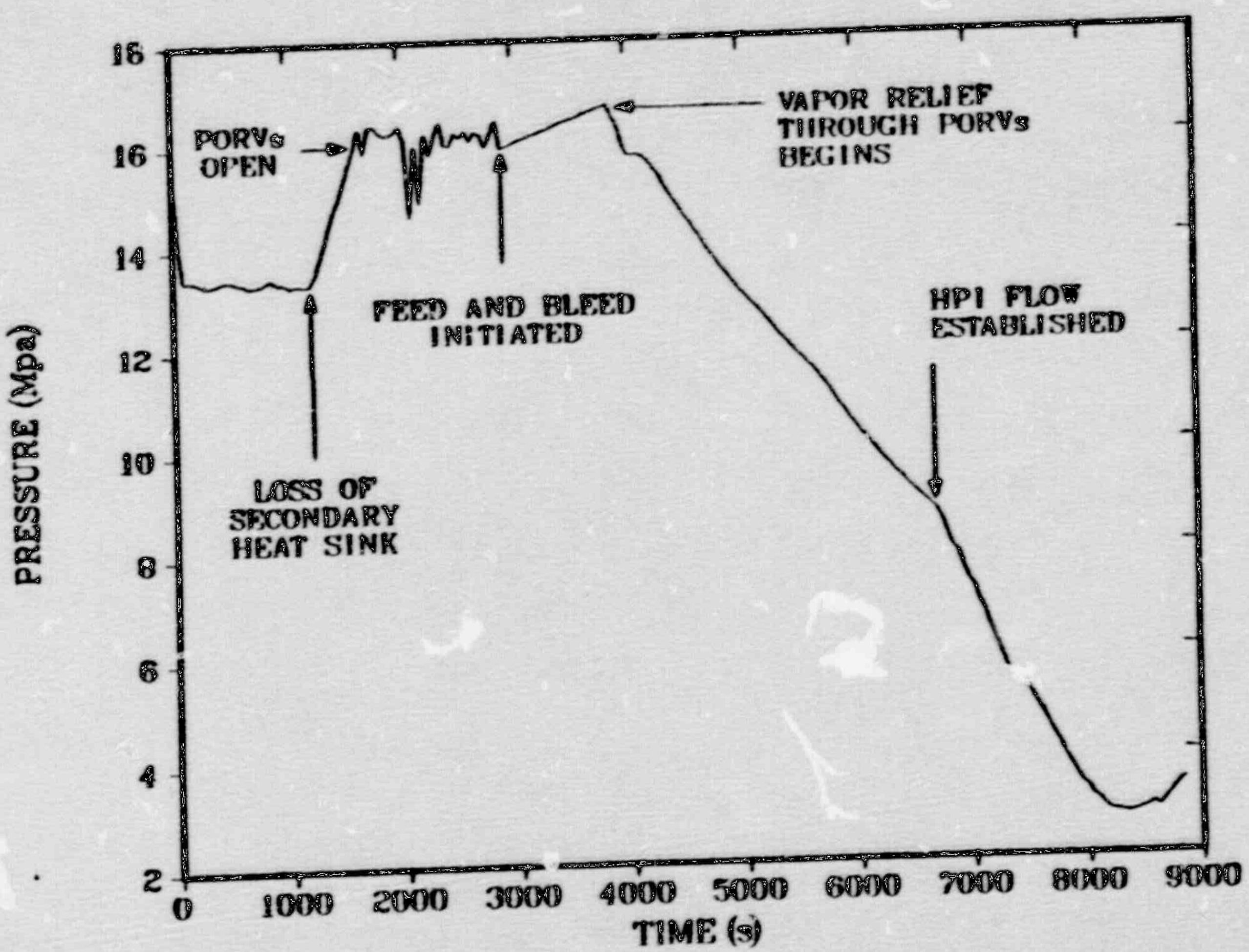
   FAILURE



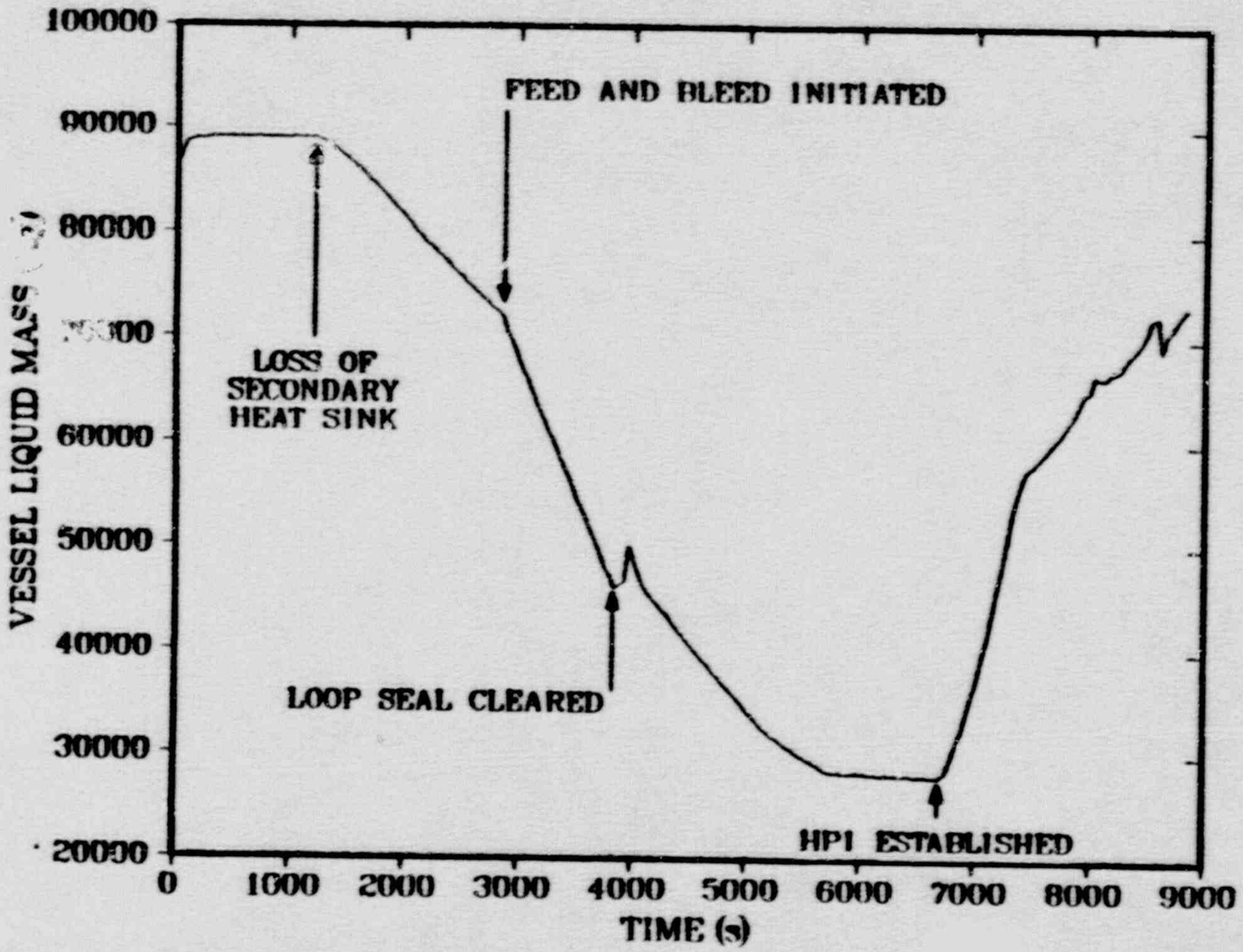
BOYACK, HENNINGER, LIME FIG. 1



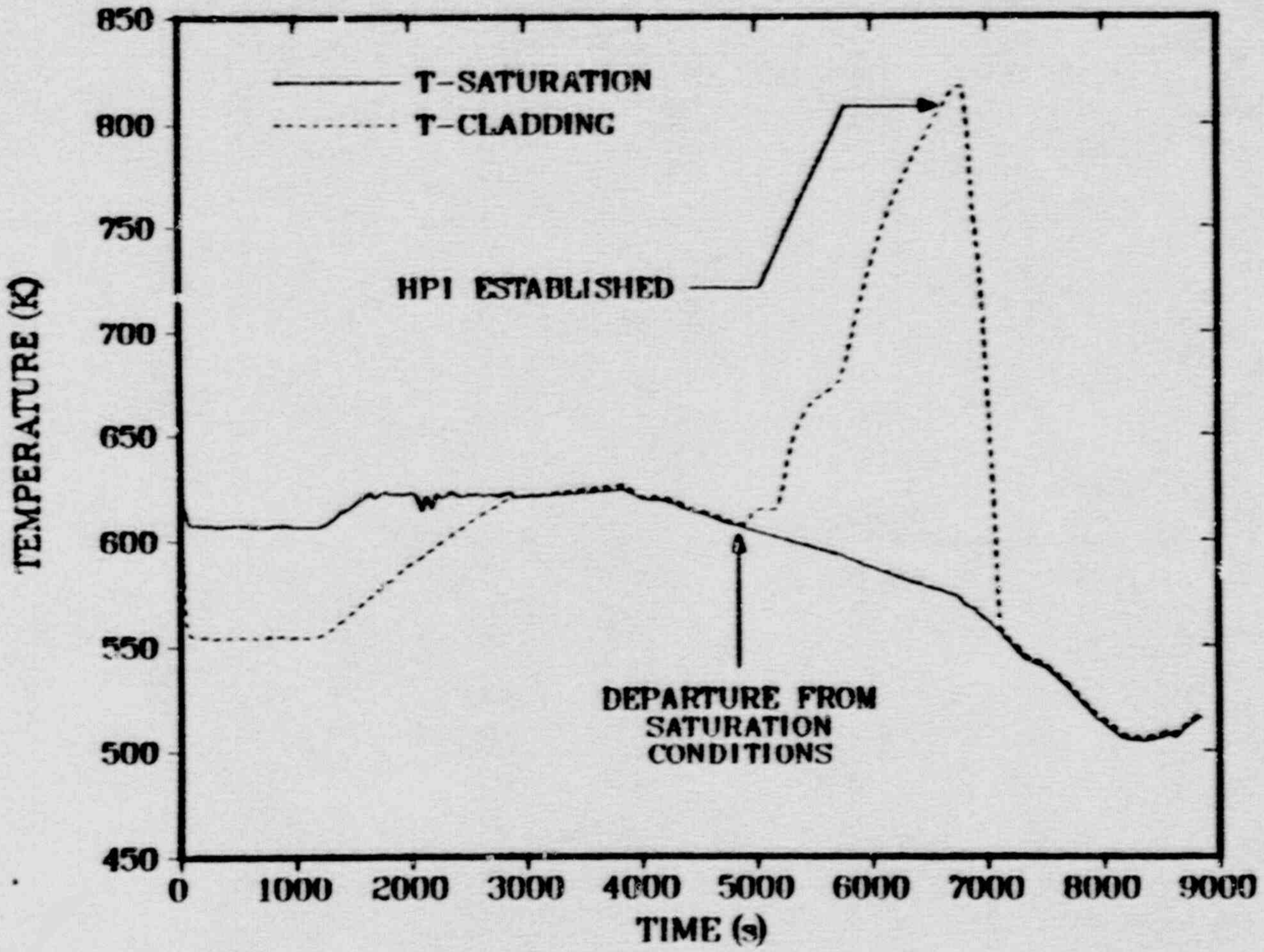
BOYACK, HENNINGER, LIME FIG.2



BOYACK, HENNINGER, LIME FIG. 4



BOYACK, HENNINGER, LIME FIG. 5



BOYACK, HENNINGER, LIME FIG.6

APPROACHES TO EXTENSION STATEMENTS

1. SIMPLE INSPECTION – PREDICT SUCCESS/FAILURE OF FAB BASED ON SIMILARITY TO CALVERT CLIFFS, OCONEE, ZION, AND H. B. ROBINSON

2. ENHANCED INSPECTION – SAME AS 1 BUT ENHANCE UNDERSTANDING BY CONSTRUCTING PLANT-SPECIFIC FAB OPERATING MAPS

3. SIMPLIFIED PLANT SPECIFIC MODELS – DEVELOP EITHER LUMPED PARAMETER MODELS OR COARSE-NODED TRACT MODELS. TEST AGAINST DETAILED MODELS AND APPLY AS APPROPRIATE.

4. DETAILED MODELS FOR EACH SPECIFIC PLANT (NOT EXTENSION).

SIMPLE INSPECTION EXAMPLE (C-E)

	ANO-2	CALVERT CLIFFS-1,-2	FT. CALHOUN	ST. LUCIE-1	MAINE YANKEE
PORV CAPACITY (LB/HR/MWt)	VENT VALVE	56.7	69.7	59.8	57.0
HPI 0 SHUTOFF HEAD (PSI)	1317	1257	1307	1257	2471
0 GPM/MWt at 1000 PSIG	0.18	0.16	0.19	0.17	0.27
0 GPM/MWt at 1600 PSIG	0	0	0	0	0.21
CHARGING CAPACITY (GPM/MWt)	0.05	0.05	0.08	0.05	0.17

FEED AND BLEED RESULTS
CALCULATION AND SIMPLE INSPECTION

VENDOR	PLANT TYPE	CALCULATION	EXTENSION	LOSHS	SAT
C-E	2X4 LOOP LP SI	CALVERT-1	CALVERT-2	Y	N
			FT. CALHOUN-1	Y	N
			MAINE YANKEE	Y	Y
			MILLSTONE-2	Y	N
			PALISADES	Y	N
			ST. LUCIE-1	Y	N
			ANO-2	NC	NC
B&W	2X4 LOOP HP SI	OCONEE-1	OCONEE-2,-3	Y	Y
			ANO-1	Y	Y
			CRYSTAL R-2	Y	Y
			TMI-1,-2	Y	Y
			RANCHO SECO	Y	Y

FEED AND BLEED RESULTS
CALCULATION AND SIMPLE INSPECTION

VENDOR	PLANT TYPE	CALCULATION	EXTENSION	LOSHS	SAT
W	4-LOOP HP SI	ZION-1	ZION-1	Y	Y
			DC COOK-1,-2	Y	Y
			TROJAN	Y	Y
			SALEM-1	Y	Y
			HADDAM NECK	Y	Y
	4-LOOP IP SI		SOUTH TEX-1,-2	Y	NC
	4-LOOP LP SI		INDIAN PT-1,-2	Y	NC
	3-LOOP HP SI		SUMMER	Y	Y
			S. HARRIS-1,-2	Y	Y
			FARLEY-1,-2	Y	Y
			BEAVER VLY-1,-2	Y	Y
			NORTH ANNA-1,-2	Y	Y
			SURRY-1,-2	Y	Y
	3-LOOP LP SI	ROBINSON-2	TURKEY PT-1,-2	Y	NC
	2-LOOP IP SI		PRAIRIE IS-1,-2	Y	NC
			KEWAUNEE	Y	NC
	2-LOOP LP SI		GINNA	NC	NC
			PT BEACH-1,-2	NC	NC

FEED & BLEED STUDIES

PWR PLANT CALCULATIONS

PRESENTED BY:
RICHARD R. SCHULTZ

ACRS SUBCOMMITTEE MEETING
AUGUST 28-29, 1990
IDAHO FALLS, IDAHO

Idaho National Engineering Laboratory

EG&G Idaho, Inc.

EC000936

KEY PARAMETERS CAN STRONGLY AFFECT THE OUTCOME OF A FEED & BLEED SEQUENCE FOR A PLANT TYPE

- SYSTEM STATE AT START OF FEED & BLEED; IN PARTICULAR THE REACTOR COOLANT SYSTEM TEMPERATURE.
- CORE POWER, I.E., HOW LONG AFTER SCRAM DOES FEED & BLEED SEQUENCE BEGIN? ALSO, EXTERNAL ENERGY LOSSES.
- MAKEUP AND HIGH PRESSURE INJECTION FLOW RATES.
- FLOW RATES THROUGH THE PORV. IN PARTICULAR, IS FLOW SINGLE OR TWO-PHASE?

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REACTOR COOLANT SYSTEM (RCS) TEMPERATURE IS A KEY PARAMETER

- RCS TEMPERATURE IMPORTANT BECAUSE:
  1. REPRESENTATIVE OF SYSTEM STATE, I.E., INITIAL ENERGY LEVEL.
  2. OPERATOR GUIDELINES FOR FEED & BLEED PROCEDURES OFTEN USE RCS TEMPERATURE.

FEED & BLEED STUDIES
PWR PLANT CALCULATIONS

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PRESENTATION COVERS KEY PARAMETERS, UNCERTAINTIES, AND INEL FEED & BLEED ANALYSES

- KEY PARAMETERS THAT AFFECT FEED & BLEED SEQUENCES.
- ANALYSIS LIMITATIONS AND UNCERTAINTIES INCLUDING MODELING PRACTICES FOR PLANT CALCULATIONS.
- SUMMARY OF INEL FEED & BLEED ANALYSES.
  1. SHORT PLANT DESCRIPTIONS INCLUDING SPECIAL PLANT FEATURES OF NOTE FOR FEED & BLEED SCENARIOS.
  2. ANALYSIS RESULTS.
  3. DISCUSSION OF FEED & BLEED OPERATIONAL ENVELOPE.
  4. DISCUSSION OF CANDIDATE PROCEDURE/EQUIPMENT IMPROVEMENTS.
- CONCLUSIONS.

CORE POWER, PORV FLOW AND ECCS FLOW DEFINE SYSTEM ENERGY GAINS AND LOSSES DURING TRANSIENT

- o <u>CORE POWER</u> - THE CORE POWER LEVEL, DETERMINED BY WHEN SCRAM OCCURRED PRIOR TO BEGINNING OF FEED & BLEED, GIVES SYSTEM ENERGY ADDITION.
- o <u>PORV AND ECCS FLOW</u> - RESULT IN NET SYSTEM ENERGY REDUCTION AS HIGHER ENERGY FLUID IS REPLACED WITH LOWER ENERGY FLUID.
- o <u>ENVIRONMENTAL LOSSES</u> - SOME POWER IS LOST TO THE ENVIRONMENT THROUGH THE SYSTEM INSULATION.

LIMITATIONS AND UNCERTAINTIES OF ANALYTICAL METHODS ARE STRONGLY LINKED TO KEY PARAMETERS AND CALCULATIONAL TOOLS

- INITIAL AND BOUNDARY CONDITIONS - UNCERTAINTIES ARE SIGNIFICANTLY GREATER IN PLANTS THAN IN EXPERIMENTAL FACILITIES.

- CODE - THERMAL-HYDRAULIC PHENOMENA CHARACTERISTIC OF FEED & BLEED TRANSIENTS ARE RELATIVELY MILD AND WELL WITHIN THE CAPABILITY OF ADVANCED THERMAL-HYDRAULIC CODES.

- INPUT MODEL - TWO FACTORS ARE OF CONCERN:
  1. NODALIZATION FIDELITY - THE NODALIZATION MUST ACCURATELY REPRESENT THE FACILITY GEOMETRY. WHETHER MODEL NODALIZATION REPRESENTS FACILITY CAN BE ASSURED WITH QUALITY-CHECK.
  2. NODALIZATION ADEQUACY - POSSIBLE CANDIDATES ARE HEAT STRUCTURE NODALIZATION AND FLOW VOLUME NODALIZATION IN REGIONS SENSITIVE TO VOID FRACTION (SURGE LINE INLET).

UNCERTAINTIES IN KEY PARAMETERS ARE CAUSED BY UNKNOWNS CONCERNING PLANT STATE AT TIME OF TRANSIENT

- o CORE POWER - LARGEST UNCERTAINTY ASSOCIATED WITH POST-TRIP FISSION POWER.
- o FEEDWATER AVAILABILITY AND STATE OF STEAM GENERATOR - WHETHER FEEDWATER WILL BE AVAILABLE AND THE DEGREE OF STEAM GENERATOR TUBE FOULING INFLUENCE THE QUANTITY OF SECONDARY INVENTORY AVAILABLE FOR BOILOFF.
- o PORV MASS FLOW CONDITIONS - WILL THE FLOW BE SINGLE OR TWO-PHASE?

UNCERTAINTIES ASSOCIATED WITH MODEL NODALIZATION ARE EVALUATED BY PERFORMING SENSITIVITY STUDIES CENTERED ON REGIONS OF CONCERN

o TYPICAL MODEL REGIONS THAT MAY REQUIRE STUDY DURING A FEED & BLEED ANALYSIS ARE:

1. STEAM GENERATOR SECONDARY INVENTORY LEVEL - DETERMINES IN PART WHEN PRIMARY FEED & BLEED MUST BEGIN.

2. PRESSURE VESSEL UPPER HEAD AND UPPER PLENUM MODELING - OF CONCERN FOR TRANSIENTS THAT DRAIN THESE VESSEL REGIONS. IS THE VESSEL INVENTORY IN THE VESSEL UPPER PLENUM AND UPPER HEAD OR THE REMAINDER OF VESSEL?

3. HEAT STRUCTURES - THE RCS HEATUP RATE IS AFFECTED BY THE HEAT STRUCTURES.

UNCERTAINTIES ASSOCIATED WITH MODEL NODALIZATION ARE EVALUATED BY PERFORMING SENSITIVITY STUDIES CENTERED ON REGIONS OF CONCERN

4. <u>HOT LEG NODALIZATION</u> - MODELING THE CONNECTION OF THE PRESSURIZER SURGE LINE TO THE HOT LEG IS OF CONCERN. WHEN SURGE LINE INLET UNCOVERS DETERMINES WHEN THE PRESSURIZER LIQUID LEVEL SWELLS AND PORV TWO-PHASE FLOW BEGINS.

5. <u>REACTOR COOLANT PUMP (RCP) GEOMETRY AND LOOP SEAL LIQUID LEVELS</u> - THE INFLUENCE OF THE RCP GEOMETRY AND THE LOOP SEAL BEHAVIOR AFFECTS THE MINIMUM AVAILABLE INVENTORY.

INEL HAS PERFORMED RELAP5 FEED & BLEED ANALYSES ON H. B. ROBINSON-1, OCONEE-1, DAVIS-BESSE-1, AND CALVERT CLIFFS-1

Vendor	Plant Type	Calculation	Extension	SGSD	Saturation
CE	2 x 4 loop LP SI	Calvert Cliffs-1	Calvert Cliffs-2	Y	N
			Fort Calhoun-1	Y	N
			Maine Yankee	Y	Y
			Millstone-2	Y	N
			Palisades	Y	N
			St. Lucie-1	Y	N
			Arkansas Nuclear One-2	NC	NC
B&W	2 x 4 loop HP SI	Oconee-1	Oconee-2, -3	Y	Y
			Ark. Nuclear One-1	Y	Y
			Crystal River-3	Y	Y
			Three Mile Island-1, -2	Y	Y
			Rancho Seco-1	Y	Y
W	4-loop HP SI	Zion-1	Zion-2	Y	Y
			DC Cook-1, -2	Y	Y
			Trojan	Y	Y
			Salem-1, -2	Y	Y
			Haddam Neck	Y	Y
	4-loop IP SI		South Texas Project-1, -2	Y	NC
	4-loop LP SI		Indian Point-2, -3	Y	NC
	3-loop HP SI		Summer	Y	Y
			Shearon Harris-1, -2	Y	Y
			Farley-1, -2	Y	Y
			Beaver Valley-1, -2	Y	Y
			North Anna-1, -2	Y	Y
			Surry-1, -2	Y	Y
	3-loop LP SI	Robinson-2	Turkey Point-3, -4	Y	NC
	2-loop IP SI		Prairie Island-1, -2	Y	NC
			Kewaunee	Y	NC
	2-loop LP SI		Ginna	NC	NC
			Point Beach-1, -2	NC	NC

Y = Yes
N = No
NC = No conclusion
SGSD = Steam generator secondary dryout

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6″

UNCERTAINTY ESTIMATES (BASED ON ENGINEERING JUDGEMENT) OF KEY PARAMETERS AFFECTING FEED & BLEED CALCULATIONS

Parameter	Uncertainty (%)
Core power	
Initial power	2
Post-trip fission power	35
Decay heat	5
PORV flow	20
Makeup flow	10
Initial OTSG liquid mass	14
Post-trip feedwater flow	100
Initial stored energy in fuel	10
RCP power	10
RCS heat structures	10

NOMINAL KEY PARAMETERS FOR TYPICAL PLANTS
FEED & BLEED ANALYSES

	Oconee-1	Calvert Cliffs-1	Zion-1	H. B. Robinson-2
Steady state power (MWt)	2584	2700	3250	2300
Total SG secondary inventory (kg)	34969	124588	173684	126792
Number of PORVs	1	2	2	2
Total rated PORV capacity (kg/s)	11.88	38.65	52.93	52.93
Total ECC flow (kg/s) at PORV set point	27.17	8.30	15.60	11.70

PWR PLANT MODELS DEVELOPED USTNG STANDARD PRACTICES

- B&W PLANT DECKS DEVELOPED AND USED TO ANALYZE FEED & BLEED PRIOR TO OTIS CALCULATIONS.
- PWR PLANT MODELS DEVELOPED IN LARGE MEASURE TO ANALYZE PRESSURIZED THERMAL SHOCK PROBLEM.
- SINCE FEED & BLEED TRANSIENTS ARE MILD, COARSE NODALIZATION GENERALLY USED.

INEL FEED & BLEED ANALYSES PERFORMED TO STUDY DAVIS-BESSE 1 AND ALSO DETERMINE PORTION OF OPERATOR ACTION ENVELOPE FOR OCONEE 1

- OCONEE 1 SENSITIVITY STUDY - PERFORMED TO DETERMINE THE LATEST TIME THAT SUCCESSFUL FEED & BLEED OPERATION COULD BE INITIATED. STUDY PERFORMED WITH SIMILAR STUDIES ON H. B. ROBINSON-2 AND CALVERT CLIFFS-1 PLANTS TO PROVIDE COMPARISONS OF BEHAVIOR CHARACTERISTICS OF PLANTS BUILT BY OTHER VENDORS.
- DAVIS-BESSE 1 FEED & BLEED ANALYSIS PERFORMED TO DETERMINE PLANT BEHAVIOR IF FEED & BLEED ACTIONS HAD BEEN UNDERTAKEN DURING JUNE, 1985 LOFW INCIDENT.

BENCHMARK CALCULATIONS PERFORMED TO DETERMINE TIME TO CORE HEATUP ASSUMING NO FEED & BLEED PROCEDURES UNDERTAKEN

- Assumed LOFW and no HPI available.
- Calculated time to core heatup:

Plant	Time to Heatup (min)
Calvert Cliffs-1	101
H. B. Robinson-2	126
Oconee-1	57

CALCULATIONS THEN PERFORMED TO DETERMINE LATEST TIME PRIMARY FEED & BLEED CAN BE INITIATED TO PREVENT CORE HEATUP

- Latest time feed & bleed can be initiated to prevent core heatup:

Plant	Latest Time (min)
Calvert Cliffs-1	31
H. B. Robinson-2	104
Oconee-1	49

- Primary feed & bleed shown to be an effective means of removing decay heat for the above plants.

DAVIS-BESSE 1 FEED & BLEED CALCULATIONS INDICATE THAT FEED & BLEED PROCEDURES CAN BE USED TO SUCCESSFULLY COOL CORE

- IF FEED & BLEED PROCEDURES INITIATED WITHIN 20 MINUTES OF LOFW AND FULL MAKEUP FLOW IS AVAILABLE, THEN THE PRIMARY SYSTEM WILL BE DEPRESSURIZED AND THE CORE WILL REMAIN COVERED.

IS PRIMARY FEED & BLEED A VIABLE METHOD FOR REMOVING CORE DECAY HEAT?

- YES; BUT THE EQUIPMENT CHARACTERISTICS OF US PWRS DIFFER CONSIDERABLY FROM PLANT TO PLANT. THUS, THE WINDOW IN WHICH PRIMARY FEED & BLEED PROCEDURES ARE FEASIBLE IS DIFFERENT FROM PLANT TO PLANT.
- THE PRESENCE OF HIGH-HEAD ECCS GREATLY INCREASES THE RANGE OF CONDITIONS FOR WHICH FEED & BLEED PROCEDURES WILL BE SUCCESSFUL.
- LARGER PORV CAPACITIES ALSO INCREASES THE RANGE OF CONDITIONS FOR SUCCESSFUL FEED & BLEED PROCEDURES.

FEED & BLEED OPERATIONAL CONSIDERATIONS INFLUENCE THE CERTAINTY OF SUCCESSFUL RECOVERY

- o INSTRUMENTATION CAPABILITIES - IMPORTANT BECAUSE OPERATOR RELIES ON SUCH DATA TO IDENTIFY NEED AND MONITOR PROGRESS OF OPERATION.
- o IN GENERAL INSTRUMENTATION HAS BEEN FOUND TO BE ADEQUATE TO IDENTIFY NEED FOR FEED & BLEED.
- o FOLLOWING THE USNRC REQUIREMENT FOR PLANTS TO INSTALL PRIMARY VESSEL LIQUID LEVEL MEASUREMENTS, INSTRUMENTATION SHOULD BE SUFFICIENT TO MONITOR PROGRESS OF OPERATION. HOWEVER, PLANT-SPECIFIC EVALUATIONS ARE NEEDED TO CONFIRM.
- o EQUIPMENT SURVIVABILITY DURING SUCH A TRANSIENT SHOULD BE EXAMINED ON A PLANT-SPECIFIC BASIS.

FEED & BLEED PROCEDURES

- o CLEAR DEFINITION OF WHEN PRIMARY FEED & BLEED RECOVERY SHOULD BE INITIATED.
- o SYSTEM CONDITIONS AT WHICH FEED & BLEED OPERATIONS SHOULD BEGIN REGARDLESS MUST BE CLEARLY DEFINED.
- o FOR PLANTS WHERE IMPORTANT SYSTEM INFORMATION IS LIMITED OR MISSING, PROCEDURES MUST BE DEVELOPED TO REDUCE THE LIKELIHOOD OF UNSUCCESSFUL FEED & BLEED OPERATIONS.
- o ALTERNATIVE COURSES OF ACTION SHOULD BE DEVELOPED TO ACCOUNT FOR UNAVAILABLE FIRST-LINE EQUIPMENT.

CONCLUSIONS

- o FEED & BLEED PROCEDURES CAN BE A USEFUL ALTERNATIVE METHOD OF DECAY HEAT REMOVAL IN MANY PWR PLANTS.
- o THE INFLUENCE OF OPERATIONAL FACTORS ON THE SUCCESS OF FEED & BLEED PROCEDURES MUST BE CONSIDERED FOR OPERATIONAL PLANTS.

Plant Instrumentation Used for Feed-and-Bleed

V. T. Berta

ACRS Meeting
Idaho Falls, Idaho

August 28-29, 1990

Outline

+ Instrument categories
+ Principal use of instrument categories
+ Operator experience with instrument behavior
+ Instruments used in F&B operations
+ Summary

Instrumentation Categories

1. PCS instruments used in both primary and secondary feed and bleed operations.

2. Instruments used in secondary feed and bleed operations.

3. Instruments used in primary feed and bleed operations.

Principal Use of Instrument Categories

Instrument Category	Principal Use
PCS instruments used in primary and secondary F&B	PCS pressure, temperature, and mass inventory tracking
SCS instruments used in secondary F&B	Secondary F&B operational verification
PCS instruments used in primary F&B	Primary F&B operational verification.

Operator Experience with Instrument Behavior

Instrument Category	Experience Source
PCS instruments used in primary and secondary F&B (category 1)	Reactor normal operation, startup, and shutdown. Reactor simulator training.
SCS instruments used in secondary F&B (category 2)	Reactor normal operation, startup, and shutdown. Reactor simulator training.

Operator Experience with Instrument Behavior

Instrument Category	Experience Source
PCS instruments used in primary F&B (category 3)	PCS pressure and CCP associated instruments: reactor normal operations.
	PORV and downstream system instruments, and HPI associated instruments: (a) inactive status (normal system operation) indication, (b) reactor simulator training for operational status indication and parameter magnitudes.

Plant Instruments for Feed and Bleed Operations

PCS instruments used in both primary and secondary F&B	Safety Grade
+ Core exit T/Cs and RTDs	yes
+ Reactor vessel level (RVLIS)	yes
+ Subcooling meter	yes
+ RCP run indication	no
+ Safety Injection (SI) indication	yes
+ Refueling Water Storage Tank (RWST) level	yes
+ Makeup/Letdown indication	no
+ Pressurizer heater indication	no

Plant Instruments for Feed and Bleed Operations

Instruments used in secondary system F&B	Safety Grade
+ TBV/ADV position indication	no
+ Condenser pressure/availability	no
+ MSIV indication	yes
+ SG pressure, temperature, and level (wr & nr)	yes (pressure, level)
+ Main feed lineup indication	no
+ Aux feed lineup indication	yes
+ MFP run & speed indication	no

Plant Instruments for Feed and Bleed Operations

Instruments used in secondary F&B (contd)	Safety grade
+ AFP run & speed indication	yes
+ Condenser/reservoir feed level	no
+ MFP/AFP discharge pressure	no
+ Feedwater regulating valve (FRV) position indication	no
+ Feedwater flow indication (high & low range)	no
+ SG tube-to-shell temperature differential (B&W only)	no

Plant Instruments for Feed and Bleed Operations

Instruments used in primary system F&B operations	Safety Grade
+ HPIP/CCP run indication	yes (HPIP)
+ Valve lineup & position indication	yes
+ HPIP Injection flow meters	yes
+ HPIP/CCP discharge pressure	yes (HPIP)
+ PORV open indication	no
+ PORV tailpipe T/Cs	no
+ ultrasonic flow indication	no
+ Quench tank pressure/level	no

Plant Instruments for Feed and Bleed Operations

Instruments used in primary system F&B operations (contd)	Safety Grade
+ Sump level	yes
+ Containment pressure	yes

Summary

1. Operators build experience of PCS instrument behavior associated with PCS energy and mass inventory tracking, and with secondary F&B systems operation through normal reactor operations and simulator training. This experience is the basis for determination of the effectiveness of F&B operations.

2. Building experience of PCS instruments associated directly with systems involved in primary F&B is obtained through simulator training.

3. The principal PCS instruments for primary and secondary F&B operations measure parameter magnitudes and are safety grade.

4. Instruments associated directly with systems used in either primary or secondary F&B operations provide parameter and status information. These instruments are used to evaluate the operational status of systems used in primary and/or secondary F&B. The principal instruments are safety grade.

OPERATOR TRAINING
FOR
FEED-AND BLEED OPERATIONS

W.F. STEINKE

ACRS MEETING
IDAHO FALLS, IDAHO

AUGUST 29, 1990

OPERATOR TRAINING

OBJECTIVES:

A. TRAINING NOW BEING PROVIDED PWR OPERATORS FOR FEED-AND-BLEED OPERATION

B. EVALUATION OF THE PWR FEED-AND-BLEED TRAINING

TRAINING

PLANT CONDITIONS REQUIRING FEED-AND-BLEED

A. LOSS OF ALL FEEDWATER

- LOSS OF MAIN FEEDWATER
- LOSS OF AUXILIARY FEEDWATER

B. SMALL BREAK LOCA

- LOSS OF HPI CAPABILITY
- LOSS OF S/G'S AS HEAT SINK

TRAINING

SUPPORTING PROCEDURES

A. EMERGENCY PROCEDURES (EOP'S)

- EVENT RELATED
- ENTRY POINT FOR ALL CONDITIONS
- EXIT STEP MAY BE ANYWHERE FROM STEP 4 TO 20

B. FUNCTIONAL RESTORATION PROCEDURES (FR'S)

- SYMPTOM BASED FUNCTION RELATED
- ARE NOT IMMEDIATELY IN EFFECT
- MUST BE COMPLETED BEFORE EXITING
- CONTAIN THE FEED-AND-BLEED STEPS

TRAINING

SIMULATOR EXERCISE

A. OBJECTIVE

- GIVEN A LOSS OF ALL FEEDWATER, WITH AN INABILITY TO FEED AT LEAST ONE S/G, INITIATE A PRIMARY FEED-AND-BLEED PRIOR TO DRYING OUT S/G'S

B. ADVANTAGES

- PLANT SPECIFIC AT MOST UTILITIES
- REAL-TIME RESPONSE

C. DISADVANTAGES

- LENGTH OF SCENARIO
- SIMULATOR MODELING

EVALUATION

FORMAL ASSESSMENTS

A. UTILITY

- BIANNUAL REQUALIFICATION WRITTEN EXAM
- OPERATIONAL EVALUATION COMPLETED BY SIMULATOR INSTRUCTOR

B. NRC LICENSE PROCESS

- INITIAL EXAM FOR OPERATOR LICENSE
- LICENSE RENEWAL AT LEAST EVERY 6 YEARS

C. INPO ACCREDITATION

- EVALUATES INSTRUCTORS, PROGRAMS, AND MATERIALS

EVALUATION

CRITERIA FOR SUCCESS

A. OPERATOR FAMILIARITY WITH PROCEDURES

- ALTERNATIVES AVAILABLE
- PREFERENCE OF ALTERNATIVES
- EXPECTED PLANT RESPONSE

B. KNOWLEDGE OF INSTRUMENTATION

- PRIMARY SIDE
- SECONDARY SIDE

C. FEED-AND-BLEED INITIATION PRIOR TO S/G DRYOUT

SUMMARY

STRENGTHS

A. PLANT SPECIFIC SIMULATORS PROVIDE AN EXCELLENT TOOL FOR EVALUATING OPERATOR RESPONSE TO EVOLUTIONS, SUCH AS FEED-AND-BLEED, WHICH CAN BE REAL-TIME SENSITIVE

B. OPERATORS RECEIVE PROCEDURE TRAINING WITH THEIR KNOWLEDGE AND CONFIDENCE LEVEL BASED ON ACTUAL PLANT RESPONSE.

C. THE METHODS USED BY EXAMINERS AND UTILITY INSTRUCTORS ARE OBJECTIVE WITH CRITICAL TASKS CLEARLY DELINEATED, PROVIDING CONSISTENT EVALUATIONS THROUGHOUT THE INDUSTRY.

SUMMARY

WEAKNESSES

A. MULTIPLE FAILURES OF ENGINEERED SAFETY FEATURES ARE REQUIRED TO ACHIEVE INITIAL CONDITIONS FOR FEED-AND-BLEED. DEVELOPING CREDIBLE SCENARIOS IS DIFFICULT.

B. FEED-AND-BLEED SCENARIOS FOR WESTINGHOUSE AND COMBUSTION ENGINEERING TAKE THIRTY TO FORTY-FIVE MINUTES TO REACH INITIATION CRITERIA DUE TO PLANT DESIGN. THIS OFTEN RESULTS IN EARLY TERMINATION OF THE EVENT.

C. SOME SIMULATOR MODELS ARE LIMITED IN THEIR CAPACITY TO PREFORM COMPLEX CALCULATIONS TO SIMULATE CONDITIONS THROUGHOUT FEED-AND-BLEED OPERATIONS

IDAHO
NATIONAL
ENGINEERING
LABORATORY

FEED-AND-BLEED FEATURES OF PWR'S IN THE FEDERAL REPUBLIC OF GERMANY

BY

SAM NAFF

PRESENTED TO

ACRS DHRS AND T\H PHENOMENA SUBCOMITTEES

AUGUST 29, 1990, IDAHO FALLS, IDAHO

EG&G Idaho, Inc.

TOPICS DISCUSSED

- INTRODUCTION
- BASIC SAFETY FEATURES RELATED TO FEED-AND-BLEED
- GERMAN RISK STUDIES
- RECENT IMPROVEMENTS
- SUMMARY

Introduction

- Nuclear Reactors In The Federal Republic Of Germany
  - 14 PWRs (340 - 1300 MW_E)
  - 7 BWRs (640 - 1260 MW_E)
  - 1 LMFBR (294 MW_E), Not Operational
  - Total On Line - 21 Producing 22311 MW_E
  - First On Line In 1969
  - Most Recent On Line In 1989

BASIC SAFETY FEATURES RELATED TO FEED-AND-BLEED (PRIOR TO RISK STUDIES)

- Hot Leg HPIS
  - MINIMIZES PRESSURIZED THERMAL SHOCK
- Automatic 100K/Hr Secondary Cooldown
  - NO OPERATOR INTERVENTION DURING FIRST HALF HOUR
- Valve Testing

German Risk Studies

- Reference Plant - Biblis B
  - 4 Loop PWR, 1240 MW_E, 3750 MW_T
  - Commercial Start January 1977
- Two Studies Called Phases A And B
  - Phase A Completed 1979

    Similar To Rasmussen Study (WASH 1400)
  - Phase B Completed June 1989

    More Triggering Events Considered
- Resulting Core Damange Risk
  - Phase A: 9×10^{-5}/Year, Phase B: 3×10^{-5}/Year

GERMAN RISK STUDIES (CONTINUED)

- DIFFERENCES BETWEEN PHASE A AND B
  - MORE TRIGGERING EVENTS CONSIDERED IN PHASE B
  - MORE SOPHISTICATED SAFETY/RISK ANALYSIS TECHNIQUES IN PHASE B
  - MORE PLANT DATA AVAILABLE FOR PHASE B
  - PLANT IMPROVEMENTS BASED ON PHASE A
  - NEW SAFETY RESEARCH RESULTS AVAILABLE FOR PHASE B
- MAIN CONSTRIBUTIONS TO RISK FROM:
  - TRANSIENTS 65%, SMALL LEAKS 25%

GERMAN RISK STUDIES (CONT'D)

FREQUENCIES OF ACCIDENT INITIATING EVENTS RELATED TO FEED-AND-BLEED (MEAN VALUE PER ANNUM)

	Phase A	Phase B
• Loss of Coolant Accidents		
- SMALL LEAK	3×10^{-3}	3×10^{-3}
• Transients		
- LOSS OF MAIN FEEDWATER	0.8	0.2
- LOSS MAIN HEAT SINK	0.3	0.4
- WITH LOSS OF MAIN FEEDWATER	---	0.3
- ATWS	3×10^{-5}	$\sim 10^{-5}$

RECENT IMPROVEMENTS

- Improved Pressurizer Valves
  - designed for both liquid and gas flow
  - additional control valves
- Grid Return Switching
- Pressurized Feedwater Storage Tank
- Use of Non-Safety Grade Water Sources
  - external connection

SUMMARY

- FEED-AND-BLEED IMPORTANT FOR ACCIDENT MANAGEMENT
- MINIMIZED OPERATOR ERROR THROUGH AUTOMATION
- RISK STUDIES USEFUL TOOL FOR IMPROVING PLANT SAFETY

Experimental Data Base For PWR Feed and Bleed

Presented by

K. G. Condie

ACRS Meeting

Idaho Falls, ID

August 29, 1990

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Feed and Bleed Data Sources

- LOFT
- SEMISCALE
- OTIS
- MIST
- PLANT TRANSIENTS

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LOFT Data Base

Experiment	Initiating Event	Recovery Procedure
L3-1	Small break	Secondary feed and steam
L3-2	Small break	Secondary feed and steam
L3-5	Small break (pumps off)	Secondary feed and steam
L3-6	Small break (pumps on)	Secondary feed and steam
L3-7	Small break	Secondary feed and steam
L9-1/L3-3	LOFW	Primary bleed, secondary F&S
L9-3	LOFW w/o scram	Primary bleed, secondary F&S
L9-4	LOFW/Loss of power w/o scram	Primary bleed
LP-FW-1	Complete loss of feedwater	Primary feed and bleed
LP-SB-3	Small Break	Secondary feed and steam

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Semiscale Data Base

Series	No. Tests	System	Recovery Procedure
SR (Primary F&B)	2	Mod-2A	Primary feed and bleed
SG (SGTR)	9	Mod-2B	Primary feed and bleed and secondary feed and steam
FS (Feed and Steam line break)	5	Mod-2C	Secondary feed and steam
NH (SBLOCA with degraded ECS)	5	Mod-2C	Secondary feed and steam
TR (Station Blackout)	2	Mod-3	Primary feed and bleed
PL (Power Loss)	5	Mod-2B	Primary feed and bleed

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OTIS/MIST Data Base

Test	System	Recovery Procedure Used
220899	OTIS	Primary feed and bleed
3301BB	MIST	Nominal test
330201	MIST	Primary feed and bleed (degraded HPI)
330302	MIST	Primary feed and bleed (delayed HPI)
330499	MIST	Primary feed and bleed (surge line uncovery)
340213 (SGTR)	MIST	Tube rupture with PORV depressurization
340799 (SGTR)	MIST	Tube rupture with pressurizer venting

Note: MIST 330xxx series experiments are all HPI-PORV cooling tests.

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Plant Transient Data

Plant	System	Problem/Recovery Procedure
TMI-2	B&W	Primary bleed only
GINNA	W	Steam generator tube rupture followed by PORV bleed to reduce pressure
CRYSTAL RIVER-3	B&W	Failed open PORV followed by 2 min of primary feed and bleed

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LOFT Experiment LP-FW-1

- Complete and unrestored loss of feedwater
- Initiated from typical PWR operating conditions
- HPIS scaled to one of three HPIS trains in PWR
- Primary feed and bleed recovery

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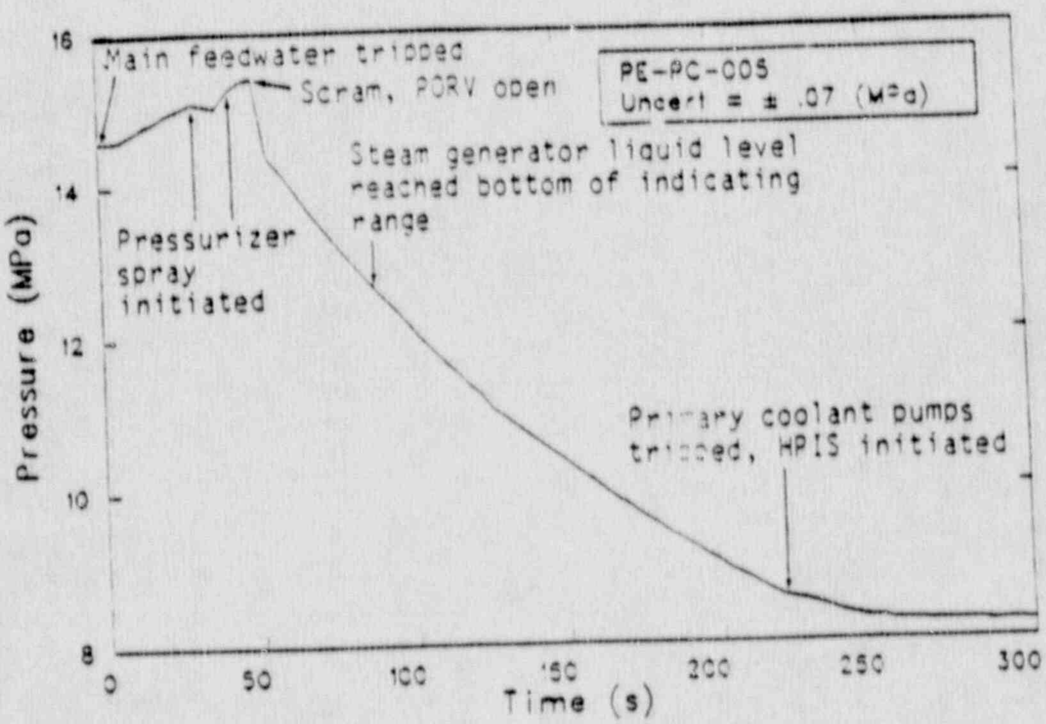
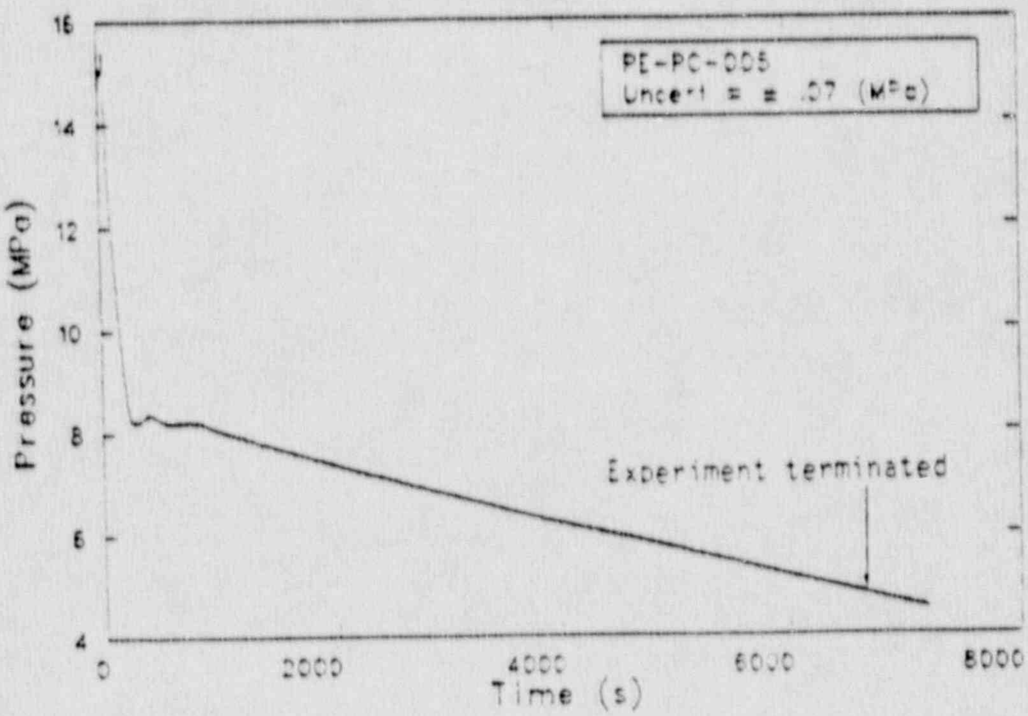
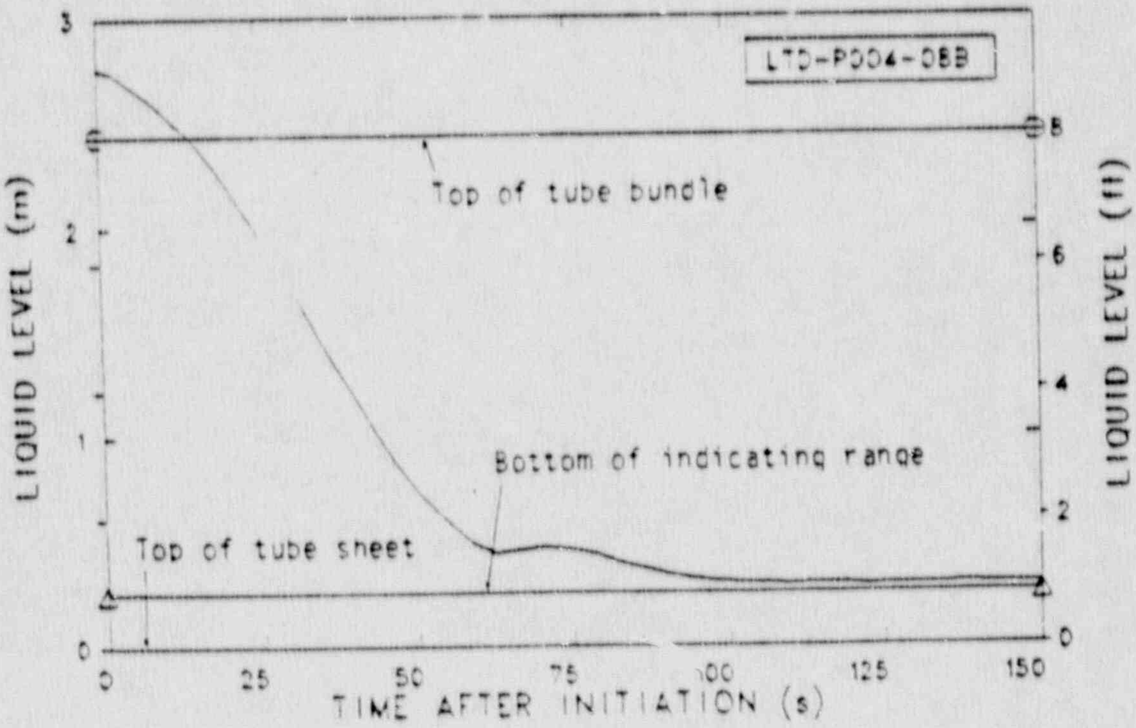
LOFT EXPERIMENT LP-FW-1
PRIMARY SYSTEM PRESSURE



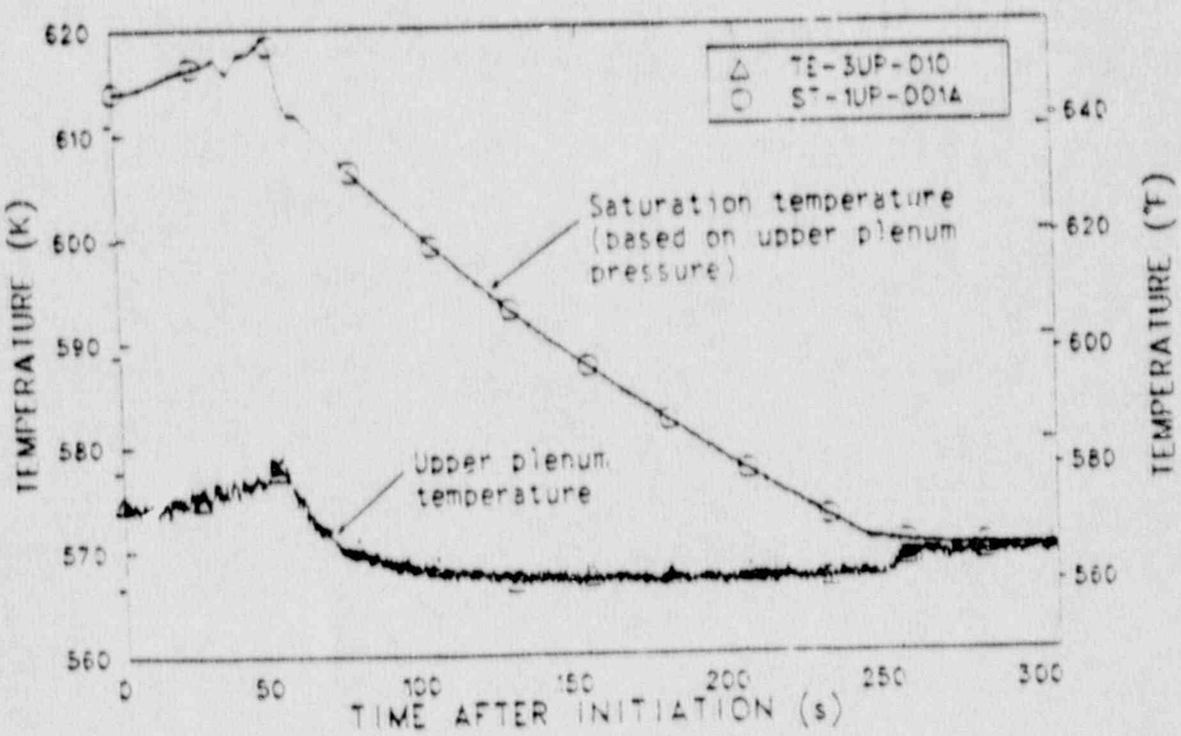
LOFT EXPERIMENT LP-FW-1
PRIMARY SYSTEM PRESSURE

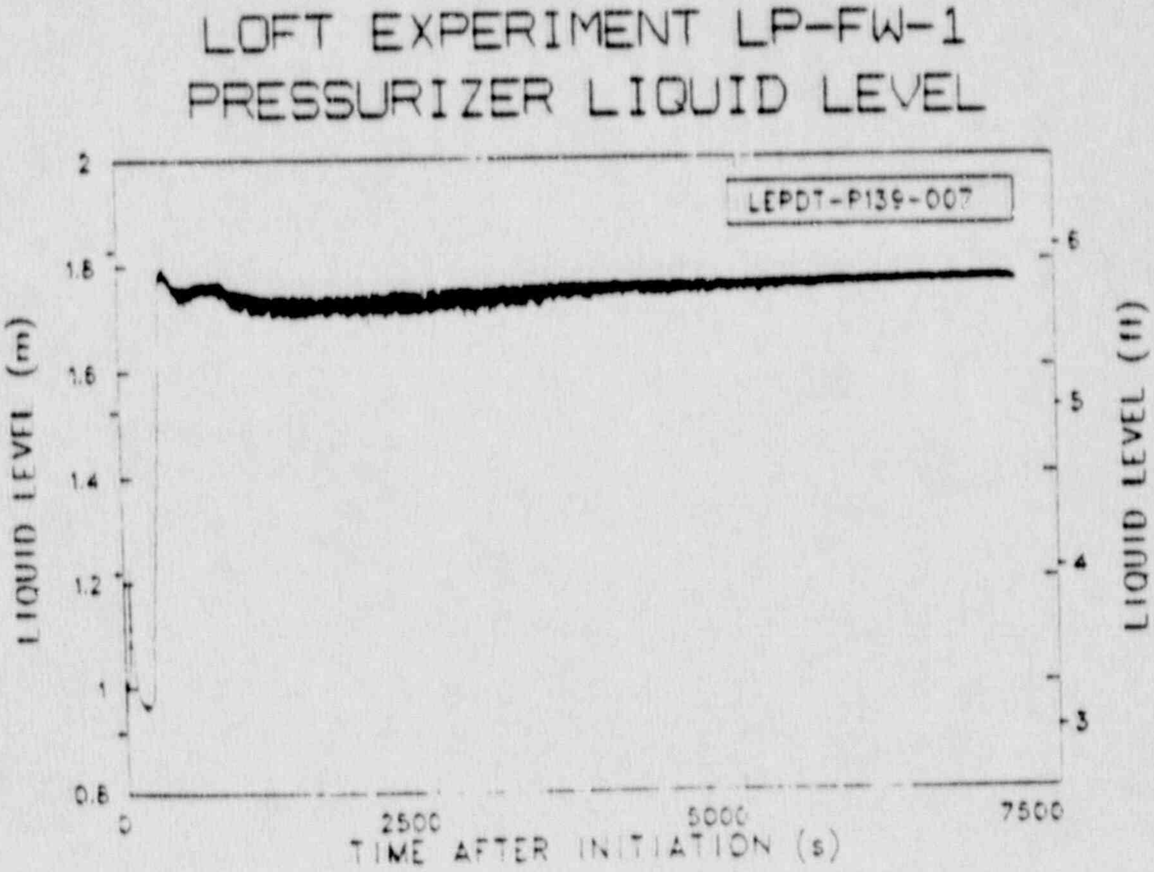


LOFT EXPERIMENT LP-FW-1
STEAM GENERATOR LIQUID LEVEL

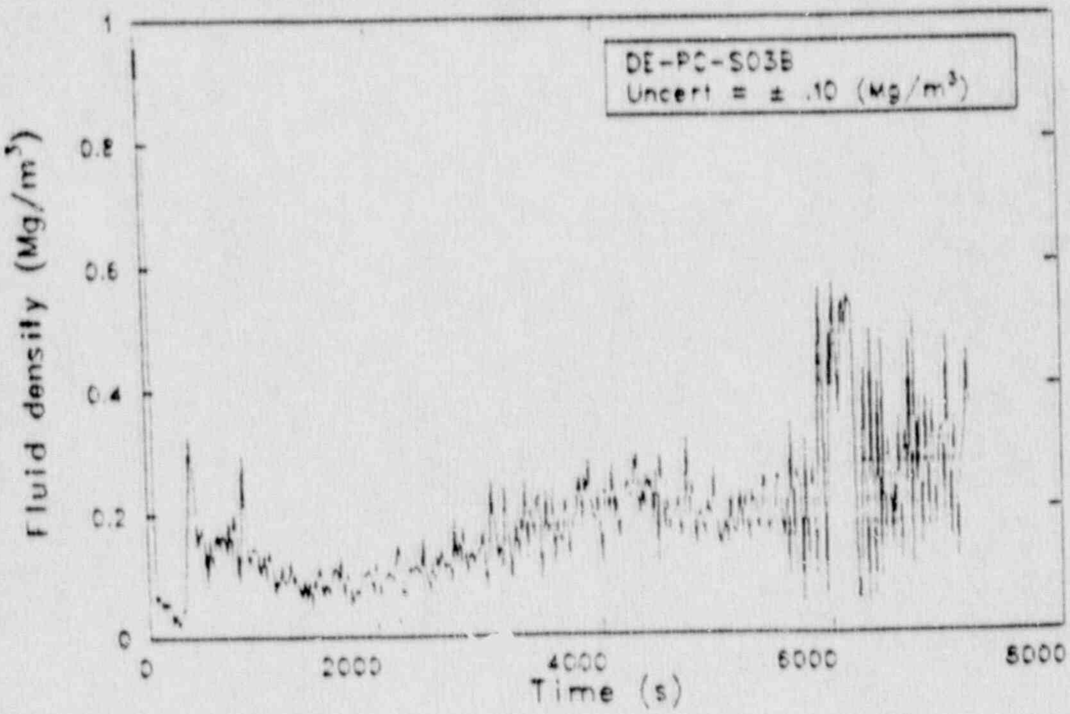


LOFT EXPERIMENT LP-FW-1
UPPER PLENUM
FLUID AND SATURATION TEMPERATURES

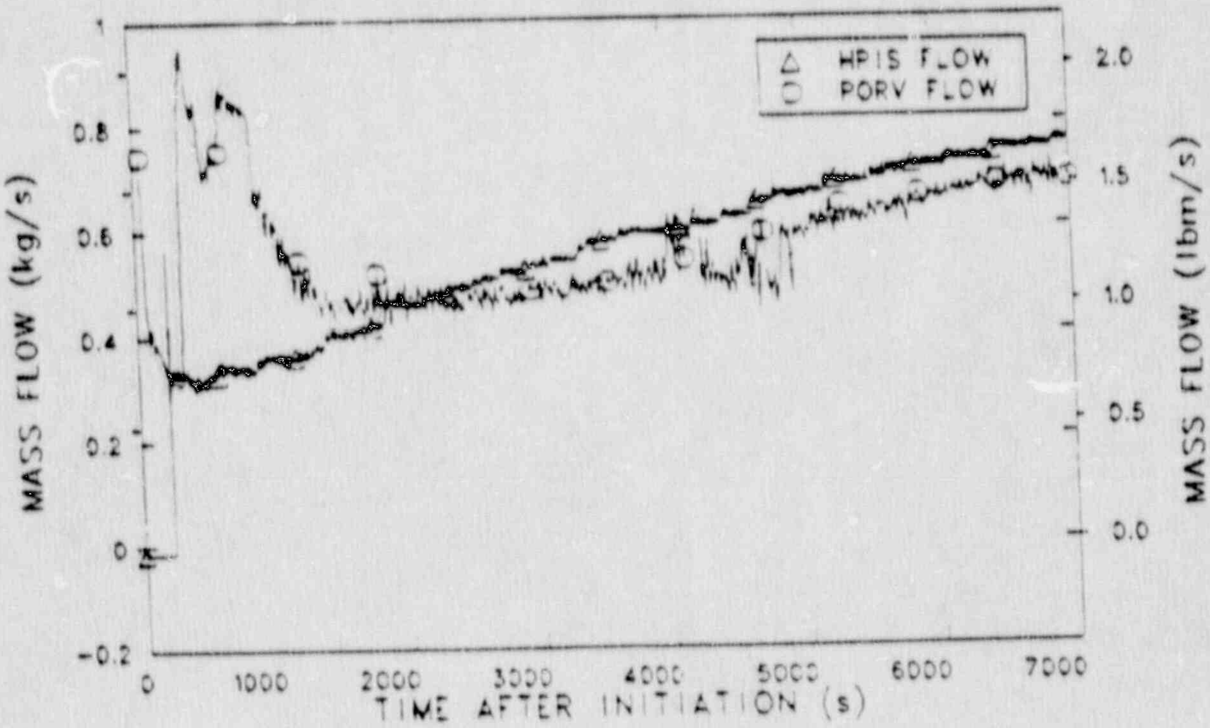


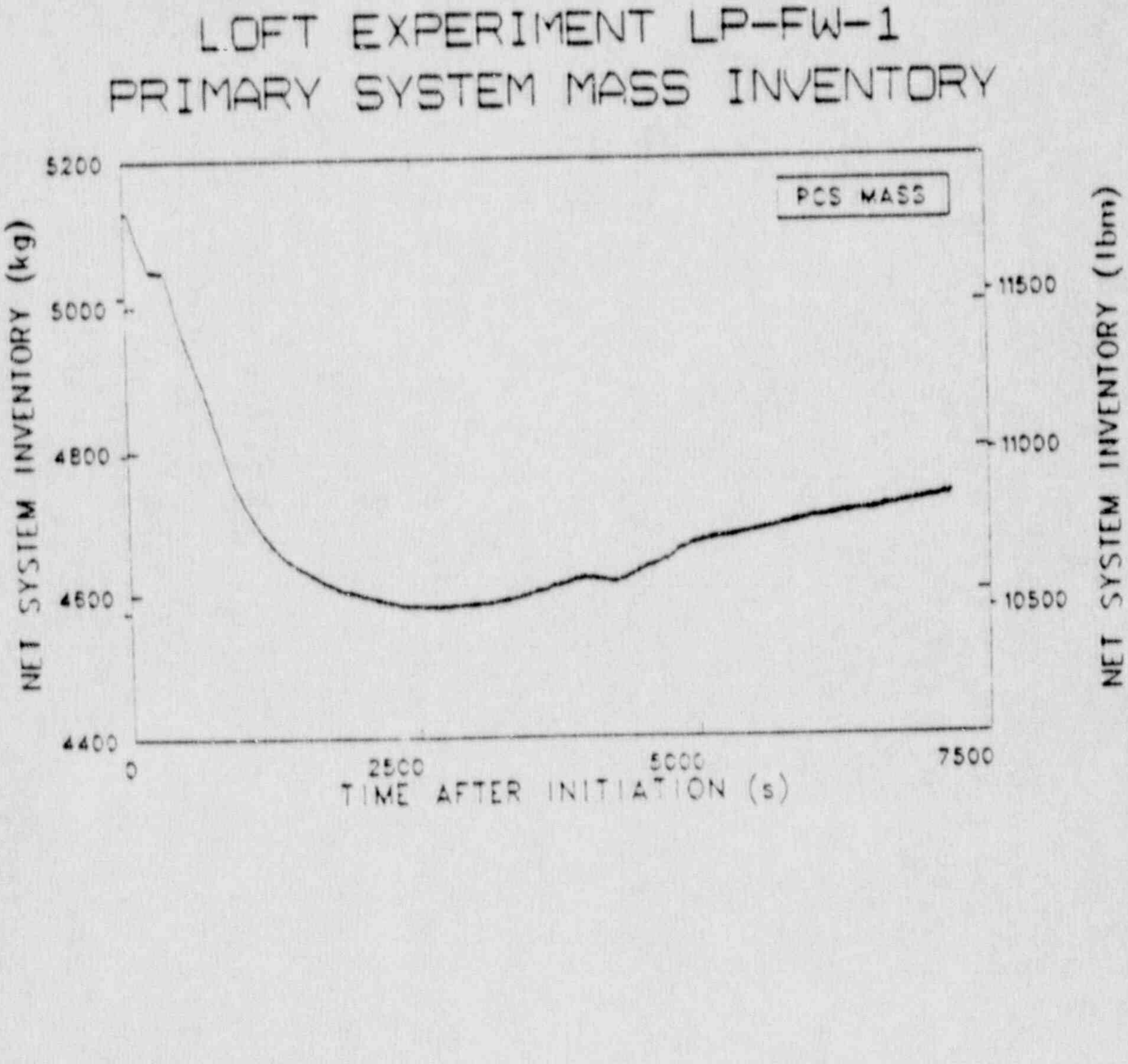

LOFT EXPERIMENT LP-FW-1
PRESSURIZER LIQUID LEVEL
LEPDT-P139-007
LIQUID LEVEL (m)
LIQUID LEVEL (ft)
TIME AFTER INITIATION (s)
2
1.8
1.6
1.4
1.2
1
0.8
6
5
4
3
0
2500
5000
7500

LOFT EXPERIMENT LP-FW-1
FLUID DENSITY UPSTREAM OF PORV



LOFT EXPERIMENT LP-FW-1
HPIS and PORV MASS FLOWRATES




LOFT EXPERIMENT LP-FW-1
PRIMARY SYSTEM MASS INVENTORY
PCS MASS
NET SYSTEM INVENTORY (kg)
NET SYSTEM INVENTORY (lbm)
5200
5000
4800
4600
4400
11500
11000
10500
0
2500
5000
7500
TIME AFTER INITIATION (s)

Semiscale Experiment S-PL-3

- Initiated from typical PWR conditions
- Loss of offsite power
- Failure of auxiliary feedwater
- Two HPIS trains
- Primary feed and bleed recovery

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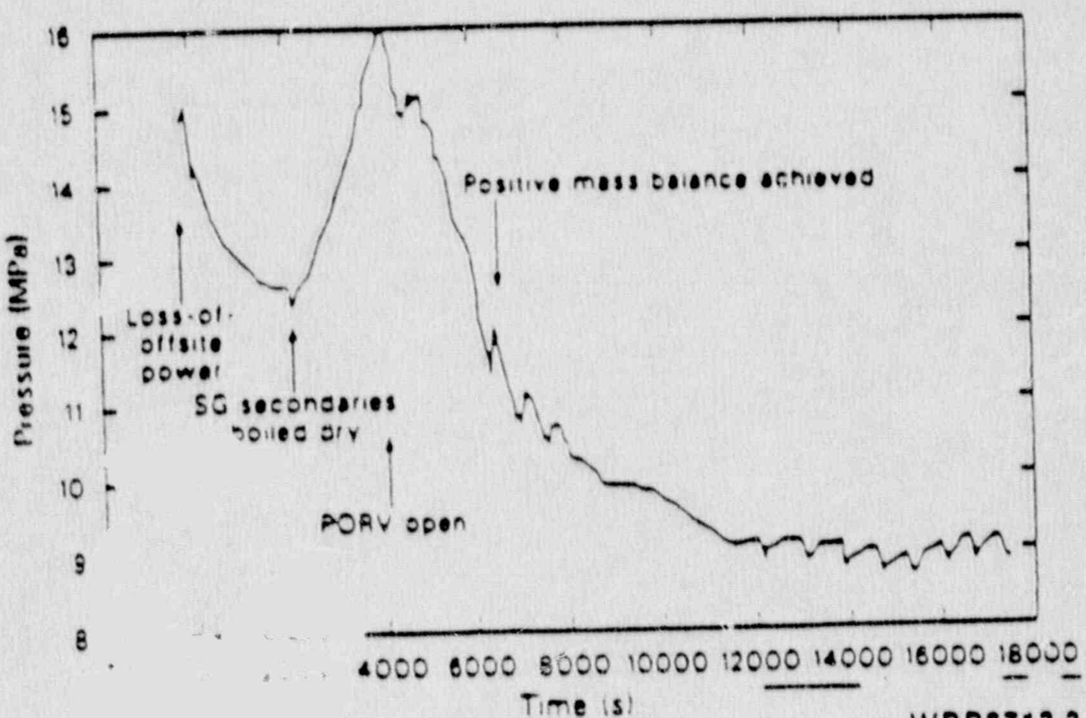
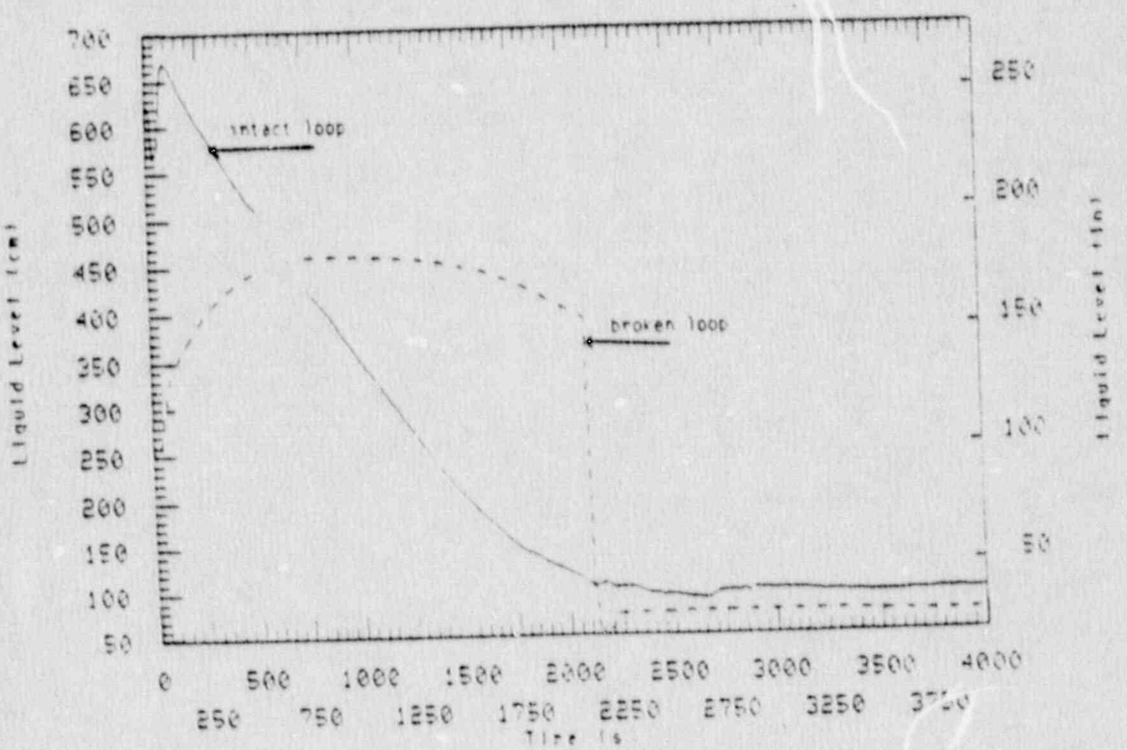
SEMISCALE EXPERIMENT PL-3
PRIMARY SYSTEM PRESSURE

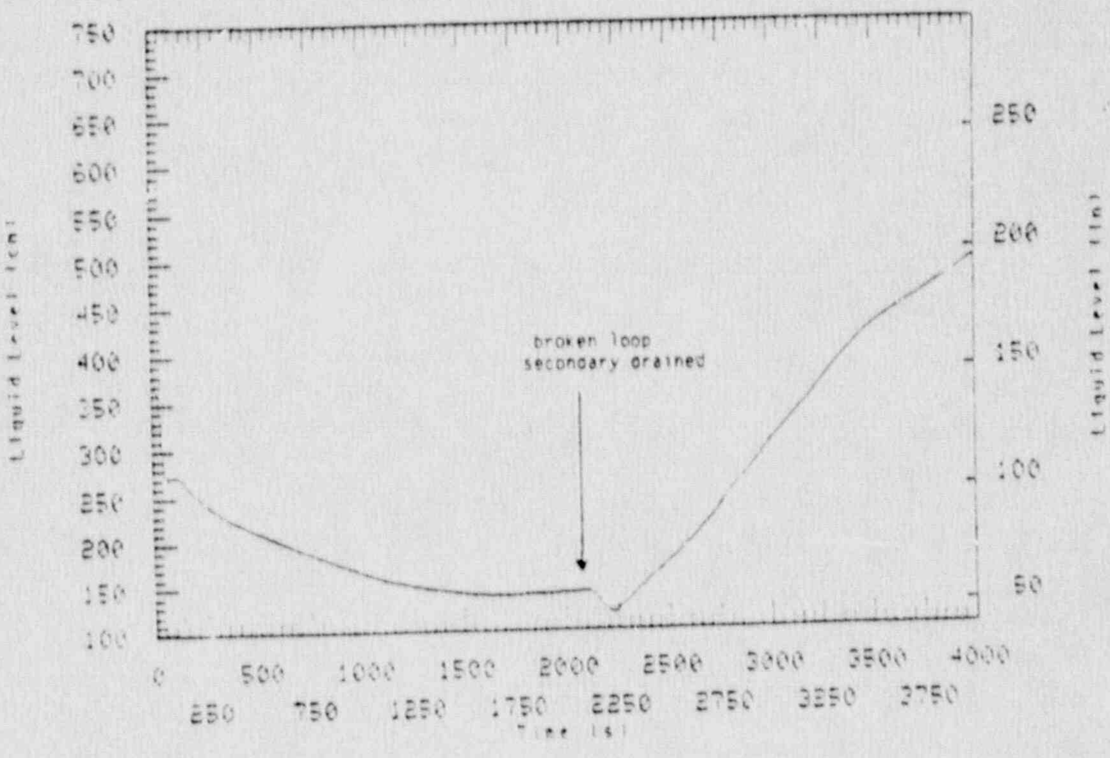


WRR8713-3

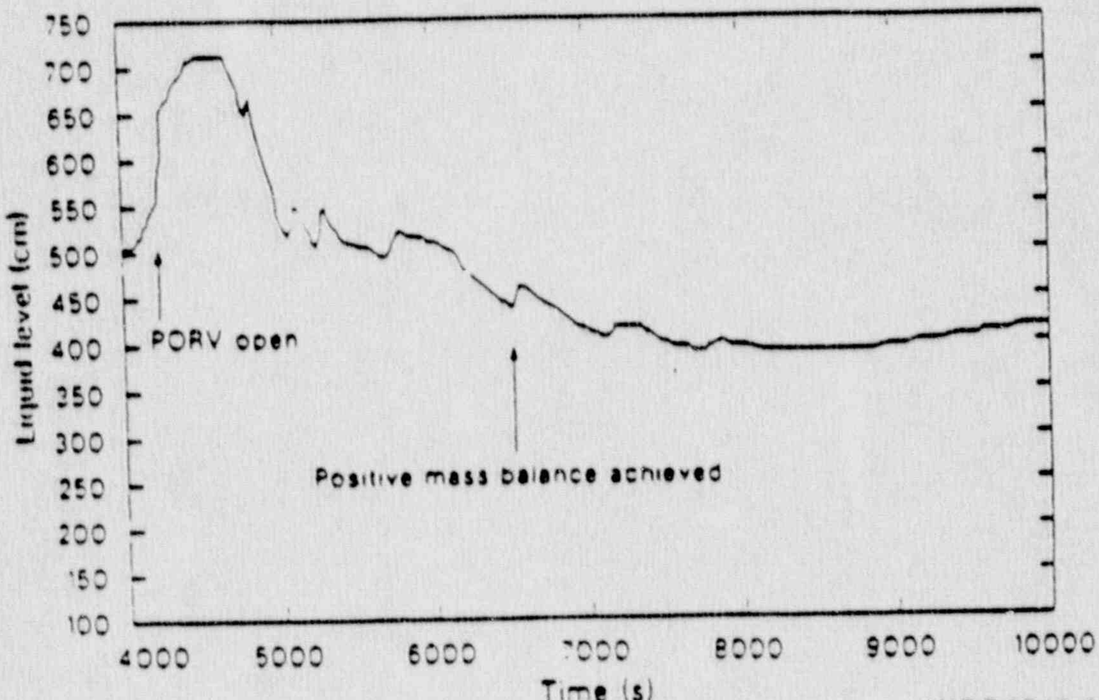
SEMISCALE EXPERIMENT S-PL-3
STEAM GENERATOR LIQUID LEVELS



SEMISCALE EXPERIMENT S-PL-3
PRESSURIZER LEVEL

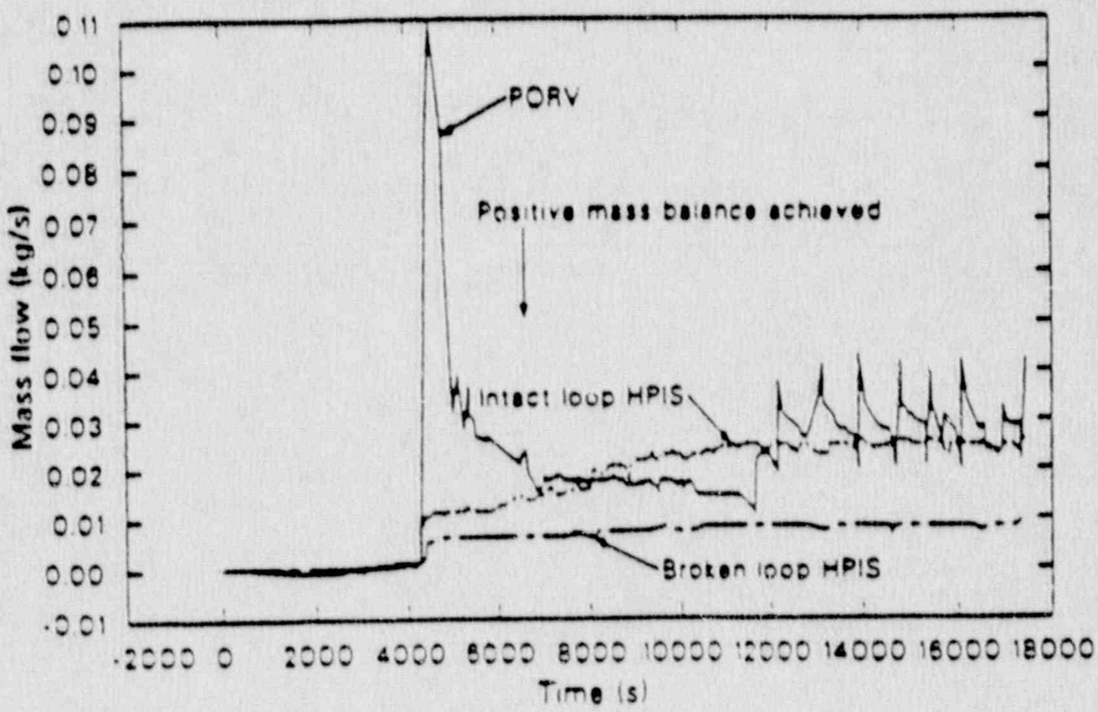


SEMISCALE EXPERIMENT S-PL-3
PRESSURIZER LEVEL

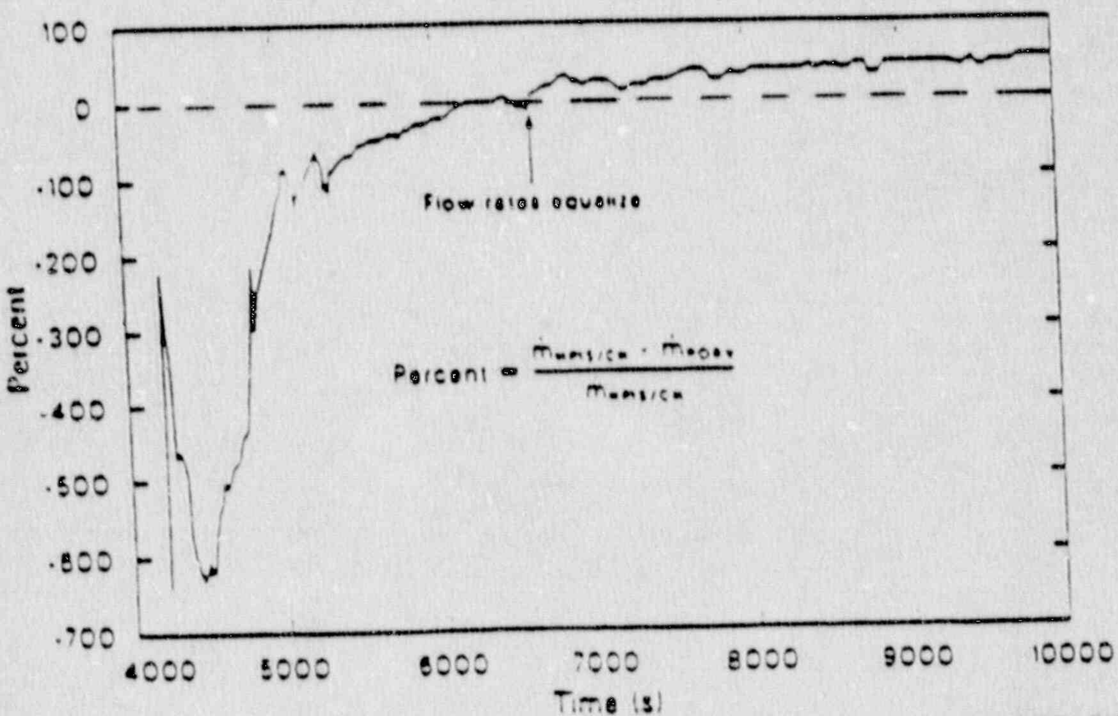


WRR8713-6

SEMISCALE EXPERIMENT S-PL-3
HPIS and PORV MASS FLOWRATES



SEMISCALE EXPERIMENT S-PL-3
PERCENT DIFFERENCE IN
HPIS and PORV FLOWRATES



WRR8713-5

Conclusions

- Good experimental data base for feed and bleed
- Secondary feed and bleed used regularly as decay heat removal mechanism
- Primary feed and bleed shown to be effective decay heat removal procedure

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REGULATORY REQUIREMENTS RELATED TO "FEED AND BLEED"

- - 10 CFR 50 DOES NOT SPECIFICALLY ADDRESS PRIMARY OR SECONDARY FEED AND BLEED

- - DECAY HEAT REMOVAL GENERAL DESIGN CRITERIA: (1) GDC-34 RESIDUAL HEAT REMOVAL AND (2) GDC-35 EMERGENCY CORE COOLING ESTABLISH SINGLE FAILURE CRITERIA. PRIMARY FEED AND BLEED PROCEDURES GO BEYOND THE GDC IN THAT THEY ASSUME MULTIPLE FAILURES.

- - NOT ALL PLANTS ARE CAPABLE OF PRIMARY FEED AND BLEED SINCE THEY DO NOT HAVE POWER OPERATED RELIEF VALVES (PORV'S).

- - PRIMARY FEED AND BLEED PROCEDURES ARE ESTABLISHED IN OWNERS GROUP EMERGENCY RESPONSE GUIDELINES (ERG'S). THESE GUIDELINES ARE REVIEWED BY THE NRC.

- - LICENSEE'S ESTABLISH PROCEDURE GENERATION PACKAGES (PGP'S). THESE ARE ALSO REVIEWED AND APPROVED BY THE NRC.

- - LICENSEE'S ARE EXPECTED TO, BUT REGULATIONS DO NOT REQUIRE THEM TO FOLLOW ERG'S. SINCE EOP'S ARE PLANT SPECIFIC LICENSEE PROCEDURES MAY DEVIATE FROM ERG'S. THERE SHOULD BE ADEQUATE TECHNICAL JUSTIFICATION FOR DEVIATIONS.

- - NRC INSPECTION PROCESS REVIEWS EOP'S. FEED AND BLEED PROCEDURES AND OTHER EOP'S REVIEWED ON A SAMPLING BASIS.
  (1) PROCEDURES REVIEWED AGAINST ERG
  (2) PROCEDURES REVIEWED AGAINST PGP
  (3) PROCEDURES REVIEWED FOR WORKABILITY.
      SCENARIOS RUN ON SIMULATOR.
  (4) OPERATORS UNDERSTAND PROCEDURES.
      (NOTE: THIS IS DONE FORMALLY DURING LICENSED OPERATOR EXAM PROCESS)