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NUCLEAR REGULATORY COMMISSION

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BRIEFING ON INTERIM REPORT ON BWR MARK I

CONTAINMENT ISSUES

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Public Meeting

One White Flint North

Rockville, Maryland

Friday, July 22, 1988

The Commission met, pursuant to notice, at 10:00 a.m., the Honorable Lando W. Zech, Jr., Chairman of the Commission, presiding.

COMMISSIONERS PRESENT:

Lando W. Zech, Chairman

Thomas M. Roberts, Commissioner

Kenneth M. Rogers, Commissioner

Kenneth C. Carr, Commissioner

STAFF AND PRESENTERS SEATED AT TABLE:

S. Chilk, SECY

W. Parler, OGC

V. Stello, EDO

T. Speis

L. Soffer

T. Murley

E. Beckjord

PROCEEDINGS

CHAIRMAN ZECH: Good morning, ladies and gentlemen.

Today the Commission will be briefed by the NRC's Office of Research and the Office of Nuclear Reactor Regulation on the status of the boiling water reactor Mark I containment performance improvement program.

These proposed regulatory initiatives are in response to concerns about the performance of these containments during a postulated severe core melt accident.

The Staff informed the Commission over a year ago of their intention to investigate the performance of BWR Mark I's as part of an integrated approach to the closure of severe accident issues.

In May of this year, the Staff developed an integrated plan for closure of severe accident issues which provided the Commission a public schedule and framework for the integration and closure of severe accident issues.

Today's meeting will provide the status report on the BWR Mark I portion of the containment performance assessment program, with final recommendations to the Commission expected in early fall of this year.

Containment performance studies for other containment types is scheduled for completion in the fall of 1989. We would also be interested in hearing today about any industry activities associated with the resolution of containment

performance issues.

It is my understanding that copies of the viewgraphs for today's meeting at available at the entrance. This is an information briefing, and a status report briefing, and no formal vote will be taken today on this issue.

Do any of my fellow Commissioners have any opening comments to make? If not, Mr. Stello, you may proceed.

MR. STELLO: Thank you, Mr. Chairman.

I think it is important for the Commission to hear the status of this important program. We have previously presented the Commission with an overall plan, I think it was December of last year. We had a status briefing, and finally expect that we will have our final recommendations to the Commission for decision in the fall of this year. I think it is important to have the opportunity for whatever discussion the Commission chooses to have here that will provide further guidance to the Staff in developing our final recommendations, and it will be very useful to us to have the benefit of this meeting and the discussion with the Commission at this time, and we hope that it will be useful to the Commission. We know it will be useful to the Staff.

I have asked Dr. Murley to make some opening comments at the start of this, and then we will go to the detailed briefing, and at any time the Commission wishes, we will stop with questions by Dr. Speis from Research. So with that brief

introduction, let me ask Dr. Murley to begin.

CHAIRMAN ZECH: Thank you very much. You may proceed.

MR. MURLEY: Thank you, Mr. Chairman.

We have to approach this issue with a broad view, and I think it is important to understand the reasoning of how we got where we did, and that's why I wanted to take a minute at the beginning to explain the reasoning.

As you mentioned, Mr. Chairman, in your opening remarks, this is one program in the context of an integrated program for closure of the severe accident issue. It's only one element for a certain class of plants, namely the BWR Mark I plants. It is not meant to resolve the entire severe accident issue, even for this one class of plants. We still have to consider improved operations and individual plant exams, for example.

Last summer Vic Stello asked us to take a fresh look at the Mark I issues. We did that. We have been reporting back to the Commission periodically on our -- what we're finding, and one thing I think is important, that we did not find that the BWR Mark I plants had higher risk profiles than any other class of plants as a type.

Of the available risks, some Mark I plants were higher and some lower than average, but they did not stand out as a class.

So there is no special reason to single out the BWR Mark I plants for special treatment based solely on public health or risk grounds. Nonetheless, our defense-in-depth philosophy tells us that we should look at each one of the safety barriers separately; that is prevention and mitigation, and so forth.

When we do that and follow that path, then the Mark I containment appeared to be vulnerable to early failure during certain core melt sequences where the reactor pressure vessel was breached, and that is the reason that caused us to put the emphasis on the BWR Mark I that we have.

This was due principally to the smaller size of containment, but also there's some configurations and geometrical configuration considerations.

There has been substantial technical controversy among the experts concerning these failure modes, so even that question of the vulnerability is open to, I would say, a substantial amount of disagreement among the experts.

We found that if we focused narrowly on the issue of containment failure modes, we would be led down the path again to the point where the experts are still disagreeing amongst themselves. We didn't want to go down that path if we could avoid it.

The research to resolve the technical issue of containment failure, particularly as Dr. Speis will mention in

a minute, there are certain failure modes that are of concern -- the research to resolve those technical issues, in my judgment at least, is going to be very difficult and the issue is not likely to be resolved soon.

So that led us to ask is there another path? And I think the answer is yes, if we take a broader view of overall risk reduction.

For example, suppose we could find means for arresting the course of core melt accidents, or otherwise retaining the core in the pressure vessel. That then would minimize the importance of any of the technical disagreements over whether containments fail and how, and what the modes are. I just use that as an example of a way of broadening our thinking that led us to where we're at. So in this sense one could view the pressure vessel, for example, as part of the containment system.

As we took this broader approach, then, this line of reasoning led us to conclude that we should take a balanced approach to the Mark I issue -- you'll hear about that this morning -- a balanced approach being accident prevention, accident management, accident mitigation. This is particularly appropriate, we feel, because the BWR Mark I reactor system, in that system, the reactor system, the safety systems and the containment systems are very tightly coupled, so it's not easy even if one wanted to, to separate prevention from mitigation.

So if it appears today that we are mixing up prevention and mitigation, it's not to cause confusion or to minimize the defense-in-depth philosophy. Indeed, we agree with that. But it is a natural consequence of the decision that we took to take a broad, balanced approach to the issue. So what you will hear today is discussion of prevention, management and mitigation, and I wanted to say how we got to that point and the reasoning that went behind it.

Okay, Themmy.

CHAIRMAN ZECH: Okay, Dr. Speis, you may proceed.

MR. SPEIS: Thank you, Mr. Chairman.

If we go to page No. 2 of the outline, I'll go through a brief outline of the presentation today. We will discuss some of the activities, the background of the activities relating to this program. We will give you a brief overview of the severe accident program and how the Mark I effort relates to it, discuss the objectives of this program -- those have been discussed already, to some extent -- then discuss more specifically the severe accident challenges to the Mark I containment, then briefly also discuss our present understanding of the Mark I containment failure modes, as well as the Mark I containment margins; and I mean by that, the margins between the design and best estimate failure potential for failure.

Also I will discuss, summarize some of the

conclusions that came from a workshop that was held to discuss the issues relating to the Mark I severe accident challenges failure modes and potential improvements; summarize the PRA insights, and based on these PRA insights and our bigger view of the Mark I issue which led us to these balanced approach Dr. Murley discussed, and then here we will discuss in more detail the balanced approach which consists of the elements of accident prevention or accident management and accident mitigation, summarize the industry efforts, as you requested, Mr. Chairman, and then say something about where we are at this point in time, give you an indication of our preliminary conclusions, and also establish our activities and our future staff actions before we arrive at the final recommendations due to you in the fall.

Some background which has been discussed, I will only spend a minute or so. The proposal of the five-element program for containment performance improvement that was presented to the Commission, to the ACRS, back in June 1986, if you recall, that program was basically mitigation-oriented, as Dr. Murley alluded to. In June or July of '87, two licensees informed the Staff of their intention to investigate containment and safety enhancement. In July of '87, we briefed the Commission on our plan to close severe accidents, and at that time we discussed our more integrated approach to the resolution of severe accident issues, including the issues relating to the BWR Mark

I.

Also, at that meeting we informed the Commission that we had met with key scientists from laboratories and universities doing work for the Commission, and separately also had met with industry scientists, and at that time the range of technical opinions expressed about the relevant issues, about the challenges to containment, about the potential failure modes were wide. There was basically no clear consensus of whether the improvements that were proposed were the right ones; whether they were the right ones in reducing risk; whether they were cost-effective, and a number of other things.

And after reviewing the conclusions from those two meetings, we decided that we would take some more time to look into this issue more closely, do more calculations, some additional well-focused research, to be able to arrive at a better understanding of the issues, the technical issues related to the Mark I problem.

And basically what I will be telling you later on is some of the additional things that we have done and concluded as a result of the additional time.

On page 4, Mr. Chairman, I have a figure which comes from the severe accident integration plan that was presented last month. It's from SECY 88-147 and it shows that the severe accident program has a number of elements and, of course, one of the main elements is the containment performance

improvements for all containments, as well as the subclass for Mark I's, which we will be talking about today. So we have discussed this before, so this is presented here for completeness, to put this program in its proper context, and I will go straight to page 5, which discusses the containment performance improvement program itself, the general one.

Again, Dr. Murley discussed this to some extent. This program arose as a result of concerns related to the ability of containments to withstand some generic challenges associated with low likelihood severe accident scenarios, and we have this program underway to determine what actions, if any, should be taken to reduce the vulnerability of these containments to severe accident challenges.

Our efforts, of course, at this point in time are focused initially on Mark I's and as Mr. Stello said, this presentation is the status of our efforts, and our final recommendations will be given to you in the fall of this year.

We also in parallel are pursuing activities relating to the other containments, and our schedule calls for briefing and making our recommendations to the Commission by the end of next year.

I would like to stress at this point that this effort, this containment performance improvement effort, is generic in nature. We are focusing on generic vulnerabilities of these containments, and not plant-unique, which is the

primary focus of the IP program. So those two programs complement each other and, of course, we plan to brief you on the IP program next week, and we discussed this complementarity between the containment performance and the IP and the integrated plan that --

CHAIRMAN ZECH: As regards generic requirements, it is my understanding that the Mark I BWR containment does vary in model and class, sometimes in containment volumes and rating and other factors. Does the likelihood of containment failure due to severe core damage also vary according to these various parameters? And is that what you mean by plant-specific as opposed to generic?

MR. SPEIS: Yes. We are looking at in this program some of the more generic --

CHAIRMAN ZECH: But it does vary, according to --

MR. SPEIS: Yes.

CHAIRMAN ZECH: -- and they're not the same?

MR. SPEIS: Yes, there are similarities in the volumes, in the design pressures, and the best estimate capability. For example, the thickness of the line will vary somewhere from maybe less than one inch to two inches.

CHAIRMAN ZECH: But you do think you can come up with generic --

MR. SPEIS: We think generic, but they have to be complemented by specific analysis on a plant-specific basis to

make sure that whatever we come up with generically does make sense on a plant-specific basis.

CHAIRMAN ZECH: Right. So you have to think both generically and plant-specific?

MR. SPEIS: Yes, sir.

CHAIRMAN ZECH: All right. And you're doing that?

MR. SPEIS: Yes. That is very important.

CHAIRMAN ZECH: All right. Thank you.

MR. SPEIS: If we go to page 6, going to the Mark I itself, again this containment could be challenged principally due to its smaller size. We have identified the number of failure modes which I will discuss later in some detail, but as Dr. Murley pointed out, we must emphasize that we haven't seen Mark I plants as standing out in the population -- among the population of other plants as a class by themselves.

Again, estimates of containment failure, again for some specific failure modes, are highly uncertain, and that is the reason that we are pursuing a more integrated approach to this issue.

I have provided a picture of the Mark I containment on the next viewgraph. Basically there are 24 of these containments, Mark I containments, there are 17 different sites. The Mark I containment, as you see in the picture, is typified by an inverted light bulb design and, of course, with a cone-shapped suppression pool that you see below there.

All these plants, except Brunswick Units 1 and 2, have steel lined reinforced concrete containments. But again, as you pointed out, Mr. Chairman, there are differences even within this class. For example, I have somewhere here the volumes. They vary from maybe 100,000 cubic feet up to three or four hundred thousand cubic feet. The design pressure varies to some extent. I already mentioned the liner, which is the real structural boundary, is made up on carbon steel, and it varies from .7 to 2.5 inches along the circumference.

You see here the biological shield outside the structural boundary. You have the suppression pool, of course, which is there for the purpose of basically to condense steam, given design basis accidents, but of course it can serve a very useful and effective means of reducing radionuclides and reducing the fission product source term even under a large number of severe accident scenarios.

In fact, one of the things that we are looking at as part of the improvements is possibly to vent these containments if you have an overpressurization, potential overpressurization failure mode, and take advantage of the suppression pool to scrub the fission products.

I also have an additional picture which shows some more details. It shows the vent header, it shows the downcomer pipes, but this is something that you know already, and it has been provided here for completeness.

Let's go to the next page, page 9, because there I want to talk a little bit more about the work that we have been doing the last year to get a much better understanding of the challenges to the containment and the potential failure modes.

This is very crucial, because if you are going down the road to fix something, you have to know what's wrong with it, so --

What basically we have been doing, we have examined very carefully these failure modes, again given a severe accident. We have attempted to separate the most probable of these failure modes, and concurrently the most risk-significant from the less-probable of no risk significance; again, given a severe accident, in most cases where the vessel fails and the containment itself is challenged.

Our approach has been based on a combination of engineering analyses. We have done experiments, the industry and NRC have been doing work in this area. We have been doing calculations. We have done a -- both we and the industry have done a large number of PRAs which provide additional insights into the classification of these failure modes.

You see here from the list that I have summarized on page 9 a number of failure modes have been identified. I have identified the first one. Again you should always bear in mind that we are talking about most of these failure modes, given a severe accident.

The first one, it's failure of the containment via overpressurization. Basically this is a failure mode that can take place before the core itself melts. This is important for some plants, in the absence of wet well venting, but if there is wet well venting, this sequence disappears. Basically here this is a sequence that is initiated from loss of long-term decay heat removal. You boil the suppression pool, the steam leads to the pressurization of the drywell, and eventually the containment fails, and then at that point the pool itself flashes, and you lose NPSH, and then you lose subsequent cooling to the core itself, and it leads to a core melt.

But again, if you are able to vent during that pressurization and avoid loss of the drywell, then the importance of this failure mode goes away.

I have listed another failure mode, the so-called steam explosion. This is a failure mode that is due to large scale of molten material interacting with water. We have listed this as of no risk importance, based on a large number of studies that have been performed.

The other one that I have listed as No. 3, failure to isolate, this is a failure mode that is not really related to the phenomena itself, but to the reliability of the valve, so -- to the isolation valves.

The next one, hydrogen burn detonation, as you know, Mark I containments are all inerted at the present time, with

nitrogen, so the failure mode of the containment from this type of scenario is considered again low. The only time that a Mark I is non-inerted is during a 24-hour period where maintenance and other actions are taking place. And one of the original proposals calls for reducing this 24-hour deinerting period to a 12-hour deinerting period, but we thought the risk of it going from 24 to 12 hours is very, very small.

One of the important sequences that can challenge the containment of the Mark I is overpressurization and overtemperature sequences. This is the result of an extended core-concrete interaction that follow the breach of the reactor pressure vessel and the dumping of the corium into the concrete below. That interaction between the corium and the concrete produces noncondensible gases and aerosols and the noncondensible gases lead to the overpressurization of the containment. So you have a potential pressure and temperature problem there. So these are important scenarios that can challenge the Mark I containment.

Again, this is the type of scenario that could be prevented by containment -- by venting of the containment. That doesn't mean that it should be done. Venting is a very -- it's something that has to be looked at very carefully, the pluses and the minuses, before one finally comes up with such a recommendation, but again, in general, if venting can be made effective, and if one is satisfied that the minuses have been

reduced, then venting is a way of reducing the overpressurization failure.

The other one failure that I have listed, No. 7 here, is the one that Dr. Murley discussed, that has received -- has been the topic of intense discussion in the last year or so. This is the direct attack of the liner of the containment from the corium itself, after it penetrates the vessel, and then it rushes into the liner and attacks it from a thermal standpoint. There are different views on this issue, technical views, and as Tom said, I'm not so sure in the near future we will be able to say with certainty that this failure has this type of probability or some other probability.

What is important, though, is that in the overall context of things, there is consensus that if we can introduce water into the containment, both into the volume of the containment and the volume of the drywell, as well as in the cavity itself, that water is very effective in reducing the source term itself.

For example, we have some early calculations indicating that the reduction of the source term can be a factor of 10 or higher. So again, not only the water can reduce the source term itself, but also possibly it could help delay or even delay the liner failure. But again, there are many questions in this area, and different views, and as we told you when we briefed you on the integrated plan, this is an

area that we will be doing much more work on in the next year or two, basically confirmatory work, to understand much more this particular containment failure mode.

So again, this is our present understanding. We think there are still uncertainties, but I think we have a pretty good understanding of where the uncertainties are, and what are the more risk significant failure modes versus the non-risk significant failure modes.

And again, this is the effort that we have been going through the last six months to a year, and in some of these areas we will continue to work.

If I go to the next page, I have given a table of the Mark I structural margins. We have learned quite a bit about the relative magnitude of these margins between design and failure over the last few years. We have done quite a bit of research in this area, we have done scale models of steel containments of 1/8 and to 1/32 scale, and based on these experiments, as well as extremely sophisticated analyses involving multidimensional cores, we have reached the conclusion that the Mark I containments, as well as the other containments, have sufficient margins above the design pressure itself.

For example, I have indicated here that if the containment is challenged from a pressure and temperature standpoint, the failure mode will take place in the torus

itself and the estimated failure pressure can range anywhere from 130 to 180 pounds per square inch, even though the design pressure itself is somewhere around 50 pounds per square inch gauge.

You see below that if significant core-concrete interaction takes place, this leads to hot aerosols and gases, hot gases and, of course, that raises the temperature of the containment, and you see that those margins are basically reduced somehow if you are dealing with higher temperatures.

So I think this is important.

One of the things we're doing in the Mark I, as well as the other containments, is to understand those margins to the extent one can take advantage in both accident management and in accident mitigation strategies that we are pursuing.

I would like to say something about the next, on page 11, about the workshop that we had at the beginning of this year. We called together, I would say, most of the experts in the United States, both from the industry side, laboratories, universities, people from the Staff were there. We heard detailed technical presentations of different views, as well as the basis of those views, for three days. The industry at those meetings emphasized the prevention of severe accidents. They also stressed that any fixes should be plant-specific, and they should derive from the individual plant examination program.

The variety of use and the probability of liner meltthrough consisted of elements like the way the vessel fails and releases the debris itself. There are different views as to the coherency or incoherency of the debris leaving the vessel itself, whether all of it leaves at once or whether the failure and the manner of spreading takes place over many hours, and that has substantial consequences on the liner itself.

Industry believes that water can prevent liner meltthrough. At this time, we as the Staff believe that water is beneficial, there is no question about it, but again there is no consensus on whether the liner fails and when. But again, as I stressed earlier, that is general agreement that water in the drywell is extremely useful to delay and prevent not only the liner, but to reduce the fission product release itself, and that is very important, which means that we can proceed, even though there are some areas of uncertainty, we can still proceed to make decisions and come forward with recommendations.

We think that the reliability of the ADS pressure is important, and improvements can be made there with modest cost.

Again, I mentioned venting. Venting was discussed extensively. It has the potential to reduce some core melt sequences and reduce the -- reduce the likelihood of some core melt sequences and, of course, it reduces consequences. It can

buy more time and, of course, there is always the downside of it, which we are looking at very carefully as part of a number of programs that we have underway.

As I also said already, we will need some additional research, most of it confirmatory, especially in the way the vessel fails and the way the core debris is released, and that is a generic problem, of course, in the severe accident area for all containment types and for all vessel types.

COMMISSIONER ROGERS: Before you leave that --

MR. SPEIS: Yes.

COMMISSIONER ROGERS: -- could you just sketch out very briefly what some of these improvements in the ADS are that you would be considering, and what do you mean by minor cost?

MR. SPEIS: Can you discuss it?

MR. SOFFER: Yes. Basically we are talking about increasing nitrogen gas bottle supply to enhance the reliability of the valve operators. There are some slight changes in logic. There are changes that would increase the temperature capability of some of the cables and some of the circuitry.

MR. MURLEY: They are relatively modest kinds of improvements.

MR. SPEIS: I'd like, on page 12, to summarize the PRA insights which will lead us into our strategy, and at that

time Dr. Murley will take over.

The dominant accident initiators in general have been shown to be important for boiling water reactors or station blackout sequences and ATWS sequences, and in a number of cases, loss of decay heat removal sequences, which I discussed earlier.

I think there have been -- there are something like 12 PRAs on Mark I types of plants. We have access to eight of them. Six of those have been done by NRC, and six by industry, and I understand that four more PRAs are underway for a total of 16.

As Dr. Murley said already, there is a wide variation in accident likelihood from these PRAs. Of course, some of them have been performed over a large period of time, in the last six to 10 years. Different models, different scenarios, different understanding of the technology.

Again we see that the BWRs don't stand as a class as far as risk is concerned, and we -- based on this insight and the summary that was given by Dr. Murley -- we think that further reductions in severe accident risk can be accomplished via prevention management, accident management, which means retaining the degraded core as much as possible in vessel, and accident mitigation.

I say here also that implementation of adequate venting procedures can reduce the core melt frequency for

sequences. These are the loss of decay heat removal sequences.

With this background and perspective, now Dr. Murley will go into some additional discussion of the Staff's approach, the so-called balanced approach, which involves prevention, mitigation, and --

COMMISSIONER ROGERS: Just before we leave that, you mentioned that there are disadvantages to venting, and it hasn't been clear to me just what they are. I haven't seen anything from you folks on that. I know you're uncomfortable with it. I wonder if you could just sum if, if you will.

MR. MURLEY: Yes, I'm going to.

COMMISSIONER ROGERS: Fine.

MR. MURLEY: I outlined kind of the reasoning of how we got to thinking the way we did, and Themmy amplified on it. Where it led us was to this balanced approach; namely, accident prevention, accident management, and accident mitigation.

I think we are all quite familiar with what we mean by prevention and mitigation, but the area where I believe we need to put more emphasis, we have not in the past perhaps put as much as we should, and that is the area of accident management.

It is possible to control the course of a core damage accident, even once you're beyond the design basis; that is, even once the fuel starts to overheat and melt, it does not mean that the plant automatically leads to breaching the vessel

and even containment failure.

It should be obvious, but we haven't focused on what we can do to enhance the capability of the plant to keep any debris in the vessel, but one only has to look at TMI-2 to realize that that in fact is what happened at -- during that accident.

The next chart, please.

CHAIRMAN ZECH: Page No. 14.

MR. MURLEY: Page No. 14. The accident prevention enhancements that we are considering are several:

First one listed is to accelerate the implementation of the ATWS rule, and I should say we have already started that. I started that last summer, to make sure that the BWR Mark I plants goes to the top of the queue and were implementing the ATWS rule, all the aspects of the ATWS rule.

We have now taken those actions. Most of the plants have implemented the various features of the rule.

Likewise, with regard to station blackout, we have not yet taken action, but I have asked the Staff to see what we can do to put the BWR Mark Is at the top of the queue on implementing station blackout.

I'll drop down to the bottom. I think the next of importance really is to improve emergency operating procedures.

CHAIRMAN ZECH: Before you go on to that, let me mention station blackout. In your paper, you note that the

implementation of ATWS, as well as station blackout rules, would reduce the likelihood of core damage, and I'd be interested in hearing what you might have to say on the implementation of those two rules regarding the risk of BWR Mark I's, for example, compared to PWRs. Could you comment on that a bit? Will those two rules make any significant impact on a comparison, for example, between BWR Mark I's and PWRs?

MR. MURLEY: I'll take a general answer, and then perhaps either Themmy or someone from my staff can answer in detail.

In BWRs, we find consistently that there is three accident sequences that dominate the risk. They are ATWS, station blackout, and overpressure transients. We think we can find ways to reduce the overpressure transients for these plants, so that leaves ATWS and station blackout then as the dominant risk contributors for BWRs. So we are attacking the right sequences for boilers, we are quite convinced of that.

Now how it would impact BWRs relative to PWRs, Themmy, are you prepared to --

MR. SPEIS: I don't have that number. The only thing I have, I can give you some quantified information, is that for station blackout, you know, it is an important sequence, and for example, if we can -- if a plant can increase its coping capability from two hours to eight hours, then the contribution of station blackout can be improved by a factor of 10. So we

are talking about substantial improvements in lessening the contribution of station blackout to the total core melt by accelerating the implementation. So I'm talking in general, you know, if you go from one point to another point.

MR. MURLEY: My staff advises me we should not try to give you a definitive answer at the table here. I would prefer not to do that, but we could -- we can try and answer that in writing.

CHAIRMAN ZECH: All right, fine.

MR. STELLO: But I believe we ought to, at least qualitatively. It is important. Those have consistently been shown to be important dominant sequences in the BWRS, and if it qualitatively -- we can answer that even further. In a BWR, you have many different ways in which to keep a core cool. So as long as you have an availability of electricity to supply electricity to various pumping systems -- and I think one time I counted, there are like 14 different systems -- you qualitatively know that a BWR is easier, just by its design, to prevent a core meltdown, and that makes it, by definition then, more sensitive to a back-up.

So inherently and qualitatively speaking, I think it's fairly obvious that they are important and they can make significant contributions to risk reduction by implementing those two features, ATWS and station blackout consistently show as being important.

CHAIRMAN ZECH: All right. Well, I think it would be of interest to the Commission to give us something on that when you can put it together.

MR. STELLO: Well, that is part of what we are doing in the 1150 program, and it will be included in it. You will see those sensitivities for the five most studied plants that we have.

CHAIRMAN ZECH: Well, since you made the point that ATWS and station blackout would reduce the likelihood of core damage, I think it's just kind of an obvious question. Yes, it does that; does it do that for PWRs, too? I presume it does.

MR. MURLEY: Yes. Yes.

CHAIRMAN ZECH: Make an improvement, so, in other words, then, is there greater improvement to BWRs than PWRs and, if so, what is the rationale that goes with it?

MR. STELLO: Let me answer it, and we'll try to get you specific analyses.

Qualitatively, the answer is clearly yes. And it is also important for PWRs, but it's more important for BWRs.

CHAIRMAN ZECH: Well, this is what I'm trying to find out, and also give us, you know, the rationale behind that. I think it would be of interest to the Commission.

MR. STELLO: And we will give you our analysis as part of that, that shows specifically in qualitative terms, to the best of our ability to do such analysis.

CHAIRMAN ZECH: Fine. I appreciate that.

MR. STELLO: We will.

CHAIRMAN ZECH: All right, let's proceed.

MR. MURLEY: At the bottom, the next item that we are looking at, and we will implement is improved operating, emergency operating procedures. The BWR Owners Group is now working on Revision 4. In fact, that revision is under review in NRR, and will be approved soon, we believe.

Once that's approved, then BWRs can implement it, and there is a general feeling on the Staff that these emergency procedures are significantly better for dealing with severe accidents than the previous procedures.

A third area that we are looking at for accident prevention is back-up source of water. Typically this would be the fire-water system. And some plants I'll mention in a minute have already taken steps to provide tie-ins from the fire-water system to their RHR system. So that means in effect that during a severe accident, we have now a completely new source of water supply for injection into the vessel, or even, for that matter, for containment spray purposes.

The fourth item is hardened vent capability, with the ability to open and reclose independent of AC power. Really this means independent of offsite and normal emergency diesel AC power. It could be that a utility would choose to bring in an alternate AC power supply, because by doing that, they can

meet several objectives, one of which is the station blackout rule.

We are finding, by the way, all through here the benefit of additional AC power supplies.

The hardened vent means --

MR. STELLO: I was going to say, you'll recall, Mr. Chairman, that we indicated that in the statement of considerations of the rule, that that was the Commission's preference in the solution of station blackout was in fact to supplement power supplies.

CHAIRMAN ZECH: Yes.

MR. MURLEY: And the studies that we are doing here reinforce that belief for severe accidents.

CHAIRMAN ZECH: Very good.

MR. MURLEY: The hardened vent is -- what that means is a hard pipe directly from the torus to the stack. The vents that generally are installed now are not hardened; that is, they go through the standby gas treatment system, several of them do, at least, and that is just a few psi system, so that at any actuation of the vent, it would blow out the ductwork and release steam and perhaps some radioactivity to the reactor building. There could be workers in the building at the time, or there could be equipment that was not qualified for those conditions.

Commissioner Rogers, you asked what are the side

effects of venting, and that is one, that --

COMMISSIONER ROGERS: Not if it's hardened.

MR. MURLEY: That's right. But if it's hardened, then that bypasses that particular problem.

I'll say a few more words about venting. I was initially skeptical last year that all the ramifications of containment venting had really been thought out, and that's because I'd seen the way it had been implemented at some of the plants, and it varied, quite frankly, all over the place.

So I asked the industry to do some homework last summer. The BWR Owners Group took that challenge on, as did Boston Edison in particular, and they have done some really quite excellent studies.

This is the BWR Owners Group study on venting that answered the questions that we asked, and indeed, we found that all the ramifications had not been considered, and in fact the way the venting had been implemented was probably not workable in some plants, or at least was not effective in what it was intended for.

So we find yet when the studies are all done, I have become convinced that venting is beneficial for accident prevention. There is little question that that's the case. But it has to be implemented carefully, and by carefully, I mean it has to have a pipe size that's large enough to take away the decay heat, and it also should not blow out into the

reactor building where it can damage equipment or people that are out there trying to cope with the accident.

So my conclusion -- we still -- this is not a firm recommendation yet, but it's certainly the way that we're headed -- is that venting is a good sensible procedure, it needs to be implemented carefully.

MR. STELLO: We ought to make clear that there is an issue on venting of the BWRs that was longstanding as part of the NUREG 737 -- am I right that they were included in the 737?

MR. SPEIS: Initial procedures.

MR. STELLO: Following TMI. They had this capability. I think where we are today is we now understand that the rather simplistic things that we had suggested at that point maybe were just too simple, but the idea of going in that direction is looking like if you do it correctly, it does have merit, and it is not that significant a change in a facility.

COMMISSIONER ROBERTS: It's not what?

MR. STELLO: Significant in terms of -- we're talking strictly the Mark I boiling water reactor.

CHAIRMAN ZECH: But are you --

MR. STELLO: We are not talking about the venting issue for the PWR. This is strictly the Mark I issue, which was already -- the Commission had already issued and decided on an issue of venting for the Mark I's in the 737. This goes beyond that.

CHAIRMAN ZECH: Are you saying that the way you're -- the direction you're going in means that you believe that it's possible to come up with the venting design and procedure that would apply to all BWR Mark I's?

MR. STELLO: That's the thinking we have at the time.

CHAIRMAN ZECH: A generic type design?

COMMISSIONER ROBERTS: Not plant-specific?

MR. MURLEY: Well, there -- excuse me. There are -- when you get down to details, they're all plant-specific, but every BWR now has in its operating procedures venting as a procedure. But when you go and look at how they have actually implemented in the procedures, you find that it varies all over the place. As I mentioned, some plants only have a one-inch line off their torus that they vent, which is -- it's just not useful at all for taking away any amounts of decay heat. Others have actually hardened pipes already. So it -- one thing we have concluded, that since they have got it in their procedures, the studies that the Owners Group themselves have done, they concluded very strongly that venting is a safety benefit, but that now you step to my conclusion, and that is it's got to be done correctly, though, to get that benefit.

CHAIRMAN ZECH: Which would lead one to believe that perhaps if the BWR Mark I containments have different features to them, that perhaps it would be a plant-specific vent, although the concept would be the same?

MR. MURLEY: Yes.

CHAIRMAN ZECH: In other words, the size and your emphasis on the careful design and so forth. It seems to me that it may have to have some plant-specific considerations into it.

MR. MURLEY: I should point out we're not talking about a separate filtered vent. The suppression pool is the filtration system, so all we're talking is a line from the air space of the suppression pool that would go to the stack, and the notion of the hardened vent is that some plants might have to put in a pipe that goes around any ductwork or any low pressure piping system. I'll mention that in a minute. Pilgrim has already done that, for example. It's not -- it's not a very significant thing, in my judgment, to do.

CHAIRMAN ZECH: These are the things you are still working on, I presume, and that you hope to conclude here in the next few months, so that I guess it was in the fall that you said, this year, you'll come to the Commission with a final recommendation.

MR. MURLEY: That's true.

MR. STELLO: We're not prepared today and --

CHAIRMAN ZECH: I understand, all the details, but this is the direction you're going --

MR. STELLO: That's correct.

CHAIRMAN ZECH: -- and --

MR. STELLO: We will finalize our recommendation this fall for the Commission.

CHAIRMAN ZECH: All right.

COMMISSIONER CARR: It is significant to have it work when you want it to work, and not work when you don't want it to.

MR. MURLEY: That's correct.

CHAIRMAN ZECH: Yes, that's exactly right, and this is why I do think that since it seems to me, anyway, that there are features of the Mark I's that are not the same, that it would be very important to -- carefully is your word, and I certainly agree with that, Tom -- very carefully ensure that any kind of a vent would indeed contribute to safety, and not the other way around. And so it may require some kind of plant-specific features that it would seem to me, and I'm sure you'll be looking into that as you proceed in the next few months.

MR. STELLO: Yes, Mr. Chairman.

COMMISSIONER ROGERS: I'd like to just say that I am very pleased to hear, you know, what you've been telling us today, and to commend the Staff for really taking a very careful approach here on this one, because I know that were reasons raised as to why not to move right ahead, and isn't it something that just obviously should be approved, and I think that your taking a very careful and studied approach to this

question has in the long run produced a much better result, and something we are going to feel a lot more comfortable with, and I found in talking to some of the people in the field that had received your 17 questions, that after they had really carefully considered them, they felt that they were very helpful in understanding their own situations much better.

So I think that, you know, you should hang in there when you feel you're on the right track and insist that all the issues be looked at that you're uncomfortable for, which is exactly what you've done here, and I just want to commend you.

MR. MURLEY: Thank you.

I'll have the next chart, please -- I guess it's 15 -- and move to the second aspect which is the -- as I said, the one I wanted to give more emphasis than I have in the past, and that is accident management.

Here again, some of the features that we are considering for accident management are the same that one finds for accident prevention. Improved emergency operating procedures, I expect that we will go ahead and approve Revision 4 very soon.

Back-up source for core cooling, that could be used to prevent a core melt accident, but it could also be used to arrest the progression of an accident that is underway. So it does have accident management capabilities as well.

The hardened vent, we have talked about.

We mentioned also improved reliability of the automatic depressurization system, ADS, and I think Mr. Soffer mentioned the sorts of things that we are considering there.

Some plants, for example, have decided, as looking through their own risk assessment, they have decided that it is important that they have DC power and so they have decided to bring in back-up gas-fired generators to make sure they can charge the batteries if they were to run down during a station blackout event.

These are just an example of the kinds of things that we are considering for accident management.

For accident mitigation, there are again the hardened vents can have -- can play a role in reducing any offsite fission product releases, even after the core is damaged and even after you have a molten core, if one can vent through the torus, then you have a system for scrubbing out fission products. So here again, a vent is of use.

The back-up supply of water, I think I mentioned that this typically is the fire-water system, and having a spool piece, a piece of pipe that connects the fire-water system, the RHR system, and procedures and training that allow the operators to do that, then allow one to, during a severe accident, to tie in the fire-water supply to the RHR, and that allows containment drywell spray capability, which could lead to fission product scrubbing, even in the event of a core melt

accident.

COMMISSIONER ROGERS: Excuse me. On that use of fire-water supply, aren't there some negatives on that, as well? I mean suppose that you do then need it for a fire.

MR. MURLEY: I guess -- I don't know whether we've systematically looked at that, but the thinking is that once you're into this sequence, the -- you do whatever you can to try to control the debris or to control the fission products. There's very little that a fire could make it worse, and I don't think just by tying into the fire-water system, I don't think it would remove the capability for fire suppression, for example. But I must say we haven't totally thought it out. Maybe we need to take a look at that.

On core debris control measures, we are looking at that. It's not a major effort that we're looking at, but this could be, for example, some bricks or materials down in the area underneath the vessel.

If we move to No. 17, you asked, Mr. Chairman, to discuss the industry efforts. First I should say it's not on this chart, but IDCOR has set up a severe accident working group, and they had their first meeting this week, and --

MR. STELLO: NUMARC.

MR. MURLEY: Excuse me, NUMARC. NUMARC set up the severe accident working group. They had this first meeting this week. They intend to work with us very closely. I have

had some discussions with NUMARC, and they are -- they said that they're going to approach this very positively, particularly in the accident management area, and work with the Staff.

The BWR Owners Group is discussing Revision 4 of the emergency operating procedures, actually the procedure guidelines, and that includes venting. We are very close to having that reviewed and approved.

Now two plants have taken some steps to improve their containments. Vermont Yankee has, it says, installed additional containment spray. Actually what they have done is, as I mentioned, they have tied in the fire-water system to their RHR system.

They have also taken some steps to provide more reliable AC power. They have an additional diesel generator which was already on site that they have improved and tied in to be able to operate some valves, so that one can take advantage of this additional water supply.

Vermont Yankee has also done a study of some I think 30 or 40 areas that their consultants have told them are possible ways to improve their containment. They have done, I think, quite a professional job of studying those. They have picked some out to implement and some they decided not for specific reasons.

So they are going beyond what we have required

already, but some of the things that they have done are the sorts of things that we're already considering recommending when we come to the Commission this fall.

Pilgrim, in addition, has a comprehensive safety enhancement program, and I list here some of the things they've done. They have brought on a third diesel generator on site. They have brought in back-up nitrogen supply. They used the fire protection diesel driven pumps for decay heat removal, and that is by tying in the fire-water system to the RHR system.

I believe they have also taken some steps to make the diesel more reliable.

It is not mentioned here, but they have gone and hardened their vent, but they have not installed it. There is some confusion on this matter. I think there's some thought that maybe the NRC Staff is preventing them from installing it, and that's not the case. I confirmed this with them just this week. They are holding themselves up. They said they want to wait until the NRC Staff completes our review and approval of Revision 4 of the emergency operating procedures.

COMMISSIONER CARR: Isn't it -- haven't they installed it and it's blank?

MR. MURLEY: That's right. They have installed the hardware. There's one more piece that would need to be installed to make it operational, plus, I think, some electrical connections and so forth. I think the valves are in

already, it's just they need to be connected.

In any case, it's -- once they decide to move ahead, then presumably we will review it and approve it.

COMMISSIONER ROBERTS: Maybe you've already said, but where do you stand on the Staff approval of Revision 4 to the Owners Group?

MR. MURLEY: We are nearly done with our review. My understanding is it will be in a month or so.

Yes, my staff confirms that it's imminent.

Chart 18, preliminary conclusions. I have, I guess, alluded to some of these as we have gone. Our studies aren't complete, but these are the things that appear tentatively attractive to us.

I would put No. 1 as the improved emergency operating procedures. I think I mentioned we have already started to implement the remaining ATWS requirements, and we will do so for station blackout, we will accelerate those.

The other areas that look attractive are back-up water supply, hardened vent, and improved reliability of ADS.

One of the things that we need to do in the next coming months is to get a better understanding of how much risk reduction these particular factions would entail, what they would cost, and just generally do the regulatory analysis we would need. It would get to the questions, Mr. Chairman, that I think that you had asked earlier. So that will be done in

the coming months.

19, please. Summary then of future Staff actions. We are going to complete a survey that we have undertaken of Mark I plants to make sure we understand what equipment they have, and just how they have implemented venting, for example, so that we understand it here.

I mentioned we are going to complete the assessment of the improvements, and the implementation of ATWS station blackout requirements.

Also there is an item here we are going to continue confirmatory research, which is quite a large program. I wonder, Eric, did you have anything to add on that?

MR. BECKJORD: On the confirmatory --

MR. MURLEY: Yes.

MR. BECKJORD: Well, there were just three points that I would make.

First of all, what has been done on research that's applicable to this. You've heard about a number of those items today relating to the effectiveness of spray and heat removal, and the effectiveness of cutting down on the source term, also on containment capabilities, the pressure capabilities of these containments, and the question of liner failure. We -- in the past year experiments were done on that question, and as noted, those were inconclusive.

Since that time, industry has done some testing on

their own, and I think, as indicated, at this point, we are not sure that the liner will fail, we are not sure that it won't fail, and some more work on that may be indicated. That's one of the things that we will be looking at.

There is research under way right now which affects the Mark I. That's been -- the accident management work has gotten under way this year, and we are studying, as Tom said, the question of venting, the effect of venting on risk.

Now that we have this paper, we are going to be looking between now and the final recommendation to the Commission what's indicated in any further work and confirmatory research that would be important, and I expect that we will include that recommendation in the final paper.

And the other point I'd like to make is that if when we do determine what else should be done on confirmatory research, I would -- it would be my intention to go to the industry, the owners groups, to see what we can put together in the way of a cooperative program, much in the same way as we did on some B&W matters earlier this year, and we were able to get a good program out of that, a good cooperative program. So I would attempt to do the same thing in this case.

MR. MURLEY: Okay. Could I have the last slide, please. 20.

It should be pretty clear from this discussion that Research and NRR are working in lock step in this, and we are

very close on this whole matter.

This just summarizes that the activities we have ahead of us are to analyze the risk reduction potential of the various improvements that we're looking at; to look at the costs, prepare regulatory analysis, and then come to the Commission in the fall with our conclusions.

That summarizes my presentation.

MR. STELLO: That's it, Mr. Chairman.

CHAIRMAN ZECH: All right. Thank you very much.

Any questions, my fellow Commissioners? Commissioner Roberts?

COMMISSIONER ROBERTS: No question, just a comment. I think it's important to remember what both Dr. Murley and Dr. Speis emphasized, I think pointedly, that BWR Mark I plants are not risk outliers.

MR. MURLEY: Correct.

COMMISSIONER ROBERTS: That's all I have.

MR. STELLO: Well, Mr. Chairman, I want to say that what we have -- I don't want to disagree with that, but there clearly are things that can and ought to be done --

COMMISSIONER ROBERTS: I don't disagree with that.

MR. STELLO: -- and we are going to come to the Commission with those recommendations in the fall.

CHAIRMAN ZECH: All right. Thank you.

Commissioner Carr?

COMMISSIONER CARR: Could I pin you down a little more on the "in fall," you'll be back in the fall with these answers? That's a long -- you know --

MR. STELLO: At this meeting I would prefer --

COMMISSIONER CARR: The next month is August, and that's right here.

MR. STELLO: September 21st is fall. And I say, well, since September 21st is fall, we want to sort of make that the date. What I'd rather do is to sit down carefully -- I get frustrated when I have to continue to change these dates for the Commission, and I want to take the time this time to know a little bit more before we finalize that date so I don't have to continue to change it, and with the patience of the Commission, we'll go back and do that and come up with a date that we're pretty sure we're going to meet.

COMMISSIONER CARR: Dr. Murley knows that we're all going to want an answer pretty soon. He also has a promissory note.

MR. MURLEY: Yes.

MR. STELLO: We will do the best we can, but again I want to make sure that we can live up to this commitment; because it's going to be looked at by many.

COMMISSIONER CARR: If you get those improved procedures out in a month or so, that's about -- may perhaps coincide with the Pilgrim desire to start up. Are we going to

require them to practice those procedures before they start up, or have you --

MR. MURLEY: If they -- it depends on the timing, but if they choose to implement them before start-up, absolutely, we will require them to be trained on the simulator. We'll probably want to observe them. Yes, there's no question. I think, quite frankly, they're waiting for us.

CHAIRMAN ZECH: Commissioner Rogers?

COMMISSIONER ROGERS: Well, I was just a little concerned about what the training aspects of the emergency operating procedures plan will be, and how fast that can be taken care of once those procedures are out.

MR. MURLEY: I don't have a good generic answer for you. Some plants, I know -- Pilgrim being one -- are well along in their training, and they could implement them quickly. But for a plant that has not yet started to revise their procedures and to train their people, it could be some time.

COMMISSIONER ROGERS: Do you have any idea of how long a training program on this specific aspect would entail, what that would be?

MR. STELLO: Maybe I can help. I recall when, I think it was Vermont Yankee made the first switch, I believe they had to program those to do the retraining during a refueling outage so they would be able to cycle the operators in, in some systematic way, and I think that was like six or

eight weeks. Maybe that helps you.

COMMISSIONER ROGERS: Okay.

CHAIRMAN ZECH: Do you feel that the emergency operating procedures for the Mark I plants represent a reasonable starting point for development of accident management strategies? In other words, could you carry that on, emergency operating procedures, would it go forward into your thinking regarding severe accidents?

MR. MURLEY: Yes. In fact, I think the Revision 4 of the emergency procedure guidelines are well into the -- what we call severe accident space, and the notion of pushing them even further is kind of what I had in mind for accident management.

The BWR Owners Group is ahead of the others, so our job is to also work with the other owners groups. But you're exactly right, that's where we're heading.

CHAIRMAN ZECH: Well, let me just say, too, I believe that, you know, the whole issue we're talking about, I know we were just talking about the Mark I's today, and the containment for the Mark I's, but the whole issue of severe accidents is such an important one, and I think moving in that direction, and all the related issues and the way you're integrating that, Mr. Stello, I think is exactly the right approach to take.

I do think that regarding the Mark I containments, that it is important that if you are moving towards vents, that you do so just as you have stated, carefully and deliberately,

and make sure we make things safer than present problems that could result, perhaps, in detracting from safety. That's extremely important. And I do think, too, that as you analyzed the different features, perhaps, in the Mark I containments, that we also review very carefully any design so that again we contribute to safety rather than detract from safety.

So I think that the Commission will be very anxious to follow closely the rationale you're using as you approach your recommendation in the fall.

We are talking about a very important issue, even though it is applicable to only the BWR plants with Mark I containments. As far as I'm concerned, the concept of venting, perhaps, goes beyond just that group of plants, and I'm sure that you will be thinking about that as you move along.

Let me just say I think that the Staff has acted very responsibly in this regard. I know there has been criticism that we are not moving ahead rapidly enough. I, for one, want to make sure we do the right thing, and that we contribute to safety, rather than detract from safety.

We also, of course, are interested in if you have made this conclusion, when you do make it, to move expeditiously towards such an improvement. But so it is a combination of continued careful analysis, plus the priority of moving it ahead so that if you have made the conclusion that we should go ahead and take whatever regulatory actions that we

think are appropriate. But I commend the Staff for the approach you are taking. I, too, think you are on exactly the right track, and we will be anxiously watching your progress and waiting for your final recommendation.

Again, let's contribute to safety, rather than detract from safety.

Any other comments?

COMMISSIONER CARR: I have one comment.

CHAIRMAN ZECH: Yes.

COMMISSIONER CARR: If you're going to -- when you authorize that vent to be installed, do you install intend to provide guidance on when to use it?

MR. MURLEY: That is embedded in the procedures, and as we review the procedures --

COMMISSIONER CARR: It's a very tough decision.

MR. MURLEY: We are very mindful of how it's being used, and the implications of its use, but that's embedded in the procedures.

CHAIRMAN ZECH: And I agree with that, it's a very important comment from Commissioner Carr, and along the same line, I think it's going to be important to decide who's going to make that decision, who's going to make the decision to vent the plant. My understanding of what you've got in mind is it would be the utility itself, and that is, of course, something I'm sure that you will want to consider. But that is indeed

also a very important decision.

MR. STELLO: You can assure that we will also include such a step in a procedure as part of our monitoring accidents at plants. We would probably clearly be aware of and involved in, whether we wished to or not.

CHAIRMAN ZECH: And I think that is most appropriate, because it would be a very important decision to make.

MR. MURLEY: Mr. Chairman, there is one point on this discussion. As the studies were done, and particularly with the Boston Edison study, what emerged was that the vent in a BWR Mark I would be used approximately 99 percent of the time to prevent a core melt accident, and only less than 1 percent of the time would it be used in mitigation.

So that's what, as I said, convinced me of the importance of its use, and so that most of the time, 99.4 percent of the time, it would be venting steam and not any substantial fission products.

COMMISSIONER CARR: But to prevent a buildup of pressure, to rupture containment is --

MR. MURLEY: That's right. So the venting that we're talking about here --

COMMISSIONER CARR: You're really looking at a controlled release instead of an uncontrolled release?

MR. MURLEY: It's primarily to remove decay heat, so that you don't rupture the containment and don't melt the core.

COMMISSIONER CARR: A controlled release of pressure there.

CHAIRMAN ZECH: And you're talking about again releasing nonfission products 99.4 percent of the time?

MR. MURLEY: That's correct.

CHAIRMAN ZECH: And it's that .6 percent of the time that you would, of course, be very concerned about venting under that circumstance, too. There's a lot of difference between the 99.4 percent when you release steam, and the .6 percent when you might release fission products.

MR. MURLEY: And it should go without saying that these conclusions only apply to the plants that we looked at, the Mark I plants. They don't apply necessarily to any other BWRs or PWRs, the issue of venting. We have yet to look at that and come to a conclusion.

CHAIRMAN ZECH: Dr. Speis, do you have a comment that you're anxious to make?

MR. SPEIS: No. I wanted to make sure that he made the last comment.

CHAIRMAN ZECH: All right.

Mr. Stello, anything else?

MR. STELLO: No, sir, I'm finished.

CHAIRMAN ZECH: All right. Thank you very much. We stand adjourned.

[Whereupon, at 11:20 a.m., the meeting was

adjourned.]

CERTIFICATE OF TRANSCRIBER

This is to certify that the attached events of a meeting of the U.S. Nuclear Regulatory Commission entitled:

TITLE OF MEETING: BRIEFING ON INTERIM REPORT ON BWR MARK I CONTAINMENT ISSUES

PLACE OF MEETING: Washington, D.C.

DATE OF MEETING: FRIDAY, JULY 22, 1988

were transcribed by me. I further certify that said transcription is accurate and complete, to the best of my ability, and that the transcript is a true and accurate record of the foregoing events.

Ann Riley

Ann Riley & Associates, Ltd.

COMMISSION BRIEFING
ON
STATUS OF MARK I CONTAINMENT
PERFORMANCE EVALUATION

THEMIS P. SPEIS, RES
THOMAS E. MURLEY, NRR
U. S. NUCLEAR REGULATORY COMMISSION
JULY 22, 1988

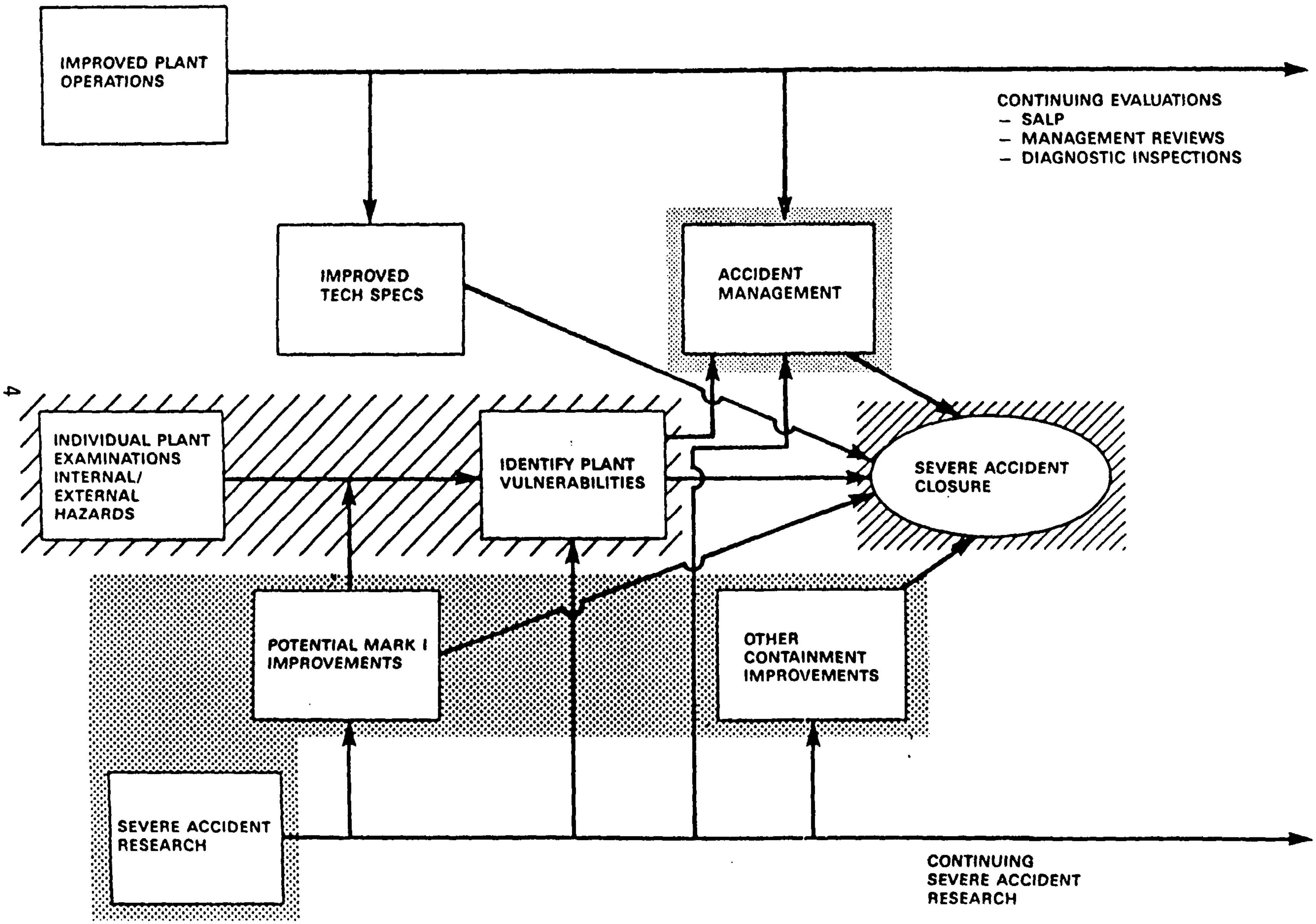
BRIEFING OUTLINE

- BACKGROUND
- SEVERE ACCIDENT PROGRAM
- CONTAINMENT PERFORMANCE IMPROVEMENTS PROGRAM OBJECTIVES
- CHALLENGES TO MARK I CONTAINMENTS
- MARK I CONTAINMENT FAILURE MODES
- MARK I CONTAINMENT MARGINS
- MARK I WORKSHOP RESULTS/CONCLUSIONS
- PRA INSIGHTS FOR BWR's
- STAFF'S APPROACH TO MARK I IMPROVEMENTS
  - ACCIDENT PREVENTION
  - ACCIDENT MANAGEMENT
  - ACCIDENT MITIGATION
- INDUSTRY EFFORTS
- PRELIMINARY CONCLUSIONS
- STATUS OF ACTIVITIES/FUTURE STAFF ACTIONS

BACKGROUND

- JUNE 1986, STAFF PROPOSED 5 ELEMENT PROGRAM FOR MARK I CONTAINMENT PERFORMANCE ENHANCEMENT
- JUNE-JULY 1987, TWO LICENSEES INFORMED THE STAFF OF THEIR INTENTION TO INVESTIGATE CONTAINMENT AND SAFETY ENHANCEMENT
- JULY 1987, STAFF BRIEFED COMMISSION ON A PLAN FOR CLOSURE OF SEVERE ACCIDENT ISSUES
- DECEMBER 1987, "MARK I CONTAINMENT PERFORMANCE PROGRAM PLAN", (SECY-87-297)
- FEBRUARY 1988, WORKSHOP ON MARK I ISSUES
- MAY, 1988, "INTEGRATION PLAN FOR CLOSURE OF SEVERE ACCIDENT ISSUES", (SECY-88-147)

FIGURE 1
SEVERE ACCIDENT PROGRAM - SCHEMATIC



<u>CONTAINMENT PERFORMANCE IMPROVEMENT PROGRAM</u>

- <u>OBJECTIVE:</u>

  DETERMINE WHAT ACTIONS, IF ANY, SHOULD BE TAKEN TO REDUCE VULNERABILITY OF CONTAINMENTS TO SEVERE ACCIDENT CHALLENGES

- STAFF EFFORTS FOCUSED INITIALLY ON MARK I's

- OTHER CONTAINMENT TYPES TO BE ADDRESSED, AS WELL

<u>BWR MARK I CONTAINMENT CHALLENGES</u>

- CONTAINMENT COULD BE CHALLENGED BY LARGE SCALE CORE MELT, PRINCIPALLY DUE TO SMALLER SIZE

- SEVERAL EARLY CONTAINMENT FAILURE MODES IDENTIFIED

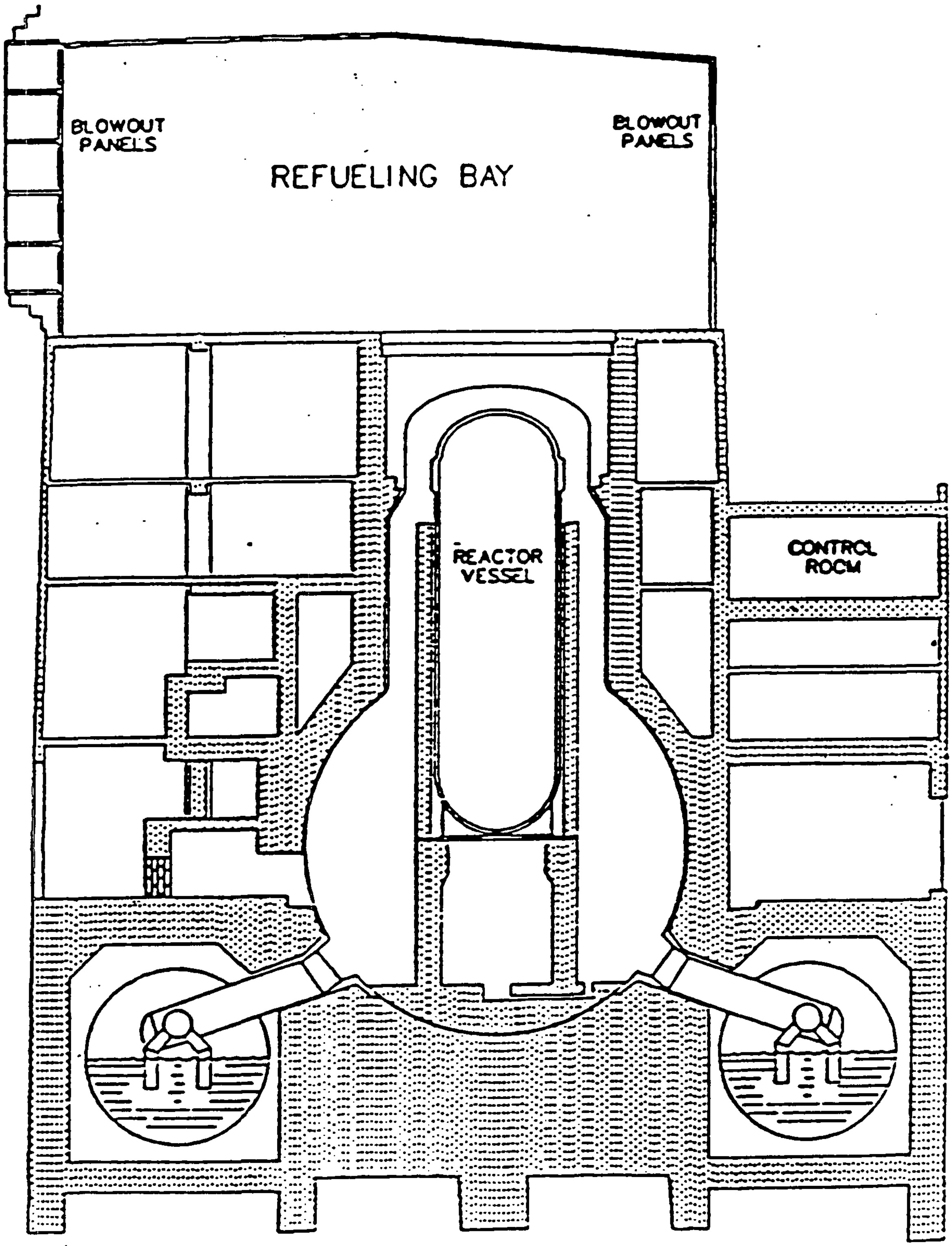
BUT, MUST EMPHASIZE THAT

- BWR MARK I PLANTS ARE <u>NOT</u> RISK OUTLIERS AS A CLASS, AND

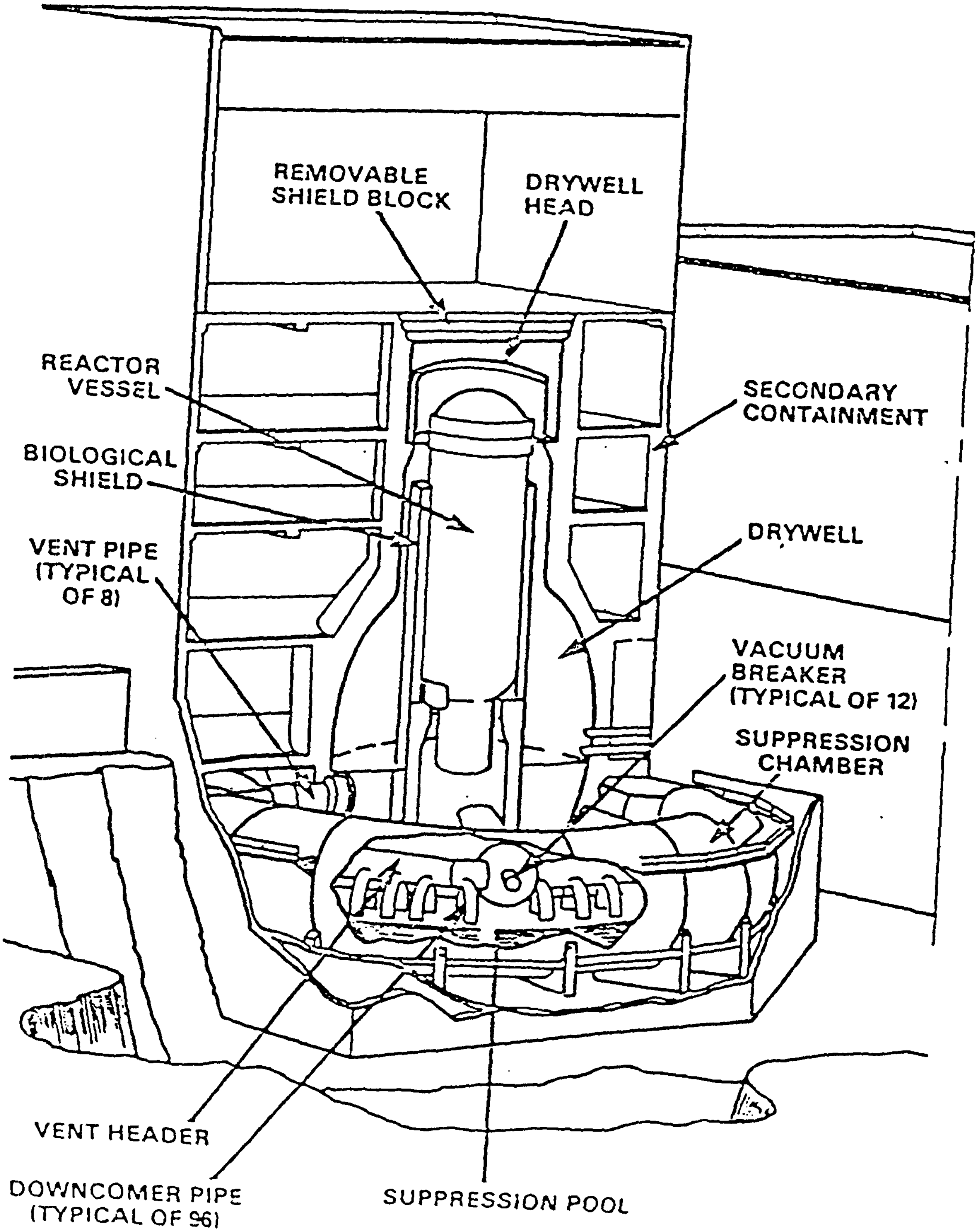
- ESTIMATES OF CONTAINMENT FAILURE, ESPECIALLY LINER MELT-THROUGH, ARE HIGHLY UNCERTAIN

LOCATION OF THE MK I PRIMARY CONTAINMENT WITHIN THE SECONDARY CONTAINMENT (REACTOR BUILDING)

ORNL-DWG 82-5181 ETD



-BWR PRIMARY CONTAINMENT IS PROVIDED BY THE DRYWELL AND WETWELL; SECONDARY CONTAINMENT IS PROVIDED BY THE SURROUNDING STRUCTURE.



FAILURE MODES IN MARK I CONTAINMENTS

	FAILURE MODE	RISK IMPORTANCE
1.	OVERPRESSURIZATION: OVERPRESSURIZATION LEADING TO CORE DAMAGE (I.E., CONTAINMENT FAILURE BEFORE CORE MELTING)	YES+
2.	STEAM EXPLOSION: MISSILE	NO
3.	FAILURE TO ISOLATE*	NO
4.	HYDROGEN BURN/DETONATION	NO
5.	OVERPRESSURIZATION: (CORIUM/CONCRETE INTERACTION PLUS STEAM)	YES
6.	OVERTEMPERATURE: (CORIUM/CONCRETE INTERACTION)	YES
7.	STEEL CONTAINMENT MELT-THROUGH	VARIABLE**
8.	INTERFACING LOCA: (CONTAINMENT BYPASS)*	NO

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*MITIGATION FEATURES ARE INEFFECTIVE AGAINST THESE FAILURES. THEIR PROBABILITY CAN BE REDUCED BY PROCEDURAL/DESIGN CHANGES.

**DEPENDS ON CORIUM'S ABILITY TO FLOW TO AND MELT THROUGH THE LINER

+IN THE ABSENCE OF WETWELL VENTING

MARK-I STRUCTURAL MARGINS

ACCIDENT CONDITIONS	FAILURE MODE	ESTIMATED FAILURE PRESSURE RANGE
PRESSURE/TEMPERATURE CHALLENGE (BEFORE VESSEL BREACH OR WITH COOLABLE DEBRIS)	TORUS FAILURE IN WETWELL	130 - 180 PSIG
	LEAKAGE THROUGH DRYWELL HEAD FLANGE	120 - 180 PSIG
SIGNIFICANT CORE-CONCRETE INTERACTION BUT NO SHELL MELT THROUGH	LEAKAGE THROUGH DRYWELL HEAD FLANGE	125 - 150 PSIG (AT 800F^{O}) 50 - 90 PSIG (AT 1200F^{O})

- O PRESSURES REQUIRED TO BURST THE CONTAINMENT SHELL ARE GREATER THAN FOR THESE MODES
- O WHETHER "LOW" TEMPERATURE FAILURE IS IN WETWELL OR DRYWELL DEPENDS ON PLANT-SPECIFIC DETAILS OF HEAD BOLT DESIGNS AND PRELOADS USED.
- O MARK-I OWNERS' GROUP IS CURRENTLY SPONSORING A STUDY OF PLANT-TO-PLANT VARIABILITY.
- O "HIGH" TEMPERATURE SCENARIOS FORCE FAILURES INTO THE DRYWELL.

SUMMARY OF FEB. 24-26, 1988 BWR MARK I WORKSHOP

- THREE-DAY MEETING WITH 150 INDUSTRY, RESEARCHER, STAFF AND PUBLIC REPRESENTATIVES

- INDUSTRY EMPHASIS ON PREVENTION. ANY FIXES SHOULD BE PLANT SPECIFIC FROM IPE.

- VARIETY OF VIEWS ON PROBABILITY OF LINER MELT-THROUGH
  - MANNER OF VESSEL FAILURE AND RELEASE OF DEBRIS IMPORTANT
  - INDUSTRY BELIEVES WATER CAN PREVENT LINER MELT-THROUGH
  - WATER BENEFICIAL, BUT NO CONSENSUS FROM NRC RESEARCHERS ON WHETHER LINER FAILS AND WHEN

- GENERAL AGREEMENT--WATER IN DRYWELL USEFUL TO DELAY/ PREVENT SHELL FAILURE AND TO REDUCE FISSION PRODUCT RELEASES

- AGREEMENT THAT ADS RELIABILITY IMPORTANT. IMPROVEMENTS ACHIEVABLE AT MODEST COST.

- POTENTIAL POSITIVE AND NEGATIVE SAFETY IMPACTS OF VENTING
  - REDUCE CORE-MELT LIKELIHOOD, REDUCE CONSEQUENCES, BUY TIME
  - POTENTIAL FOR UNNECESSARY RELEASE, INCREASE CORE-MELT LIKELIHOOD FOR SOME SEQUENCES

- MORE FOCUSED RESEARCH NEEDED ON
  - VESSEL FAILURE AND DEBRIS RELEASE
  - VESSEL FAILURE CHARACTERISTICS AND LIKELIHOOD OF LINER MELT-THROUGH WITH WATER

PRA INSIGHTS FOR BWRs

- DOMINANT ACCIDENT INITIATORS (INTERNAL) ARE:
  - STATION BLACKOUT (SBO)
  - ATWS
  - LOSS OF DECAY HEAT REMOVAL (TW)+
- WIDE VARIATION IN ACCIDENT LIKELIHOOD
- OVERALL RISK LOW
- FURTHER REDUCTIONS IN SEVERE ACCIDENT RISK VIA ACCIDENT PREVENTION, MANAGEMENT, MITIGATION (BALANCED APPROACH) POSSIBLE
- IMPLEMENTATION OF ADEQUATE VENTING PROCEDURES CAN REDUCE THE CORE MELT FREQUENCY FOR TW SEQUENCES BY AN ORDER OF MAGNITUDE OR MORE

+IN THE ABSENCE OF WETWELL VENTING

STAFF APPROACH

BALANCED APPROACH
TO
REDUCE OVERALL RISK

ACCIDENT PREVENTION

REDUCE THE LIKELIHOOD OF AN ACCIDENT OCCURRING

ACCIDENT MANAGEMENT

CONTROL THE COURSE OF AN ACCIDENT AND RETURN PLANT TO STABLE STATE

ACCIDENT MITIGATION

REDUCE THE CHALLENGE TO CONTAINMENT AND THE MAGNITUDE OF RADIOACTIVE RELEASES TO ENVIRONMENT

POTENTIAL ACCIDENT PREVENTION ENHANCEMENTS

- ACCELERATE IMPLEMENTATION OF ATWS (SOME REQUIREMENTS FOR SOME PLANTS) AND STATION BLACKOUT RULE
- BACKUP SOURCE OF WATER TO RHR SYSTEM WITH PUMPING CAPABILITY INDEPENDENT OF NORMAL AND EMERGENCY AC POWER SOURCES
- HARDENED VENT CAPABILITY WITH ABILITY TO OPEN AND RECLOSE INDEPENDENTLY OF AC POWER
- IMPROVED EMERGENCY OPERATING PROCEDURES

POTENTIAL ACCIDENT MANAGEMENT ENHANCEMENTS

- BACKUP SOURCE OF WATER TO RHR SYSTEM TO COOL CORE AND TO ARREST FURTHER PROGRESSION OF ACCIDENT
- HARDENED VENT CAPABILITY
- IMPROVED EMERGENCY OPERATING PROCEDURES
- BACKUP GENERATOR TO CHARGE BATTERIES
- IMPROVED RELIABILITY OF AUTOMATIC DEPRESSURIZATION SYSTEM (ADS)

POTENTIAL ACCIDENT MITIGATION ENHANCEMENTS

- BACKUP SOURCE OF WATER FOR CONTAINMENT AND DEBRIS COOLING, AND FISSION PRODUCT SCRUBBING

- HARDENED VENT CAPABILITY

- CORE DEBRIS CONTROL MEASURES

INDUSTRY EFFORTS

- BWROG IS DISCUSSING WITH STAFF REVISION 4 TO THE EPG's, WHICH INCLUDES VENTING OF CONTAINMENT
- VERMONT YANKEE INTENDS TO INSTALL ADDITIONAL CONTAINMENT SPRAY SYSTEM CAPACITY DURING 1989 REFUELING OUTAGE
- PILGRIM HAS DEVELOPED A SAFETY ENHANCEMENT PROGRAM WHICH INCLUDES:
  - THIRD ONSITE DIESEL GENERATOR
  - BACKUP NITGROGEN SUPPLY FOR ADS AND MAINTAINING CONTAINMENT INERTED
  - USE OF FIRE PROTECTION DIESEL DRIVEN PUMPS FOR DECAY HEAT REMOVAL
  - INCREASED CONTAINMENT SPRAY CAPABILITY

PRELIMINARY CONCLUSIONS

STAFF ASSESSMENTS NOT YET COMPLETE, BUT THE FOLLOWING TENTATIVELY APPEAR ATTRACTIVE IN TERMS OF BOTH POTENTIAL RISK REDUCTION AND IMPLEMENTATION COSTS:

- ACCELERATED IMPLEMENTATION OF REMAINING ATWS AND STATION BLACKOUT REQUIREMENTS
- IMPROVED EMERGENCY OPERATING PROCEDURES
- BACKUP SOURCE OF WATER TO RHR AND CONTAINMENT SPRAYS WITH PUMPING CAPABILITY INDEPENDENT OF NORMAL AND EMERGENCY AC POWER SOURCES
- HARDENED VENT CAPABILITY WITH ABILITY TO OPEN AND RECLOSE INDEPENDENTLY OF AC POWER
- IMPROVED RELIABILITY OF AUTOMATIC DEPRESSURIZATION SYSTEM (ADS)

FUTURE STAFF ACTIONS

1. COMPLETE SURVEY OF MARK I PLANTS WITH REGARD TO EQUIPMENT AVAILABILITY FOR SAFETY ENHANCEMENTS

2. COMPLETE STAFF ASSESSMENT OF POTENTIAL MARK I IMPROVEMENTS

3. ACCELERATE IMPLEMENTATION OF REMAINING ATWS AND STATION BLACKOUT REQUIREMENTS

4. IMPLEMENT IMPROVED EMERGENCY OPERATING PROCEDURES AND TRAINING RELATED TO ACCIDENT MANAGEMENT

5. CONTINUE CONFIRMATORY RESEARCH ON MARK I VESSEL FAILURE PROGRESSION, THE POTENTIAL FOR LINER MELTTHROUGH, AND SOURCE TERMS ASSOCIATED WITH A NUMBER OF SEVERE ACCIDENT MANAGEMENT STRATEGIES

ACTIVITIES TO COMPLETE ASSESSMENT OF POTENTIAL MARK I IMPROVEMENTS

- ESTIMATE IMPACT OF POTENTIAL IMPROVEMENTS ON CORE MELT FREQUENCY FOR DECAY HEAT REMOVAL ACCIDENT SEQUENCES (PREVENTIVE VALUE)
- ESTIMATE IMPACT OF POTENTIAL IMPROVEMENTS ON CONTAINMENT INTEGRITY AND SOURCE TERMS (ACCIDENT MANAGEMENT AND MITIGATIVE VALUE)
- QUANTIFY ANTICIPATED RISK REDUCTION
- ESTIMATE IMPACT OF POTENTIAL IMPROVEMENTS
- PREPARE REGULATORY ANALYSIS IN CONFORMANCE WITH 10 CFR 50.109
- CONSIDER OTHER FACTORS AS APPROPRIATE
- PRESENT THE RESULTS TO THE COMMISSION

July 15, 1988

POLICY ISSUE
(Information)

SECY-88-206

For: The Commissioners

From: Victor Stello, Jr.
Executive Director for Operations

Subject: STATUS OF MARK I CONTAINMENT PERFORMANCE EVALUATION

Purpose: To present the status of the BWR MARK I containment performance improvement program as discussed in SECY 87-297 and SECY 88-147.

Summary: As noted in the Integration Plan for Closure of Severe Accident Issues (SECY 88-147), the staff has undertaken a program to determine what actions, if any, should be taken to reduce the vulnerability of containments to severe accident challenges. Staff efforts have focused initially on the BWR MARK I containment. The staff has almost completed its assessment of generic severe accident challenges and failure modes as well as potential containment performance improvements for the MARK I containment. The staff expects to complete its MARK I assessment and to make recommendations to the Commission in the fall of 1988.

The containment performance improvement effort is one main element of the integrated approach to closure of severe accident issues, as indicated in SECY 88-147. Other main elements include a) the Individual Plant Examinations (IPEs), b) improved plant operations, c) severe accident research program, d) examination of external events, and e) a program on accident management. The containment performance improvement program is related to the IPE effort, and is considered complementary to it, since this effort is primarily focused on the potential generic vulnerabilities of specific containment classes, whereas the IPE effort is focused on plant unique vulnerabilities. Containment performance studies for the other containment types are scheduled for completion in the Fall of 1989.

Probabilistic Risk Assessment (PRA) studies have been performed for a number of BWR's with MARK I containments. Although these PRA studies do not show the BWR MARK I plants to be risk outliers as a class relative to other plant designs, they do suggest that the MARK I containment could be challenged by a large scale core melt accident, principally due to its smaller size. However, estimates of containment failure likelihood under such conditions are based on uncertain calculations of complex accident conditions, where even the experts in the field do not agree on the likelihood of containment failure.

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492-3916

In placing this issue in perspective, therefore, it is important that our primary attention should be focused on reducing overall risk, and not merely on reducing the conditional containment failure probability by itself.

The staff has concluded that the optimum way to reduce overall risk in BWR MARK I plants is to pursue a balanced approach utilizing accident prevention, accident management and accident mitigation. Most recent PRA studies indicate that BWR MARK I risk is dominated by Station Blackout and ATWS sequences. Therefore, improvements in electrical power supply reliability and in reactor scram reliability are elements of the balanced approach being pursued by the staff. The balanced approach includes: a) accident prevention - those features or measures that are expected to reduce the likelihood of an accident occurring, b) accident management - those features or measures that the operating staff can use to control the course of an accident and return the plant to a controlled, safe state, and c) accident mitigation - those features or measures that can reduce the magnitude of radioactive releases to the environment in the event of an accident.

<u>Background:</u> The Reactor Safety Study (WASH-1400) issued in 1975 found that for the Peach Bottom BWR the probability of accidents leading to core melt was relatively low. However, the containment could be severely challenged if a large core melt did occur. These challenges tended to offset the benefits of low core melt probabilities. The study acknowledged the uncertainty in extrapolating core damage accidents to other BWR plants, but implied that the containment challenges were similar. This study clearly demonstrated the importance of the containment function.

The Three Mile Island (TMI) accident in 1979 demonstrated that accidents leading to core melt can occur, and that operator actions are an important factor in subsequent accident progression. A number of actions by both the NRC and the industry followed the TMI accident.

These actions emphasized improved plant operations, human factor considerations, realistic performance of systems and probabilistic risk assessments. Also the scope and diversity of research into severe accident phenomena was increased substantially. While many of the programs being conducted by the staff deal with understanding severe accident phenomena and examining the risk contribution from systems and components, improving plant operations is an area in which actions resulting in substantial risk reductions are possible and are being taken. Emphasis on improving plant operations is a critical element of the staff's overall closure plan for severe accidents. Among the procedural improvements was a requirement for implementing emergency operating procedures based upon the symptoms of events that could lead to accidents, as well as the management of

events once an accident had been initiated. One important result of this requirement has been the development of a strategy for containment venting at MARK I plants to help prevent and to some extent mitigate accidents. This strategy should be viewed as a last-ditch strategy which is not to be taken lightly and not to be taken without full recognition of possible competing risks involved.

Research since the TMI accident has identified the primary containment challenges and potential failure modes for BWR MARK I containments (see Table 1). Research has also resulted in a significantly improved understanding of early containment failure modes such as very early overpressure and overtemperature challenges as well as in-vessel steam explosions (low likelihood), and combustible gas induced containment failure (low likelihood for MARK I plants). A great deal of attention has been given over the years to the design, construction, and leak testing of containments. We have learned much about the relative magnitude of the margins between design and failure from overpressure and overtemperature challenges.

These margins of safety provided by applying conservative loading combinations in the design of containments have been the subject of considerable research and evaluation, and these studies have shown the ability of modern containment systems to survive realistic pressure loading challenges well beyond design levels. Because of these margins, the various containment types presently utilized in the United States have the capability to withstand, to varying degrees, many of the challenges presented by severe accidents even though not designed primarily for that purpose. For each type of containment, however, there remain failure mechanisms depending on both the accident scenarios involved and the containment types. For example, recent research has identified a potential MARK I containment failure mechanism associated with possible meltthrough of the steel containment shell. Regarding this potential failure mode there is a wide range of views about its relative probability (see Enclosure 4). Both the NRC and industry currently have ongoing research programs to address this issue including efforts to estimate its likelihood as well as the consequences of loss of containment integrity via this failure mechanism. For example, even though, as mentioned above, there is a wide range of views among researchers on the relative probability of liner failure, there is broad agreement that the presence of water in the containment will scrub fission products and could reduce radionuclide releases even if containment shell meltthrough were to occur. As will be seen later in this paper, one of the safety enhancement strategies which the staff is presently evaluating involves the use of a backup water supply for use in mitigating the potential consequences of this failure mechanism.

A five-element program was proposed in June 1986 to enhance the performance of the MARK I containment. Elements of this program

included a) hydrogen control, b) containment drywell spray, c) containment venting, d) core debris control, and e) emergency procedures and training. A primary purpose of this program was to preserve for as long as possible suppression pool scrubbing for the principal core damage and risk contributing scenarios. After the initial proposal, the staff held two separate meetings in early 1987 with researchers representing NRC contractors, and with those representing industry. There was a wide range of views expressed regarding accident phenomenology as well as the efficacy of the various improvements. The range of views differed not only between NRC contractors and industry, but differed significantly among NRC contractors as well. In view of the lack of technical consensus on the effectiveness of the proposed improvements, the staff undertook additional efforts and evaluations.

In July 1987, the staff informed the Commission that it intended to examine the MARK I issue in the context of an integrated approach to the closure of severe accident issues.

On December 8, 1987, the staff issued a plan (SECY 87-297) for resolving generic severe accident containment performance issues for MARK I and other containment types.

As part of the additional efforts noted above, a workshop was held on February 24-26, 1988 to discuss a number of issues associated with MARK I containment challenges, failure modes and potential containment improvements with researchers, industry representatives and interested members of the public. A major topic at the workshop was the phenomena associated with containment shell meltthrough, means to reduce its likelihood, and methods to mitigate its consequences. A summary of the primary conclusions and insights is provided in Appendix 1.

Discussion: MARK I designs have been used for 24 U.S. plants (see Table 2) at 17 different sites. All MARK I units are typified by an inverted light-bulb design with a torus-shaped suppression pool filling the lower area (see Figure 1). All but two units have steel containment shells constructed on a concrete pedestal. Brunswick Units 1 and 2 have steel lined reinforced concrete containments. There are dimensional, material and equipment differences among the MARK I plants, but they all share the same pressure suppression concept and geometry.

Challenges to MARK I Containments - Probabilistic Risk Assessment (PRA) studies for BWRs indicate that accidents initiated by transients rather than Loss-Of-Coolant Accidents (LOCAs) dominate the total core damage frequency estimates. These studies also indicate that the estimated likelihood of core damaging accidents for existing MARK I plants is predicted to vary widely over two orders of magnitude or more. Although a strict comparison is not warranted since the studies were performed over a 12-year period and the significant improvements

in emergency operating procedures (EOPs) and Anticipated Transients Without Scram (ATWS) protection are not reflected in all of them (also a number of these studies were intended as conservative bounding analyses for use in directing more detailed analyses of the final PRA), the results nonetheless indicate that additional efforts towards accident prevention, as one element of a balanced approach, can be expected to bring about further reductions in severe accident risk. The principal accident sequences that have been shown to dominate the total core damage frequency estimates consist of Anticipated Transients Without Scram (ATWS) and Station Blackout (SBO). Draft NUREG-1150, for example, indicates that the dominant contribution to core damage frequency at Peach Bottom is due to Station Blackout. These PRA studies also show, importantly, that the overall risk is low and that the adequate protection standard has been achieved.

Table 1 shows the potential challenges to a BWR MARK I containment. The most risk significant containment failure modes consist of: (1) very early failure due to steam overpressurization (in the absence of wetwell venting) leading to core damage (i.e., containment failure <u>before</u> core melting), (2) failure by meltthrough of the steel containment liner, especially under dry containment conditions, (3) failure by overpressurization due to non-condensable gas generation and steam blow-down following RPV failure at high reactor coolant system pressure, and (4) failure by overtemperature/overpressure due to core-concrete interactions.

<u>Approach to Safety Enhancements</u> - The staff is pursuing a balanced approach involving accident prevention, accident management, and accident mitigation. As part of this approach, the staff is presently conducting a survey of each plant utilizing the MARK I containment to determine actual equipment in place (e.g. alternate power supplies, spray system capability) that could be utilized for safety enhancements. Industry efforts being pursued by several licensees as well as the BWR Owners Group (BWROG) are also being closely followed. The elements of this balanced approach are summarized below. As can be seen, several proposed enhancements, such as an additional source of water and a venting capability, are expected to be effective in more than one element of risk reduction.

<u>Accident Prevention</u> - Potential accident prevention enhancements under consideration include: (1) accelerating the implementation of some outstanding requirements for some plants under the ATWS rule and accelerating implementation of the recent Station Blackout rule, (2) assuring an additional source of water (such as from an external fire hose connection) to the residual heat removal (RHR) system together with a pumping capability that is independent of normal and emergency AC power, (3) provision of a hardened venting capability (to preclude rupture of existing

ductwork in the reactor building under severe accident conditions), and (4) improved emergency operating procedures (EOPs). Although implementation of the ATWS and Station Blackout rules will reduce the likelihood of core damage accidents, the staff judges that the risk reduction associated with some of these additional enhancements could be significant. For example, assurance of an additional source of water to the RHR together with an AC independent pumping capability could permit water to be injected into the reactor vessel for core cooling and could reduce the risks from Station Blackout to a very low level. Similarly, a reliable venting capability could assure a path for removal of long-term decay heat and could reduce the likelihood of core-melt accidents due to loss of long-term decay heat removal. Finally, improved procedures clearly would be expected to reduce the likelihood of such accidents.

Accident Management under consideration - Potential accident management enhancements include: (1) an improved venting capability, (2) improved procedures, (3) a backup generator to charge batteries, (4) assurance of an additional source of water to the RHR system, and (5) improved reliability of the automatic depressurization system (ADS). Improvements in venting and in procedures would permit enhanced capability of the operating personnel to cope with an accident. An additional source of water to the RHR system would permit water injection into the reactor vessel to quench and reduce the likelihood of further progression of an accident. A backup generator would permit additional flexibility in the management of station blackout by permitting longer available times to recover a source of AC power, while enhanced ADS reliability would increase the likelihood of being able to depressurize the reactor coolant system to allow the utilization of additional low pressure systems for core cooling.

Accident Mitigation under consideration - Potential accident mitigation enhancements include: (1) an improved venting capability, (2) assurance of an additional source of water to the drywell spray system, and (3) core debris control measures. A hardened venting capability making use of the suppression pool to scrub particulate fission products with an elevated release via the plant stack and with the ability to open and reclose the valves independently of AC power offers significant mitigation capabilities when containment integrity may be threatened. However, there are potentially significant negative aspects to venting. Untimely or inadvertent venting could, for example, hasten the onset of core damage for some sequences and also could result in unnecessary fission product releases for those sequences where the containment remains intact. The staff believes that venting, when properly incorporated into an integrated accident management strategy, including appropriate operator training, can offer effective accident mitigation. A separate filtered vent of the type being used in some European

countries is not considered warranted for the MARK I because of existing suppression pool scrubbing capabilities.

Assurance of additional sources of water to the RHR and to the containment (via spraying the containment atmosphere and also flooding the containment cavity) can reduce radionuclide releases by scrubbing fission products, and can also potentially reduce the likelihood of liner meltthrough.

With regard to core debris controls, if technical feasibility could be established, curbs in the drywell could reduce the likelihood, or delay the occurrence, of containment shell meltthrough. Curbs or weir walls in the torus room under the wetwell could retain sufficient water to permit fission product scrubbing. However, the technical feasibility for such controls has not been established, and the design and installation costs and occupational exposure during installation could be significant.

Preliminary Conclusions - Although staff assessments are not yet complete, the following safety enhancements tentatively appear attractive in terms of their potential risk reduction capability as well as implementation costs: 1) accelerated implementation of existing ATWS and Station Blackout requirements, 2) assurance of a backup water supply to the RHR and other containment systems (e.g. drywell sprays) with normal and emergency AC independent pumping capability, 3) a hardened venting capability with the ability to open and reclose it independently of AC power, 4) improved reliability of the ADS, and 5) improved emergency operating procedures.

Industry Efforts - In June and July 1987, two licensees utilizing MARK I plants (Vermont Yankee Nuclear Power Corporation and Boston Edison Company) informed the staff that they had voluntarily begun investigation of several containment and safety enhancement initiatives. Vermont Yankee has indicated that they plan to install additional spray system capability during their 1989 refueling outage but that no further work on venting is currently warranted, pending the NRC's decisions on the MARK I containment performance improvement program.

Boston Edison has submitted a Safety Enhancement Program (SEP) for their Pilgrim plant. The staff has completed an initial review of the Pilgrim plant modifications and generally finds them to be acceptable. It is anticipated that the safety improvements will be installed prior to restart from the current outage with the exception of certain modifications to the proposed torus vent system. The licensee recently notified the NRC that it has decided not to complete installation of the hardened torus vent system pending the NRC's decision on the MARK I program.

The staff has also met with representatives of the BWR Owners Group (BWROG) to discuss issues concerning containment venting. The staff intends to continue to follow closely industry efforts and initiatives in this area and will report these more fully in the final MARK I report.

Implementation - A number of the potential enhancements involve plant backfits. The staff will analyze these in accordance with the backfit rule, 10 CFR 50.109. However, as noted in SECY 88-147, specific plant and operational improvements may be identified which do not meet the backfit rule, but if implemented, would significantly alter the risk profile of the plant, improve the balance of reliance on both prevention and mitigation, or substantively reduce uncertainties in our understanding. Any such improvements identified will be brought forward to the Commission with recommended action on a case-by-case basis.

Consideration will also be given to the Commission's Safety Goals (a proposed staff implementation plan is expected to reach the Commission prior to completion of the final MARK I report and will assist in resolving related matters) and the anticipated final NUREG-1150 evaluation of Peach Bottom.

One of the main questions yet to be answered is the timing and schedule for MARK I improvements. Some of the proposed improvements, for instance, the accelerated implementation of ATWS and Station Blackout requirements and the improved emergency operating procedures can be implemented now or in the near future. Others, such as a backup water supply to the RHR, a hardened venting system, and improved ADS, will require some engineering design and analysis for each plant. Furthermore, it may be desirable to integrate some of the proposed improvements with other safety improvements that may emerge from the IPE program at each BWR MARK I plant. This topic will be discussed more fully in the recommendations to the Commission in the fall, 1988. Implementation options could take the form of Orders, Generic Letters, or Rulemaking. This issue will also be addressed as part of the staff's final recommendations.

Future Staff Actions: The following future staff actions have been identified:

1. Complete survey of MARK I plants with regard to equipment capable of enhancing containment performance;
2. Complete the staff assessment of potential MARK I improvements and make recommendations to the Commission by Fall of 1988;
3. Accelerate implementation of the more risk significant approved MARK I plant hardware and procedural improvements such as ATWS and SBO;
4. Complete research and assure implementation of improved BWR emergency operating procedures (EOPs) and training related to accident management (prevention and mitigation);

5. Continue confirmatory research related to MARK I vessel failure progression, liner meltthrough, source terms and related accident analysis methods; and
6. Complete containment performance assessments for the other containment types by the end of 1989.

As noted in SECY 88-147, this paper is being provided for information and no Commission decisions are being requested in connection with this paper. The staff remains receptive should the Commission wish to provide further comments.

Victor Stello, Jr.
Executive Director
for Operations

Enclosures

1. Table 1, MARK I Containment Challenges & Failure Modes
2. Table 2, MARK I Plants
3. Figure 1, MARK I Containment
4. Appendix 1, MARK I Workshop Conclusions and Insights

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TABLE 1
MARK I CHALLENGES & RELATIVE LIKELIHOOD OF FAILURE MODES

CONTAINMENT CHALLENGE	CONTAINMENT FAILURE MODE	CONTAINMENT FAILURE TIME	RISK IMPORTANCE
COMBUSTION*	DRYWELL RUPTURE	PRIOR TO OR AFTER VESSEL BREACH	NO
OVERPRESSURE	TEAR IN WETWELL AIRSPACE OR LEAKS THROUGH DRYWELL UPPER HEAD SEAL**	PRIOR TO CORE MELT	YES+
EARLY OVERPRESSURE/ OVERTEMPERATURE	TEAR IN WETWELL AIRSPACE & LEAKS THROUGH DRYWELL UPPER HEAD SEAL**	AT, OR AFTER RPV FAILURE	YES
EARLY OVERTEMPERATURE	LINER MELTTHROUGH	AFTER VESSEL BREACH	VARIABLE***
LATE OVERPRESSURE/ OVERTEMPERATURE	LEAKS THROUGH DRYWELL UPPER HEAD SEAL WITH POTENTIAL FOR A TEAR IN WETWELL AIRSPACE	SEVERAL HOURS++ AFTER START OF CCI+++	YES
CORE CONCRETE INTERACTION	BASEMAT MELTTHROUGH	MANY HOURS AFTER START OF CCI	NO
BYPASS	INTERFACING SYSTEMS LOCA	AT ACCIDENT INITIATION	NO
FAILURE TO ISOLATE	CONTAINMENT BYPASS	AT ACCIDENT INITIATION	NO
RAPID OVERPRESSURE/ MISSILES	STEAM EXPLOSIONS/MISSILES	PRIOR TO OR AT VESSEL FAILURE	NO

* FOR DEINERTED CONTAINMENT
** BASED ON CHICAGO BRIDGE & IRON ANALYSIS OF PEACH BOTTOM
*** DEPENDS ON CORIUM'S ABILITY TO FLOW TO AND MELT THROUGH THE LINER
\+ IN THE ABSENCE OF WETWELL VENTING
++ TIME TO FAILURE IS SHORTER FOR LIMESTONE (HIGH GAS CONTENT) AS COMPARED TO OTHER LESS GASEOUS CONCRETE AGGREGATES
+++ CCI - CORE CONCRETE INTERACTION

TABLE 2
MARK I PLANTS

PLANT NAME/LOCATION	POWER LEVEL (MWE)	BWR CLASS OR MODEL	CONTAIN. DESIGN PRESSURE (PSIG)	DRYWELL VOLUME (100,000 FT^3)	CONTAIN. FREE VOL. (FT^3)/MWE*	WETWELL WATER VOLUME (100,000 FT^3)
DUANE ARNOLD PALO, IA	545	BWR/4	56	1.2	389	0.6
BROWNS FERRY 1, 2 & 3 DECATUR, AL	1067	BWR/4	56	1.6	270	1.4
BRUNSWICK 1 & 2 SOUTHPORT, NC (REINFORCED CONCRETE CONTAINMENT)	790	BWR/4	62	1.6	365	0.9
COOPER BROWNSVILLE, NB	778	BWR/4	56	1.3	312	0.9
DRESDEN 2 & 3 MORRIS, IL	794	BWR/3	62	1.6	346	1.1
FERMI 2 LAGUNA BEACH, MI	1100	BWR/4	56	1.6	268	1.2
JAMES A. FITZPATRICK SCRIBA, NY	821	BWR/4	56	1.5	322	1.1
EDWIN I. HATCH 1 & 2 BAXLEY, GA	786	BWR/4	56	1.5	329	.9
HOPE CREEK SALEM, NJ	1070	BWR/4	62	1.7	283	1.2

* DRYWELL PLUS WETWELL

Enclosure 2

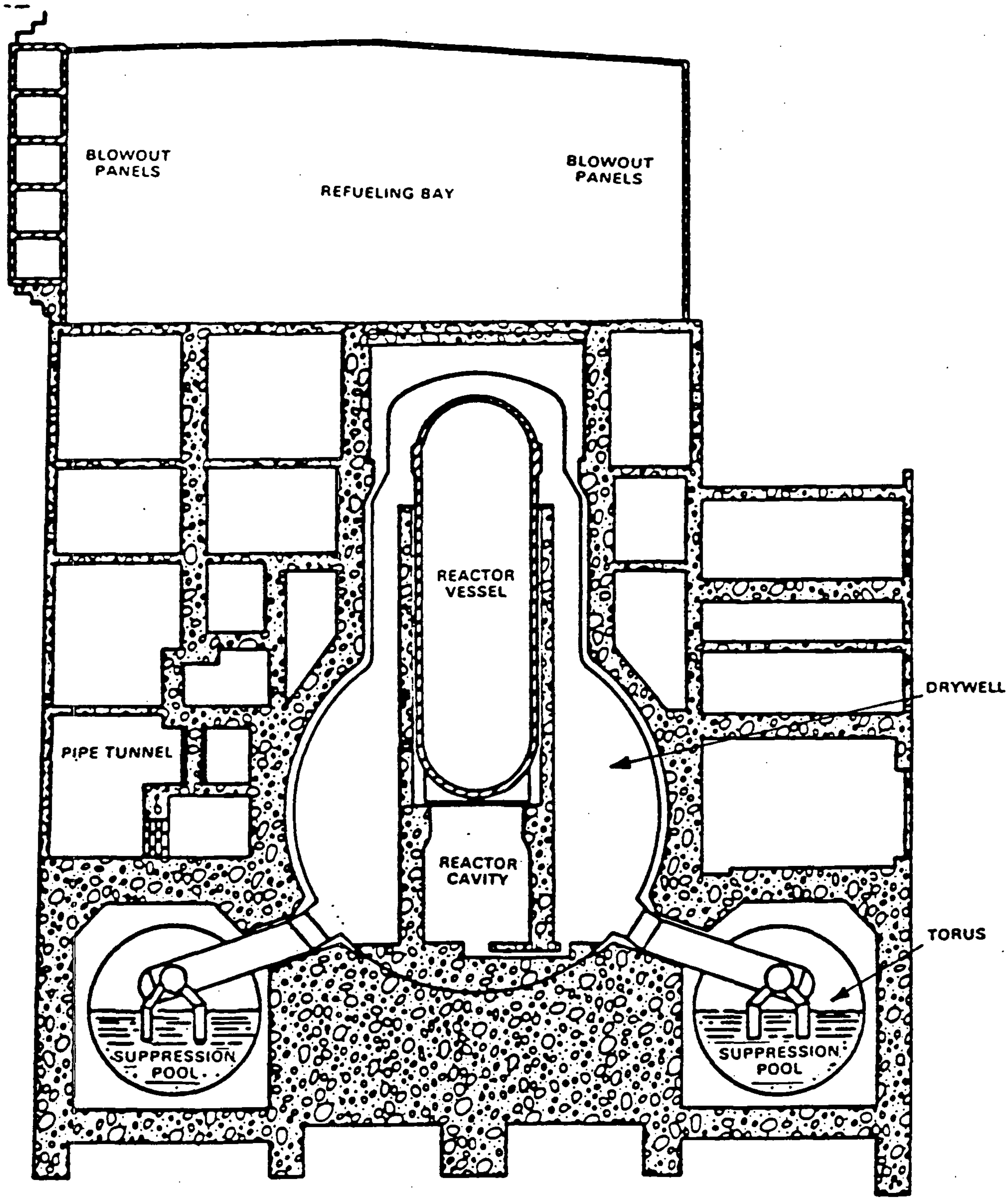
TABLE 2
MARK I PLANTS (CONT'D)

PLANT NAME/LOCATION	POWER LEVEL (MWE)	BWR CLASS OR MODEL	CONTAIN. DESIGN PRESSURE (PSIG)	DRYWELL VOLUME ($100,000\ FT^3$)	CONTAIN. FREE VOL. (FT^3)/MWE*	WETWELL WATER VOLUME ($100,000\ FT^3$)
MILLSTONE I WATERFORD, CT	660	BWR/3	62	1.5	389	1.0
MONTICELLO MONTICELLO, MN	536	BWR/3	56	1.3	443	0.7
NINE MILE POINT 1 SCRIBA, NY	610	BWR/2	35	1.8	492	0.9
OYSTER CREEK 1 TOMS RIVER, NJ	620	BWR/2	45	1.8	495	0.8
PEACH BOTTOM 2 & 3 PEACH BOTTOM, PA	1065	BWR/4	62	1.8	276	1.2
PILGRIM 1 PLYMOUTH, MA	670	BWR/3	56	1.5	399	0.8
QUAD CITIES 1 & 2 CORDOVA, IL	789	BWR/3	62	1.6	348	1.1
VERMONT YANKEE VERNON, VT	514	BWR/4	56	1.3	479	0.7

* DRYWELL PLUS WETWELL

ENCLOSURE 3

MARK I CONTAINMENT



ENCLOSURE 4

APPENDIX 1

MARK I WORKSHOP CONCLUSIONS AND INSIGHTS

A workshop was held in Baltimore, Maryland on February 24-26, 1988, to discuss the challenges to BWR MARK I containment integrity, failure modes, and potential improvements to prevent, delay or mitigate containment failure. The workshop provided an opportunity for the staff to incorporate the opinions of industry representatives, the research community and interested members of the public into the resolution process for severe accident issues related to MARK I containments. The severe accident containment challenges and failure modes were identified as hydrogen ignition overpressures, early overpressure/overtemperature failure, core debris attack on the steel containment shell (shell meltthrough), late overpressure/overtemperature failures, containment bypass failures, containment isolation failures, and rapid steam pressure and missile failures. Potential improvements discussed related to hydrogen control, containment sprays, venting of containment, core debris control, automatic depressurization, and related procedures and training. The conclusions and insights gained at the work-shop related to the challenges and potential improvements are discussed below.

Early containment failure is that failure which occurs prior to or soon after reactor pressure vessel breach. The early overpressure/overtemperature containment failure modes identified were containment leakage (e.g., through the drywell head seal); drywell rupture; torus tear; and penetration/valve failure (e.g., purge/vent valves) due to high temperature. Uncertainties in loading estimates were attributed to uncertainties in core meltdown and relocation (e.g., zirconium oxidation, and debris composition); reactor pressure vessel failure mode; and direct containment heating. The general consensus seemed to be that the greater threat to the containment would arise as a result of overpressure rather than overtemperature. A comprehensive structural evaluation was presented which predicted a failure location in the wetwell airspace at approximately 159 psig for Peach Bottom with drywell head seal leakage at a lower pressure.

Core debris attack on the steel containment shell has been the topic of limited experimentation and much discussion. Some of the workshop attendees agreed that presence of water in the drywell is likely since past accidents involved only insufficient cooling, not total lack of cooling. Also, there seemed to be a consensus of opinion that water addition for station blackout and other situations would be beneficial for aerosol scrubbing. However, the degree of impact of water on debris spreading and cooling was not clear. Computer codes and models were identified as available with which many, but not all, potential processes leading to shell attack could be predicted for specific, narrowly defined scenarios. The attendees did not agree, however, on the rate of heat loss from core debris during its entrance into and spread across the

drywell floor; nor the rate, composition, temperature and relative probability with which it leaves the vessel. It was, however, noted that if corium in contact with the shell is less than 5 cm deep and has a low super-heat, the shell most likely will not perforate (meltthrough), while a debris depth greater than 20 cm would cause perforation. There was no prediction of shell failure or survivability for corium depths from 5 cm to 20 cm at the containment shell.

The late overpressure/overtemperature failure is postulated to result from extended core-concrete-interactions which would occur following the reactor pressure vessel failure and subsequent spreading of the core debris on the pedestal floor. The thermal and chemical interactions between the core debris, concrete surroundings and containment atmosphere have the potential for producing non-condensable gases (including flammable hydrogen and carbon monoxide) and hot aerosols. The uncertainties in late overpressure/overtemperature challenges were attributed to uncertainty in the extent of core-concrete interactions and the subsequent magnitude of non-condensable gas addition to the containment, and the mechanism and magnitude of upward heat transfer from the core debris to the containment atmosphere. Although no consensus was reached as to the magnitude of this challenge, it was generally concluded that venting could be used to potentially prevent containment failure by overpressure from non-condensables. Overpressure and overtemperature from deflagration of combustible gases could be prevented by the pre-existing/pre-accident inerted condition in containment.

The containment bypass failure mode represents those failures which occur at accident initiation and result in a direct path between the drywell atmosphere and the reactor building without going through the suppression pool wetwell. Included are penetration seal failures, failure to isolate penetrations, and an interfacing system loss of coolant accident (LOCA). It was generally recognized that although failure to isolate and an interfacing system LOCA could present mechanisms to release significant quantities of fission products to the environment, the probability of such events was low. The potential for seal failure, however, was recognized as being sensitive to the drywell temperature and pressure. Drywell pressures and temperatures during severe accidents could substantially exceed the environmental qualifications for the seals and, thus, their integrity could not be assured. The survivability of the penetration seals is related to the phenomenological uncertainties associated with the core and reactor vessel failures.

Rapid steam pressures with missile generation is based on a postulated in-vessel steam explosion which blows the reactor head off the vessel (alpha mode failure) and into the drywell head resulting in containment failure. In order to create a steam explosion, the water in the reactor vessel bottom head has to have a specific confined "pre-mix" of fuel followed by an instantaneous slumping of a specific minimum amount of fuel into the water to trigger the reaction. If the reactor pressure is greater than 150 psig, an external trigger is required to initiate the reaction. Furthermore, any non-fuel debris, such as steel members, in the water would inhibit the reaction. The probability of the alpha containment failure mode in BWRs is considered to be small enough that further consideration is not warranted. First, the large number of control-rod guide tubes in the lower plenum would likely prevent a

large coherent steam explosion, and would also provide an energy absorption capability to reduce steam explosion pressure loadings. Second, the large above core structures of steam dryers and separators would strongly reduce any slug impact pressure upon the upper head.

Potential improvements in hydrogen control centered around (1) the reduction of the current 24 hour period allowed for operating the plant in a deinerted status, and (2) means of preventing oxygen in-leakage during the course of a severe accident. The point was made that the current technical specification operating limit of 24 hours provides useful plant flexibility. This provision is needed in order to gain access to the containment for the purpose of evaluating and repairing possible leaks. Those addressing this issue stated that risk assessments to date indicate that there is not a significant risk associated with this type of operation, although due care must be exercised in undertaking such operation. The need to provide assurance that oxygen in-leakage is unlikely, including the use of compressed nitrogen supplies for operating strategic valves, was also discussed.

The primary discussion related to containment sprays centered around the modifications required to the existing containment spray system in order to make it functional during station blackout. The two changes suggested were (1) to provide a back-up source of water independent of normal and emergency AC power sources to deliver it, and (2) to reduce the number of spray header nozzles so that the resultant flow would be more evenly distributed at a lower flow rate. It was concluded that a back-up source of water could have both preventive and mitigative benefits. For example, during station blackout, the supplementary water supply could be injected into the reactor coolant system to help prevent or arrest core melt. Water injection into the containment spray after core-melt could significantly reduce the release of fission products. Furthermore, containment spray operation might reduce the likelihood of or delay containment failure by cooling of the containment shell, and might have the additional benefit of retarding the corium flow across the drywell floor. Modification of the spray nozzles was questioned by some since it would reduce the effectiveness of a system intended to be used for design basis accidents (DBA). It was noted, however, that no credit had been given by the staff for BWR containment sprays for fission product or pressure reduction in evaluation of design basis accidents. Furthermore, the additional spray effectiveness was considered uncertain in view of the fact that the major mitigative effect of water in the drywell was achieved by providing a water layer on top of corium on the drywell floor to reduce and scrub fission product aerosols released during core concrete interactions. Consequently, there was some opinion that modification of existing spray nozzles was not justified.

The third improvement discussed was venting the containment to prevent containment failure by overpressurization. It was concluded that successful venting of containment could for some accident sequences reduce the core melt frequency, reduce accident consequences, and delay containment failure. However, based on current plant procedures which direct the operator to vent containment and the existing vent line sizes and restrictions, venting may not be successful to prevent containment failure due to early overpressure challenges. If venting is not successful and containment fails, the hydrogen produced during the accident would be expelled into the reactor building. The deflagration of this hydrogen (in the reactor building) could result in a sufficient pressure spike to fail the reactor building. Any subsequent release

of fission products through the rupture in containment would be directly to the environment. Procedures which require early venting could be successful for some severe accident sequences in preventing early overpressure failure, but could result in inadvertent venting and the resulting unnecessary release of radioactivity to the environment. Venting the containment would release some of the nitrogen and noble gases. Provided conditions conducive to the operation of the vacuum breakers are created, de-inerting of the containment and combustible gas ignition could ensue. Utility representatives stated that the decision to vent the containment is made by the operator. However, it was noted that the utility's management has approved the operator's decision to vent by virtue of having approved the symptom-based procedures.

The potential core debris control improvements discussed included curbs of refractory material in the drywell near the liner; additional high pressure water cooling in the drywell; sacrificial materials to help create a coolable geometry in the drywell; curbs or weir walls in the torus room under the wetwell; and the use of fire sprays in the reactor building. In general, consensus appeared that more detailed evaluations are needed to resolve the necessity and feasibility of most of the schemes. This was especially true in view of the fact that plant specific geometries, equipment and attendant vulnerabilities seemed to indicate that generalizations may not be possible. Some concerns were also expressed that the effects of the modifications on design basis accidents may not have been fully examined.

Discussions by the participants indicated that use of the Automatic Depressurization System (ADS) could reduce the frequency and consequences of a severe accident. Although the ADS is considered generally reliable for most severe accident sequences, for some SBO sequences its operation cannot presently be assured. Although the reactor vessel may fail somewhat sooner, it would be depressurized when it does fail and thus eliminate the concern of containment failure due to direct containment heating. Utility sponsored calculations showed that ADS actuation leads to substantial cooling of the coolant system and safety relief valve line structural surfaces which, in turn, increases the fission product retention capability. However, there is the potential for revaporization after reactor pressure vessel failure. Some limited industry calculations for station blackout sequences claimed an order of magnitude reduction in source term attributed to ADS operation and fission product revaporization. However, no consensus was reached on this issue. Several participants indicated that the availability of the ADS could be extended beyond the usual time assumed (about 6 hours) in the event of some station blackout scenarios by operator action to strip unnecessary loads from the DC bus.

There was unanimous opinion that proper operating procedures and operator training are required in order to successfully manage a severe accident and to minimize offsite consequences. With proper training and procedures, the operator error rate could be reduced substantially. However, there was no consensus of opinion as to what constituted proper training and procedures. Some believed that the existing EPGs and EOPs were sufficient, while others maintained that the PRA insights had not yet been incorporated into them.