Transcript of Proceedings
NUCLEAR REGULATORY COMMISSION

DISCUSSION OF ORNL REPORT,
"POTENTIAL PRECURSORS TO SEVERE CORE DAMAGE"

PUBLIC MEETING

WEDNESDAY, JULY 21, 1982

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Office of the Secretary

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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DISCUSSION OF ORNL REPORT,

"POTENTIAL PRECURSORS TO SEVERE CORE DAMAGE"

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PUBLIC MEETING

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Chairman's Conference Room
Room 1130
1717 "H" Street, N.W.
Washington, D. C.

Wednesday, July 21, 1982

The Commission met, pursuant to notice, at 10:05 o'clock a.m., NUNZIO J. PALLADINO, Chairman of the Commission, presiding.

COMMISSIONERS PRESENT:

NUNZIO PALLADINO, Chairman of the Commission

VICTOR GILINSKY, Member of the Commission

JOHN F. AHEARNE, Member of the Commission

THOMAS ROBERTS, Member of the Commission

JAMES ASSELSTINE, Member of the Commission

STAFF AND PRESENTERS SEATED AT THE COMMISSION TABLE:

R. BERNERO
J. MINARICK
S. CHILK

AUDIENCE SPEAKERS:

R. DENNIG

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P R O C E E D I N G S

CHAIRMAN PALLADINO: Good morning ladies and gentlemen. The Commission meets this morning to receive a briefing on the recently published report, entitled, "Potential Precursors to Severe Core Damage, 1969 - 1979, Status Report."

This report was prepared for the Nuclear Regulatory Commission by the Oak Ridge National Laboratory. The report presents the initial reports of a program begun as a result of a recommendation by the Lewis Committee following the review of the WASH-1400 Reactor Safety Study.

The Committee recommended that operational data should be used more frequently to assist the risks from nuclear power plants. As indicated in the title, the report covers the licensing events for the period 1969 to 1979. As noted in the preface, the report has been released for peer review and public comment.

We look forward to the highlighting of the report. Unless any of my fellow Commissioners have opening remarks, I will turn the meeting over to Mr. Bernero.

(No response.)

MR. BERNERO: Thank you, Mr. Chairman. As you said we are here briefing you on a status report that was just published with a little bit of excitement. For purposes of giving you an overview of this report, I would like to open with some introductory remarks to give you an idea of where this activity from which this report comes, where that fits into things and what sort of work we have in progress and intended related to this report.

May I have the first slide, please?

(Slide.)

MR. BERNERO: I will merely give you some introductory remarks and then the bulk of the presentation will be by the gentleman on my left, Mr. Joseph Minarick, who is the principal author of the report and he can go into whatever depth you want. He has some carefully selected overview slides to cover the substance of the methodology and the basic results from the report.

May I have the next slide, please?

(Slide.)

MR. BERNERO: This first introductory slide has the title, "Analysis and Evaluation of Operational Data."

COMMISSIONER GILINSKY: It looks as if they had a little melt down in there.

MR. BERNERO: They said there was a faulty bulb. While they are fixing that, let me go on.

Some months ago, I was even trying to dig through my file to determine the exact date. The Commission had a briefing on the analysis and evaluation of operational data in totality where you had all the office directors up here, you may recall, where Carl Michaelson and Harold Denton and Dick DeYoung and Bob Minogue each told you what they were doing in their portion of the analysis and evaluation of operational data.

It was at that time that among other things, Bob Minogue told you in a quiet way of this report and its initial results. The draft was in hand at that time undergoing peer review.

This work represents an important aspect of information gathering and evaluation that we are trying to concentrate on more and more. We do a lot at the front end. We predict things. We analyze things, plant safety, and so forth, but now that we have 400 to 500 reactor years of operational experience behind us, there is a lot to be gained by going back and look at what has happened, what are the small events, the perturbations, the upset conditions. How have the plants responded, and not merely in PRS space, but in the whole thing, the thermal hydraulic transience and --

COMMISSIONER GILINSKY: PRA space?

MR. BERNERO: Well, in PRA predictions. In this particular area, we are talking about probabilistic risk analysis where we have PRA's that we are all somewhat familiar with where a prediction is made of plant reliability.

Now in that prediction, we have initiating event frequencies taken unusually from some limited set of operational experience and rather complex predictions of functional reliability, how reliable is the high pressure injection system.

COMMISSIONER GILINSKY: Wait a minute. Aren't the LER's part of the information base that goes into --

MR. BERNERO: Yes, they are.

COMMISSIONER GILINSKY: -- the analysis in the first place?

MR. BERNERO: If you recall, in WASH-1400, back in 1972 and 1973 an attempt to get much out of the LER's was frustrating because there were very few LER's available at that time. There was not a good solid data base in nuclear power plant experience, that is, commercial nuclear power plant experience.

So what was done in WASH-1400, for instance, pipe failure rates were obtained by comparing with oil refineries and things like that.

COMMISSIONER GILINSKY: But we are not going back to those analyses. We are talking about more recent ones.

MR. BERNERO: But those are our PRA's. We have PRA's like WASH-1400 that have been developed with that data base knowing that it is weak. Now what we are doing when we have these predicted combinations leading to core melt accidents, we are looking back at operational experience and saying, "Let's look at these 11 years. Are the initiating event frequencies turning out to be the way we --

COMMISSIONER GILINSKY: Let's see. Haven't you used the experience of these 11 years to fortify your data base?

MR. BERNERO: Yes, we have, and this is one way we are doing it. But in this particular instance what we are looking at is the 11 years -- wait, I will give you an example, small break LOCA, you will see later, is one that is born out to be a higher level of occurrence now in our PRA's. We use a higher probability of occurrence for small break LOCA than WASH-1400 did.

One of the ways that we learn to change that number was from LER experience. Now we didn't wait for this report. This report merely bears out, yes, indeed, it is approximately an order of magnitude higher, the occurrence of that initiating event.

What we are looking at now in this context is in retrospect is experience bearing out our expected level of occurrence for initiating events, our functional reliability, subsytems on demand, are they turning on and functioning or turning on and failing -- failing to turn on -- with the predicted characteristics and recognizing that you can't sit here and wait for statistical body of core melt results, can you at least extrapolate and determine are the expected probabilities of core melt based on this experience similar to or consonant with our prediction.

Other than that, there is trend analysis and I think it is important. Many people have the feeling that we should see a bathtub curve that new plants are less reliable, and then there is a steadying out when you get the bugs out of them and then toward the end of life, they might come up and be unreliable.

So we would look for trends such as that and again being very careful to make sure that what we detect is statistically reliable.

CHAIRMAN PALLADINO: Did you say it right? You said a bathtub curve that shows the newer plants would be less reliable.

MR. BERNERO: Yes. They would trip more and have more bugs in them in the first year or so until they debug.

CHAIRMAN PALLADINO: I see. That is what you meant by a "new" plant.

MR. BERNERO: Then they would stabalize. Then when they get very old, they might go up.

COMMISSIONER AHEARNE: That is a hypothesis.

MR. BERNERO: Yes, hypothesis.

COMMISSIONER ROBERTS: Pure speculaton.

MR. BERNERO: Yes, we would look for such a trend if it exists.

We would also look for trends of increasing or decreasing reliability in any subsystem that would be significant.

May I have the next slide, please?

(Slide.)

MR. BERNERO: Now among the things that we are doing with LER's, you have heard on separate occasions reports where we have used the LER's to extract the specific reliability rates for valves, for pumps, for control rod motors, for diesel generators, and for many other components.

In this particular arena here, this effort we have with Oak Ridge Nuclear Safety Information Center, the work that is completed and upon which this status report is based covers the 11 year period of LER's, 1969 through 1979, basically the pre-TMI era because one would not expect much change to show up.

COMMISSIONER AHEARNE: Well, including TMI.

MR. BERNERO: Yes, including the year of TMI. In this particular context the only PRA of real utility is WASH-1400 itself. So when one interprets the event significance, you are basically forced to adapt or modify WASH-1400 event trees to interpret what a PWR is going or what a BWR is doing, and this report, NUREG/CR-2497, was put out as a status report because we thought the work was significant and needs as much peer review as it can get.

The work is progress is covering the 1980 to 1981 LER's once again using WASH-1400 event trees, and we expect to have a second status report or supplement to this one, a draft approximately in December 1982, this December. Then we would expect to do further on certainty and sensitivity analysis and now we have many more PRA's available to us. So we want to see whether the plant-specific PRA's are indeed more useful and would give us much better insight into the interpretation of these LER's.

COMMISSIONER AHEARNE: How do you intend to use that? When you say that the plant-specific ones will be available, do you intend to go back and try to do a different selection of event trees?

MR. BERNERO: As I understand it from the discussions with staff, we will take the modified event tree and then a specific event tree from that plant and see how different it makes the result.

Now external peer review, I indicate here, we know we are dealing with extrapolation of sparse data because thankfully we don't have core melts once a month. We don't have statistical quantities of severe core damage or core melt accidents available to us.

Now we did some extensive internal peer review both the laboratory, Oak Ridge, and the staff did that. We now have this report published and I have in progress arrangements with INPO and with EPRI to obtain external peer review from knowledgeable bodies. INPO, of course, is doing a very similar thing in their evaluation of operational events and we hope to get soon a feedback from them, a comparison with this evaluation of the very same events.

CHAIRMAN PALLADINO: Is this going to the ACRS for comment?

MR. BERNERO: It is going to the ACRS and, of course, the reliability subcommittee is expected to deal with it. Dave Okrent chairs that committee and has a strong interest in all we do. I fully expect that we will have discussions of it with them. They haven't so notified us yet, but I fully expect it.

CHAIRMAN PALLADINO: How about members of the team that worked on WASH-1400?

MR. BERNERO: Many of those -- and when I said that we had internal peer review, I used the staff here, we used the AEOD staff, NRR staff and we have an advisory committee in research for statistics, the American Statistical Association Advisory Committee, and we also got some advise from a subcommittee of that group.

CHAIRMAN PALLADINO: How about people like Rasmussen?

MR. BERNERO: Now is the time for that. We felt that we had to publish it. Norm Rasmussen has looked at the draft, but we were a little bit troubled. We had the draft sitting around for so long in a quasi-public state. It was in the PDR just so that people could see that it wasn't being hidden somewhere. A number of professionals in the field had it. INPO had it, Any number of people had it.

So we felt that it was appropriate to get it out with a clean cover so anyone who wants it can get it and refer to it.

CHAIRMAN PALLADINO: But you do plan to have some of these people work on it?

MR. BERNERO: Oh, yes. This is a continuing effort.

COMMISSIONER GILINSKY: Will we hear about it?

MR. BERNERO: All right. I would like to go on now and turn the floor over to Joe Minarick for the actual briefing on the report.

COMMISSIONER GILINSKY: Before you get started, I wonder if you could explain the relationship of Science Applications, Inc. to Oak Ridge to NRC?

MR. MINARICK: The project is funded through Oak Ridge National Laboratory. Most of the technical work to date has been done by Science Applications with support from Oak Ridge National Laboratory, the Nuclear Safety Information Center and they have also provided administration support.

COMMISSIONER GILINSKY: And you are from?

MR. MINARICK: Science Applications in Oak Ridge.

COMMISSIONER GILINSKY: Is there any particular reason for this arrangement?

MR. BERNERO: The prime contract is with NSIC/Cottrell. They are the clearing house for LER's, the center for it and we look to them for this effort and they from time to time use SAI quite extensively.

MR. MINARICK: I would like to start with the second slide.

COMMISSIONER GILINSKY: This is basically SAI work?

MR. BERNERO: This particular analysis, yes. The two authors on the cover are both SAI employees.

COMMISSIONER GILINSKY: So it is really not an Oak Ridge study; it is an SAI study.

MR. MINARICK: The study was done in SAI's offices in Oak Ridge at the lab and it has been extensively peer reviewed at the lab.

COMMISSIONER GILINSKY: I don't think it is any worse for that. I am just trying to understand.

COMMISSIONER AHEARNE: It is probably similar to many of our other NUREG/CR's, and no different.

MR. BERNERO: It is a laboratory choosing to use subcontractor suport as it sees fit with, of course, some oversight from us. If you read the document, you will find that I wrote the forward and Cottrell wrote the preface. We both consider ourselves deeply responsible for this work even though it is basically a piece of SAI work done at Oak Ridge.

(Slide.)

MR. MINARICK: The beginning slide wil be somewhat of a review of what has already been said. The program deals with the identification of precursors to severe core damage accident sequences based on licensee event reports.

It was begun as Bob said based on the Lewis Committee recommendation that, "It is important, in our view, that potentially significant accident sequences, and precursors, as they appear, be subject to the kind of analysis contained in WASH-1400," and to date, we have reviewed events 1969 to 1979.

(Slide.)

MR. MINARICK: The process deals first with an initial reading of LER abstracts. These are computerized abstracts of each LER which are maintained in a data base at Oak Ridge, to chose those LER's which deserve detailed reviews for potential precursors.

Now in doing this we tried to be a sbroad as possible and the next slide lists that criteria that we used to pick LER's that we wanted to review in detail.

COMMISSIONER GILINSKY: Do you think you got most of the ones that were significant? The reason I asked that was because some of them are described in such a cryptic manner that is hard to make out what actually happened.

MR. MINARICK: It is hard to make out what happened. What we did after we had identified these 169 events that we finally came up with, we went back and randomly selected from the data base and rereviewed to try to find which ones we had missed.

We feel, based on that review, that we have identified probably about 83 percent of those in the data base.

COMMISSIONER AHEARNE: What did you do? You took some 10 percent sample?

MR. MINARICK: It was a 10 percent sample.

COMMISSIONER AHEARNE: And then what?

MR. MINARICK: Then went through the entire process a second time. For the 529 events that we selected for detailed review, we did a detailed review. We considered the specifics of the actual event, what was reported to have failed or unavailable. We considered the impact of the event on reactor plant systems at the plant --

COMMISSIONER AHEARNE: Joe, I am sorry to interrupt again, but do you intend to go through your criteria?

MR. MINARICK: I did not intend that unless you were interested in doing that.

COMMISSIONER AHEARNE: I think it would be important since the final result you get is very interesting. It is useful to have at least a clear picture laid out of the criteria.

CHAIRMAN PALLADINO: And as you go through the criteria, at least in the selection of events as potential precursors, you gave some condition. I was wondering if you could give some examples?

MR. MINARICK: Yes, sir. I will do that. May I have the next slide, please?

(Slide.)

CHAIRMAN PALLADINO: I was thinking of the ones at the bottom of this slide.

COMMISSIONER AHEARNE: He is going to go back to that slide.

MR. MINARICK: This is the first narrowing criteria that we used.

CHAIRMAN PALLADINO: But now you said, selection of events as potential precursors if they resulted in the failure or function required to mitigate an off-normal event or accident.

MR. MINARICK: This was after the first selection criteria. The first pass we used this criteria on the next page and cut the number down to 529.

MR. BERNERO: This is the first screen. It gets you from 20,000 to 500.

COMMISSIONER AHEARNE: And then this is the second screen?

MR. BERNERO: Then what you were looking at is the second screen.

MR. MINARICK: Now we decided in the beginning that for the most part we would go beyond the single failure criteria. We see numerous LER's coming in where one component is unavailable for some reason for other, and we really didn't want to deal with those unless that had a major impact in itself, and rarely they did.

The criteria for the first screening, number one, any failure to function -- completely to function -- of a system that should have functioned as a consequence of an off-normal event or accident. For example, if an auxillary feed-water system in its entirety did not work when it was called upon to work either in testing or for some other demand, and we selected that for review, detailed review. Two, any instance where more than two failures occurred, be it in one system or in multiple systems.

Three, all events that resulted in or required initiation of safety-related equipment except those that require trip and when trip was successful, and we are not interested in simple reactor trips but any time, for example, that safety injection was initiated, we pulled that event for detailed review.

Four, all complete losses of offsite power and any less frequent off-normal initiating events or accidents.

CHAIRMAN PALLAINO: But you didn't necessarily decide to --

MR. MINARICK: No. At this point we hadn't decided anything. We were just collecting a number of events that we could spend more time with. An example of number four would be things such as small break LOCA's, stuck open PORV's, steam generator tube ruptures --

CHAIRMAN PALLADINO: Is that what you mean by "any less frequent off-normal initiating events."

MR. MINARICK: Yes, sir. Anything less frequent than typically 0.1 per year of offsite power. The only thing that is not included in this which is a classic initiating event is loss of main feedwater and that is not reportable in the LER system unless something else happens that requires reporting, excessive cooldown or safety injection, but there could be other things which consequentially would require reporting, but loss of the feedwater, in general, are not reportable.

Five, any event or operating condition that was not enveloped by or proceeded differently from the plant design bases.

COMMISSIONER AHEARNE: What is an example?

MR. MINARICK: I can't think of a specific one that we selected but, for example, if they had a loss of feedwater and auxillary feedwater system came on but worked only half way, but for some reason that wasn't good enough, it still maintained its function even through its redundancy was lost, and therefore, should have done its job, but didn't for some reason.

MR. BERNERO: I am not sure you used it, but you could have used this criterian to select the Rancho Seco lightbulb incident.

MR. MINARICK: Yes, and then the final one --

CHAIRMAN PALLADINO: I am not sure what you mean by, "from the plant design bases." Do you mean an accident or a situation that we had studied and said that it was going to go a certain way.

MR. MINARICK: For example, if there was a safety analysis done and if something happened and you expected the plant to respond in a certain way and it didn't for some reason. The final one is the "Gotcha" one; any other event that, based on the reviewer's experience, could have resulted in or significantly affected a chain of events leading to potential severe core damage. Lots of these that you see in abstract form if you go by the letter of the criteria would probably not be selected, but if they smelled a little bit, if something just wasn't right about them, if the way it was reported something seemed to be missing, we pulled those also for detailed review.

COMMISSIONER AHEARNE: Who were the reviewers?

MR. MINARICK: I was a reviewer. There were other people at Nuclear Safety Information Center, Mr. Scott who was there all the time.

COMMISSIONER AHEARNE: What I am basically getting at is you use number six to give confidence but if the key is the reviewer's experience --

MR. MINARICK: That's right.

COMMISSIONER AHEARNE: It depends on how much experience the reviewer has.

MR. MINARICK: The people who did review these had been involved in operations analysis review at NSIC for many years.

COMMISSIONER AHEARNE: Now on this list of six, this is generally what you use to go from the 19,000 plus down to 529?

MR. MINARICK: Yes.

COMMISSIONER AHEARNE: Do you, in retrospect, believe that you should have added something else to this list?

MR. MINARKC: I don't think so. I will say that I remember selecting some for detailed review based on number six. There is no question about that. But my own feeling and I think this is born out by other people at Nuclear Safety

Information Center, when these reviews are going on, you can set up some criteria to select by, but for some reason, you know in reading the event even before looking at the criteria, whether it is something that deserves further review. Sometimes you won't, and you will go back to the criteria and use it for justification.

But frequently you will now just by reading the abstract that it deserves further review.

COMMISSIONER AHEARNE: The uneasiness that I have in that answer is that that almost sounds like you don't need criteria which could lead you to miss something.

MR. MINARICK: No. I think we still need criteria and that is why we use this criteria. Nothing was missed because we did not apply the criteria.

CHAIRMAN PALLADINO What fraction of the decisions were influenced by number six? How many of the 529 came from number six?

MR. MINARICK: I don't know for sure. My feeling would be 10 to 20 percent.

MR. BERNERO: Incidentally, one of the values of peer review from IMPO is that they have a cadre of very experienced plan from the industry itself doing these same reviews and we get a good cross-check that way.

COMMISSIONER AHEARNE: Do you mean going through all those LER's?

MR. BERNERO: Yes. They go through all the LER's and their peer review is going to start at the other end and it is going to go down our list in order of sifniciance.

COMMISSIONER AHEARNE: So it isn't going to do a peer review of the 19,000?

MR. BERNERO: No. Indirectly we will get that, but don't think directly.

MR. MINARICK: May I have the previous slide, please?

(Slide.)

MR. MINARICK: Based on that criteria, we selected the 529 events that we wanted to review in detail and I want to reemphasize that criteria was applied and I don't feel that there was any sloppiness or personal opinion inviolating that criteria.

COMMISSIONER AHEARNE: I was just probing to see whether you had reached a conclusion afterwards that perhaps you should have added something else.

MR. MINARICK: No, sir, we did not. Also, not only one person looked at each LER, but these were looked at by several people and then anyone who wanted to or felt one needed review, that was then reviewed.

COMMISSIONER AHEARNE: Are these then the same criteria that you are using for the 1980 and 1981 column?

MR. MINARICK: Yes, they are.

MR. BERNERO: Once again keep in mind that these are the first screened. There is no judgment made about the significance of the event. It is just whether to expend the resources on detailed review.

MR. MINARICK: Once these 529 events were selected we did a detailed review and the detailed review for each of the 529 events considered the specifics of the actual event, what was reported as unavailable or failed or what human errors occurred or what initiating events, the impact of the event on reactor plant systems at the plant in which the event occurred. Now on some plants, certain failures are more serious than in other plants. So if an LER occurred on plant "A", we reviewed the plant systems for plant "A" in making our decision.

Also we considered the need for specific systems or portions of systems in the plant at which the event occurred for mitigating off-normal events or accidents.

CHAIRMAN PALLADINO: You did say that in evaluating these 529, you did apply it to the plant at which it did occur? Somehow I got the impression that you had some sort of generic type of plant -- that comes later?

MR. MINARICK: That comes later.

CHAIRMAN PALLADINO: Thank you.

MR. MINARICK: We selected events as potential precursors. This was the selection process. If they resulted in the failure of a function required to mitigate an off-normal event or accident. For example, a total auxillary feedwater and secondary heat removal failure.

CHAIRMAN PALLADINO: Either one or both?

MR. MINARICK: As a function either the ability to deliver auxillary feedwater or deliver the ability to remove decay heat from the steam generator by the dump valves and relief valves. In actuality, there were none of the latter. They were all the former.

We selected events as precursors if they resulted in the degradation of two or more functions. An example of this would be a case where at the same time a portion of a high pressure injection system was found failed and a portion of an auxillary feedwater system was found failed -- two had to fail, not a single one. This is basically a loss of redundancy of more than one item.

Three, we included unusual initiating events, losses of offsite power and less frequent initiators.

CHAIRMAN PALLADINO: That's what loops is. Again, by less frequent events, you mean less frequent than loss of offsite power?

MR. MINARICK: Yes, sir. May I have two slides forward, please?

(Slide.)

MR. MINARICK: One hundred sixty-nine events were selected as precursors to potential severe core damage based on these reviews. These 169 events were documented, categorized and mapped onto event trees which described the sequence of actions required to mitigate a transient or accident. The event tree chosen for each precursor was based on the most likely initiating event or transient which could have been affected by the reported failures.

This information is what is in Volume 2. Volume 2 is basically a compilation of four or more pages of information on each of the 169 events.

COMMISSIONER AHEARNE: Now you say an initiating event could have been affected by the failure.

MR. MINARICK: Yes, sir. Let's as an example take the old auxillary feedwater system failure and assume it was found failed during testing. In actuality what happened was they tested the system and it was found failed. There was no loss of main feedwater and no other event where auxillary feedwater was required during the time that it was failed, but there was a potential for such events.

For these situations where we found failures where no initiating event occurred as part of the failure, we stepped back and said, "All right, what would be the most likely initiating event which would have been impacted by that failure," and we chose that.

COMMISSIONER AHEARNE: Do you mean the most likely initiating event which could have lead to that failure?

MR. MINARICK: No, sir, where mitigation of that initiator would have been impacted.

COMMISSIONER AHEARNE: All right. So the outcome of an initiating event would have been affected by that but the initiating event, itself, would not have been made more likely.

MR. MINARICK: No, it would not have been made more likely. As I said, these are the 169 events documented in Volume 2.

CHAIRMAN PALLADINO: How did you go from --

MR. MINARICK: The 529 was dropped to 169 by the detailed selection criteria for precursors which is the bottom bullet on slide two ahead of where we are now.

COMMISSIONER AHEARNE: Now, did that entail pulling the LER reports?

MR. MINARICK: Yes, sir. It entailed pulling the LER reports, looking at safety analysis reports and where possible obtaining additional information that was available at Nuclear Safety Information Center.

May I have the next slide, please?

(Slide.)

MR. MINARICK: Now if we did our job correctly, we should have identified all failures, complete failures of functions, and initiating events of interest which were reported in the LER system during 1969 to 1979.

Based on the demand failure and unavailability information contained in the potential precursors, failure probabilities were calculated for the functions included in the event trees and these are in Volume 2 used to describe each precursor.

CHAIRMAN PALLADINO: What is a demand failure?

MR. MINARICK: Most of the failures that we found were found either during testing or during an actual demand. I would say 80 percent were found during testing. There were several other failures which were simple unavailabilities. They took a diesel generator out for maintenance and when testing the second one, it failed and the system was unavailable for a short period of time.

CHAIRMAN PALLADINO: Is that what you call a demand failure?

MR. MINARICK: The demand failures are the ones that occurred either during testing or on demand because of an initiating event.

MR. BERNERO: Failure to start when commanded basically.

COMMISSIONER AHEARNE: That includes those where the demand was in part of the test?

MR. MINARICK: Yes, sir, it does. Now the next slide which is a little bit difficult to read unfortunately. This, by the way, is table C-1.

CHAIRMAN PALLADINO: Even under magnification it is difficult to read.

(Slide.)

MR. MINARICK: If you need something better, this is table C.1 on page C-5 of the main body of the report. I would like to go over briefly of one example of how we calculated these demand failure probabilities. It is one of the first fold-out pages.

As an example of how we went through this process --

CHAIRMAN PALLADINO: What is this table again?

MR. MINARICK: This is a table which describes the information we used in coming up with the demand failure probabilities that we used subsequently in the report.

As an example of how we approached the problem, let me take the auxillary feedwater system again. There were eight failure of the auxillary feedwater system that we found reported in LER's during the 11 year period.

Now some of these were failures where we felt that nothing in the short term could have been done to get the system to work. Others were failures where in actuality while the system failed, the operator could have gone over to something else in the control room and initiated the system manually.

There were several other failures where you could not do this from the control room or if you could do it from the control room, it would have taken him time and he could have done it at the component itself, the failed components. In those two cases, we felt it was unfair to count those as total failures and we applied weighting factors to those.

What we did was we took the eight events, we reviewed the events and came up with some severity factor which is basically the chance of failing to rectify the problem in the short term, say in a 20 minute period or something of that order.

CHAIRMAN PALLADINO: How did you get that?

MR. MINARICK: By actual review of what had failed during each of the events.

COMMISSIONER AHEARNE: And this is the potential to rectify?

MR. MINARICK: Potential to fail to rectify.

COMMISSIONER AHEARNE: Yes. But the potential did not have to have happened?

MR. MINARICK: That's right. In all these cases, it is difficult to day -- in these cases, I believe all these were found during testing. There was no immediate need for the system and it was repaired.

COMMISSIONER AHEARNE: All of them? Including the last one?

MR. MINARICK: The last one -- I am sorry. There wasn't immediate need and it was initiated after 20 minutes.

MR. BERNERO: It was less than 20 minutes.

MR. MINARICK: We applied these weighting factors to each of the events and came up with a failure number which was based on summing the weighting factors.

COMMISSIONER AHEARNE: On your weighting factors, did you only have the three values?

MR. MINARICK: We only had the three values and I will admit that some people will feel that they are overly pesimistic. We did not want to say that everything was a failure and just go blindly with that, so we came up with the three values.

COMMISSIONER AHEARNE: I wasn't going to criticize the choice of three or even the values. I just wanted you to explain once again the distinction between those three.

MR. MINARICK: The three values of distinction is if we felt a failure could not be rectified in approximately 20 to 30 minutes, it was a total failure.

COMMISSIONER AHEARNE: So the weighting was 1.0.

MR. MINARICK: The weighting was 1.0. If it could have been rectified by going to the actual components that failed and there at the components getting them going, we applied a weighting factor of 0.5.

COMMISSIONER AHEARNE: Again with the 20 minute time frame?

MR. MINARICK: That's right. And in the control room, something easy that the operator could simply have gone and figured out that something had not started and then something else in the control room, we would apply a 0.1 to the failure.

CHAIRMAN PALLADINO: Then how did you use those weighting factors?

MR. MINARICK: Then these effective failure numbers, these weighting factors, were summed to arrive at an effective total number of failures seen over the 11 year period.

COMMISSIONER AHEARNE: So you would count, for example, on this list rather than 8.0, you would have added up to 6.1.

MR. MINARICK: 6.1.

COMMISSIONER AHEARNE: Now does that mean that if your LER had indicated a system failure that had been rectified within 20 minutes, you would have not counted it?

MR. MINARICK: No, we still counted them and we applied these 0.1's and 0.5's to them.

COMMISSIONER AHEARNE: So then the description -- it is not only if it could have been including if it was -- so for example, if it was rectified within 20 minutes by something in the control room, it would still be 0.1?

MR. MINARICK: Yes. I will say on the control room ones that some of these and I am not sure on this auxillary feedwater one, but when the evolution was particularly complicated or unusual but still occurred in the control room, we sometimes did use a 0.5 rather than a 0.1. There are a couple of cases where that did happen. The 0.1 we are dealing with when something failed to start and the operator went over and did something. He knew the problem existed and he analyzed it very quickly and corrected it in the control room.

TMI-2 is an example where we felt that really weighted a 0.5 rather than a 0.1 because it was not instantly discovered and corrected.

COMMISSIONER AHEARNE: Are you also saying that you have applied the judgment that in addition to whether it could be controlled within the control room, you are saying how difficult would it be for the operator or operators to figure out what to do, and if it was very difficult even if controllable, then it would be a 0.5?

MR. MINARICK: Yes. There were only several cases where that occurred.

CHAIRMAN PALLADINO: How do you use the 6.1?

MR. MINARICK: The 6.1 was the effective number of failures that we came up with and this counts the one total failure which was rated 1.0 and 0.5's and 0.1's. This is the number of effective failures that we observed as reported in the LER system over the 11 year period.

We then went and tried to make reasonable demand assumptions that we expected the aggregate of auxillary feedwater systems to have seen in that 11 year period. What we assumed was 12 demands per year for testing plus one demand for shutdowns of less than 48 hours. This is engineering judgment. We felt for short shutdowns, that they would simply stay on the auxillary feedwater system, but for long shutdowns, that they would go on the auxillary feedwater system, cool down, go on the decay heat removal systems and then go up and in many cases use the auxillary feedwater system during the start-up procedure.

So what we did was we just didn't say, "Well, there are 12 testing demands per year," and that is all. We added other demands that we thought the auxillary feedwater system would have seen.

We did this for plants that have auxillary feedwater systems, PWR's, the effective number of years for PWR's and came out with approximately 5,600 demands over this period of time.

Based on that we said, therefore, we say 6.1 effective failures out of 5,600 estimated demands and hence, our demand failure probability estimate was 1.1×10^{-3}.

CHAIRMAN PALLADINO: These were the effective number of failures, the 6.1.

MR. MINARICK: Yes, sir.

CHAIRMAN PALLADINO: Now you are trying to estimate how many demands all the plants with PWR's for the whole experience?

MR. MINARICK: Yes, sir.

CHAIRMAN PALLADINO: Is it possible to confirm the number of demands?

MR. MINARICK: I cannot confirm that with the information at Oak Ridge. I would think that that would take a plant-by-plant review of information at the plants.

MR. BERNERO: It is frequently a problem because the LER's don't report successful demands. They only report the failure.

CHAIRMAN PALLADINO: Do you feel pretty confident in this 5,600?

MR. MINARICK: I feel it is a justifiable number.

CHAIRMAN PALLADINO: At least by an order of magnitude.

MR. MINARICK: Yes, certainly.

COMMISSIONER AHEARNE: Of course, that is something I would guess some of your peer review will speak to because that is operational experience.

MR. BERNERO: Yes. At Oak Ridge with the staff and with the various people who have looked at it, we haven't had any distress with that, but when we get the plant people, that could change.

CHAIRMAN PALLADINO: So now you get that one out of 1,000 times it will fail?

MR. MINARICK: That's right.

CHAIRMAN PALLADINO: Roughly over 6,000.

MR. MINARICK: So this is the process that we used. All the information that we used in developing these numbers is included in this table C-1 and is available for peer review.

COMMISSIONER AHEARNE: The way you have done that calculation, tell me if this is right or wrong. It seems to me that what you are assuming is that if appropriate operator or maintenance personnel action can occur, that it will occur, so you are downgrading the severity.

MR. MINARICK: We are assuming that if appropriate action could occur, we are saying that it would reasonably occur with those severity numbers, that is correct.

COMMISSIONER AHEARNE: So inherent in this, there is an assumption that appropriate personnel behavior will occur?

MR. MINARICK: That's right. I feel that these are reasonable --

CHAIRMAN PALLADINO: At least nine times out of ten.

MR. BERNERO: It is a recovery model. In TMI-2, the auxillary feedwater system was blocked because two remotely operated valves in the control room were closed. Now under ordinary circumstances an indicator shows, the man merely reaches over and "Click-click," he turns them on. A 0.1 severity can be assigned. This is a confusing scenario as we well know so a 0.5 severity was put on that one.

COMMISSIONER AHEARNE: I am just trying to understand and I am not looking at this particular calculation. It is just that I am assuming that you are using this as an illustrative example so that embedded in here is --

MR. BERNERO: That recovery factor.

MR. MINARICK: The recovery factor.

COMMISSIONER AHEARNE: I guess part of the reason you are using that is, as you have pointed out, that a number of the data you have are really failure on the tests and so you can't really tell whether if it failed in an actual or real demand, how the operator would react.

MR. MINARICK: That's right, but the information that we have also was that it was apparent in the short term that the operators understood what the problem was.

COMMISSIONER AHEARNE: In the test.

MR. MINARICK: In the test, that's right.

CHAIRMAN PALLADINO: Is there anything peculiar in the test that would not exist in an actual demand?

MR. BERNERO: Relaxation. In a test, they are calm. They are not excited. They are not worried. They are not stressed, and therefore in a real situation, there would be that higher level of stress which could affect their performance. Some people think that can improve their performance.

CHAIRMAN PALLADINO: Do you mean on the people or on the equipment?

MR. BERNERO: On the people.

CHAIRMAN PALLADINO: But there is nothing that would make a test different insofar as the performance of the equipment?

MR. BERNERO: Not in these particular situations. Like aux feedpumps, they pump them on recirculation and things like that. There were a few cases where valves in tests are not closing against differential pressure, something like that. But in our evaluation of the thing, we have to deal with that, the design of that.

CHAIRMAN PALLADINO: I am thinking of the following which is the best example I can think of. If I want to test something and I push a button and I don't get a response, it could be because something is wrong with the button and has nothing to do with the signal that it would actually get. Is there any difference such as that?

MR. MINARICK: If we felt reasonably confident that the licensee's assessment of a failure was correct and stated that this would not have occurred during an actual initiation and if we believe him and if he provided enough information, we did not consider -- yes, there were some of those.

Based on this process, we developed -- next side, please.

(Slide.)

MR. MINARICK -- initiating event frequencies and demand failure probabilities for different functions and initiating events of interest. These are most of the items that are included in the headings on the event trees. There are some that are included here. They are justified in Table C.1. They are items which did not have any information within the data base to come to a conclusion.

CHAIRMAN PALLADINO: You say "Combined PWR and BWR loss of offsite Power," do I divide by 70 here assuming there are 70 plants?

MR. MINARICK: No. This is a frequency per year.

CHAIRMAN PALLADINO: Per reactor?

MR. MINARICK: Per plant year.

MR. BERNERO: Per reactor per year.

CHAIRMAN PALLADINO: So it is per reactor.

MR. BERNERO: One chance in 25 per reactor per year that offsite power will be lost for 30 minutes or more and notice that condition. That is not a quick blackout.

CHAIRMAN PALLADINO: You are saying that this came from the experience?

MR. MINARICK: Yes, it did. We can go over these.

CHAIRMAN PALLADINO: No. I was just trying to understand what the meaning is.

COMMISSIONER AHEARNE: I haven't really figured out what uncertainty estimate would be appropriate to place on these but perhaps you have.

MR. MINARICK: We have not done any statistical uncertainty analysis to date on the project.

MR. BERNERO: Up to now we have arm waving. This is one of the things that is being worked on. It is very difficult.

MR. MINARICK: As you can imagine, for example, even the six auxillary feedwater system failures, that is not very significant as a statistical data base.

CHAIRMAN PALLADINO: You are saying that four percent of the time when these plants are operating, they are going to be devoid of offsite power for 30 minutes.

MR. MINARICK: Per plant year --

MR. BERNERO: Four percent chance in a year.

MR. MINARICK: Four percent chance in a year at each plant. That is a generic number.

COMMISSIONER AHEARNE: Having a loss.

CHAIRMAN PALLADINO: At that particular plant.

MR. BERNERO: That is the average for the industry.

COMMISSIONER AHEARNE: And it is four percent plus or minus.

MR. BERNERO: What did WASH-1400 predict, 0.04.

CHAIRMAN PALLADINO: Based on the data, there should be no uncertainty.

MR. BERNERO: Perhaps the more significant thing is there is variation across the country in the reliability of offsite power and this is a rather simplistic way to look at it on the national average. The grids differ. The northeast doesn't lose it very frequently but when it does, it stays down and things like that.

CHAIRMAN PALLADINO: Then you take something like this and do you assume the loss of power and say what is going to happen?

MR. MINARICK: That depends on the particulars of the 169 events and I will go into that in the next slide. Anyway, this table is a listing of the failure probabilities and that is per demand or the frequencies per reactor plant year that we observed in the precursor data.

CHAIRMAN PALLADINO: Was there something peculiar between BWR's and PWR's that they should lose power at different rates?

MR. MINARICK: I don't think so.

CHAIRMAN PALLADINO: Just different parts of the country.

MR. MINARICK: That is within the statistical bounds. I can't really say anything.

CHAIRMAN PALLADINO: Is there some implication that they are different in your analysis?

MR. MINARICK: No. I don't think you should take any implication.

COMMISSIONER AHEARNE: I don't think they are yet prepared to say that a factor of 1.6 is very significant.

CHAIRMAN PALLADINO: But since they have it listed here, I wanted to make sure what significance was being attached.

Now all of these came from the data that you got from the LER?

MR. MINARICK: That's right. From the 11 years of information in the 169 precursors.

MR. BERNERO: Then in the report they are compared to the predictions in WASH-1400.

(Slide.)

MR. MINARICK: Now based on the calculated failure probabilities that I just talked about and the degraded and failed states that existed during each percursor event, the probability of subsequently going to severe core damage given the precursor conditions was determined using the event trees that were drawn for each precursor.

COMMISSIONER AHEARNE: These event trees were the ones Bob mentioned. These are WASH-1400 event trees?

MR. MINARICK: They have been developed from WASH-1400 adapted.

COMMISSIONER AHEARNE: Could you say a few words about what that means?

MR. MINARICK: They are functionally-based trees. They are not system-based trees. We had to do that because systems differ plant to plant. I would say that they are consistent with the function trees in WASH-1400 to the core damage point.

MR. BERNERO: The logical structure of which question you ask yourself first in the systematic appraisal of whether the plant can make it or not is drawn from WASH-1400, but then since plants do differ and lack certain systems or have substantive differences in the systems, you have to --

COMMISSIONER AHEARNE: So you are saying that the primary difference between what you are using and if one goes and looks at WASH-1400 is 1400 being focussed on two specific plants.

CHAIRMAN PALLADINO: Could I understand what you mean? The probability of subsequent severe core damage given the precursor conditions? When you get that probability, do you multiply it then, for example, by 0.04 if it is offsite power?

MR. MINARICK: Yes.

CHAIRMAN PALLADINO: To get the total probability.

MR. MINARICK: Yes, and may I have the next slide?

(Slide.)

MR. MINARICK: This is an example event. This is an event tree for a loss of offsite power in a PWR. The example event of interest is a failure of the emergency power system reported in the LER --

COMMISSIONER AHEARNE: You said for PWR, but your chart is for both PWR and BWR, isn't it?

MR. MINARICK: We did use a combined number and I talk in the report about the fact that since we didn't feel that there was any real difference --

COMMISSIONER AHEARNE: All right.

MR. MINARICK: In this event, the diesel generators were found unavailable for 7.5 hours.

CHAIRMAN PALLADINO: How did you find that?

MR. MINARICK: By a review of the LER, itself. They indicated how long the system was unavailable. In this case, it was 7.5 hours.

COMMISSIONER AHEARNE: Are you saying that the previous number of 1.041 for loss of offsite power where you were saying it was for greater or equal to 30 minutes, it is really for 7.5 hours?

MR. MINARICK: Excuse me. Let me start over again in explaining the process we went through. In this example what I am talking about is a precursor event we identified in which the diesel generators were reported unavailable for 7.5 hours. That was the identified event.

CHAIRMAN PALLADINO: Where were they?

MR. MINARICK: This particular event occurred at Calvert Cliffs.

CHAIRMAN PALLADINO: This was a particular case?

MR. MINARICK: Yes, this is a particular case. This is one of the two examples in the main body of the report. We felt that there was a 50/50 chance --0.5-- that they would in the short term be able to get those diesels going if needed.

CHAIRMAN PALLADINO: What is that 0.75?

MR. MINARICK: That is a failure of the turbine generator to run back given the loss of offsite power and assuming house loads. This is where the plant actually stays on line even though the grid goes down.

CHAIRMAN PALLADINO: Where do you get that number?

MR. MINARICK: That number was an engineering judgment number. There are only a few plants that have the full runback capability from 100 percent power, or something like that. There have only been a few cases seen where it actually had been successful, so we used a 0.75 number for failure in plants.

CHAIRMAN PALLADINO: Let's see. You are analyzing the case where specifically there was a 7.5 hour unavailability of --

MR. MINARICK: At least two. I can't remember all the details of this event.

MR. BERNERO: On site AC emergency power.

MR. MINARICK: The function is the important thing.

COMMISSIONER AHEARNE: And you are combining this with the total loss of offsite power.

MR. MINARICK: That's right, and as you can see here what we did was we said, "All right, the chance of emergency power being failed was a 0.5."

CHAIRMAN PALLADINO: Where are you?

MR. MINARICK: On the event tree, down in the hashed, cross-hatched, under emergency power.

CHAIRMAN PALLADINO: Now what is it that we are doing with 0.5? We are saying that it is a 50/50 chance?

MR. MINARICK: That they could recover the diesels in the short term giving the specifics of this failure event.

COMMISSIONER AHEARNE: Is that equivalent to your severity factor?

MR. MINARICK: Yes, it is equivalent to the severity factor.

CHAIRMAN PALLADINO: Now how do you get that number?

MR. MINARICK: That was based on a review of the specifics of the failure as reported and it is equivalent to the severity factors listed in table C.1.

CHAIRMAN PALLADINO: Can I come back to the entry point? It seems to me like there is some probability needed. Not every case where you have loss of offsite power do you find a diesel generator down.

MR. MINARICK: That's right. For this specific event --

CHAIRMAN PALLADINO: So this is a conditional type of probability.

MR. MINARICK: That's right.

CHAIRMAN PALLADINO: Must not I introduct that as another factor in evaluating this?

MR. MINARICK: What we did here was to say, all right, these diesels were unavailable for 7.5 hours, what was the chance of losing offsite power for 7.5 hours? So we took the 0.041 per year times 7.5 hours over hours per year and came up with a 3.5×10^{-5} probability of losing offsite power during that 7.5 hour period.

CHAIRMAN PALLADINO: All right. So you did take care of that. Now I am ready to follow you.

MR. MINARICK: So those numbers plus the other generic failure numbers that we had developed previouly were placed on the tree and the branches which went to potential severe core damage were calculated to come up with an overall probability measure associated with this event.

COMMISSIONER AHEARNE: Could you walk through both branches?

MR. MINARICK: Yes, I can. What we said was that this event did occur at power. The chance of losing offsite power was 3.5×10^{-5}. If turbine generator run back had been successful and based on simple engineering judgment, we said that it may be successful in 25 percent of the cases, nothing would have happened and the plant would simply have been up and generating power itself, its own electric loads.

If turbine generator run back had not been successful and emergency power was required at the plant, then we felt for this event that there was a 0.5 chance that emergency power would not have been available, that weighting factor, that 0.5 chance that emergency power would have been available.

Now if emergency power was available, there are still other failures which could have caused problems. For example, we list auxiliary feedwater in here with a probability of failure. We also assume based on engineering judgment a number for the fact that the power operated relief valve may have lifted during the transient and failed to --

COMMISSIONER AHEARNE: That is 0.1?

MR. MINARICK: Yes, 0.1.

COMMISSIONER AHEARNE: That is your engineering judgment?

MR. MINARICK: That is an engineering judgment number.

CHAIRMAN PALLADINO: What is this -- (indicating.)

COMMISSIONER AHEARNE: 0.1×10^{-3}.

CHAIRMAN PALLADINO: What is that then?

COMMISSIONER AHEARNE: That is the aux feedwater. That is the case where the emergency power is successful but then the aux feedwater fails.

CHAIRMAN PALLADINO: All right. Going up means --

MR. MINARICK: Going up is success, going down is failure.

So what we included was we included the chance that a PORV would have been demanded and failed to reclose and also failure that the operator would detect it and close it for that branch which is an open PORV, we considered the potential that the high pressure injection system --

CHAIRMAN PALLADINO: Could I just ask you -- when you have 0.1 for PORV demand, are you saying only 1 out of 10 will the PORV open?

MR. MINARICK: Yes, that was an engineering judgment. These are Westinghouse plants.

CHAIRMAN PALLADINO: Are you saying that PORV's are so unrealiable that only 1 out of 10 --

MR. MINARICK: No, sir. What I am saying is in this transient where you would trip from full power, that the thermal hydraulic characteristics at the time were such that there would be a 1 chance in 10 that you would open that relief valve just because of pressure in the reactor coolant system.

It is demanded and it opens. This 0.1 has nothing to do with its closure.

CHAIRMAN PALLADINO: Whatever it is supposed to do, it would do. In 90 percent of the time --

MR. MINARICK: It would not open at all.

CHAIRMAN PALLADINO: It would not even demand it.

MR. MINARICK: It would not demand it.

CHAIRMAN PALLADINO: All right.

COMMISSIONER ASSELSTINE: But again that is based upon the particular characteristics of this particular plant.

MR. BERNERO: The B&W plant, that number would be different.

COMMISSIONER AHEARNE: That's right.

CHAIRMAN PALLADINO: Are we analyzing the particular plant here?

MR. MINARICK: The sequence is a generic sequence which is modified as much as reasonable based on the specifics of a particular plant. For example, --

COMMISSIONER ROBERTS: Is that is conflict with your earlier statement that you use functional trees rather than system?

MR. MINARICK: No.

MR. BERNERO: You ask the same questions about the functions. You will get different answers though because the functions response into PORV is a very good example. It is quite different from one plant to the next.

MR. MINARICK: We included a probability that the PORV would fail to close and that that failure would not be detected by the operator or if it was that he would err somehow in failing to close the valve either because he would not detect it open or the isolation valve itself would fail to close.

COMMISSIONER AHEARNE: That is --

MR. MINARICK: That is 2.9 x 10^{-3} and I describe in Table C.1 how I arrive at that number.

On this particular branch given that the relief valve is opened, we include a branch for failure of high pressure injection to be initiated and we also include a branch for failure of long term core cooling to work after high pressure injection has been initiated.

CHAIRMAN PALLADINO: I didn't take time to try to find out how you got these kinds of numbers.

MR. MINARICK: These numbers except for the specific failure numbers in this case, the one under emergency power, and the 7.5 hours and these other numbers were the generic numbers that I talked about deriving earlier from table C.1.

CHAIRMAN PALLADINO: If I go to that, could I figure out how you got the 3.9 x 10^{-3}?

MR. MINARICK: Yes, sir, you could. I give that information in there.

CHAIRMAN PALLADINO: Is that coming from data?

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MR. MINARICK: Again, that is derived from the number of reported incidents.

COMMISSIONER ASSELSTINE: And the weighting factors and all those other things.

CHAIRMAN PALLADINO: But you have enough LER data to come up with something on every one of these?

MR. BERNERO: It is those values that are given two slides before that were extracted from the LER's.

CHAIRMAN PALLADINO: I didn't realize you had gone all the way down to getting --

MR. MINARICK: That table includes all of the functions listed on the top of the event trees.

CHAIRMAN PALLADINO: Now when you come down, it is modest statistics, do you have some of these others in sufficient number?

MR. BERNERO: Very sparse data.

COMMISSIONER AHEARNE: Sparse data.

MR. BERNERO: We would be the first to admit that.

COMMISSIONER AHEARNE: Remember you are down to 169, right.

MR. MINARICK: That's right.

MR. BERNERO: We are down to a mere handful of events.

MR. MINARICK: And even if we have identified, for example, all of those auxiliary feedwater system failures, if that number is correct and the number that occurred is equal to the number that we found reported, what we are dealing with in that entire period are effectively six failures that you would see.

COMMISSIONER ASSELSTINE: How many failures do you recall offhand you had for long-term core cooling?

MR. MINARICK: I don't recall offhand.

MR. BERNERO: That is why we have predictions and not merely LER analysis.

COMMISSIONER AHEARNE: Joe, when you come down that tier on failure of the aux feedwater, if you go to the next block cown where you have the failure of the aux feedwater and secondary heat removal --

MR. MINARICK: Is this on emergency power success or emergency power failure?

COMMISSIONER AHEARNE: We are still on emergency power success?

MR. MINARICK: Yes.

COMMISSIONER AHEARNE: You had one branch which was the success of the aux feedwater --

MR. MINARICK: And one branch which was the failure.

COMMISSIONER AHEARNE: Now if you follow the failure over, when you get to the high pressure injection as opposed to the 1.3×10^{-3} --

MR. MINARICK: Now what this is, this event occurred after Three Mile Island when people realized that you could use feed and bleed as a potential mechanism for removing decay heat even if your auxiliary feedwater system failed and the numbers that we used for that use of the high pressure injection system was successful or not. On plants such as B&W plants where they have high pressure high injection pumps which are large and can go up against the relief valves, we assumed that the failure of doing that was 0.1. For plants where they do not have high pressure injection pumps and instead have to depressurize the system to use a safety injection pumps, we assume the 0.5 success or failure probability.

CHAIRMAN PALLADINO: Now you said you assumed. I thought all of these reflected LER data.

MR. MINARICK: In this case, this does not and this was a number which was discussed with the staff.

COMMISSIONER AHEARNE: So you are essentially saying that this is a feed and bleed success.

MR. MINARICK: This is a feed and bleed success.

CHAIRMAN PALLADINO: So when you are lacking data in some of these, you have to make some estimates.

MR. MINARICK: That's right, and I talked on table C.1 in all these cases where it is different from data, I justified the numbers that we used.

Now if we can go down on the emergency power failure curve which we assigned the probability of 0.5, there are several other things on that. The primary thing is on this plant, if emergency power is not available, there is a turbine driven auxiliary feedwater train which can be used, however, it does require operator action to initiate, I believe on this one, some of the valves which are motor operated valves need to be opened by hand and in this case, we assume that the failure probability of that one train was 0.1.

COMMISSIONER AHEARNE: This is related back to again your severity weighting?

MR. MINARICK: No. This is related to the fact that even if you lose emergency power on this plant, there is still one train of auxiliary feedwater which is turbine driven.

COMMISSIONER AHEARNE: Right. But is your 0.1 --

MR. MINARICK: It is not a severity rating, no. It is an engineering judgment based on the characteristics of the auxiliary feedwater system.

So these are the numbers on the tree. We then took and looked at the branches which could go to potential severe core damage and came up with a probability number.

CHAIRMAN PALLADINO: That is what I am reading.

COMMISSIONER AHEARNE: Let me ask you a question on the failure, the 0.5 that you calculated. The emergency power that has failed in this case, is that the diesel generators?

MR. MINARICK: Yes.

COMMISSIONER AHEARNE: And your 0.5 is the estimate. In this particular case, you are dealing with the event where the diesel generators were out for 7.5 hours.

MR. MINARICK: That's right. The specifics of that event.

COMMISSIONER AHEARNE: And the 0.5 indicates that -- does it indicate that had they been needed, that then there was a likelihood that they would have been --

MR. MINARICK: Our estimate was that based on the characteristics of why they were out that there was a 50/50 chance that if they were needed, they could have gotten going in that time period.

We did this type of approach for all 169 potential precursors and came up with a distribution of probability measures shown on the next slide. I want to make it clear that when we went through this calculation while certain aspects were plant-specific, there was a lot of generic information used and, as such, this is a measure of the probability of that sequence but the number cannot be specifically tied to a probability at the specific plant that the events occurred at.

(Slide.)

COMMISSIONER AHEARNE: What is the significance category?

MR. MINARICK: The significance category is a mechanism that we use. It is simply related to the probability measures. It is a logarithm. It is just an accounting method that we used.

COMMISSIONER AHEARNE: So it is not anything different.

MR. MINARICK: It is nothing different. It is just a way of getting these numbers onto a computer chart and use it in the computerized listings in the report.

For example, a 10^{-3} corresponds to a 30.

COMMISSIONER AHEARNE: So at least for chart purposes you could just strike that whole --

MR. MINARICK: That's right. It appears in the report this way. May I have the next slide, please?

COMMISSIONER AHEARNE: The reason I raised that -- are you saying that -- are the events that are counting in here is the culmination, is that correct?

MR. MINARICK: The probability measures we are calculating are the end result of that calculations.

COMMISSIONER AHEARNE: So if you are looking at this particular chart, this event tree, for example, what was the end number that you ended up with?

MR. MINARICK: I don't remember what it was. It was very small. It was 1.3×10^{-6}.

COMMISSIONER AHEARNE: That tracks the number. All right. So that would have shown up down here in your block between 50 and 60.

MR. MINARICK: Yes.

COMMISSIONER AHEARNE: Is there an implication and maybe it is a correct one, that you are talking about potential severe core damage so that any event is equally significant?

MR. MINARICK: We don't feel every event was equally significant and the first reason for going through these probability calculations was to rank events so that we could determine for trending which events were more significant.

COMMISSIONER AHEARNE: Let me try to say it differently. The net result of an event tree leads to --

MR. MINARICK: Potential core damage.

COMMISSIONER AHEARNE: Well, to some type of core damage.

MR. MINARICK: That's right.

COMMISSIONER AHEARNE: There are two items of significance there; one is, how significantly damaged is the core and two, how likely is the event. That is your probability. Now when we look at this kind of distribution, you are plotting explicitly the probability.

MR. MINARICK: That's right.

COMMISSIONER AHEARNE: Is there then the implication that every data point has two characteristics. One is the probability it happens and the second, given that it happens, how important is it or should one conclude that given that it happened, all events are equally important?

MR. MINARICK: While in reality, of course, there are degrees of core damage, but what we did was we did not consider those.

MR. BERNERO: I think the question is basically we are not dealing in consequence base at all. The event is a singular event, severe core damage. Really it is failure to deliver the required safety cooling water or whatever it is.

The issue is for individual events in LER's, are they significant contributors to the overall probability of suffering severe core damage or insignificant contributors. This methodology is a structured way to take an event and to evaluate its level of contribution, its level of significance, and you get either a very high probability number and therefore a high significance or you get a low probability.

COMMISSIONER AHEARNE: But you are saying that the significance is solely a function of probability.

MR. BERNERO: Yes. Now if you ran out an event tree for an initiating event, if you found a "ho-hum" LER and we lost offsite power and everything worked, you would get a very low significance.

(Slide.)

MR. MINARICK: Just as a point, the distribution is the way it is for two reasons, one, of course, is that the most significant events are a lot less frequent than the lesser significant events and two, the selection criteria was such that we tended to ignore stuff.

COMMISSIONER AHEARNE: I thought we just finished discussing that the significance is solely an expression of probability.

MR. MINARICK: It is.

COMMISSIONER AHEARNE: So --

MR. MINARICK: What I was trying to say was that the hump is in here because of the way the selection criteria worked in that events which were single failures and which you would expect to appear in large numbers are not in the --

MR. BERNERO: Nineteen thousand of them got thrown out.

MR. MINARICK: That is all I wanted to say.

CHAIRMAN PALLADINO: Did you just explain this.

COMMISSIONER AHEARNE: Feel free to ask again.

CHAIRMAN PALLADINO: My question was, could you explain the chart, but if you have done it, there is no reason and I will get with Bob later.

MR. MINARICK: The probabilities of subsequent severe core damage determined for precursors associated with initiating events were used to estimate the frequency of severe core damage during the 1969 - 1979 period. We came up with a point estimate based on this sparse information, based on only 1969 to 1979 information and it appears to be in the range of 1.7 to 4.5 x 10^{-3}.

COMMISSIONER AHEARNE: Can you go from this chart to that statement?

MR. MINARICK: I really can't. I can in a way. This chart --

CHAIRMAN PALLADINO: Would it take long to explain that chart?

MR. MINARICK: The chart or the statement?

CHAIRMAN PALLADINO: The chart because I have a feeling it relates to the statement.

MR. MINARICK: The chart does not really relate very much to the statement. The chart is simply a representation of the number of events we found with differing probabilities.

COMMISSIONER AHERNE: You had the 169.

MR. MINARICK: That's right.

COMMISSIONER AHEARNE: And you then put them through the event trees and this is now the final result of that for each one of those events, is that correct?

MR. BERNERO: Let me ask Mr. Minarick if it would be fair to say that that histogram, that chart, represents all of the contributors to severe core melt probability arranged by their significance or by their respective probability contribution so that most of the events that build up to this final result are in the highest bar, but you get some contribution from the lower bars?

CHAIRMAN PALLADINO: You are saying, for example, that those ten between 70 and 80 are in the range of 10^{-7} to 10^{-8} probability?

MR. MINARICK: That's right.

MR. BERNERO: Yes.

CHAIRMAN PALLADINO: Per what?

MR. BERNERO: Everything is per year, per reactor year. It also would tell you if you go to the top end of the significance band, I believe, and arbitrarily chose to neglect events, it will tell you how much of your limited data base you are throwing out.

If you chose to throw out Three Mile Island, don't count it. Don't count it in this distribution or other events like it, grave events. You would go up to the left hand end of that chart, and throw out that contributor.

CHAIRMAN PALLADINO: Which is it?

MR. BERNERO: From 1 to 10^{-1}. This gives you a sense of how much the data base relies on the analysis that happens to be a real core damage accident, Three Mile Island or Brown's Ferry which was so close or appeared to be.

CHAIRMAN PALLADINO: Are you saying that because it happened that its probability is between 1 and 10^{-1}.

MR. MINARICK: The probability we assigned, for example, to TMI was 1.0.

MR. BERNERO: A real event.

MR. MINARICK: It was a real event.

MR. BERNERO: You see, we use severe core damage rather than core melt.

CHAIRMAN PALLADINO: That doesn't say that that is the frequency you are going to have.

MR. BERNERO: Once per 11 years. The actual experience is once per 11 years.

MR. MINARICK: The experience is that it actually happened.

MR. BERNERO: Once in 432 reactor years out of that data base.

CHAIRMAN PALLADINO: That is one of the problems I think I was talking to John on the side. If you happen to get 1 in 10,000 reactor years during this ten year period, it will look like 1 in 10 years.

MR. BERNERO: Yes. That is why you want to see how much does it dominate the prediction.

CHAIRMAN PALLADINO: Or 1 in 400.

MR. BERNERO: That is why you would take it out and see what the result would be without it which they did.

CHAIRMAN PALLADINO: Which they did where?

MR. BERNERO: In the report. And you can see it graphically here.

CHAIRMAN PALLADINO: I am now going back to this statement, "... probabilities of subsequent severe and core damage determined for precursors associated with initiating events were used to estimate...". What does that mean?

MR. MINARICK: We did not use all of those probability calculations for all 169 precursors in deriving that number. What we did was we looked at those precursors that were associated with observed initiating events, actual losses of offsite power, actual bus failure such as Rancho Seco, but not precursors which were associated with testing and which no initiating event actually occurred at that time.

COMMISSIONER AHEARNE: But I thought previously you had said that most of your failures were associated with testing.

MR. MINARICK: A lot were.

COMMISSIONER AHEARNE: So you dropped out a lot of the --

MR. MINARICK: It doesn't affect the number.

MR. BERNERO: Keep in mind, when he looks at the testing ones, he is trying to get the reliability of a function, of a pump to turn on when called on, and now we are talking about what really could happen.

COMMISSIONER AHEARNE: I understand.

MR. MINARICK: And the reason we only use the observed initiating events is because those were the ones that actually occurred. We have no information to why you could project that others might have occurred. In reality, they did not occur so we used probability measures only associated with initiating events that occurred.

CHAIRMAN PALLADINO: I guess I need more understanding.

How did you get to this range again?

MR. MINARICK: This range was done -- let's talk about the 4.5 number first. If we take the probabilities of subsequent core damage associated with the initiating events that we saw in the precursors and you assume a frequency of 1 per 432 reactor years, plant years, for each one and add them up, you come up with a number which is 4.5×10^{-3}.

CHAIRMAN PALLADINO: What am I adding up?

MR. MINARICK: The probability measures calculated for all of the precursors associated with initiating events.

CHAIRMAN PALLADINO: For example, you say -- give me some examples.

COMMISSIONER AHEARNE: TMI then is one.

MR. MINARICK: TMI is one. Any true loss of offsite power that we observed.

CHAIRMAN PALLADINO: It is 1 out of 432.

MR. MINARICK: One out of 432. If we observed something else, a loss of offsite power, for example, where everything else worked right and I don't know what the figure is, but let's say it turned out to be 10^{-3} for that one. Then it would be $1/432 \times 10^{-3}$.

CHAIRMAN PALLADINO: Where does the 0.04 fit into that?

MR. MINARICK: For an actual observed loss of offsite power was not in the calculation. There were two things considered. If we had an emergency power failures where a loss of offsite power did not occur, we had a frequency of loss of offsite power. If a loss of offsite power actually occurred as an initiating event, then that fact was used on the event trees.

COMMISSIONER AHEARNE: So that gives you your lower bounds.

MR. MINARICK: So that gives us the 4.5×10^{-3} upper bound.

Now I talk in the report about the fact that the way this methodology works, it appears that the numbers overestimate what you are actually seeing and the reason that is the case is that when something actually does fail, we count it as failed.

If something does not fail, we still assign a failure probability to it instead of saying "0". We can't say "0" because then there is no way of working through the tree and ranking these events probabilistically so we assign a number greater than "0" to those events so that if you look at all of them, you have a number of event trees where an actual observed failure existed and you have a bunch of event trees where a failure did not exist but could have with a certain probability.

The sum total of all of those ends up with a number greater than the actual number of observed failures.

CHAIRMAN PALLADINO: Something doesn't sound right but I am sure that I am not understanding it. You say that if something fails, you are going to count it, but if it doesn't fail, you are going to give it a probability that it might have failed.

MR. MINARICK: Of failure -- that it might fail.

CHAIRMAN PALLADINO: What is the implication of that? I don't understand it.

MR. BERNERO: It gives you a conservative bias, and he is now trying to extract that.

CHAIRMAN PALLADINO: If you start with a probability of 1.0, that gives you a probability greater than 1.0.

MR. MINARICK: That's right. It will.

MR. BERNERO: As he said, the 4.5 --

CHAIRMAN PALLADINO: I don't understand a probability greater than 1.0.

MR. BERNERO: As he said, the 4.5 is conservatively biased because of that factor and now he is trying to address how to take that out.

MR. MINARICK: We feel the bias is perhaps on the order of a factor of 3 and that is where the 1.7×10^{-3} comes from, and I talk in the report about how I get that.

CHAIRMAN PALLADINO: Are there particular pages I might out to read?

MR. MINARICK: This starts in section 4 which deals with quantification of precursors and would be the one.

CHAIRMAN PALLADINO: Is that chapter 4?

MR. MINARICK: Chapter 4. So this is the estimate that we come up with. Again, we feel that it is based on very sparse data and is only applicable for 1969 through 1979.

COMMISSIONER AHEARNE: Were you going to mention that you added in, for example, loss of feedwater?

MR. MINARICK: I would prefer not to go in-to that detail here. I think it will take quite a while to work through the details. Bob, how do you feel?

MR. BERNERO: We are available --

COMMISSIONER AHEARNE: It is just that you had a slight modification of your number.

MR. MINARICK: Let me just briefly say that we did not observe loss of feedwaters in the LER data base, so we modified the numbers based on our expected numbers of losses of feedwaters from other information and the probabilities of failures of auxiliary feedwater systems. That did modify to a certain extent, not very greatly, the numbers that we actually came up with.

May I have the next slide, please?

CHAIRMAN PALLADINO: I would like to ask one more question on this chart. What do you come out with when you are all done? Do you say, yes, it is going to have a potential for severe damage and with yes, do you then come out with a probability?

MR. MINARICK: Yes, and in this particular case, it was 1.3×10^{-6} for the whole thing.

MR. BERNERO: For the whole chart. So that is the contribution to core melt probability.

CHAIRMAN PALLADINO: What was that number again?

MR. BERNERO: It was 1.3×10^{-6}.

MR. MINARICK: In the report, this is one of the two example calculations that I provide.

CHAIRMAN PALLADINO: How do you use that 1.3×10^{-6} plus all the other things that you get?

MR. MINARICK: The contributions from those events which included actual initiating events, actual losses of offsite, actual steamline breaks, actual small break LOCA's, probability contributions for those were then each one was assumed to have a frequency of 1/432 plant years, and that was the frequency times the probability was then summed for all those events to arrive at that 4.5×10^{-3}.

COMMISSIONER AHEARNE: This particular one, for example, is not in there because --

MR. BERNERO: It contributes very little.

MR. MINARICK: This one does not.

COMMISSIONER AHEARNE: Because there is no real initiating event. The final sum only takes into account those where there was a true initiating event. In this particular case, this chart is predicated upon a loss of offsite power, this particular series of events, there was no loss of offsite power.

CHAIRMAN PALLADINO: Take one where there was and what kind of number do you have for it?

MR. MINARICK: All right. Just an example off the top of my head -- nothing specific. Let's say, for example, there was an actual loss of offsite power that occurred at a plant and we worked through the whole tree and came out with some number like 10^{-3} as the probability of subsequent severe core damage.

CHAIRMAN PALLADINO: How would you get that different from what you did here?

MR. MINARICK: It would depend on the specifics of the event and what was failed or not failed or degraded. For example, if the loss of offsite power was one that we thought there was true loss of offsite power but we thought in 20 minutes or so they could have actually gotten back --

CHAIRMAN PALLADINO: Suppose there had been a loss of offsite power, must something have happened? You are taking a case and this is an assumption, an example, that there was loss of offsite power and it lead to something.

MR. MINARICK: What was did was we took all cases where there was a loss of offsite power and then actual loss of offsite power and then using the event trees figured out a probability given that the loss of offsite power occurred of subsequently going to core damage.

CHAIRMAN PALLADINO: And that ignores the probability. Oh, you would take the probability. It would be 1 in 432.

MR. BERNERO: If the initiating event occurred.

MR. MINARICK: For that particular loss of offsite power, that particular one, we saw one.

CHAIRMAN PALLADINO: So everything starts with a probability of 1 in 432 or 2 in 432?

MR. BERNERO: Yes.

CHAIRMAN PALLADINO: That is an important implication. As time goes on if it doesn't reoccur, that probability improves.

MR. MINARICK: That's right.

COMMISSIONER AHEARNE: That factor, as Hal Lewis has pointed out many times, it is really not correct to talk about it as a probability because you have seen it.

MR. BERNERO: It is an observed frequency and he routinely says that is bad statistics, and routinely does not offer an alternative.

(Laughter.)

COMMISSIONER AHEARNE: His point is --

MR. BERNERO: Oh, it is valid.

COMMISSIONER AHEARNE: -- it is not a probability at that stage. It is an observed data point. You can then draw conclusions from that data point, but it is not really equivalent to other probability characteristics.

CHAIRMAN PALLADINO: Doesn't that data point change as time goes on?

MR. BERNERO: As experience builds.

COMMISSIONER AHEARNE: The implications of the data base. The data point does not change. It happened.

CHAIRMAN PALLADINO: You could go back and say --

COMMISSIONER AHEARNE: The frequency that you draw --

CHAIRMAN PALLADINO: Suppose no other TMI takes place and you get 900 reactor years. The data at least for those 900 reactor years is different from the 1 in 432.

COMMISSIONER AHEARNE: Yes.

CHAIRMAN PALLADINO: But then I could go back and take a narrow one and you have to watch what conclusions you draw.

COMMISSIONER AHEARNE: Hal's point is that once the event has occurred, it is a data point and it is not something that probably would occur; it has occurred. Then you can draw other conclusions.

What you just said is that as time goes on if a similar event does not occur, then the experience, the frequency of the actual occurrence, decreases.

CHAIRMAN PALLADINO: Yes, that's right or if you want to tighten it to one little band, it goes up.

(Slide.)

MR. MINARICK: The probability measures we derived for all 169 precursors were also used in the ranking process and what we did was we selected four subsequent trending, 52 events with contributions to severe core damage equal to or greater than 10^{-3}. Forty-seven of these events occurred at plants which went critical after January of 1969. Hence. up to 1979 we had seen all of those plants operating experiences. These 47 events were used as a basis for determining whether significant trends were discernible in the precursors.

Next slide, please.

(Slide.)

MR. MINARICK: Let me just highlight a few things in the trends analysis. We compared the calculated initiating event frequencies and failure probabilities that we derived earlier and that is at table C.1 with previous estimates. The previous estimate was WASH-1400. With three exceptions these numbers were all within factors of 10 of what had been done in WASH-1400.

We determined trends in instantaneous failure rates as a function of plant age. As the plant ages in general, do you see a descreasing number of an increasing number or a constant failure rate?

With only one exception where there was very sparse data where there appeared to be some increase in failure rate, all the others were either constant or decreasing in failure rates.

CHAIRMAN PALLADINO: Are you saying that you couldn't find any trend as a function of plant age?

MR. MINARICK: No. On this case, these are for failure rates, for example, loss of auxiliary feedwater and feedwater function, high pressure injection function, as a function of plant age we feel in this analysis that we are either seeing a constant failure rate with respect to plant age or in some cases, there appears to be a decreasing failure rate.

CHAIRMAN PALLADINO: With plant age.

MR. MINARICK: With plant age, yes.

CHAIRMAN PALLADINO: I am surprised that you would even go that far with this sparse data. I know you are trying to get the best out of what you have.

MR. BERNERO: They are setting in place the methodology in the analysis and the report is replete with tests to see whether there is statistical significance to the thing. Basically the message is, there is really not yet statistical significance to trends which is one way of saying at least they are not bold or dramatic trends.

Remember, this is a period where plants were coming on line and decreasing with plant age if there is infant burn-in might be seen.

MR. MINARICK: We did consider the variation in the number of total significant events and this is not auxiliary feedwater failures or high pressure injection failures but all of the 47 events that occurred at plants which went critical in 1969 and beyond as a function of plant age, and we felt that we could not demonstrate any strong variation in the number of significant events as a function of plant age.

We considered potential differences between plant types and among vendors, architect/engineers and plant power ratings based on the number of significant events. Again, in this case, we feel we cannot demonstrate any significant differences between any of those categories.

COMMISSIONER ROBERTS: In plant power rating, you can't --

MR. MINARICK: No, sir. We found that we could demonstrate none.

COMMISSIONER AHEARNE: In looking at your trend charts and so forth, my conclusion was that when you say you can't demonstrate something, that is driven by the small amount of data rather than -- another way of putting it would be there is no correlation.

MR. MINARICK: With the date we had, we found no trend.

COMMISSIONER AHEARNE: Right, but with the data you had, it is not obvious you would be able to see a trend if one was there.

MR. MINARICK: I think with the data we have, we would have either seen the trend or not. Let's talk about the plant age one. May I have slide, the third one after the one that you have there.

(Slide.)

MR. MINARICK: This is a slide that shows the number of events per plant in different age categories. The dots are the number of events that occurred within these day brackets per plant. For example, within the 0 to 200 day bracket, we typically saw 0.22 or something like that per plant.

The lines with the --horizontal lines at the end indicate 95 percent confidence intervals on these data. You can see that if you apply that 95 percent confidence interval on those data points that while, just looking at the data points, there seems to be a decreasing trend, once you try to say what does the 95 percent mean to you, we felt that there was sufficient bracketing that you could not see.

COMMISSIONER AHEARNE: You can't tell.

MR. BERNERO: You can't tell statistically, but you seemed to be saying that the methodology --

COMMISSIONER AHEARNE: No, the data. I was saying that I don't think the data is really good enough to lead you to conclude whether -- I am just trying to point out that it doesn't seem to me you can be positive and say there is no trend.

MR. BERNERO: I would say this. I believe intuitively there is a trend of increasing reliability with age or decreasing failure. What this is saying is the data in its bald character shows us a slight trend of that nature, but it is not statistically significant.

COMMISSIONER AHEARNE: Right.

MR. BERNERO: That is what the report says.

COMMISSIONER AHEARNE: I was essentially saying that throughout all of it, all of your trends, you are basically data limited. So it wasn't obvious to me that much more than that was significant. I am saying that in many ways the data isn't enough to lead you to conclude that the function of BWR or PWR or old plants/new plants --

MR. BERNERO: Really, at this stage of a data base the whole purpose of having this analysis is to have the structure in place to take advantage of the data as it builds.

COMMISSIONER AHEARNE: Of course.

MR. BERNERO: This would only pick up the most grievous trend.

COMMISSIONER AHEARNE: Yes, that's right.

COMMISSIONER ROBERTS: How many reactor years are you going to pick up in 1980 and 1981?

MR. BERNERO: About another 25 percent.

MR. MINARICK: About 140 or maybe 150 reactor years.

MR. BERNERO: We have to be very careful.

COMMISSIONER ROBERTS: That two year period is going to increase your data base by 25 percent?

MR. BERNERO: By about 25 percent, yes, and changes in plants have been going in during that time period and so one would see perhaps the beginning of trends, but the trend problem will exist in spades there because it is a smaller data base and you are looking for trends.

MR. MINARICK: May I have the next slide, please?

(Slide.)

MR. MINARICK: This is a summary slide.

CHAIRMAN PALLADINO: Did we skip one?

MR. BERNERO: We are actually trying to expedite things a little bit and I suggested to him that he go to the summary.

MR. MINARICK: It is not my fault.

(Laughter.)

MR. BERNERO: The summary actually absorbs the content of the slides that he skipped.

MR. MINARICK: This is a summary slide. The period covered in the report is 1969 to 1979. The total number of LERs searched was 19,400. The number selected for detailed review was 529. The number selected as precursors was 169. The number of significant events and these are not significant because they are significant--

MR. BERNERO: You defined it.

(Laughter.)

MR. MINARICK: We said that those greater than or equal to 10^{-3} and the cutoff was to get enough for trending and to exclude the obviously minor events.

The point estimate we feel is in the range of 1.7 to 4.5×10^{-3} per reactor year. Reasonable agreement exists between the Accident Sequence Precursor and Reactor Safety Study initiating event frequencies and function failure probabilities.

No variation with plant age can be demonstrated in the number of significant events. No apparent differences exist between plant types and among vendors, A/E's and plant power ratings.

CHAIRMAN PALLADINO: I don't understand the middle one, "Reasonable agreement exists between ...", what is ASP?

MR. MINARICK: Accident Sequence Precursor.

CHAIRMAN PALLADINO: "... and Reactor Safety Study initiating event frequencies and function failure probabilities."

MR. MINARICK: That's right.

CHAIRMAN PALLADINO: You seem to come out with different answers.

MR. MINARICK: These are the probabilities on a function basis, on a system basis and the initiating event frequencies that we find.

CHAIRMAN PALLADINO: I don't follow that. If there is reasonable agreement between this study regarding the initiating event frequencies and failure probabilities, why do you come out with different answers? Or are you answering different questions?

MR. BERNERO: I think that is a very important issue. If you look at the table and in one of your slides there that we jumped over, there is a comparison and it is taken right from the report of where small LOCA disagrees by a decade and others agreed quite closely and really what this is telling you is that there are some differences in the prediction of the reliability of functions and there are also coming from these LERs events that were not even predicted in WASH-1400, such as, the TMI sequence, the Rancho Seco lightbulb.

You could argue that it was predicted. There is a footnote in WASH-1400 about it, but WASH-1400 did a Westinghouse plant where the frequency of PORV actuation is so low, that the event is not significant.

CHAIRMAN PALLADINO: I see.

MR. BERNERO: The Rancho Seco lightbulb is a classic example of incompleteness. It wasn't even in the book. So you have a combination of things and that gives you the overall picture and you recognize the biases and uncertainties of this thing. My own feeling is you should only count these things in decades. This is about 10^{-3}, this result, 1 in 1,000 and it is a good order of magnitude above WASH-1400.

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CHAIRMAN PALLADINO: I certainly will be interested by what we will receive from the ACRS and the various peer review people.

MR. BERNERO: Yes.

CHAIRMAN PALLADINO: It seems like a very significant and important piece of work and one that we certainly have to deal with in one way or another. That is about as much as I can conclude.

COMMISSIONER AHEARNE: May I ask a question?

CHAIRMAN PALLADINO: Go ahead.

COMMISSIONER AHEARNE: Could you say a few words about in your report you point out that TMI, Browns Ferry and Rancho Seco contribute, as I recall, something like 82 perecent.

MR. MINARICK: That was from the summation process and it is inherent in the probabilities of subsequent core damage that we signed to each of those events. TMI was the 1 in the 1/432. Both Browns Ferry and Rancho Seco were above 0.1. When those are added and then the remaining are added, what you see is that those three events end up being 82 percent of that total.

COMMISSIONER AHEARNE: All right. Now you have in your report on table 4-2 of precursors listed by significance category.

MR. MINARICK: Yes.

COMMISSIONER AHEARNE: This is then a listing of that final calculation that you were talking about, is that correct?

MR. MINARICK: This is a listing of each precursor whether or not it was included in the final summation for all 169.

COMMISSIONER AHEARNE: Ranked by the calculation.

MR. MINARICK: Ranked by probability measure. The calculational method --

COMMISSIONER AHEARNE: But you have the 1/432 on top of that, don't you? This ranking already includes --

MR. MINARICK: No, it does not include the 142.

COMMISSIONER AHEARNE: So nevertheless TMI-2 comes out first because it is a "1".

MR. MINARICK: It is a "1".

COMMISSIONER AHEARNE: Browns Ferry and Rancho Seco are less than 1, but still end up being close to the top. When you go down through this list, could you make any comment or maybe Bob would be better in making a comment on the relative significance of what we in the past have called non-safety system events.

MR. BERNERO: In the past, for instance, a dramatic example, we called auxiliary feedwater system a balance of plant system and it pervades the top of this list especially when it is a functional loss. I don't think it is fair to say that we still call it a non-safety grade system. In fact, the Standard Review Plan even has a reliability test for it. But you see this, I think it is very interesting to know the first one, PORV, failure at TMI was a non-safety system.

The Browns Ferry fire, of course, was a separate thing. Rancho Seco lightbulb was not a nuclear instrumentation, non-safety instrumentation. You find an awful lot of it there. This is one of the fundamental lessons of looking at the whole plant rather than segregating it.

COMMISSIONER AHEARNE: I know you have a lot of caveats that you have placed around this and you are still in the peer review process, <u>et cetera</u>, are there any initial conclusions you are reaching though with regard to additional efforts that we might put in, additional efforts either research, or NRR or I&E ought to be putting in, based on this?

MR. BERNERO: As far as this work in particular is concerned, we think it is a very fruitful place to continue working, to keep at it, as the data base builds. It is also useful in a subjective way as a ranking and one can systematically go down and look at the safety issues, is something being done abour problems like this, and you can look down this list and address that.

COMMISSIONER AHEARNE: I recognize that. I am asking or speaking as the program sponsor within the agency, are you or research making or planning on making any recommendations based upon this study at the present time?

MR. BERNERO: Not specifically, not any regulatory recommendation, a continuation of the work and, of course, this supports, in my mind, is a good support for the developments we see coming up in the supplementary use of PRA for a supplement to the conventional safety analysis.

But I don't at this time see any any specific harvest to say, "Gee, evaluation of this list says, here is another unresolved safety issue." We haven't run across anything like that.

COMMISSIONER AHEARNE: Or a refocussing of efforts in say safety technology.

MR. BERNERO: In a way we are using this information there already in the ordering and ranking of safety issues.

COMMISSIONER AHEARNE: Joe, could you make any comments on the significance of operator or non-operator maintenance type errors?

MR. MINARICK: We found in the significant precursors that 38 percent of them involved operator error to the point where we felt that it was a strong and important factor in the way the precursor went. That compares to 36 percent for all of the precursors and compares with about 29 percent for 1979 LERs in general. That 1979 number is more based on what the plants reported. I didn't go through and reanalyze each event. Our 38 percent is based on actually a review of the precursor event and whether or not the reviewer felt that there was some sort of an error involved.

COMMISSIONER AHEARNE: So in some cases your conclusion on human error might be different than the original reporting?

MR. MINARICK: That's right. Because if the LER did not report it as human error --

COMMISSIONER AHEARNE: Are you drawing any distinction between human error and operator error?

MR. MINARICK: No, I am not.

COMMISSIONER AHEARNE: They are equivalent.

MR. MINARICK: Yes.

COMMISSIONER AHEARNE: So, for example, if it was a maintenance error, you would classify --

MR. MINARICK: We would class that as a human error.

COMMISSIONER AHEARNE: I have two more questions. One question is, obviously, Bob, within here and you have mentioned the fact that this is reaching a number of 10^{-3}. Would you care to comment on the significance of that?

MR. BERNERO: By chance, I have had that opportunity quite a few times in the last few weeks.

(Laughter.)

MR. BERNERO: The Three Mile Island trauma was in a dramatic way of saying there is less reliability there than you think it is. Here painstaking analysis of 11 year data says the same thing, says it in quantitative terms and says that the apparent reliability level with regard to prevention of severe core damage or core melt.

Because we have that problem, it is difficult to distinguish those two.

CHAIRMAN PALLADINO: But it is an important distinction.

MR. BERNERO: Yes, it is, but we consciously use the core damage here. Now that level of probability looks like it is about a decade higher than we are discussing as a design objective for nuclear power plants, and therefore, this general pattern says that you should concentrate on system reliability. Of course, I think we are. We are concentrating on those aspects of system reliability that are evidenced in these significant precursors and a careful look at it and a recurring look at the data, ideally we should be looking at plant experience for all of these trends and for all of these experiences in a much more timely way.

It would be very nice if we had this in 1978 and perhaps could have acted on it a little more quickly.

COMMISSIONER AHEARNE: Final question, you had mentioned, I think earlier, that you had interacted with AEOD on this.

MR. BERNERO: Yes.

COMMISSIONER AHEARNE: Do they have any specific comments on the approach taken, any general comment on the approach taken, or the conclusions reached?

MR. BERNERO: Bob Dennig of AEOD is a principal peer for us. He used to be in our group, in fact. He is in AEOD and is the preeminent specialist in reliability.

COMMISSIONER AHEARNE: I am asking you. I didn't see either Jack or Carl here.

MR. BERNERO: Bob is here. He has technical comments on the methodology but overall this is basically the same methodology that INPO is using, but there is a lot of specific difference and I didn't know that you wanted to go to that depth.

COMMISSIONER AHEARNE: I was wanting more of a summary position of AEOD on this approach. Could Bob perhaps speak to that.

MR. BERNERO: Bob is here, I believe.

COMMISSIONER AHEARNE: Basically my question is, given particularly the title of the report and AEOD is the office within the agency charged with doing this kind of work--

MR. DENNING: We followed the precursor study program for about a year and a half now and I have been involved in sitting in the draft review meetings and I think Mr. Minarick will agree that we have submitted quite a bit of detailed comments about the methodology per se. From our standpoint the most interesting things and the most important things are developing an alternative approach, a quantitative approach, for ranking things as to significance. We think that is important, and that the approach that Joe is taking is a viable one and a good one.

We have more problems. I personally had more problems with this bottom line, the frequency of core damage number averaged over all the plants for the ten years and the mechanics of that calculation. So if I could I would not focus on that number at all.

As far as using the results of the report in AEOD we are using the precursors to benchmark the retrieval code that we have been working on, sequence coding, as Joe has said. They manually went through 19,000 LERs. We are trying to make it possible for people to pull out the degraded function loss of system function LERs without having to wade through by hand.

So we are using the precursors that they selected as test cases to make sure that we can pull out the same kinds of information more readily. I have also been instructed to look into the possibility of automating this quantification process, the quote-unquote, "probability measure" process for purposes of ranking or selecting significance as a trial way of doing it.

My personal opinion is that the process and the recipe for doing that is still very much ad hoc and judgmental and it would take a very large effort to automate that process, to put in all the 0.1's and 0.5's and make these judgments automatically. I don't think we are there yet.

But at least we are contemplating that possibility.

COMMISSIONER AHEARNE: I would just comment that I found or am finding these reports fascinating. It seems to be a very significant improvement over anything I had seen so far in trying to go through a fairly rigorous approach. There are obviously still a lot of problems to resolve, uncertainty being one of them, but nevertheless, it certainly was much better than anything else I had had a chance to read.

MR. MINARICK: Thank you.

CHAIRMAN PALLADINO: I did have one concern or maybe a word of caution or maybe I should ask you a question and let you tell me the word of caution. When one tries to use events as a basis for probabilities, one can be very grossly mislead. If you have a situation, for example, with 10 discs or balls in a bag and one of them is orange and the others are all white, and you happen to pick it out on the first or second try and then that is all your data, it doesn't change the probability.

I am sure you are far more competent in this field than I am and whatever will come out, you will keep us informed of.

MR. BERNERO: Yes. We will, of course, continue as I said with the peer review process of this and later efforts and further development of the methodology and we will be keeping you informed of results as we go along.

CHAIRMAN PALLADINO: I found it very interesting. I wish I had had more time to understand it as completely as I would like to, but I found it very valuable. Before we adjourn, I will need a very short agenda planning session.

Anything more on this?

(No response.)

CHAIRMAN PALLADINO: Thank you very much. We appreciate your coming. We are adjourned.

(Whereupon, at 12:08 o'clock p.m., the meeting was adjourned, to reconvene at the Call of the Chair.)

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NUCLEAR REGULATORY COMMISSION

This is to certify that the attached proceedings before the
NUCLEAR REGULATORY COMMISSION

in the matter of: Discussion of ORNL Report, "Potential Precursors to Severe Core Damage"

Date of Proceeding: Wednesday, July 21, 1982

Docket Number: ______

Place of Proceeding Room 1130, 1717 "H" St., N.W.

Washington, D. C.

were held as herein appears, and that this is the original transcript thereof for the file of the Commission.

Marilynn M. Nations
Official Reporter (typed)

[signature]
Official Reporter (Signature)

NRC BRIEFING

ON PRECURSOR STUDY

JULY 21, 1982

INTRODUCTION:	R. M. BERNERO NRC
STUDY BRIEFING:	J. W. MINARICK SAI--OAK RIDGE

ANALYSIS AND EVALUATION OF OPERATIONAL DATA

- o SEQUENCE AND FREQUENCY ANALYSIS OF LER'S
- o PRA'S PREDICT
  - INITIATING EVENT FREQUENCIES
  - FUNCTION FAILURES
  - COMBINATIONS WHICH LEAD TO CORE MELT ACCIDENTS
- o LER ANALYSIS CAN PROVIDE
  - CHECK ON PREDICTIONS
  - IDENTIFICATION OF UNPREDICTED EVENTS
  - TRENDS

LER ANALYSIS

WORK COMPLETED

- 1969 TO 1979 LER'S
- ADAPT WASH-1400 EVENT TREES
- PUBLISH STATUS (REPORT NUREG/CR-2497)

WORK IN PROGRESS

- 1980 TO 1981 LER'S
- USE WASH-1400 EVENT TREES
- PUBLISH STATUS REPORT (APPROX. DECEMBER 1982)
- FURTHER UNCERTAINTY AND SENSITIVITY ANALYSIS
- CHECK AGAINST PLANT-SPECIFIC PRA'S, ETC.
- EXTERNAL PEER REVIEW

PRECURSORS TO POTENTIAL SEVERE CORE DAMAGE ACCIDENTS: 1969-1979

J. W. Minarick
C. A. Kukielka

Science Applications, Inc.

NUCLEAR OPERATIONS ANALYSIS CENTER
OAK RIDGE NATIONAL LABORATORY

ACCIDENT SEQUENCE PRECURSOR PROGRAM

- IDENTIFICATION OF PRECURSORS TO SEVERE CORE DAMAGE ACCIDENT SEQUENCES BASED ON LICENSEE EVENT REPORTS OF HISTORIC EVENTS AT REACTOR PLANTS.

- BEGAN IN 1979 BASED ON LEWIS COMMITTEE RECOMMENDATION THAT "IT IS IMPORTANT, IN OUR VIEW, THAT POTENTIALLY SIGNIFICANT (ACCIDENT) SEQUENCES, AND PRECURSORS, AS THEY APPEAR, BE SUBJECT TO THE KIND OF ANALYSIS CONTAINED IN WASH-1400. . ."

- EVENTS WHICH OCCURRED BETWEEN 1969-1979 HAVE BEEN RE-VIEWED TO DATE.

- INITIAL READING OF LER ABSTRACTS TO CHOOSE THOSE LERs WHICH DESERVE DETAILED REVIEWS FOR POTENTIAL PRECURSORS.

- DETAILED REVIEW OF SELECTED LERs CONSIDERING:

  - SPECIFICS OF ACTUAL EVENT

  - IMPACT OF EVENT ON REACTOR PLANT SYSTEMS AT THE PLANT AT WHICH THE EVENT OCCURRED.

  - NEED FOR SPECIFIC SYSTEMS/PORTIONS OF SYSTEMS IN THE PLANT AT WHICH THE EVENT OCCURRED FOR MITIGATING OFF-NORMAL EVENTS AND ACCIDENTS.

- SELECTION OF EVENTS AS POTENTIAL PRECURSORS IF THEY:

  - RESULTED IN THE FAILURE OF A FUNCTION REQUIRED TO MITIGATE AN OFF-NORMAL EVENT OR ACCIDENT.

  - RESULTED IN THE DEGRADATION OF TWO OR MORE FUNCTIONS.

  - INCLUDED UNUSUAL INITIATING EVENTS (LOOPS AND LESS FREQUENT EVENTS).

CRITERIA FOR SELECTION OF LERs FOR DETAILED REVIEW AS PRECURSORS

1. ANY FAILURE TO FUNCTION OF A SYSTEM THAT SHOULD HAVE FUNCTIONED AS A CONSEQUENCE OF AN OFF-NORMAL EVENT OR ACCIDENT,
2. ANY INSTANCE WHERE TWO OR MORE FAILURES OCCURRED,
3. ALL EVENTS THAT RESULTED IN OR REQUIRED INITIATION OF SAFETY-RELATED EQUIPMENT (EXCEPT EVENTS THAT ONLY REQUIRED TRIP AND WHEN TRIP WAS SUCCESSFUL),
4. ALL COMPLETE LOSSES OF OFFSITE POWER AND ANY LESS FREQUENT OFF-NORMAL INITIATING EVENTS OR ACCIDENTS,
5. ANY EVENT OR OPERATING CONDITION THAT WAS NOT ENVELOPED BY OR PROCEEDED DIFFERENTLY FROM THE PLANT DESIGN BASES, AND
6. ANY OTHER EVENT THAT, BASED ON THE REVIEWER'S EXPERIENCE, COULD HAVE RESULTED IN OR SIGNIFICANTLY AFFECTED A CHAIN OF EVENTS LEADING TO POTENTIAL SEVERE CORE DAMAGE.

- 169 EVENTS WERE SELECTED AS PRECURSORS TO POTENTIAL SEVERE CORE DAMAGE.

- THESE WERE DOCUMENTED, CATEGORIZED, AND “MAPPED” ONTO EVENT TREES WHICH DESCRIBED THE SEQUENCE OF ACTIONS REQUIRED TO MITIGATE A TRANSIENT OR ACCIDENT. THE EVENT TREE CHOSEN FOR EACH PRECURSOR WAS BASED ON THE MOST LIKELY INITIATING EVENT OR TRANSIENT WHICH COULD HAVE BEEN AFFECTED BY THE REPORTED FAILURES.

- BASED ON THE DEMAND FAILURE AND UNAVAILABILITY INFORMATION CONTAINED IN THE POTENTIAL PRECURSORS, FAILURE PROBABILITIES WERE CALCULATED FOR THE FUNCTIONS INCLUDED IN EVENT TREES USED TO DESCRIBE EACH PRECURSOR.

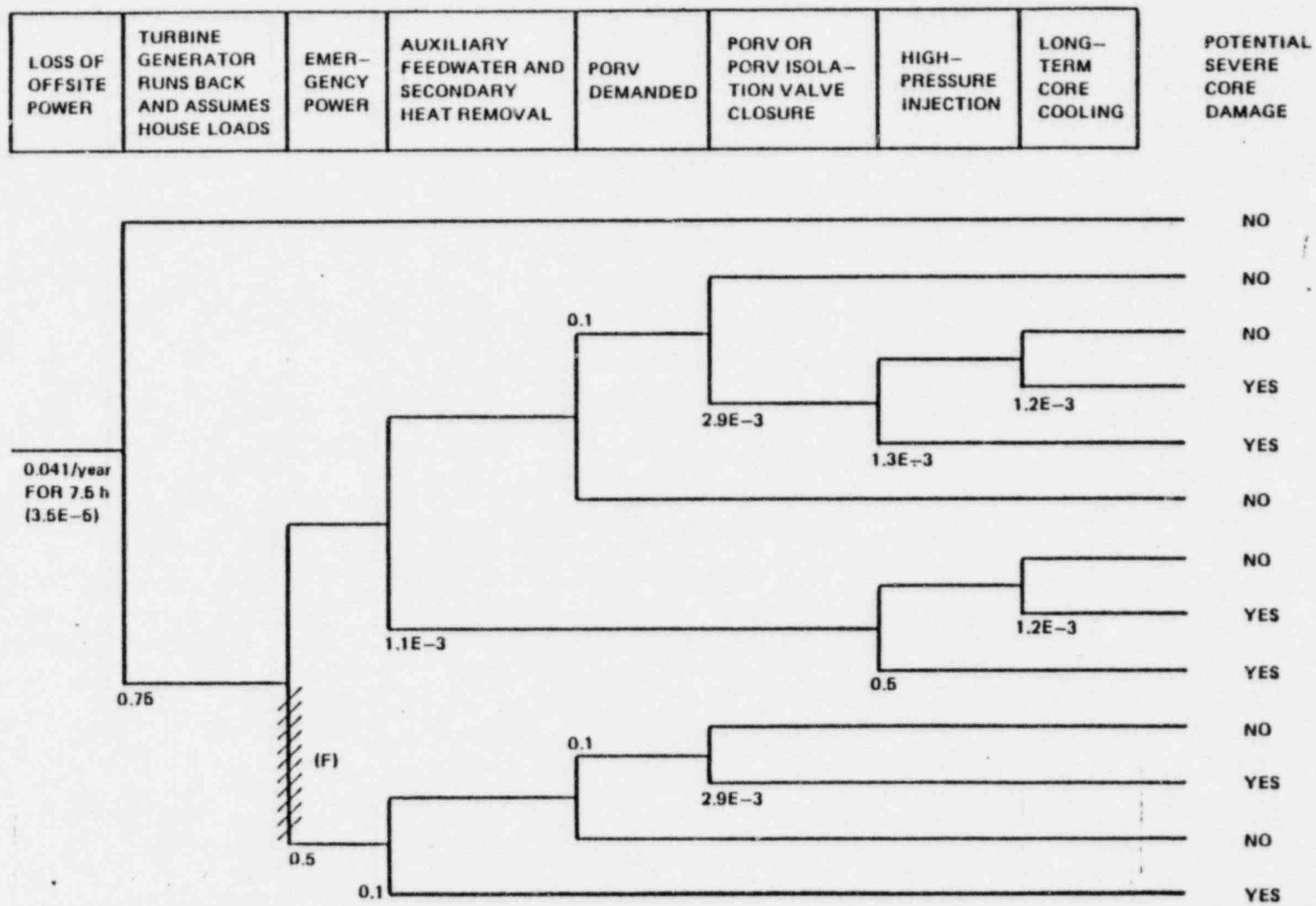
Table C.1. Initiating event frequency and function failure probability estimates

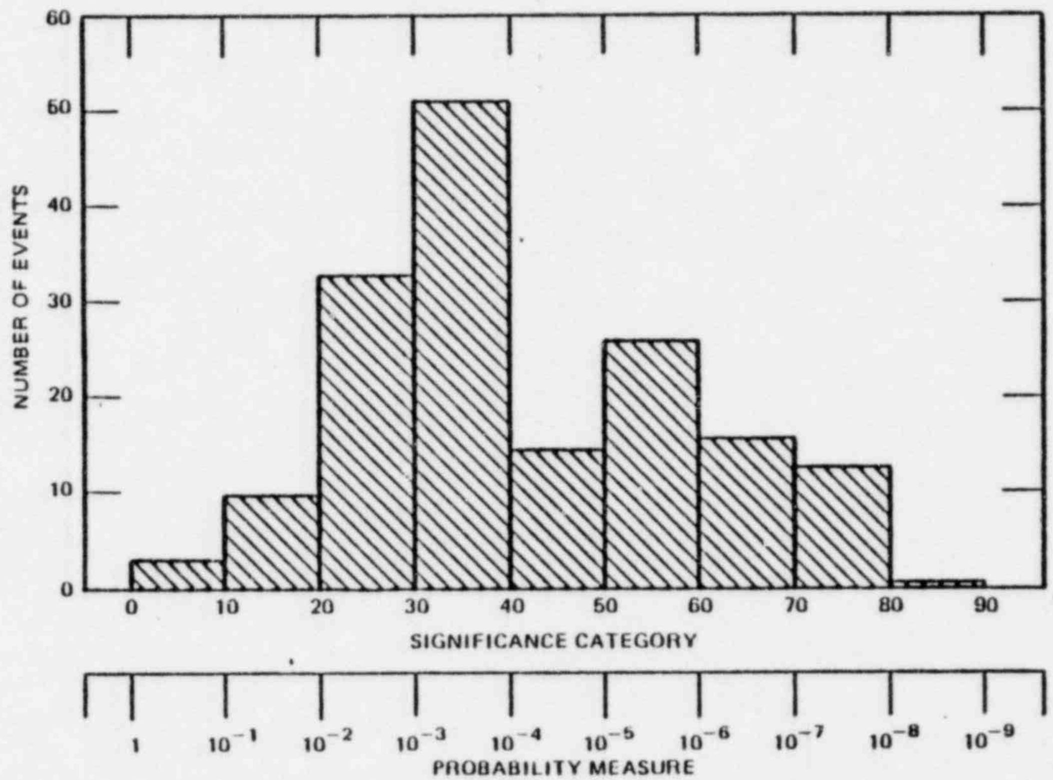
Initiating event/function under consideration	Event description: NSIC accession number	Event description: Event date	Event description: Plant	Event description: Plant age (d)	Event description: Description	Event description: Severity	Total number of events × severity	Total number of events and potential events × severity	Observation period or demands assumptions	Initiating event frequency estimate (per year)	Demand failure probability estimate (per demand): Minimum function	Demand failure probability estimate (per demand): Maximum function	Value used in ASP calculations
PWR loss of main feedwater													
Initiating event	Initiating event frequency for a PWR LOFW was determined based on a review of main-feedwater-related events reported in NUREG-0611 (pp. II-15 through II-27). Eighty LOFW initiating events occurred over a three-calendar-year period. Approximately 50% appeared to be rectifiable in the short term. Westinghouse LOFW events were used for this estimate because the majority of PWR operating hours are contributed by Westinghouse plants.						40		72 post-1968 plant operating years	5.6×10^{-1}			5.6×10^{-1}/year
Reactor trip failure	Demand failure probability for failure to trip was assumed to be equal to value calculated in WASH-1400 (p. II-97).												3.6×10^{-3}/D
AFW and secondary heat removal failure given trip success	81523	June 18, 1973	Turkey Point 4	7	Failure of pumps to auto-start due to failure to install fuses	0.1	6.1	6.1	12 per plant year due to testing plus 1 per shutdown of <48 h plus 2 per shutdown >48 h. Based on 1979 operational data from NUREG/CR-1496, an average of 7.9 outages of <48 h and 3.7 outages of >48 h occurred per plant. This results in 5624 expected demands.		1.1×10^{-3}	1.1×10^{-3}	1.1×10^{-3}/D
	90421	Apr. 7, 1974	Point Beach 1	1252	Failure to deliver flow due to clogged suction stainers	1.0							
	91676	May 8, 1974	Turkey Point 3	365	Failure of pumps to start due to overtightened packings and controller malfunction	1.0							
	108078	Nov. 5, 1975	Kewaunee	608	Failure to deliver flow due to clogged suction strainers	1.0							
	133706	Dec. 11, 1977	Davis-Besse 1	121	Loss of AFW pump control due to mechanical binding and blown control power fuses	1.0							
	137305	Mar. 25, 1978	Farley	228	Failure of turbine-driven pumps to start plus open bypass valves	0.5							
	138830	Mar. 20, 1978	Rancho Seco	1281	Failure of AFW to deliver flow due to NNI failure	1.0							
	153164	Mar. 28, 1979	TMI-2	365	Failure of AFW to deliver flow due to closed valves	0.5							
AFW and secondary heat removal failure given failure to trip	Demand failure probability for failure of AFW and secondary heat removal given failure to trip assumed to be 10 times failure probability calculated for AFW and secondary heat removal given trip.												1.1×10^{-2}/D
PORV not demanded	Probability that the PORV would not be demanded following a reactor trip with successful AFW initiation was assumed to be 0.9.												0.9/D
Failure of open PORV to close and failure of operator to detect failure and close isolation valve	Probability that the PORV would stick open once it was open was assumed equal to 0.01/D. Probability of the operator failing to isolate the open valve was based on precursor information: 7 events involving a failed-open PORV with 2 of these events involving a failure to isolate the valve. (These events are detailed in the discussion of small LOCA initiating events herein.) This results in a combined failure probability of 0.0029.												2.9×10^{-3}/D
Failure of HPI given failure of PORV or PORV isolation valve to close	78418	Feb. 2, 1973	Maine Yankee	102	Failure of charging pump valves to open due to ice accumulation	1.0	2.0	5.0	12 per plant year due to testing, which result in 2472 total demands.		8.1×10^{-4}	2.0×10^{-3}	1.3×10^{-3}/D
	125106	May 6, 1977	Salem 1	146	Failure to clear pumps from overpressure protection during plant heatup (potential failure on demand)	1.0							

INITIATING EVENT FREQUENCIES AND DEMAND FAILURE PROBABILITIES DETERMINED USING PRECURSOR INFORMATION

EVENT	FREQUENCY OR FAILURE PROBABILITY
COMBINED PWR AND BWR LOSS OF OFFSITE POWER (≥30 MIN), PER YEAR	0.041
PWR LOSS OF OFFSITE POWER (≥30 MIN), PER YEAR	0.048
BWR LOSS OF OFFSITE POWER (≥30 MIN), PER YEAR	0.030
PWR SMALL LOCA, PER YEAR	8.3×10^{-3}
BWR SMALL LOCA, PER YEAR	2.1×10^{-2}
PWR AFW FAILURE, PER DEMAND	1.1×10^{-3}
PWR HPI FAILURE, PER DEMAND	1.3×10^{-3}
PWR LONG-TERM CORE COOLING (SUMP RECIRCULATION) FAILURE,PER DEMAND	1.2×10^{-3}
PWR EMERGENCY POWER FAILURE, PER DEMAND	1.8×10^{-3}
PWR STEAM GENERATOR ISOLATION FAILURE, PER DEMAND	1.2×10^{-3}
PWR HPI FOR STEAM LINE BREAK MITIGATION (CONCENTRATED BORIC ACID INJECTION) FAILURE, PER DEMAND	2.8×10^{-3}
BWR RCIC AND HPCI FAILURE, PER DEMAND	3.9×10^{-3}
BWR ADS FAILURE, PER DEMAND	2.7×10^{-2}
BWR EMERGENCY POWER FAILURE, PER DEMAND	5.0×10^{-3}
BWR HPCI FAILURE, PER DEMAND	5.7×10^{-2}
BWR REACTOR VESSEL ISOLATION FAILURE, PER DEMAND	3.0×10^{-3}

- BASED ON THE CALCULATED FAILURE PROBABILITIES AND FAILED AND DEGRADED STATES WHICH EXISTED DURING THE EVENT, THE PROBABILITY OF SUBSEQUENT SEVERE CORE DAMAGE GIVEN THE PRECURSOR CONDITIONS WAS DETERMINED USING THE EVENT TREES.


LOSS OF OFFSITE POWER
TURBINE GENERATOR RUNS BACK AND ASSUMES HOUSE LOADS
EMER- GENCY POWER
AUXILIARY FEEDWATER AND SECONDARY HEAT REMOVAL
PORV DEMANDED
PORV OR PORV ISOLA- TION VALVE CLOSURE
HIGH- PRESSURE INJECTION
LONG- TERM CORE COOLING
POTENTIAL SEVERE CORE DAMAGE
0.041/year FOR 7.5 h (3.5E-6)
0.75
0.5
(F)
1.1E-3
0.1
0.1
2.9E-3
1.3E-3
1.2E-3
0.5
1.2E-3
0.1
2.9E-3
0.1
NO
NO
NO
YES
YES
NO
NO
YES
YES
NO
YES
NO
YES


NUMBER OF EVENTS
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
SIGNIFICANCE CATEGORY
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
PROBABILITY MEASURE

- THE PROBABILITIES OF SUBSEQUENT SEVERE AND CORE DAMAGE DETERMINED FOR PRECURSORS ASSOCIATED WITH INITIATING EVENTS WERE USED TO ESTIMATE THE FREQUENCY OF SEVERE CORE DAMAGE DURING THE 1969-1979 PERIOD.
- THIS POINT ESTIMATE IS IN THE RANGE OF 1.7×10^{-3} TO 4.5×10^{-3}

- THE FIFTY-TWO EVENTS WITH A CONTRIBUTION TO SEVERE CORE DAMAGE EQUAL TO OR GREATER THAN 10^{-3} WERE SELECTED AS SIGNIFICANT PRECURSORS. FORTY-SEVEN OF THESE EVENTS OCCURRED AT PLANTS WHICH WENT CRITICAL AFTER JANUARY, 1969.

- THESE FORTY-SEVEN EVENTS WERE USED AS A BASIS FOR DETERMINING WHETHER SIGNIFICANT TRENDS WERE DISCERNIBLE IN THE PRECURSORS

TRENDS ANALYSIS

- COMPARISON OF CALCULATED INITIATING EVENT FREQUENCIES AND FUNCTION FAILURE PROBABILITIES WITH PREVIOUS ESTIMATES
- DETERMINATION OF TRENDS IN INSTANTANEOUS FAILURE RATES AS A FUNCTION OF PLANT AGE
- DEVELOPMENT OF TIME LINES TO VISUALLY INDICATE WHERE AND WHEN IN PLANT LIFE THESE EVENTS OCCURRED
- CONSIDERATION OF VARIATION IN NUMBER OF SIGNIFICANT EVENTS PER PLANT AS A FUNCTION OF PLANT AGE
- CONSIDERATION OF POTENTIAL DIFFERENCES BETWEEN PLANT TYPES AND AMONG VENDORS, A/E's, AND PLANT POWER RATINGS BASED ON THE NUMBER OF SIGNIFICANT EVENTS
- IDENTIFICATION OF DEGRADED FUNCTION EVENTS THAT OCCURRED WITHIN ONE MONTH OF EACH SIGNIFICANT PRECURSOR
- DETERMINATION OF PERCENTAGES OF PRECURSORS INVOLVING HUMAN ERROR
- ESTIMATION OF PROBABILITY OF A DIESEL GENERATOR FAILING TO START, GIVEN A NON-TESTING LOSS-OF-OFFSITE POWER DEMAND

Table 5.1. Initiating event frequencies and demand failure probabilities determined using precursor information compared with values determined in the *Reactor Safety Study*

Event	Frequency or failure probability	
	ASP value	*Reactor Safety Study* value
Loss of offsite power (combined PWR and BWR) (≥30 min), per year	0.041	0.04[a]
PWR loss of offsite power (≥30 min), per year	0.048	
BWR loss of offsite power (≥30 min), per year	0.030	
PWR small LOCA, per year	8.3×10^{-3}	10^{-3} [b]
BWR small LOCA, per year	2.1×10^{-2}	10^{-3} [c]
PWR AFW failure, per demand	1.1×10^{-3}	3.7×10^{-5} (7×10^{-6} to 3×10^{-4})[d]
PWR HPI failure, per demand	1.3×10^{-3}	8.6×10^{-3} (4.4×10^{-3} to 2.7×10^{-2})[e]
PWR long-term core cooling (sump recirculation) failure, per demand	1.2×10^{-3}	1.3×10^{-2} (4.4×10^{-3} to 3.1×10^{-2})[f]
PWR emergency power failure, per demand	1.8×10^{-3}	1×10^{-5} [g]
PWR steam generator isolation failure, per demand	1.2×10^{-7}	
PWR HPI for steam line break mitigation (concentrated boric acid injection) failure, per demand	2.8×10^{-3}	
BWR RCIC and HPCI failure, per demand	3.9×10^{-4}	7.8×10^{-4} [h]
BWR ADS failure, per demand	2.7×10^{-2}	5×10^{-3} (3.3×10^{-3} to 7.5×10^{-3})[i]
BWR emergency power failure, per demand	5.0×10^{-4}	1×10^{-5} [j]
BWR HPCI failure, per demand	5.7×10^{-2}	9.8×10^{-2} (6.8×10^{-2} to 1.4×10^{-1})[k]
BWR reactor vessel isolation failure, per demand	3.0×10^{-3}	

[a] Ref. 1, p. I-85/86, footnote 3.

[b] Ref. 1, p. 63.

[c] Ref. 1, Sect. 5.3.4.1, p. 64.

[d] Ref. 1, Table II 5-8.

[e] Ref. 1, p. II-144.

[f] Ref. 1, p. II-176.

[g] Ref. 1, p. II-90.

[h] Ref. 1, p. 56.

[i] Ref. 1, p. II-405.

[j] Ref. 1, p. II-355.

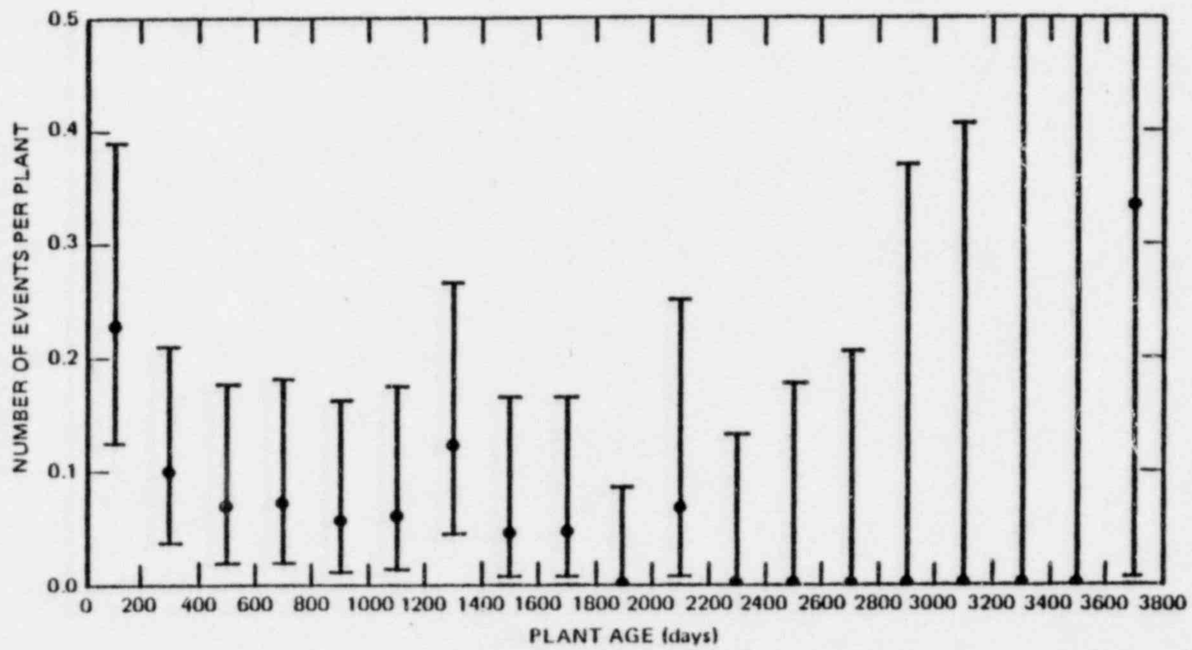
[k] The *Reactor Safety Study* failure probabilities include a test and maintenance contribution that would not be included in numbers derived from testing. The nontest and maintenance failure probability is 1.3×10^{-2}/D (median) (Ref. 1, p. II-395).

Table 5.2. Total time on test plot trend indications

Initiating event or demand failure	Failure rate trend[a]
PWR and BWR loss of offsite power	Decreasing
PWR loss of offsite power	Decreasing
BWR loss of offsite power	Constant (perhaps increasing)
PWR small LOCA	Constant (perhaps decreasing)[b]
BWR small LOCA	Decreasing[b]
PWR AFW demand failure	Decreasing
PWR HPI demand failure	Decreasing[b]
PWR long-term core cooling (sump recirculation) demand failure	Constant (perhaps increasing)[b]
PWR emergency power demand failure	Decreasing
PWR steam generator isolation demand failure	Constant[b]
PWR HPI for steam line break mitigation demand failure	Decreasing
BWR HPCI and RCIC demand failure	Decreasing
BWR ADS demand failure	Increasing[b]
BWR emergency power demand failure	Constant (perhaps increasing)
BWR reactor vessel isolation demand failure	Decreasing[b]

[a]See Appendix D for cautions in interpreting these trends.

[b]This conclusion was based on a small number of observed events.


NUMBER OF EVENTS PER PLANT
0.0
0.1
0.2
0.3
0.4
0.5
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800
PLANT AGE (days)

ACCIDENT SEQUENCE PRECURSOR STUDY HIGHLIGHTS

PERIOD COVERED	1969-1979
TOTAL NUMBER OF LERs SEARCHED	19,400
NUMBER SELECTED FOR DETAILED REVIEW	529
NUMBER SELECTED AS PRECURSORS	169
NUMBER OF SIGNIFICANT EVENTS	52

A POINT ESTIMATE OF THE FREQUENCY OF SEVERE CORE DAMAGE CALCULATED FROM PRECURSOR INFORMATION FOR THE YEARS 1969-1979 LIES BETWEEN 1.7×10^{-3} AND 4.5×10^{-3} PER REACTOR YEAR.

REASONABLE AGREEMENT EXISTS BETWEEN ASP AND REACTOR SAFETY STUDY INITIATING EVENT FREQUENCIES AND FUNCTION FAILURE PROBABILITIES.

NO VARIATION WITH PLANT AGE CAN BE DEMONSTRATED IN THE NUMBER OF SIGNIFICANT EVENTS.

NO APPARENT DIFFERENCES EXIST BETWEEN PLANT TYPES AND AMONG VENDORS, ARCHITECT-ENGINEERS, AND PLANT POWER RATINGS.

12/81

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Meeting Title: Discussion of ORNL Report - "Potential Precursors to Severe Core Damage"

MEETING DATE: 7/21/82 Open ✓ Closed ___

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1. Transcript (w) viewgraphs attached)	1	1		
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