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SUBCOMMITTEE ON CLASS 9 ACCIDENTS

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SUBCOMMITTEE ON CLASS 9 ACCIDENTS

OF THE

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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Taos Room
Regent Hotel
201 Marquette Street
Albuquerque, New Mexico

Tuesday, June 30, 1981

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The meeting was convened, pursuant to notice, at 8:35 a. m., Dr. William Kerr, Chairman, presiding.

PRESENT:

ACRS Members:

Dr. William Kerr

Mr. David Ward

Dr. David Okrent

Mr. Michael Bender

Dr. Chester Siess

Dr. Carson Mark

Consultants:

Dr. Zenon Zudans

Dr. Melvin First

PRESENT, Continued:

Designated Federal Employee:

Mr. Richard Savio

NRC Staff:

Dr. Robert Curtis

Dr. James Meyer

Dr. Mark Cunningham

Sandia Laboratories Representative:

Dr. Alan Benjamin

I N D E X

Class 9
Accidents
6/30/81
Tape 1
JMcPhee

P R O C E E D I N G S

DR. KERR: The meeting of the Advisory Committee on Reactor Safeguards, Subcommittee on Class 9 Accidents, will come to order.

My name is William Kerr. Other members of the Subcommittee present today are Mr. Ward, Mr. Okrent, Mr. Bender, Mr. Siess, and Mr. Mark. We also have as consultant Mr. Zudans and Mr. First.

The meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act and the Government in Sunshine Act. Richard Savio is the designated federal employee.

Rules for participation in today's meeting were announced as part of the notice of the meeting, published in the Federal Register of June 8, 1981.

A transcript of the meeting is being kept and will be available as stated in the Federal Register notice. I request that each speaker identify himself and use a microphone.

We have received no written comments or requests for time to make oral statements from members of the public.

The purpose of the meeting is to discuss the consideration of, analysis of, and possible use of filtered-vented containment systems in connection with the operation of nuclear power plants. The Subcommittee is here today to gather information about a number of studies that have been made on containment venting. Of principal and immediate interest, I would suppose, are studies that deal with containment already in place. Since there is some variety of these containments, venting considerations are expected to be influenced by this variety.

Venting is likely to be called for only in accidents which produce large releases of fission products, at least into the containment volume; thus, venting must include filter systems capable of dealing with the unusual situations expected to accompany a severe accident.

And finally, there is the decision as to when venting is to occur. For example, should it be automatic, triggered by some pre-selected set of conditions, or should a decision be made by the operator or by the NRC or, God help us, by the ACRS?

This question, although perhaps as much political as technical, has to be an important consideration in the use of filtered-vented containment.

I look forward to the information that we are gather today and will go directly then to the published agenda, which has as first presentor Mr. Meyer from the NRC. Mr. Meyer?

MR. MEYER: My name is Jim Meyer. I am a member of the Reactor Systems Branch of the Office of Nuclear

Reactor Regulation.

I would like to take a few minutes this morning to give the Subcommittee an overview of the present NRR strategy concerning the role of filtered-vented containment systems in our addressing of core melt accidents. In doing this, I will be concentrating on Zion/Indian Point effort. I have made presentations in the past to the Subcommittee and full committee on this program, and I will be assuming that the subcommittee members are familiar with the Zion and Indian Point program.

I think, although some points are perhaps obvious, that to introduce the subject, it would be appropriate to make three basic points. The first point is that the purpose of a filtered-vented containment system is to prevent containment failure. This is, of course, obvious. However, it is perhaps not as obvious that this may be one of the important criteria for judging whether to proceed with a filtered-vented containment system, and what I mean by that is that, exclusive of questions of risk reduction, it may be the judgment, for example, of the staff, that there is considerable improved safety gained by preventing containment failure by such a means as a filtered-vented containment system.

Added to that consideration is one that has been discussed in some detail, namely the use of a filtered-vented containment system to reduce risks, using a probabilistic risk assessment methodology in order to make that judgment. I have in the past referred to a risk reduction factor of 10 as a guideline by which we can make a judgment as to whether a particular mitigation stra' qy is appropriate or not, and in some of the following presentati_ns, that issue will be addressed in some detail.

The third point is to keep in mind that the filtered-vented containment system is one of many possibilities in terms of mitigation features and strategies to prevent containment failure. Such other features as passive containment heat removal, strengthening of containments themselves, increasing volume of containments, all are directed to th' same end, namely the preventing of containment failure, a failure that would have otherwise occurred if the accident progressed into a core melt.

With these basic ideas in front of us, I would like to very briefly speak about t.e present activities within the Office of Nuclear Reactor Regulation, that is the licensing activities, give you some perspective as to the design approach, in particular as it differs from the traditional design basis accident approach, and then give a very brief summary of how we see the filtered vent coming into play in our addressing of the Zion/Indian Point activity.

The first vu-graph, then, gives a summary of our licensing activities. The first is the Zion/Indian Point program which is a rather complete, extensive program addressing all of the issues associated with core melt from the probabilities of various accident sequences, determination of dominant sequences, the containment failure loading characteristics and containment failures characteristics themselves, as well as mitigation strategies to accommodate these accidents so that the containment integrity is maintained.

In addition to that, as I mentioned before, there would be a judgment as to how much risk reduction is afforded in such a mitigation strategy. In addition to that, there is a requirement for the near-term construction permits and manufacturing licenses in NUREG 718 that these licensees, in order to not preclude the possibility of a filtered-vent system in the future, to provide for a 3-foot diameter or equivalent penetration in the containment. Several of the submittals have come in, in particular for Allens Creek, for Pilgrim 2, and for the manufacturing license for offshore power, and in each case, the licensees have indicated that they will provide such a penetration.

In addition to not precluding the possibility of filtered vent, this penetration could also be used for a passive containment heat fuel system, another strategy that we are considering.

You are perhaps familiar with the probabilistic risk assessment that was performed by Limerick. In that assessment, there is the further investigation of a vent with a container to prevent containment failure. As I understand it, it is not a filtered vent, but it is a vent to prevent containment failure from failure of heat removal to suppression core.

And then there are a number of activities regarding rulemaking, basically to coordinate with the primary activity in research in the area of rulemaking.

DR. OKRENT: What is the schedule for the issuance of the report that gives the results of the analyses on Zion/ Indian Point by both the licensees and the staff?

MR. MEYER: The licensees have postponed the publication of their investigation of mitigation strategies until the end of August. This has been postponed now several times. We are hoping that this is the last postponement. We hope, then, at the end of August to see how the utilities are approaching the question of mitigation strategies for Zion and Indian Point.

The staff is committed to wait for the submittal of that report and incorporation the information of the licensees' report into our final report, so the final report would have to come sometime after that.

We are preparing an interim report. When I go back on Monday, I hope that what we are referring to as an NRC draft will be ready for further NRC peer review.

DR. OKRENT: Does that mean there will be no submittals by the licensees before the end of August?

MR. MEYER: That is correct, as I understand it. This includes the large PRA work going on, contracted to Pickard, Lowe and Garrick.

Any other questions?

DR. KERR: Please continue.

MR. MEYER: I would very briefly like to run through, although these are not cast in concrete, how we feel the approach to thinking of a filtered vent system might be different than what we would normally think of as an engineered safety feature for design basis accidents.

We are making every attempt to do mechanistic/realistic analysis, as opposed to the more traditional approach of conservative analysis, to determine what the design requirements would have to be for these safety features, trying to make effective use of probabilistic risk assessment in drawing our overall conclusions.

Third, because we are talking about low probability events as initiators, we feel it is important to consider low probability external events, like large seismic events, in considering the design requirements for these features, and, lastly, we feel that --

DR. KERR: I am sorry. Did you say because you are considering low probability events, you think it is appropriate for you to consider low probability external --

MR. MEYER: Low probability but major consequence initiators, included in that category being large seismic events. And finally, the consideration of cost-benefit assessment in our overall judgment as to whether or not to recommend a filtered vent or any other mitigation strategy.

MR. SEISS: I still do not understand your answer to Dr. Kerr. You are considering low probability initiating events simultaneously with low probability external events, or just low probability external events as initiators?

MR. MEYER: As initiators, and being careful to make sure that the design of the mitigation feature would be such that the device would not be impaired in its function substantially by that initiating event.

DR. KERR: Well, the statement was, because the event that is likely to call for the use of the FVC is a low probability event, you consider it appropriate to consider the effect of low probabilty external events on the system. Wasn't that what you said?

MR. MEYER: That is correct.

DR. KERR: To me, that is a non sequitur, but I did not disagree with it. I just wanted to make sure I understood it.

DR. ZUDANS: What is the significance of factor of 10 or any other factor on a low probability event, anyway?

MR. MEYER: Well, there are two questions that we are trying to address in the Zion/Indian Point program; that is, what is the risk from, say, the Indian Point 2 unit, and the more immediate question is, what kind of risk reduction could be gained by incorporating a mitigating feature like a filtered vent, and the probabilistic risk methodology gives us a quantitative way of making that judgment; at least this is what it is purported to be able to do.

The factor of 10 itself is a guideline judgment for talking purposes, for presenting to such forums as the Subcommittee, in order to get feedback as to whether this might be an appropriate --

DR. ZUDANS: I guess the guideline of the factor of 10 is derived from the reports that you got that it was achievable with this type of system, then.

MR. MEYER: Yes.

DR. ZUDANS: Now, what I am talking about is something else. The final consequences are, say, something like 10^{-4}, and by a factor of 10, you make them 10^{-5}, but a 10^{-4} is already insignificant. What is the improvement?

MR. MEYER: That is why I divided the question into two parts. I agree with you that it may turn out that whatever the number you choose, it may be determined to be an insignificant contribution to --

DR. ZUDANS: The consequences.

MR. MEYER: -- the consequences of risk.

DR. ZUDANS: That is what I am talking about.

MR. MEYER: And if that judgment is made, then the issue of a further reduction of a factor of 10 becomes less clear. These are subjects we hope will be addressed in the rulemaking. They are very crucial, generic types of issues. What we tried to do in the area that I am responsible for is to address a more specific question: what will be gained? Putting aside the level of risk from the plant, what will be gained by installing a mitigation strategy A or B in terms of this reduction?

In order to make a final judgment, it is a both/and situation. You have to have the expectation of large risk reduction as well as the judgment that it is contributing in the sense of residual risk from the plant itself.

MR. BENDER: Could I ask a question about the top point up there, the mechanistic/realistic analysis versus conservative analysis? The previous conservative analysis, as I understood it, was an arbitrary accident having certain constituents in it, reaching certain pressures. What is the realistic/mechanistic analysis approach?

MR. MEYER: I can give you two examples. One is that we have excluded some consideration of major contributors, the double-ended pipe rupture, in a well designed plant, because there would be risk analysis that would indicate that that is a very low probability event relative to, for example, station blackout.

MR. BENDER: Well, a double-ended pipe rupture can be of any size, so let's start by saying what size break is in the picture. And is that being dealt with probabilistically?

MR. MEYER: Well, the break sizes are divided into three families, the large break and then the so-called S2 break, which is half inch to 2 inches, and the S1 break, which is 2 inches to, I believe, 5 inches. So the AB family would cover breaks beyond 5 inches, but it usually refers to the double-ended pipe rupture.

MR. BENDER: But you are not answering the question I asked, which was what size break is within the spectrum of the mechanistic/realistic analysis that you want to address?

MR. MEYER: The breaks from a half inch to 5 inches.

MR. BENDER: And so that would encompass things like the leak valve and other things opening, as well as a break in a pipe? And you are not planning to go beyond that? Is that your understanding?

MR. MEYER: Well, I am not prepared today to talk to what has come out of the Zion/Indian Point program per se, but one of the results of the program is that all the accidents in the core melt scenario start looking alike, and you are either talking about accidents where they have containment heat removal or they do not have it, and so, although AB is a low probability, we think now that it can be accommodated by it.

MR. BENDER: Give me another example of the size of the AB sequence, which I understand to be breaks up to 5 inches.

MR. MEYER: The AB sequence is breaks larger than 5 inches. Perhaps the more relevant example would be that we are proceeding with realistic analysis in terms of determining the pressure loadings on the containment. It would be much easier to determine conservative loadings along the lines of what were determined for the WASH-1400 study, but using conservative analyses might lead us to false conclusions regarding the need for a mitigation feature, so the reason I put that on there is to emphasize that, from a number of standpoints, it is important to do the best job in doing a mechanistic/realistic analysis.

MR. BENDER: Well, let me try to understand that one point. If I start with the heat-up of the constituents in the containment, I would start probably by saying there is stored energy in the system. You are adding additional energy because of the after-heat, and I could use some postulates concerning what those sources of energy are and come to some pressure gradient.

I could also consider the heat losses from the system, and I could consider the mechanisms for putting heat removal into the system in order to get to the mechanisti^

results.

How realistic are you being? Are you being so realistic as to say there is time to put certain kinds of heat removal capability in, or are you being realistic only in the sense of saying there can only be so many sources of heat? How do I draw that line?

MR. MEYER: Well, just taking passive containment heat removal as an example, just from the structures in containment, we have adjusted what we feel is a conservative model in the codes that we are using to be more realistic so that the MARCH analysis, for example, would not give us an overestimate of the pressure history because we have not taken proper account of the passive heat things.

MR. BENDER: The term "more" does not have a real quantitative meaning. You can assume some less pressure build-up because of heat absorption, or you could assume a lot of less pressure build-up if you take credit for all of the heat-absorbing devices in the system and others that might be introduced, like sprays.

I am trying to find out right now what is realistic. Are you going to not take credit for sprays?

MR. MEYER: No, we do. We do take credit for sprays. We do take credit, under certain circumstances, for the fan coolers, the containment coolers, and I am not sure how much detail you want to get into for this.

MR. BENDER: Well, I am trying to see what happens. Are you going to get to the core melt stage and are you going to assume that the coolers exist or do not exist at those stages, too?

MR. MEYER: We are using the classical WASH-1400 approach in terms of defining what of the active EC engineered safety are on and what are not, and guided by those definitions of what systems are on and off, we proceed with what we feel is our best shot at a mechanistic analysis.

MR. BENDER: Well, I have probably explored the matter enough now on it, although I am not completely clear on where you are going.

DR. FIRST: I share your confusion here, and I, too, would like to see if we could get that point clear, because I think, if we do not, we are going to confront it continually for the rest of the day.

DR. OKRENT: I am not sure what the question is. I thought what he said was, in any accident scenario, they consider, for example, if AC power is available, that those systems run by AC power could be available but there is some chance that they would have failed, for a variety of reasons, that they failed before the incident, they do not start, or so forth. But he is using PRA analysis to judge whether equipment is available or not for a particular scenario, and then, given the equipment, he is trying to analyze the accident using what they call mechanistic, not conservative, assumptions.

DR. KERR: Is that what you are saying. Mr. Meyer?

MR. MEYER: Yes. I, we --

DR. KERR: If it is yes, that is enough.

MR. MEYER: Yes.

DR. ZUDANS: I would like to say something. Your analysis is mechanistic and realistic analysis, and you say you are using MARCH code for that. I have comments to that. In order to follow the points of doing probabilistic risk assessment, you have to have as realistic a condition as possible defined, and the MARCH code is not suited for design purposes, so aren't you really starting out from a very wrong premise, anyway?

MR. MEYER: Well, I did not say that using it in a mechanistic way is necessarily using it as a design tool.

DR. ZUDANS: But that is what you are using to describe the conditions in the containment. That is what everybody else is in all of these reports, and we had a MARCH code meeting where it was clearly stated that it should not be used for design purposes.

DR. KERR: Gentlemen, I think these questions are very relevant and questions that have to be answered in one's consideration of the staff's analysis, but are we going to be able to answer them until we see the report which should, presumably, give rather detailed information on how the analysis was done?

DR. ZUDANS: Well, I think that the idea --

DR. KERR: I will leave that to your discretion, but we are getting into a lot of detail -- detail which is certainly important to understand the analysis, but I am not sure that we are going to be able to get the amount of detail we need in this forum.

DR. ZUDANS: Mr. Chairman, I do not really need the detail now. I just wanted to raise this question so that the subsequent presenters take that into mind, into their consideration.

DR. KERR: And the question was whether MARCH is a suitable vehicle --

DR. ZUDANS: Suitable for design purposes that need it now in order to do any risk assessment on any system that you want to implement.

MR. MEYER: That is one of the topics I intend to address at the July 9 full committee meeting, and I think it would be appropriate to defer that very important issue. I do not mean to slight it, but that important issue to the full committee.

DR. KERR: You are going to say yes or no at that time?

MR. MEYER: To what question?

DR. KERR: Whether MARCH is a suitable tool for this sort of analysis. Or are you going to say maybe?

SPEAKER: Or partly?

MR. MEYER: I will be saying something along the lines that MARCH is a valuable code capability --

DR. ZUDANS: That is not the point. We do not disagree that MARCH is valuable, the MARCH is the only game in the town, but what I am saying is that you are making very big other decisions. You are going to set the rules how to design FVCS.

DR. KERR: Are you going to be present at the July 9 meeting?

DR. ZUDANS: I have not been asked to be there.

DR. KERR: We do not know at this point. I just wanted to know whether you are going to have to deal with Mr. Zudans at that time or not.

DR. ZUDANS: Probably not. I just want you to understand what my concern is, being in the MARCH meeting.

MR. MEYER: I appreciate your concern. I am not prepared to go into in detail today because the subject matter is somewhat different. We will not be setting up specific design criteria for a filtered vent based on MARCH analysis.

DR. ZUDANS: Oh, that is right, because these reports that I read to you, done by Sandia and otherwise, take MARCH as the gospel. They are on the MARCH code and say this is what it will be.

DR. OKRENT: Zenon the Sandia people are going to stand up. You will have your chance to find out whether they really take it as gospel or not. Why don't you wait?

DR. ZUDANS: Well, we will give them a chance to think about it.

Tape 2a

MR. MEYER: We did write, Roger Matson did write a letter to Richard Fraley a few days ago addressing this point, and I believe that copies were distributed to ACRS members. I know we sent one to Professor Kerr.

DR ZUDANS: But did it reach Los Angeles yet?

DR. KERR: Please continue. Oh, Mr. Okrent?

DR. OKRENT: Could I ask a question? I would like to understand why the factor of 10 is thought to be a necessary condition for judging the usefulness of a filtered-vented containment system when, to my knowledge, it is not being used as a factor that is used to judge a whole host of other proposed improvements in fact.

I suspect, if I ent down to TMI action plant, very few, if any, would meet the test of reducing risk by a factor of 10.

DR. KERR: Is that a question or a statement?

DR. OKRENT: It is a question. I want to know why the factor of 10 is proposed here.

MR. MEYER: Well, this factor of 10, first of all, is not meant, at least at the present stage, to be a necessary condition, and it will be -- if it is used, it will be applied uniformly to judge any mitigation strategies associated with core melt accidents. Why it has not been used in other TMI-related actions, I really cannot answer.

DR. OKRENT: Well, let me request, then, that you meet with your higher-ups and tell us in July whether in fact you think there is something special about this feature which requires a factor of 10 when it is not a requirement, to my knowledge, on other proposed improvements.

Could I ask one other question? When you do what are called mechanistic/realistic analyses, there remain uncertainties. Sometimes you can put some handle on them; sometimes it is very hard to. But, nevertheless, there are these, and if you come up with only what some people call a point estimate or a best estimate, this could be quite different from the expected value.

How do you propose to deal with this possibly large difference in arriving at your future evaluations and decision and cost-benefit assessment, et cetera?

MR. MEYER: Again, I was intending to address this on July 9 under the heading of how we were addressing --

DR. KERR: Will that be soon enough?

DR. OKRENT: I am willing to hear it on July 9, but the question is not tied into MARCH. It is tied into the entire --

MR. MEYER: No, that is very correct.

DR. OKRENT: Okay.

MR. MEYER: In fact, it is an important question in considering what the containment failure pressure is, and we have steadily moved the estimate of containment failure pressure up from what it had been assumed to be based on containment structural analysis, and we are trying to firm up now what the uncertainties are associated with that number so that we can fold that kind of information into the judgments regarding, for example, whether there is any even low probability of the Zion containment failing during the so-called steam spike, as an example.

So we would be taking into account the uncertainties associated with the pressure history and the uncertainties associated with our estimate of the containment failure pressures in order to make that judgment.

DR. KERR: We look forward to that. Why don't you continue with today's presentation?

DR. ZUDANS: The speaker used the term that is exactly what I objected to, steam spike. This is not the real spike; it is a consequence of the code.

DR. KERR: We make note of your objection.

Please continue, Mr. Meyer, and keep in mind that Mr. Zudans does not like steam spikes.

DR. ZUDANS: No, I do like them, but they are just not right.

DR. KERR: I do not like them, either, but --

MR. MEYER: If the committee would like me to go into our present feelings on the role of the filtered vent as we see it in the Zion and Indian Point action, I can do so at this time. However, considering schedule and whether that is germane or not --

DR. KERR: My agenda says that you are going to talk about how FVCS fits into the total NRR strategy for addressing core melt accidents. Now, have you addressed that, or did you know that that was what you were to talk about?

MR. MEYER: I feel that I have addressed that point. If there are any questions related to that point, I will be glad to --

DR. KERR: Could you give me, in a couple of sentences, how it fits into your total strategy?

MR. MEYER: Well, the total strategy is to determine, for various types of reactor systems and containment systems, what the failure characteristics are of those containments, and then to consider filtered vents, as I mentioned before, as well as a host of other types of mitigation strategies in order to assess which is the most appropriate way to go in order to prevent those containment failures.

MR. BENDER: Mr. Chairman, I am concerned about a term that has been used here, one I believe to be promiscuously but perhaps improperly, and that is the term "containment failure." This scheme, if it works and can be shown to have some risk reduction value, may prevent over-pressure of containments, if over-pressure is a mechanism for failure.

I am not clear that it offers any other relief from failure characteristics of containments, but you may have some different perception. Have I judged it right? Is it over-pressure you are trying to avoid?

MR. MEYER: It is basically over-pressure, slow over-pressurization failure of the containment.

MR. BENDER: Slow over-pressure?

MR. MEYER: As opposed to over-pressurization from a hydrogen burn, for example, or over-pressurization -- well, I --

DR. OKRENT: You can say "steam spike." It is all right.

(Laughter.)

MR. MEYER: I was going to say "steam spike."

MR. BENDER: We will allow you to use that term.

DR. KERR: It is just that, when you use it, you have to use it recognizing that Mr. Zudans does not like it. It is okay if you use it.

(Laughter.)

MR. BENDER: I just wanted to clarify the point.

I do not really want to argue with you about it.

MR. MEYER: Yes. It does not address the steam explosions; it does not address hydrogen burn; it does not address the Beta failures, the failure to isolate containment, or the event V, and it does not address base melts or the Epsilon failure. That is entirely correct.

MR. BENDER: It is just a slow pressure increase which might be mitigated by venting.

MR. MEYER: That is correct.

DR. KERR: Does that complete your presentation?

MR. MEYER: Yes.

DR. KERR: Other questions or comments?

(No response.)

Thank you, Mr. Meyer.

Next is Mr. Cunningham, who will talk about the program on DCC rulemaking.

MR. CUNNINGTON: My name is Mark Cunningham. I am with the Division of Risk Analysis in the Office of Nuclear Regulatory Research.

My part of the presentation today is a discussion of how the vented containment work that you will be hearing about fits into our overall plan for the degraded core cooling rulemaking.

As may be relatively obvious, there are many, many things that go into the determination of the DCC rule. The technical which we will talk about today is one part of it, but there are other parts that are involved, economic analysis, processes to the development of the decision process.

DR. ZUDANS: What is DCC?

MR. CUNNINGHAM: Degraded core cooling.

DR. ZUDANS: Is that the same thing as ICC?

DR. KERR: Oh, no.

DR. KERR: Would you say what DCC is again, please.

MR. CUNNINGHAM: Degraded core cooling rulemaking.

DR. KERR: That is not the same as inadequate core cooling. It is the next step beyond inadequate.

DR. ZUDANS: Oh, core cooling.

MR. MARK: Is there intended a contrast between technical input in Zion/Indian Point?

MR. CUNNINGHAM: Well, there is an inference there that it is not, the Zion/Indian Point experience is not technical, that it was not intended to be that way. The technical input, I was thinking more of the research programs that are going on.

MR. MARK: Well, then, it is the technical input including the observations made on Zion/Indian Point.

MR. CUNNINGHAM: Yes, sir. So, basically, there are just many inputs to the process.

What I think the intent of today's meeting is, is to talk about the technical aspects of it as I was using it there, and again, there are a number of things, a number of areas that come into play, experimental work that Dr. Curtis will talk about, the codevelopment work that is involved, and there is the part which I intend to talk about the most, which relates most to the vented containment program, which is the value impact evaluation of various prevention and mitigation features.

As you can see, I have listed a few there, the vented containment, the FVCS -- the ASHRS is the alternate shutdown heat removal system, MCRD is the molten core retention devices -- and then others. I had listed those because those are programs that we have underway now, and others I will get to in just a second.

What we are planning in the future in relating to what we call now the DCC rulemaking research support program will be the integration of the various programs that we have had underway, Dr. Benjamin's vented containment program, the program on alternate shutdown heat removal systems, the molten core retention device work that we have done, and some others, into one program that will try to develop a consistent set of analyses and reports on many, many different types of mitigation and prevention features.

As Dr. Meyer was saying, we do not want to be in the situation where we are relying on the vented containment as the only possible mitigation feature. So as you can see, we want to get into a broader spectrum of features, different types of venting systems or pressure reduction systems, stronger containments, many different types of things like this. We want to develop a consistent value impact study, in other words, on a broad spectrum of options.

DR. KERR: Excuse me. Put that back on, please. Let's look at number 4 as an example. When you talk about increased containment of volume pressure capability or pressure suppression features, is that in the context of existing containment or new containments or both? How does one interpret that item?

MR. CUNNINGHAM: I think we intend it to be either existing containments -- well, that one may actually be for new containments. It is hard to see how you would be involved in increasing the strength of a present, an already in-place containment, very easily.

DR. KERR: In your present thinking, do you assume that the rule that,at least if it goes in the direction that you think it should go, will deal separately with existing and new containments, or how will that demarcation be made as you presently think of the direction that things should take?

MR. CUNNINGHAM: I a not sure that we are even that far along in our thinking to say for sure, but in my own opinion, I guess it would be hard to combine present containments with new containments in one package. I would think they would have to be dealt with separately. But again, we are not very far along in our thinking about this.

DR. KERR: Thank you.

MR. BENDER: I hate to keep interrupting and slowing you down further, but the time frame in which these things are going to be done is not clear to me. Some of these approaches would require considerable research. Some of them require considerable design. When we talk about a rulemaking of the sort that we are discussing here, what are the premises under which the rulemaking will be developed? Are you going to write one which says the technology is in place and that is the basis for the rule, or is it going to be a speculative kind of rule?

MR. CUNNINGHAM: The answer to that might be a little clearer if you will let me go through the next couple of slides. It explains what we are going to be doing in this part of the program, and then I will get back to that.

MR. BENDER: Well, I am willing to wait and come back again to it.

MR. CUNNINGHAM: Okay

The method by which we want to do this is somewhat iterative, in part because of the situation we are in where we at first have to present an interim rule for comment and then develop a final rule. Because of that, we want to go through two iterations, the first being a somewhat semi-quantitative or qualitative evaluation to narrow down the field of options, that we clearly cannot spend the resources that would be required to look at all of those options that I showed you in the same degree of complexity.

So we intend to go through a first iteration, as I said, somewhat qualitatively, semi-quantitatively, so that that would be the basis for the interim, for the publication of the interim rule. In the time frame between the interim rule and the final rule, we would be again pursuing this in a more complex level, so that we would have the benefit of that information at the time of the final discussions on the, quote, final rule.

MR. BENDER: Is that an answer to the question that I asked?

MR. CUNNINGHAM: I am not sure.

MR. BENDER: Is it intended to be?

MR. CUNNINGHAM: It was an attempt to be. Yes, it was an attempt to be.

MR. BENDER: Let me try again, then, to ask the question so that at least it is clear. It is going to take time to do things, and even the final rule, presumably, is going to be out in the year or two. When is the rule going to be out?

MR. CUNNINGHAM: It is my understanding that the interim rule will be published, I believe they are shooting for about a year from now, and then the final rule will be a year or so, I think, after that.

MR. BENDER: Well, a year or two is what I said.

MR. CUNNINGHAM: Yes, okay, a year or two.

MR. BENDER: And I look at the things that need to be done, and I say, well, it is not likely that I can get very many of these done in the next 2 years. Does that mean they are ruled out?

MR. CUNNINGHAM: I guess what we will have to go with is that, given that rule schedule, we will have to develop the best we can, and if something is not in place, we will have to consider it as one of the matters for judgment, but if the information is not there, if the information is 5 years away, say --

MR. BENDER: Well, as a basis for being able to judge the effectiveness of the rule, I think it is important that you include in the value/impact the time requirements for addressing each of these eleven items that you have listed down here in order to get a realistic basis for judging their effectiveness. Without it, I think the rule will not have meaning, and that is the thrust of my question.

MR. CUNNINGHAM: Am I interpreting correctly your -- we have to recognize up front that there will be parts of it that we will not get to, and we have to consider that, that lack of knowledge, as part of the process in determining what the rule would be?

MR. BENDER: I would think so. The peonle that are on the receiving end of the rule have to act on something, and if the technology is not there, for one reason or another, then the rule cannot be implemented.

MR. CUNNINGHAM: I guess I agree with you, sir, that we have to consider what we will not know as well as what we will know.

MR. BENDER: Fine.

DR. OKRENT: There is a corollary to this point, and that is whether or not the NRC is devoting sufficient resources to getting the information. The ACRS has been saying for some time that the resources that were being devoted in this region of research and study are insufficient. I think they remain insufficient, and in fact, what you have done is outlined a program and by no means allocated the resources that could make it possible to get the information in time, even if the information could be developed, if it did not require long term research, just required effort.

No answer is needed.

MR. CUNNINGHAM: Thank you.

DR. OKRENT: Action would be appreciated, however.

MR. CUNNINGHAM: Yes, sir.

(Laughter.)

MR. WARD: Mark, can I ask a question? Item 2 defines, says you are going to evaluate the value of each option or set of options. How are you, what is your figure of merit there? Are we talking about the factor of 10 reduction in risk, or are you going to make some comparative reduction?

MR. CUNNINGTON: We will be looking at comparative risk reduction, without any particular goal in mind but simply comparative.

MR. WARD: Okay, and when you go to compare the cost and the reduction in risk, what sort of numbers are you going to use there? I mean, do you have any guidelines as to what an appropriate cost of a given reduction in risk is?

MR. CUNNINGHAM: In this particular program, we will not really be deciding at what level of cost or value a particular mitigation feature becomes appropriate or required. That is part of the rulemaking process that is going to be handled elsewhere, but there will be different programs to study --

MR. WARD: Where else?

MR. CUNNINGHAM: Where else? It will be -- well, there is nothing in place right now to do this. It is part of our responsibility, in developing rules, within the division, to start those programs.

MR. WARD: I ask because frequently, when tough questions arise, and I mean tough ones, because I think they are, the answers we get say something about, well, that is going to be developed during rulemaking, as if somehow, spontaneously, the rulemaking process will solve the tougher problems.

None of us -- and I am sure you do not think that it will. So somewhere there has to be something that attacks those tough problems.

MR. CUNNINGHAM: Yes, sir, that is correct. When people say that it will be taken care of in the rulemaking, what it comes down to is that will then be our responsibility to do that, and my management within the division recognizes that, but we have not yet gotten to the point where we could really explain it in detail.

DR. ZUDANS: In the activity that will precede the final rulemaking, certain things will be tested out and decided that they represent improvement, whichever way you want to qualify. Is then the rulemaking going to be prescriptive and just say, you shall do this, or will the industry be asked to come up with other ways of achieving the same objective?

MR. CUNNINGHAM: We really do not have any firm determination of that now. I would expect that we would try to avoid prescription. We would try to say, these are the kinds of criteria we are trying to achieve, and you come in and then suggest to us what might be the best way to do it, and we will have a body -- hopefully, we will have a body of knowledge that can help us decide if that is the appropriate way of doing it.

DR. KERR: Mr. Okrent?

DR. OKRENT: Let me follow. If we go back to Mr. Meyer's presentation, he described the, what do you call it, deterministic/realistic approach, where, for example, the large double-ended pipe break accident was not being considered. You said the mitigation features are going to be considered on the value, the reduction in risk that they contribute, but does this mean that you will be considering the reduction in risk just within a sort of narrow deterministic envelope of possibilities and not considering, for example, the reduction in risk involved with a large double-ended pipe break, for example?

I am having trouble putting those two things together.

MR. CUNNINGHAM: I think we are trying to do it somewhat consistently with the way Dr. Meyer was doing it. I will put it in a little bit different vein, perhaps, that we intend to use as the basis for these things available risk assessments, and within that context, we will take the relative value or the relative contribution of, say, large double-ended breaks, and that will give us, in a sense, a starting point to tell us what the relative value is of that to begin with in relation to small breaks or transients, and then we will investigate the capabilities of the features for the different types, not really a priori excluding any, but the risk assessment telling us that a mitigation feature to handle simply large LOCA's probably would not be risk effective.

DR. KERR: Mr. Okrent?

DR. OKRENT: I would like to follow up your last answer. You said you expect to use the available risk assessments. The ones you show are the RSS and RSS-MAP results. It is not clear to me that they have necessarily included all important accident sources or given them proper weight; in fact, I would say categorically, I do not think that particular group of studies has. So it is not, at the moment, clear to me whether you will have a sufficiently broad source of accident sources from what you said.

Secondly, I cannot tell from what you said how you plan to factor in the uncertainties and what the probability or frequency of different serious accident scenarios is. If you take the results as being something like WASH-1400 and end up with a median frequency of core melt of one in 20,000 per reactor-year, you will get a different value impact than if you decide it is one in 5,000 per year or one in 3,000 per year, and something that looked non-cost effective would be cost effective.

Similarly, if the numbers should be one in 200,000 instead of one in 20,000, you could have a conclusion going the other way. How would you expect to deal with the uncertainties in the PRA results?

MR. CUNNINGHAM: In answer to the first question, as the slides presented, it is really intended to be what we call the phase one of the program. In phase one, we will be using the RSS and RSS-MAP results. As we go into phase two, we will be inclined to incorporate the results from other PRA's, also. I am not sure if that answers that question, but we recognize the limitations of RSS-MAP and the safety study and want to look at a broader spectrum of PRA's in the second phase.

Tape 3a

DR. KERR: Mr. Cunningham, I note that the presentation is scheduled for 20 minutes, and it includes you and another person, I think. Is that correct?

MR. CUNNINGHAM: I think I was going to take the 20 minutes, and then Dr. Benjamin will go into -- he will do his primarily from the next item on the agenda.

DR. KERR: Okay, good enough. Thank you.

MR. CUNNINGHAM: To try to answer Dr. Okrent's second question, again, you are correct that, underlying all of this work, there are some particular assumptions of what we take to be correct and more or less correct in the various studies. I guess, as we go along, we have to decide what we think are the major assumptions that we are making, what we accepting, and do parametric studies, sensitivity studies, to see how things change, if we change an assumption such as the one in 20,000 number that you quoted. Clearly, we cannot get them all, but we will have to work on the ones we think are the most important.

DR. KERR: Thank you. Please continue.

MR. CUNNINGHAM: My last slide, really, has already been addressed in some respects, that we are talking about, for the first phase of the program, hoping to have a report early next year, in the spring of next year, to try to be consistent with the publication of an interim rule in the late fall of next year.

DR. KERR: The program initiation to which one refers here is a program of research? Is that what is meant by program?

MR. CUNNINGHAM: Yes, that is correct. The program which will envelop the vented containment work and things that have been done in the past into what we call now the degraded core cooling rulemaking.

DR. KERR: In that context, then, what is meant by a first iteration? A first iteration of what?

MR. CUNNINGHAM. The first iteration in looking at the eleven mitigation options and prevention options that we have included, the first semi-quantitative go-through of those to narrow the field.

DR. KERR: Okay.

MR. CUNNINGHAM: Again, the last bullet, that we hope to have this done, the second iteration, the more detailed iteration, in about the third quarter of fiscal 83, again trying to be consistent with what timing there is on the rule itself.

MR. BENDER: I want to just reaffirm what I think the understanding was, that the rulemaking, final rulemaking, would come after the report in the third quarter of FY 83?

MR. CUNNINGHAM: That is my understanding, yes, sir. That is the intent.

MR. BENDER: Thank you.

MR. CUNNINGHAM: That is all I have, Dr. Kerr.

DR. KERR: Thank you, Mr. Cunningham. Are there other questions?

(No response.)

That brings us then to Mr. Benjamin.

DR. BENJAMIN: The handouts that I am passing out to you include vu-graph material that I am going to be using in this presentation that is entitled "Risk Assessment Applications to Filtered Venting," and also the next one which deals with design concepts, so it includes what is allocated as being about an hour and a half on the agenda.

DR. KERR: Let's see, 90 minutes. That means there should be about 180 vu-graphs, doesn't it?

(Laughter.)

DR. BENJAMIN: I usually try to figure one vu-graph per 3 min , myself, but I did more than that in this case.

The topics which I propose to cover are to briefly start with an overview dealing with the filtered-vented containment program, specifically, as opposed to degraded core rulemaking, which Mr. Cunningham talked about, and then to talk about the methodologies for probabilistic risk assessment that we have developed, try to address some of the questions that I have heard this morning from some of the ACRS members and consultants in terms of how we are approaching some of these questions.

In particular, we have been concentrating on BWR-MARK I containments with the application of this risk assessment methodology, so some of it will be a little bit specific to that type of containment.

Then I will go into how we are using the risk assessment in the process of developing design concepts, how we are using risk assessment right now for the BWR-MARK I containment in order to point the way to what appears to be the best design concepts to pursue, and then the last item deals with design concepts for the Indian Point reactor which came out of the Zion/Indian Point study that the lab did for NRC about a year ago. On the last item, I will tailor how much detail I go into according to how much time there is and whether or not you are already familiar with some of these things.

To go over the objectives, the objectives of the program have been develop conceptual designs of vent-filter systems for various containment types, including backfitting into existing reactors and incorporation into new reactors; assess the values versus impacts, looking at the reduction in radioactive releases and overall risks for core-melt accidents, first of all, and then, as impacts, the effects on non-core-melt accidents and on normal operations, and the costs; and to specify system performance and safety design requirements.

The end products of the work we are doing are oriented, I would say, particularly toward rulemaking and possible licensing of features based on filtered venting if it is decided during rulemaking that such licensing or such features should be required.

We are attempting to answer what we consider to be the important questions, whether filtered-vented containment systems have a net positive risk reduction potential or a net negative one, whether they are cost effective compared to other possibilities, such as preventive measures, which brings us a little bit more toward the degraded core rulemaking research program, and whether the uncertainties have been resolved sufficiently to enable us to make conclusions in these first two areas and what needs to be done in order to resolve them; and then, for licensing, design standards and performance requirements.

DR. KERR: Mr. Benjamin, in your treatment, do you distinguish between existing plants and new plants?

DR. BENJAMIN: We distinguish between existing plants and new plants in terms of what types of design features can be considered to be practical to implement. For example, in filtered venting, we would consider it to be impractical to implement a filtered venting system that required a very large containment penetration, let us say something of 6-foot diameter or larger, in order to vent containment. We would consider perhaps a 3-foot containment penetration to be reasonable.

In new reactors, that limitation would not necessarily apply. There are other types of considerations, also, where if one started from the design stage in the containment, it would be easier to implement certain features that would be difficult to implement on a backfitting basis in current containments.

DR. KERR: Okay, so I think the answer is yes, you do, and you have given me a couple of examples.

DR. ZUDANS: When you talk about MARK I, you are really only talking about existing.

DR. BENJAMIN: We have been concentrating on containments so far.

DR. ZUDANS: So it is a backfitting question.

DR. BENJAMIN: Well, it is primarily oriented towards systems that can be backfitted, although they could also be incorporated into new reactors, of course, also.

DR. ZUDANS: But who is going to build MARK I now?

DR. BENJAMIN: I beg your pardon?

DR. ZUDANS: Who is going to build new MARK I?

DR. BENJAMIN: Who is going to build new ones?

DR. ZUDANS: Yes. New MARK I's, I mean.

DR. BENJAMIN: I take it that is a rhetorical question. I guess --

DR. KERR: Yes, I think that is a good interpretation. Why don't you continue?

DR. BENJAMIN: All right, fine.

MR. BENDER: It is more than a rhetorical question. It is a matter of whether the result will have any usefulness or not.

DR. ZUDANS: That is exactly it.

MR. BENDER: I think, if you are looking at MARK I's and you are not planning on building any more of them, what is --

DR. KERR: He said he was looking at backfits, Mike, and if he looks at backfits, you would look at backfits possible to MARK I. I do not understand what the problem is.

DR. BENJAMIN: We are not looking --

DR. KERR: We will agree that you are not planning on building new MARK I's, right?

DR. ZUDANS: Well, the question was not that. The question was whether they are looking only in the backfitting more or are thinking about the future.

DR. KERR: Well, I thought he said -- well, maybe you should say what you said. I thought you said right now you were --

MR. BENDER: We are just trying to understand what he is saying.

DR. KERR: -- you were looking primarily at backfits.

DR. BENJAMIN: To the present time, we are concentrating on backfits into four types of reactors, not just MARK I containments but also large, dry PWR containments, ice condenser PWR containments, and MARK III BWR containments. We are using case studies which represent existing plants. For the large, dry PWR, Indian Point has been our case study so far, although we may also look at Surry, since the Zion/Indian Point risk assessment is not available for us to use for the large, dry PWR containment.

For the MARK I, we are looking at Peach Bottom as a case study; for the ice condenser, Sequoyah, and for the MARK III, Grand Gulf, and these then represent a conscious effort to determine how filtered venting systems would be backfit and how they would improve reactor risks or reduce reactor risks for existing plants.

We are treating the question of new plants more as a corollary. If one were starting from scratch, is there one way, is there a particular way in which one could achieve better results than what we can achieve with existing plants? It is more of a corollary to the work we are doing than a fundamental part of it, at least as the work has developed so far.

MR. BENDER: I want to continue to address the matter of priority of effort and how to get the results on a timely basis. That is most of the reason why I have been pushing a certain amount of questioning here.

I see the regulatory staff developing a rule that says, on an interim basis, put in a big venting provision in the form of an opening, with the anticipation that something will be added to it later on. I would like to know, fairly early in life, whether that provision is the right kind of provision or not. I would like to have it in time for the interim rule.

I am interested in backfits in the sense of knowing whether designing for ultimate strength, as opposed to the ASME design strength capability, based on factored loads, is the best approach. I am not right now clear how you are going at this. Are we going to hear that later?

DR. BENJAMIN: Well, I had not planned to address those specific questions, but I will comment on it a little bit now if you like.

The question about whether to dedicate a containment penetration to filtered venting, I guess this is a personal opinion more than anything. I do not believe that that really is a very momentous item, because normally, containment penetrations -- normally, in containments, there are penetrations provided for contingency that are not used, anyway, so, to me, that means that you are going to take one of these contingency penetrations and put a sign over it that says, "For possible use in filtered venting," when we are talking about new reactors.

Now, my understanding, also, is that this 3-foot containment penetration is for near-term construction permits reactors rather than existing reactors, where there would not be any particular problem with doing this.

The second part of the question about ultimate strength compared to design pressures in containments we have not addressed on this program. There are programs -- this is not directly answering your question, but perhaps it is relevant -- there is a program beginning to look at trying to determine what the ultimate strength of containment, various types of containments, really is and what type of failures will occur and where they will occur. This type of information could be fed into programs like filtered venting program.

We are assuming that we have a certain amount of strength beyond design pressure. Typically, we will assume that we can allow the pressure in the containment to go up about 30 percent, let us say, or perhaps even as much as 50 percent, above the design pressure of the containment, before venting is initiated. Most analyses that have been done with regard to setting containment failure pressures have assumed something like a factor of 2 between the design pressure and the ultimate failure pressure of containments, and recent data and analysis seems to indicate that in fact a failure pressure is probably better than that factor of 2.

MR. BENDER: If I get back to some of Dr. Okrent's line of questioning, which goes along the lines of saying, what is the probability of over-pressure leading to failure, what is the probability that you can protect the public best by not venting as opposed to venting?, I have to think about what the ultimate strength of the structure is and what the working conditions are under which it has to be addressed, and I think I have to deal with those for the as-built systems if I am going to do something about backfit, for example.

I think I have to think about them for those that are in the construction permit stage in terms of whether just putting in an opening is enough. Can I just say that is enough of a proviso to allow for future rulemaking, because the risk of not doing enough has some significance, too, and so I would like to know that in going through this baseline study of reactors, where you are examining the design features, you are addressing the issues that are going to have to be addressed as vented-filtered containment is ultimately utilized.

I agree with you that an opening in a containment is a fairly small addition to the system, but does it really deal with the issue? That, I think, is what I am trying to point to.

DR. BENJAMIN: Well, I can only say that I agree with that sentiment, and I would also say that we are addressing the questions of what type of design provisions have to be included, besides just a hole in containment, in order to have an effective venting system, and this is part of our program and as a part of the information that we give to the NRC.

I think that may become a little bit more obvious as I go through this presentation.

MR. BENDER. Thank you. I will stop now.

DR. BENJAMIN: All right.

Let me get into the area of the risk assessment work as it applies to filtered venting by starting with what the purposes of the risk assessment are.

The first purpose is to look at a variety of venting strategies or a variety of strategies, mitigation strategies,that utilize containment venting; to select the one or two that appear to be best from a risk reduction perspective.

The second is to look at a variety of filtering concepts, to also choose the best from a risk reduction perspective.

The third purpose of this is to establish design criteria for reliabilities in the vent filter system.

The fourth one is to establish design criteria for fission product decontamination requirements.

The fifth is to estimate the net risk reduction potential, including both positive and negative aspects of risk introduced by the system.

And then the last two have to do with assessing sensitivities to phenomenological uncertainties and to system response uncertainties, and if you abide with me, I will get to what types of uncertainties we are considering and how we are considering them.

Let me first show a vu-graph that illustrates the logistical format that we have developed for doing the risk assessment. It gives the primary tasks involved in this risk assessment. The first step is to review the plant characteristics, in which we primarily use the FSAR and consult with the vendor to obtain data dealing with the plant characteristics, and to the extent possible, we also consult with the plant personnel for the baseline plant that we are looking at.

We then evaluate existing risk analyses which come from programs like the Reactor Safety Study, RSSMAP, and IREP, and which form the baseline or the starting point for the risk analysis we do in filtered venting.

We perform preliminary accident analyses. We use the MARCH code as a tool, not really the only tool because we also exercise engineering-type calculations to look at possible deviations from the assumptions that are embodied in the MARCH code, and we do this in a way that feeds into our sensitivity analyses, which are over there.

These then lead to formulating candidate venting strategies. The next step down here is to identify possible system interactions that can be introduced by the vent filter system. The FSAR and vendor provide most of the source of data for that.

We identify major vent system failure modes through a kind of failure modes and effect analysis, and we incorporate these into an event tree logic that includes possible failure modes of the vent filter system in addition to failure modes of other systems.

We estimate vent system failure probabilities. This is done, at this point in the analysis, without the benefit of detailed design, so it does not involve fault tree analysis, but, rather, estimates of what we think would be reasonable ranges for failure parameters that we can later assess with regard to sensitivity of risk to these failure probabilities.

We establish risk measures, which I will describe in a minute, using a CRAC code as a tool. We perform detailed accident evaluation with MARCH and CORRAL codes as a tool, and we quantify the risk and assess the sensitivity to uncertainties, and we have developed a kind of bookkeeping code at Sandia to quantify the risk.

Now, I want to discuss four areas here that were brought up this morning already in which I think you are interested. One has to do with the types of accidents that we consider in the risk assessments. Another has to do with the event tree logic and the types of system failures that we consider in deriving event trees.

Another has to do with the risk measures that we use, what we define to be risk for purposes of this comparison, and the other has to do with the sensitivity analysis and, in particular, the phenomenological and system response uncertainties that we consider.

This chart shows essentially the variety of different types of accidents that we have considered for the MARK I BWR. These come primarily, since it is the Peach Bottom reactor that we are using as a baseline, from the Reactor Safety Study, but we redo the probabilities of the accidents according to more recent information that has become available since the Reactor Safety Study, and we recalculate what we think those probabilities are.

In this chart, as you can see, there are accidents initiated by transients with stuck-open relief valves or other abnormal transient events, et cetera, and various system failure modes that are listed over in this part of the vu-graph, such as ECCS failure, reactor protection system failure, containment cooling failure, electrical power failure, and beyond this, not shown, are the possible failure modes introduced by the vent filter system, which I will discuss in the next one.

In evaluating the probabilities of these different types of accidents, we have determined that the primary differences between the probabilities that we have evaluated and those in the Reactor Safety Study have to do with accidents with a stuck-open relief valve in the primary system, and the particular source of this difference has to do with the availability of the power conversion system in cases where the primary system depressurizes and there is no longer a source of high pressure steam to the steam jet air ejectors in the condenser to provide a vacuum.

In certain BWR's, Peach Bottom being one, there is no tie-in from the auxiliary boiler to the steam jet air ejectors, and so we were not able to take credit for that as in other reactors it would have been possible to.

And we did not -- to establish the probabilities, the dashed lines here, the dashed bar represents probability corresponding to this particular stuck-open relief valve accident, also not taking credit for mechani al vacuum pumps, which are not normally used for maintaining condenser vacuum because of the fact that they release radioactive fission products to the environment.

But we recognized that it would be fairly easy to provide a tie-in between the auxiliary boiler and the steam jet air ejectors, and so we allowed that that would be a part of any venting or any mitigation strategy or any strategy to reduce the risks in a reactor. The first step would be to provide a tie-in that would circumvent this particular problem, at least in part.

Our event tree logic is based on using event trees that have an initiating event tree that describes essentially the accident sequences in the Reactor Safety Study; a mitigation event that describes two things, first of all, the possible failure modes of the vent filter system, and, secondly, branch points that represent phenomenological and system response uncertainties for which we want to do a sensitivity study and assess the possible risks associated with one set of assumptions as opposed to a different set of phenomenological assumptions.

The third one is a containment event tree in which we have included not only those containment failure modes that are already present in the Reactor Safety Study, but also a number of additional containment failure modes which are occasioned by the filtered venting system such as, for example, bypass of the filters or premature opening of the vents or failure to close, those types of failures. It also includes certain types of failure modes that were neglected in WASH-1400, such as basemat melt-through, because they were not important in the context of that study but become more important, conceivably, in the context of this study.

DR. KERR: How do you decide what sorts of numbers are appropriate to use for the probability of vessel steam explosion or pressure spikes?

DR. BENJAMIN: I have a vu-graph that shows that specifically and gives the actual numbers we have considered, so I will answer that question.

DR. KERR: Have you taken into account the probability that, given that a vent system is available, the decisionmaking authorities will not use it? I mean, that failure mode.

DR. BENJAMIN: We have taken into -- well, first of all,the vent filter systems that we have considered have been mostly passive, in addition to passive operation, also passively actuated, such as a relief valve type of system. We have allowed for the possibility that there may be a design feature which allows the operator to turn it off, some back-up valve which the operator could turn off, and attempted to assign a probability to the event that the operator does turn it off, and that the venting system is then not available.

We would assign, we have been typically looking at probabilities like one in 100 for that possibility, although we also look at how the risk would be affected by other probabilities assigned to that type of failure mode.

DR. KERR: Does the guidance which leads you to assume that the actuation will be automatic come from the NRC, or is that just your best judgment that that is the way to do it?

DR. BENJAMIN: Well, I would say it comes more from our best judgments about the way to do it, and it depends on the accidents -- it depends in part on the risk assessment and the accidents that dominate the risk. It depends on whether, to mitigate the effects of an accident, you need to have an anticipatory action where either an operator or automatic controls would provide the opening of a vent, or whether it is sufficient to have a vent actuation that is purely based on the current pressuring containment, such as either a relief valve or a rupture disk, and in terms of the MARK I BWR's, it appears apparent that passively actuated venting is possible, and if it possible, it is considered to be preferable, simply because it is passive rather than active.

DR. KERR: I do not understand. I would have assumed that one would use automatic and manual. Are those terms synonymous with passive and active, or what you do mean by passive as contrasted with active?

DR. BENJAMIN: Well, by passive actuation of the vent, I am talking about a vent which is actuated when the pressure in containment reaches a particular level and opens as a result of that pressure forcing it open. In that case, there are no operator actions necessary. There is no manual or automatic control necessary.

DR. SIESS: Do you mean a rupture disk?

DR. BENJAMIN: Either a rupture disk or a relief valve.

DR. KERR: Okay, I think I understand it. By active, you mean that somebody has to consciously make a decision and do something. Is that it?

DR. BENJAMIN: Yes.

DR. KERR: Thank you.

Tape 4a

MR. BENDER: In the event tree logic program up there, you have some listings down below it. Some of these seem to be mitigative and some appear to be events, failure events. Is the intent to try to assign a probability to the effect of mitigation as a function of the event? Is that what you are trying to convey to us?

For example, the ECCS pumps fails after NPSH loss, and then the next thing says recovery before pool depletion. Are those thought to be alternative actions of some sort or what?

DR. BENJAMIN: Well, the question about ECCS pump failure after NPSH loss is attempting to deal with a system response uncertainty. That is, the WASH-1400 assumptions have been that the pumps, when they begin to cavitate, will fail and that you will no longer have ECCS delivery to the core. These assumptions have been thought to be very conservative, both at the NRC and in the industry, and in our discussions with people in the industry, there is strong evidence that the pumps would not fail, at least not immediately or not for some period of time.

We have put in there, then, a branch point which says, let's look at both possibilities, and the first possibility, the pumps fail when the net positive suction head is lost, either to venting or to containment failure -- both lead to loss of net positive suction head for some accidents.

In the second case, we say the pumps survive and they do not then fail until the water in the pool is depleted -- this is the suppression pool containment -- and when the water in the pool is depleted below the suction intake for the pumps, then the pumps would fail.

Now, the next event there deals with the possibility that the operator or through some procedure that may or may not be accounted for, recovery may be obtained prior to loss of the water from the suppression pool -- it takes several days to lose the water -- and that event provides for that possibility. In this particular case, we assign a probability to recovery on the basis of the amount of time available and using essentially the WASH-1400 type estimates of likelihood of recovery as a function of time.

In other events involving possible recoveries, we look at -- again, we parameterize the problem, and we will say, suppose that recovery can be effective before the core melts through the reactor vessel; how would that affect our conclusions regarding filter venting systems, how effective they would be, and then we treat that, then, as an either/or type situation and attempt to assess the sensitivity of the risk and the value of the vent filter to these various possible recovery modes.

MR. BENDER: If I understand what you are saying, your approach would be to look at the mitigative actions or mitigative conditions that might occur at each stage in the progression of the accident, the venting being perhaps somewhere along the way, one of the mitigative actions that would be taken. Is that a wrong understanding?

DR. BENJAMIN: No, that is correct, and I would add that part of the intent of the program is to compare the relative effectiveness of filter venting to other possibilities such as preventive measures, such as passive containment cooling and other mitigative measures, and so we have put in our event tree the flexibility to consider other possible approaches, and we are doing so.

We are not concentrating as much on the other possible approaches, except to estimate how much the risk reduction from these other approaches might accomplish. We are not going into those estimates in as much detail as we are for filtered venting, but we are trying to establish a comparison between filtered venting and other approaches.

Also, we have things in this event tree that apply to adjuncts to the filtered venting system, things that should or could be done in conjunction with filtered venting in order to mitigate accidents, and in particular, I point out the second item, which deals with external water tie-in. On the MARK I BWR, we found that for filtered venting to be particularly effective, it would be very advisable to have a tie-in from the high pressure service water system to the residual heat removal system, lower pressure coolant injection system, a tie-in that currently exists but is not safety grade and is therefore not taken credit for.

The purpose of the tie-in is to continue to provide water to the core as venting goes on and as either the pumps fail due to cavitation or the pool is depleted due to venting. So this event, then, appears as an event on the event tree because it is one of the strategies we are considering. Does this answer your question?

MR. BENDER: Well, I think it does. I would elaborate for just a half minute. The path of progression seems to be an important consideration in trying to use this approach, and you have to be sure you've got all the paths identified. You have shown the ones that dominates WASH-1400. Is the plan to use other plan to develop other paths of accident progression beyond those that already exist in WASH-1400?

DR. BENJAMIN: Well, if you mean by that paths of accident progression that represent possible changes in the progression as a result of the vent system --

MR. BENDER: Well, let me say, I don't know that WASH-1400 identified all the ways in which containment cooling could fail.

DR. BENJAMIN: No.

MR. BENDER: Hopefully, they did, but if they did not, then the logic may fall down, and so I just want to ask whether you are thinking in those terms or not.

DR. BENJAMIN: Well, we are attempting to include, to answer that question in one way, we are attempting to include insights from more programs like RSSMAP and IREP that go into questions of containment cooling failure modes that were not considered in the Reactor Safety Study, and to adopt what has been learned since then.

Also, we are attempting to assess whether there is any possibility that the vent system itself could lead to failures of other systems such as containment cooling, if the vent system were to not operate properly or to operate prematurely, and so we have attempted to include all possible failure modes that we can identify on the basis of the information currently available and people that we have access to.

MR. BENDER: Thank you.

DR. KERR: Mr. Siess?

DR. SIESS: You have used the terms "mitigation" and "prevention" quite a bit, and it has not been clear to me just what you are mitigating and just what you are preventing and whether you are always mitigating the same thing and always preventing the same thing or whether you are using the terms differently. Is it possible to clarify that once?

DR. BENJAMIN: Yes. The terms have been used by many people, and they mean different things sometimes to different people. I use the term "prevention" to mean design features in plants that prevent any fuel damage from occurring.

DR. SIESS: Well, you have been using "prevention" to mean prevent over-pressure from occurring.

DR. BENJAMIN: No, I do not believe so.

DR. SIESS: Well, that is what venting does.

DR. BENJAMIN: Yes. Well, I have using "preventive features" in talking about other features besides filtered venting. When I am talking about preventive features, I have meant to talk about features such as improved reliabilities in existing systems or additional decay heat removal systems.

DR. SIESS: Now, that is preventing what?

DR. BENJAMIN: And this is preventing --

DR. SIESS: A core melt?

DR. BENJAMIN: A core melt, yes.

DR. SIESS: And then what are you mitigating?

DR. BENJAMIN: "Mitigation" I use as a term that reduces the consequences, meaning to reduce the consequences --

DR. SIESS: Of what?

DR. BENJAMIN: -- of the accident, given severe fuel damage occurs.

DR. SIESS: Say, mitigating the consequences of a core melt?

DR. BENJAMIN: Yes.

DR. SIESS: So mitigation and prevention always refer to a core melt, either preventing a core melt or mitigating the consequences of a core melt, or severe fuel damage?

DR. BENJAMIN: I think some people would say that prevention means essentially preventing the initiation of the accident so that there is also, in essence, a reduction in the number of accident initiators.

DR. SIESS: I do not think there is any question about what prevention or mitigation mean. The only question in my mind is what they are modifying.

DR. BENJAMIN: I am sorry, I did not understand that.

DR. SIESS: I know precisely what they mean, but you are using the words "mitigation" and "prevention" without saying mitigating what or preventing what, and I think it would help a great deal if I knew -- for example, I mitigate the consequences of a core melt by venting, but I also prevent over-pressure or I may prevent doses to the public. So one man's mitigation is another man's prevention.

DR. ZUDANS: Would it be descriptive if you used "prevent" accident initiation and "mitigate" everything that happens after it is initiated? That is what you mean?

DR. SIESS: No, because --

DR. ZUDANS: You don't have to wait for core melt to mitigate.

DR. SIESS: -- if you have a pipe break, the ECCS will prevent a core melt, but if the ECCS does not work, then you need something else to prevent over-pressure. You mitigate the consequences of the pipe break with ECCS. You mitigate the consequences of the core melt with something else.

There is a whole sequence of things in turn.

DR. KERR: Does that make things clearer, Mr. Benjamin?

(Laughter.)

DR. BENJAMIN: I shall try, but I may be unable to.

DR. KERR: No, I say, does that explanation make things clearer to you?

DR. BENJAMIN: Uh --

DR. KERR: I had hoped you would say yes.

(Laughter.)

DR. BENJAMIN: The differences are, I think, fairly clear in my mind.

DR. KERR: Good. Go ahead.

(Laughter.)

DR. BENJAMIN: Shall I go ahead?

DR. KERR: Mr. Benjamin, my agenda calls for a 10-minute break at some period. Is there any best period in your presentation, or is this a good time?

DR. BENJAMIN: I think it would be a good idea for me to go through four more vu-graphs, if that is possible, and then that would be a good time for a break.

DR. KERR: That is possible. Let's do it.

DR. BENJAMIN: All right.

The next issue has to do with measures for comparing risks, and we have been using two measures of risk for purposes of screening different options for preventing or mitigating accidents, in whoever's terms you use, and those two measures are probability of core melting and what we have termed equivalent weighted releases.

We then, after the screening, go to more detailed consequence calculations with the CRAC code, but let me describe what I mean, first of all, by equivalent weighted releases, which is the key to the comparisons we have done so far.

Equivalent weighted releases is an attempt to assign to each accident a particular number that represents the release of fission products to the environment outside containment for that accident. The way that we do that is to assign weighting factors to the various fission product groups that are important in the CRAC code that determines consequences.

The way that we determine these weighting factors is to run the CRAC code in order to assess the relative importance of the various fission product groups in producing certain kinds of consequences, and the particular kinds of consequences that we used as an index are these three: bone marrow dose to an individual one mile from the reactor, thyroid dose to an individual one mile from the reactor, and total population dose.

From those indices, we were able to determine the weighting factors shown here, three sets of weighting factors for the various fission product groups, and we use those --

DR. OKRENT: Excuse me. Before you go on, just so I understand the basis for those figures, taking any one of those, for example, the bone marrow dose, is that arrived at by taking the PWR categories 1 through 7 and their probabilities and getting an effective answer by multiplying and summing, or is that for a specific release, PWR 2?

DR. BENJAMIN: To be specific about how we did that one, we took a BWR 2 type of release and we ran the CRAC code assuming the release of each fission product individually -- first xenon, then krypton, then iodine, then cesium, et cetera, and we assessed or determined from those CRAC code runs what the numbers of consequences in those categories were, what the dose, essentially, per REM released was.

DR. OKRENT: All right. So this is for BWR 2.

DR. BENJAMIN: BWR 2, yes.

DR. OKRENT: Okay, thank you.

DR. KERR: That is for fission product availability of the kind that was being used at the time the WASH-1400 study was made?

DR. BENJAMIN: Do you mean release fractions from WASH-1400?

DR. KERR: Yes. And what one thought about the chemistry and physics and fission products released at that time. You have not modified that on the basis of any later information or consideration, or have you?

DR. BENJAMIN: For this particular application, the specific answer to your question is yes, but the more detailed answer is that we are looking at a REMs received per curies released, a ratio of dose per release, in order to determine these weighting factors, and therefore, since it is normalized to the release, the release does not really very significantly come into this particular aspect of the problem. It certainly does come into the risk evaluation later on, and for that, we do not use WASH-1400 releases. We have reevaluated the releases. We have done it by a process of using the MARCH and CORRAL codes, and we have also assessed the sensitivities of the risks to other assumptions than what are embodied in MARCH and CORRAL, and I intend to get to that aspect of it.

DR. KERR: Is the implication that MARCH and CORRAL give some later information than that that was available when the WASH-1400 study was done?

DR. BENJAMIN: Yes, yes, that is true. MARCH was not available in WASH-1400. Those calculations were done by hand, containment response calculations. CORRAL was available. There have been some changes in CORRAL since WASH-1400, particularly dealing with iodine deposition, so that does represent some improvement, I believe, since the reactor safety study.

MR. BENDER: Just so somebody else might try to understand what you are saying, I would presume that what is being done is to exercise MARCH, CORRAL, and CRAC for exemplary cases and then to go back and adjust the analyses based on potential for error in the assumptions of efficient product transport and release in order to determine what the range of values might be, and then to pick up frc.a that your best estimate of which one is the right one?

DR. BENJAMIN: Up until your last statement, I would say that is a good description of what we are attempting to do.

MR. BENDER: All right. What is the last statement supposed to be, then, because that is the crucial question.

DR. BENJAMIN: All right. Let me then go to those vu-graphs that deal with that question.

What we attempt to do is to identify the sources of uncertainty that we consider to have the largest effect on the end results that we are looking for and tc assign what we call conservative criteria, on the one hand, to those phenomenological and system uncertainties and non-conservative criteria, on the other hand, and if I could loosely describe what those are, I would say the conservative criteria that we assign are based on Reactor Safety Study type of assumptions. They are consistent with many of the assumptions in the Reactor Safe:y Study; for example, failure condition for RHR pumps. We have already discussed that one, so I will not discuss that any further.

The probability of steam explosions came up earlier, causing a missile that fails containment. It was assumed to be one chance out of 100 in the Reactor Safety Study.

The probability of what have been called steam spikes, somewhat of a misnomer for BWR's, where the steam is suppressed in the suppression pool, but it still applies in principle because of the hydrogen produced, assigned a probability of .2 or .05 in the Reactor Safety Study, depending on the pressure in containment and the iodine release form, taken to be molecular iodine in the Reactor Safety Study, with a little bit of organic iodine.

I am going to flip between these two charts. Other sources of uncertainty that we consider to be major have to do with particulate deposition on primary systems structure, particulate fallout in containment, if it is not failed prior to the meltdown, particulate and iodine removal in suppression pool, particularly at saturated conditions, and particulate removal in crushed rock bed at superheated conditions I included, since it is one of the design concepts that we were considering.

Now, by the non-conservative criteria, what we have attempted to do is to review various opinions that have been published and presented such as Morewitz and others at EPRI and other people that represent predominantly an industry view on what would be best estimates, and we have attempted at this point to incorporate those into an estimate of what might be considered non-conservative criteria for these uncertainties. I hesitate to call them best estimates. I would not call them best estimates because we have not determined exactly what best estimates are in these particular issues, where they fall between the conservative and non-conservative criteria.

MR. BENDER: Is the term "non-conservative" proper? Maybe it is less conservative.

DR. BENJAMIN: Very well. I consider them to be definitely non-conservative in some aspects. For example, assigning zero probability to a steam explosion failing containment would have to be a called a non-conservative assumption because that is the lowest that one could take.

DR. SIESS: That does not make it non-conservative.

DR. BENJAMIN: You do not believe so?

DR SIESS: That does not automatically make it non-conservative. It may in fact be zero, in which case it is correct.

DR. BENJAMIN: It may.

DR. OKRENT: I am willing to defend his statement that that is non-conservative for BWR, for example, where you have a small containment, and if there is some chance of it running into water, you do not need very much reaction.

DR. KERR: Please continue, Mr. Benjamin.

MR. BENDER: Well, no, let me be sure that I have got the whole picture. I am not really trying to take issue with whether it should be "less" or "non." It just seemed like "less" was more logically the term you wanted to use.

But what seems to be showing up here is a range. On the one extreme is conservative, and on the other is something called non-conservative, and I have to pick a number for decision purposes, and I think that is the problem we ran into with WASH-1400. In some cases, we did not know where to make the decision because the range was very broad, and I would like to know how you are dealing with that. You said no best estimate. I think you have to pick a point, and I want to know, how do you go about picking the point between those two ranges?

DR. BENJAMIN: Well, that is a very pertinent question and a difficult one to address directly, but I will indicate essentially how we have been using these ranges of uncertainty, and perhaps it will shed some light on that.

MR. BENDER: Okay.

DR. BENJAMIN: This is getting into some of the results, and I will not concentrate on the magnitude of the results right now because I intended to do that later, but we have tried to determine the range of possible risk reduction of various types of strategies, including non-conservative, what I will call the non-conservative assumption set, which would be this side of the bar, of the cross hatch, and the conservative assumption set, which would be this part of the cross hatch, and to determine whether these uncertainties, first of all, are such that they would make it impossible for us to determine whether a particular strategy was good or not and how good it was.

If they were such as to make it impossible for us to arrive at conclusions, then we would have to go and attempt to narrow it down as much as possible and find what "best estimate" really means. If it is not such as to make conclusions impossible or difficult to make, then we would say that we can make certain conclusions based on the existing ranges of uncertainty that we feel will apply even after resolution of these uncertainties.

In the case of the MARK I BWR, the basic conclusions seem to be that those strategies that appear attractive with the conservative assumptions also appear to be attractive with the non-conservative assumptions. The levels of risk are different by as much as an order of magnitude up here, where we are talking about the containment as is, down to approaching two orders of magnitude for certain strategies.

Another aspect of it is that those features, mitigation features in this case, which give results that are less than sensitive to the phenomenological uncertainties than others, have an inherent benefit. It means that one then has more assurance that these systems will provide benefits than a system that is very sensitive to the uncertainties, the existing uncertainties and phenomenology and system response.

So I think, to answer your question, we are able to come up with key conclusions on the basis of the existing uncertainties, and we recognize the need to try to obtain best estimates. We feel that that particular issue, however, is not really something that can be addressed in the filter venting program directly; it has to be addressed by those people that do the phenomenological research, that are doing the experiments and the analysis of these various phenomenon issues, and we have to provide them with a perspective on what issues need to be resolved for purposes of our analyses, and then they have to be responsive in looking at these issues and trying to resolve them.

MR. BENDER: Well, I think your approach makes fairly good sense. It does emphasize the importance of having the phenomenological information in hand when you make these decisions.

DR. ZUDENS: One question on that. When you went to this range and made the conclusions that you really did not need the best estimate to make a judgment on some particular strategy, did you run either the one, what you call conservative, versus the non-conservative, or did you mix between different items in some way?

DR. BENJAMIN: We first ran the conservative assumption set versus the non-conservative assumption set, and these results are shown.

We then are in the process of assessing the sensitivity to individual assumptions, varied one at a time, to determine which of these uncertainties are most important from the point of view of the risk with and without the mitigation features.

DR. ZUDANS: You have a reason to believe that any kind of a mix from these two groups would otherwise fall in that cross hatch, right?

DR. BENJAMIN: I cannot identify any cases in which they fall out of range, although I cannot say that we have conclusively finished the analysis and be able to determine whether in fact there might be some combinations that would fall outside the range. I do not believe so, but I cannot say with surety right now.

We are still working on these problems.

DR. ZUDANS: Thank you.

DR. BENJAMIN: I think this might be a good place for a break if you would like to take one now.

DR. KERR: I declare a 10-minute break. We will resume at 10:50.

(Brief recess.)

DR. KERR: May we resume, please.

DR. ZUDANS: Could you put that last graph that you had with those bar charts, cross hatch, back up? The last graph on which the range evaluated in terms of equivalent curies.

DR. KERR: Did you have a question?

DR. ZUDANS: Yes.

DR. KERR: Would you please put the previous chart on, Mr. Benjamin.

DR. ZUDANS: Where do the venting strategies show up in these bar charts?

DR. BENJAMIN: If you do not mind, I would like to get into that with a little bit of introduction. This is my next set of vu-graphs.

DR. ZUDANS: But do they show up here?

DR. BENJAMIN: Yes, they show up there. They are in these three cases.

DR. ZUDANS: All right, thank you.

DR. BENJAMIN: May I start now? Is everybody back?

DR. KERR: Please continue.

DR. BENJAMIN: I would like to talk about how we are using this risk assessment to synthesize filtered venting systems and determining the types of filtered venting systems and adjunct types of design provisions that have to be included to make the difference as far as risk is concerned.

To introduce the subject, this is a very simple schematic of just a vent filter system that illustrates a couple of points that I want to make at the outset. First of all, we are venting from the wet well, so that we are using the suppression pool as a filtering and scrubbing medium prior to venting.

In most of the work that we have done so far, we have considered this valve to be a relief valve. It opens at about 100 psi and closes at somewhat lower pressure, but we also have looked a little and intend to look a little bit more in terms of venting actuation being a rupture disk or something where the pressure in containment does not necessarily remain high but can be reduced. And then venting goes through filters and then to a stack.

DR. KERR: Excuse me. Are you going to say something about how you pick the appropriate opening pressure?

Well, we picked the opening pressure for the MARK I BWR by taking the design pressure, which was about 71 psi absolute and considering the failure pressure that has been estimated so far, which is about 175 psi absolute, and we have assumed that venting would start when the pressure reached about 100 psi. It happens that for the MARK I BWR, which is a small containment, the particular p. ssure at which the vent is open above design pressure and less than failure pressure does not critically affect the risk unless, of course, you come too close to failure pressure and the containment fails, because of the fact that it is a small containment, and if you are in an accident sequence where you are producing steam that is not condensed in the suppression pool or producing non-condensables, not condensed in the suppression pool because the pool is saturated, or producing non-condensables from the core-concrete interaction, it does not take very much to over-pressurize the containment.

Consequently, these scenarios, in the MARK I BWR, will generally lead to containment failure if something is not done to prevent it from happening.

DR. KERR: What I had in mind, one might take this to an extreme -- I do not know how extreme -- and say, since you have a good filter and a stack, you do not really need to keep the containment closed at all. The way to prevent overpressure is just always have the vent open and let her fly.

Now, you do that if you conclude that there is a lower risk by whatever there is in containment out through the filter to the outside world. If, on the other hand, you conclude that there is some additional risk in releasing that, then it seems to me there is some premium in going t . high but on the other hand, you do not want to go to a pressure high enough so that there is some risk that the containment will fail catastrophically.

So what I am trying to get at is, have you thought about the strategy of picking the appropriate pressure at which release occurs, or is there such a strategy?

DR. BENJAMIN: Well, I think the strategy would preclude opening the vent before a design pressure is reached, because there are accidents such as the design basis accident, where design pressure is never reached, and yet there is some release of fission products, and accidents such as what happened at Three Mile Island, which is, of course, not a BWR, but if the vents had been opened from the beginning of the accident, the consequences in that accident would obviously have been much larger than they really were.

So opening the containment before design pressure is reached would seem to me to be unacceptable from a risk perspective as well as common sense.

Now, where, between design pressure and failure pressure, the vents should be opened, I cannot say that we can provide at this point very much useful information in the way of conclusions other than to say we feel confident that the containment would not be threatened if the pressure in containment were about 30 percent above the design pressure. Containments are usually tested out at pressures perhaps 10 or 20 percent above design pressure before they are qualified.

A further definition about what pressure to open at would seem to me to require a little bit more information from containment failure studies that have not been done yet, and so I guess that may not be --

DR. KERR: Would your study up until now lead you to conclude that this is an important issue or that it really does not make too much difference whether you open at 20 percent above design or 50 percent above design or -- I do not personally have any feel for this at all. I just -- it seems to me intuitively it could be an important issue, but I do not know how important.

I think it depends on the containment type, to a great extent. In a large, dry containment like Indian Point, it makes a significant difference because there are accident sequences, notably some accident sequences with hydrogen burns, in which the containment pressure may exceed design pressure by significant amounts but may not fail the containment. That is because you have a lar e containment which is already quite strong, and there are questions about whether accidents that are thought to threaten containment in that case really do or not; in other words, there are many accidents that fall in the range where the pressures rise between design pressures and failure pressures, and then the choice of the opening pressure would be important for that type of containment.

I do not believe that the BWR that we have been looking at has that particular distinction because the types of accidents that dominate the risk are accidents in which the containment cooling is unavai le and there is continual production of steam which is not condensed in the suppression pool, and eventually, containment failure pressure is reached.

DR. KERR: Well, let me hypothesize a situation of the kind to which I think Mr. Meyer referred earlier this morning, in which one is not getting an extremely rapid build-up of pressure, but rather a slow and significant build-up of pressure, and one has some sort of automatic system that is set to release at, let us say, 40 percent above design pressure.

Now, it is one of the responsibilities of the operator, I guess, to tell the governor of the state that, based on our projections, there is a pressure build-up, and at 8 a. m. tomorrow morning, that relief valve or whatever it is that releases pressure is going to blow, and we are going to start releasing things through the vent because it is set at 30 percent, but if it was set at 50 percent, it might not have to be released.

I just foresee situations in which -- I think this is a low probability event, so it may not really require any major amount of consideration, but it does seem to me it could have an influence on what one might do and what one's plans for. I certainly have not thought about it enough so that I could give a recipe, but it is hard for me to believe that it cannot be an important consideration.

DR. BENJAMIN: Yes.

MR. BENDER: Could I address another aspect of the same problem. There is a question of when to vent and what to vent, and part of the issue that comes up in looking at these over-pressuring of the vents is the fact that there is a lot of air in these containments, and the air has a low heat capacity, and it expands with temperature, and that is probably the over-pressure thing that is causing you concern, anyhow, so that it is a question of whether, if you vent it early in life, you could displace a lot of that gas that was going to lead to over-pressure later on.

I think the Limerick study sort of suggested that some early venting would be a good idea. I am not sure what kind of venting they had in mind. It also influences the kind of filtration that you do. If you vent early, then you will know pretty well what the vented content is, because most of the fission products are still where you want them, namely in the fuel, and so the filter can be something of a different character, and I am curious to know whether that aspect of vented - filtered containment is being taken into account when you do these studies.

DR. BENJAMIN: We have considered the possibility of venting early. In the Indian Point study, for a particular purpose, we did it to bring the containment pressure down prior to a pressure spike that could occur as a result of either hydrogen burning or steam generation from the core debris quenching in water, so we considered that as one alternative to handle types of accidents that may be threatened by containment spikes, venting containment prior to any significant melting.

We have not done a risk analysis on that issue yet because we have not gotten into that on large, dry containments. Venting early -- you mentioned the Limerick study. I believe they were venting early if you use that word to mean venting before a melting occurs. Yes, that is true. But I do not believe they were venting early if you are talking about venting before the container design pressure is exceeded.

DR. KERR: Well, I did not try to be that explicit because it is a fairly arbitrary decision as to where you vent, at what pressure you vent. There is some advantage in venting well before the design pressure is reached if you know why the pressure is going up, and I think it is going to be a matter of what determines these decisions, and from a public risk statement, during the venting, when you know what the fission product content is, it has a lot of meaning. It is better to be able to call a governor and tell him, we are going to vent now because we know the level of activity in the containment is very low, and so if it turns out that the filters do not work very well, there is still no public risk.

That is the kind of logic that I want to be able to argue with state officials about, and that the Regulatory Commission ought to be thinking about, because that was the problem at Three Mile Island, and I am hopeful that you will deal with that.

DR. BENJAMIN: I do not think venting in Three Mile Island would have accomplished anything because containment sprays and coolers were on and the pressure was always down until the hydrogen burn occurred and there was a pressure spike, and at that point there were fission products in containment.

In the case of the BWR, we are venting before melting occurs. We are venting when the pressure in containment gets to a point where containment design pressure is exceeded, and we are venting steam and essentially no fission products in the BWR, so really, for the dominant accident sequences in the BWR, venting occurs when the atmosphere is well defined and does not contain significant fission products.

Early venting for any other reason, if the containment systems are working, then there is no pressure that needs to be vented, unless there has already been a melt-down.

DR. KERR: Well, there is another reason. The reason is to provide more ceiling for the containment by getting rid of things that could cause over-pressure later on. That is one of the reasons for wanting to do early venting.

Another reason for doing it is, if you are going to worry about something coming out, then it is better to get rid of that inventory which you wanted to get rid of before something does come out.

Now, I realize that there was not a need to vent at TMI. Had TMI been an ice condenser of fairly low pressure, you would have been sweating the question out very seriously. You might still not have vented. And so there continues to be this question of when to make the decision and what the conditions are for making it. I think it is an important part of the risk question.

DR. ZUDANS: Could I add just a thought to that? Couldn't that be one of your range parameters to study?

DR. BENJAMIN: When to vent?

DR. ZUDANS: That is right, because now you fix the pressure where you vent, and you vary many other things.

DR. BENJAMIN: We could, I suppose, include the possibility of venting before design pressure is reached to see how that affects the risk, but I believe the answer to the question is already fairly well ascertainable, that it will increase the risk rather than decrease it.

DR. ZUDANS: Yes, but it may not do that. You may be able to clear the atmosphere to such an extent that subsequent events, you do not have to vent at all when you get fission products in.

DR. KERR: Mr. Meyer?

DR. MEYER: May I add to that? There is another competing risk that is introduced by early venting of non-condensables. If, as the accident progresses, you have a very large mole fraction of steam and then initiate containment cooling, you could be in a situation of having a large vacuum on your containment --

DR. ZUDANS: Oh, you will, right.

DR. MEYER: -- and have a failure mode in that way.

MR. BENDER: You would have to look at that as a risk, that is all.

DR. MEYER: It is competing risk of thinking about venting your non-condensables.

DR. ZUDANS: But you also talk about vacuum breakers to cover that condition. That is part of the game, you know.

DR. MEYER: The vacuum breaker is the solution, but under certain circumstances, it would have to be, as I understand it, a very major vacuum breaker to accommodate that kind of --

DR. ZUDANS: Yes, but if you vent at all and get the steam, and later on one of your systems condenses the steam, you have to have something to prevent an accident.

DR. MEYER: That is correct.

DR. ZUDANS: And Mr. Bender's thought is a very good one in the sense that if you did that early, you may find out by studies that it does not do you any good; that is fine. But if you could reach a state where you, by early venting, prevent the further over-pressurization to the extent of threatening the containment when the fission products are there, you do not have to vent at all afterwards. Is this possible or is that just a -- do you see what I mean?

DR. BENJAMIN: Well, let me take note that that is an item to be considered.

DR. ZUDANS: Now, if the venting has to be continued once you start it, that is not a question.

DR. KERR: You convinced him. See, he is taking note.

DR. ZUDANS: I do not want him to a good idea, because that may --

DR. KERR: I do not, either.

DR. ZUDANS: We will do further design later.

DR. KERR: Please continue, Mr. Benjamin.

DR. BENJAMIN: This chart shows the effectiveness of various prevention and mitigation strategies involving containment venting in terms of probability of core melting in this case. What I am attempting to do here is to illustrate how various venting strategies and designs come out of the risk assessment.

In this particular case, we find that various prevention type measures such as your auxiliary boiler tie-ins, your steam jet air ejectors, plus passive containment cooling or plus independent RHR-LPCI system result in fairly small amounts of reduction to the risk as it is calculated, or to the probability of core melting, because of the residual effect of ATWS sequences, the failure to scram, that inclusion of an improved reactor protection system would result in about an order of magnitude in the probability of core melting based on the considerations that, in talking to some of the people at GE, that they consider it possible to improve the reliability of the scram system to a point where it would be about an order of magnitude better than what was used in WASH-1400 as being the reliability of the scram system.

Now, with containment venting, containment venting by itself does not significantly affect the probability of core melting, but containment venting with a tie-in between the high pressure service water and the low pressure coolant injection system does, through a means that I will describe in just a minute.

We have considered the same kinds of approaches or comparison of approaches, considering the equivalent weight of releases as the index of risk measure with these cross hatches, as I indicated before, indicating the range of uncertainty from the conservative to the non-conservative assumption set, and we get the results that are shown here.

DR. ZUDANS: Which ones of these blocks -- this is the question I asked -- which one of the three blocks at the bottom compare -- to which of the upper blocks do these bottom blocks compare, like this, any one, like your case (G)? What is the comparative case without venting? I could not identify it by the title.

DR. BENJAMIN: Case (G) would be the same as case (C) except that it includes venting through a three --

DR. ZUDANS: The same as case (C), right? So the releases overlap in this case. The improvement is not that obvious.

DR. BENJAMIN: Yes, and the reason is because in this case, even though you vent containment, you eventually deplete the water in the suppression pool and you lose your emergency core cooling, and you have a melt-down, and you do not have any benefit of scrubbing in the suppression pool, since the suppression pool has been depleted.

This was the point on why a tie-in from the high pressure service water system to the low pressure low pressure coolant injection system was necessary to provide significant risk reduction.

DR. ZUDANS: Now, which case is comparative to (H)?

DR. BENJAMIN: Case (H), you would be comparing case (C) again to case (H).

DR. ZUDANS: No. Case (C) could have a tie-in without venting, could it not? Case (C) is not a comparative case.

DR. BENJAMIN: It is comparative in the sense that case (C) represents existing containments without a venting system and with a tie-in provided from the aux boiler to the steam jet air ejectors. Case (H) represents changes that would be needed to accommodate a vent system tha· included not only the opening in the containment itself but also another feature that would be specifically oriented toward the venting strategy. Let me show what that is.

This represents a system that has containment venting. It has two paths of containment venting, first of all, and let me describe why that is. A lower path opens at a lower pressure than the upper path. It is a smaller vent path, and it represents a vent path corresponding to an orifice diameter of about 7 inches, which represents a venting rate that would be necessary to mitigate most accidents in which pressure build-up is relatively slow.

The top venting path opens at a higher pressure and also recloses at the higher pressure, and it is a 3-foot diameter venting pene‿ration which handles ATWS, steam produced during ATWS events. In the ATWS event, the automatic depressurization system could be used to bring the pressure in the reactor vessel down to a point where the tie-in to the high pressure service water system could continue to provide enough water to the core so that the core would remain enough covered to prevent the meltdown, and the vent size would be sufficient to keep the containment from overpressurizing. There would be no filters necessary because the core had not melted.

The high pressure service water tie-in is a tie-in which essentially takes river water, in this case, and the tie-in goes to the core directly, through the low pressure coolant injection system. The tie-in currently exists on BWR containment, and it is used merely as a means of providing make-up water essentially as water in the form of steam is being vented from containment.

There is also a tie-in shown to the dry well sprays which happen to exist in Peach Bottom containment but not in all containment, and in this case, the dry well sprays were postulated as a way of keeping the dry well temperatures cool enough during the core-concrete interaction phase of the accident so that you would not have a threat of failing the containment seals, the dry well seals, due to high temperatures, both from thermal radiation and from hot gases produced during the core-to-concrete interaction, and would not therefore have, as a possible bypass mode to the vent filter system, leakage through the dry well fields.

There is also a possible tie-in directly to the suppression pool that this system could afford to make up water in the suppression pool in case there was a reduction of the level of the suppression pool, but with this system, the suppression pool level would not be reduced very significantly, very fast, because the pumps which normally take water from the suppression pool would be bypassed by the high pressure service water pumps. Otherwise, these pumps would have to operate under conditions beyond their design basis.

DR. ZUDANS: Well, that is quite nice and clear, but then all these tie-in features could be used without vent, too.

DR. BENJAMIN: What would happen without venting in this case is that the containment would over-pressurize.

DR. ZUDANS: Well, not if you spray cold spray up there. Why would it over-pressurize? Keep on condensing.

DR. BENJAMIN: Well, in the sequences that dominate the risk, the suppression pool cooling system is not available, and the suppression pool becomes saturated. Providing this tie-in to the core would keep the core covered, but steam being vented through the release valves into the suppression pool would not be condensed in the pool and would eventually wind up in rupturing of the containment.

DR. ZUDANS: That is if you do not provide such suppression pool atmosphere cooling as you have in a dry well. You could easily do that prior to venting it out.

DR. BENJAMIN: Well, there are, of course, suppression pool cooling systems available which, in accident sequences that are important for risk, fail. There are important accident sequences in which current suppression pool cooling systems fail. If they were available, then a significant part of the risk, a very significant part, would no longer exist.

There are wet well sprays also available, but then the problem with adding water directly here would be that the water level would rise, and you would be threatening the structure because of the additional weight of the water.

DR. KERR: The point is that it is not fair to increase the reliability of containment heat removal, because then you will not get an accident.

DR. ZUDANS: Yes, and then you cannot justify the filter vent system, either.

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DR. ZUDANS: Referring to Case H, you don't have comparison to judge the benefits of the filter vent system. What you are saying is that the Case H is designed around the filter vent system to do a better job in justifying it. You could do all those things without it and maybe not. Now, your coolers are not operational. The spray might not be operational, too. So, you still will overpressurize, and of course, if the suppression pool pressure increases, it will start pumping the water back into the dry well, will it not?

DR. BENJAMIN: The point I wished to make was that this type of tie-in to an external water system would not work if there was not a venting system.

DR. ZUDANS: That is what I want to hear, why not?

DR. BENJAMIN: Because you would be adding water to the system without taking it out. The venting system provides a steady state mass conservation type of situation. You are providing water into a system, and you are taking it out in the form of steam. That prevents the water inventory from becoming too large or becoming too small.

DR. ZUDANS: That isn't clear, I don't think.

MR. BENDER: In order to make that case you have to show that there is not sufficient volume in there to make that water addition meaningful. Now,the point you made, I think, was that too much water will threaten the integrity of the TORUS, and it may. I don't know what is needed, but there is a lot of volume in there, and it seems to me that you ought to be showing much much headroom there is in terms of adding water as one of the parameters that ought to be looked at. Is that unreasonable?

DR. BENJAMIN: Adding water to the suppression pool, there are limits to how much water can be added to the suppression pool.

MR. BENDER: There are indeed. I would be the first one to agree with that, but there is some capability to add water.

DR. BENJAMIN: Yes.

MR. BENDER: And I don't know what that increment is, do you?

DR. BENJAMIN: No, I don't, but I do know that the water level is very dependent on the vent submergence depth, and the vent submergence depth does not have a very wide range of latitude. If you increase the water level to the point where the vent submergence depth becomes higher, it does prevent a structural problem in that the pressure drop across the vent then becomes much higher, and it creates a number of potential problems that can otherwise be avoided.

MR. BENDER: It would be a mistake for us to try to analyze this accident right here. I guess I would argue that you ought to look at that aspect of it, along with considering the filtering.

DR. SIESS: Did you say that the TORUS would fail if it were full of water, just from the weight of the water?

DR. BENJAMIN: If it were completely full of water?

DR. SIESS: Yes. I thought you said that that would endanger the TORUS.

DR. BENJAMIN: Yes, I believe I said that, and I think that is true.

DR. SIESS: Just from the static weight of the water?

DR. BENJAMIN: I believe so.

DR. ZUDANS: No, not from static weight of water. That is incorrect.

DR. SIESS: I have not made any calculations, but I just find it hard to believe.

DR. KERR: Mr. Levy, you had a comment. If you would not mind coming to a mike so that we could get it recorded, I would appreciate it.

MR. LEVY: I think many years ago in discussing this in front of ACRS it was pointed out that at atmospheric pressure you could actually feel the TORUS in the drywell up to recovery, but that will have to be at atmospheric pressure.

DR. KERR: Thank you, sir.

DR. OKRENT: Can I ask a different question? If you were at the 90 PSI pressure, you currently show it without a path through the filters. Is it a different kind of filter system you would need if you sent that discharge to the filters? Would it complicate your design markedly to send that discharge through the filters? I recognize that you described a scenario in which you envisaged that there would not be a large fission product load for the 90 PSIG, but I am trying to understand the different part of the design philosophy.

DR. BENJAMIN: If you had to provide filters for an accident, the demands on the filter system would be much greater because of the fact that you would have a tremendous heat load and the steam that was being vented, no practically sized filter could handle that heat load without active components to take the heat up, and rather large active components at that. The rate of venting in the ATWS sequence is an order of magnitude higher than that necessary for other sequences, and that, also, would require filters that were an order of magnitude larger than what would otherwise be needed for the other accidents.

DR. OKRENT: I am trying to understand whether heat capacity in what you call the filters could serve the purpose here. In other words suppose there were a large pool of water on the way to the filters;that would buy a certain amount of time, I agree. It would have to be infinite to buy infinite time, but has that been ruled out as a meaningful aspect?

DR. KERR: You might have those rocks frozen.

DR. OKRENT: I guess that is a possibility, but I wasn't proposing that particular one.

DR. BENJAMIN: That has been ruled out. You take a water pool the size of a BWI suppression pool which contains over 1 million gallons of water, a large component, costs 7 to 9 million dollars to build one, and during an ATWS sequence you can heat that up to saturation temperature in a period of about an hour or two, if I am not mistaken. I think that is right, about an hour or two.

So, on that basis it would be impractical to try to remove the heat. When you are considering that in this particular design we are talking about adding 5000 gallons per minute of water to the core which is vaporized into steam as it is being added and being vented, that amounts to heat still being produced in the core during an ATWS event that is something on the order of about 15 percent of operating power. That is an awful lot of heat.

DR. KERR: What happens if you put boron in the water that you are adding?

DR. BENJAMIN: That could certainly increase the possibility that you would be able to bring the reactor subcritical.

MR. BENDER: I am bothered by this particular scenario that you are describing. If we are going to presume an ATWS that continues to generate heat at 15 or 20 percent of a design power, this whole idea will fall down, and it seems to me that the issue we are addressing is not one having to do with generating more than afterheating for a period of time, and if we are addressing the ATWS situation as one of the levels of probability that we have dealt with by this mechanism I would think we would probably need to think more about what other circumstances are occurring at that time. Somehow the reactor will be shutdown subsequent to an ATWS if we are getting to the point of core melting, and so we need to think about a different kind of circumstance, and I don't like the logic that is going with this. I may be wrong about it.

DR. BENJAMIN: Let me add one more point in regard to the ATWS here. If the core melted down, if there was another failure that prevented water from being delivered to the core and steam from being vented out to balance water inventory and the core melted down in this particular design candidate the high pressure valve would close, and the low pressure part would open because now we are not producing steam at 15 percent of operating power. At that point after the core melts down the event path would be through the filters and to the stack.

So, I would say that the protection for an ATWS sequence resulting in a meltdown would be the same as it would be for other sequences resulting in meltdown.

MR. BENDER: I am more concerned about the heat generation rate and how long it is going to go on and what can be done about it and what flow rate and what constituencies are implied by that kind of circumstance.

DR. KERR: Why don't you continue your presentation. I don't think you are going to solve Mr. Bender's problem this morning, but it is certainly a real one.

Mr. Okrent, did you get your question dealt with?

DR. OKRENT: It is enough for now.

DR. KERR: Mr. Siess?

Excuse me, please continue, Mr. Benjamin?

DR. BENJAMIN: I have not addressed yet the question of what types of filters whould be used, and I would like to address that now from a risk reduction perspective.

This chart shows equivalent weighted releases in terms of individual bone marrow dose, individual thyroid dose and total population dose given a core meltdown. This is not the risk per se because I am not presenting these equivalent weighted releases per reactor year but rather given a core meltdown what are the equivalent weighted releases, and I am comparing here four cases, no venting case but taking credit for this tie-in with the aux boiler and the steam jet air rejectors, venting to the atmosphere with the high pressure service water tie-in that I described but no filters in the low flow path, venting with crushed rock type filters in the low flow path and venting through high efficiency filters which would include something like charcoal absorbers and HEPA filters perhaps and other possible high efficiency filters that would essentially take out all the particulate and iodine matter but not the nobles, except possibly --

MR. BENDER: Remind me what the cross hatched section represents?

DR. BENJAMIN: The cross hatched section, again, is the difference between the conservative and non-conservative assumption, sir. The dashed area here represents the difference between, if I had done this in terms of risk, the relative reduction in risk from no venting to venting.

DR. SIESS: I don't understand that. Will you explain the white part again?

DR. BENJAMIN: The white part represents the fact that the probability of core melting without venting and without the high pressure service water tie-in is a factor of 10 roughly higher than the probability of core melting with venting and with the high pressure service water tie-in.

DR. SIESS: Why is there no white part on any bar except the top bar?

DR.BENJAMIN: It is included to represent the relative difference between the risk and not the absolute -- these figures in that case would not apply. It is put here to remind myself and others that if I were doing this on the basis of equivalent weighted releases per reactor year, the difference between no venting and venting would be that amount which would represent here about a factor of 100, and the difference doing it on the basis of equivalent weighted release, given a core meltdown occurring, the difference is much less between the venting case and the no-venting case.

DR. SIESS: Venting reduces the probability of core melting. How could that work out?

DR. BENJAMIN: It reduces the probability of core melting if the tie-in to the external water source is implemented by saving the containment and preventing interruption of emergency core cooling water that would occur otherwise with the containment failing.

DR. SIESS: So, it is not the venting that reduces the probability but the direct tie-in to the water.

DR. BENJAMIN: They do so in conjunction. If the containment failed in the Mark 1 BWR which is a free-standing steel structure, there is a relatively high probability that emergency core cooling would, also, fail as a result of gross geometry disruptions caused by the containment failure, at least that is the way we consider it right now. Prevention of containment failure also prevents that type of gross geometry rupture that could result in failure of ECCS availability.

DR. SIESS: I give up.

MR. WARD: What this vugraph seems to say is the venting does not do much good. If I look at this the crushed rock does not do you any good. The high efficiency filter whatever that means does not do you much good. So, it is only venting in the first place to the atmosphere so that you can make use of this additional cooling system which does any good. Is that right?

DR. BENJAMIN: No, I would not look at it that way. The reduction of probability of core melt leads to a factor of 10 reduction in risk, and be reminded here that I am considering some specific consequence measures that are not necessarily indicative of the total range of consequences. In fact, we are doing CRAC code calculations to look at consequences more concerned with public health, such as latent cancer fatalities and early fatalities to look a little bit more into that, but in the context of these measures it says that a factor of 10 reduction in risk is due to the combination of venting and high pressure and service water tie-in, and then depending upon whether conservative or non-conservative assumptions more accurately represents the real world there is from a factor of 3 to 10 in this case additional reduction in risk due to the mitigated features of the vent filter system, and in this particular meaure it is more like a factor of 10 to 100, and in this one something between, I guess.

DR. KERR: If you go to the A set of graphs, the top one, there is a line labeled vent to atmosphere and then a bar labeled crushed rock. The difference between those could be due to a slip of the pen of the artist. They are close enough to the same thing, which would appear to say possibly that there isn't any difference between the vent to atmosphere without the crushed rock and the vent to the atmosphere with the crushed rock. It must not say that from what you have just said.

DR. BENJAMIN: In this particular case it says that an individual standing one mile from the reactor will receive the same bone marrow dose whether you vent through crushed rock or you vent directly to the atmosphere, and the reason is because we have a 500 foot stack, and fission products essentially go over his head.

DR. KERR: That is interesting because the top is labeled equivalent curies release. So, equivalent means equivalent to an individual standing one mile away with a 500 foot stack. Is that right?

DR. BENJAMIN: Equivalent curies released, as you remember from the discusion of the weighting factors on fission products was based on the ratio of dose received to rems released. It means that for an individual standing one mile from the reactor --

DR. KERR: It would not be much difference whether you went through the filter or not. Is that right?

DR. BENJAMIN: Yes, that is what this graph means.

MR. WARD: So what we are really seeing there is the benefit of the 500 foot stack, and that is why the Group C there does not show --

DR. BENJAMIN: Let me try to clarify that a little bit more. Population dose which is not a function of the stack height shows a difference between venting directly to the atmosphere and venting through rock of about a factor of 3. We have done some --

MR. WARD: Could you clarify that a minute; the stack height should help some, I think, with the population dose, with the short-lived noble gases that have more chance to decay. Do you credit that?

DR. BENJAMIN: The crushed rock should help or --

MR. WARD: No, the tall stack effectively isolates the short-lived fission products from the population for X minutes or X hours. That must give some benefit as far as the calculation of the total population dose.

DR. BENJAMIN: We have not specifically given credit to all fission products in the stack.

MR.WARD: No, I mean in the atmosphere.

DR. BENJAMIN: You mean the elevation?

MR. WARD: Yes.

DR. BENJAMIN: That would be accounted for, yes, of course. That is accounted for, and I did not mention that in our determination of equivalent weighted releases. We differentiated between elevated and ground releases so that the elevation of the stack in dispersing plume effects and all of that has been accounted for.

I did, also, want to point out that we have done some CRAC code calculations to look at these questions that are being raised now, relative value of venting to the atmosphere or venting through crushed rock with and without a stack, and I should mention that these results are indicative of the particular population characteristics at Peach Bottom which have a peculiarity about them, and that is there are very few people within 10 miles of the reactor at Peach Bottom.

Now, with that information one derives the result that it does not matter very much whether you vent through a stack or you vent at containment level. It is because of the population distribution around Peach Bottom. We have not considered other sites yet, although this is part of the scope of work in the degraded core rule making research program.

There does show to be some difference between venting without a filter and venting with a rock filter, and it appears that depending on which consequence measure, it appears to be on the order of a factor of 3 to 5 reduction in the consequence attainable from venting through crushed rock.

Not shown here is that with high efficiency filters there is no additional benefit in a consequence point of view, and the reason is mainly because of the noble gases which then dominate the risk, particularly krypton or depending on which assumption set is used bypass accidents that then dominate the risk, bypass accidents being things like steam explosions if one is talking about the conservative assumptions and leakages, isolation periods and containment, those types of accidents.

So, high-efficiency filters beyond a fairly nominally sized crushed rock filter do not appear to buy us any consequence reduction.

DR. ZUDANS: Looking at this chart the cross hatched areas cover the sensitivity ranges that you defined earlier, different assumptions in all cases. That is a true statement?

DR. BENJAMIN: Yes.

DR. ZUDANS: Okay, under those conditions you really don't know where your best estimate point would be, and it may or may not mean any significant improvement. When you get into a very low range of mean risks like 10^{-5} or 4 or 6 a factor of 10 does not really mean anything, does it?

DR. BENJAMIN: I think it does, if you are talking about the difference between 100 people being killed and

10 people being killed.

DR. ZUDANS: I am not really talking about that many people being killed, many one in 100 years or something like that. I mean it is not a very strong argument. It is not like having 1000 versus 1. In fact, if you look at the early fatalities, you really don't have to worry right now.

DR. BENJAMIN: The early fatalities I did not specifically mention because they are subject to, very strongly subject to some assumption in the CRAC code dealing with thresholds, for example, dose thresholds that they are very sensitive to, and I did not want to stress those at this point, but the other point that you make about whether this argues for or against a filtered venting system --

DR. ZUDANS: I would say it argues against it definitely. Stack alone does a better job, less risk, no additional hard work to worry about.

DR. BENJAMIN: I am sorry, you are saying no stack does --

DR. ZUDANS: Stack alone, stack only.

DR. BENJAMIN: To me it makes a strong argument against requiring filters in the venting system, but it does not reduce the effectiveness of the argument that venting by itself has advantages.

DR. ZUDANS: Oh, I see, when you say stack you do have that 90 PSI pressure.

DR. BENJAMIN: Yes, and, also, recall that we are using the suppression pool as essentially a filter in this design.

DR. KERR: Let me see if I understand your earlier comment. A difference between no venting and the stack only is that in the stack only you now have high pressure service water available whereas with no venting you don't have it available. Did I understand correctly?

DR. BENJAMIN: Yes.

DR. ZUDANS: That is a good point if you just had a vent and not the cross connection of high pressure service water system. That would not do you any good.

DR. KERR: The assumption is that the reason you need this is because you lost the ability to cool the water in the TORUS. That is the major risk contributor you said earlier, I think.

The suppression pool cooling capability has been lost. That is the big risk contributor, and that is the reason you need to vent. That is a major reason, at least.

DR. BENJAMIN: I agree with your statements put in the form that that is the big risk contributor, yes, that is true. It is not the only risk contributor.

DR. KERR: No, of course not. That would lead one to ask a question, it seems to me, if I can get high-pressure service water in to keep the core covered, is it any less likely that I could get it in to cool the water in the TORUS which strikes me as being an alternative way of suppressing pressure. Has that been looked at?

DR. BENJAMIN: Let me try to understand your question a little bit better. Are you talking about with containment venting as being a feature?

DR. KERR: Let us suppose that what I am trying to do is to avoid pressurizing the containment. One way of doing that is to open it up. Another way of avoiding it is to remove heat. I have lost the ability to remove heat in the particular accident scenario which is a large risk contributor because my heat removal system has failed and presumably it has failed because I cannot add water to it because that is the way you remove heat. Your approach to the vented filter is to handle at least one part of the scenario by bringing in high pressure service water which strikes me as being dandy, but is it any less possible to bring in high pressure service water to rejuvenate theheat exchangers that would remove heat from the TORUS?

Rather than putting the water in the reactor vessel, why not put it in the heat exchanger.

MR. WARD: Or some other water supply.

DR. KERR: Mr. Cunningham has an answer.

DR. CUNNINGHAM: You are getting to a point that is well taken, that Alan has been working in a program that specifically presumes that you are working with a vent system.

There is another program at Sandia which specifically looks at not worrying about vents but removing heat. This is one of the situations where you are in the middle.

DR. KERR: So, I ought to be asking that question of the other Sandia program.

DR. CUNNINGHAM: Or part of the reason that we are integrating the programs into the DCC rule making program is just to take care of these kinds of questions because there is that gray area in between, and there are other kinds of options that may be equally viable or equally important in terms of risk reduction and maybe much easier.

MR. WARD: Yes, but you seem to be at a point in the program where you might want to decide that there is no point in worrying about venting anymore, that the only advantage you have got of venting is it provides a mechanism for removing heat from the suppression pool, and there might be another way that is more effective, more efficient in doing that, and venting per se does not appear to do much as far as risk reduction is concerned.

That is sure what I conclude from these vugraphs. Now, if you conclude something else, I would like to hear it.

DR. OKRENT: I don't understand your conclusions, Dave. Could you put the vugraph back on about effectiveness?

Let us look at the bottom one which I think is the most significant one because that is total population dose, and if you forget the white portion marked risk, there is, as I guess, about a fact^r of 5 to 7 between no venting and venting with rock. I don't see that as a neglible factor. In fact, I doubt that you can find any --

DR. KERR: Wait, Dave. There is a difference. Venting with rock assumes you have high-pressure service water.

DR. ZUDANS: That is right.

DR. OKRENT: No, I am sorry, that is the white part.

DR. KERR: No.

DR. ZUDANS: Not if we understood him correctly.

DR. BENJAMIN: I think, if I may interrupt that Professor Okrent is correct about that. This is given a core meltdown the difference, the mitigation effect is given a core meltdown which implies that there is no water delivery onto the core.

DR. KERR: That is the reason I asked my earlier question. I thought that no venting assumed that you had no high-pressure water, and then when you went to venting you put in the high pressure water.

DR. BENJAMIN: Let me try to elaborate a little bit. There is, even then, with that type system a probability associated with failure of the high-pressure service tie in. There are even with the high-pressure service water tie in accidents in which that tie is not effective because of the fact that there are valve failures implied by the accident which would make it ineffective. There are additional accidents. There is a residue of accidents after these things have been implemented in which failures of one sort or another could negate the effect of the accident. Loss of power is a good example, loss of off site and on site AC power would negate the effect of the high pressure service water tie in. What this chart represents is all those accidents that are left over when the high-pressure service water tie in and vent system have been implemented in which those systems do not prevent core melting, and those necessarily then imply that the high-pressure service water tie in would have been defeated.

Then what the graph shows is the relative advantages of the vent system with various filtering components given that all these failures have occurred despite our best efforts to keep providing water and to keep the containment pressure down.

DR. KERR: But the no venting one assumes that even with high-pressure water you will get core melt. Is that valid?

DR. BENJAMIN: No The venting one --

DR. KERR: No, the no-venting one. The no-venting bar assumes that even with the high-pressure tie or whatever you get core melt? I am not trying to put words in your mouth. I am just trying to understand,and I thought you said that it assumes that you will get core melt, whereas the vent assumes that you won't get core melt in at leas a fairly important sequence because you will have the high-pressure water which will permit you to cool the core.

MR. BENDER: I guess I misunderstood. I thought that what he is showing up there are all cases involving core melt.

DR. OKRENT: With the orange bars, forget the white. Just look at the lower group in orange.

MR. BENDER: Do they all assume core melt?

DR. BENJAMIN: Let me describe how these were derived, and perhaps that will shed a little bit of light on it. We took all the accidents represented by the event tree. We evaluated for them equivalent weighted releases, multiplied them by their probabilities, divided by decontamination factors where appropriate and summed them up to get total equivalent weighted releases per reactor year because probability is in it.

We then divided that by the probability of core melting, the total probability of core melting to get the probability, to get this graph which implies mitigation effectiveness given a core melt. I don't know if that makes it clear or not. I guess it does not say.

DR.FIRST: What do you call that number when you get all through? Does it have some dimensions or is it a ratio or what?

You have multipled and divided a number of important factors, and what do you call the answer?

DR. BENJAMIN: We call it, I don't know that we have determined the name. We call it equivalent weighted releases given the occurrence of a core meltdown.

DR. FIRST: You see, this is not a comparative number. You have got some numbers there 10 to a factor, and that certainly does not tell us anything comparative. It is giving us an absolute value it seems to me. What are we comparing it -- what is it equivalent to? What is number one or standard or whatever you want to call it?

DR. BENJAMIN: What these numbers repreent, I think, is what I am trying to look at in these cases is mitigation effectiveness. I think one of the considerations in deciding on a vent filter system is this. Let us assume that we have a core melt situation. Then would a vent filter system provide any good for you? I think that is one of the considerations that has been expressed by members of the ACRS. Assume that we cannot prevent a core meltdown and that the last line of defense is a filter venting system. Then does the filter venting system really buy us anything in that event? What I have attempted to show in this graph, the quantified part of it is given that a core meltdown occurs, how much releases could we expect. Given that a core meltdown occurs, how much releases could we expect, and how would they be affected by having various types of filter systems? It looks at the back end of the problem or the last resort, last defense type consideration, and that is the motivation for looking at it in these terms.

DR. FIRST: I am a little confused because the units you are using here are curies released, and how does the probability of an accident enter into that number?

DR. SIESS: If you take off the white, there is no problem. Is that correct?

If you leave off the white bars, there are no probabilities on that graph?

DR. BENJAMIN: Yes, that is correct.

DR. FIRST: So that is an absolute number then of 10^8 curies on your upper bar without the risk factor.

DR. BENJAMIN: It means given a core meltdown occurs you expect that equivalent weighted release which is not the same as total release in curies is between 10^7, in this case between 10^7 and 10^8 curies. It is referenced in this case to equivalent tellurium curies.

DR. ZUDANS: At any rate this shows what effect the venting has.

DR. BENJAMIN: The main purpose was to show the relative difference whether anything could be gained by using filters of more and more complexity.

DR. ZUDANS: Here venting by itself because I guess the high-pressure service water connection has done its job already.

MR. BENDER: Could I take a shot at just trying to find out what is happening? Let us look only at the orange curve. Forget the rest of them for a minute. When there is no venting, the presumption is that whatever fission product activity can come out will come out because the containment is going to burst. Is that the presumption?

DR. BENJAMIN: Excuse me, when there is no venting?

MR. BENDER: There is no venting, so that the curies released are the curies that are in the core that would come out when the containment burst. Is that what we are looking at?

DR. BENJAMIN: Yes. It would come out over a period of time either when the containment burst if the meltdown had occurred before the containment burst or when the core melted if the meltdown occurs after the containment burst.

MR. BENDER: Fine. The next line which shows atmosphere means venting but without filters, and some radioactivity is coming out. What is it that comes out at that stage? What are you releasing?

DR. BENJAMIN: We are releasing the core inventory reduced by the released fractions from the core, reduced, also, by deposition in the primary system, reduced by deposition in the containment and reduced by scrubbing in the suppression pool and what is left then is released.

MR. BENDER: Now, what nuclides dominate?

DR. BENJAMIN: I beg your pardon?

MR. BENDER: What nuclides dominate under those circumstances.

DR. BENJAMIN: That depends on the strategy and in the case where --

MR. BENDER: Just start with the atmosphere one. I want to know for the atmosphere one first.

DR. BENJAMIN: In the case of the non-conservative part the noble gases dominate, particularly krypt- -- I will back off on that, but it is the noble gases that dominate in this particular case here. On this side it is some of the other fission products, such as cesium and iodine --

MR. BENDER: So it is the rare earths you are saying and iodine.

DR. BENJAMIN: Yes, because of the steam explosion cntribution and other contributions.

MR. BENDER: And then when we go to rock what is captured?

DR. BENJAMIN: Rock captures particulate matter and that is all it captures.

MR. BENDER: Okay, so that is mainly rare earths.

DR. BENJAMIN: So, it is mainly rare earths and depending upon whether we have assumed that iodine is particulate or gaseous it may capture iodine.

MR. BENDER: And then the last one captures the iodine essenti ally.

DR. BENJAMIN: The last one captures the iodine and zenon.

MR. BENDER: Now, if I ask between rock and the high-efficiency filters what assumptions I have to make about the effectiveness of them, how is that dealt with? How do I know that the rock will capture the rare earths?

DR. BENJAMIN: We have attempted to include that as one of the uncertainties by assigning a range of possible decontamination factors in the rock bed. That is one of the areas that should be explored more thoroughly if it is determined that vent filter systems with rock does look like a promising idea.

MR. BENDER: That is where there is a -- you are taking credit for them now on some assumed basis. I am trying to understand how those assumptions were developed.

DR. BENJAMIN: Let me give you essentially the data base that we used for determining effectiveness of rock and capturing particles. We used essentially the Swedish experiments for particulates being vented through crushed rock filters in an airstream, and we attempted first to extrapolate those experiments to the particular design that we were contemplating for the BWR and that is extrapolate them by the size of the filter predominantly. It appeared from those experiments that under the flow rates, if it was designed correctly for the right flow rates that you would be able to obtain very substantial capture of particulate matter with a reasonably sized rock bed. The uncertainties had to do with the fact that the heating of the rocks was a concern, if the rocks became heated to the point where they were not condensing steam very much or there was someother mechanism for subsequent release of fission products after they had been captured on the rocks due to heating. We were not sure how to account for this. So, we assigned an uncertainty. We assumed essentially that the rocks could take about, let me see if I recall it correctly, the combination of the suppression pool if it is not saturated and the rocks would take 99 out of 1000, a decontamination factor of 1000 overall in particles. If the pool was saturated we assume that the rocks could take a decontamination factor of 10 to 100, I recall depending on whether they were heat[illegible] not and decontamination factors. This kind of gives you an idea of how we --

MR. BENDER: I think you have told me enough. Now, when you go to the high-efficiency filter, just to close it up, that presumes what?

DR. BENJAMIN: The high-efficiency filter presumes something on the order of,decontamination factors on the order of 1000 to 5000 in that range roughly for everything except xenon, krypton and organic iodine, no even for organic iodine in that case. Organic iodine is captured. So just xenon and krypton. Xenon is captured with an efficiency of decontamination factor of 50, as I recall in this particular design.

DR. FIRST: That is only if you have a very deep charcoal bed which is not necessarily true of your high-efficiency for iodine and particulate matter.

MR.BENDER: Did you have an experimental basis for it or was this --

DR. BENJAMIN: We have an experimental basis for the capture of xenon in deep charcoal beds. We have adsorption coefficients which are determined from experiments, and so we were able to design a charcoal bed that could capture the majority of xenon, and it involved 100 tons of charcoal.

MR. BENDER: So, if we wanted to judge the validity of these assessments here, we would go back and look at the experimental data and try to make a judgment as to whether the extrapolation is meaningful when you put the risk factor into it. Have I overstated it? You have to accept the experimental base as being valid in order to deal with the risk reduction.

DR. BENJAMIN: I would say that that is true.

MR. BENDER: Okay, I just wanted to be sure.

DR. KERR: Mr. Benjamin, I recognize that the Committee has contributed a great deal to your presentation this morning, but we were shooting at an ending time of somewhere around 12:20, and from mylook at your slides we are not going to be very close to that. I guess it was that long coffee break that we took.

MR. WARD: Mr. Chairman, could I ask one more question on the subject we were just on?

DR. KERR: Is it pertinent and and cryptic?

MR. WARD: Right.

DR. KERR: Okay.

MR.WARD: I am just trying to relate 100 tons of charcoal and the size of the system. What sort of mass flow do you have through the system? Do you recall the number for that, Alan?

DR. BENJAMIN: The charcoal filters were designed for, I think, 40 feet per minute of flow. We did the design for that on the Indian Point study and it was assuming 40,000 cubic feet per minute of flow.

MR. WARD: Okay, that is fine. Thank you very much.

DR. ZUDANS: Could yop put that slide back again because I did not have a chance to ask the real question. Could you explain the difference between no venting in atmosphere in orange because in both cases everything that you have goes to atmosphere anyway without any filtering effect. Is the difference because you assume certain mode of failure of containment?

DR. BENJAMIN: Yes,essentially that is true. In the case of no venting the failure could occur in the drywell and then the fission products, some of then could be released directly from the drywell into the atmosphere.

DR. ZUDANS: You assume that all of it opens up and everything goes away?

DR. BENJAMIN: No, some of the fission products are assumed to have a direct path of release to the environment, and some are assumed to go into the secondary containment where they are partially deposited in the secondary containment, but in the case of the venting, the venting is always from the wet well. So the suppression pool is always available as a filtering medium.

DR. ZUDANS: So actually the difference between no venting and atmosphere is in the way you assume the failure of the containment takes place. It could take place in that suppression pool, not in drywell.

DR, BENJAMIN: They have different scenarios involved.

DR. ZUDANS: Yes, and they would be the same then. Then you would not have difference between no venting and atomosphere.

DR. BENJAMIN: If the failure occurred in the wet well, not below the water level but above the water level, then the suppression pool could conceivably be available as a filtering medium. One would then have to question how severe a failure it was and whether the failure was such that the depressurization caused rapid movement of water in structural materials that rendered the geometry ineffective and that was considered to be a possibility.

DR. ZUDANS: At any rate, it struck me that the most benefit is derived from the way the assumption of failure of containment is factored into your calculations.

DR. SIESS: You have different failures, and you have averaged. Is that right?

DR. BENJAMIN: No.

DR. SIESS: This is not one scenario, is it?

DR. KERR: I urge that we carry on this conference so that all of these priceless words are recorded.

DR. SIESS: Am I correct that you have several different scenarios, and this represents some kind of an average of them, and some of those scenarios the containment ruptures in the dry well and some in the wet well. Is that what you were saying?

DR. BENJAMIN: No.

DR. SIESS: It is not one scenario, is it?

DR. BENJAMIN: Certainly not one scenario. It is all of the large number of scenarios that were considered in the analysis.

DR. ZUDANS: But only one containment failure mode?

DR. BENJAMIN: No.

DR. SIESS: No, he said the dry well can fail. The wet well can fail above the water line. The wet well can fail below the water line. That is what I heard. Am I right?

DR. BENJAMIN: Yes, and that is essentially right. It was assumed in the no venting cases, and let me particularly emphasize that this is for the Mark 1 BWR, and this does not apply in the same way to other BWR's, that if the containment failed in the wet well above the water level it would result in significant enough geometry distortions so that the suppression capability of the pool would no longer be available.

DR. SIESS: You said it was assumed. Was it assumed for all scenarios or was the assumption of where the containment failed a function of the scenario of the accident sequence or whatever term is appropriate?

DR. BENJAMIN: I am not sure I can provide any more light on what you are asking me.

DR. KERR: Let me try to interpret. I think you said that for all scenarios in which the wet well failed it was assumed that the distortion was such that you lost water. You had no more suppression capability.

DR. BENJAMIN: Yes.

DR. KERR: For any scenario that involves failure of the wet well, and that was your question, wasn't it Chet?

DR. SIESS: Are there other scenarios?

DR. KERR: Yes, there is a scenario that involves failure of the dry well.

MR. BENDER: Were the scenarios weighted? Did you take the releases that go with different kinds of failure modes? They all can happen, and if you are going to fail the containment due to overpressure and weight the activity release to get that curve or did you just take the worst one and say, "That is the one."

DR. BENJAMIN: In cases where containment failure was due to overpressurization the weighting between types of failure, that is location of failure more than anything was based on what was used in WASH 1400. Essentially that was that 80 percent of the fission products went into the secondary containment and 20 percent went to the atmosphere.

MR. BENDER: Thank you.

DR. KERR: Additional clarification? Please?

DR. FIRST: I would like to refer to the green bar since nobody else has brought those up. I am a little bit baffled by the fact that the thyroid dose comes from iodine I have always assumed, and as we look through those four categories you have there there is an enormous difference in the amount of iodine that is going to be di charged from the four scenarios. I have had the advantage of looking at your paper about four times that you provided for the 16th Air Cleaning Conference and I am fairly familiar with the figures here. Now, what I don't understand is after you put the discharged gases and the accumulated isotopes through the high efficiency filter which contains iodine plus HEPA filters you have very much iodine coming out into the environment so that you don't change the individual thyroid dose by this very effective filtration method. Could you explain that?

DR. BENJAMIN: I explain it in two ways. First of all there is a contribution from the noble gases to thyroid dose, even though it is not -- the importance of the nobles is not nearly as much as for iodine.

DR.FIRST: But quite a different factor, I would say.

DR. BENJAMIN: Yes. Secondly, there are accidents that bypass the filters, and that is what we may be seeing in these results here that the risk may be dominated by accidents that have not gone through the filter, and that, in fact, is one of the intents of the risk analysis to consider accidents in which the vent filter itself is not effective, as well as accidents in which it is effective.

DR. FIRST: This may be true, but you have homogenized a whole bunch of scenarios into that last one, high efficiency because in your paper you first go on the assumption that you are going to use a shallow bed of charcoal and then you go on another assumption that you are going to use the 100 tons of charcoal and this is going to take out the xeonon or 50 percent of it. Now, you are bringing in still another scenario that something else is going to happen whereby the filters are going to be bypassed, and I don't remember seeing that in your paper in any case, and how do we interpret these bars if you have all these hidden aspects?

DR. BENJAMIN: The paper you refer to is an outgrowth of the Zion/Indian Point Study which was different in one key aspect from this study and the key aspect was that there was no risk assessment done, and the Zion/Indian Point Study we had no risk assessment, no fault tree data to use.

We, therefore, selected particular accident sequences to look at in detail, and those accident sequences were accident sequences that we felt could challenge a vent filter system in different ways. We did not look at bypass accidents or include them into the overall risk because we did not do a risk analysis. We are looking at the effectiveness of the vent filter system in handling one or two or three particular accidents. The difference here is that we are looking at all accidents. One of the conclusions of the Zion/Indian Point Study which I believe was in that paper was that before any decisions about vent filter systems could be made or any designs could be reasonably formulated there would have to be a risk assessment that considered the competing risks of vent filters including the accidents where failures in the vent filter system could make things worse rather than better, and it was clearly pointed out that that was not done in the time frame of the Zion/Indian Point Study but needed to be done. What we have attempted to do is to do that in this current study for Peach Bottom, and that is why there is a difference in the way the results look.

DR. FIRST: We don't have the publication on your latest study. So that is what makes it very hard to understand, since I have been interpreting these graphs on the basis of your older study.

DR. BENJAMIN: This is very recent information which has not been published yet, and I am providing you with what we have been doing recently. It will be published, and when it is we will be happy to give you and anybody else who wants one a copy.

DR. ZUDANS: You assume no cooling of rock here? No rock cooling?

DR. BENJAMIN: No rock cooling. No active system to cool the rocks.

DR. ZUDANS: How long can you live with that, rock like that in given scenarios?

DR. KERR: Do you understand that question? I don't.

DR. ZUDANS: The rock will get heated up because it is continuously getting hot steam there, and eventually you have to start cooling or it will become worse than not having it.

DR. OKRENT: How will it become worse, Zenon?

DR. ZUDANS: It will start giving out what it retains.

DR. OKRENT: How would that be worse?

DR. ZUDANS: It would get everything back out as if we didn't have --

DR. OKRENT: I am trying to understand how it would be worse?

DR. ZUDANS: It would then release more than -- not worse than no rock, let us say it this way.

DR. OKRENT: This would be under atmospheric pressures, whereas the container is under several atmospheres. So, it is bound to be cooler.

DR. KERR: Zenon, you would not object if I let him continue his presentation, would you?

DR. ZUDANS: No, because the report discusses the rock cooling as a very important aspect. I just wanted to know whether this is based with some active cooling or not.

Go ahead then.

DR. KERR: Please continue, Mr. Benjamin.

DR. BENJAMIN: I think I have pretty much covered the subject of the risk assessment for Peach Bottom. The other area that I was going to discuss had to do with design concepts that were developed during the Zion/Indian Point Study which are discussed in the paper that was just mentioned. I would like to ask the Chairman if the ACRS first of all would like to hear that aspect of the work, and secondly whether it might not be better to have lunch first and then talk about it after lunch.

DR. KERR: I think I will answer the second question first, and I think the answer is probably yes, and I want to consider the afternoon schedule before answering the first question.

DR. BENJAMIN: All right.

DR. KERR: So, we will recess for lunch and be back at 1:30.

(Thereupon, at 12:30 p.m., a recess was taken until 1:30 p.m., the same day.)

MILLION

AFTERNOON SESSION 1:32 P.M.

MR. LEVY: I am going to report on a small study performed for EPRI, which was initiated to try to examine what one might do for a degraded core. The primary emphasis of the study was on pressure suppression type of containment, both boiling water reactor or ice containment for pressurized water reactors.

I think the scope of the study -- as mentioned on this chart, there is a report that describes the study in detail, which you can get from EPRI. The scope of the study was to quick-like describe what PWR pressure suppression and a BWR ice containment look like, and I will not do that here today.

The second thing was to examine what improvements have been proposed to date on containment, up to October 1980 and, again, that was done in the report and I might add in that area that a considerable amount of work had been done on the dry containment, but very little had been done on the pressure suppression type, except by extrapolation.

I think the next step was to try to examine what method you should use to evaluate these improvements and what your strategy might be. Finally, we were asked to make a preliminary evaluation of vent, long vent/filter and what some of their merits are and what some of the alternatives might be.

I think one conclusion that is really pretty apparent and that everybody has reached is in order to evaluate these improvements, whether they be vent/filters or alternate, the probablistic risk assessment method is necessary in terms of deciding what to do. I think another important consideration, as we described it, is that somebody has to define what kind of a risk reduction factor you are looking for.

Your answer will vary depending on what kind of an objective you set for yourself. The way the study was performed, we focused on what we called the dominant risk scenario. What we did is, first, try to classify them and their probability of causing containment failure. The next thing we did is, we tried to identify what type of a containment failure we are talking about. Is it overpressure, is it penetration of the base mat or that kind thing. Another thing we find to be quite important was the type of failure and its timing and I will come back and describe that later.

In a pressure suppression boiling water reactor system, as you heard this morning, you can very often fail the containment before you have actually got a core melt, and it is the containment failure that leads to the core melt. So, if you can actually prevent a containment failure, you have in fact prevented core melt and this may explain some of the confusion.

In this particular case, I believe that venting is not a mitigation thing; it is actually a preventing thing, because it prevents the core melt from occurring. The way we did this was to evaluate what alternatives we had to prevent the cause of the containment failures and we looked at both preventive and other techniques.

We then looked how applicable was the vent to prevent the containment failure, and then we looked -- we put a vent in. To make it work, would it require some other mitigation features? Finally, we assessed what the benefit of the vent and the vent/filter was and we also looked at some alternate mitigating features that might prevent containment failures.

I think this next chart I will show, even though quite detailed, pretty well illustrates the method we have used and I strongly recommend it to all those people who are looking at those degraded cores.

This is for BWR pressure suppression. I think the first column deals with the probability of the occurrence of the event. As you recognize, what we are concerned with here is either containment failure, because it will lead to core melt, or core melt followed by containment failure. Both of those are very high risk events.

They are arranged by probability of occurrence, low, very low, very, very low and there is, in my view, about an order of magnitude difference between the low and the very low, but I won't be very precise in the numbers.

In the BWR the high risks with the low probability event are produced by the loss of the long-term heat sink. I think this was discussed this morning. What we are talking about is that the core is kept covered, the heat is dumped to the suppression pool. You have no way to remove the heat from the suppression pool, so the pressure in the containment climbs. There is a slow pressurization effect which will eventually lead to containment failure.

What I mean by slow is that it will take place over about 10 to 20 hours type of pressurication effect. It is important to realize in this particular case that the containment failure will occur prior to fuel failure and that, in fact, it is the containment failure that produces the core melt and the release of the fission products.

I think that might help explain some of the answers that were presented this morning. Now, there are many ways to counteract this event. The design strategy, one, would be to put some preventive features which, really, do not lead to this increase in presure -- and this was brought out, "Why don't you add another way to cool the pool?"

That will clearly reduce the probability of this even occurring and, therefore, reduce your risks

DR. ZUDANS: Could I -- just to make sure that you meant it -- here the containment failure leads to the core melt?

MR. LEVY: Yes.

DR. ZUDANS: Why?

MR. LEVY: In this particular -- much of our work is patterned after WASH-1400. In WASH-1400 the assumption was made that any time you had containment failure, it was a practically one-to-one correspondence that you have core melt. The explanation of it was that in the Limerick plant every time you had a containment failure you automatically lost NPSH to the pumps.

As a result of th s, you did not have any system to put water into the core, so containment failure practically led automatically to the core becoming uncovered and the fuel beginning to melt. That is an inherent one relationship and I would like, again, to clarify a question this morning.

Those positions were taken without trying to find out whether it was the wet well failing or the dry well failing, whether the failure was above the line or below the water line. The assumption was made that any failure of the container by overpressurization led to core melt and led to certain release of fission products.

Now, there were some variations in the fission products, depending upon the amount of energy with which the associated release was associated with.

As we point out in our report, we believe that that is a key assumption that needs to be examined in considerably more detail, both whether there is a one-to-one probability and probably in much more detail about how the containment itself will fail, whether it will fail in the wet well or the dry wall, below or above the water line. It makes quite a bit of difference.

I think in this particular case we examine the event and the event turned out to be extremely practical. It turns out to be a good way to solve the problem, because all the vent does, it just permits you to relieve the pressure. You do not have to have a filter, because you haven't got any fission products, so adding a filter is not going to buy you anything for this system. It might explain why some of these vent filters don't do very much for you, because for this very high risk event they actually contribute very little -- you don't have any fission products to filter at this point.

So, I think a vent in this particular case is an alternate solution to trying to keep the containment cool. That is the way it should be looked at. The second and most important risk event which has, again, a low probability of occurrence, is the failure to shut down the reactor. This has been referred to as ATWS, or failure to scram.

In this particular case you get rapid over-pressurization of the containment. In this case, instead of having hours, you are dealing in minutes. The overpressurization of the reactor takes place between about 15 to 20 minutes and that is what you are dealing with.

I think in this particular case, again, the containment failure will occur prior to fuel melt. You notice I didn't say prior to fuel failure, because we expect to have some fuel failure. But clearly the fuel failures in this event will not lead to fuel melt. So, again, the containment failure will precede the fuel melt and, therefore, while we have to deal with fission products, they are not substantial fission products; they would be primarily gasseous release of fission products.

Now, in this particular case, again, the first design strategy is to look at preventive features and a preventive feature is to clearly reduce the probability of ATWS. You can improve your liquid poison system, you can improve your control outdrive system, you could do all sorts of things of this type, and these are all preventive.

The second alternative that you can look at is the venting, which, again, is the chart that was put on this morning, in which you actually vent the container. Now, you have got to understand that in this case you are generating about 15 to 30 percent power out of this boiling water reactor and, therefore, it takes a very large vent.

We concluded that the vent system was impractical, that if I had to solve the problem, that would not be the way I would solve it as an engineer. I would solve it by preventing ATWS; that is a much more meaningful approach to the problem.

The reason is, we found that that system would require approximately 300,000 to 500,000 CFM vent, which is a very substantial vent, and we did not think that that was a practical way to go, that probably the preventive features would be preferable and would be the way to do it.

I think we also looked, as part of the discussion this morning, to the idea of adding water, cold water, like you just spray cold water. I think you will find the report, for example, by spraying 6000 gallons per minute of water into the containment, what you do is you buy yourself twice the amount of time.

You reach overpressurization, instead of doing it in 15 to 30 minutes, it will now take you twice more -- twice as long. So, the idea of spraying water, as brought out by the speaker, is not a solution to avoiding the containment failure; it buys you time. Eventually, you know, the water will take the space and you will fail, but you can buy enough time to maybe correct the ATWS situation, and that might be a way to help or ameliorate the ATWS situation.

Now, these two events dominate the risks in a BWR. Now, we come to the next series of probability events. These are the cases in which you actually cannot keep the core covered. You have a loss of primary water -- those are dominated by small breaks -- and in these events, what you have is you are not re-covering the core with your ECCS system.

Now, if you have a noninerted containment, the principal type of failure you will have is due to the formation of hydrogen, the possibility that the hydrogen will burn and that you have a pressure spike from the hydrogen. Now, in this particular case, again, this event will occur before you have a very great core melt; you would have what is called a minimal core melt. The event will take place prior to vessel melt.

Again, the design strategy can have some preventive features. The preventive feature is to improve your way to add water to the core and in so doing you will reduce the probability of this event.

In this particular case, the vent is not practical. This pressure spike comes at you so fast that you cannot build a vent capable of handling such spikes. I think clearly in this event, even if you decided to go with a vent, you would have to provide some hydrogen control. I think, because the vent cannot handle the pressure spike, you would first have to control the hydrogen and maybe you could then use the vent after that, and I discuss that later.

There are in this event other mitigation features, I don't have to tell you that. There are many ways to post-inert the containment, if you so desire. You could go back to preinerted containment. There are many schemes in which you fight this problem to avoid the hydrogen burn.

One of the schemes clearly is to burn the hydrogen in place, and I think that is another way to therefore help this problem with mitigation.

DR. ZUDANS: Could I ask you a question? In the previous case, did I understand you correctly that spraying water, or what the previous speaker referred to as connection to high pressure service water, that that would not solve the problem of ATWS?

MR. LEVY: In my view it is a solution to the problem, but I consider it impractical. You would be going on and on for several hours dumping 300,000 to 500,000 CFM containing a lot of steam and bringing a lot of water to containment.

By the way, this case -- that prevents a preventive fix. It is no longer a mitigation fix. What that is doing is it is preventing core melt from occurring. Now, if you ask me how to do that, I would do it differently. Rather than dumping 500,000 CFM of steam and going on for many hours, what I clearly would do is try to bring the power of this machine down.

That makes a lot more sense to me as an engineer and if the systems we have to prevent ATWS are not strong enough, I would make them stronger.

DR. ZUDANS: Well, that means that the value of a vent under those conditions is questionable.

MR. LEVY: I give a personal viewpoint from years of engineering judgment of a 500,000 CFM vent going on and on -- you know, you have got to finally decide how you are going to terminate this event and I think eventually you have to put something that makes it go subcritical. I am saying if I know what that is, I will bring it forward and make it go sooner.

But that is, you know, a personal opinion. We have evaluated it in the report. We give a personal opinion -- see, I think this is where I was trying to clarify. Some of these things that are mitigation now are becoming prevention. My definition of prevention is something that prevents core melt, not just fuel failure.

I think in this case we are really preventing. The vent is just a preventing device. It stops the containment failing, which if it fails, would then have led to core melt, because you no longer could pump water in the core.

I think the next one is if you have an inerted containment. If you have inerted containment, the mode of failure of the containment will not be from the hydrogen, because you don't have a hydrogen burn, you are inerted. The containment will fail from the generation of noncondensable gasses.

It is either enough hydrogen from all the various metal water reaction or, by the best calculation, probably the generation of CO2 as the molten metal reacts with the concrete.

Now, in this particular case, really, the containment failure will occur after vessel melt-through, so this even is dealing with a much more degraded event, in which you have really had a vessel melt-through and in which you now have a very different set of circumstances in terms of fission product release.

Now, again, you can put in preventive features. The secret is to improve your core makeup water systems. In this case a vent/filter is practical. Really, if you have a vent/filter, I think you don't need any other mitigation features, though you could develop some other mitigation features, such as, for example, eliminating the noncondensable gasses by reducing them. You could, for example, find a way to burn the hydrogen or you could find a way to reduce the CO2 that is generated. That is another way to mitigate the event.

There are schemes all through this event, if you look at them in this orderly way.

Now, the last two are the cases that deal with the steam explosion, and I think, again, in this case a vent is impractical. Finally, the penetration of the base met, and this is, really, if you have done everything else, you finally penetrate through the base mat -- again, in this particular case, the vent is not a very satisfactory solution.

It turns out that if you penetrate through the base mat, you relieve your pressure that way. The way the WASH-1400 numbers are done, that is a very effective filter. So, the idea of venting at that point, and filtering, doesn't buy you very much.

The next chart gives a similar set of step-by-step for the PWR, the ice containment. I don't want to take your time on that one, except to outline the difference. In a PWR it turns out that you usually get containment failure from actually having got a degraded core. The series of events that lead to a containment failing that then leads to core melt, subsequently leads to core melt, are not the higher probability events in a PWR.

In a PWR, what you have is, you have to have a core melt, which in turn generates hydrogen, which in turn leads to the containment failure, and that is a different sequence in the way the machines really get into these kind of difficulties. What you find, as you read this, is that you need hydrogen control practically for every event.

Once you have hydrogen control, then I think you can move to make the vent work. I won't take you through the PWR sequence here, but you have got pretty well a feel for what it is. In my view, what is key to understand these is what fails the containment is slow overpressure, high overpressure, spike overpressure, when did the fission product get released or not, and you have got to look at the whole range of alternatives that you have to make your choice correctly.

Now, let me illustrate what happens in a BWR. This illustrates a BWR-MARK III, in which, again, what you have, you cannot remove heat from the containment. Now, if you want to do anything about it, you get curve 1, the containment pressure climbing and after a while exceeding the design pressure, which is about 30 PSIA.

I think you could do another thing, you could first add water to the pool, you could use your pool dump, and that is really your curve 4. That is 2-1/2 million pounds of water you could add to this pool. I think that buys you time; instead of really climbing along curve 1, you are now climbing along curve 4.

Now, if you were on curve 1 and you decide you want to vent, you would start to vent, as shown there where the arrow is, you start to vent and you first vent with air -- all it would take is about 370 CFM -- and you could first vent air.

Eventually you would run out of air to vent and now you are beginning to boil off steam, so you start to boil off steam, as shown there, at about 14,000 CFM; that would be the size vent you would need at that point. I think if you added water to the pool, you don't have to boil off the steam so early. You can hang on and on.

Now, in the case shown below, you first start your vent, starting from curve 4, you start the vent at 270 CFM. You start to boil off steam, as shown there, and you would need a venting rate of 10,600 CFM. If you added on terms another 2-1/2 million pounds of water, you wouldn't be boiling off steam until 71 hours, which is surely more than enough to restore power and get all of these systems going to cool the suppression pool.

I think this illustrates how this scheme works.

This is the case where you had a degraded core. As I say, it is not the dominant event. You want to find out whether a vent/filter will work. I think if you have a degraded core, and assuming you have hydrogen -- so, really, you have taken care of the hydrogen control system. This says you really do not have hydrogen burn. You have either preinerted or you have done something different, or you burn the hydrogen in place, so it cannot give you a pressure spike to fail the container.

Now, in this particular case, we just assumed here that this was a preinerted containment and, as you realize now, the MARK-III is like that. This is not a viable alternative, but it is just a way to illustrate what would happen to your plant.

I think case 1 is if you have 5000 pounds of hydrogen released in 15 minutes, case 2 if you have 500 pounds released in 30 minutes, and case 3 is if you have 5000 pounds released in 15 minutes, but you have half the venting capacity. The reason we did this is to find out if you really needed the full safety grade on these vent/filters.

The vent/filter we came out as a result of this is about a 10,000-20,000 CFM system. We designed it so it was very similar to an off-gas treatment system, on the basis that this is all we would have to really deal with in this particular event during the period of time when the hydrogen is being generated and the fission products are being released.

This shows what you do the containment pressure as a result of that.

Now, let me try to illustrate for you the risk reduction. This is in a BWR. You have got to understand these risk reductions are done with what I would call a very crude method to assess these risks. It just takes your releases and finds a quick way to calculate, really, the fatalities, the latent cancer and the property damage.

Shown there is the WASH-1400 case. This is a typical MARK-I design, inerted containment. The first case, what we did is, we took the two major risk events, which is really the failure of the long-term event and the ATWS, and we decided to improve both of those. Both of those were improved by preventive means.

In case 1 we used the NRC Alternate 4 in their ATWS report and employed their numbers for the probability of core melt -- I want to make it clear I do not sponsor those numbers, but those were used in this report. I think for the case of containment cooling we used the independent RHR system. We added another RHR system independently to cool the containment.

As a result of this, as you notice, we were substantially capable to reduce the risk. In case 2 we replaced the independent RHR system by this vent plus a little water addition. What this tells you is that case 2 is very similar to case 1 or, another way of stating it, all the vent does is play the same role as another way to cool the containment.

I think somebody asked what did the event buy you. I am saying to solve the problem you have in a BWR MARK-I you could either go to a vent and vent water to the pool or, if you don't like that fix, you could find a way to cool the containment with an independent RHR system. They are about equivalent and one could be traded for the other, depending what you prefer to install on your plant.

For the case 3, what we did is, we took case 2 and then we added a filter vent. The only time this becomes effective is in those cases in which you actually have a core melt. This is the case where you fail to keep the core covered, but in the boiling water reactors those cases are of such low probability, that you don't get very much out of it.

The second reason you don't get very much out of it is that you already get all the benefit of the pool, because the vent was located on the wet well. So, you practically have already a filter made to order, so adding a filter to the vent to compensate for the very low probability of the event does not buy you very much.

DR. OKRENT: Can I raise a couple of questions? I guess you have said it, but it needs to be emphasized, that you have made certain assumptions about what are the dominant scenarios and excluded other scenarios in arriving at these conclusions.

His conclusions could be altered markedly if one introduced different kinds of scenarios or changed the relative ranking of some of these scenarios. Is that a fair statement?

MR. LEVY: That is a fair statement. I think all of these numbers are presented, starting from the WASH-1400 scenario, selecting the dominant one, employing the WASH-1400 number. I want to make that clear. We stayed with their releases, all of their things, so, you know, if you have a different design in which you changed, these could change. I am not disagreeing with anything that has been said -- or a different plan design.

DR. OKRENT: A more technical question. In the discussion this morning it was mentioned, but I think not discussed in any detail, that if one vents the air out of the containment, leaving primarily steam atmosphere, and if there were some mechanism for spray in the containment, you could have a later event in which you condensed this steam pretty rapidly.

Have you looked at that aspect and arrived at any conclusions as to what you would do about it, if anything?

MR. LEVY: We would do one or two things. One, we would avoid that condition from occurring by trying to keep the pool subcool. This was part of the reason why you want to add water to the pool. If you can keep adding enough water to the pool, you can always keep it subcool, so that you always have some noncondensable in that containment at that point. That is one solution and probably the better solution, in my view.

The second solution is that if you finally decide to boil off this thing, then I think you would have to clearly go to vacuum breaker to preserve that containment. This is part of the reason why I feel the ATWS one is not a practical solution. Those vacuum breakers would get pretty good --- the vent for the long-term cooling, the vacuum breaker could be designed, we have even looked at what they look like, they are do-able.

DR. OKRENT: Say that, again.

MR. LEVY: In the ATWS case, where you really have converted this to all steam, I think the vacuum breaker might get quite big.

DR. OKRENT: But for the other case you think --

MR. LEVY: They are do-able, right.

I personally would tend to do one or two things. I would try to avoid to fail this containment with 100 percent steam. That sounds to me the preferred engineering solution.

MR. BENDER: Sol, have you identified the places that are vulnerable in the event of a vacuum? Of course, the light bulb -- it is a light steel shell -- but stiffening it internally might make it resistant to internal collapse. Has any of that sort of thing ever been looked at?

MR. LEVY: No, and it brings out the same point I made several times, that in many of these studies, just the idea that you have containment failure, it is assumed that everything just goes to core melt and everything else. I believe there is a major effort to be done in trying to understand how containment fails, where it fails, and where the containment failures actually leads to a problem or not.

As you probably know, in a MARK-III condition there are some major things that come to play. Where the wet well is low pressure and the dry well is high pressure, you are going to fail the dry well first, and that makes a lot of difference in the world, because if you still have the pool, you could still filter through the pool.

Now, you have to make sure you still have the ECCS systems and all of these kinds of things, but I think, in my view, if there is a major area that needs to be looked at in detail, it is containment failure modes and clearly understanding what they are. I think it would make a lot of difference, and you may find that if in a MARK-I they always occur in a wet well, then a filter won't buy you anything, because, really, all it does is depressurize the wet well anyway. That is what its primary function is, relying on a pool as a filter.

I am not pushing that, but I want to make sure you understand it. I think the way they are designed, they will tend to operate at very close to identical pressure, so I am not ready to say which one of these two will go first.

DR. OKRENT: There might be a bypass mode from dry well to wet well and still have wet well failure. Then you would like the filter.

MR. LEVY: No argument. If you bypass the pool, you need a filter.

MR. BENDER: I don't want to promote any of these ideas, either, but the name of the game is controlled failure. Venting is just a form of controlled failure, you are just letting the stuff out in a certain way and we may as well consider other ways of controlling the failure besides that mode.

I don't think we ought to ignore that point.

MR. LEVY: That brings me to my last chart.

DR. OKRENT: Can I ask you one more question on this scheme, condensation and vacuum? If one, in fact, built up an essentially all steam atmosphere one way or another, one must know noncondensables. Do you envisage the possibility that you would lock out the core spray system under the circumstance that venting had permitted this, and if you could, that then whatever tendency to condense that might occur later could be dealt with with a modest kind of vacuum breaker? Is that a reasonable approach, or do you think you just can't count on locking out the spray?

MR. LEVY: I separate the two events, because the ATWS event practically remains at a constant power, because you practically set up a steady state performance at a constant power and you practically have constant power versus, really, a process that involved decay heat, in which you are actually coming down in power.

So, when you are talking one set of event versus the other, the amount of steam that you create decreases with time. There are certain things you can do for that case to probably, in my view, lock and reinstitute the thing. I tend to operate that I don't like to lock ECCS systems I have. I don't know why, it is one of the 10 rules. If you have got them, don't start to lock them, because you may lock them at the wrong time. So, I like to leave those systems there available and I would rather cope with the problem and then coming out and dealing with it.

I think there are some cases where I think you could do it. There are, I think, in this case, some ready solutions by trying to keep the pool subcool, which, in my view, is a very reasonable approach.

DR. ZUDANS: With respect to the same question, condensation, are there any tests to, in fact, confirm the fact that it will condense? It is possible theoretically to condense the entire volume, because as you reduce the pressure, there is a temperature there to evaporate continuously.

MR. LEVY: Well, I think it is a question of what water temperature you bring in at what spray level.

DR. ZUDANS: Right, and what temperature you have in the containment.

MR. LEVY: One of the considerations we had is to fix the spray following Dave Okrent's suggestion here. I think one of the suggestions we had is that if you took your suction from the pool, you know, that would not be a problem, because it is saturated water anyway. So, during this very degenerating event you could just lock it to keep only water from the pool instead of going out to the storage tank.

If you did that, it would just be spraying water from the pool and, therefore, will not give you a depressurization event. That is one way to do this. On the other hand, if you bring real cold water from the outside, you will depressurize it. I believe there are ways to put vacuum breakers to handle it -- I don't think it is nondo-able --

because you can only take so much heat with the spray of water you are going to bring in.

DR. ZUDANS: In addition to the fact that you could do it with vacuum breakers, the reduction in pressure would promote evaporation within the container. It is not likely -- of course, I don't see theoretically how you can condense the entire volume instantaneously --

MR. LEVY: You won't.

DR. ZUDANS: There is no way to do it.

MR. LEVY: No way, that is correct. So, I think you are not going to get a spike and you are already at pretty high pressure, I don't have to tell you that, at MARK-I you are probably already at about 90 pounds. So, you are coming down from that, and I think it wouldn't take very much gas, really, to stop it from really going down.

DR. ZUDANS: This problem may not be real, I don't know.

MR. LEVY: I think the way we looked at was to assume we were going to condense and size of vacuum breaker, and it was not an unreasonable vacuum breaker. As I say, I described one case we made a quick study on. They are about the type of vacuum breaker that you could find.

Let me go to my last chart. We found that the key to this is to decide what you are trying to do, assuming you have decided to make some improvements. We conclude that you could find preventive features for every dominant risk scenario and that in some of these risk scenarios I concluded that preventive features are preferable to venting, and I have outlined that is preferable for the case of ATWS -- I am giving a personal opinion.

We believe that the vent is a practical solution for loss of long-term heat sink, that that is a viable way to prevent core melt. For the case where you really uncover the core and you get into degraded core, the vent won't do you any good unless you have hydrogen control to make the vent practical and what we found is that, really, the vent/filter was of negligible benefit because, really, those events have a very low probability of occurring -- I want to make that clear, as Dr. Okrent pointed out.

DR. OKRENT: Well, I didn't point out that they have a negligible probability of occurring. I would have to question the original assumptions that these are the correct dominant scenarios. For instance, seismic events were not included in any of the risk studies to which you alluded, and there is a variety of other scenarios that are not included.

So, I think there really needs to be, again, a repeated caveat that these are all conclusions that you might draw if you take the original assumptions as being valid. They could be altered markedly.

MR. LEVY: I think if you read our report, you will see some recommendations that PRA should be kept up to date and brought up to date to recognize new findings and new things.

In the PWR ice containment we, again, find that preventive features are available. We find that in the PWR, where, really, the degraded core is the most probable event, hydrogen control is required to make the vent practical. We did not get an opportunity to run some numbers, but we wouldn't be surprised, again, that the vent filter would not have a very substantial benefit and the reasons are many ways the size as the ice containment -- the same as the pressure suppression water containment.

The reason is, you would again locate this vent and filter on the wet well side, or after the ice, and so you would get the ice acting, again, as a filter to trap a lot of the fission products. So, adding a filter after that, you don't get as much benefit as you would get in other applications.

I think the other conclusions we have made are that, clearly, PRA methodology is most important. We set out to see if there was a way to deal with design strategy and what we are saying is that if somebody can tell us what the dominant risk scenarios are, then you can proceed with a design strategy that looks at the scenario, when they occur, whether they occur before core melt, after core melt, you can look at the whole thing, and I think you could then develop solutions to the problem in a much more orderly way.

We finally want to stress that both pressure suppression and ice containment provide a filter prior to venting, if the venting is located on the wet well and if you do not bypass this dry well. I think that concludes my presentation.

DR. KERR: Thank you, Dr. Levy. Are there questions?

DR. MARK: Is it really true that all containments would be in trouble if you create a vacuum inside?

MR. LEVY: Most of them, actually, have a vacuum breaker of lighter weight. To my knowledge, most containments have a vacuum for which --

DR. MARK: I was just asking the structure, not the mitigation device for getting low pressure.

MR. BENDER: I think the answer is likely to be that the prestressed concrete containments are probably very resistant to vacuums. The dry well and the wet well in the PWR's are probably not all that bad, except that some of them are lined. I think that with a little stiffening and a little looking, most of them could survive a vacuum -- maybe not of 15 pounds, but maybe more than 3 pounds, which is what people say is the limit now.

DR. ZUDANS: Three pounds only comes from wind load considerations and that is just a number.

MR. BENDER: Yes, that is what I am saying. We might not get 15 pounds, but we might get half of it.

DR. ZUDANS: The ice condenser now takes quite substantial external pressures because of asymmetric load, so it probably can do a lot more.

Chet is right, all concrete containments will take it.

DR. KERR: Are there other questions for Dr. Levy?

Thank you very much.

Our next speaker is Mr. Finlayson from the Aerospace Corporation, who will discuss underground siting as an alternative to FVCS or vice versa.

MR. FINLAYSON: Gentlemen, I am pleased to be with you here this afternoon to tell you a little bit about the results of a study which were completed some time ago as they related to the filtered venting containment systems.

In order to put the study in perspective, let me tell you just a little bit about the study itself. First of all, this study is somewhat different from some of the others you have heard from today. It is one that was completed about three years ago. The study was conducted as a result of a requirement levied in 1966 by the California State Legislature.

DR. OKRENT: Excuse me, you said '66 and I think --

MR. FINLAYSON: Seventy-six. Excuse me.

This required the California Energy Commission to conduct a study of underground nuclear power plant siting. The historical background for this may be of some interest to you in that the Legislature conducted a series of hearings in 1976 on the safety of reactors, in which they had a large number of people come and visit them representing all sides of the reactor safety issue.

The legislators, you have to all bear in mind, are essentially lawyers and I don't think I need to say anything more about that, except to point out that even though they are lawyers, they did recognize that there is a thing called Murphy's Law, which those of us who are engineers understand, and they sort of came to the conclusion that although the probability of a core melt accident might be very, very low, that there was a possibility that a core melt accident might happen, and so in their naivete they thought that perhaps undergrounding might represent the ultimate passive protective system for reactors.

If you buried a reactor deep enough, you could just quit worrying about whether the emergency core-cooling system was defective, or any of the other engineered safety features which were included on it, that in the event of one of these low probability events, they thought it could survive.

I think perhaps this was based to some extent upon their observation and their having been given a presentation by some of the weapons effects people who came from the Nevada test site and told them about the effectiveness of burial with respect to bomb explosions, and how the fission products have been contained by such a mechanism.

So, the other thing that they thought was that if you wanted to get the cost of an underground nuclear power plant, that all you would have to do would be make an advertisement in the newspaper for bids on the price of one of them and in 10 days someone would come in with a price that they would quote and be willing to deliver one to you immediately.

So, they, along with the requirement to conduct this study, put a 1-year time limit on its performance, which put the whole program into some difficult times. The three things they asked for were that the technological and economic feasibility of the system be evaluated, that the radiological effectiveness be determined, and that the need for added protection also be evaluated.

In order to perform this study and to get decent cost estimates, which were thought to be a substantial portion of this element of technical and economic feasibility, we felt it was essential that we have good design figures for it.

So, we hired two architect-engineer firms to prepare designs and costs for the study. The two firms were Sargent and Lundy, who looked a buried concept, essentially a cut and cover kind of a concept, and the Underground Design Consultants, which is a relatively small firm of some people who specialize in tunneling kinds of activities, but who were supported in their design of a reactor by Gibbs and Hill, who were the major subcontractor for them and, of course, are famous because they are the only architect-engineer that has ever really designed and built an underground nuclear power plant, which they did for the Thieus plant in France.

These two architect-engineer firms prepared designs and costs. A separate study was conducted into the radiological and environmental impacts. This was conducted by a small firm known as ARA Corp, Advanced Research and Applications Corporation, which was a spinoff of Science Applications, Incorporated, and subsequently many of the team members from ARA Corp have gone back to Science Applications.

That was basically SAI, and they were supported in most of our analysis of the containment response by Intermountain Technology, Incorporated from Idaho Falls. In addition, we had some preliminary map studies for siting capabilities done by the California Division of Mines and Geology, and socioeconomic analyses done as well.

The aggregate total funding was about a million-and-a-half dollars. In the analysis itself, one of the fundamental decisions that was made early in the study was that we didn't have the time or the money to do a good probablistic analysis of underground nuclear power plants.

That would have required a design that went far beyond the design level which is available from a conceptual design and so we ruled out the probablistic analysis at the outset, but concentrated, instead, on evaluating the consequences of what we felt were critical accident sequences, and I will say a little bit more about that a little later on.

One of the first studies that was made, even before the designers came on board, was intended to try to evaluate the kinds of containment failure modes that an underground plant would have to survive. We sort of subdivided -- by the way, the baseline plants for these studies were pressurized water reactors with large containment systems, large, dry containment systems -- we had a secondary study on boiling water reactors, but the principal design effort was done for pressurized water reactors.

These containment failure modes which you see here represent sort of a baseline mode which I would like to speak about. We observed that there were, really, basically four failure modes, steam explosion, overpressure mode, which could occur either through hydrogen-burning combustion or through steam overpressurization, penetration leakage modes and a melt-through mode.

Now, strictly on the basis of evaluating the WASH-1400 results and the results are still applicable, even though there may be somewhat more up-to-date results, you can quickly draw the conclusion that melt-through failure modes have the highest probability of occurrences and the PWR 6 and 7 events run about 90 percent of the probability of severe core melt damate events.

On the other hand, the overpressurization and steam explosion, which represent together something like about 10 percent of the probability of failure, dominate the risk. From those two elements, overpressurization alone, strictly from steam overpressurization, represents about 70 percent of the latent fatality risk potential, the hydrogen burning about 10 percent, and the steam explosion at that time represented about 10 percent of the risk potential for the total.

So, between the three of them, they represent something like 85 and 90 percent of the total risk potential, even though they are only 10 percent of the probability of failure occurring there.

So, we realize that in order to make an underground system work, it would have to be effective against over-pressurization failure mode and in early studies we discovered that the concept of simply burying an ordinary reactor containment structure which is designed to be pressure-tight to increasing depths was not an effective way of preventing failure.

No matter how deep you put it, if you assume that your engineering safety features have failed, you ultimately will fail the containment, irrespective of the depth. So, consequently, we concluded that we had to build in some sort of a pressure relief system and this pressure relief system looks very much like an underground version of the filtered vented containment system, and I will show you pictures of that in a short time.

The steam explosions with the WASH-1400 concept of a steam explosion, it was almost impossible to avoid the containment failure through that kind of a mechanism. The energy which is associated with that missile that is developed when you blow the top end of the reactor off can penetrate almost any depth of ordinary burial that you might make.

Fortunately, the probability of that event -- we seem to have come to the conclusion that the probability of that event occurring has been reduced substantially in recent times. Otherwise, this is a very difficult problem to live with in any kind of a concept.

Penetration leakage concept, all of our designs involve a secondary containment in which, since the systems would be at low pressure, the penetration leakage could be considered to be a rather negligible problem.

As far as the melt-through is concerned, in fact, since the probability of the other events was decreased, melt-through was still a given, if you will. The ultimate probability of melt-through actually increases in an underground nuclear power plant.

I think I have gone through all the comments which I need to make about the relative risk contributions from these various failure modes, except to point out on this last one that because the underground construction shifts that accident risk spectrum towards the melt-through concept, it tends to force the accident risk spectrum toward low fatality conditions instead of the high fatality ones that are associated with the melt-through.

Let me just say a little bit about the guidelines that were used on our study, because they influence the results. First of all, we decided that we did not want to impose an entirely new licensing process upon the underground nuclear power plants, and so we felt that we would assume that the plant was designed against a standard design basis accidents in accordance with the licensing requirements.

We added the accident mitigation system to prevent a major containment failure, but we concluded that in the spirit of the low probability of the event, we would not ask the designers to make this a class 1 seismic design, but to merely do it to the best engineering standards.

We tried to design the system so that operations could be carried on in a perfectly normal tradition. The typical concept for undergrounding is to try to squeeze everything together and minimize the underground excavation. We said, well, we don't want to impose on the normal operations and maintenance and safety requirements, so we will give ourselves plenty of space and see what happens to the costs if you do that. So, that was an explicit requirement for it.

We didn't have enough money to do an optimization of the cost, and so we said, well, we want this to be a low cost kind of an activity. We don't want any frills put on these systems. That was inherent in all the design studies that were conducted.

The part about the risk analysis I have already talked to you about.

Let me just say a little bit about how the accident mitigation system, as this essentially filtered better containment system was called in their study, was designed. Because we were not doing a risk analysis, we designed the study basically against an envelope of severe accident conditions that would put the principal demends upon the capacities of the system in one way or another.

There were three of the accident scenarios which seemed to dominate that. One was the loss-of-coolant accident, without an effective emergency core cooling system, which dominated the early pressurization of the system and for rapid pressurizers in an early response requirement -- that gives you the most serious problem.

Then the second one was the loss-of-all-electric power concept, basically the TMLB-prime-delta scenario from WASH-1400, which is described here, and I will come to that in just a moment. It provided some of the most severe requirements of all the systems.

Finally, a sort of a half-breed accident scenario in which you lost -- there was a loss-of-coolant accident in which you had a degraded emergency core cooling system operation. The emergency core cooling system was assumed to fail temporarily until you had a core melt achieved, and then it became available to you, and at that time you began to pump water in and pumped in all the available water from your refueling storage water pool.

That imposed the largest demands on the capacity for the containment system, the accident mitigation system per se in terms of its heat capacity requirements.

In this insert figure here I have shown you the results as they were derived by Intermountain Technology for the temperature and the pressure response of the system to the loss-of-all-electric power accidents. Here you can see that we find that the accident itself is a relatively slowly progressing accident.

The pressure rises in the system and it is a sort of a high pressure kind of failure concept. The pressure operates against a relief valve until all the water is boiled away, and then you get a very rapid spike of pressure, a little cooling here as you get melt-through -- decrease in pressure, excuse me -- as you get the melt-through of the reactor pressure vessel, and then, when that happens, the pressure is suddenly dropped low enough so that the emergency core cooling systems can respond. They do and they dump all of the water into this and you get an immediate pressure increase, which drives the system almost to the failure limits of the containment and, given enough time thereafter, operating against the decay heat, the pressure just continues to rise until ultimately the containment will fail, unless you do have some pressure relief system, and then you can get this pressure reduction as you see here.

One of the interesting observations of this study, though, was that in the long-term problem, as time goes on, you get a constant pressure heating of the containment, and the temperatures continue to rise for periods of weeks here until you get temperatures as high as about 700 degrees Fahrenheit after a period of a couple of weeks.

Now, this was kind of a surprise to most of us. We hadn't figured on this kind of a problem, because the penetration seals are not designed to stand those kinds of temperatures. The penetration seals are designed to operate at around 400 degrees Fahrenheit and at about that time they begin to fail.

So, 700 degrees, you can figure that you essentially will have insignificant effectiveness out of your seals unless you can do something about that.

DR. ZUDANS: At that kind of a temperature, you would have a substantial amount of heat conducted to the outside of the containment. Was that included?

MR. FINLAYSON: Yes, and that is why at this point the temperature begins to turn around. Then you can get on the outside of the containment, the effectiveness of external coolants begins to become effective. Until then it just continues to rise.

Let me show you a schematic diagram before I show you some of the actual figures, so that you can get a little bit better feel for how the accident mitigation systems operated in this system and their resemblance to the filtered venting containment system.

This is a picture of the so-called berm-contained or buried plant. It was simply a covered kind of construction. It consisted of basically a full-sized primary containment structure 150 feet in diameter and a couple of hundred feet tall, enclosed within a very large atmospherical, dome-shaped structure which was then buried beneath backfilled earth materials.

Now, at the bottom of this backfilled earth material a cobble-filled expansion region was first emplaced, which was designed to allow the gasses from the system to be released into this large expansion volume and the rock-filled environment there acted both as a filter and as a mechanism for condensing the steam that was dumped into the system there.

Now, this bed down here underneath the ground was connected to the primary containment structure by 24 1-foot diameter pipes. Each of these 24 1-foot diameter pipes had 3 so-called rupture disks. It is not essential that they be rupture disks; there was a lot of debate on what was the appropriate type of an interface for these.

Finally, we did go with the rupture disks that were designed to rupture in several different ways. This one up here, that is essentially on the containment floor here, ruptured at pressures of the order of 100 psi, in excess of the design pressure, but within the ultimate failure limits of the system.

These are located on the interior of the containment system and you actually can see the core-melting process going on here and were designed somewhat differently. They were designed to fail either through failure because of high temperatures or because of high pressures. So, there was a eutectic metal system that was placed in here that would fail even if the pressures didn't get up high enough to fail th system from the 100 psi pressures, so that you could get release of these fission products in the underground system.

One other observation. This is the baseline accident mitigation system design, in which the intent was to let the native properties of a soil material act as your filtering mechanism. It was recognized, however, that that might not always be practical, and so in addition to that design we asked them to do an engineered filtered concept, and here you see the one which most closely resembles the filetered vented containment system.

This figure, which was prepared by Sargent and Lundy, shows you a more detailed picture of how this same system is laid out. Here, again, you can see these 24 1-foot diameter pipes again, leading out into what is now a toroidal ring-shaped, rock-filled containment vessel down here, which is connected by a stack, then, to the atmosphere.

The upper portion of this system was filled with sand and charcoal filter beds and so on, in order to provide and tailor the kind of filtering requirements to meet the needs of the system. You can see that has a strong resemblance to the kind of filtered vented containment systems we have been talking about this morning.

The mine cavern construction was quite similar to the berm-contained in its accident mitigation concept. The layout, as you can see, is perhaps more typical of the kinds of things which you may be accustomed to thinking for underground plants.

There were several underground caverns which were designed. This one here in the center contains the nuclear steam supply system, this one here, the large one, is designed to take the turbine generator and associated equipment, and this one over here on the far side is the auxiliary cavern.

The accident mitigation system were these unvented tunnels that you can see shown in dotted lines here along the bottom of the structure coming out of the reactor cavern. These were the baseline designs and the level 3 designs. They were, again, connected by the stacks which came to the surface and the rock-filled construction was tailored, again, to meet the needs of the system.

As one of the variables, then, we asked the Sargent and Lundy people to provide us with a design of a surface structure, then, containing basically this same kind of a concept applied directly to a surface system to find out what the relative cost impact for this system would be.

Here you see the same basic layout, the same 1-foot diamter pipes connected to a toroidal header here, the header than connected by several pipes that go over into a large rectangular box filled, again, with stones about 8 inches in diameter, thereafter accompanied by appropriate filtering systems and stacks.

I am going to pass over some of these things. I will only say that from the technological feasibility standpoint it seemed that there were really no engineering design problems that were significant for any of these features and we felt that buried structures of any design and the surface filtered venting containment system could all be designed without any particular engineering problems.

As far as the economic feasibility is concerned, there were several impacts. The schedule was stretched by a couple of additional years by going underground and so the total projected construction period, including licensing problems in this period some years ago, was assumed to be around 11 or 12 years -- I guess we would have to change that right now, although which direction, I am not sure, depending on the outcome of NRC's nuclear licensing procedures.

The cost estimates are shown roughly here, and I will just show them here in sort of rough form, and then go through them in a little bit more detail. Each of the architect-engineers was asked to prepare his own surface power plant design and that is why you see a couple of different prices here, and then to compare their buried plants against them, so we can get relative plant designs against their own surface prices, too, for the surface plants.

You can see that compared to the surface plant design for Sargent and Lundy, you are looking at a cost that is increased about 14 percent. On the other hand, this filtered vented containment system can be added to the surface plant for a relatively trivial increase of around 2 percent.

The same thing is roughly true for the UDC design, except that the relative cost for the underground system is about 25 percent for their mine cavern.

Let me show you just a little more detail, so we can see where the cost increments come from.

DR. KERR: Mr. Finlayson, we are getting a little behind on our schedule, so I hope you could abbreviate as much as you can without destroying our communication too much.

MR. FINLAYSON: Okay. I would just point out, then, that the accident mitigation systems themselves for the surface plants here can be seen to add around 4 million dollars to the system and for the underground nuclear power plants, they add somewhat similar amounts. So that portion of the plant itself is a relatively trivial increment.

Underground really impacts in the structures end, where the big expenses are involved.

The next slide then, talks about the radiological effectiveness. It presents the results of the ARA Corp study. These studies were then basically designed to show the relative effectiveness against what can be compared to the PWR 2 kind of scenario in terms of fission products releases from a surface plant, with the same kind of fission products releases within the containment structure and then released through the accident mitigation systems or, if you will, filtered venting containment system.

It was observed that dramatic impacts on the consequences were obtained with these concepts. As far as, really, fatalities were concerned, they were essentially reduced to negligible quantities. Latent cancer deaths were equally small by comparison with the very large numbers that you would get from failures in the BWR 2 range.

Although ranges of values that you see here don't reflect a risk analysis, again, they reflect some specific sites that were selected for evaluation against these individual kinds of concepts. The impacts with early illnesses are similarly very substant'ᐧ and, of course, the economic consequences are reduced from numbers which are measured in the billions of dollars to those which are measured in thousands of dollars.

What are the implications? If you have a problem which is basically a kind of a problem which is an over-pressurization kind of a failure mechanism, this kind of a system can produce dramatic effects. It is remarkably effective against it.

Whether the system is undergro.nd or at the surface, our calculations would not have given any differences with respect to the public health and economic consequences. It all depended primarily upon the fundamental effectiveness of the accident mitigation system. It was an assumption that you could make as reliable as you wished to, and without adding significantly to the cost.

I will only expound on that if you wish me to. As a consequence, this is the case you can produce some very dramatic impacts on potential --

DR. ZUDANS: What you are listing under underground, if I understand you correctly, equally applies to above ground, but provided the accident mitigation system is operational.

MR. FINLAYSON: Right.

DR. ZUDANS: That is also true for underground. If you don't have accident mitigation systems, it doesn't buy you anything.

MR. FINLAYSON: That is absolutely correct. That is what I tried to point out at the first of this. You cannot bury a nuclear plant deep enough to prevent an overpressurization failure, if the accident is severe enough.

DR. ZUDANS: I don't know how you get zero there.

MR. FINLAYSON: Well, it isn't really zero. I am sorry.

DR. ZUDANS: Oh, close to zero.

MR. FINLAYSON: But the fatality zone about the buried plant is extremely small. There are other things which I guess I could talk about, but I think I will pass on them, except to say just, finally, that as far -- we looked at a variety of other alternative containment concepts. It was our observation that all containment concepts, including underground siting, share total elimination of all containment failure modes that you can think about.

It appeared to us that there were certain qualitative advantages to underground siting in accordance with the kinds of designs which we had put together, for essentially all of the failure modes, too. One of the things which makes you wonder about that, of course, is the assumption that the accident mitigation systems were operating effectively, so we tried to give at least a qualitative evaluation of what would happen if they didn't work perfectly.

Here, again, the implication is that you are driven toward these containment failure mechanisms which shift you toward inherently lower casualty types of events, ones in which you utilize the ground to filter in and reduce many of the particular fission products that contribute to at least the late fatalities, and the early fatalities as well, to a serious portion of the risk.

One of the cogent observations was that you can do the same thing on the surface for a heck of a lot less money, but with perhaps qualititatively somewhat less effectiveness as far as all of the containment failure modes are concerned.

With respect to the need for the underground nuclear power plants, the State didn't really try to come to grips with how safe is safe enough. It really begged off that question, and agreed that it was sort of a problem in which the social and political issues dominated the technical aspects of it.

But the underground plant might help to reduce the public fears of a catastrophic accident. The observation was that the solution is expensive, and whether or not they ultimately resolve it is uncertain.

DR. KERR: Thank you, sir. Are there questions?

MR. MARK: You said that you can't bury deep enough to avoid the possibility of containment vessel rupture unless you have good, improved features. However, the population exposure would nevertheless be rated to be a great deal less even if you did have a rupture?

MR. FINLAYSON: Well, it depends on a lot of things. It becomes a very site-specific problem at that point, because if you start out with a leaktight containment and bury it deeply, so that you can build up quite high pressures in it, and you get a catastrophic failure, then you have to be concerned that you won't open a vent path that vents directly in a sort of a puff-type release directly to the atmosphere.

Now, if you would pick your site well and choose the materials that you bury the structure in, you can get a fairly high confidence that you won't vent directly to the surface. It becomes very much like the bomb kind of a problem. If you choose your materials correctly, you can minimize the probability of that.

Under certain circumstances you would have to worry about it, anyway.

DR. ZUDANS: But then you would have to open it remotely.

MR. FINLAYSON: Well, it is not going to be operational after this happens.

DR. ZUDANS: Yes, but there are 300-or-so people down there. That means something, too.

MR. FINLAYSON: Oh, I am sorry. I may have misunderstood your question. None of our designs was intended to be operated remotely.

DR. ZUDANS: I understand, but, therefore, if your containment fails, you would have to include the people that are there. They would be affected immediately.

MR. FINLAYSON: In any case, the designs always included a primary containment system, which gives the operator the same kind of time to react to the system that he has for a surface plant, so you are not talking about him being exposed to fission products immediately upon the failure of the fuel in the reactor pressure vessel.

He has the same protection that he would have in the surface plant and the same kind of time to respond to it, which means he has, probably, for almost all circumstances, hours before he has to be out of the system.

MR. BENDER: Mr. Finlayson, you heard the discussion this morning, I am sure, about the question of how large a failure could be accommodated by these mitigation devices. Did you look into that matter here? How big a burst could be dealt with?

MR. FINLAYSON: Well, if I understand your question correctly, I think you are asking me whether or not this could cope with an ATWS kind of an event as opposed to --

MR. BENDER: Well, a large pipe break.

MR. FINLAYSON: The problem was designed to cope with essentially all of the problems, with the possible exception of an ATWS. I guess I am inclined to agree with Mr. Levy that that problem needs to be dealt with in some other way. We only tried to worry about problems which involved, really, the decay heat removal aspects of it.

MR. BENDER: I had in mind just the flow rate requirements through the mitigation device that you had here, this toroidal --

MR. FINLAYSON: Well, in answer to that question, the most demanding case for the flow rate requirement was this loss-of-all-electric power problem that I showed you. It actually imposed the highest flow rates on the system. It did not impose the largest heat capacity problem, but it did impart the largest flow rate.

With the 24 1-foot diameter pipes, there is about three times as much as effective surface area to move the -- effective cross sectional area -- to move the material out that you have as compared to, say, a single 3-foot diameter penetration.

There was general agreement that there was ample volume for it to carry the capacity of the flow.

DR. KERR: Other questions? Thank you, Mr. Finlayson.

The next item on my agenda is a discussion by Mr. Curtis of planned research on filtered/vented containment systems.

MR. CURTIS: I will attempt to be brief. The scope and schedule of our research on filtered/vented containment, as you are undoubtedly aware, will depend upon expressed NRR needs and upon the graded core rulemaking needs, particularly as developed in the cost-benefit studies that Mark was talking about.

Our research in this area needs to be put into a perspective by discussing the fact that our principal contribution, at this time, at least, is to develop a better integrated phenomenological data base to assess the total containment threat from severe core accidents.

This includes work on core-concrete interactions, core-concrete interactions in the presence of water, the hydrogen program in developing the source, in assessing control measures, and in assessing equipment survivability under hydrogen burn conditions and, also, in assessing steam generation kinetics, whether you call them steam explosions, steam spikes, or whatever.

The other part of the research is to develop a better-integrated source term in the total fission product release and transport work which is going on. It starts with the release from the fuel, the way it is held up in the primary system, the way it is held up in the containment system, aerosol considerations of various depletion factors, so that we have a better term, a better measure of the nature of the containment threat and, also, a better measure of the radiological source from which the public has to be protected.

Add to that, in general, work going on in the Division of Engineering Technology to assess containment design margins. These studies are designed to do just what the title says, what kind of design margins are actually present in containments, along with the severe accident sequence analysis studies to integrate considerations of core melt prevention and core melt integration.

Specifically, what are we doing? Well, the report will be a continuation of the work that Benjamin talked about and we have two other programs, one at Oak Ridge as a part of the fission products release and transport, to make an assessment and test filtered materials. This is an integral part of the aerosol release and transport program, to look at the effectiveness of filtered materials, and these filter tests are simply an add-on to the basic studies of the more natural factors that are involved there.

DR. OKRENT: Sorry, what kind of filters are you talking about now? What kinds of loads of radioactive materials on the filters, and what conditions are these filters exposed to that you are doing research on?

DR. CURTIS: First of all,the tests have not yet been started and the test conditions have not been specified in detail.

DR. OKRENT: Well, what is their objective? Has that been specified?

DR. CURTIS: Yes. We have tests on aerosol release and transport. We believe that these can be made to be representative of the aerosol source present in containment at varous stages of the accident, or from the presence of steam or, perhaps, without it.

It seems as a reasonable add-on these tests could incorporate filter materials to test the effectiveness of the proposed filter materials.

DR. OKRENT: I don't find that a satisfactory explanation of the objectives, I must say. I don't think I know what it is you are really trying to find out from these filter tests, what it is you think you need to know, in the first place, and why there is any reason to assume that these add-on experiments will provide something that you need to know, if you need to know it.

DR. KERR: Do you want to try, again?

DR. CURTIS: No. Should I try again?

DR. KERR: Well, do you understand Dr. Okrent's concern?

DR. CURTIS: I understand the question. I am not sure that I have a convincing answer.

MR. BENDER: Do you know what filter media they are going to try to test?

DR. CURTIS: We have work looking at charcoal performance, other high efficiency filters, and the -- I think the program is available to test those materials that come out of conceptual designs.

DR. KERR: Would you interpret Mr. Benjamin's results, albeit certainly preliminary, to say that one does not gain very much by charcoal filters as compared with rock filters, or have you had a chance to study his results?

DR. CURTIS: I saw the charts that Mr. Benjamin put up for the first time this morning and --

DR. KERR: The results coming out of his program, at least, may have some influence on what you do test?

DR. CURTIS: Yes, absolutely.

DR. ZUDANS: If the results are to be believed, there is no need to test any filter; it would not do any good anyway.

DR. OKRENT: I am sorry, I have heard that said more than once, and I don't get that reading from his bar chart for man rems, so either you are reading it differently than I, or we are reading it the same and drawing different conclusions.

DR. ZUDANS: I see the bar charts oc ɔy the same area.

DR. OKRENT: I don't know what it means to say the same area. There is a displacement of some factor and, further-more, you can think of some scenarios, and it doesn't take too much effort -- I have heard Eversole, for example, argue that this is one that has not been looked at enough in a specific way, whereby you bypass the suppression pool, in which case there is a significant difference, whether or not you have a filter after the pool.

So, I wish you would be cautious about drawing that conclusion.

DR. KERR: Let's not be misunderstood. I was not trying to push a conclusion. I was just trying to find out --

DR. OKRENT: No, I mean the one that Zenon is drawing.

DR. ZUDANS: Well, that may be because that is what we were shown. Now, I understand if a header would break in a MARK-I containment, you have your condition there.

DR. OKRENT: But even without that, he did have some factor of 2, as I recall, roughly --

DR. KERR: But, David, if you give a lot of weight to the scenario in which the filter is bypassed, it doesn't seem to me it makes much difference whether you have tested the filter or not.

DR. OKRENT: No, what is bypassed is the suppression level.

DR. KERR: Then it might make a difference.

DR. FIRST: What kind of tests do you contemplate on charcoals beds and heaper(?) filters and so on, if in running these tests for 30 years -- what sort of information are you seeking that isn't already in the literature?

DR. CURTIS: I guess I would presume that these tests would concentrate on the dominant species that come out of the fission product release.

DR. FIRST: A particle, no matter what you want to call its composition, and as far as the volatile compounds are concerned, most of the interest has been on iodine up to the present time -- what other species would be of interest to test? We also have a good deal of information on noble gas retention.

DR. KERR: Is it anticipated that the tests will be an effort to verify existing data or that you will be looking for data which do not now exist?

DR. CURTIS: The presumption is that experimental information requirements will come out of the rulemaking process and out of the analysis of the tradeoffs that are involved in the laundry list that Cunningham gave us, which can be properly addressed as an adjunct to the fission product release and transport program.

DR. KERR: So, you may not form what may be needed until rulemaking.

DR. CURTIS: We have set aside some funds on a contingency basis in the expectation that there will be specific information needs coming out of the filtered/vented containment study and the graded core rulemaking which can be addressed in an expedient way using the Oak Ridge aerosol facilities.

We have set those funds aside in order to be responsive to whatever information needs do develop.

DR. OKRENT: Can I ask, is this presentation supposed to cover whether or not the program described earlier by Mr. Cunningham is being funded at the level comensurate with the needs of the NRC, or is that some other research program?

DR. CURTIS: Do you want to answer the question of what is the current funding level?

DR. OKRENT: No, I am just wondering, are you supposed to be covering his aspect as well in what you are telling us now? I can't tell from the agenda. It just says planned research in FVCS.

DR. KERR: Do you understand the question, Mr. Curtis?

DR. CURTIS: Yes, I understand the question. For the near term we probably expect continuation at 300,000.

DR. KERR: I think we are trying to find out if you know about Mr. Cunningham's program and if you have dollars to answer his question.

DR. CURTIS: And I said that I thought it would be continued at about 300,000.

DR. KERR: So, the answer is that you do know about Mr. Cunningham's needs and that 300K will take care of them? It is possible that they might be taken care of?

MR.CUNNINGHAM: That is correct.

Now, I am not sure what your question was, Dr. Okrent.

DR. OKRENT: All right, I will start earlier. We heard a presentation earlier today in which you described some efforts looking at various kinds of possible approaches to risk reduction. In Mr. Curtis' presentation I thought he said that they would look to be guided in what they decided to do, in part, by what came out of your program.

MR. CUNNINGHAM: Yes.

DR. OKRENT: Did I hear that correctly so far?

MR. CUNNINGHAM: Yes.

DR. OKRENT: Fine. Now, I am trying to understand whether under the current agenda item, which is called planned research in FVCS, this is supposed to address the question of whether the effort that Mr. Cunningham described and which you are counti[illegible] on is funded adequately, or is that not to be covered in this agenda item?

DR.CUNNINGHAM: I don't believe it was intended to be covered here. I interpreted this to be Mr. Curtis' programs that are related to the DCC work or the vented containment work.

DR. OKRENT: Okay, and were we going to hear whether the funding was adequate or not for the effort Mr. Cunningham discussed some time today, or is that not a subject of discussion?

DR. KERR: Well, I guess I should respond partly to this, and I would assume that since this is related to filtered/vented containment, that there would be some correlation between funding and doing.

DR. OKRENT: Yes, they are counting on the results of Mr. Cunningham's work to guide them and this is all somehow supposed to fit into some schedule that relates to the rule-making, a point Mr. Bender was emphasizing or belaboring this morning.

Now I am trying to get back at the question of whether or not there is an adequate priority and schedule and level of effort on the work Mr. Cunningham was talking about, since that seems to be a prelude to much of what else people are going to do.

Okay, is the background for my question clear?

MR. CUNNINGHAM: Yes, sir. I had not intended to go into, and I am not sure I really can go into making judgment on whether the level that we are funding this at is adequate.

DR. OKRENT: Maybe we can hear about it in Mr.Siess' subcommittee.

MR. SIESS: No. I was going to ask Mr. Cunningham who is responsible for making the judgment as to whether the research grant in a particular area is adequate other than the ACRS.

MR. CUNNINGHAM: I would say certainly a great deal of the burden resides on the management of research, the Office of Research.

MR. SIESS: You mean above your level?

MR. CUNNINGHAM: Above my level. I am about as low as they get, sir.

(Laughter.)

What has gone on in determining levels above me --

DR. KERR: What do you think would happen if you told whoever is just above you that you didn't have enough money to do what you are supposed to do? He wouldn't listen? He would say you weren't supposed to worry about that?

MR. CUNNINGHAM: I suppose he would listen, but it would obviously take a fair amount of discussion to decide, again, the priorities which they assign.

DR. KERR: No, but see, it is up to him to decide whether your work is more important than somebody else's, but in some sense you can comment on whether you think you have enough money to do your job, can't you?

MR. CUNNINGHAM: Yes, sir. I guess I was thinking more of the latter. I can make some judgment about whether, with the funds that are available, we can do what I was discussing this morning.

DR. KERR: If you had five or 10 minutes to think about that, what would you conclude?

MR. CUNNINGHAM: I would guess that the level of funding we are intending for fiscal '82 would be at about the right level for this particular program.

MR. BENDER: I am bothered by the kinds of questions we are asking the kinds of answers you are giving. Have you discussed it at all within your ranks to decide how much is needed and what the objectives are? And whether this program is the right one?

MR. CUNNINGHAM: Are you talking, sir, in terms of the specific value impact program I was discussing this morning or --

MR. BENDER: I am talking about Mr. Curtis' discussion of his funding level and your responses to our questions here that this is about right.

MR. CUNNINGHAM: When I was talking about right, I was talking about the funding for the particular specific issue of the value impact. There are obviously many other issues within the onus of the DCC rulemaking responsibilities that we have that also involve Mr. Curtis that I do not think have been adequately thought out as yet.

MR. BENDER: Wouldn't it be more appropriate for the two of you to say, "We need to discuss this more and we will report back to you," and give us a time when you would do that?

SPEAKER: You have got to tell them what you want to hear.

MR. CUNNINGHAM: Well, again, I see two levels. There are things that certainly could be discussed between Mr. Curtis and myself about this program and the value impact program and how it relates to his accident evaluation needs. There is also the, perhaps the larger level, which is my division's needs of Mr. Curtis to support other areas of the DCC rulemaking work as well as this particular issue.

We have just started thinking about those kinds of discussions with Mr. Curtis.

MR. BENDER: Who do we have to ask to find out what the whole research program should be, whether it is funded at the right level, whether it will be suitable for your value impact evaluation and whether it can be used for rulemaking purposes?

MR. CUNNINGHAM: The responsibility, as I understand it, sir, for the coordination, the development of the programs for the DCC rulemaking are with Mr. Bernaro, my boss, Mr. Bernaro.

MR. BENDER: Who?

MR. CUNNINGHAM: Bob Bernaro.

DR. SIESS: Let me get something clear. You are both in research, right?

MR. CUNNINGHAM: Yes, sir.

DR. SIESS: You are in what division?

MR. CUNNINGHAM: The Division of Risk Analysis.

DR. SIESS: You are in?

DR. CURTIS: The Division of Accident Evaluation.

DR. SIESS: And what is the question that you have been told to answer? You know, I am simplifying it. The function of research is to answer questions, so you have been given some question that you are supposed to spend money on to get an answer.

I expect to get two answers, since they are two different divisions, and I hope they didn't give you the same question.

Let Cunningham answer first.

MR. CUNNINGHAM: The question that I am supposed to address is, what kind of risk reduction potential and costs would be associated with a spectrum of possible prevention and mitigation options.

DR. SIESS: Of which vented/filtered containment is one.

MR. CUNNINGHAM: Correct.

DR. SIESS: Okay. And your questions?

DR. CURTIS: I am charged with developing a better phenomenological data base to evaluate all of the threats to containment, poured concrete, steam generation, steam generation rates, whether they be explosive rapid or otherwise, hydrogen production control, fission product release from fuel transport through the system and the nature of the radiological source term that is in containment at the time of containment failure, to provide analytical methods to accompany this experimental data base and to extrapolate the data base to severe accident analysis, and to support rulemaking by providing both the data base and analytical methods.

DR. SIESS: Now, is there any other area in the Office of Nuclear Regulatory Research that has been given any assignments that relate to the subject of today's meeting?

DR. CURTIS: Yes, Engineering Technology, its structural section, is looking at containment design margins and the structural problems associated with containment systems.

I have one more resource. I have a research group at INEL charged with looking at the engineering feasibility, with particular emphasis on backfit, of mitigation systems as proposed.

DR. SIESS: As proposed by Mr. Cunningham's people?

DR. CURTIS: Yes. So far, they have concentrated very largely on hydrogen in the ice condenser system and they have not yet looked at filtered/vented containment.

However, filtered/vented containments are within the total work scope.

DR. SIESS: So, the implementation of a filtered/ vented containment concept, the research that is related to implementation of it, is still in the future? Mr. Cunningham's group is still looking at whether it is cost beneficial and you are looking at the threat that it might alleviate, and you put some money aside for possible work on filter materials?

DR. CURTIS: And we have people identified to look at the engineering feasibility in a more detailed way than is done in a cost-benefit study.

DR. SIESS: But in FY82 or FY83 or when?

DR. CURTIS: The latter two tasks, the filter tests and the engineering feasibility, are assignments which have been identified as being within the work scope of ongoing programs but have not yet started.

DR. SIESS: Thank you. That is a lot clearer to me; I don't know whether it helped anybody else or not.

DR. OKRENT: Let's see, did you say that was 300K for FY82 for Mr. Cunningham's work?

DR. CURTIS: If I did, I may be obsolete.

MR. CUNNINGHAM: For fiscal '82 we are talking, for the DCC program, on the order of 1 million dollars.

DR. KERR: For all types? For the entire study? The cost-benefit study.

MR. CUNNINGHAM: Yes, for fiscal '82.

DR. CURTIS: The number I gave you was an early projection for filtered/vented containment, which has now been merged with --

MR. CUNNINGHAM: That is correct. That 300-400 has been what the filtered/vented program by itself has been over the past couple of years.

DR. OKRENT: So, that 300-400 is what Mr. Benjamin's program has been?

DR. CURTIS: Has been and is now merged --

DR. OKRENT: Okay, well, the only comment I would like to make is it still seems to be in a reactive mode and if Commissioner Galinsky, instead of choosing an ice condenser and hydrogen, had chosen a MARK-III and something else, I suppose everybody else would be working on something else than hydrogen and an ince condenser.

DR. SIESS: We asked the Commission to give them guidance.

DR. OKRENT: But the research programs are supposed to anticipate a little bit what the broad spectrum is.

DR. CURTIS: The Idaho work that I described have been directed to begin their data gathering on the MARK-III system as of a month or so ago and have that ready to look at at the next --

DR. KERR: Are there further questions? I guess not. Thank you, Mr. Curtis.

At this point I shall declare a 10-minute break. We will get started again at a quarter to four.

(Brief recess.)

MR. STARK: Good afternoon. I am Steve Stark, Manager of BWR Evaluation Programs. Also joining me today is Dr. Deborah Hankins and we will be responding to a request made to us from the ACRS staff to describe the decision process that we went through to conclude to add to the BWR-6 MARK-III standard plan a containment overpressure relief system.

These are the topics that we will be reviewing today after a few introductory remarks. I will be describing the group of improvements that we have sought to incorporate into the BWR-6 standard plant and then focus specifically on the containment overpressure relief system.

Following that, Dr. Hankins will go into a description of the containment design features, describing the suppression pool and its scrubbing capability and how, with the vent system included, we would, in fact, possibly have the capability of a filtered vent system on the BWR.

Then I will summarize.

We are planning to incorporate into the BWR-6 a containment overpressure relief system and our motivation for doing this is to provide an alternate decay heat removal system for the boiling water reactors. With the addition of this system, we achieve a significant additional reduction in risk beyond that already obtained by making many of the post-TMI improvements.

Now, if we look at the system which we plan to install and, by the way, it is being provided for a plant as an alternate decay heat removal system, not as a filtered vent as the objective, or for handling post-accident conditions, but if we do go ahead and install that system, we should look at it for its possible capabilities as a filtered vent following degraded core conditions.

For example, if a filtered vent is ultimately required, then this system would satisfy the objectives that would be motivating such a requirement. First, and probably most important, would be that it would be providing an alternate decay heat removal system.

I think it has been clarified today that probably the greatest amount of risk reduction that a filtered vent provides is by providing an alternate decay heat removal system.

Secondly, with the suppression pool scrubbing capability of the MARK-III containment and the fission product pathway which assures that any fission products would be passed into the pool, the addition of a containment overpressure relief system would, in essence, provide you a a filtered/vented containment.

Before I go ahead and identify the specific changes that we are planning to incorporate into the BWR-6 containment, I wanted to briefly touch upon the results of the post-TMI review that we have performed, where we have identified that there are quite a few features already incorporated into the BWR-6 that gives it a substantial preventive capability for the potential existence of any inadequate core cooling or further degradation to degraded core conditions.

I think that having this preventive capability is perhaps more valuable and better protection than having mitigative capabilities. We have previously presented this type of information before to the ACRS and I think you are familiar with it, so I won't go into any detail on it.

As part of our post-TMI review of the BWR-6 plant, we have performed a preliminary risk assessment, and much of the objective of this risk assessment was to identify what improvements we can make to the design to achieve a further reduction in risk.

Coming out of that preliminary risk assessment we did identify the four improvements which we plan to incorporate into the standard plant design. First of all, we plan to include an automatic depressurization system which provides for automatic depressurization for transient events, which may give a challenge to adequate core cooling in addition to the present capability of having the automatic depressurization system for LOCA conditions.

In this case, even without having high pressure, if the water level got near to the top of the fuel, the safety relief valve would be automatically activated to depressurize the reactor vessel and to make available for injection the low pressure ECCS systems which could then maintain core coverage.

The second improvement that we plan to make is really a group of improvements to the RCIC system to increase its reliability. We are adding automatic restart for the RCIC system and then, also, improving its isolation logic to reduce the probability that it might isolate, just on its normal initiation, a transient pressure spike.

Now, the first two improvements are ones that have already also been identified by the NRC. What we did with our preliminary risk assessment was to verify that, really, those were very wise actions to take and that they would have a significant improvement on the safety of the plant.

DR. KERR: Excuse me, Mr. Stark. I can hear you okay, but I am not sure about the rest of the audience. I hate to tie you too close to that microphone, but it would be helpful.

MR. STARK: Going beyond those recommendations made by the NRC following its TMI review, we have also identified an improvement that goes beyond their recommendation, and that is to incorporate into the design the containment overpressure relief system.

Once again, I will will mention that our motivation for providing this improvement is to provide an alternate decay heat removal system. One of the results of the WASH-1400 study was to identify that loss of decay heat removal was one of the dominant contributors to potential degraded core conditions. So, with the addition of this system, we see significant reduction in the probability of core melt.

In addition, we have identified the ATWS alternate 3-A, plus additional modifications already made in response to the Browns Ferry event to improve our ATWS mitigation capabilities.

MR. WARD: Mr. Stark, which of these can be or will be backfit into plans that are under construction?

MR. STARK: Well, many of the operating plants and those under construction are already committing on an independent basis to the automatic depressurization system to handle transient events, and the improvements on the RCIC system, because these were requirements from the NRC action plan.

Of course, the containment overpressure relief system goes beyond the NRC action plan and you tell these, well, you will be looking at that system improvement on an individual basis as a possible action that they want to take. Some action has already been taken in at least one instance; one utility that has performed a detailed risk assessment for a MARK-II plant identified that that is an improvement that they want to make to their plant.

MR. WARD: But all four, the third and fourth are appropriate for backfitting? They can be backfitted?

MR. STARK: Most likely the containment overpressure relief system is a feasible change that could be backfitted to a MARK-I or II plant, yes. Then, of course, the ATWS situation is being pursued on its own course and we will see what resolution is reached there.

DR. SIESS: I got confused. I thought he was asking about backfitting on MARK-III and you answered on MARK-I and II.

MR. STARK: Likewise, the utilities which are now constructing MARK-III's could decide to implement containment overpressure release. Now, when we are saying that we are planning to incorporate it on our standard plant, that would be for plants constructed in the future.

Here I have a chart which identifies the probability of different sequences leading to degrade ore conditions, and we can see the reduction in the probability of each of these sequences leading to degraded core conditions that results from making these improvements.

One of the reasons that we took the action on the core containment overpressure relief was that prior to this improvement, loss of decay heat removal system was the dominant sequence potentially leading to core damage. So, it was perhaps the most fertile area to seed a reduction in the probability of degraded core conditions.

Overall, when we look at all four of these improvements made together, we obtained approximately a tenfold reduction in the probability of core melt. This is, of course, approximately the value that the staff said earlier today was their objective in the degraded core arena.

DR. KERR: Excuse me, what is a SORV?

MR. BENDER: Stuck open relief valve.

DR. KERR: I have been told, thank you.

MR. STARK: Now I would like to go into a little bit more detail about our containment overpressure relief system. This is a modification to the design to provide an alternate decay heat removal system. The benefit of adding that means that we have -- that it would prevent core damage for, of course, a loss of decay heat removal event.

Now, we already have existing in the BWR-6 design substantial capability to remove decay heat. Of course, the first line of defense there is your normal system, the main condenser to remove decay heat. Backing that up are your various modes of operation of your decay heat removal system to, first of all, shut down cooling, and then, finally, suppression pool cooling.

So, there are four lines of defense for removing decay heat before a containment overpressure relief system would be considered for actuation.

Briefly, the conceptual design for the system would be to add a 24-inch vent line and this includes, also, the addition of appropriate valves and controls and to direct that vent line to the plant vent. Air would be provided for the controls to decrease the dependency on electrical power for opening the valves.

Finally, one action that still has to be taken is to review the equipment for its capability. One of the impacts of making this change is that it increases the potential temperature and pressure within the containment, and so we would want to review the environmental capability of the equipment needed to maintain safe shutdown to assure that it could continue to perform its function.

DR. MARK: Surely an added system of this sort could have, if it were thought of in those terms, could have some bearing on sabotage feasibility. Has it been given thought from that point of view?

MR. STARK: I think I understand your questions, and let me try to answer what I understand to be the question. Providing the system is similar to, and perhaps more advantageous than providing an additional makeup capability to the vessel to remove decay heat, we already have quite substantial capability for supplying water to the reactor vessel in the BWR-6. We have approximately 13 pumps that can supply water directly to the vessel.

So, for defense against sabotage, there is really no great motivation toward adding an additional system. We can easily supply water to the core. Perhaps a greater challenge for us is to make sure that we can remove energy from the entire system. What the addition of containment overpressure relief does is, it allows us the capability to remove that decay heat from the system.

MR. BENDER: Steven, if I understand correctly, by putting in the relief, you allow the use of any pump that can supply water to the core, the suppression pool in any way. Is that the right interpretation?

MR. STARK: Well, we have at least three functions to perform following a transient that might call on this system. One is to maintain a shutdown condition. Number two is to provide adequate core cooling and there we would use any one of the pumps that deliver water to the reactor vessel to maintain that adequate core cooling.

MR. BENDER: With the vent, do you have more or less pumps available, or just the same number?

MR. STARK: The same number of pumps to provide water to the reactor vessel.

MR. BENDER: Okay, that is really the only question I had.

DR. KERR: Can you tell me where the vents vent to and from? It says here directed to plan vent. I am not sure that I know what a plant vent is.

MR. STARK: The plant vent on the MARK-III standard plant has an exit height of 40 meters, so the release elevation would be 40 meters.

DR. KERR: Where does it exist the containment?

MR. STARK: It exits the containment from penetration that is already provided and, actually, it is a 42-inch penetration that we have through the containment, and then we are tapping off of that line that is already present with isolation valves after the downstream isolation valve.

What we are adding to the plant is a tap into that line in a 24-inch line and a valve on it.

DR. KERR: I thought I heard you say that the addition of this vent increased the temperature of the containment, and I didn't understand that at all.

MR. STARK: Currently the design conditions for post-LOCA events for the MARK-III containment are 185 degrees. The suppression pool should not go over 185 degrees in any transient or accident event. We perform analyses to demonstrate that that is so.

In the event where we have lost capability through normal means to remove decay heat, the pool could increase in this design up to 230 degrees, approximately, so it would be some temperature increase and this would increase the environmental requirements on some systems.

DR. KERR: Let me see if I understand. You don't mean that installing this vent causes that increase. You mean that the new mode of operation which you might bring into existence would require that one have operational systems that would operate in this environment.

MR. STARK: That is correct. Only under this mode of operation, if normal decay heat is not available, we had to resort to using this system, then it is possible that the temperature could increase.

MR. BENDER: That relief pressure is associated with, you said, 250 degree?

MR. STARK: Two hundred and thirty degrees, approximately. What we are basing that on, approximately the nominal design pressure for the containment, 15 psig, so we would plan to actuate, manually actuate this system at the design pressure of 15 psig.

DR ZUDANS: Which pumps are used to refill the pool?

MR. STARK: Well, the first water source that we would utilize would be the upper pool dump, and that supplies an additional 200,000 gallons to the pool, or about 20 percent of the pool's capability. If we need, we are also looking at supplying additional capability of providing water to the suppression pool.

DR. ZUDANS: These are what you would call alternate residual heat removal systems?

MR. STARK: Yes, both providing the vent and providing the water makeup would be a total system, would comprise a total system.

I think it is clear now what type of a transient we are postulating that this system protects against. It is any transient or accident that causes a loss of the main condenser first, and then followed by the circumstance that none of the other decay heat removal systems are available.

We would be assuring adequate core cooling by providing water to the reactor vessel through RCIC, HPCS, or the other ECCS systems, or the normal systems that provide to the reactor vessel, such as sea water. Then the reactor would be depressurized as specified in the emergency procedures at normal conditions, 100 degrees F. per hour.

With this discharge of steam into the suppression pool through the safety release valves, the suppression pool would heat up with time, reaching about 170 degrees at several hours into the transient, and then with more time, increasing the temperature and bringing the suppression pool to a boiling condition.

As the containment pressure responded by increasing its pressure, once it finally reached 15 psig, then the system would be manually actuated to control the pressure within the containment and protect against loss of the containment, and as water was needed to be made up to the suppression pool, it would be added, first, from the upper pool down, and then from other capability which would be provided.

MR. BENDER: The valve has a regulating capability? It is not just an open and shut valve. It regulates that pressure.

MR. STARK: In the current status of our design we are not planning on providing a controlling capability. It would be a valve that we would fully open.

MR. BENDER: And leave open?

MR. STARK: And leave open until we could recover the needed decay heat removal, say, by the outside power becoming available again or being able to reconnect to the main condenser, and then we could close that valve and stop the vent, and this could be done at any time along the transient.

DR. OKRENT: Would you need any additional vacuum breaker equipment on your outer containment building as a result?

MR. STARK: At this point in time we have not identified the need for additional vacuum breaker capability. We are considering putting an inner lock on the containment spray, so that while the vent valve is open there would be a possibility of automatic actuation of the containment sprays.

DR. OKRENT: This is what Mr. Levy didn't like.

MR. STAR Yes. You can see that it is a subject of current discussion.

So, we believe that with the addition of the containment overpressure relief system, we have substantially reduced the risk and provided much additional capability in the decay heat removal are. Now, I think that possibly this system has a function that goes beyond an alternate decay heat removal system and it is to this point that Dr. Hankins will be discussing.

DR. KERR: Are there questions of Mr. Stark?

DR. SIESS: At the time you relieve the 15 psig in the outer chamber, what would be the pressure in the dry well?

MR. STARK: Let me think for a moment on your question.

(Pause.)

I believe that the pressure in the dry well would be approximately equal to the pressure in the wet well. This would be due to the probable cause of the initiating event would be a transient, in this case, the energy released from the reactor vessel would be through the safety release valve, so it would be discharged to the pool.

So, it would be a slow pressurization, first, of the wet well, and then the vaccum breakers between the dry well and the wet well could open up and increase the pressure of the dry well.

DR. SIESS: Let me say why I asked and maybe Dr.

Watkins' presentation is going to answer it. Are there fission products in the dry well?

MR. STARK: For the case that we are looking at, at the alternate decay heat removal system, we are not anticipating any significant core damage. This is a system to be used prior to core damage.

MR. BENDER: Steve, can I ask a corollary question before you leave? When you open the containment and de-pressurize, what temperature does the suppression pool go to?

MR. STARK: Well, of course, if the vent was opened at 15 psig, the pool would be at that time at 230 degrees. Then, as the containment depressurized, the pool would generate steam bubbles and flash and maintain its saturation temperature, so it would follow the saturation temperature, corresponding to the pressure within the containment.

MR. BENDER: You have thought about the flashing aspect?

MR. STARK: Yes, we have.

Thank you. Now, Dr. Hankins.

DR. KERR: Thank you, Mr. Stark.

GREENWOOD

Tape 6B end of a[illegible]rnoon follows RSM

DR. HANKINS: Steve has just described the containment overpressure relief which we see as being a significant preventer of degraded core accidents, and I am going to describe our studies that we have done in the area of mitigation of degraded core accidents and specifically what we have done is tried to quantify the capability of the pressure suppression pool as a mitigator of core melt accidents.

Those of you who are familiar with the Mark 3 design recognize that it is a multi-compartment model. You have an inner dry well, an outward primary containment and a third shield building. In the case of a LOCA initiated accident you would have release of fission products to the dry well area, and then they would have to pass through the horizontal vents, through the suppression pool in order to be released to the containment atmosphere before they could be released to the environment. In case of a transient initiated event they would be discharged through the safety relief valve discharge lines into the pressure suppression pool and then again up into the containment atmosphere before they would be available for release.

In our Mark 3 standard plant design we feel that for an overpressurization event our analyses indicate that the most probable failure location is at the knuckle region. So, you are talking about approximately 130 feet from the surface of the suppression pool to the failure location, and by the way that is not an open space to travel up that distance. It is quite a torturous path of getting by equipment and racks, and it is, again, there should be significant retention of any fission products if they make it through the suppression pool in the first place.

I know --

MR. BENDER: What kind of fission products are you thinking of?

DR. HANKINS: In the case where you have sub-cooled pool we believe that the only fission products realistically that are going to make it through the pool in any significant number will be the noble gases.

MR. BENDER: They are not going to be trapped. What is it that you expect to take advantage of by this torturous path?

DR. HANKINS: Oh, by the torturous path, again, cesium iodide vapor or some kind of particulates.

MR. BENDER: That is farther down the accident.

DR. HANKINS: Right.

MR. BENDER: Thank you.

DR. HANKINS: One of the reasons we feel that the suppression pool will be there given this core melt accident is because first of all containment failure, again, in the suppression pool area, we feel is unlikely for the standard plant because we have a concrete fill in the area between the primary containment and the shield building. This fill was required as a part of new loads concerns, and it so well reinforces the area that we do believe that, in fact, the containment will fail at the knuckle region due to an overpressure. There are potentially to main overpressure events, one being a steam overpressure caused by loss of RHR or loss of heat removal accident that we have been talking about this morning and, also, a hydrogen combustion. In the case of a hydrogen combustion we believe that the containment will fail, but the dry well will not, and that is based on our structural analysis of the relative pressure capabilities of the containment versus the dry well. The numbers that are given on this chart are yield conditions. We believe that the ultimate capability of the containment is about 60. We have not identified the ultimate capability of the dry well, but then it would be something much higher than 70.

DR. KERR: Excuse me, what is the significance of the EST? I presume you have made calculations. So it must not mean estimate.

DR. HAWKINS: It is an estimate. We have made calculations, but our numbers or our calculations are not polished to the point where we feel confident to present them in any form other than an estimate.

DR. KERR: Thank you.

DR. OKRENT: Is there a vacuum breaker in this design between the containment outer well?

DR. HANKINS: Yes, well, there are two sets of vacuum breakers, the dry well vacuum breakers which open if the pressure in the dry well, of course, is less than the containment. There are the containment vacuum breakers that go from the chill building annulus into the containment space.

DR. OKRENT: And have you looked at where the most likely failure point would be in the containment if one postulated increasingly severe earthquakes?

DR. HANKINS: We have not done any seismic analysis.

You have been talking a lot about bypassing the suppression pool. Before I get into our quantification of the capability of the suppression pool, I would like to mention that we have looked at accidents that bypass the pool.

Now, remembering that today we are talking about Mark 3, not addressing myself to Mark 1 and for those events that do bypass the pool, such as a hydrogen detonation which would simultaneously fail the dry well and the containment, of course, you are not going to get any suppression pool scrubbing, and in the case of, also, with cases of steam explosions. However, with steam explosions a significant number of the fission products that result in large consequences are already in the pool prior to the time the steam explosion occurs and, also, there is the case of the failure to isolate. It should be noted that the filtered vents that have been discussed, also, will not assure filtration of fission products for those accidents.

DR. SIESS: As I recall it, the dry well was not designed initially as a leak-tight structure. There was a lot of discussion about the leakage. It was pointed out that it was not intended to be leak tight, that the containment provided that function, that its function was simply to divert the pressure, divert the flow to the suppression pool.

Now, under the conditions you have described for a LOCA there would be some bypass of the suppression pool simply because of leakage from that concrete structure at 70 PSIG. Is that taken into account in the analysis?

DR. HANKINS: It is taken into account, and as you stated it is only important in a LOCA because of course, in a transient there are no bypasses. In the case of a LOCA the only actual measurements that we have on a Mark 3 were made at Cushain, and I believe the dry well leakage at that time was measured at 74 CFM and if you postulate the flow rates for the core concrete interaction which is what you should be interested in, it turns out that it is on the order of 1 part in 1000, and that is assuming you assume no retention in the leakage paths, but if you recall from the containment experiments that were done, Hillyer and others, that in fact, that had a very difficult time in a steam environment which of course, is what you would have in the dry well in the case of a LOCA, getting anything through those leak paths because they plug up with steam very easily, but on a dry basis we did measure 74 CFM which, again is about 1 part in 1000 based on the estimated flow rates for core concrete interaction.

DR. SIESS: That is unfiltered.

DR. HANKINS: That is unfiltered.

DR. SIESS: Is that counting in your dose calculations?

DR. HANKINS: You will see that the dose calculations are done on a parametric basis.

DR. FIRST: Would you identify the passive filter on that diagram, please?

DR. HANKINS: This? We are saying that the suppression pool itself provides a large passive filter.

DR. FIRST: That is not really a filter by the classical definition of the word. Filter has a very definite meaning.

DR. HANKINS: In the sense that it filters out products, it is a filter, if you want to get into the chemical.

DR. FIRST: I suggest you look it up in a dictionary.

DR. HANKINS: Okay.

MR. BENDER: Why don't you just call it a trap, and that will make Dr. First happy, and we will understand.

DR. HANKINS: Okay, whatever.

In order to quantify pool scrubbing for degraded core accidents we conducted a literature search to determine what data existed on pool scrubbing, and what we found out was that the DF or the filtration ability of the suppressor pool is very strongly a function of the particle size that you are trying to filter. It is a strong function of the bubble size and the rise time of the bubble through the pool and whether or not the pool is at saturated or sub-cooled conditions.

We took a look at, I think there were a total of about 15 different references in the literature and from them in recognizing that these were for the most part very small scale experiments, they were passaged through maybe one to two feet of water, some very high flow rates. We felt that the literature data could be extrapolated to values of about 100 for a saturated pool and at least 1000 for a sub-cooled pool where you do have some condensing.

However, we did recognize that the data base was weak. In particular there was no data on cesium iodide itself, although there was some data on sodium iodide which of course is chemically very similar, but again since cesium iodide is currently the accepted form of iodine, there was really no data on cesium iodide. We, also, felt that the data base was somewhat weak, in that it did not provide any good models of suppression pool scrubbing, and we believe in looking at the data that even for a saturated pool condition and the expected flow rates from a degraded core accident that you can get DF's on the order of 1000.

I guess there was some talk earlier about the aerosol filtration program testing charcoal filters and HEPA filters. I was hoping that there would be some mention of testing pools of water, also, as a filtration mechanism.

MR. WARD: Is there any effect here of, I guess they call it channeling through this trap? Let us say that all of the blowdown from the dry well comes in to one side of the pool, do you assume you still get the DF of 1000 in that case?

DR. HANKINS: Now, recall that the fission products are released after the LOCA blowdown period. So, we are talking about very low flow rates and those flow rates in looking at the flow rate per vent and the expected vent uncovering you find out that the bubble sizes are still considered relatively small. They are on the order of 1 to 3 centimeters. That is expected bubble size. We are currently in the process of looking at some small scale testing of the phenomenon through vents.

Of course, in the case of the quenchers, the quenchers have 1 centimeter holes. So, the expected bubble size is about

1 centimeter, and in terms of channeling, when we talk about saturated pools, basically that is what we are talking about because the bubbles do not condense, even if they are state. In the case of a subcooled pool you would expect substantial condensation and therefore the bubbles would, I expect, be even smaller.

MR. WARD: I guess I was thinking more about channeling in the gross sense. For example, in your transient through the safety relief valves, does the effluent in the pool from the safety relief valves well distributed? Is it always going to be well distributed all around the pool or is it --

DR. HANKINS: No, the flow rates are such that they would probably be going out one safety relief valve. Again, at the time the fission products are coming off you have very, very low flow rates. We are talking about, probably something less than 100 pounds per second of steam in terms of looking at LOCA's and transients. That is an extremely low flow rate.

MR. BENDER: One way to look at this is to think about the contact time of the bubbles in the pool. Is that what you are doing?

DR. HANKINS: That is right. It is dependent on the size of the bubbles and the rise time, and of course, the size of the bubble is also influencing the rise time. The bigger bubbles rise faster. Bubbles on the order of 1 to 3 centimeters rise about 1 foot a second, and again, they are traveling through about 15 to 20 feet of water, both in the case of the LOCA and the transient.

DR. FIRST: May I suggest that gas will not go through in a uniformly volumetric way. What will probably happen is that there will be periodic surges of overpressure which will bring a large volume of gas through the pool and the bubble size in spite of the openings being 1 centimeter can obviously be much larger since the gas doesn't have to go through as a sphere. It may go through as a long cylinder, and under these circumstances the decontamination factor of 1000, I think is very, very optimistic.

DR.HANKINS: For a sub-cooled pool where you are condensing the bubbles?

DR.FIRST: Yes.

DR. HANKINS: We did observe flow through the SRV's, through the quenchers at Coshain.

DR. KERR: Excuse me, did you hear her say that she is condensing the bubbles?

DR. FIRST: She is in a condensing situation. The bubbles are not going to condense necessarily all the way because of the heat transfer. You can only condense so much.

DR. HANKINS: We are talking about a sub-cooled pool, and we are talking about steam.

DR. FIRST: I understand, but the way to calculate that is to look at the heat transfer from a bubble to the liquid, and even though it is sub-cooled, it is the temperature differential between the gas and the liquid that counts.

DR. HANKINS: I was going to say that we looked at the SRV discharges at Coshain and you can see the bubbles as they start to emerge from the quenchers, and then you never see another bubble.

DR. FIRST: You cannot see anything less than about 100 micrometers anyway.

DR. HANKINS: If we could get bubbles that small that would be great. Mass transfer would be super.

MR. STARK: We have performed tests out of the plant on the quencher to temperatures exceeding 200 degrees and have observed condensation for all of those tests.

DR. HANKINS: At much higher flow rates than what we are talking here.

DR. KERR: I think we may have to solve this question by using champagne. Why don't you continue.

DR. HANKINS: Okay.

DR. ZUDANS: While you thinking, you said that the flow rates are such that likely they will be discharged to a single SRV, and that means that all the condensation will have to take place around that particular structure.

DR. HANKINS: That is right.

DR. ZUDANS: Have you looked at how this flow distribution will take place?

DR. HANKINS: That is one of the things we are looking at, but again because we have gone to such high temperatures on our tests we believe that it is still going to have complete condensation of the steam when you are sub-cooled, keeping in mind that there is some hydrogen there. You will not, obviously, condense the hydrogen. So, the remaining bubble will, in fact, be a hydrogen bubble, and probably larger than 100 microns.

In order to quantify the pool scrubbing, in addition to the literature survey and as I mentioned the small-scale tests that we are embarking on, we treated the DF for the entire plant in a parametric way to see was there really a benefit at going for very, very large DF's, and here is an example of a couple of evaluations we did. One is a realistic evaluation and I was happy to hear this morning that the staff felt that more realistic evaluations should be used rather than the conservative ones for degraded core rule making decisions where we assume that we had a sub-cooled pool, and we, also, assumed a DF of about 10 for plate out and natural removal factors.

We took an average containment failure time. It is sort of an average for looking at a number of transients and breaks and assumed a gradual release from containment, and that was releasing 100 percent of the fission products over about an eight-hour period. That would correspond to a very large cra..x, but not necessarily the whole top of the containment disappearing.

We, also, did a conservative evaluation where we assumed that the pool was saturated. We took no credit for containment sprays. We took no credit for a natural plate-out, and we assumed that we would have a very rapid core meltdown and release. It was assumed with a relase time, containment failure time of about one hour and the entire inventory released in about a one hour period, which is essentially a pump release.

MR. WARD: The DF you are talking about for the plate-out is in the reactor vessel?

DR. HANKINS: It is unspecified because we were looking at a range of accidents. In case of a LOCA it could be a DF of 10 in the dry well. In the case of a transient it could be a DF of 10 in the primary containment. One could, also, assume the containment sprays were operational because as I said this is treating it parametrically. We used the CRAC computer code and what we did after struggling for a long time, we found a way to turn off the evacuation model in CRAC. As you know, essentially all CRAC analyses that are done to date assume the evaculation pretty much along the lines of the evacuation model that was used in WASH 1400.

We wanted to see the results if we forced hypothetical people to stand at certain distances from the plant throughout the course of the accident and then remain at that distance throughout their lifetime. So this lifetime dose is actually about an 80-year dose, and it includes the acute exposure from the cloud, pluse chronic exposure to the ground, reingestion, and of course, you can see for the realistic case you get extremely low doses. Actually they are less than 10 CFR 100 at about 1/2 mile. This is because it is essentially a noble gas dose.

In the conservative case the doses are higher. However, the doses are still below the acute threshold, again, remembering that this is a lifetime dose, and so it includes the acute, plus the chronic. The acute part was still below the threshold for acute fatalities, and so in either case you still get no acute fatalities within 1/2 mile of the plant.

DR, KERR: What is the threshold for acute fatalities.

DR. HANKINS: There is no threshold for whole body. It is done in the CRAC code on an organ-by-organ basis, for instance for the bone marrow, I believe that the threshold is about 325?

DR. KERR: I don't know. I was asking for information.

DR. HANKINS: Yes, it is done on an organ-by-organ basis, and I could not tell you which each one was, b.t they were all below the threshold. It is about on the order of 40 to 60 percent of this dose gives the acute, and the rest is chronic.

DR. OKRENT: Could you put that back a minute, please? Two rather different points, we did hear a short presentation once by Sequoia people and maybe there is somebody in the room who would be able to clarify this later today, but my recollection is they estimated about 800 rem whole body at the site boundary, if they took assumptions similar to what you call your conservative evaluation. Now, I don't know whether it is because their site boundary was less than 1/2 mile or what, but I am interested in knowing whether it is just that kind of thing or something else that leads to those different results.

DR KERR: Would more suppression pool make a difference?

DR. OKRENT: No, because this is just a question of what is released afterwards, the noble gases basically.

DR. HANKINS: I believe I have seen that. That was in their hydrogen control stuff.

DR. OKRENT: Right

DR. HANKINS: My recollection, and correct me if I wrong, if anybody is here, I believe they used the meteorology assumptions. I don't believe they used the CRAC code which is a more realistic model. It uses a finite cloud. It uses hour-by-hour meteorological assumptions.

DR.OKRENT: I see. That might be.

DR. HANKINS: That would constitute the difference.

DR. RENFRO: I am David Renfro with TVA. I was going to address this in the next presentation. I will go ahead and speak to it now.

The number was 900 rems. So, I don't think that is too far off, a factor of two, or two and one-half or something like that. It was based on a very simple ratio type calculation from the design basis LOCA calculation that is done at the SAR. All we did was take into account the difference in the amount of gas that was released. This was low population zone whole body dose. I believe it is 1000 meters.

DR. HANKINS: Then it is true, you used the licensing meteorology?

DR. RENFRO: Yes.

DR. HANKINS: The 95 percent meteorology assumptions. That would account for it.

DR. KERR: Thank you.

DR. OKRENT: More importantly,assuming there is some kind of appreciable decontamination factor for steam plus other things going through a pool, if that decontamination factor gets large enough, it seems to me what becomes important is to find out now what are the avenues where you may not, in fact, be able to take advantage of this and in fact are these a factor of 100 less probable? How do we know that they are not perhaps just 10 percent less probable than the things we have been looking at? Do we know them that well and so forth? Otherwise one may get an early optimism that is later dampened by other people's pessimistic results.

DR. HANKINS: I agree.

What happens is once you quantify large factors of the pool, you then become dominated by accidents which bypass the pool, and as I indicated before, we have looked in the process of doing a standard plant PRA and in that we are looking at the accidents that bypass the pool.

Again, as I indicated for most of those accidents, there are like hydrogen detonations, steam explosions, stuck open dry well vacuum breakers would be one that would be probably a reliability question, but for those phenomena there are, also, ones that a filtered vent will not work. Obviously in the case of the dry well vacuum breakers, yes, but there I guess my feeling is a personal opinion thatone should put their money into correcting bypass mechanisms, maybe rather than putting on a new filtered vent and increasing the reliability of the dry well vacuum breaker.

DR. OKRENT: I have not seen enough detailed studies to be able to tell that those paths which might bypass a large decontaminating feature automatically lead to large relea[illegible] from your outer containment rapidly or not. Perhaps you are convinced. I would say that is maybe awkward. I would prefer that that were not the case in fact so that you could take advantage of other features if it turns out to be helpful.

DR. HANKINS: Sure.

DR. KERR: Mr. Siess?

DR. SIESS: In your two calculations, realistic and conservative you varied three parameters. Can you give me any idea of how much of a difference in the answer is due to the release time which you said was about eight hours for the realistic and about --

DR. HANKINS: You mean the duration of the release?

DR. SIESS: Duration of the release, yes.

DR. HANKINS: Okay, duration of release is in the difference between one hour and eight hours, and again it is going to vary by the time of the release. It is something less than a factor of two.

DR. SIESS: Thank you.

DR. HANKINS: The time of release is by far the dominant factor and for every three hours you delay the release you drop by about a factor of two.

So the difference between a four-hour release and a one-hour release again is about a factor of two.

So there may be approximately a factor of four overall due to the difference in the time of release and the duration of release. We found no early fatalities in our assessment. We started looking at the latent effects. Again, you are all aware that the latent effects are always computed based on the linear hypothesis. So, using the linear hypothesis and comparing to other risks in life, comparable life shortening effects, and these are -- the reference for these non-radiation effects are Professor Cohen's paper in health physics. We compared the risk of various things that we do every day in our lives compared to the loss of life expectancy with, say, something like radiation.

DR. KERR: Ms. Hankins, did you ever read Mark Twain's story about going to church and listening to a tremendous sermon, so good that he was about to contribute $20, and the minister kept preaching and -- don't oversell us.

DR. HANKINS: Okay, let me just say that I think the important thing is the realistic case and the 10 CFR 100 limit.

DR. SIESS: What is so bad about this town in Brazil?

DR. HANKINS: That place in Brazil is a tourist resort,and I guess they have high thorium and uranium content in the soils.

MR. STARK: I found it interesting that the women seemed to be able to do better without men, in that there is not as much life-shortening effect as men doing without women.

I would like to quickly summarize. First of all, we saw from our post-TMI review that the BWR has quite a few features already designed within it that are quite substantial preventers to degraded core condition, and it is probably wiser to try to prevent a degraded core accident than try to cope with it after you have it, and because of that we have identified quite a few improvements for the BWR along the preventive lines to further reduce the probability of core melt.

One of these is the containment overpressure release system that can be utilized as an alternate decay heat removal system to back up the current decay heat removal capability.

In addition to that the containment overpressure release system does possibly have a -- could be considered for utilization as a filtered vent.

The way that this could be done is that in essence we already have a fission product absorber in the suppression pool, and with the addition of containment overpressure relief. That matched with the suppression pool could comprise a filtered vent system.

If the filtered vent were required the BWR 6 containment overpressure release system would satisfy probably what the objectives would be for a filtered vent system.

DR. KERR: Thank you, Mr. Stark. Are there questions?

Mr. Bender?

MR. BENDER: Could I make a point?

DR. KERR: I don't know whether you can or not, but you can try.

MR. BENDER: The point was made earlier today that in the cesium iodide trapping mechanism or pools of water some experiments might be appropriate, and I gathered GE is looking into the phenomenon more.

Is GE suggesting that the Nuclear Regulatory Commission sponsor some experimental work to find out about this trapping capability?

MR. STARK: Yes, we are strongly recommending that the Nuclear Regulatory Commission pursue and develop quantiative information especially experimental information that will help the industry and the NRC reach a consensus of opinion of what the capability of the absorption of fission products in the suppression pool really is. Right now we saw today that we have numbers that vary between one that the staff has used for a conservative case to 1000 that we at GE have used as a realistic case, and I think there needs to be a meeting of the minds so that we can move on and do things realistically.

MR. BENDER: Have you identified the variables that need to be investigated?

MR. STARK: Debby, do you want to address that question?

DR. HANKINS: I think it was about six weeks ago that myself and Steve and another associate met with Rick Sherry and Walt Dostep, NRC staff, and we, also, met with Tom Hurley, and we outlined at that time what we felt were the important variables, some of which I mentioned today, particle size, chemical form, bubble size, rise time of temperature, and in the meantime we had actually already begun small-scale testing of our own varying these different parameters and trying to model the suppression pool scrubbing as a function of the different parameters.

MR. BENDER: Thank you. That is enough.

DR. HANKINS: We strongly recommended that.

MR. STARK: We do feel that testing of fission product absorption in suppression pools should have priority versus testing of filter efficiency for various exotic filters.

Thank you.

DR. ZUDANS: Just to make sure I understood you correctly, when you said that if the filter vent configuration is required that the existing pool with the additional containment oil pressure relief already would satisfy the requirements. In other words, you do not plan to add anything in addition to that?

MR. STARK: That is correct, except perhaps procesures to direct the operator on how to use the system in a degraded core condition, but we feel from what we have seen today that probably the greatest benefit of the filtered vent is first of all as an alternate decay heat removal system.

We have that in the containment overpressure release capability. A second although probably more minor benefit is that it acts as a filter for any potential release, and as a protection for containment overpressurization. With the pool we have a filtering mechanism and with the containment overpressure release we have a containment protection system

MR. BENDER: Steve, just so we can keep the record clear, do you mean degraded core cooling condition in which fuel has not yet had any significant failures?

MR. STARK: When we say that we are planning to incorporate containment overpressure release into the standard plant, that is for an alternate decay heat removal system to be used prior to the existence of a degraded core condition, actually to protect against that occurring.

MR. BENDER: That is enough.

MR. STARK: Okay, I am saying though that it could be considered in addition though for degraded core conditions.

MR. BENDER: I tried to make the point because we constantly worry about whether the operators can make the decisions at the right time, and when they have to discriminate between good and bad conditions the symptoms that have to go with the action have to be clarified, and we will probably have to hear more about whether there is a good symptomatic basis for deciding when to open and when to close that valve.

You open it when the pressure says open it, but I would not want to open it when there was a reason not to.

MR. STARK: Yes, I agree with you. The development of the emergency procedures should be -- we should make quite sure are explicit in dealing with how to use the system and the symptoms that should specify its use.

MR. BENDER: I don't see any way in which I could support the use of it without knowing that those symptoms are known and that the operator can properly discriminate.

MR. WARD: Just one more question. Does General Electric plan any research to establish the effectiveness of the pool in removing fission products in the degraded core situation?

MR. STARK: Yes, we do, as we have already described. We are initiating some small-scale suppression pool scrubbing tests. In addition we are seeking funding for larger scale test, and right now we have communicated with EPRI about the possibility of such funding.

We would, also, be willing to talk with the Nuclear

Regulatory Commission about funding for such tests.

DR. KERR: Talk about their funding you or you funding them?

MR. STARK: About our performing the tests and their funding them.

DR. FIRST: Dr. Hankins said that you did not get any very useful information from small-scale tests. So what are you doing them for?

MR. STARK: We believe that --

DR. FIRST: What you advocate is all for small-scale tests, if my memory is correct.

DR. KERR: Do you have something to add, Dr. Hankins?

DR.HANKINS: The small-scale tests were in 2 to 4 feet of water. What we are proposing is small scale but yet still 7 to 20 feet of water.

They are not as small scale.

DR. KERR: A big small scale test is better than a small small scale test.

DR. HANKINS: They are very controlled conditions at degraded core flow rates in expected conditions.

DR. FIRST: Are you aware of the fact that there has been a good deal of bubble work done in connection with liquid metal fast breeder reactor research and these may have great application to the problems you are presenting?

DR. HANKINS: In sodium?

DR. FIRST: Yes.

DR. HANKINS: I am not sure how we would make the transition.

DR. FIRST: Are you familiar with the work?

DR. HANKINS: No.

DR. FIRST: Then how do you know whether you can make it or not?

DR. HANKINS: But there has been work, I understand on the steam generator tube bubbling which I understand was, also, funded by the NRC.

MR. BENDER: I could just make an observation that even the NRC is having trouble translating that information for sodium purposes. So, your point is well taken.

MR. STARK: Thank you.

DR. KERR: Thank you, sir.

Mr. Renfro, if you are here, we appreciate your patience.

MR. RENFRO: I do appreciate the opportunity to be invited to speak today. I feel a little bit like Daniel in the lion's den, being the only utility representative here. Maybe GE feels the same way with the vendors.

It is a change to speak to a generic issue like filtered vented containment in an information type setting such as this rather than something that is directly related to the Sequoia licensing process. I will try to be brief today and touch on a study that was done about one year ago, a little over one year ago for the Sequoia plant.

At that time Commissioner Galanski had not pointed out the hydrogen problem to everybody's edification. So, we were not sure exactly what we would face in the licensing process. Early in 1980, the TVA board of directors felt like a commitment to some kind of Class 9 accident mitigation system might be required to break this licensing log jam that had resulted from TMI.

We performed a brief overview study of several different mitigation concepts at that time. Filtered vented containment was one of these concepts. There were a total of seven. The others included venting to an additional containment building that would be constructed on site, venting to the other units,containment building on site, augmenting the existing air containment cooling, pre-inerting the containment with nitrogen, post-accident injection of haline(?) and controlled ignition.

Conceptual designs were done for each of these seven concepts, most of them in-house. We did engage some AE's to do a couple of the concepts, controlled ignition and filtered vented containment. We had Sargent and Lundy and Burns and Rowe do filtered venting containment conceptual designs.

I would like to give those firms credit for the amount of work they did in the limited time. We evaluated the work for all seven of these conceptual designs in-house in five areas.

These five areas were effectiveness,technical feasibility, additional risk, reliability and initial cost. The study was completed in April 1980,and has been documented a couple of places since then. We submitted a complete report of the study to the NRC September 2, 1980 on the Sequoyah docket, more for information or background than directly related to the Sequoyah licensing process.

In addition, Ray Schuman of Burns and Rowe presented a paper at the NS conference last fall on their conceptual design for filtered vented containment.

TVA specified the design parameters for the AE's work. In general since we did not have any regulatory guidance we consciously chose to restrict these design requirements for the system to be non-safety grade, considered the hydrogen producing events to be unlikely enough that a full-blown safety treatment was not required.

Arguments can be made that if enough safety systems have already failed to cause a degraded core vent that a fully safety grade Class 9 mitigation system might not significantly reduce the risk more than a non-safety system would. Conservatism and rugged design can still produce a capable system, even without being redundant in seismic

Category I.

Some more design criteria and general design criteria.

Since a major contributor to the degraded core situation could be the loss of all AC power we felt like the system should be as passive as practical. We specified an elevated release point. We felt like a combination of a manually actuated, motor operated isolation valve and a passive rupture disk should be used for initiation of filtered vent for the slow overpressurization case.

At some point in the accident sequence when containment consequences appear probable but before the overpressurization actually occurs, we felt like the operator should manually open all the containment isolation valves. However, this did not open the containment to the filtered vent until the remaining barrier, the passive rupture disk is removed.

Another desirable feature that we felt like should be specified and included and practical in the conceptual designs was a forced exhaust mode. This was first done, I guess, in the UCLA study where if the containment isolation function was lost the fans could be turned on and most of the effluent from the containment be filtered and released that way.

The last general area we felt like hydrogen control should be provided in the filtered vent system just to protect the system itself due to the temperature pressure effects from hydrogen combustion.

DR. KERR: Excuse me, let me see if I understand the combination of the rupture disk and the valve? If you have, say, a single exit line or whatever, you would have a valve or two valves in series or something. Since you said not safety grade, I assume you would have one valve in series with a rupture disk and it is operated normally closed, but if you see the pressure increasing and think you may want to release to a filter at some point you open the valve and then you depend on the rupture disk to decide when the process begins.

MR. RENFRO: That is correct, and as we have said today there could be a number of alternatives to venting. We felt like we wanted both in series. So, the operator had to make a conscious decision to allow the vent to begin but that the rupture disk would be set at such a pressure that it -- well, I will touch on that just a little later.

It is this next slide.

DR. KERR: You are going to tell me why you prefer that to having a pressure gauge which the operator reads before he opens the valve?

MR. RENFRO: No, we feel like he would either act on pressure or act on other indications.

DR. KERR: No, I mean to open the valve, but the pressure disk would make the final decision.

MR. RENFRO: That is correct.

DR. KERR: Rupture disk. Now, that is because you think it is more accurate than a pressure gauge or something.

Go ahead. I am a little puzzled by that choice of alternatives, but you can probably clarify it for me.

MR. RENFRO: We considered doing those in parallel where you could vent or you could depend on the passive disk. That may be a more defensible position. We are trying to sort of combine the best of both worlds.

DR. KERR: I am not being critical at this point. I was just trying to understand how you made the decision to do it the way you did.

MR. RENFRO: The idea was to allow the operator to make the decision to open the vent but yet not allow the containment to be vented unless it really needed to be.

In other words, if he wanted to override the rupture disk he had that capability.

DR. SIESS: No, wait a minute. How could he override the rupture disk?

DR. ZUDANS: Unless he had a parallel line.

MR. RENFRO: I am saying he does not have to open the valves, and he can close the valves after the rupture disk is opened. What I am saying is we are trying to say if the guy does not want to vent, if the governor says, "Don't vent," for example, you don't have to depend on that passive rupture disk being in place. It is not a blind system. He has some intervention that he can --

DR. ZUDANS: He can close it, but the ruptured disk probably would break even if he didn't open them up.

MR. RENFRO: We had intended for it to be at a pressure above the design capability of the containment. So, theoretically it would still be there after he had opened the vent, and then it would go at some higher pressure.

MR. BENDER: The real constraint you are putting on the operator with the rupture disk is not to let him vent before the pressure reached a certain level. Is that correct?

DR. KERR: It sounds to me like the philosophy that is used when you have a firing squad, and you have five people with guns, only one of whom has a bullet. So, the guy who does it does not really know when he has done it, and the operator opens the valve, but he doesn't know when the thing goes.

MR. RENFRO: I started to say that a while ago. It is sort of taking the responsibility away from him. Yet we didn't feel like we wanted to put in a completely passive system that he did not have any control over. We would like to be able to throttle the system or close the system off eventually.

DR. FIRST: A passive system that is an active system does not really follow the definition because one thinks of a passive system as something that does not require the intervention of the operator. We discussed this this morning, and I don't see how you can call this system a passive system which does not necessarily mean it is not a good system, but it is not the right word for it.

MR. RENFRO: I agree. I am not trying to say that the system is entirely passive. In all of the filter vented designs that we came up or the AE's came up with there were active components, and I will be addressing those later. Certainly the containment isolation valves were one of the active components.

We have just been talking about decontamination factors. Several sources have estimated that a DF of 100 would reduce the consequences of this event to where other containment failure modes would begin to dominate.

We did not specify DF or noble gases. We did not feel like it was practical to require any kind of extended holdup or cryogenic treatment. The design temperature was estimated to be 750 degrees. The vent initiation pressure was set at 35 PSIA. This is above the containment design pressure of 27 PSIA. It is quite a bit less than the actual containment capability of 55 to 60 PSIA.

DR. SIESS: That figure is wrong.

That figure says, "Design pressure 55 PSIA.

DR. KERR: That is for the filter, isn't it?

MR. RENFRO: Yes, that is not for the containment. That is for the filtered vent system.

DR. SEISS: Containment design pressure is what?

MR. RENFRO: Twenty-seven PSIA. I believe it was established at previous ACRS meeting that the Sequoyah containment was good to approximately 45 PSIG. This is where we got the number 55 to 60 PSIA for design of the filtered vent system.

Without having any design basis accident specified we chose a couple of accidents to look at to try to bound the problem or look at the problem from two different aspects. One case was a complete core melt following a large LOCA. The second case was a partial core melt following a small LOCA at periodic partial hydrogen burns. The first case was AD. The second case was S2D. Note that the S2D case is the one that was eventually, quote, DBA for the Sequoyah ignition system.

We bootlegged preliminary March results from Batelle Columbus, used these as a basis for the steam and non-condensable flow rates to estimate the size of the system. Representative peak flow was estimated to get the system flow dimensions. Total heat was estimated as size of system for the necessary heat capacity.

A composite of those two cases was used by the architect engineers for their conceptual designs. This is the Sargent and Lundy conceptual design. As you can see the basic components are a single vent line from each containment 54 inches in diameter. The isolation valve rupture disk arrangement is as specified by TVA as we discussed earlier. The first treatment stage was a water quench tank. It featured Mark 2 type downcomers. This was more or less for convenience or maybe because Sargent and Lundy had some experience in this area.

Moisture treatment seems to be one of the more difficult problems with the HEPA charcoal filters. To overcome this they specified a moisture separator as the first stage of treatment following the quench tank.

The filtration included a HEPA filter, a heater, again, for moisture treatment; fire protection and cooling systems were provided for the iodine filter next in stream. These are not shown on the sketch and an after HEPA filter was included and then a stack relief.

MR. BENDER: Excuse me, David, just to understand what is happening here, the constituents of the fluid then is venting to the quench tank. What assumpti[illegible] [illegible]re made, steam, air,carryover of hydrogen; what things are in there?

MR. RENFRO: One of the problems we had was just the question you asked. What are the constituents, and how do they vary as a function of time? We estimated a total heat load and sort of a beginning and a final composition of the effluent, but we really did not give the AE's much information about the constituents as a function of time.

Of course, there was steam included. It was estimated that once all the non-condensables, excuse me, once all the condensables were quenched the flow rates would drop from this, and these figures of four hundred something thousand to around three hundred thousand.

MR. BENDER: How about things like concrete reactions with fuel? Has the accident progressed that far with its venting system?

MR. RENFRO: The large LOCA that went to complete core melt, the case one, we did include CO, CO_2 from the concrete.

MR. BENDER: And if there some reaction with metal and the fuel that created aerosols, they would come, too, I guess?

MR. RENFRO: That is correct. Now, we did not really evaluate the radio nuclides and the loadup on the filters or anything like that.

MR. BENDER: I just wanted to see if I understand.

MR. RENFRO: This is more of a thermal hydraulic.

MR. BENDER: Thank you.

MR. WARD: Do you think the quench tank here would perform about as well as the BWR suppression pool in removing fission products?

MR. RENFRO: I really cannot express an opinion. I don't know if GE has looked at the Mark 2 decontamination. They have already left the meeting. So, I cannot answer that.

DR.FIRST: Actually it is probably irrelevant because the following equipment will do much more in any case. The end result will be the same.

MR. WARD: Yes, but I just wonder if you needed it to support the performance of the BWR design suppression pool effectiveness, I wonder if you need the rest of the system.

DR. FIRST: You think rocks might be better.

MR. RENFRO: I think the system was just as much for heat capacity as filtration, and the filtration was really intended to be provided by the after filters as shown here. That sort of serves a double purpose, but it is not really intended just for decontamination.

DR. FIRST: I am glad they put the right name on this device in your sketch.

MR. RENFRO: Which device is that?

DR. FIRST: Quench tank. They did not call it a filter.

MR. RENFRO: Some special features of this design include the fact that it is mostly passive, except for the containment isolation valves and for the filter support systems. These filter support systems might not be essential for partial cleanup of the effluent. This particular conceptual design only operates in the overpressure event. It does not operate in the forced exhaust mode because no bypass was provided for the quench tank.

Although this design used proven components and does not look like it would require a lot of development, it was not evaluated further in our study.

We were only going to evaluate one conceptual design in detail, and we chose to evaluate the next concept that I will talk about.

DR. ZUDANS: All of this is non-safe degraded as you said in the beginning and no seismic category 1. What kind of requirement; how can you satisfy the requirement that it be there when you need it?

You know, like you said yourself, many other Class I pieces already have failed, and there you are relying on something that is not even close to it as far as the quality.

DR. KERR: Is that a question or a comment?

DR. ZUDANS: It is a question. What expectations do you have? What is the probability of it being there, and how does that affect the releases?

DR. KERR: I think he is asking for your estimate of the probability of a simultaneous LOCA and earthquake.

MR. RENFRO: I was afraid he was going to talk about seismic events. We don't seem to have looked at seismic events as initiators quite as much as other things. I really cannot say how reliable this is if it is not in seismic Category 1.

It was our estimation that --

DR. KERR: But you can say you decided on this one. Is it in the same category? It is, also, not seismic.

MR. RENFRO: That is correct. The only seismic Category 1 components in either of these designs are the containment isolation valves because they are required to be. We were, at this stage of our study about one year and one-half ago, we were not -- we were trying not to penalize unduly the cost factors that would come out of this. We were trying to look at these systems as something that if we committed to them we could do economically and feasibly without going the whole safety system seismic Category 1 classification.

I think there are arguments both ways. I am certainly not disagreeing with your statement. This is the second conceptual design. This was performed by Burns and Rowe. You can see the basic components again. Here there are two vent lines from each containment. Each of these was 36 inches, and they merge into a 54 inch line. The first stage of treatment is the suppression pool. It has approximately 600,000 gallons of water. It is about 11 feet deep. It is chemically treated with sodium thiosulfate to aid in iodine removal. Above the pool there is an air plenum. It has a water spray provided to draw suction from the suppression pool. It is provided to remove iodine in addition to the pool.

The flow rate for the pump was about 11,000 GPN. The plenum was about 9 feet tall. Both of these two components were about 100 by 100 feet.

Ab ve this airspace a sand filter was provided. It is about 100 feet by 150 feet. It is 9 feet thick, and it is graded, coarse gravel followed by finer sand and coarse gravel again on top, supported by a concrete grid.

Dilution plenum is provided downstream of the sand filter. This was the way Burns and Rowe chose to treat the hydrogen problem, diluting the effluent from the sand filter by about a factor of two. The dilution fans would provide about 300,000 CFM, and it was estimated that the peak flow of the effluent would be about 300,000 CFM following its condensation in the suppression pool.

The exhaust fans here were provided for the forced exhaust function if the containment isolation feature was lost. They are about 30,000 CFM each. Again, an elevated stack release was specified.

This design has several special features. It was underground for natural shielding and chemical filling operations.

It is basically passive except for the spray system which is probably somewhat optional. The hydrogen dilution is an important active system, but it would be hard to conceive of a way to treat the hydrogen without an active system. One important difference between these two designs is that design uses a water pool spray combination for iodine removal instead of charcoal filters. It was felt that they were cheaper and less conditioning of the gas would be required. No fire protection would be required.

This system as designed was able to operate in several modes. Of course, the standard overpressure mode high capacity venting through the suppression pool; this would work down to about 5 PSIG because of the head of the suppression pool.

A bypass was provided that would go directly into this air plenum above the pool and still get the benefit of the sprays before it entered the sand filter.

In addition, the forced exhaust mode could be used if the rupture disk had already burst, and since no bypass of the disk was provided you could not use the forced exhaust mode unless you had had the overpressure event to occur previously.

DR. SIESS: Where is the rupture disk?

MR. RENFRO: The rupture disk is not shown on this diagram.

DR. SIESS: You have got three valves here, and you had two valves before, and you have got two lines here where you had one before.

MR. RENFRO: Well, there are actually three valves here to accomplish the same purpose three did in the other design.

DR. SEISS: What three in that?

MR. RENFRO: Three isolation valves. The other valves are to be able to lock up on containment.

DR. SEISS: Why do you have two relief lines here rather than one in the other?

MR. RENFRO: That was just the way Burns and Rowe chose to present it. I guess they felt like this added a little bit of redundancy to one of the active features of the system in case you could not get one isolation valve open you could go to the other.

DR. SEISS: And why did you say you had the exhaust fans?

MR. RENFRO: The UCLA study that Dr. Okrent was associated with a few years ago incorporated this feature. I am not sure how that really impacts the risk of the plant, how significant it is. The concept is that if somehow the containment isolation function was lost, some penetration was leaking, the forced exhaust mode could be used to try to suck most of the containment effluent through the filter system and reduce the pressure that way rather than letting it leak through the penetration.

Okay, this concept was the one that we selected to do a little more detailed evaluation on, not necessarily because we felt like it worked better, just because we thought it was a little more ambitious, offered a little more room for evaluation.

Briefly, I will go over five areas that we evaluated the concept on. The first area is effectiveness. Assuming they worked as intended, how well did the mitigation systems mitigate the event? Of course, the filtered venting containment is limited by the size as we hav talked about today. A reasonable size might not be able to handle the rapid mass and energy releases at some points in the accident such as vessel melt, rapid hydrogen combustion.

The filtered vent effectiveness would, also, be limited by the operator reaction, since we included him in the chain. The operator might be reluctant to allow the possibility of this deliberate release, and for the system to work he would have to open the containment isolation valves before the system is needed.

The second area that we evaluated was technical feasibility. I feel like whatever practical problems needed to be overcome, what further development was needed should be addressed. One of the areas was large penetrations .

To add those to an existing primary and secondary containment structure would probably be a difficult design problem. Another area where we felt like more research and development was necessary was in the sand filter. Although they have been used at a few sites, and they are considered to be rugged and passive, quite a bit of work remains to be done, especially to demonstrate that you can maintain reasonable pressure drops as the bed compacts and ages in the presence of high moisture in the flow streams.

Another area we evaluated was additional risks that the system might introduce, what additional consequences could result from the use or the misuse or from its effect on other systems.

Of course, we all recognize the most serious drawback is probably the intentional release of radioactivity. We spoke earlier of the 900 rem that TVA had estimated which was whole body low population zone dose. With release of that magnitude a bypass of the containment structures when they are most needed would be a difficult decision to accept. This involves both the obvious off site dose that we have talked about, but I think it, also, involves the less obvious but very important main control room dose to the operator.

Another hazard that we saw was the potential for creating a negative pressure in the containment. We have touched on that earlier.

Reliability. It is difficult to design a completely passive system. The design we evaluated in detail here had several active components which, of course, reduced the reliability below the design that would be more passive. However, there were good reasons for using these active components. The sprays were used to reduce the filtration size necessary. The dilution fans were used to treat the hydrogen problem. It would be hard to conceive of a way to achieve that passively.

Isolation valves were used to allow the operator to have some intervention in the initiation of the throttling or the termination of the venting.

The last area that we evaluated was cost and schedule. An order of magnitude cost estimate in 1980 dollars was $15.4 million. This is for non-seismic structure; this is an initial cost. It does not include any maintenance or equipment replacement. This was based on a 42-month design and construction schedule; no plant down time cost is included.

DR. KERR: Mr. Renfro, if I interpret order of magnitude as I understand it, that could mean that your estimate is uncertain over a range of 1-1/2 to 150 million. Is that what you mean?

MR. RENFRO: I think when cost people speak of order of magnitude they don't speak of it as engineers do. I certainly don't think it would go to 150. This may be plus or minus 50 percent, 25 percent, more along those lines.

DR. FIRST: Could you explain more about this hydrogen protective system? What is the rationale for believing that the hydrogen concentration will be less than twice the lower explosive limit?

MR. RENFRO: This is --

DR. FIRST: Did I get my question across?

MR. RENFRO: This is one of the areas I --

DR. FIRST: My question was what is the rationale for believing that the hydrogen concentration in the off gas will be less than twice the lower explosive limit?

MR.RENFRO: This is one of the areas that I am going to recommend further research be done in, of course, to know exactly what parameters are at what level during the accident as the accident progresses. At the time, the figures that we estimated for these two cases, one of which included partial burns, one of which did not showed that the effluent was about 8 percent hydrogen. So a factor of two would have fixed the problem. That is certainly open to question.

DR. ZUDANS: But this seems like a complicated flow arrangement, and how do you expect to achieve the flow from here up and out and flow to here at the same time and not create a counterflow?

DR. KERR: Can you see to what Mr. Zudans is pointing or should he come up closer?

MR. RENFRO: If you could identify the vugraph we could all see it.

DR. ZUDANS: The one before this one. Up where you have the hydrogen dilution.

MR. RENFRO: You are saying what is to prevent backflow from the plenum through the sand filter?

DR. ZUDANS: Yes.

MR. RENFRO: I believe there were backdraft dampers specified. I have got the detailed sketch back there if you would like me to look but I am pretty sure that is the way they handled the problem.

In other words, when these fans were turned on there were dampers, and the dampers might have been associated with these fans. That may not be correct. I guess that is what this is, is the backdraft damper here. So, I am not sure what the answer is to your question.

DR. KERR: I know what an M and a V, but what is a G?

MR. RENFRO: I don't know.

DR. KERR: It is a 600,000 cubic foot per minute G, isn't it.

MR. RENFRO: Yes, there are two others on the left. I don't know what the G stands for, but that symbol I am pretty sure is a backdraft damper. Now, this is Burns and Rowe's sketch. I am not sure what their nomenclature means.

DR. ZUDANS: Is it not likely that that mixture could explode someplace before it reaches the upper plenum?

MR. RENFRO: That is one of the problems we saw with this design. The hydrogen is going to reach its maximum concentration right after the suppression pool.

Now, the only way I could rationalize this was to say that there really are not any good ignition sources in there. If you have got a pool of water and a sand filter there probably are not any components, any instrumentation or any pumps or valves likely to cause an accidental spark. So, the problem with diluting the effluent down here in the water space would be that the sand filter requirements would go up enormously. So, it was to try to cut down on the size requirements for the sand filter that it was done the way it was, but that is certainly one of the drawbacks. This is not a perfect way to treat the hydrogen problem.

DR. WARD: Dave, I believe you mentioned the volume of the pool. What is it?

MR. RENFRO: It is 600,000 gallons.

DR. KERR: Are there other questions?

MR. RENFRO: Let me just briefly summarize what our conclusions were from this study? April 1980 when we drew these conclusions we did not believe it was necessary or even prudent for TVA to commit to a concept that was intended to mitigate the effects of a complete core melt. A less severe accident more like Three Mile Island should be the interim design goal until rule making has been completed. With this in mind, control combustion using thermal igniters was eventually selected by TVA as a hydrogen mitigation, not as a core melt mitigation and it is currently licensed for use in Sequoyah.

Let me just point out a few areas, most of which are very aware to everyone here, but some areas of further study that we saw, some kind of refinement of operator instructions and accident sequence progression details. When should the system be opened, throttled? When should it be closed? Should we vent early in the accident after design pressure, at some pressure above the design but still below the ultimate capacity of the containment? I feel like more work needs to be done on the design and testing of rugged passive filter media, such as sand filters, more work probably on the holdup of noble gases to see if that is feasible at all. Attention needs to be paid to the hydrogen treatment, whether we should combust, dilute or inert.

Since the system should be designed for peaks as far as possible, how realistic are the peaks that we are calculating? This affects the size of the system, of course; passive versus active trade-off affects the size. How passive is practical? The more passive the system generally the larger it has to be.

In conclusion we feel it is very important that a realistic cost benefit be performed. Does the filter venting containment appreciably reduce the risk? This answer requires a better knowledge of the accident progression and the conditions to assess the benefits of such a system and a better knowledge of a workable filtered vented containment design to assess the cost of such a system.

MR. BENDER: David, I think that any list like that should include some study of the constituents and certainly the temperature basis for the operation of the filter system, both of which could have a big impact on its effectiveness.

MR. RENFRO: I agree. We need to understand exactly what is going to happen in the accident to know how big to make the system, when to initiate the system, what parameters the system has to withstand.

DR. KERR: Of course, you will never know exactly what is going to happen in the accident. So you doom the study to oblivion if you have to know that.

MR. RENFRO: I might just comment sort of on the side, we were asked to participate in this paper that Burns and Rowe presented at the A&S conference. We were so unsure of the design criteria we had given them to do their design that we really did not participate in their paper. When we gave the numbers like 467,000 CFM, you know that could have easily been some other number. So, I agree you are not going to know exactly what is going to happen but at least from our perspective we certainly need to know a lot more before we could ever design a filtered vent system.

Are there any more questions?

DR. WARD: One question. This add on would be perhaps $15 million. Do you have a rough idea of how much is invested in the existing containment system at Sequoyah?

MR. RENFRO: No, I don't.

DR. KERR: Other questions?

Thank you, Mr. Renfro.

(Thereupon, at 5:35 p.m., the meeting was concluded.)

NUCLEAR REGULATORY COMMISSION

This is to certify that the attached proceedings before the

____

in the matter of: ACRS/Subcommittee on Class 9 Accidents

Date of Proceeding: June 30, 1981

Docket Number: ____________________

Place of Proceeding: Albuquerque, New Mexico

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

Michael Connolly

Official Reporter (Typed)

Michael Connolly by ...

Official Reporter (Signature)

Risk Implications of Containment Failure Modes

- CONTAINMENT FAILURE MODES
  - MELT-THROUGH HAS HIGHEST PROBABILITY OF OCCURRENCE
  - OVERPRESSURIZATION AND STEAM EXPLOSIONS LEAD TO HIGHEST CONSEQUENCES

- UNDERGROUND SYSTEM DESIGN EFFECTS
  - OVERPRESSURIZATION - PRESSURE RELIEF SYSTEMS
  - STEAM EXPLOSIONS - ROCK AND SOIL OVERBURDEN
  - PENETRATION LEAKAGE - SECONDARY CONTAINMENT
  - MELT-THROUGH - PROBABILITY INCREASED

- RELATIVE RISK CONTRIBUTIONS FROM FAILURE MODES
  - OVERPRESSURIZATIONS AND STEAM EXPLOSIONS DOMINATE HIGH FATALITY PORTIONS OF RISK SPECTRUM
  - PENETRATION LEAKAGE AND MELT-THROUGH DOMINATE LOW FATALITY END OF SPECTRUM
  - UNDERGROUND CONSTRUCTION SHIFTS ACCIDENT RISK SPECTRUM TOWARD LOW FATALITY CONDITIONS

CONCEPTUAL EVALUATION OF FILTERED-VENTING CONTAINMENT SYSTEMS

RESULTS BASED UPON STATE OF CALIFORNIA'S STUDY

OF UNDERGROUND NUCLEAR POWER PLANT DESIGNS

BY FRED C. FINLAYSON

THE AEROSPACE CORPORATION

LOS ANGELES, CALIFORNIA

PRESENTATION TO ACRS CLASS 9 ACCIDENT SUBCOMMITTEE

ALBUQUERQUE, NEW MEXICO

JUNE 30, 1981

Public Health and Economic Consequences

FATALITIES

CONTRIBUTORS	FATALITY RANGE SURFACE	FATALITY RANGE UNDERGROUND
EARLY DEATHS	17-450	0
LATENT CANCER DEATHS	3900-6300	0

ECONOMIC CONSEQUENCES

SOURCE	SURFACE ($ Billions)	UNDERGROUND ($ Thousands)
EVACUATION AND RELOCATION	0.13 - 7.2	0
FARMLAND	0.13 - 1.3	0
MEDICAL TREATMENT	0.079 - 0.12	1 - 16
TOTAL	0.34 - 8.6	1 - 16

HEALTH CONSEQUENCES

HEALTH EFFECTS	RANGE OF EFFECTS SURFACE	RANGE OF EFFECTS UNDERGROUND
EARLY ILLNESSES	160-7700	0
THYROID CANCERS	3300-17000	<1-3
THYROID NODULES	4600-17000	<1-5
PRENATAL DEATHS	1-18	0
GENETIC DISORDERS	2600-4300	0
SPONTANEOUS ABORTIONS	840-1400	0
TEMPORARY STERILITY	340-12000	0

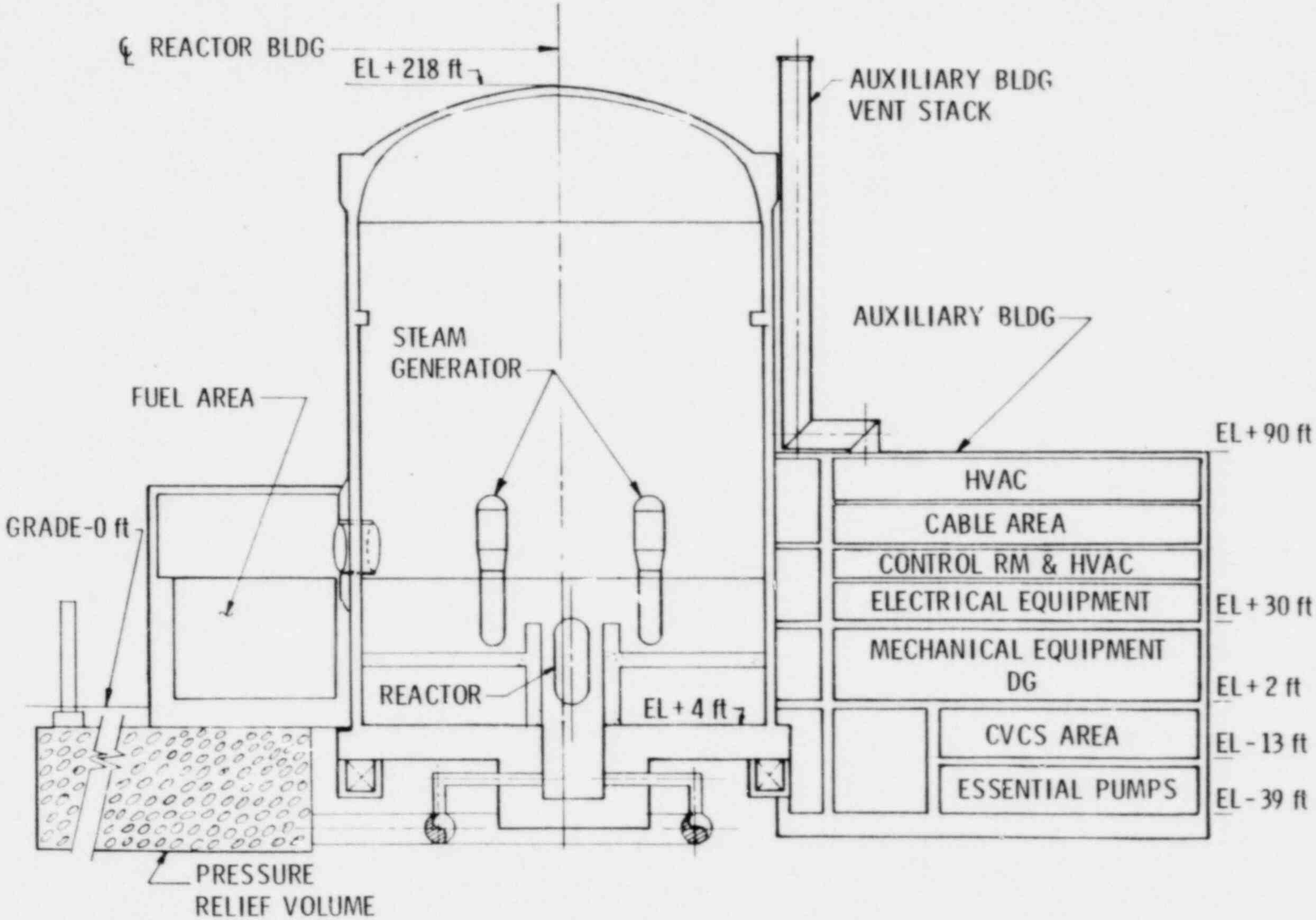
- STUDY RESULTS DO NOT REPRESENT RANGES OF CONSEQUENCES DERIVED FROM PROBABILISTIC RISK ANALYSES
  - RESULTS BASED UPON CALCULATED CONSEQUENCES FOR MOST SEVERE REACTOR ACCIDENTS POSTULATED FOR SURFACE AND UNDERGROUND PLANTS
  - UNDERGROUND PLANTS ASSUMED TO HAVE FUNCTIONING ACCIDENT MITIGATION SYSTEMS
- RESULTS IDENTIFIED WITH "UNDERGROUND" HEADINGS IN TABLES NOT NECESSARILY UNIQUE TO UNDERGROUND FACILITIES
  - SIMILAR THEORETICAL RESULTS WOULD BE DERIVED FOR SURFACE-SITED FACILITIES WITH FUNCTIONING ACCIDENT MITIGATION SYSTEMS

Comparative Costs of Surface and Underground Nuclear Power Plants

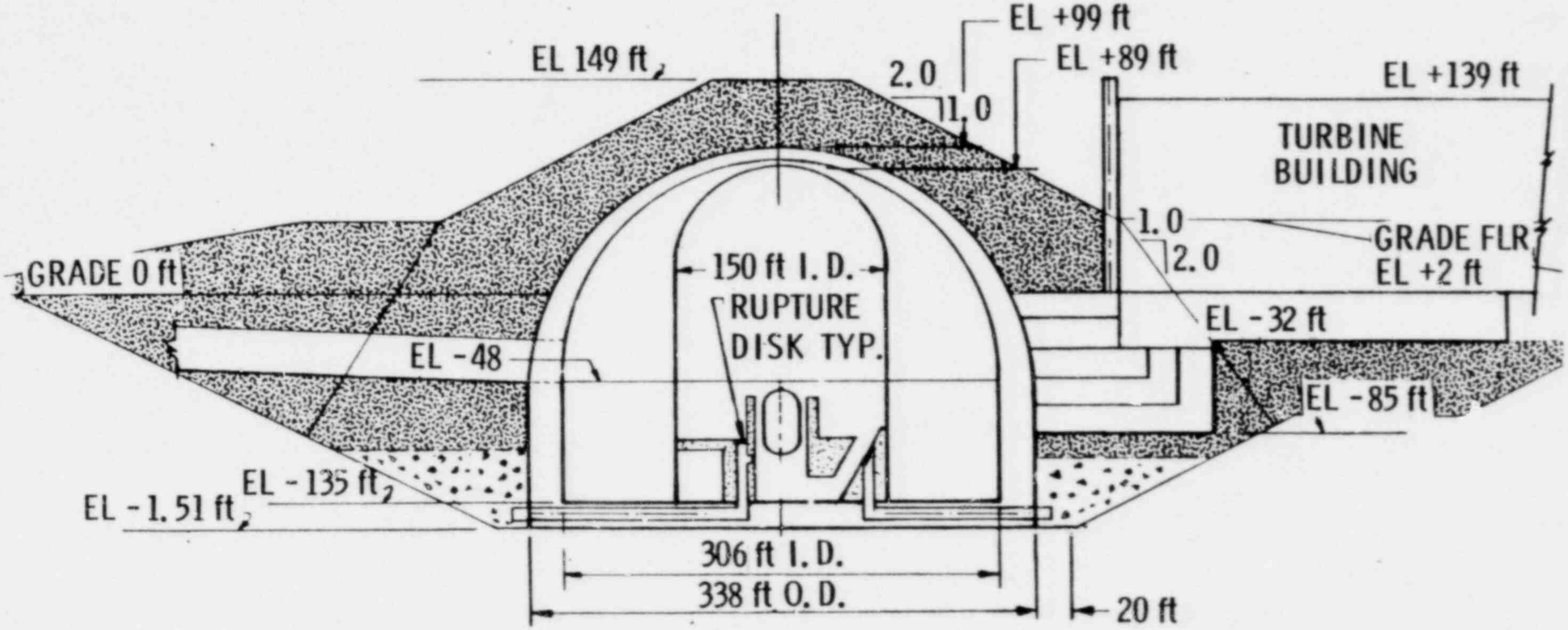
COST ITEM		PLANT COSTS (M$)				
DIRECT CONSTRUCTION		SURFACE			SUBSURFACE	
NRC ACC. No.	ITEM	UDC	S&L	LVL. -3 MOD	BERM	MINED CAVERNS
20	LAND	(a)	(a)	(a)	(a)	(a)
21	STRUCTURES	196	193	200	257	182
22	REACTOR	150	171	171	173	153
23	TURBINE-GENERATOR	133	199	200	207	150
24	ELECTRICAL	37	50	50	58	49
25	MISCELLANEOUS	14	20	20	20	19
27	EXCAVATION AND BACKFILL	(c)	2	4	15	75
28	ACCIDENT MITIGATION	-		4	5	3
35	SUBSTATION	3	4	4	4	4
91	CONSTRUCTION SERVICES	(d)	8	8	10	(d)
-	CONTINGENCY, TOTAL	45	(b)	(b)	(b)	101
TOTAL		578	647	661	744	736
INDIRECT		343	181	181	206	432
TOTAL CONSTRUCTION COST		921	828	842	950	1168
$/KW		708	637	647	731	898
ESCALATION, 9% (compounded annually)		1100	1033	1049	1105	1233
AFDC 10% (simple interest)		722	618	632	763	1029
GRAND TOTAL PROJECT COST		2743	2479	2523	2818	3430
PERCENT DIFFERENTIAL		-	-	1.8	13.6	25

Notes: (a) - Land costs not included in estimates
(b) - Contingency cost included as part of individual direct cost item
(c) - Not specifically known, estimated at about 2 million dollars
(d) - Included in indirect cost subtotal

Surface Plant with Level-3 Accident Mitigation System

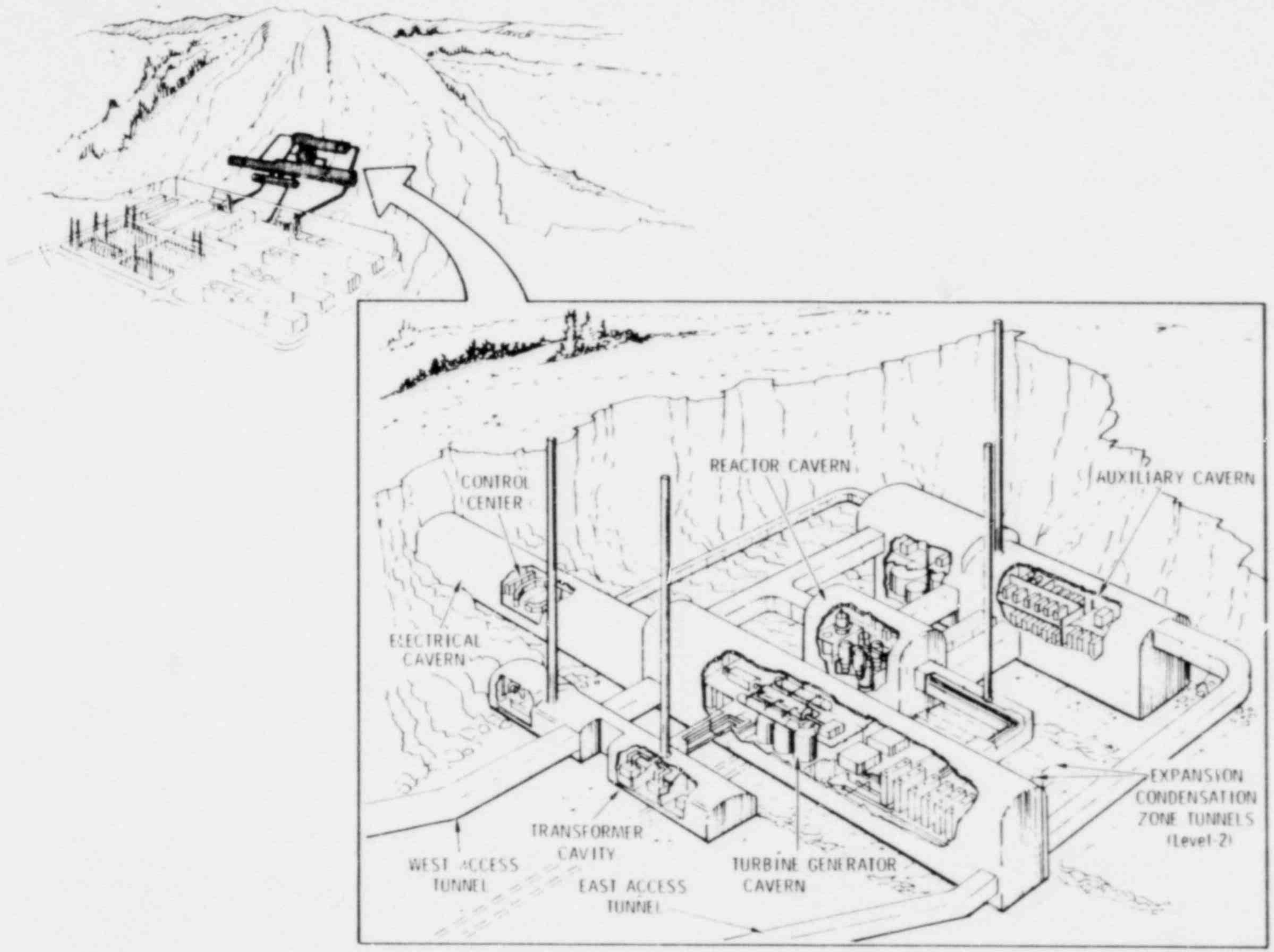


Schematic Diagram of Berm-Contained Plant with Level-2 Accident Mitigation System



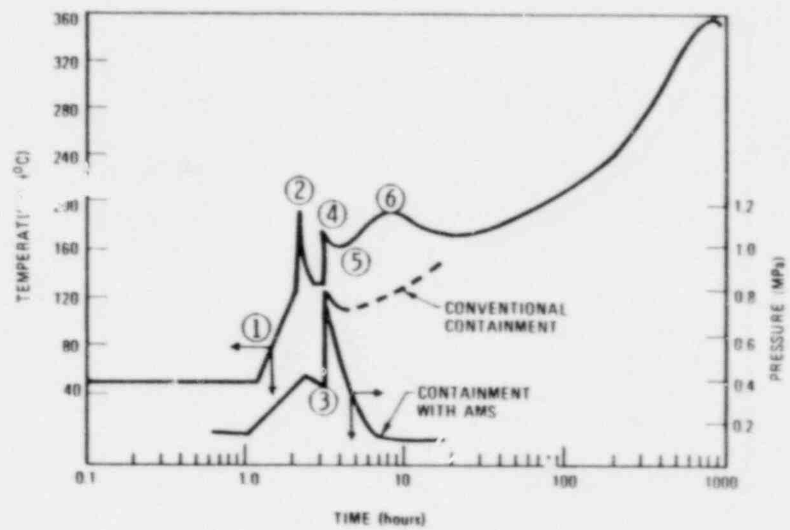
CH-3718

Mined-Cavern Underground Nuclear Power Plant



Accident-Induced Primary Containment Environment

- ACCIDENT MITIGATION SYSTEM (AMS) REQUIREMENTS
  - ENVELOPE OF SEVERE ACCIDENT CONDITIONS
    - LOSS-OF-COOLANT ACCIDENT, WITHOUT ECCS
    - LOSS-OF-ALL-ELECTRIC POWER
    - LOSS-OF-COOLANT ACCIDENT, WITH DEGRADED ECCS OPERATION
- MOST DEMANDING PRESSURE / TEMPERATURE CONDITIONS
  - LOSS-OF-ALL-ELECTRIC POWER ACCIDENT
  - PEAK CONTAINMENT PRESSURES OCCUR AT REACTOR VESSEL MELT-THROUGH
  - PRIMARY CONTAINMENT FAILS, IF NO AMS
  - PRESSURES REDUCED RAPIDLY WITH AMS
  - LONG-TERM CONTAINMENT TEMPERATURES HIGH
  - PENETRATION SEAL INTEGRITY CHALLENGED ABOVE 200° C



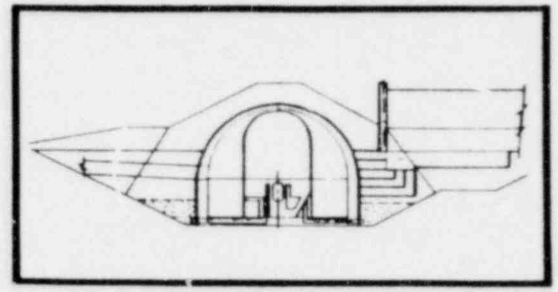
① BOILOFF OF PRIMARY SYSTEM WATER THROUGH RELIEF VALVES
② HYDROGEN BURN FROM 50% Zr-H_2O REACTION
③ REACTOR VESSEL MELT-THROUGH
④ CORE QUENCHED, 50% Zr-H_2O REACTION, AUXILIARY VOLUME OPENED TO CONTAINMENT
⑤ CORE REMELTS
⑥ CONTAINMENT BASE MAT MELT-THROUGH AND METAL-WATER REACTIONS COMPLETED

Study Objectives and Participants

- CALIFORNIA LEGISLATURE REQUIRED (1976) A STUDY OF UNDERGROUND NUCLEAR POWER PLANT SITING
- OBJECTIVES - TO DETERMINE:
  - TECHNICAL AND ECONOMIC FEASIBILITY
  - RADIOLOGICAL EFFECTIVENESS
  - NEED FOR ADDED PROTECTION
- EIGHT MAJOR PARTICIPANTS INVOLVED
  - SYSTEMS MANAGEMENT - THE AEROSPACE CORPORATION
  - TWO ARCHITECT-ENGINEER FIRMS PREPARED DESIGNS / COSTS
    - BURIED CONCEPT: SARGENT AND LUNDY
    - MINED-CAVERNS: UNDERGROUND DESIGN CONSULTANTS / GIBBS AND HILL
  - RADIOLOGICAL / ENVIRONMENTAL IMPACT ANALYSTS
  - CALIFORNIA DIVISION OF MINES AND GEOLOGY
  - SOCIOECONOMIC ANALYSTS
- PERIOD OF PERFORMANCE: ABOUT ONE YEAR (1977-1978)
- AGGREGATE TOTAL FUNDING: ABOUT $1.5 MILLION

Technological Feasibility

- PRIMARY CONTAINMENT
  - PRESSURES REDUCED RAPIDLY BY ACCIDENT MITIGATION SYSTEM
  - HIGH TEMPERATURES CHALLENGE SEAL INTEGRITY
- SECONDARY CONTAINMENT
  - DESIGN LOADS FROM STATIC OVERBURDEN AND SEISMIC STRESSES
- ACCIDENT MITIGATION SYSTEM (AMS)
  - EXTERNAL CONDENSATION/FILTER ZONES CONNECTED TO PRIMARY CONTAINMENT BY PIPES OR TUNNELS
  - PRESSURE-TEMPERATURE SENSITIVE RUPTURE DISKS ISOLATE AMS INTERFACE
  - HIGH QUALITY DESIGN/CONSTRUCTION STANDARDS TO BE USED
    - NRC CAT I SEISMIC STANDARDS NOT REQUIRED
- FEASIBILITY
  - NO INSURMOUNTABLE CONSTRUCTION PROBLEMS IDENTIFIED
  - NO APPARENT IMPINGEMENT ON OPERATIONAL/SAFETY REQUIREMENTS
  - NO MAJOR LICENSING PROBLEMS APPARENT



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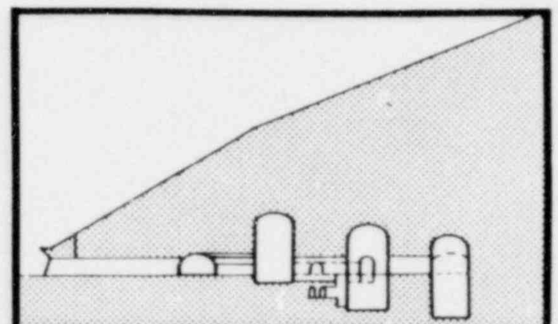
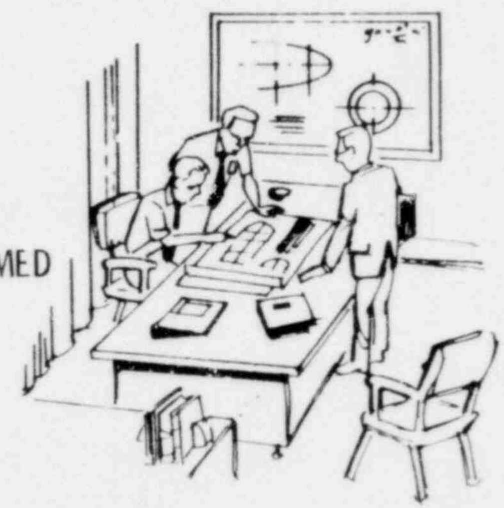


MINED-CAVERN

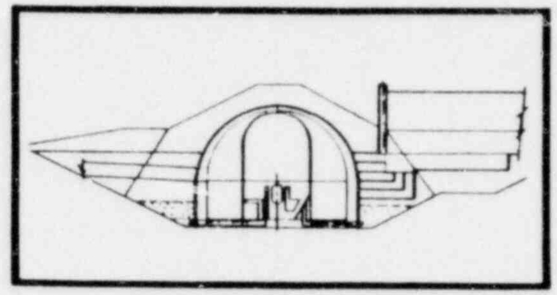
Guidelines for Underground Designs

- STANDARD NRC DESIGN BASIS ACCIDENTS USED
- "ACCIDENT MITIGATION SYSTEMS" ADDED TO PREVENT MAJOR CONTAINMENT FAILURES
  - REQUIRED FOR CORE-MELT ACCIDENT CONDITIONS
- IMPACTS ON NORMAL OPERATIONS, MAINTENANCE, SAFETY MINIMIZED
- LOW-COST (no frills) UNDERGROUND DESIGNS PREPARED
- NO RISK ANALYSIS CONDUCTED OF PUBLIC HEALTH IMPACTS
  - COMPARATIVE ANALYSES OF SEVERE ACCIDENT IMPACTS PERFORMED



Underground Facility Design Features

- PRIMARY CONTAINMENTS
- SECONDARY CONTAINMENTS
- ACCIDENT MITIGATION SYSTEMS
  - PRESSURE-RELIEF MECHANISMS
  - PASSIVE, HIGHLY REDUNDANT CONCEPTS
  - FISSION PRODUCTS FILTERED / TRAPPED THROUGH NATURAL PROPERTIES OF SOIL AND ROCK
- STANDARDIZED NUCLEAR STEAM SUPPLY SYSTEMS
  - 3800 MWt (1300 MWe) PWR AND BWR UNITS



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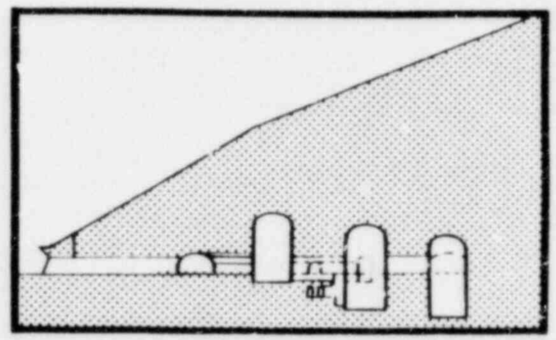


MINED - CAVERN

Economic Feasibility

- SCHEDULE
  - 1990 STARTUP ASSUMED FOR ALL CONCEPTS
  - TWO ADDITIONAL YEARS REQUIRED FOR UNDERGROUND CONSTRUCTION
  - PROJECTED TOTAL CONSTRUCTION PERIOD: 11-12 YEARS
- COST ESTIMATES
  - UNDERGROUND FACILITIES 14-25% MORE EXPENSIVE THAN SURFACE PLANTS
  - MODIFIED SURFACE FACILITIES (accident mitigation systems added) HAVE SMALLER (+2%) COST INCREASES
- PROTOTYPE vs MATURE INDUSTRY COST ESTIMATES
  - BASELINE COST ESTIMATES ASSUMED "MATURE" CONSTRUCTION METHODS
  - PROTOTYPE PLANTS COULD COST ABOUT 30% MORE THAN BASELINE ESTIMATES

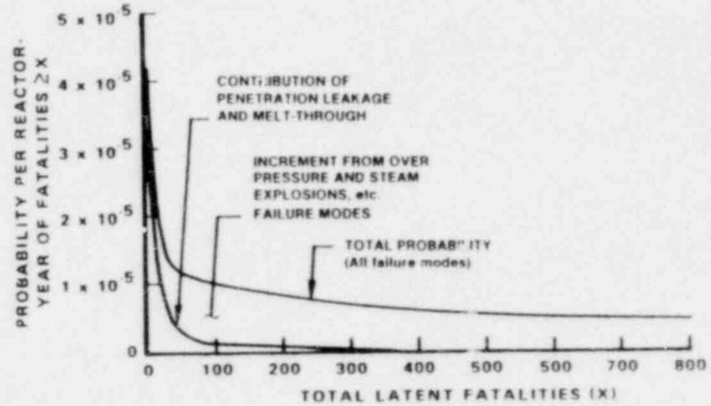
CONCEPT	CONSTUCT COSTS *	GRAND TOTAL**
S&L ENGINEERS		
• SURFACE	830 M$	2480 M$
• BURIED	950	2820
• SURFACE–AMS	840	2520
UDC / G&H		
• SURFACE	920	2740
• MINED-CAVERN	1170	3430

* Direct and indirect costs (constant 1977 dollars)

**Escalation (9% componded); AFDC (10% simple)

Assessment

- EFFECTIVENESS OF ALTERNATIVE CONTAINMENT CONCEPTS
  - NO CONTAINMENT CONCEPT (including underground siting) ASSURES TOTAL ELIMINATION OF ALL CONTAINMENT FAILURE MODES
  - UNDERGROUND SITING QUALITATIVELY BETTER THAN ALTERNATIVES
  - IN THE EVENT OF DEGRADED PERFORMANCE OF ACCIDENT MITIGATION SYSTEMS, CONTAINMENT FAILURE MODES IN UNDERGROUND PLANTS SHIFTED TOWARDS LOWER CASUALTY EVENTS
  - ALTERNATIVE SURFACE-SITED CONTAINMENT CONCEPTS ARE RELATIVELY INEXPENSIVE

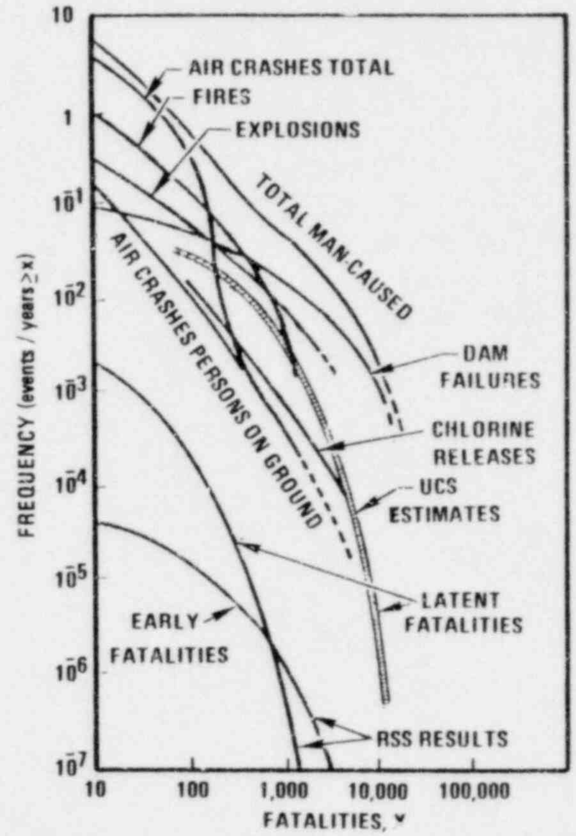


- NEED FOR REACTOR ACCIDENT RISK REDUCTION
  - SOCIAL AND POLITICAL ISSUES DOMINATE CONCLUSIONS
  - UNDERGROUND PLANTS MIGHT HELP TO REDUCE PUBLIC FEARS OF CATASTROPHIC ACCIDENTS
  - BUT SOLUTION IS EXPENSIVE AND RESOLUTION OF FEARS UNCERTAIN

Radiological Effectiveness

- CALCULATED PUBLIC HEALTH IMPACTS VIRTUALLY ELIMINATED
  - EARLY AND DELAYED DEATHS REDUCED TO NEAR-ZERO LEVELS
  - NON-FATAL HEALTH EFFECTS ALSO REDUCED BY FACTORS OF HUNDREDS TO TENS OF THOUSANDS
- PUBLIC ECONOMIC IMPACTS ALSO VIRTUALLY ELIMINATED
  - NO EVACUATION AND RELOCATION REQUIRED
  - MEDICAL TREATMENT COSTS NOMINAL
- IMPROVED RADIOLOGICAL EFFECTIVENESS DUE TO:
  - POSTULATED RELIABILITY OF PASSIVE UNDERGROUND ACCIDENT MITIGATION SYSTEMS
  - EFFECTIVENESS OF NATIVE SOIL AND ROCK AS NATURAL FILTER / TRAP FOR FISSION PRODUCTS
- ACCIDENT MITIGATION SYSTEM CONCEPT COULD BE APPLIED TO SURFACE-SITED FACILITIES

ACCIDENT RISKS



Effectiveness of Alternative Concepts

ALTERNATIVE CONTAINMENT CONCEPTS	EFFECT ON CONTAINMENT FAILURE MODES			
FUNCTIONING SYSTEMS	OVERPRESSURE	STEAM EXPLOSIONS	PENETRATION LEAKAGES	MELT-THROUGH FOUNDATION
UNDERGROUND SITING	E	E/R	E/R	I
DUAL CONTAINMENT	U	R	R	U/I
CONTROLLED-FILTERED VENTING	E	U	R	I
W/DUAL CONTAINMENT	E	R	E/R	I
STRONGER CONTAINMENT	U	U/R	U	U
THINNED BASE MAT	R/U	U	U	I
MALFUNCTIONING SYSTEMS				
UNDERGROUND SITING	R/E	E/R	R/E	I
CONTROLLED-FILTERED VENTING	R/U	U	R/U	I/U
W/DUAL CONTAINMENT	R/E	R	R/E	I

DEFINITIONS

E = ELIMINATED
R = REDUCED
U = UNAFFECTED
I = INCREASED

UNDERGROUND SITING AND CONTROLLED-FILTERED VENTING CONCEPTS ASSUME USE OF LEVEL 2/3 ACCIDENT MITIGATION SYSTEM OR EQUIVALENT

Finlayson presentation

CONCEPTUAL EVALUATION OF FILTERED-VENTING CONTAINMENT SYSTEMS

RESULTS BASED UPON STATE OF CALIFORNIA'S STUDY

OF UNDERGROUND NUCLEAR POWER PLANT DESIGNS

BY FRED C. FINLAYSON

THE AEROSPACE CORPORATION

LOS ANGELES, CALIFORNIA

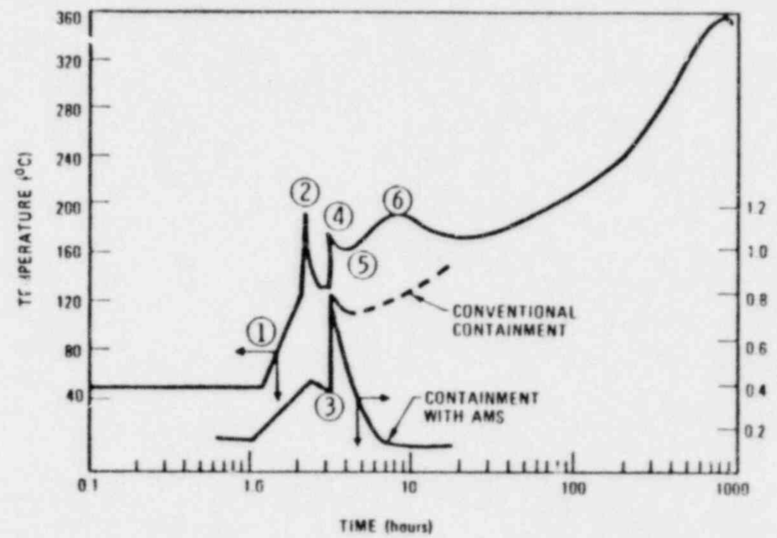
PRESENTATION TO ACRS CLASS 9 ACCIDENT SUBCOMMITTEE

ALBUQUERQUE, NEW MEXICO

JUNE 30, 1981

Accident-Induced Primary Containment Environment

- ACCIDENT MITIGATION SYSTEM (AMS) REQUIREMENTS
  - ENVELOPE OF SEVERE ACCIDENT CONDITIONS
    - LOSS-OF-COOLANT ACCIDENT, WITHOUT ECCS
    - LOSS-OF-ALL-ELECTRIC POWER
    - LOSS-OF-COOLANT ACCIDENT, WITH DEGRADED ECCS OPERATION
- MOST DEMANDING PRESSURE / TEMPERATURE CONDITIONS
  - LOSS-OF-ALL-ELECTRIC POWER ACCIDENT
  - PEAK CONTAINMENT PRESSURES OCCUR AT REACTOR VESSEL MELT-THROUGH
  - PRIMARY CONTAINMENT FAILS, IF NO AMS
  - PRESSURES REDUCED RAPIDLY WITH AMS
  - LONG-TERM CONTAINMENT TEMPERATURES HIGH
  - PENETRATION SEAL INTEGRITY CHALLENGED ABOVE 200° C



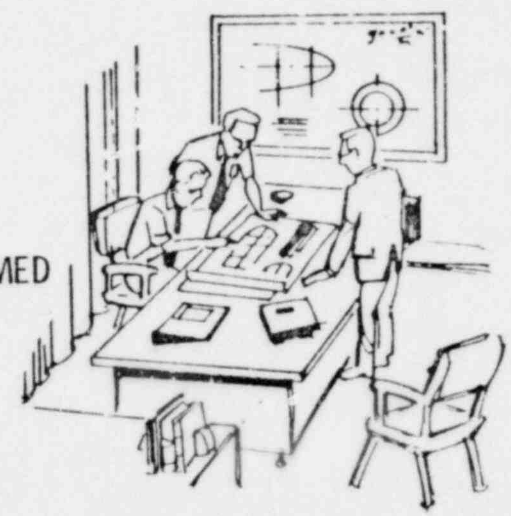
1. BOILOFF OF PRIMARY SYSTEM WATER THROUGH RELIEF VALVES
2. HYDROGEN BURN FROM 50% $Zr\text{-}H_2O$ REACTION
3. REACTOR VESSEL MELT-THROUGH
4. CORE QUENCHED, 50% $Zr\text{-}H_2O$ REACTION, AUXILIARY VOLUME OPENED TO CONTAINMENT
5. CORE REMELTS
6. CONTAINMENT BASE MAT MELT-THROUGH AND METAL-WATER REACTIONS COMPLETED

Study Objectives and Participants

- CALIFORNIA LEGISLATURE REQUIRED (1976) A STUDY OF UNDERGROUND NUCLEAR POWER PLANT SITING
- OBJECTIVES - TO DETERMINE:
  - TECHNICAL AND ECONOMIC FEASIBILITY
  - RADIOLOGICAL EFFECTIVENESS
  - NEED FOR ADDED PROTECTION
- EIGHT MAJOR PARTICIPANTS INVOLVED
  - SYSTEMS MANAGEMENT - THE AEROSPACE CORPORATION
  - TWO ARCHITECT-ENGINEER FIRMS PREPARED DESIGNS / COSTS
    - BURIED CONCEPT: SARGENT AND LUNDY
    - MINED-CAVERNS: UNDERGROUND DESIGN CONSULTANTS / GIBBS AND HILL
  - RADIOLOGICAL / ENVIRONMENTAL IMPACT ANALYSTS
  - CALIFORNIA DIVISION OF MINES AND GEOLOGY
  - SOCIOECONOMIC ANALYSTS
- PERIOD OF PERFORMANCE: ABOUT ONE YEAR (1977-1978)
- AGGREGATE TOTAL FUNDING: ABOUT $1.5 MILLION

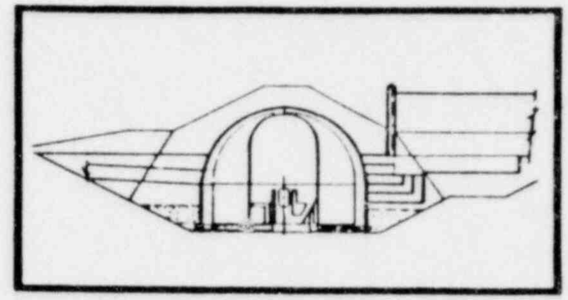
Guidelines for Underground Designs

- STANDARD NRC DESIGN BASIS ACCIDENTS USED
- "ACCIDENT MITIGATION SYSTEMS" ADDED TO PREVENT MAJOR CONTAINMENT FAILURES
  - REQUIRED FOR CORE-MELT ACCIDENT CONDITIONS
- IMPACTS ON NORMAL OPERATIONS, MAINTENANCE, SAFETY MINIMIZED
- LOW-COST (no frills) UNDERGROUND DESIGNS PREPARED
- NO RISK ANALYSIS CONDUCTED OF PUBLIC HEALTH IMPACTS
  - COMPARATIVE ANALYSES OF SEVERE ACCIDENT IMPACTS PERFORMED

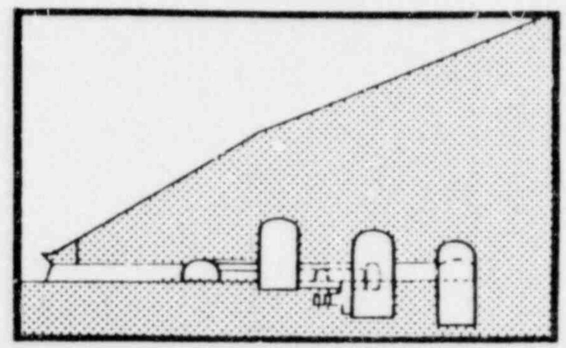


Underground Facility Design Features

- PRIMARY CONTAINMENTS
- SECONDARY CONTAINMENTS
- ACCIDENT MITIGATION SYSTEMS
  - PRESSURE-RELIEF MECHANISMS
  - PASSIVE, HIGHLY REDUNDANT CONCEPTS
  - FISSION PRODUCTS FILTERED / TRAPPED THROUGH NATURAL PROPERTIES OF SOIL AND ROCK
- STANDARDIZED NUCLEAR STEAM SUPPLY SYSTEMS
  - 3800 MWt (1300 MWe) PWR AND BWR UNITS



BURIED

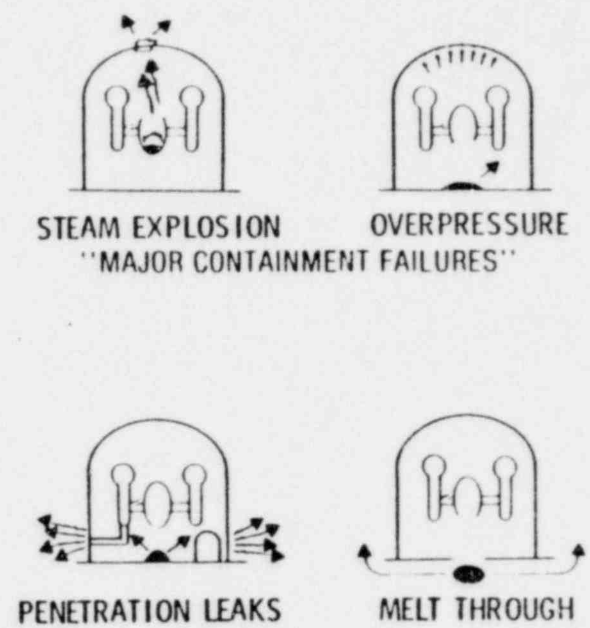


MINED - CAVERN

Risk Implications of Containment Failure Modes

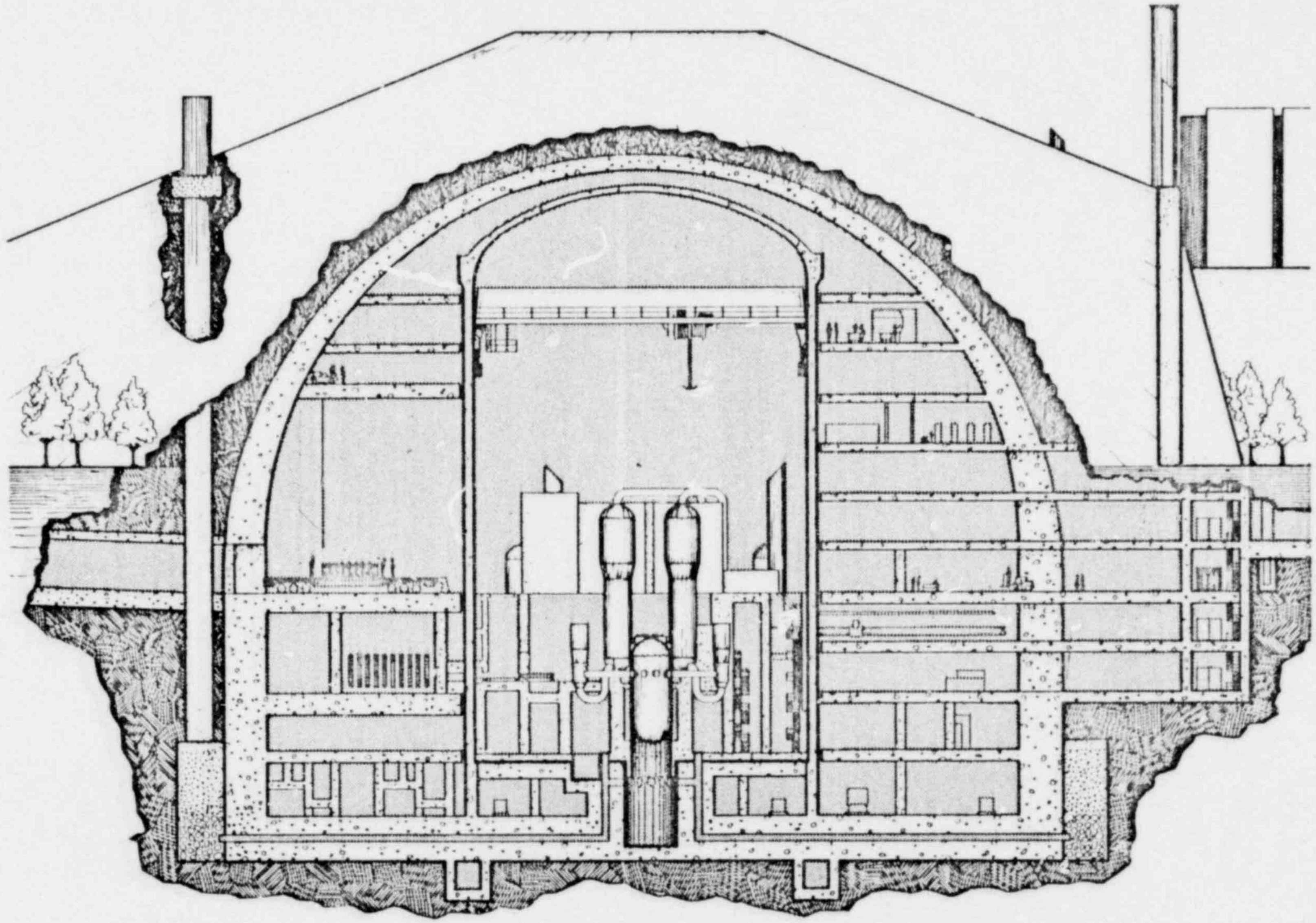
- CONTAINMENT FAILURE MODES
  - MELT-THROUGH HAS HIGHEST PROBABILITY OF OCCURRENCE
  - OVERPRESSURIZATION AND STEAM EXPLOSIONS LEAD TO HIGHEST CONSEQUENCES
- UNDERGROUND SYSTEM DESIGN EFFECTS
  - OVERPRESSURIZATION - PRESSURE RELIEF SYSTEMS
  - STEAM EXPLOSIONS - ROCK AND SOIL OVERBURDEN
  - PENETRATION LEAKAGE - SECONDARY CONTAINMENT
  - MELT-THROUGH - PROBABILITY INCREASED
- RELATIVE RISK CONTRIBUTIONS FROM FAILURE MODES
  - OVERPRESSURIZATIONS AND STEAM EXPLOSIONS DOMINATE HIGH FATALITY PORTIONS OF RISK SPECTRUM
  - PENETRATION LEAKAGE AND MELT-THROUGH DOMINATE LOW FATALITY END OF SPECTRUM
  - UNDERGROUND CONSTRUCTION SHIFTS ACCIDENT RISK SPECTRUM TOWARD LOW FATALITY CONDITIONS

CONTAINMENT FAILURE MODES

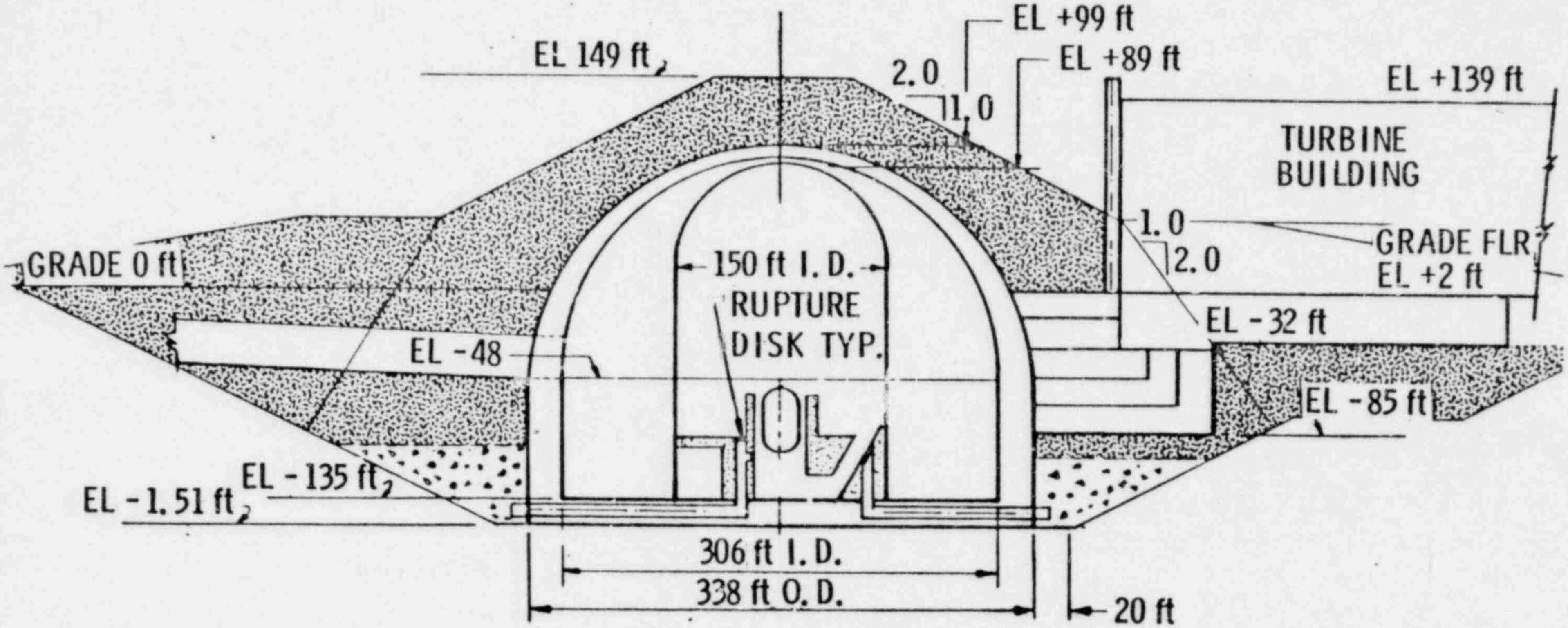


CH-3709

Buried Underground Nuclear Power Plant



Schematic Diagram of Berm-Contained Plant with Level-2 Accident Mitigation System



Renfro presentation
(7/80)

BACKGROUND
OF TVA STUDY

PURPOSE - PROPOSE AND EVALUATE MITIGATIONS FOR CLASS 9 ACCIDENTS AT SEQUOYAH NUCLEAR PLANT

REQUESTED BY - TVA BOARD OF DIRECTORS (NOT NRC)

DATE - FEBRUARY -APRIL 1980

SCOPE - 7 CONCEPTS PROPOSED (INCLUDING FILTERED VENTED CONTAINMENT - FVC)

- CONCEPTUAL DESIGNS DEVELOPED
- DESIGNS EVALUATED (INCLUDING COST)

FVC

DESIGN PARAMETERS

(GENERAL)

NOT SAFETY-GRADE (EXCEPT FOR PENETRATIONS)

NOT SEISMIC CATEGORY I (EXCEPT FOR PENETRATIONS)

NO REDUNDANCY (EXCEPT FOR PENETRATIONS)

QUALITY GROUP C (EXCEPT FOR PENETRATIONS)

NO TORNADO

FVC

DESIGN PARAMETERS

(GENERAL-CONT.)

PASSIVE WHERE PRACTICAL

STACK RELEASE

MANUAL ISOLATION VALVES

RUPTURE DISK - OVERPRESSURE EVENT

EXHAUST FANS (IF PRACTICAL) - CONTAINMENT ISOLATION FAILURE EVENT

HYDROGEN CONTROL (IF PRACTICAL)

rVC

DESIGN PARAMETERS

(SPECIFIC)

DECONTAMINATION FACTOR - 100 - PARTICULATES, IODINE

1 - NOBLE GASES

DESIGN TEMPERATURE - 750^{o} F

VENT INITIATION PRESSURE - 35 PSIA

DESIGN PRESSURE - 55 PSIA

FVC

DESIGN PARAMETERS

(SPECIFIC)

CASE 1 - CORE MELT (LARGE LOCA, NO BURN)

PEAK FLOW - 400,000 CFM

(LASTS APPROXIMATELY 600 SEC, THEN DROPS)

TOTAL DURATION - 12 HOURS

TOTAL HEAT - 600×10^6 B

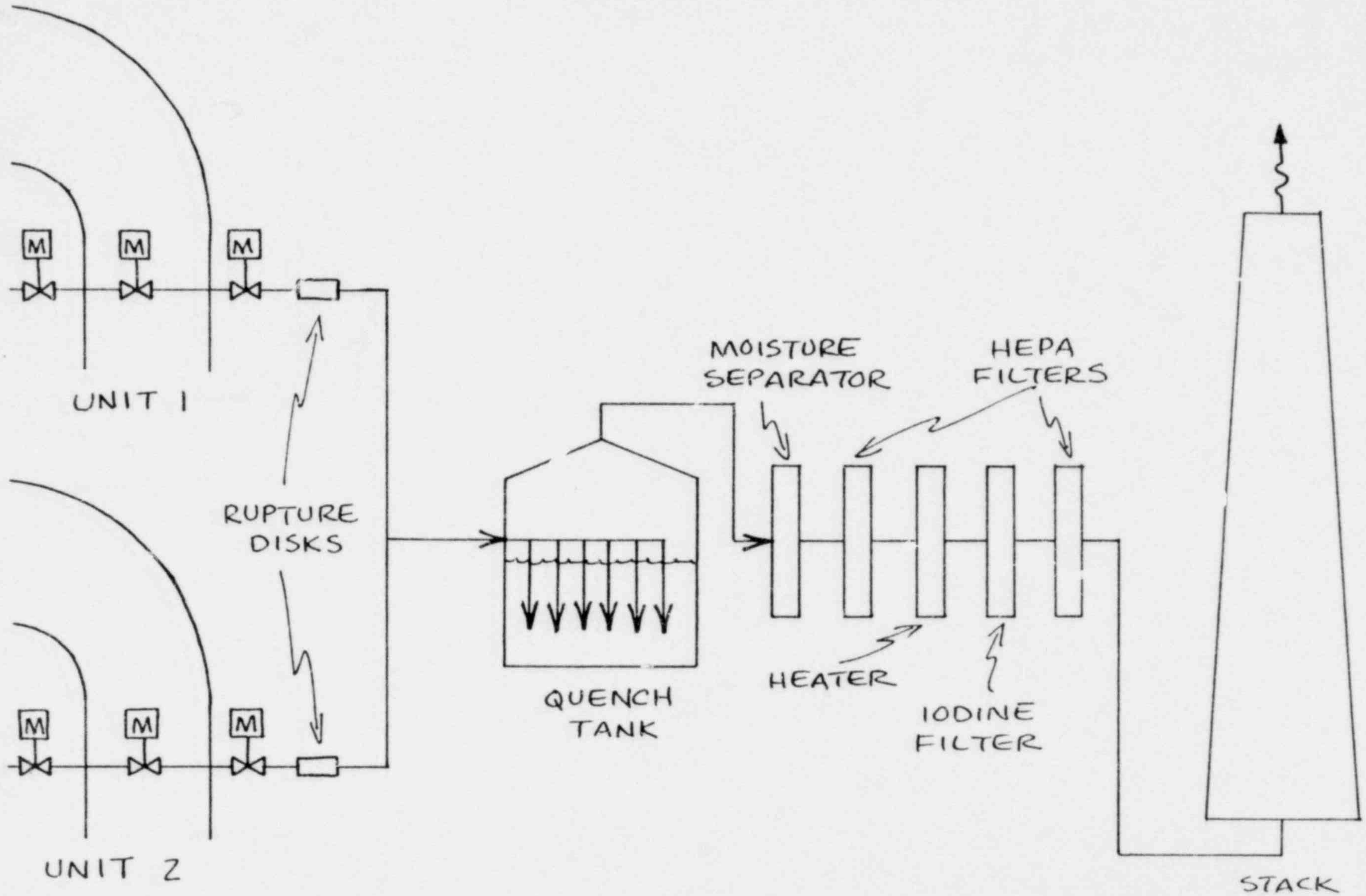
CASE 2 - DEGRADED CORE (SMALL LOCA, H_2 BURN)

PEAK FLOW - 467,000 CFM

(LASTS APPROXIMATELY 100 SEC, THEN DROPS)

TOTAL DURATION - 2-3 HOURS

TOTAL HEAT - 200×10^6 B



SARGENT & LUNDY

FVC

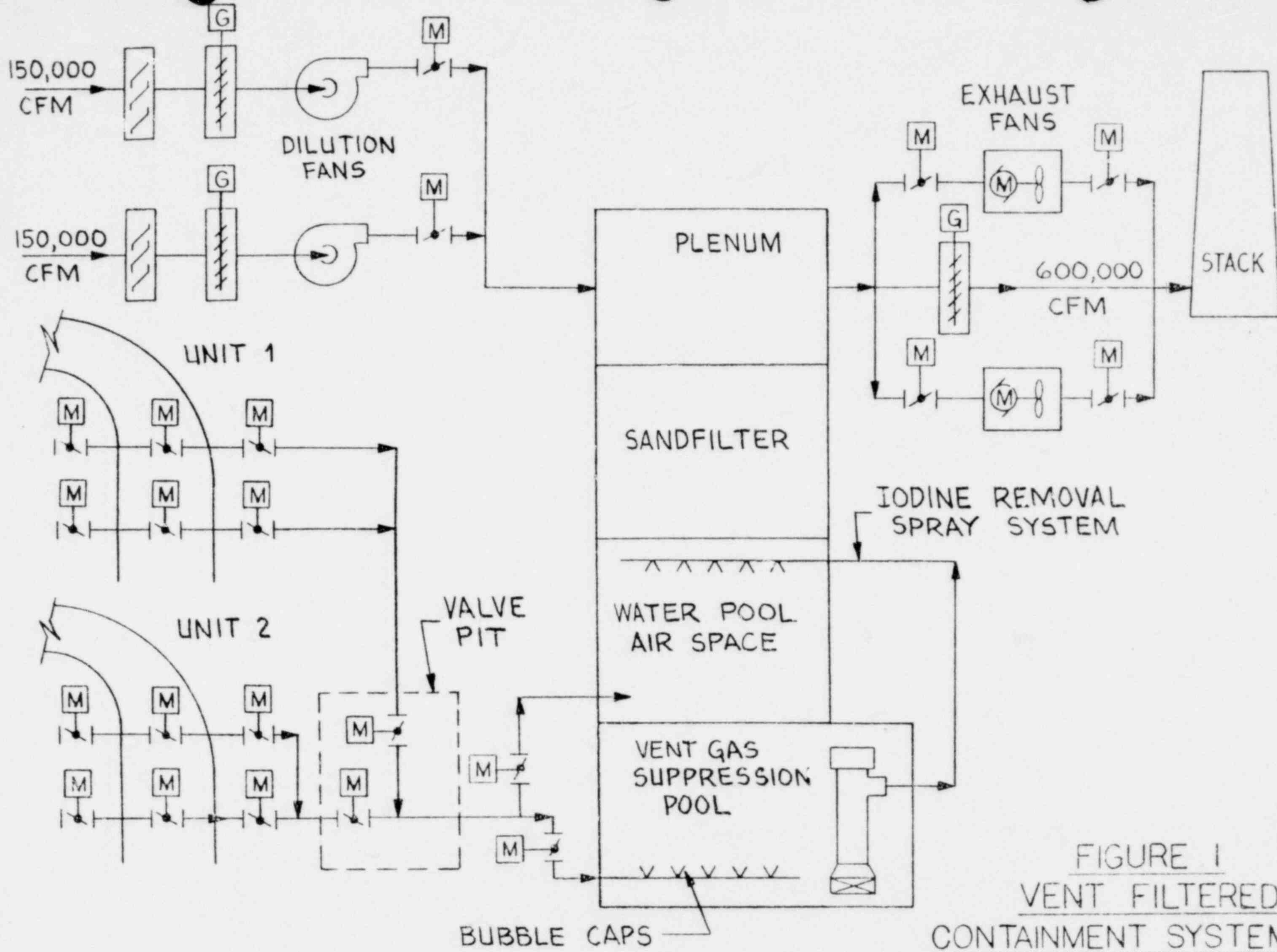


FIGURE 1
VENT FILTERED
CONTAINMENT SYSTEM

EVALUATION
(CONCEPT B)

EFFECTIVENESS

- LIMITED TO SLOW PRESSURE TRANSIENTS
- LIMITED BY OPERATOR ACTION

TECHNICAL FEASIBILITY

- CONTAINMENT CONNECTION
- SAND FILTER DESIGN/TESTING

ADDITIONAL RISKS

- DELIBERATE RELEASE
- NEGATIVE CONTAINMENT PRESSURE

RELIABILITY

- ACTIVE COMPONENTS

INITIAL COST

- $15.4M

  (ORDER OF MAGNITUDE, 1980 DOLLARS)

CONCLUSIONS OF STUDY

FOR SEQUOYAH

UNTIL RULEMAKING COMPLETED, COMMITMENT BY TVA TO MITIGATION OF COMPLETE CORE MELT NOT PRUDENT.

CONTROLLED COMBUSTION SELECTED BY TVA FOR MITIGATION OF HYDROGEN FROM DEGRADED CORE.

SOME NEEDS FOR
FURTHER STUDY

VENT INITIATION GUIDELINES

PASSIVE FILTER DESIGN/TESTING

TREATMENT OF HYDROGEN

SIZING TRADE-OFFS

REALISTIC COST-BENEFIT

J. Milligan

NRR ACTIVITIES: FILTERED VENTED CONTAINMENT SYSTEMS

- ZION/INDIAN POINT PROGRAM
- NEAR TERM CPs/MLs
- LIMERICK (PRA)
- RULEMAKING

V. Morgan (2

HOW APPROACH DIFFERS FROM DBA ANALYSIS

- MECHANISTIC/REALISTIC ANALYSIS VS CONSERVATIVE ANALYSIS
- PROBABILISTIC RISK ASSESSMENT: IMPORTANT ROLE
- CONSIDERATION OF LOW-PROBABILITY EXTERNAL EVENTS
- COST/BENEFIT ASSESSMENT

EPRI PROJECT TPS 80-721

EPRI NP-1747

REVIEW OF PROPOSED IMPROVEMENTS, INCLUDING FILTER/VENT OF BWR PRESSURE - SUPPRESSION AND PWR ICE CONTAINMENTS

BY

S. LEVY, INC.

SLI
6/30/81

SCOPE OF STUDY

- SUMMARY DESCRIPTION OF BWR PRESSURE SUPPRESSION AND PWR ICE CONTAINMENTS
- IMPROVEMENTS PROPOSED TO OCTOBER 1980
- METHODOLOGY AND STRATEGY FOR DESIGN IMPROVEMENTS
- PRELIMINARY EVALUATION OF VENT, VENT/FILTER AND MERITS

SLI
6/30/81

METHODOLOGY AND DESIGN STRATEGY

- PRA METHODOLOGY NECESSARY TO EVALUATE IMPROVEMENTS

- FOCUS ON DOMINANT RISK SCENARIOS AND IDENTIFY
  - PROBABILITY AND CAUSE OF CONTAINMENT FAILURE
  - TYPE AND TIMING OF CONTAINMENT FAILURE

- EVALUATE
  - ALTERNATES TO PREVENT CAUSE OF CONTAINMENT FAILURE
  - APPLICABILITY OF VENT TO PREVENT CONTAINMENT FAILURE
  - OTHER MITIGATION FEATURES REQUIRED BY VENT
  - BENEFIT OF VENT, VENT/FILTER
  - ALTERNATE MITIGATIVE FEATURES TO PREVENT CONTAINMENT FAILURE

SLI
6/30/81

TABLE V.1 DOMINANT CONTAINMENT FAILURE SCENARIOS

FOR PRESSURE SUPPRESION TYPE CONTAINMENTS

Probability of Occurrence	Cause of Failure	Type of Failure	Timing of Failure	Design Strategy
Low	Loss of Long Term Heat Sink	Slow Over-pressurization	Prior to Fuel Failure	Other preventive features Vent practical No other mitigation required or practical
Low	Failure to Shut Down Reactor	Rapid Over-pressurization	Prior to Fuel Melt	Other preventive features Vent impractical No other mitigation practical
Very Low	Loss of Primary Water & Insufficient Core Water Makeup in Non-Inerted Containment	Pressure Spike from Hydrogen Burn	Minimal Core Melt; prior to vessel melt-through	Other preventive features Vent alone impractical Hydrogen control required Other mitigation features
Very low	Loss of Primary Water and Insufficient Core Water Makeup in Inerted Containment	Rapid Over-pressurization from non-condensible gases	After Vessel Melt-through	Other preventive features Vent filter practical No other mitigation req'd Other mitigation features
Very, very low	Loss of Primary Water & Insufficient Core Water Makeup	Steam Explosion from finely dispersed fuel coming in contact with water	After Core Melt or Vessel Melt-through	Other preventive features Vent impractical No other mitigation practical
Very, very low	Loss of Primary Water & Insufficient Core Water Makeup in Containment Capable of Coping with Hydrogen Burn and Non-Condensible	Penetration of Basemat	After Vessel Melt-through	Other preventive features Vent not required Other mitigation practical

SLI
6/30/81

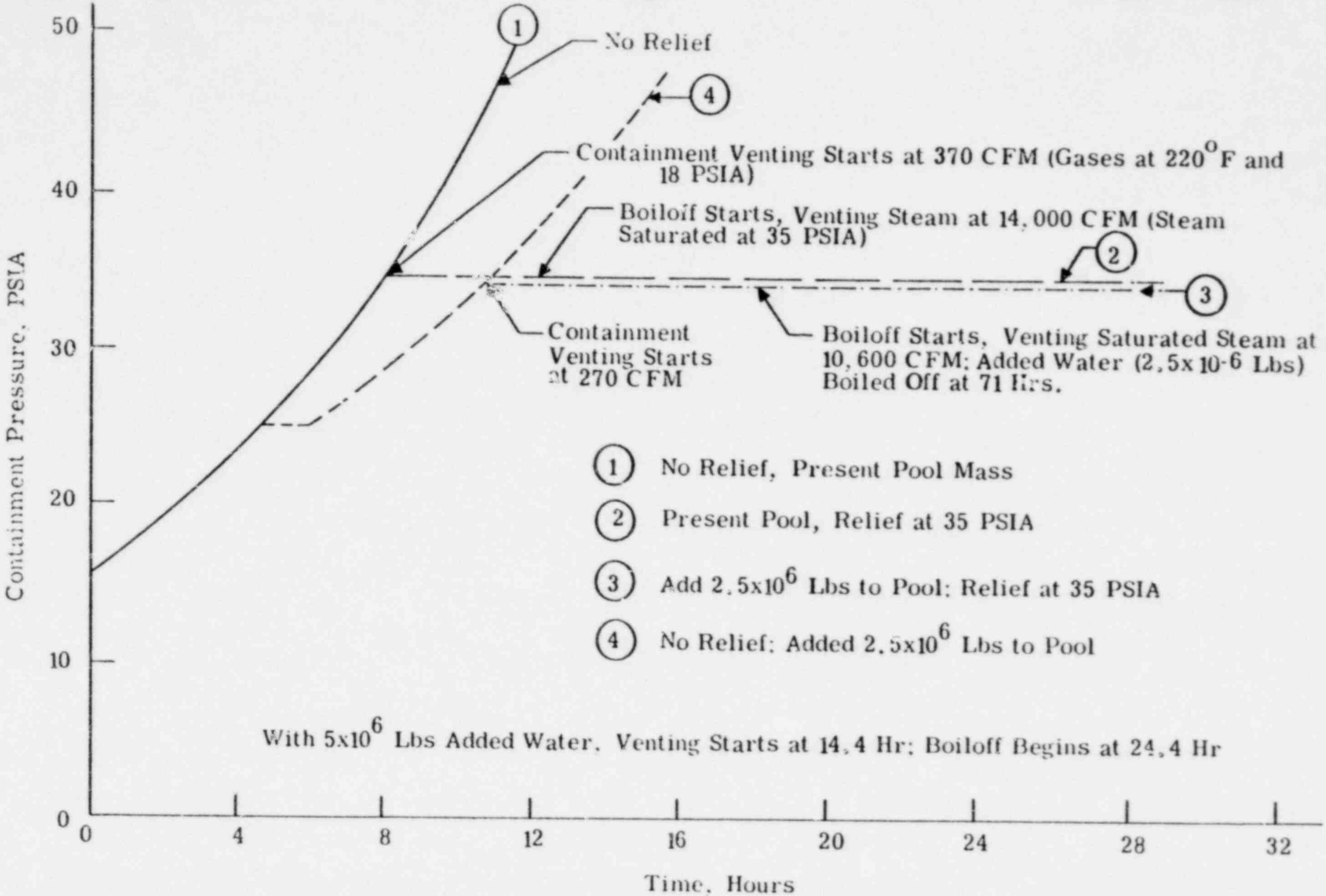
DOMINANT CONTAINMENT FAILURE SCENARIOS FOR

PWR ICE CONTAINMENT

Probability of Occurrence	Cause of Failure	Type of Failure	Timing of Failure	Design Strategy
Low	Failure of Core Decay Heat Removal	Pressure Spike from Hydrogen Burning	Minimal Core Melt; Prior to Vessel Melt Through	Other preventive featur Vent alone not practica Hydrogen control req'd Other mitigation featur
Low	Loss of Primary Water and Insufficient Water Makeup	Pressure Spike from Hydrogen Burning	Minimal Core Melt; Prior to Vessel Melt Through	Other preventive featur Vent alone not practica Hydrogen control req'd Other mitigation featur
Very low	Loss of Long-Term Heat Sink	Slow Overpressurization	Prior to Fuel Failure	Other preventive featur Vent practical No other mitigation features
Very low	Failure of Core Decay Heat Removal or Loss of Primary Water and Insufficient Water Makeup with Controlled Hydrogen Burning	Rapid Overpressurization from Non-Condensible Gases	After Vessel Melt Through	Other preventive featur Vent/filter practical Other mitigation featur
Very, very low	Failure of Core Decay Heat Removal or Loss of Primary Water and Insufficient Water Makeup with Controlled Hydrogen Burning	Steam Explosion from Finely Dispersed Fuel Coming into Contact with Water	After Core Melt or Vessel Melt Through	Other preventive featur Vent impractical No other mitigation features
Very, very low	Failure of Core Decay Heat Removal or Loss of Primary Water and Insufficient Water Makeup with Controlled Hydrogen Burning with Controlled Burning and Capability to Handle Non-Conden-	Penetration of Basemat	After Vessel Melt Through	Other preventive feature Vent not required Filter and other mitigation features

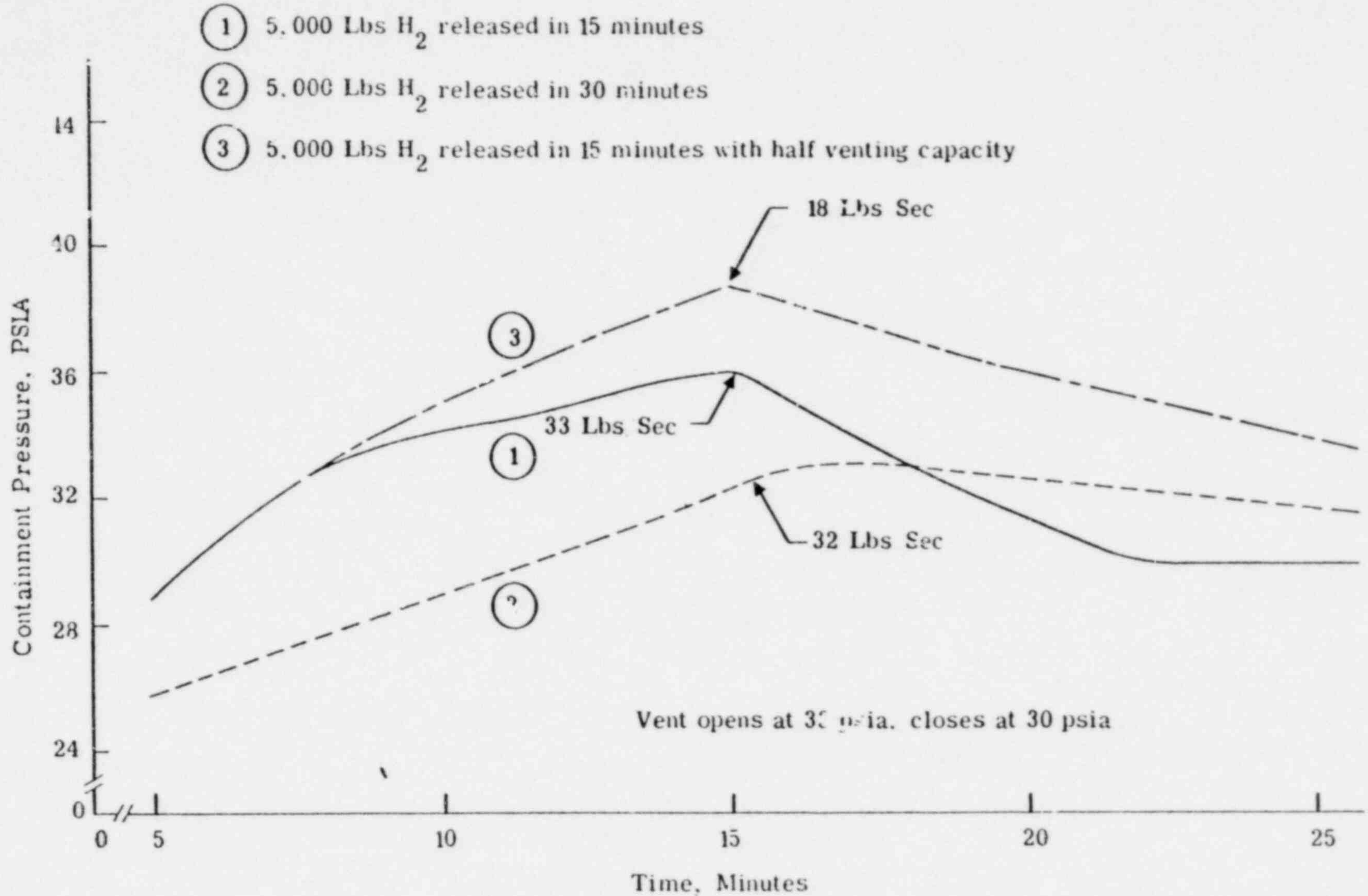
H_2 control needed; then vent will work

SLI
6/30/81



Loss of Long Term Cooling in BWR MARK III

SLL
6/30/81



Venting Capability Required for BWR MARK III

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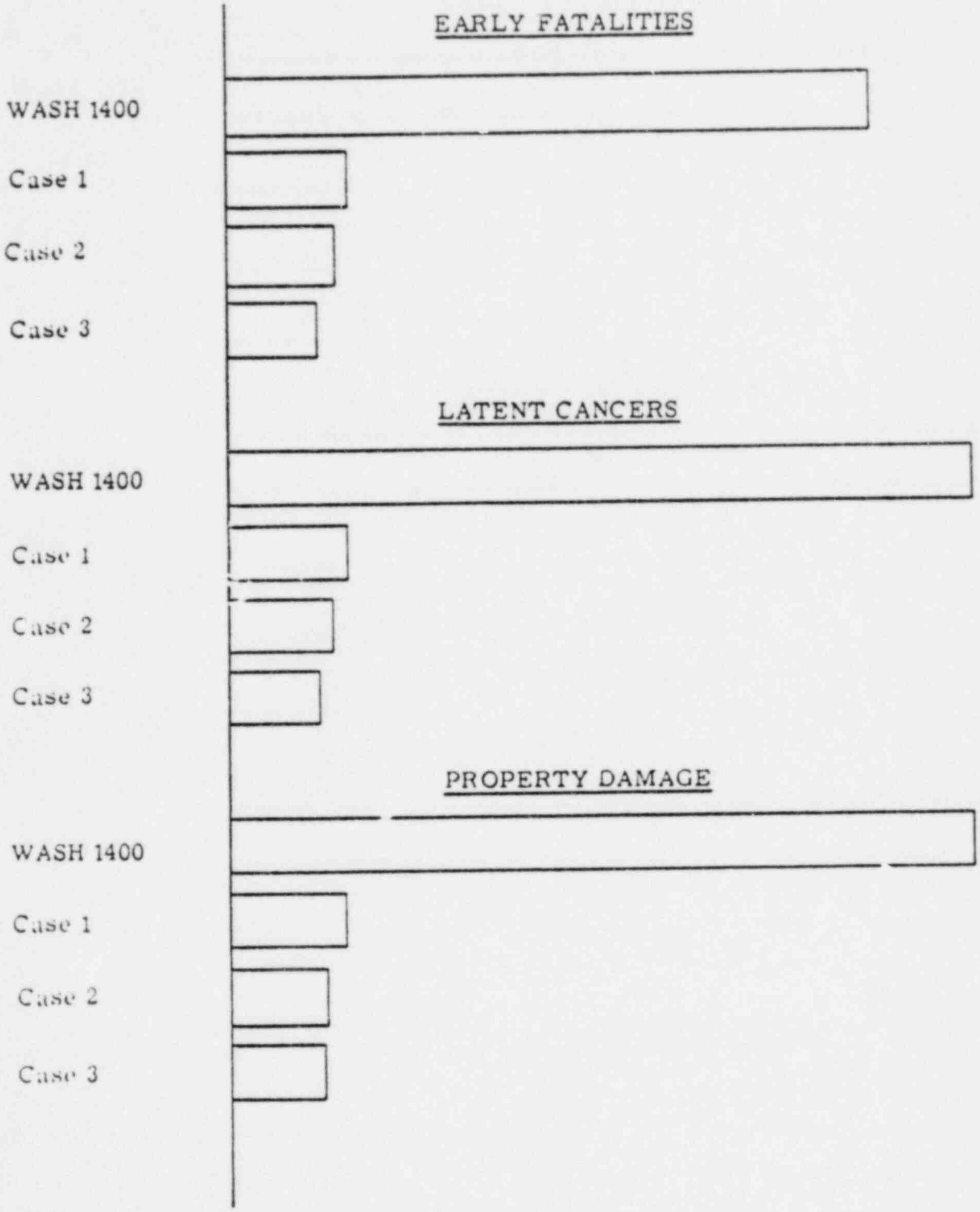


Relative Comparison of Risks for a BWR MARK I
For Case 1, NRC Alternate 4 and Independent RHR System
For Case 2, NRC Alternate 4 with Water Addition Plus Vent
For Case 3, Case 2 Plus a Filter/Vent System

SLI
6/30/81

CONCLUSIONS

BWR PRESSURE SUPPRESSION CONTAINMENT

- PREVENTIVE FEATURES AVAILABLE FOR DOMINANT RISK SCENARIOS AND ARE PREFERABLE FOR ATWS
- VENT PRACTICAL SOLUTION FOR LOSS OF LONG-TERM HEAT SINK
- FOR INSUFFICIENT WATER MAKEUP
  - HYDROGEN CONTROL REQUIRED FOR NON-INERTED CONTAINMENTS TO MAKE VENT PRACTICAL
  - VENT/FILTER OF NEGLIGIBLE BENEFIT

PWR ICE CONTAINMENT

- PREVENTIVE FEATURES AVAILABLE FOR DOMINANT RISK SCENARIOS
- HYDROGEN CONTROL REQUIRED TO MAKE VENT PRACTICAL
- VENT/FILTER OF MINIMAL BENEFIT

OTHERS

- PRA METHODOLOGY AND DESIGN STRATEGY OF GREAT VALUE
- PRESSURE SUPPRESSION AND ICE CONTAINMENT PROVIDE WATER/ICE FILTER PRIOR TO VENTING

SLI
6/30/81

EPRI

EPRI NP-1747
TPS 80-72*
Final Report
April 1981

SUMMARY AND RECOMMENDATIONS

The purpose of this study is to carry out a review and evaluation of potential improvements including filter/vent of BWR pressure suppression and PWR ice containments. The report does not consider whether or not any of the improvements should be implemented. This issue is best addressed through detailed risk assessments of specific plant designs and it goes well beyond the scope of this work. The summary findings and recommendations of this study were arranged by topical subject. They are as follows:

A. METHODOLOGY FOR IMPROVEMENT EVALUATIONS

Findings

1. Probability Risk Assessment is the only meaningful methodology to evaluate improvements for BWR pressure suppression and PWR ice containments.

2. An overall safety goal or a target risk reduction goal for degraded cores is needed to bound the evaluation of improvements and to make a choice between available alternates.

3. Periodic updating of probabilistic risk assessments is necessary to take into account new research findings, improved model development, differing design features, and latest NRC requirements. Such updating is necessary to preserve the timeliness of improvement evaluations.

Recommendations

1. Define the risk impact of the TMI Action Plan as it gets implemented.

2. Generate a probabilistic assessment of amount of hydrogen released and of time for its release for typical BWR and PWR plants.

3. Evaluate the probability of core melt when containment overpressure failure precedes it. This probability was taken to be one in the Reactor Safety Study because containment failure meant lack of net positive suction head for the emergency core cooling systems. Many plants have since been designed where this is no longer true. Whether or not containment failure leads to core melt will depend on the physical interaction of the containment failure with the engineered safety systems and their control systems.

B. REVIEW OF IMPROVEMENTS PROPOSED TO DATE

Findings

1. Studies of improvements in BWR pressure suppression and PWR ice containments are quite limited. Practically in every case, they are direct extrapolations of studies of PWR dry containments. Generally, preventive concepts have not been considered or evaluated for comparison to proposed mitigation improvements.

2. Most studies have focused upon filter/vent of the containment without defining the specific separate events they are expected to overcome.

Recommendations

None.

C. DESIGN STRATEGY FOR IMPROVEMENT

Findings

1. A satisfactory design improvement strategy applied in this study was to focus on the two to three dominant risk scenarios and examine both preventive and mitigative means to reduce them.

2. In applying the design strategy, it is worthwhile to separate those scenarios in which containment failure precedes core melt from those in which containment failure follows core melt. A balanced design might specify that the risks from the two different sets of scenarios be about equivalent.

3. In the BWR pressure suppression designs, the risks are dominated by transient events followed by loss of long term cooling or failure to shut down the reactor.

Both scenarios produce containment failure before core melt by overpressure due to excessive energy being deposited in the suppression pool. Recent NRC evaluations of failure to scram enhance the importance of such scenarios.

4. The risks produced by loss of coolant type accidents in which degraded cores cause containment failures are quite limited (2 to 4 percent of total risks) in BWR pressure suppression systems. In other words, substantial overall risk reductions can be achieved in BWR pressure suppression systems without any improvement in degraded cores; a corollary statement is that improvements oriented towards degraded cores in BWR pressure suppression containments would have a very small impact on present overall risks. For BWR loss of coolant accidents which are followed by core damage, containment failure is due to burning of hydrogen in non-inerted BWR pressure suppression containments and excessive generation of non-condensable gases in inerted containments.

5. In the PWR ice containment, the dominant scenarios are transient events followed by complete loss of capability to remove decay heat from the reactor core or small breaks which lead to core uncovery and meltdown preceding containment failure. Recent reassessment and research show that the probability of steam explosion is very low under such circumstances and the risks associated with such events should come down. The dominant failure mechanism is burning of hydrogen in the non-inerted PWR ice containments followed by excessive generation of non-condensable gases if means are found to control hydrogen burning.

6. The risks produced by loss of long term cooling in the PWR ice containment are quite small. This results, for example, from keeping the core covered with water with a feed and bleed type operation while the steam generator and the containment heat removal system are not available. The containment failure mode is one of overpressure before core melt due to excess energy being deposited in the containment atmosphere.

Recommendations

1. A systematic grouping of high risk events by type of containment failure and by their timing with respect to the occurrence of degraded core should be carried out. It is of great assistance in formulating a meaningful design improvement strategy.

D. DESIGN IMPROVEMENT BENEFITS (EXCLUDING FILTER/VENT)

Findings

1. In the dominant BWR pressure suppression accident scenarios of loss of long term cooling and failure to shut down the reactor, additional or improved preventive long term heat removal and standby liquid poison systems are shown to be capable of reducing the risks for such events by an order of magnitude. Such systems have the advantage of being similar to designs previously applied while not having to be concerned with the uncertainties that prevail with degraded cores. For the dominant PWR ice containment scenarios, a similar order of magnitude risk reduction can be obtained by additional or improved reactor core decay heat removal and emergency core cooling systems.

2. For non-inerted BWR pressure suppression containments where little or no maintainable equipment is located in the wetwell, the most practical means to control hydrogen burn is to pre-inert the containment. The benefits of inerting are quite small since events involving degraded cores have such a small risk contribution in BWR. For non-inerted Mark III BWR pressure suppression and PWR ice containments, pre-inerting is not advisable due to the amount of equipment which is located in the wetwell and which needs to be maintained. For such containment designs, post-inerting with a gas such as CO_2 after the accident but before formation of a significant amount of hydrogen has been proposed*. Such a system will require development of accurate and reliable hydrogen or other detectors to actuate the post-inerting. It also has the disadvantage of adding another non-condensable gas to the containment and of requiring rapid introduction of CO_2 to cover the entire spectrum of degraded cores. Another highly developmental system for control of hydrogen in non-inerted containments is to attempt to burn the hydrogen in place and to remove the heat of reaction from the containment atmosphere by spraying water. Here again, the benefits of all such systems are quite small for BWR pressure suppression containments. They will be larger for PWR ice suppression containments but their contribution to risk reduction is still not overly significant.

*Suggested by General Electric

Recommendations

1. An accurate probabilistic assessment should be prepared to establish the risk reduction associated with pre-inerting and post-inerting of BWR pressure suppression and PWR ice containments

2. A development program should be initiated to establish practicality of burning hydrogen in place.

E. FILTER/VENT CONCEPTS

Findings

1. BWR pressure suppression and PWR ice containments have several inherent advantages should filter/vent systems be employed. By putting the filter/vent on the wetwell portion of the containment, it insures that steam, gases and radioactivity produced during accidents go through the ice or pool of water. This permits deposition of energy in the water and ice which also act as efficient traps for fission products. The filter/vent system can be small as high flow rates to cope with large heat generation and fission products are not necessary. Steam generation as the molten core comes in contact with water can also be quenched and the containment pressure rise is small.

2. Filter/vent systems were scoped to handle loss of long term cooling, failure to shut down the reactor and loss of coolant accidents for BWR pressure suppression containments.

a. In the case of loss of long term cooling, the vent will initially release gases from the containment atmosphere, and eventually release steam from suppression pool boil off. Because of the wet steam involved and lack of fission products, venting while bypassing the filter is acceptable. The steam flow rate to be vented was calculated to be about 10,000 CFM for a typical Mark III containment pressure at 20 to 30 percent above containment design presure. A connection to add cold water to the suppression pool was found desirable because it will delay the need to vent for several hours and provide a water source for continued venting.

b. In the case of failure to shut down the reactor, a vent can be used to release boiloff steam from the suppression pool. The steam venting flow rates are in excess of 400,000 CFM in a typical Mark III containment and again due to the wet steam, a filter would not be useful. This type of vent will work if reactor core geometry is maintained during pool boiloff and if the relief valve quenchers do not produce excessive containment condensation loads at temperatures up to saturation temperature. While the above assumptions are realistic, the vent size and flow are so large that this alternative is not considered attractive. Here again, it was found that addition of cold water to the pool can extend the time available to correct the failure to scram.

c. In the case of loss of coolant accidents which produce degraded cores, a separate filter/vent similar to the Standby Gas Treatment System can cope with the degraded core if hydrogen burning is not a problem. Its capacity for a typical Mark III would be 20,000 CFM if it is designed to open at 10 percent above the containment design pressure, and to close at design pressure. Smaller vents could be utilized if the vent opening and closing pressure is increased.

d. Because of its very large size, it is doubtful that the vent proposed for failure to shut down the reactor provides a meaningful risk reduction beyond providing more time to correct the situation. On the other hand, an order of magnitude risk reduction is obtained by employing the vents proposed for each of the loss of long term cooling and loss of coolant accidents. However, the risks produced by loss of coolant accidents are so small in BWRs relative to the other accidents that it is difficult to justify providing a filter/vent for such accidents.

3. Very similar filter/vent systems of about 20,000 CFM are expected to apply to PWR ice containments if hydrogen burning can be controlled. In this instance, an order of magnitude risk reduction will result for the dominant scenarios of small breaks or loss of capability to remove decay heat from the reactor core.

Recommendation

1. A more detailed evaluation of filter/vent in PWR ice containment is recommended.

F. OTHER COMMENTS

Findings

1. Core catchers or core ladles are of little value in reducing the overall risks in BWRs with inerted containments because risk is dominated by scenarios that produce containment failure before core melt due to great uncertainties with their designs and their small contribution to reducing the non-condensable gas generation, or extending the time for basemat penetration.

2. In addition, core catchers or core ladles are of little value to non-inerted BWR pressure suppression or PWR ice containments because they are effective only after a significant hydrogen release and the possibility of a hydrogen burn.

Recommendation

1. A probabilistic assessment of assuring water in the containment in case of core melt might be useful.

D. [illegible]
D. Hanauer

GENERAL ELECTRIC COMPANY

BWR/6 MARK III STANDARD PLANT

REVIEW OF CONTAINMENT OVERPRESSURE RELIEF

ALBUQUERQUE, NEW MEXICO
JUNE 30, 1981

TOPICS

- INTRODUCTION
- KEY BWR SAFETY FEATURES
- BWR/6 STANDARD PLANT IMPROVEMENTS
- CONTAINMENT OVERPRESSURE RELIEF
- CONTAINMENT DESIGN FEATURES
- FISSION PRODUCT RETENTION
- SUMMARY

INTRODUCTION

- o CONTAINMENT OVERPRESSURE RELIEF PLANNED IMPROVMENT FOR BWR/6 MARK III STANDARD PLANT
  - PROVIDE ALTERNATE DECAY HEAT REMOVAL
  - FURTHER REDUCES RISK

- o IF FILTERED VENT REQUIRED, IMPROVED STANDARD PLANT WOULD SATIFY OJECTIVES
  - SUPPRESSION POOL SCRUBBING
  - CONTAINMENT OVERPRESSURE RELIEF

KEY BWR SAFETY FEATURES

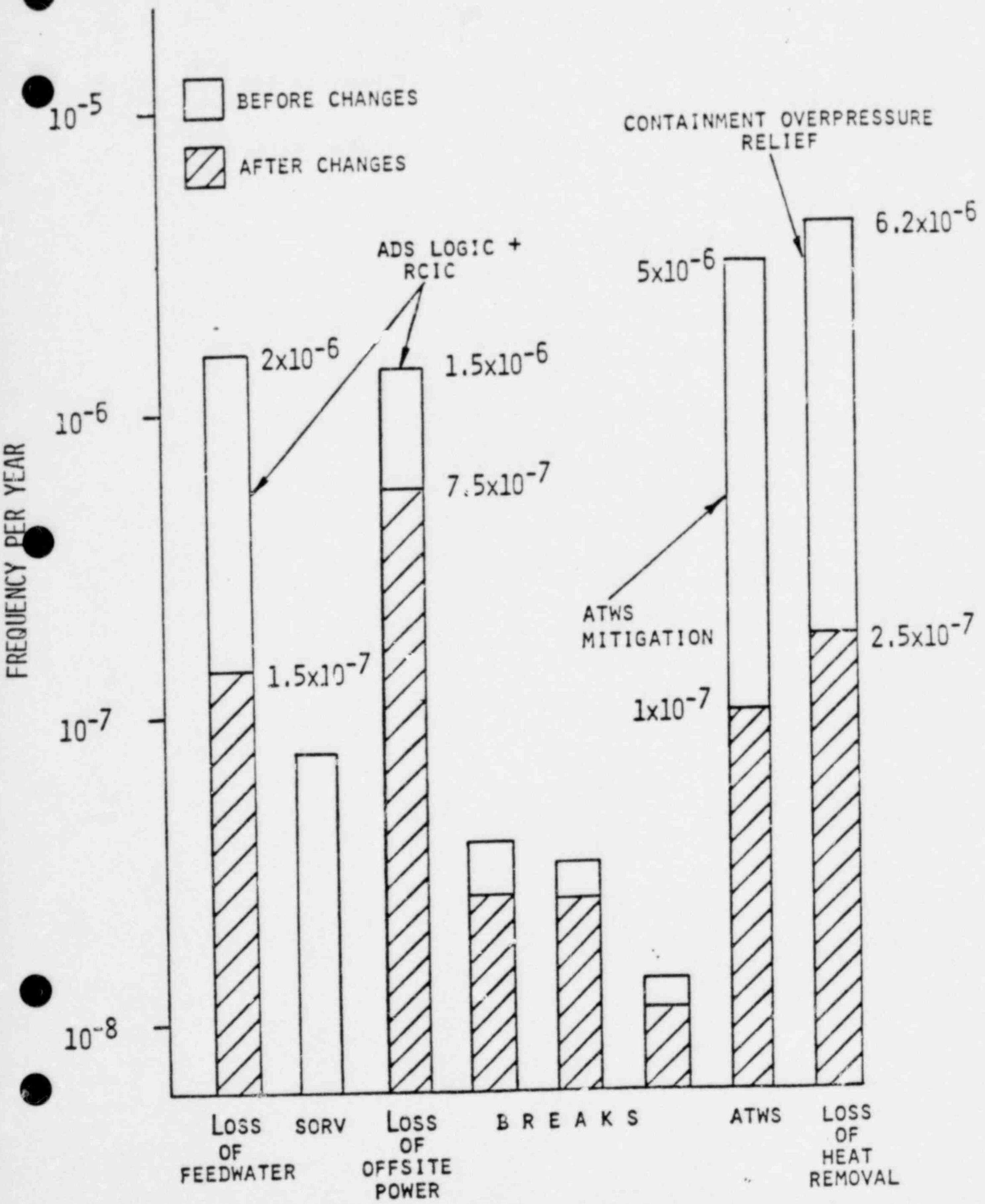
- FOR LOSS OF HEAT SINK
  - LARGE PASSIVE SUPPRESSION POOL
  - STORE DECAY HEAT FOR ~6 HOURS WITH VESSEL ISOLATED
  - ALLOWS OPERATOR TO MONITOR CORE COOLING FUNCTIONS WITHOUT DISTRACTION
- TO SUPPLY WATER TO CORE
  - HIGH PRESSURE SYSTEMS
    - FEEDWATER
    - CORE SPRAY
    - REACTOR CORE ISOLATION COOLING
    - CONTROL ROD DRIVE COOLING
  - DEPRESSURIZATION
    - MAIN CONDENSER
    - SAFETY RELIEF VALVE DISCHARGE TO SUPPRESSION POOL (AUTOMATIC OR MANUAL)
  - LOW PRESSURE SYSTEMS
    - LOW PRESSURE COOLANT INJECTION
    - LOW PRESSURE CORE SPRAY
    - CONDENSATE
- OTHER BENEFICIAL BWR/6 FEATURES
  - STUCK OPEN RELIEF VALVE: MILD BWR TRANSIENT
  - WATER LEVEL DIRECTLY MONITORED ON REACTOR VESSEL
  - BOILING IS NORMAL MODE OF BWR OPERATION
  - NON CONDENSIBLE GASES EASILY VENTED
  - NATURAL CIRCULATION SIMPLER IN BWR: INTERNAL TO REACTOR VESSEL AND NOT INTERRUPTED BY NON CONDENSIBLE GASES
  - SPRAY COOLING AND STEAM COOLING OF UNCOVERED CORE
  - CONTAINMENT ISOLATION ON ECCS INITIATION, SECONDARY CONTAINMENT WITH LEAKAGE FILTRATION
  - EMERGENCY OPERATION: SIMPLE AND SIMILAR TO NORMAL OPERATION

BWR/6 STANDARD PLANT IMPROVMENTS

POST TMI PLANNED IMPROVEMENTS

IMPROVEMENTS	BENEFIT
AUTOMATIC DEPRESSURIZATION SYSTEM LOGIC IMPROVEMENT	AUTOMATIC DEPRESSURIZATION AND ACCESS TO LOW PRESSURE SYSTEMS IF NEEDED FOR TRANSIENTS
INCREASE AVAILABILITY OF REACTOR CORE ISOLATION COOLING	MORE LIKELY TO KEEP CORE COVERED AT HIGH PRESSURE
PROVIDE CONTAINMENT OVERPRESSURE RELIEF CAPABILITY FOR USE BEFORE CORE DAMAGE	REMOVE DECAY HEAT IF CONTAINMENT PRESSURE AND TEMPERATURE CONTROL NOT AVAILABLE, PREVENT CONTAINMENT FAILURE AND POSSIBLE CORE DAMAGE
ATWS MITIGATION "ALTERNATE 3A + BROWNS FERRY MODIFICATIONS	INCREASE SCRAM, ALTERNATE SHUTDOWN RELIABILITY

CORE DAMAGE CONTRIBUTORS



CONTAINMENT OVERPRESSURE RELIEF

- o AN ALTERNATE DECAY HEAT REMOVAL SYSTEM
  - PREVENTS CORE DAMAGE FOR LOSS OF DECAY HEAT REMOVAL EVENT

- o EXISTING BWR/6 DECAY HEAT REMOVAL SYSTEMS
  - MAIN CONDENSOR
  - SHUTDOWN COOLING
  - ALTERNATE SHUTDOWN COOLING
  - SUPPRESSION POOL COOLING

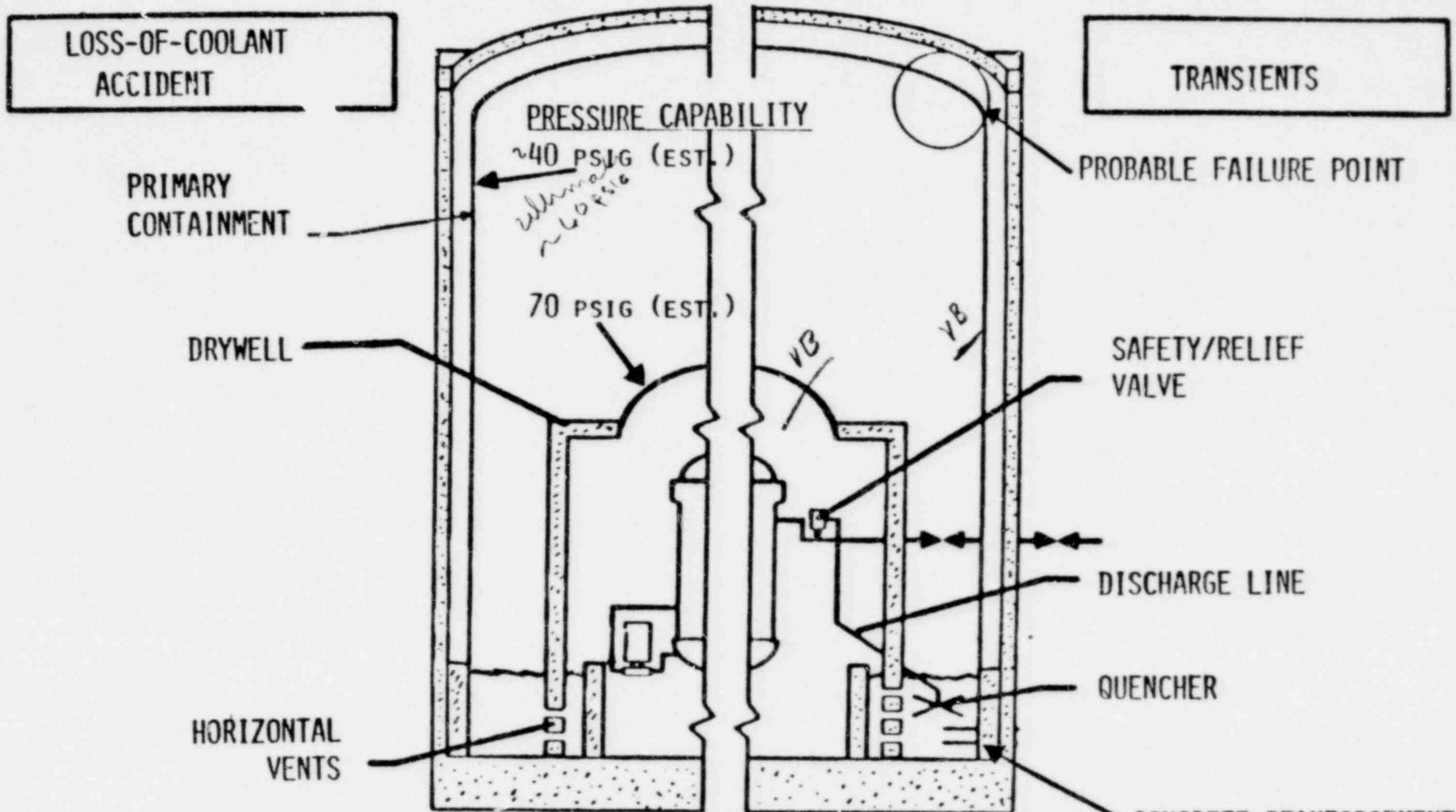
- o DESIGN CONCEPT
  - ADD 24" VENT LINE (+ VALVES & CONTROLS) DIRECTED TO PLANT VENT
  - PROVIDE AIR FOR CONTROL
  - REVIEW EQUIPMENT CAPABILITY

CONTAINMENT OVERPRESSURE RELIEF (CONT.)

- o POSTULATED EVENT SEQUENCE FOLLOWING COR IMPLEMENTATION
  - TRANSIENT EVENT WITH LOSS OF ALL CURRENT DECAY HEAT REMOVAL CAPABILITY
  - RCIC/HPCS/OTHER ECCS MAINTAIN VESSEL LEVEL
  - MANUAL REACTOR VESSEL DEPRESSURIZATION
  - S/RV DISCHARGE BOILS POOL, PRESSURIZING CONTAINMENT
  - OPERATOR OPENS CONTAINMENT RELIEF VALVE
  - OPERATOR REFILLS POOL
- o OFFERS SIGNIFICANT REDUCTION IN CORE DAMAGE PROBABILITY

CONTAINMENT DESIGN FEATURES

- PRESSURE CAPABILITY
- SUPPRESSION POOL SCRUBBING PATHWAYS



- LARGE, PASSIVE FILTER FOR TRANSIENT AND ACCIDENT EVENTS
- RELATIVE STRUCTURAL PRESSURE CAPABILITY INSURES FILTERING

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POOL SCRUBBING DATA BASE

RESULTS OF LITERATURE SEARCH

- DECONTAMINATION FACTOR (DF)

$$DF = \frac{\text{CURIES IN}}{\text{CURIES OUT}}$$

- CURRENT DATA ON PARTICULATES (CONTROLLING FISSION PRODUCTS)
    - DF FUNCTION OF
        - PARTICLE SIZE
        - BUBBLE SIZE AND RISE TIME
        - SATURATED OR SUBCOOLED POOL
    - LITERATURE EXTRAPOLATION INDICATES
        - SATURATED POOL DF = 100
        - SUBCOOLED POOL DF = 1000

- DATA BASE WEAK IN KEY AREAS
    - NO DATA ON CsI
    - NO POOL SCRUBBING MODELS FOR PARTICLES

- EXPECTED POOL DFs = 10^3 FOR DOMINANT SEQUENCES

SENSITIVITY OF CORE MELTDOWN CONSEQUENCES TO FISSION PRODUCT RETENTION

REALISTIC EVALUATION

- DF = 10,000
- 4 HOUR CONTAINMENT FAILURE TIME, GRADUAL RELEASE

MILES FROM SITE	LIFETIME WHOLE* BODY DOSE (REM)
0.5	23
0.75	18
1.25	13
4.25	5

CONSERVATIVE EVALUATION

- DF = 100
- RAPID CORE MELTDOWN AND RELEASE

MILES FROM SITE	LIFETIME WHOLE* BODY DOSE (REM)
0.5	375
1.5	164
4.5	73
9.25	25

HEALTH EFFECTS:

- NO EARLY FATALITIES FOR EITHER CASE

* NO EVACUATION

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HEALTH EFFECTS (CONTINUED)

- LATENT EFFECTS

REALISTIC EVALUATION	COMPARABLE EFFECTS ASSUMING LINEAR HYPOTHESIS	CONSERVATIVE EVALUATION
	• 160 REM – LIVING IN GUAPARI, BRAZIL	• 1.5 MILES FROM PLANT AT TIME OF ACCIDENT
	• 100 REM – ALLOWED OCCUPATION EXPOSURE FOR 20 YEARS – OR BEING AN UNMARRIED MALE FOR 3 YEARS – OR BEING 10% OVERWEIGHT FOR 14 YEARS	• 2.7 MILES FROM PLANT AT TIME OF ACCIDENT
	• 40 REM – LIVING IN KERALA, INDIA – BEING 10% OVERWEIGHT FOR 6 YEARS	• 7 MILES FROM PLANT AT TIME OF ACCIDENT
• 0.5 MILES FROM PLANT AT TIME OF ACCIDENT	• 25 REM – 10CFR100 LEGAL LIMIT – NO CLINICAL EFFECTS – COMPARABLE TO NATURAL BACKGROUND IN LEADVILLE, COLORADO	• 9 MILES FROM PLANT AT TIME OF ACCIDENT
• 2 MILES FROM PLANT AT TIME OF ACCIDENT	• 10 REM – US AVERAGE NATURAL BACKGROUND RADIATION	

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SUMMARY

- o POST-TMI REVIEW CONFIRMS CAPABILITY OF BWR TO RESPOND TO DEGRADED TRANSIENTS
- o PLANNED IMPROVEMENTS FOR BWR/6 FURTHER REDUCE PROBABILITY OF CORE DAMAGE
- o CONTAINMENT OVERPRESSURE RELIEF PROVIDES ALTERNATE DECAY HEAT REMOVAL
- o SUPPRESSION POOL SCRUBBING PROVIDES A HIGHLY EFFICIENT FILTER
- o IF FILTERED VENT REQUIRED, BWR/6 CONTAINMENT OVERPRESSURE RELIEF WOULD SATISFY OBJECTIVES