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In the matter of:

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

Combined Meeting of ACRS Subcommittees
on Metal Components and Structural Engineering

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NUCLEAR REGULATORY COMMISSION

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

COMBINED MEETING OF ACRS SUBCOMMITTEES ON

METAL COMPONENTS AND STRUCTURAL ENGINEERING

Room 1046

1717 H Street, N.W.

Washington, D.C.

Thursday, May 23, 1985

The Subcommittee on Metal Components and the Subcommittee on Structural Engineering of the Advisory Committee on Reactor Safeguards convened, pursuant to notice, at 8:35 a.m., Paul Shewmon, Chairman, Metal Components Subcommittee, presiding.

PRESENT:

PAUL G. SHEWMON, Chairman,

C.P. SIESS, Member

JESSE C. EBERSOLE, Member

HAROLD ETHERINGTON, Member

ROBERT C. AXTMANN, Member

CARLYLE MICHELSON, Member

J. HUTCHINSON, ACRS Consultant

E. RODABAUGH, ACRS Consultant

PRESENT (Continued):

MYER BENDER, ACRS Consultant

S. BUSH, ACRS Consultant

ACRS Staff Member:

ELPIDIO IGNE

SPEAKERS:

L. Shao

R. Vollmer

B.D. Liaw

B. Bosnak

R. Klecker

C. Serpan

S. Hou

J. O'Brien

W. Johnston

B. Elliot

W. Shack

Mr. Vagans

Mr. Shields

PROCEEDINGS

MR. SHEWMON: Let us begin the festivities. This is a meeting of the ACRS combined Subcommittees on Metal Components and Structural Engineering. I am Paul Shewmon, Metal Components Subcommittee Chairman. Co-chairing this meeting on my left is Chester Siess, Structural Engineering Subcommittee Chairman, and Co-chairman of the meeting.

Other ACRS members in attendance are Bob Axtmann, Harold Etherington, Jess Ebersole and Carlyle Michelson. Consultants are E. Rodabaugh, J. Hutchinson, and Mike Bender and S. Bush.

The purpose of the meeting is to review the NRC Piping Review Committee reports including its recommendations. We will also discuss the proposed rule changes in GDC-4 to account for the leak before break concept in operating plants and plants under construction.

Elpidio Igne is the ACRS Staff member for this meeting.

The rules for participation in today's meeting have been announced as a part of the notice of the meeting published in the Federal Register on May 2. It is requested that everybody speak up so we can get your words on the record. If you can't, the young lady will probably wave her hands and let you know.

We have received no written comments or requests for

time to make oral statements from members of the public.

The NRC has had a monumental effort on reviewing their piping systems as exposed to various loads and design procedures there for, and what we will hear about today or go over is most of this. I think it will be an interesting meeting.

I have no other introductory comments or requests. If other members do -- Chet?

MR. SIESS: Paul, just for the record, I think that the other subcommittee involved is the Subcommittee on Seismic Design of Piping, and not the Structural Engineering Subcommittee. I happen to chair both of them. I'm not sure who the other members are in either case, but that's just for the record.

MR. SHEWMON: Okay. Any other comments?

[No response.]

Why don't you go ahead then?

[Slide.]

MR. SHAO: My name is Larry Shao, I am the Co-Chairman of the NRC Pipe Review Committee. Dick Vollmer is the other co-chairman, and today with me is Spence Bush who is the Vice-Chairman of the NRC Piping Committee. Spence is also the Chairman of the Task Group on Pipe Cracks.

Also today my secretary is the Secretary of NRC Pipe Review Committee and he is bringing all the viewgraphs.

As soon as he comes in, I will just read the viewgraphs to you. The other full task chairman is Shou-Nien Hou. He is the Chairman of the Task Group on Seismic Design. And Mr. Klecker is the Task Group Chairman on Pipe Breaks, and John O'Brien, who is the Chairman of the Task Group on load combination and other dynamic loads.

Today we're also going to speak on another subject, and that will be covered by Bob Bosnak and Chuck Serpan and supposedly Bill Johnston, too.

The first chapter of the Piping Committee report has been completed and we have published five reports. And these reports have been submitted to the EDO. I also sent a complete set of the report to ACRS. I don't know whether you have received it or not.

I will present the introduction and background, and each task group chairman will present the findings of their volumes. I also will present Volume 5 which is the summary and conclusion of all the findings.

Let me give you some background of this NRC Piping Review Committee.

[Slide.]

In May 1983, the EDO requested the staff to prepare a comprehensive proposal on how to modify NRC's present position on piping. The proposal should include a comprehensive review of all the current NRC positions to

identify the areas and the issues that the staff should work on. The main objective is to make recommendations on how and where to modify the current requirements.

The other objective is to identify an area where further work is necessary.

In July of 1983 a comprehensive proposal was prepared and was submitted to EDO. It was approved by the EDO in August, and the NRC Piping Review Committee was formed and the first meeting was called in October 1983.

What was the basis for reassessment?

[Slide.]

Most of the current positions were developed many years ago, and these positions were written mostly based on judgment and without significant data.

Recently, they have a lot of data in the area of piping, and these data are not only in this country, but also in foreign countries. Also, we have a lot of operating experience that we can draw from.

In addition, there have been new developments in areas such as structural mechanics, and PRA. Right now, the experts think some of our positions we thought were conservative, but may not be conservative. It may diminish the overall safety. For instance, the stiff piping systems induced high thermal stresses and nozzle loads, and they are adversly influenced by construction, maintenance and

inspection errors.

So we feel that some of the present position need increasing requirements while others need decreasing requirements in order to get a more reliable piping system.

[Slide.]

Let me talk about some other technical issues we are faced with. At that time, the proposal tried to categorize all the technical issues in four major areas. The four major areas are pipe cracks, seismic design, pipe break and load combinations and other dynamic loads.

In the pipe cracking area the BWR piping has this strange intergranular stress corrosion cracking. A few years ago the cracking was limited to small diameter piping. In recent years, the large diameter piping has the IGSCC.

Some other questions we are faced with: can we detect cracks reliably, can we size the cracks reliably? Would a degraded piping leak before break? What is the effectiveness of the short-term fixes and long-term fixes? What is the basis for continued operations?

In the seismic design area we feel that we have enough information that certain positions can be changed now. For instance, because Part 100, Appendix A required OBE to be at least one-half SSE. Since in designing OBE one uses lower damping values and lower allowable stresses in many areas and in many cases, OBE controls the design. But according to the

OBE, the OBE should be -- the ratio of OBE to SSE should be much less than one and a half.

The other area we can work on is the damping values.

MR. SHEWMON: Before you leave that, what will be recommended? Something like a fourth, or will we get into how it will be decoupled later?

MR. SHAO: I think we recommend to decouple OBE from SSE and depending on the cases, I think the OBE should be based on temperature. So we want them to decouple from SSE.

MR. SHEWMON: Okay.

MR. SHAO: Another area we can work on is the damping values. There's a lot of research on damping values recently. And the damping value position is listed in Reg Guide 1.61. The piping at 2% or 3% whether it's OBE or SSE. But we feel these damping values are too low, and the low damping value results in unrealistic, high dynamic loads.

PVRC -- that's the Pressure Vessel Research Committee -- Subcommittee on Piping System, Spence Bush is the chairman of that subcommittee -- recommends certain damping value, and these damping values have been approved by ASME code. And NR has been using it on a case-by-case basis. And we feel it should be used generically.

Another new area we can work on is the peak broadening requirement for floor response spectra. Instead of using the peak broadening we use peak shifting requirement.

The other area that has a lot of conservatism is the so-called multiple independent supports. That's in our Standard Review Plan. We tried to envelope all the spectra that have multiple independent suppports, and that gives a lot of conservatism in piping design.

Usually, a considered design will result in many supports and many snubbers. And you know sometimes a snubber is not very dependable. The hydraulic snubber has a tendency to leak and a mechanical snubber has a tendency to lock up.

MR. BENDER: Getting back to the damping value for just a minute. The damping values in the piping system seem to be very conservative. They don't take credit for very much damping. What about the structural attachments? Are you going to deal with those as such?

MR. SHAO: This committee deals only with damping. Only with piping.

MR. BENDER: Well, I'm not talking about that. The thing that holds the pipe in place contributes to the damping characteristics, and I guess I didn't understand how they were dealt with. The piping is rigidly anchored or tied to the attachment, and the vibration is coming from the structure. Something should be dealt with, and I just never got a feeling for what was being done.

MR. SHAO: Okay. There are many variables in deciding piping damping values. Just like you said, the

attachment -- whether the piping is r d or flexible and the type of support. There are a lot of ables.

We tried to decide which va able is more important but it's very, very difficult. So finally, I think we have to decide based on frequency. They're only using one variable right now. It's almost impossible to tackle the problem because there are so many variables.

MR. SHEWMON: Mike, as a non-structural engineer I'd always kind of hoped those things would pull out of the wall so it wouldn't muck up the piping system.

[Laughter.]

MR. BUSH: Perhaps I could comment. We're in the Pressure Vessel Research Committee and WRC Bulletin 300, which is the object that Mike is looking at currently has a so-called industry position which represents many, many man years of design practice put together in order to essentially come up with approaches other than rigid snubbers in many locations, the object being to get rid of about 90 percent of the snubbers.

Furthermore, in recognition of the very point that Mike made, the Pressure Vessel Research Executive Committee has authorized us, the technical committee on piping, to in essence re-examine Section MF of ASME-3 which has to do with the design, fabrication and installation of supports with the idea of making specific suggestions in order to optimize these

designs. I think the general consensus is at this stage they are far from being optimum.

MR. SHEWMON: Okay. Go ahead, Larry.

MR. SHAO: The next subject is the pipe breaks. The NRC position has been in the Standard Review Plan and Reg Guide 1.46. To posture a pipe break, for the pipe break area we use the area of the pipe -- so-called double-ended guiilotine break. The pipe relocation is based on the stress criteria. The stress criteria for Class 1 piping, for instance, is any stresses over 2.4sm with a cumulative usage factor of over .1, one has to posture a pipe break.

But even though the stress number and the usage factor is less than these numbers, one still has to postulate two intermediate breaks and also, breaks at the terminal end. Because of this position, they have massive pipe whip restraints to keep the pipe from whipping.

So we feel this position should be assessed. Also, we have new information that says a lot of piping most likely will leak before break rather than have a full guillotine break.

MR. EBERSOLE: Can you tell me what do you arrive at for longitudinal splits?

MR. EBERSOLE: For longitudinal splits you go to the area of the flaw. Area of the pipe.

MR. EBERSOLE: One cross-sectional area?

MR. SHAO: Right.

MR. ETHERINGTON: Isn't it two cross-sectional areas? It's a double-ended break or the equivalent for a split.

MR. SHAO: The two cross-sectional. You could have double-ended in two areas. 200 percent of the area.

Another area is in the load combination. Here, the load combination means two things; one called event combination and one is response combination. The event combination are such as where the LOCA should be combined with SSE, and these are called event combinations.

A response combination is a combination of stresses and deformations. We feel that we have more information now. I think certain positions we took in the past should be modified in a few areas.

Other dynamic loads are those such as water hammer load and vibrational loads. There are certain questions in our minds; should we accept the linear dynamic analysis? What should be the allowables for these dynamic loads? How do you minimize the unanticipated water hammer? So these are the questions which are to be addressed.

MR. EBERSOLE: There's been some interesting experience recently where 400-pound systems have been subjected to 1100 or 2200 pounds and they have survivied. Are there any positions about inadvertent excess pressures derived

from valve performance or valve malperformance? It's turned out that these things have held together.

MR. SHAO: You say the piping --?

MR. EBERSOLE: This is a coupling of the high to low pressure systems. The inadvertent valve operation? Several of these things have happened.

MR. SHAO: They happen and the pipes can take the load?

MR. EBERSOLE: They hung together, yes.

MR. SHAO: Usually the piping has more strength than the allowable.

MR. EBERSOLE: Well, one would like to argue that that was by intent rather than accident.

MR. VOLLMER: I think what you are referring to is essentially sort of event B incidences really. But I think what we're talking about here mostly are design requirements and I don't suspect that we will try to incorporate into the plant designs the ability to accomodate an event like that.

MR. EBERSOLE: I was sort of putting it in the context of a water hammer --

MR. SHAO: It is very, very difficult to design for water hammers. The only thing we can do is minimize the frequency.

[Slide.]

MR. SHAO: The approach is to set up an NRC Piping

Review Committee with participation from NRR, RES, IE, the regional offices and other consultants.

[Slide.]

The scope and objectives of this committee is to review all the current requirements for both BWR and PWR pipings. To review the domestic and foreign information, to review all the operating experience that we can get, and the objective is to make recommendation on where and how we can change the provisions, and also identify areas where further work is necessary.

[Slide.]

This is the makeup of the NRC Piping Review Committee. We have a main committee with Vollmer and me as co-chairmen and Spence is the vice chairman, and we have two taks groups on pipe crack and pipe break and seismic design and load combinations.

[Slide.]

This is the list of consultants we have used, and they are supposed to be experts in material size, NDE, fracture mechanics, seismic design, piping design and structural mechanics. They have helped staff in doing the evaluation and preparing position papers.

[Slide.]

We have worked closely with industry mainly because the industry has done a lot of work in this area, and we try

to glean whatever information we can get from the industry.

In the BWR pipe crack area, we work with the BWR owners group, we work with EPRI, GE and also, the ASME Code Section XI.

In the seismic design/load combination/pipe break area, we work with PVRC, ASME Code Sections III and XI, and also the AIF-related committees. By the way, there are two subcommittees in AIF that are related to our area. They have a subcommittee on seismic design and also a subcommittee on load combinations.

[Slide.]

How do we get the foreign information? In the BWR pipe crack area we review all the foreign experience, research information and positions. There was a CSNI meeting on pipe cracks that was held in February 1984 in Paris. I think Dick Vollmer, Spence Bush and Chuck Serpan attended that meeting. I think, Paul, did you go there, too.

Then we also have foreign experts to review our draft report. We have people from Japan, Sweden, England and Germany. I think Japan is Professor Ando from Japan and Tomkins of England and Professor Kussmaul of German and deKazinczy of Sweden.

They were here in the United States, spent a week, reviewed the report and wrote up comments. I think they're in the back of Volume 1.

[Slide.]

In the seismic design/load combination pipe breaks, we also reviewed the foreign experience for research information and looked at the foreign positions. In this case, we sent questionnaires to foreign countries, and a lot of countries answered our questionnaire. We also get information from international conferences and meetings. We got whatever information we could get.

MR. BENDER: Are you going to sum up what the foreign comments amount to?

MR. SHAO: Okay. In all areas or a particular area?

MR. BENDER: I thought you might say something like in general, they agree with our approach but they have some difference in detail in certain areas, or they disagree sharply somewhere.

MR. SHAO: Okay, let me summarize what they say about pipe cracks first.

[Slide.]

This is the conclusions about our draft report on BWR pipe cracks. I think in general they feel -- even though they feel the pipe will most likely leak before break, I think they think it's prudent to replace with material that's more resistant to IGSCC. This is essentially the conclusion of our report.

MR. SHEWMON: They also say, "we feel that more

elaborate and stringent rules should be laid down for flaw acceptability." The 20 percent rule on powerful crack size they call into question some, so there are other things.

[Slide.]

MR. SHAO: These are the five reports we have published. We also sent a letter to Dircks, that's the attachment at the end. In fact, we're concerned the work of the NRC Piping Review Committee has been completed. Now it's up to the program office to write implementation documents and review Reg Guides and the Standard Review Plan or make changes in regulations.

MR. SHEWMON: Thank you very much. Any other questions?

MR. MICHELSON: Yes. Since this, I guess, is the introduction and overview, let me tell you something that's troubling me a little bit and then you can tell me if you're going to talk about it later or how the situation is being handled.

Your work is dealing strictly with pipes and pressure boundary and how they might be supported and fail and so forth. My interest is also in other components, though, manhole covers, valve bonnets, pump flanges, things of this sort, which are bolted connections and whose failure may not follow the same kinds of thoughts that you have when you're dealing with piping.

Where are these other types of potential massive pressure boundary leaks being handled, or how will they be handled? Anybody want to answer?

MR. SHAO: Your comment is certainly valuable, but it is not on the agenda today. I don't think I can address it.

MR. MICHELSON: I think before we start considering rule changes and so forth, which are really addressing what happens when it leaks, you have to consider the possibility leaks other than a pipe leaking.

MR. SHEWMON: We will get into pump housings and valve bonnets and elbows before the day is out, whether Larry thinks that's on the agenda or not.

MR. MICHELSON: Okay. Because it's a part of the picture when you start looking at --

MR. SHEWMON: Yes. Does this mean that the Piping Committee looked not at elbows but only at straight runs of pipe?

MR. SHAO: The only area we looked at that's related to your question is, we feel that a lot of positions back leak before break. So the leak detection requirement is very important. So we made the recommendation we should tighten the leak rate criteria.

MR. EBERSOLE: But when you do a calculation or when you consider the ways in which this can happen, do you only

consider straight runs of pipe, or were elbows and valve housings also considered?

MR. SHAO: When you detect leaks, sometimes you don't know where the leak is coming from. So when you tighten the leak detection criteria, you tighten the whole thing.

MR. SHEWMON: Good. When you do leak before break analyses, do you only consider straight runs of pipe?

MR. SHAO: And elbows, too.

MR. SHEWMON: Well, then, do you consider the flanges and housings and components he is talking about?

MR. SHAO: No, we don't consider those.

MR. SHEWMON: So you consider only straight runs of pipe.

MR. SHAO: And elbows.

MR. SHEWMON: Okay. Elbows. Well, you're halfway there.

MR. BENDER: Do you want to ask about T's?

MR. MICHELSON: Also, some utilities have used some interesting expansion joints and so forth in lower energy systems which don't fail the same way that a pipe fails.

MR. SHEWMON: It's a good question. Bring it up again. Are there other questions?

MR. EBERSOLE: This business of putting pipes into one common basket bothers me a little bit. I can't get excited about breaks of the primary looping piping, but when

you start talking about extrapolating your break logic out to service systems and then disregaring the dynamic effects of that, you run into this problem: You experience the failure by disruption of some sort, splits if you want to it that way, and as an end result of that, you disable the counterpart systems which are servicing the plant to keep the core cool.

What is suggested here is that you're not going to look at the dynamic effects of such damage to support systems. Is this true?

MR. SHAO: This is not true. The position we recommend is you can use leak before break only when justified. The position is still the same unless you put evidence to justify leak before break. So far, we only got justification on some of the primary piping. We don't have any justification on secondary piping yet.

Suppose somebody says, I do all kinds of research, I do all kind of analysis; I can show you leak before break. And if staff reviews it and we agree, then okay. If we don't agree, they have to posit a full break again.

MR. SHEWMON: We are not dealing with in-service water systems today or in the proposed rule changes.

MR. EBERSOLE: You'd be dealing with main feedwater piping, wouldn't you?

MR. SHEWMON: I don't know.

MR. SHAO: The position is good for all piping. But

remember, they can only propose leak before break when justified.

MR. SHEWMON: Is the feedwater system part of that place where they will use it, or not?

MR. SHAO: Yes. They can use it if it's Class 2 piping.

MR. EBERSOLE: You understand what I'm saying? A feedwater system failure can disrupt the counterpart feedwater system.

MR. SHAO: Yes. But obviously, I can't use leak before break on feedwater systems. They have to do a lot of analysis for evidence to show that this particular material will leak before break.

MR. SHEWMON: Well, bring it up again.

MR. JOHNSTON: Mr. Chairman, those topics will be covered later because you're asking Larry questions that have to do with how we approach the licensing aspect of it, which is not really the function of the committee. Others will cover that later today.

MR. SHEWMON: Fine.

MR. BENDER: I want to make a comment about Carl's question. I think that piping really is one of a number of components, and he suggested a bunch of others. I don't have any real concern about what the staff is suggesting here. It seems to me that for the purpose of having some consistent

argument about system reliability, you really just have to look at whether the criteria that are being set forth are consistent with the criteria in other parts of the system.

My perception is that the leak problem is more serious in parts of the system that Carl has talked about. But taking some of the conservatism out of this component doesn't seem to be inconsistent with that argument.

MR. SHEWMON: Any other questions? Fine, thank you.

MR. VOLLMER: Before we leave, I'd like to make one comment with respect to Mr. Michelson's comment. There is a fair amount of activity going on with respect to bolting. It's being considered now as a generic safety issue. The staff is working with a number of industry committees on this, and I think the staff shares your concern that bolts can contribute a lot of problems with regard to safety piping both pulling out of walls and separation from flanges and valves and things like that.

So it wasn't really considered part of this charter. Perhaps the ACRS would like a separate briefing on the subject because I think there's a fair amount of work that could be presented.

SPEAKER: I think the whole point is, though, before reaching a decision on the rulemaking, one has to look at more than leaks coming from pipes.

MR. SHEWMON: No. If you're concerned about piping,

then whether or not the bolts are an additional concern is a separate question.

MR. MICHELSON: Well, the concern I have is that the rulemaking was written far broader than -- it was not limited just to the failure of pipes alone. In fact, they didn't even define what they meant by piping rulemaking. So I had a little problem with it. You know, is it expected to light the leaks from pipes, and if so, then how are the rest of the leaks being handled? It isn't clear in the rulemaking. We'll get to that later, I assume.

MR. SHEWMON: Okay. Spence?

MR. BUSH: While he's setting up the slide projector I could comment that Section XI, for example, recognizes and has expanded the situation with regard to examination because there have been some distinct anomalies in this respect.

There are new sections to the Code, there are new appendices to the Code, in an attempt to address the situation so that you have, shall I say, earlier warning than you have now. Now, that's only part of the picture. But probably Bob Bosnak is closer to it.

I don't think we worried too much about bodies and heads unless you get erosion fabrication problems because the usually the design safety factor is provided. But I think you're really concerned with release, cracking of enough bolts so that you could have a release aspect, which gets back to

the bolt situation.

MR. MICHELSON: There's one more aspect, though, that I'd like to think about a little bit and that is how will expansion joints be handled with the situation, since they behave failurewise considerably different.

MR. BUSH: In advance, I think I should indicate that these slides are based on NUREG-1061, Volume 1. NUREG-1061, Volume 1 has now been on the streets for more than a year, and I think in the case of some slides, I would like to show you where positive progress has been made. In other words, where there's a concern listed and an action has been taken to partially or completely resolve the concern I will attempt to indicate it at the time, even though it doesn't appear on the slide.

[Slide.]

Basically, most of the concern in this report on stress corrosion cracking dealt with the recirculation system because of the incidents that occurred. And there, the subcommittee did examine what had occurred since the last report on PWR pipe cracking, and the Persine report which was 1979 on BWR pipe cracking, and decided there were no obvious trends with regard to PWR's and with regard to BWR's the action was all on the larger size piping and the recirculation system. So the decision was made to limit the charter pretty much and the scope to that area.

So it would be the piping that you see here in the risers, so we're talking of piping that runs 26 to 28 inches in diameter with risers of about 20 inches and some attachments that are somewhat snmaller. That's the scene of action.

[Slide.]

This is an out of date slide in the sense that it was action at the time of the event. It indicates examinations that have been done, how much of the systems have been examined in the research system. Obviously, other plants in the interim period have taken positive action with regard to overlays or replacement.

[Slide.]

This is simply an example of the type of crack that can occur. This is one of many types. You can get multiple branching. They can have a very narrow crack front representing a small fraction of circumference, or a small distance axially, or they can be very long. In some instances, they can go 360 degrees.

[Slide.]

These are the critical conditions leading to stress corrosion, and basically you need all three of them to occur for IGSCC. High stress, sensitized material and agressive environment. Our concern in this instance has been almost exclusively in intergranualr stress corrosion cracking as

contrasted to transgranular stress corrosion cracking. That means that you need the heat input from the weld to sensitize the heat-affected zone. Your cracking will then occur in that region and continue up through the heat-affected zone.

Some of the concerns that we'll see later in the fracture mechanics area have to do with a crack of substantial length that may simply move over into the weld metal. This is a relatively rare occurrence. From a stress corrosion point of view it will only occur when you have very low delta ferrite, which means that you have a poor weld to start with. Normally, the delta ferrite would have to be below 2 percent, more likely a half percent. However, there are mechanisms; fatigue being one, where you could have a crack that would progress halfway through the wall and then could move into the weld. One of the concerns that you'll see later and I'll cite with regard to IWB-3640 relates to this issue.

The aggressive environment. That's a relative term. Agressive environment in this case simply indicates if you have some oxygen in your water in a boiling water reactor that's enough to be aggressive in this instance. So you don't have to have anything of great severity.

[Slide.]

This is a three dimensional plot of the same thing, simply showing that it basically would indicate the type of diagram that one would use to establish the impact of

contaminants such as oxygen, sensitization or total stress level.

[Slide.]

From this point on, I'll be dealing mainly with the conclusions and recommendations, specific aspects that were developed within the report. Here's a rather specific one. In essense, it states we may not be able to depend on one factor alone and so you should consider two, if possible, all three of them. Going back to that diagram. You should do something about the material, preferably change it if you can and that has been done, of course. You can control your water chemistry in terms of oxygen and other ionic species that are present. And you can hopefully minimize the stress by the use of some stress reversal process such as induction heating stress improvement.

[Slide.]

Here's one that deals with explicitly with water chemistry. You'll note that it suggests a reduction of the levels of ionic species as well as the control of oxygen. There's been some work done in this area. One of the things we don't know is could there be adverse side effects if you change the water chemistry. There's work here, there's some work in Sweden, but one has to ask in the long term could you have adverse effects and we don't quite have the answers but certainly it appears to be very promising in this respact, and

certainly it warrants examination. It has a very definite plus in that this approach would not only minimize the problem of intergranual stress corrosion but it would probably control or eliminate transgranular stress corrosion in the rare event that such occurred.

[Slide.]

Induction heating stress improvement. The IHSI is generally considered the more effective method than heat sink welding, which means that you are using a cold sink such as water inside after you've made a few weld passes, or last pass heat sink welding which is the LPHSW. It's more controllable in some respects; it can be done after the fact, and many planrts have, indeed, used this.

I might mention in passing that there was a valiant battle fought to try to get this one in the Code, not so much that it's necessary in one context, but to establish what I'd call controls, but we finally, as they say in the pipe game, threw in the towel. In the last main committee we decided that there's no way of getting over six or eight --

In any event, if you can reduce the residual stress you will certainly help yourself a great deal.

MR. ETHERINGTON: In the hydrogen experiments, have we any information on how much increases of hydrogen the steam vents?

MR. BUSH: There have been controlled experiments at

Dresden and I'm almost certain that these have been measured, Harold. I would guess that Bill Shack or one of the others have been keeping up. I confess I haven't kept up to this degree.

MR. SHACK: Could you repeat the question again? They hydrogen comes out as ammonia.

MR. ETHERINGTON: On the hydrogen experiments, how much of the hydrogen --

MR. SHACK: Well, it comes out in the form of ammonia combined with --

MR. SHEWMON: The answer is apparently not at all for hydrogen.

MR. SHACK: Not hydrogen as a chemical element. It comes out combined with ammonia and gives you some increase. You get it in the PWR but it's not in a volatile form.

MR. ETHERINGTON: There is hydrogen in the steam, though, isn't there, because we've had explosions.

SPEAKER: You're correct, there's hydrogen.

[Slide.]

MR. BUSH: This slide relates to a caveat. There's a substantial ignorance factor in it and that is that the preference is that if you're going to use induction heating stress improvement you use it in a material that doesn't have cracks in it. But the ideal time would be, say, at a near-term operating license. The facts of life are you can't

do it because you have plants that haven't been operating. And this simply establishes the caveat that if you're going to do IHSI and you have pipe that is known to be cracked, it is desirable to minimize the crack size before that because of, I call it, unknowns. It may be a proble; we can't assess it. You do a fracture mechanics calculation and you are somewhat in a never-never land down there. So it is simply, I would say, a conservative position with regard to this.

Among other things at this time, there is the concern about well, when you detect a flaw you can measure the length fairly well, but we have little confidence in the business of depth sizing. And I will address this a little later more explicitly.

[Slide.]

The other answer, of course, is to tear everything out, and that has been done in a number of plants now. They've simply taken the recirculation system out essentially, and put another material in. The suggestion here is the preferred material would be 316NG. This was based on looking at what information was available and making a decision as to 316 versus 347NG or 304NG or, of course, reverting to the low carbon grades which have been used in the past, which posed problems because of the lower strength allowables. That means you have to beef up the wall, so you run into a situation there.

I would comment that the Germans did do just this. When they had cracking, they took out all of the piping and used 347NG. Perhaps in this country one reason that the 347 hasn't been pursued is that there were bad experiences back in the 1950's in plants such as Purex and Redax and other places where there's a lot of weld cracking. And I think people still hark back to that. They haven't had the same problem with the 316NG.

So this simply suggests that this is an approach, and it appears that it will eliminate or certainly take very special circumstances to have intergranular stress corrosion cracking. I would comment that this does not solve the transgranular problem in the event that such should occur, but that requires very high stresses.

[Slide.]

MR. SHEWMON: Spence, one can, I hear, in lab tests crack 316NG also.

MR. BUSH: That's right. Bill Shack has done it quite often.

MR. SHEWMON: But in a sense, if we go back 10 years we can say that what you're saying about 316NG is exactly what GE was saying about 304. And what you say against that is that the Japanese have good experience. Do they have enough years of experience to say whether it's likely? I guess they don't have the life of plant experience yet.

MR. BUSH: No. The Japanese, interestingly enough, have had a few sessions on this and this is very interesting because they generally are very careful in what they say. They state unequivocally now they have no stress corrosion problem -- intergranular stress corrosion problem. To arrive at a statement as definitive as that from someone up in the Japanese hierarchy indicates to me that they are quite certain of their situation. They have had transgranular cracking, and this has occurred in Japan. It was a very special case with severe cold weather. I am unaware of validated cases of intergranular cracking in the nuclear grade material.

MR. SHEWMON: All of their plants would then be stress adjusted and new piping or new material?

MR. BUSH: Yes. Well certainly, they have new material and I believe generally they have tried to relieve the residual stresses or reverse the residual stresses. I do not know of any action on their part with regard to water chemistry. In fact, the last time I contacted them in this area was several months ago, and my feeling was they were not pursuing this one at all.

MR. BENDER: Spence, just a question that Paul asked, about what the real duration of experience is. What is the longest equivalent exposure?

MR. BUSH: In these grade materials?

MR. BENDER: Yes. Do you have any feeling for it?

MR. BUSH: I don't know. John has his hand up, or is he just sitting there? I don't think he did. This is not his area.

In actual plants, I think we only measure -- the actual experience in Navy non-nuclear applications it goes more. I think we have to recognize that all we're talking of here really is a carbon precipitation, and we do have many, many years of experience with the low carbon. The only difference in this instance fundamentally being that we have stuck nitrogen in to give us strengthening. So if we talk about the ELC grades, I think I could probably cite 20 or 30 years of experience in various industries under environments that are as aggressive or more so than this, where we see little or no intergranular stress corrosion factor. Essentially none to my knowledge.

So I believe that the experience in this respect is positive. I have to do it, you realize, by analogy. I can't say I can point to a 316NG at a nuclear plant and say I have so many plant sequential years of the thing, but I can by analogy use the others. And in this respect I think one can derive a substantial level of confidence. Yes, Milt?

MR. VAGANS: Milt Vagans, Materials Engineering Branch. A lot of their evidence is also from a fairly extensive research program where they've had not only laboratory specimens but simulated loop specimens and in-loop

testing where they tested the standard 304NG, and in every case, 304 has cracked. In every case. And in no cases have they had any cracking in their nuclear grades. And that's really the biggest part of their statement.

MR. SHEWMON: Fine. Well, we'll watch it. Maybe a few of us will still be here when it starts to crack.

[Laughter.]

Go ahead.

MR. NESTELL: James Nestell from MPR Associates here in Washington. I know for a fact that many nozzle safe ends with low carbon or extra low carbon grade were replaced in the mid-seventies when sensitized safe ends became a concern. And I know for a fact that at Peach Bottom, three safe ends are cracked, and that's .02 carbon material. Or less.

MR. BUSH: There have been some, I agree. But not -- generally at the low grades there isn't very much. Because I also remember some of them, in fact, in about three months at Nine Mile Point but they were higher carbon.

[Slide.]

This again represents a conservatism with regard to the length of the cracks, and fundamentally the concern here would be the circumferential length. The axial cracks as such tend to be self-limiting. They run out of the heat-affected zone, they run into the weld, and therefore, they're quite short. The circumferential cracks have no such limitation;

they can measure 10 degrees, they can measure 30 degrees and in some instances they're reported to be 360 degrees. And what this in essence states is that because of the lack of confidence in sizing -- and the sizing in this instance has to do more with the depth sizing -- if you put a link there then you will not exceed a stable condition.

In other words, you could make a calculation assuming the crack is through-wall, place all of the necessary dynamic and static loads on and still show that your crack essentially is stable. That's the purpose of this particular statement.

And this tends to be joint-specific because some will have higher loads than others.

[Slide.]

This cites IWB-3640 which is a section of ASME XI. I would indicate briefly this reverts back to 1979 when we wrote the NUREG having to do with BWR pipe cracking and it actually reported foreign experience, one of which was the case of cracking in a German reactor which resulted in their replacement with 347NG. Knowing that both the Regulatory Commission and the ASME Code tend to operate at paces that are sometimes snail-like, I decided we should start action, so we began to develop something.

Now, I think you should recognize that IWB-3640 and its supporting Appendix is not considered to be a permanent

fix. It has one and only one purpose, that is, to buy time. If you find cracks and you need to go out and buy replacement piping, it's not something that you do overnight and this would permit you to buy perhaps a year, or year and a half or so of time while you're gathering your material and taking other necessary action. That was the purpose of IWB-3640. It can be interpreted differently but that was the original intent.

This states that it was adequate. There were reservations. I could bring an update. Many of the reservations had to do with the situation with regard to a crack running into a weld. The other aspect of it, of course, had to do with the inability to adequately depth size the crack.

With regard to depth sizing, there are other slide on it, but I would indicate that a great deal of work has occurred in the last year. I am not 100 percent convinced at this stage but I will say that they are getting good results on depth sizing at this stage. They're also getting good results on sizing even though overlay cladding, which I didn't think would be very feasible. That's one aspect of the situation.

The other one had to do with the properties of the weldments. It was recognized rather belatedly that the notch toughness of submerged metal arc welds and submerged arc welds

were dramatically lower than is the case of tungsten inert gas welds in base metal. It may run below 50 percent.

In fact, while we were writing this report, there were experiments being conducted at the Taylen Basin that did indeed show there was such a change.

A very brief status report: after two or three iterations, finally a position has been developed resulting in new tables, still using the same approach which is limit load, dealing explicitly with the submerged metal arc and submerged arc welds.

This has been discussed at considerable length with the Nuclear Regulatory Commission, the appropriate portions of the organization. It passed Section XI. It went to the main committee on the 3rd of May. There were no negative votes at the main committee, no oral negative votes. There was one person who didn't vote at the time. I have not seen the results of the letter ballots yet, but I think there's at least a reasonable probability that it will pass at this time.

MR. SHEWMON: What passed? The acknowledgment that the toughness is one-half of what they thought it was?

MR. BUSH: This is a completely revised position that incorporates tables explicitly dealing with the submerged metal arc. So what you now have is the table that covers the normal material, tig weld or base metal in the normal and upset modes, and the same thing for emergency in faulted

conditions, and there are comparable tables developed for the less tough weldments in there. And it's given, in essence, in terms of the permissible depth of flaw that can be handled under those circumstances.

MR. SHEWMON: When you've got a sub arc weld then the flaw has to be -- you can have a smaller flaw and you can still operate with it, or what?

MR. BUSH: That's correct. That's exactly what the situation is. In other words, the lower toughness is taken into consideration in there, so your flaws, your acceptable flaws will be consistently lower in value.

Now, since they're a function of the length of the flaw and the load conditions, about all you can say is they will all be less to a substantial degree. Now, that's right across the board.

MR. SHEWMON: And less is expressed partly in length and partly in depth.

MR. BUSH: Yes, that's right.

MR. SHEWMON: So we're back to whether or not the depth means anything.

MR. BUSH: The depth is the controlling factor. As I say, we have increased confidence in the sizing. As I say, you might say that the jury is still out to a degree, but there certainly has been marked improvement over the last six months in that respect. And with regard to this, --

incidentally, the sizing is not very good at or below 15 percent. But that's an academic issue because we don' worry about flaws that are that small. They aren't the issue.

The sizing seems to be quite good when you get up above 15 percent and on up in the range you're concerned with, which particularly in this instance is around 40 or 50 percent.

MR. SHEWMON: Okay.

MR. RODABAUGH: Spence, Jesse made a comment I thought was very pertinent to what we're talking about. He said that due to leakage of a valve, the downstream piping got up to what, three or four times the design pressure?

MR. EBERSOLE: Yes.

MR. RODABAUGH: There have been lots of first tests run which would show that that's to be expected four times at least in Class 2 and 3 piping.

Rather typically, a piece of piping would stand six times the design pressure. Now, what bothers me is I see here when we have a cracked pipe, we have an advertised factor of safety on the normal conditions of 2.77. Well, this is not too far off the Class 1 piping practice, but Class 2 and 3 piping practice the aim is to get a factor of safety of 4 on pipe ruptures. It seems to me the factors of safety are too low.

MR. BUSH: What we're talking of here, you realize,

is essentially Class 1 piping.

MR. RODABAUGH: Well, you see you've broadened your discussion by talking about the feedwater piping, steam piping.

MR. BUSH: Not talking in this context. In other words, if it were feedwater piping I would worry about thermal conditions; I wouldn't worry about stress corrosion. After all, you're talking about ferritic piping, not feedwater piping. So this is a stress corrosion problem in austenitic stainless steel.

MR. RODABAUGH: Well, if someplace along the line we make it clear that IWB-3640 is intended for Class 3 piping only -- and even there I think the factor of safety is a bit on the low side.

Not Class 3, Class 1, I'm sorry.

MR. BUSH: I recognize your point or the thing. As I say, this is not a permanent fix. You also realize that as soon as the flaws get up to about 40 percent, the action has been taken to jack up the wall thickness by a factor of two or more. And so now, it's an interesting design calculation but in the region that you're concerned with, namely, about six inches, you have twice the wall thickness. So you now have to ask yourself how will that respond to load conditions.

I think the general feeling is that it will respond favorably. In other words, it won't do much. But you have a

valid point. The intent, of course, -- this was developed primarily for the primary system.

[Slide.]

This again represents conservatisms. In essence, what you're doing here is simply saying all right, if I've got a through-wall flaw it can be only so long circumferentially. You put your factor of safety on there. Part of this had to do, again, with our ability to evaluate these. You'll notice it talks about the SSE loading conditions, limit load analyses as well as the maximum crack length.

An important one here has to do with a crack length that would result in a leak rate greater than the normal makeup capacity. And notice also, it's modified according to the SECY document, in this instance with regard to the criteria.

In essence what this would come down to when the report is written it would be a circumferential flaw about roughly 25 percent of the circumference. That would be the permissible length.

MR. BENDER: Spence, to use this criterion you have to have some understanding of the rate at which the crack is growing in length.

MR. BUSH: That's right.

MR. BENDER: And I'm not sure that I've heard what the basis is for projecting that rate.

MR. BUSH: Well, we don't know that much about that aspect, probably. In fact, that's one of the never-never lands. I would mention in passing in this respect that many of our so-called long flaws, the ones that were reported as being long flaws, some of the utilities decided well, are they really long flaws or not. So in some instances they brought in teams using special techniques; some from Germany, some from the States. They actually, on the so-called 360 degree flaws, went in and used the more advanced techniques and reported no flaw. You had an artifact. You had a loop condition

They went further than that; they actually looked and sure enough, no crack. So my suspicion at this stage of the game is that apparently, a substantial percentage of our so-called long flaws, the ones that are close to 360, quite probably are artifacts.

MR. BENDER: Well, I wasn't trying to argue --

MR. BUSH: But that doesn't address your question. You're really concerned if I've got an arc of 25 degrees, how long will it stay at 25 degrees.

MR. BENDER: The staff, I know, is going to try and make some argument that says the frequency of inspection relates to the length of the flaw. And that means that if the flaw has been observed to be a certain length, the frequency with which you look to see whether it's grown or not has to be

adjusted somewhat. I don't have much of a feeling right now as to how that criterion is going to be applied. And I was hoping you might tell me.

MR. BUSH: Well, B.D. Liaw is sitting back there and I think NUREG-0313 addresses it in part but only in part. Rev. 2 is aimed at answering some of that, but not all of it.

MR. LIAW: B.D. Liaw, NRR Staff. The growth rate in the test data provided by GE and Argonne means that we can find a problem and recognize that there is some kind of certainty and that's why we feel uncomfortable with regular inspection frequency as a result. Therefore, before they replace the piping, we do augmented inspection. And the type of growth rate that industry ought to consider in evaluating the growth of the crack will be included in the forthcoming document.

[Slide.]

MR. BUSH: In essence, this slide has one message; that is, that axial cracks as such don't represent a major problem. I think that is the general consensus now. Most of them that I have seen have been measured.

MR. SHEWMON: Before you leave that one, I have heard of the -- the erosion problems I have heard of have always been in steam lines where there is likely to be two-phase flow around elbows. Has there been any cracking or erosion or thinning of elbows in primary systems that you have

ever heard of?

MR. BUSH: Well, most that I have heard of that's been severe has been where you have two phase. Because when you have wet steam, it's a lovely cutting mechanism. I would imagine that there are certain conditions in turbulent flow where you could get some wall thinning but I'm not aware, at least in my library of failures, of explicit cases where there's damage. I'm not saying it can't occur. Most of the bad ones I know of all have had to do with wet steam.

MR. SHEWMON: Yes, but the question of axial cracks always comes up and what you say is quite correct; that you're talking about an axial crack in weld metal. And I was wondering whether there were any other axial ones, but I don't know of any others, so go ahead.

MR. BUSH: To answer that one, there have been axial cracks. There have been a few cases of transgranular cracking where they were not related to weld metal that have had an axial orientation. That was a very special case; it represented kind of a mistreatment of the material in severe cold working in the localized area. And I don't think it was related necessarily to operating modes either; I think it was conditions of the material.

[Slide.]

This simply says that what we had in the Code wasn't any good. But we generally agree to that. The Code Case

N-335 is on the street, is being used. There's another code case that amplifies on it. And expanding on this, there's been very substantial action over the last 12 to 15 months in this area within industrial, within the Code groups, within the Nuclear Regulatory Commission, and they're looking at factors such as the human variable which is recognized as a significant one in this type of an examination. They're looking at the business of improved and consistent techniques that could be used, not necessarily going to totally different techniques. Defining procedures.

And as a result of this, I would say the probability of detection of cracks when they get above about 10 percent or so is now quite high. I would not say it's 95 percent but I would say it's probably close to 85 or 90 percent. The probability of sizing is not that good. It's variable. It's still very strongly dependent on the individual. The length is not bad, that's fairly easy to size. The depth still is a problem, however some of the teams that are going through the sizing exercises now down at Charlotte, my understanding is they're doing quite well. The only problem is that one team will do very well and the next team won't do so well. So we still have a ways to go.

[Slide.]

This simply says that we need to do more in this area, and that's just exactly what I was talking about. I

believe we're making progress but I don't think we're there yet. But we are a great deal better off than we were even a year ago.

[Slide.]

This again talks about personnel and procedure qualification. Again, positive work is being done there. In this respect, I might mention I have a new hat I'm wearing now; I descended, I guess, to the throne or something like that; by difference of their Section XI I'm now the Chairman. And we reorganized in recognition of a major effort in the area of non-destructive examination. We've now raised that to a subgroup status. We have a whole series of task groups. They meet, they're very active. On Monday you wander around and you'll see 30 people in this room and 20 in that and 15 or 20 in another room, all working on some aspects of this business of personnel qualification, procedure qualification, et cetera.

The effort is belated; it should have been done some years ago I recognize, but at least I would say substantial progress is being made at this time.

MR. SHEWMON: We're talking about personnel for NDE work, is that right?

MR. BUSH: That's correct.

MR. SHEWMON: And pretty soon Glen Reid will get at you and talk about how maintenance people should be chosen, or

something.

MR. BUSH: I washed my hands of that matter as being a non-expert.

[Slide.]

In this area, this is a recommendation. I was at Charlotte about three weeks ago for other reasons. They were having a workshop at the time and I was getting feedback. I didn't participate in the meeting but I was getting positive feedback that they were being quite successful. Quite frankly, a year ago if I'd been asked the question I would have said, I don't think they'll do that well.

Again, I suspect there's a substantial variability factor here but they're doing better than I would have anticipated as of a year ago.

MR. SHEWMON: Is the outside of this repair work welded? I'm sorry, ground?

MR. BUSH: They're doing very little with regard to the surface. B.D., I think you had a comment.

MR. LIAW: Let me add something. NRC, IE headquarters, NRR and the regions have a list of all qualified examiners who have passed the qualification test at Charlotte. So the first thing an NRC inspector checks when someone comes to inspect pipes, is to see whether that person or persons are on the list. And we keep track of well they perform in terms of detection.

MR. SHEWMON: Okay.

MR. BUSH: We're making progress. One has to recognize that when an examination is done where you have, you know, a reasonable timeframe, it may not be the same thing you do when you're in SWP clothes and have a substantial number of welds. But again, I believe that program is recognized and I think we've been moving up the curve to a degree. As I say, I'm still not satisfied but I feel we are making progress.

[Slide.]

This one is very difficult to read. It's the summation of -- and there is a handout there -- of things that should be done in the research and development area such as more reliable manual UT inspection methods, automated UT equipment. Number one I think is done. Number two is slow.

Dimensioning flaws -- progress is being made. Inspection techniques for detection and dimensioning by weld overlay, I mentioned that already. The effect of detection characterization after doing stress improvement -- I have seen no data on that to date.

The next item on transfer methods I will pass over.

Austenitic butt welds on metal -- that's to get through where you only have one-sided access. Again, we're not making too much progress in that area. It's a difficult problem. ID cladding -- that's reliability of advance techniques.

Every one of these areas, with the possible exception of the transfer method, is being investigated and in some instances substantial progress has been made.

[Slide.]

This gets back to the qualifications of operators; the item that B.D. just mentioned. You have to complete the course based on a statistical sample. Additional classroom training once a year. These are suggestions; however, I might mention that the Code is moving in this direction to essentially establish national certification.

UT procedures should specify the equipment to be used and the procedure combination should be qualified, and the deficiencies in the Code should be corrected. And I believe we are making progress in that area.

[Slide.]

Calibration blocks -- these are suggestions for improving the Code. That's been worked on. Calibration reflectors -- that's pretty well set out. They have conformed to other angles including L-waves, usually 70 degree. They are doing beam spread correction and I'm not sure about the skewed scan situation where you have an off-line crack. That's a very difficult situation. And they have moved away from the 50 percent DAC to a more realistic value, say 20 percent.

[Slide.]

This has to do with experience -- I believe you've seen most of this. It talks about centrifugally cast, which is not a matter for here. It indicates again that the minimum requires of Section XI are inadequate, and we recognize that. It also indicates the difficulty of going through a weld to make an examination of the other side. That's simply a loss of signal problem.

The operator variable is cited in here. These factors essentially were mirrored in the previous slide and actually is being taken in almost every instance.

[Slide.]

I think this is a very significant suggestion or recommendation. The operating experience and the fracture mechanics both indicate leak before break is a most likely mode of piping failure. And in essence it states that they recommend that the limits on unidentified leakage in BWR's be decreased to three gpm and that the surveillance interval be decreased to four hours or less.

I would indicate in passing that before we wrote this we looked around and we found indeed that there are some utilities that are doing this or better at this time, BWR's. So it's not an impossible task to do. It obviously represents some restraints. Some are at least at 24 hours, but the feeling here is that -- well, this one has more teeth than many but I would say this is a very substantive

recommendation.

MR. BENDER: Spence, if I were a PRA guy, which I'm not, I would be asking the question of what is the likelihood of a double-ended pipe break in terms of its frequency of occurrence, based on this kind of argument. How has it changed over the period as a result of this program? Do people try to ask that question?

MR. BUSH: We talked about it. In this material, one of the problems you have is your leak rates, your throughwall cracks in this area, you're often talking of leakage that is in the terms of .0003 or .0004 gpm. That's a rather small number. Obviously, it takes quite a while to detect it.

Now, there are certain techniques -- activation monitors, things of that nature will pick up such activity. You could use sensitive strips in there, you could use acoustic emission. But these are pretty special things. You certainly would not find a small leak like that.

The situation here is -- and all I've found is -- that generally, you can have leaks where the rates of growth are sufficiently slow that they get a little bigger, a little bigger and a little bigger. The closest one I can ever think of was the Nine Mile Point situation which was a combination of bad design and sensitized steel where, you know, they let the vessel grow and put a bending moment on the pipe, which

was never intended. And in that case, we had a pretty good size crack.

Otherwise, there have been cracks up to 60 percent through-wall 360 that just kind of sat there. One of them went all the way through. So on a PRA basis, the numbers depend on your input assumptions.

MR. VOLLMER: Let me comment on Mr. Bender's question. We did take a look at this in Volume 1 of NUREG-1061 and found that if you use the best numbers we have available from pipe breaks for accident analysis or overall risk, one can't justify on a cost-benefit basis doing much to the piping systems of BWR's. So therefore, the scheme that we have used is one which would encourage utilities to change out pipes that were bad by saying once it is cracked, basically you have to keep augmented inspection, and try to encourage them, for piping that is sound, to move to mitigation by hydrogen-water chemistry and stress improvement techniques, and again, get them out of augmented inspection.

So if you just take a look at the cost-benefit of making the changed piping, it will never hack it. So that's why the recommendation on the short and long-term program to the Commission did not have any real specific requirements in terms of replacement of material, but rather they've been oriented toward leak rate requirements and in-service inspection requirements.

MR. SIESS: I heard a couple interesting answers but I didn't hear anybody answer Mike's question. Does that mean we don't have any PRA types around? Mike says what's the probability of a double-ended pipe break.

MR. VOLLMER: With this material it's very low.

MR. SIESS: Now, actually there's two questions. One is, what's the probability of a double-ended pipe break; the other is, what's the probability of a double-ended pipe break without leak before break.

Now, it seems to me the second one is the one you got around to addressing, am I correct?

MR. SHEWMON: You give us the data base where you've got several datapoints and then we'll calculate your probabilities.

MR. SIESS: Well, on historic probability, you know, you can still take so many years and end up a number.

MR. EBERSOLE: I would just plead for a hard look at the system aspects of this. And to extrapolate a little bit what I said a while ago, you know, NRC Staff puts heavy dependence on this simple redundancy, the single failure criterion. Not to include these things that do happen like this over-pressurization of low pressure systems. And therefore, one time over-pressurization I think ought to be considered. And I think most of this rationale here is based on the notion that you have a pipe under constant pressure.

Whereas, lots of our pipes are standing on the backside of valves under no pressure at all and it can proceed to crack and you don't have any leaks until you put the load on it.

MR. BUSH: Well, not necessarily, Jesse. You can do both. You can get what I will call pure stress corrosion cracking. And I don't like to use that term; I usually talk about corrosion fatigue, because almost every system sees cycles of a varying degree, and so I think you have to consider them as such.

I think what we have here is the materials are pretty doggone tough, and you admittedly might get into the situation Chet mentioned where you get wall thinning down to, you know, 10 percent by some highly improbable mechanism where everything grew at exactly the same rate. And then you would have the situation.

And indeed, there was a failure, you might call it, of this type that occurred last year in Germany. They did the same thing. The only thing is they made a design error and they put in a wall that was 10 percent of what it was supposed to be. Same type of situation, and it did just what you said.

It took a few numbers of cycles and then it failed.

MR. EBERSOLE: Well, what I'm really saying is that the pipe can fail without having stress due to internal pressure, can it not? Just due to weld stresses. And just sit there and crack.

MR. BUSH: It can crack but I don't think it would fail under those circumstances. It's driving into a negative stress field. Because you have to have a balancing of stresses, so if they're tensile on the inside, they have to be compressive on the outside. So if you have zero loads otherwise, either bending or -- I would say you'd go into a negative K field, and it would tend to go to an extreme.

I think what you'd have is the crack would grow to a certain depth and then it would tend to start growing out, because it's growing into a negative K field in that case.

MR. SHEWMON: Gentlemen, as soon as we let Spence finish, we get a break.

[Slide.]

MR. BUSH: This simply says if you're going to replace things and you're going to build new plants, you should optimize them for examination, for accessibility, recognizing that if it's going to be replacements, you're not going to throw away pumps and valves so you still have the problem. But otherwise, you should do it. Certainly, any new plant that were designed, if that were to occur, you should do that.

[Slide.]

This is a summation of all the things I've talked about. Short-term solutions. It's in there. It simply was my attempt, you might say at an accident or event tree.

[Slide.]

This I think is important, covering what has been done with regard to design state, NTOL, with regard to actions that can be taken. Overlay welds, when you have cracking. Residual stress improvement almost across the board. Hydrogen water chemistry is a general recommendation. You want to have an improved baseline on your ultrasonic, and if you have the option at the design stage or otherwise then you would go to a new material. I don't think anybody is going to tear out material -- well, I wouldn't say that, the Germans did it. But generally, I think you're going to have to have cracking before you take that action.

[Slide.]

This is the categorization of welds. The first one would be a new material, and the actions that are taken. The second one would be where you have improved resistance but you can't guarantee it. The third one is where we are with our normal materials.

[Slide.]

These are suggested materials. Most of the emphasis I mentioned would be on 316NG. The other options exist for use. And this really is more B.D. Liaw's because this moves into NUREG 0313, Rev. 2.

This is based before you find cracks, because ass oon as you find cracks the situation changes.

That was the last slide, and I'm sorry I was longwinded.

MR. SHEWMON: Are there any questions?

MR. BENDER: Spence, you mentioned earlier that there were still some uncertainties about what the detrimental effects of hydrogen injection might be. Can you be more explicit? What things are of concern?

MR. BUSH: I'm not sure there are any detrimental effects in the context of degradation of components. One obvious factor is that you generate a lot of nitrogen 16, and that means you'd better think about shielding your turbine, et cetera, because you are certainly going to expose your people out there because the levels do get substantially higher. That's one area.

Another area is, of course, if you are generating material and even though it is supposed to be ammonia, depending on how you control things you can still have an excess, and people always ask: well, could this have an adverse effect on the vessel, and things of that nature.

I think by and large, the answer is we wouldn't expect it but we just don't know very much about that situation. The Japanese, most non-nuclear, are doing a lot of work there and we hope to be able to take advantage of their hydrogen work and ask ourselves the question: well, based on extrapolations from these experiments, do we have sufficient

confidence. Those are some examples. I'm sure there are more.

MR. BENDER: Well, I know the vessel question comes up periodically.

MR. BUSH: I don't think it's a major issue myself.

MR. BENDER: But since hydrogen is injected in the BWR systems continuously, and you have had that kind of experience, is there some reason why it could be different in a BWR?

MR. BUSH: I can't think so. Just those questions.

MR. EBERSOLE: Along that same line, there are prodigious quantities of hydrogen and oxygen, stoichiometric quantities, that have come out in the condensers and must be stripped and added, then, to the shaft in-leakage from the turbine. This makes a mixture. Now, you're going to add hydrogen. What's the volumetric increase we're talking about in hydrogen flow? Is it going to upset the explosion designs of the system downstream?

MR. BUSH: I can't answer that question.

MR. ETHERINGTON: It was answered by saying you don't get hydrogen, you get ammonia. But I don't quite buy that.

MR. EBERSOLE: I don't understand that ammonia bit. There's already lots of hydrogen.

SPEAKER: I need to correct my statement. You do

get hydrogen out. I gave you a partly wrong answer. You get ammonia along with it. You're perfectly correct; you get more hydrogen out. They have the recombiners in there. They've had to modify them. Dresden has been running this experiment now for more than a year and a half and they have had no problems.

MR. BENDER: The only significance of ammonia is that it permits you to carry the N16 out into the turbine. I think that's really the issue. There will be an incremental increase in hydrogen. My intuition says it's not significant for explosion hazard purposes, but I don't know until I see the numbers.

SPEAKER: The only problem they've had at Dresden is with the catalytic process. And apparently, in past history some particles of the catalyst have gotten into the upstream portions, and they have had some occasional poppings and stuff like that upstream. And they think that is due to contamination or material inside the system. Again, that's all part of what seems to go along with recombiners.

The other one that has caused potential trouble that's not been mentioned yet is the possible action of the hydrogen on the fuel. There was some concern on that, but that appears to be pretty well taken care of as a non-issue. There is an inspection I think not yet completed of the fuel out at Dresden that will presumably put that to rest.

MR. ETHERINGTON: Well, the hydrogen couldn't be more than in a PWR, would it?

SPEAKER: No, it's not more than a PWR. The difference being that they use zirc-4 in the PWR and zirc alloy 2 in the BWR and there's a little more susceptibility in zirc alloy 2. But as I say, the specialists don't really think it's a problem.

MR. BUSH: I looked at this at considerable length for a production reactor years ago, and we pretty much convinced ourselves, based on nuclear extensive work that that was kind of a second order effect. But it doesn't you can't get into trouble, but usually you have to work at it hard. Your oxide film has to be pretty poor, and things of that nature.

MR. SHEWMON: Okay, if that's it we'll take a 15 minute break and then go to seismic.

[Recess.]

MR. SHEWMON: Let's go back on the record.

MR. LIAW: Good morning, gentlemen and ladies. I'm not going to use any viewgraphs, but before I discuss the implementation scheme of the Pipe Crack Review Committee recommendations let me just give some codification to the issues you discussed earlier.

One, Mr. Chairman, you asked whether or not we have seen experience. We have experience on the crack in the

low-carbon or nuclear grade materials. I guess the gentleman from MPR indicated that there is some cracking, and I just simply want to add some qualifiers to that.

Yes, some cracking in the crevice region in the area where one has seen substantial repair, grinding. And those are the cases we have seen; not the principal matter or 317L or 316NG.

Back to the subject that I will discuss. First, we submitted to the Commission on November 7 the staff long-range plan to deal with the problem. We met with the Commission sometime in January. As a result of that, the Commission sanctioned the staff long-range plan; however, at the request of Commissioner Roberts, the Commission directed the staff to develop the long-range implementation plan to see how we would impose that either as a requirement or some industry action.

The elements to be included in this implementation plan are as follows: We will take the Piping Review Committee's recommendation as contained in 1061, Volume 1, and also, public comments. You know that we published 1061, Volume 1 and we seek public comments.

We have received several of them, and the comments relate to, for example, why two cycle for overlay welds. Whether or not the hydrogen chemistry are being imposed as a requirement. And we are prepared to address that.

In terms of the staff position, technical position,

that will be contained in a revised document, so-called 0361, Revision 2.

We prepared a draft about a year ago, however, substantial rewrites will be needed because at that time, there was not a technical document as represented now by 1061, Volume 1. Again, we had to incorporate public comments on that one.

The present schedule is for the staff to complete our Commission paper by the end of June and submit to CRGR, then publish for public comment for a period of about 30 days. We are projecting that by the end of September we should be able to submit the whole package to the Commission for their approval. I presume that when we submit the paper to the Commission, a copy will be provided to ACRS, too.

The reason for this schedular sweepage is principally due to the difficulty the ASME Code Committee is having, or was having in resolving problems involving the low toughness of certain type of weldments, originally raised by Professor Paris.

Professor Paris, in his letter to Commissioner Roberts and the staff, characterized the use of the original IWB-3640 as being dangerous. And that has caused some problem as you can understand. As a result, we withheld our endorsement of that portion of the Code until this issue is resolved. And I'm glad to report to you that we worked

closely with Code people, informally and formally both, and finally, the task force in the week of April 15th meeting in Nwe Orleans, they were able to reach some kind of an agreement.

I understand that the whole package is out to the main committee now in ASME. As Dr. Bush alluded to it earlier. I certainly hope that as soon as the main committee passes it and even before they formally put it into the winter agenda we will proceed to finalize the staff position and finish up the Commission paper.

MR. SHEWMON: This basically comes down to how much smaller the crack size, the critical crack size is in this material? Or what?

MR. LIAW: There are two aspects of it; long range, we would take their recommendation; if you want to replace piping material and whether or not you have to have IGSI along with it, and whether or not you have the water chemistry --

MR. SHEWMON: No, I mean the IWB or whatever it is, 3640.

MR. LIAW: Yes, that's pretty much changed with the indicated level of cracking of CESSAR is the circumferential extent of the cracking, and a different curve for a different stress level. In a sense, the combination of the extent of cracking, crack length, versus the crack path.

MR. SHEWMON: And now there's one curve for fatigue

welds and one curve for sub arc welds?

MR. LIAW: No, only two criteria. The curve ought to sastisfy both criteria. So for high toughness weld, it will continue to be the criterion; for low toughness material, the J value will be the governing criterion.

MR. BENDER: B.D., back up for a minute. What was Paris' concern?

MR. LIAW: That will be a separate subject, but since you asked, --

MR. BENDER: I just want to get it into context more than anything else.

MR. SHEWMON: B.D. talks about that at the end of the program so we've at least got the right person.

MR. SHAO: Professor Paris says you can use limit load for some of the low thoughness material.

MR. BUSH: I might comment that as chairman of the subgroup who had responsibility in the presence of Professor Paris and others, I went around the table to find out what the feeling was, and what it came down to basically was that the analytic procedures were not -- you were in a never-never land there so far as being able to unequivocally predict. And then I asked the question: how many of you would expect the pipe to fail if you had a crack of this depth, and the answer was -- I didn't get any hands up that said they expect the pipe to fail.

So it really comes down to the adequacy or the sophistication of the analytic procedure. And so one way to do it is to make the flaw smaller, and the procedure then -- the less sophisticated procedure -- still has a more comfortable margin. So I wouldn't say the problem goes away but it's more relaxed.

MR. SHEWMON: But do I then have a J number in the Code?

MR. BUSH: No, I'm sorry. I think B.D. is not correct. Both limit load approaches -- all the diagrams that are in there use the same basis. They use a multiplication factor to go from one to the other, which is based on the experimental evidence. And so the tables all look alike except the numbers are different.

MR. KLECKER: Ray Klecker, NRR. You are quite right in terms of the tables. However, the tables have been established on the basis of J-type calculations. So they are J analyses, in effect.

However, for the user, the answers were all calculated similarly as they were in IWB-3641 and 42.

MR. SHEWMON: One of the things we'll talk about this afternoon is aged stainless steel castings, and when Bill talked to me over the phone, he talked about a J number and if the grade integral was greater than 2 then in some units it didn't get defined, then we hope the staff will accept that,

and if not, they wouldn't. And we will get into that when we get to Paris' stuff this afternoon or when we get to you?

MR. KLECKER: I'm going to talk a little about how we do the J analyses for the cast stainless and the reason for our limits on it. It's a little different approach, let's say, than IWB-3640 in that we didn't look at all the J-t analyses. They carried it all the way through and found the limiting goes that way. And then, using the formulas that one uses for limit load analysis and comparing them to get the answers you arrive at the multiplication factor, essentially the stresses. And the net result is, of course, you get a much smaller crack.

Now, for the higher loads, it's a very conservative approach.

MR. SHEWMON: Okay. Did that answer your question, Mike?

MR. BENDER: Well, I didn't want to get into an elaborate thing. If B.D. wants to say --

MR. LIAW: That's all I was going to say, so we might as well get it over with.

The reason we feel it's important to resolve this concern is because once the standards are incorporated into the Code, in effect, by Section XI of the ASME Code, once it is endorsed by the NRC it becomes part of the regulation. And that means anybody can use it, even for PWR. Even though,

like Spence indicated earlier, the original intent was for short-term operation until someone can change over to the resistant piping.

Professor Paris wrote the NRC several times, but the one that seems to have attracted most attention because we had provided formal response, was the one he wrote to Commissioner Roberts. And I could categorize it into three major areas. Number one, original ASME Section XI, IWB-3640 is "dangerous" because it did not account for load toughness welds. The value curve of the limit loads.

And as indicated earlier by both myself and Spence, this thing has been resolved with the full committee and has been agreed upon by all concerned parties.

MR. BENDER: The statement you're making is that if the flaw that's being detected is small enough, then the concerns about load toughness welds will disappear?

MR. LIAW: Yes.

MR. BENDER: Would that satisfy Paris' argument? Has he ever been asked whether that's a valid point or not?

MR. LIAW: Well, before the committee meeting in New Orleans, I spoke to him, encouraging him to participate, and he said because of his previous commitments, or some problem, he was not able to attend. And I explained to him, hey, Paul, you raised the issue. I think people worked so hard to resolve it, I think you owe it to them to go. But he didn't.

MR. BENDER: But he knows about it and he hasn't written another letter saying --

MR. LIAW: He has not written anymore letters.

MR. SHEWMON: B.D., the limit load says that you've got a crack part way through and the remaining ligament will go fully plastic, then you can calculate failure stresses on the basis of that. Is that right?

MR. LIAW: That's right.

MR. SHEWMON: And if that ligament is low toughness, then it may break in a brittle fashion.

MR. LIAW: Right, before you reach that --

MR. SHEWMON: And that then, in that condition, the limit load would not be conservative or proper as a way to tell --

MR. LIAW: It will not --

MR. BUSH: Not necessarily brittle; it simply wouldn't sustain the load.

MR. LIAW: Let me continue. The second thing is the thermal stresses should be included in establishing the acceptance criteria. And this item, we don't disagree with.

And the new proposed IWB-3640 will address this one.

MR. BUSH: Yes, this is taken care of, and I would defer probably to Bob Bosnak as to whether these are adequate or not, but it was generally considered to be acceptable for this purpose.

MR. LIAW: The third concern expressed to us was the need to demonstrate material ductility, and this one is a little bit complicated. Conceptually, we don't disagree. I mean, you have to have ductility in your material. Not only for piping but sometimes even for concrete, like Professor Newmark used to advocate.

However, the way he approached it, is one has to require the utility to postulate the failure of supports or other physical limitations. And that is where we have major disagreement. We told him that we, as a regulator, we are not going to trade one evil for another one, in that we allow demonstration of piping integrity through leak before break so that they don't have to postulate a break. That's the whole idea.

And what he is asking is to replace that and postulate support failure or physical limitations.

MR. SHEWMON: This is the failure of the support of the steam generator? Or what kind of support are we talking about?

MR. LIAW: Everything. To the maximum extent.

MR. BENDER: He's looking for a high initial stress.

MR. LIAW: That's right.

MR. BENDER: As a mechanism for driving a crack.

MR. LIAW: And we told Professor Paris when the Piping Review Committee met with him that as a regulator, we

don't believe it was appropriate to do it as a regulatory requirement. However, the utility proposed to do that, and we could consider that and give it evaluation.

MR. BENDER: I'm reasonably well educated if everybody else is.

MR. SHEWMON: Okay, let's get back to 0313, then.

One of the things that Spence said in his presentation was that credit for stress adjustment in some way didn't through the Code Committee at this point. It seems to me that a more important point for this audience is what credit the staff would give for stress adjustment.

MR. LIAW: IGSI or other scheme to address the stress for non-cracked pipe, the current staff position, as we implement it every day, is not to give credit for that.

MR. SHEWMON: Is not to give credit for stress adjustment.

MR. LIAW: Right. If cracks are verified.

MR. SHEWMON: Okay, and if cracks aren't verified?

MR. LIAW: If cracks are verified, we either -- depending on the degree of the reported crack, then. If it's very short, -- this on a case-by-case basis, and maybe ask them for a third-party verification. You know, like Fitzpatrick. In addition to the normal contractor they also have KWU in there to verify it.

MR. SHEWMON: Okay. But is there anything to

motivate, at this point, a utility to do stress adjustment on its welds in a new plant?

MR. LIAW: Yes, because that's -- in fact, we seek some kind of commitment from the utility to do it in the first refueling cycle at the latest. I can give you one example, Grand Gulf Unit 1. They have 22 welds or about, which were not mitigated when we gave them an operating license.

And since the issue can only be justified on the basis of occupational exposure, whether to do it before.

MR. SHEWMON: Okay, right.

MR. LIAW: Let me try to summarize what I said.

In a sense, this today is not really affecting the utility program plan to seek a long-term resolution, as we indicated in the Commission paper, SECY 84-301, in that if one chooses to replace the piping, there is procedural guidance issued to them which allows them to do the job under the so-called 50.59. That means the staff determined that there are no unresolved safety issues involved. So they do not have to have staff approval before they do the job.

And for plants that are operating with piping that is susceptible to cracking, the staff guidance has been contained in SECY 267C, which was reviewed by almost everybody, including ACRS full committee and subcommittees and also, the Commission. In a sense, the Commission imposed that, pursuant to 10 CFR 50.55A(g)6(2). Anytime the

Commission sees this problem and wants to seek further assurance for reliability. Let's not even talk about safety; for further assurance and reliability of the piping or the material, the Commission could impose augmented inspection.

The elements contained in SECY 267C were incorporated in Generic Letter 84-11 with slight deviations because of your comments. At that time, you recommended to the Commission that there should be some limit on the crack depth. As a result, we modified those elements in 267C and incorporated them in Generic Letter 84-11.

So what I'm saying to you is despite all this delay, we are not really affecting utilities' programmatic planning for seeking long-term resolution. And also, as Mr. Vollmer indicated earlier, the cost-benefit number does not justify taking immediate, more drastic action. And that's what Mr. Vollmer, when he spoke to the Commission, that's what we committed to the Commission. And they seem not to have a problem with that.

MR. SHEWMON: Now, there will not be a third revision of NUREG-0313, is that it? What will bring out your position will be NUREG-1061, revised?

MR. LIAW: No, it will be 0313, Revision 2.

MR. SHEWMON: And when is that due out?

MR. LIAW: Early September. We'll give it to you before that.

MR. SHEWMON: Okay.

MR. LIAW: That's all I had to say unless you have some questions.

MR. SHEWMON: Okay, thank you very much.

MR. LIAW: Are you going to talk about Paul Paris' concerns again, or did that satisfy what you had in mind?

MR. SHEWMON: I would like to have somebody explain to me just when is a low toughness weld brittle and when is it ductile, because I always sort of thought if you've got a low-toughness thing big enough you could consider it brittle.

MR. LIAW: I have a few viewgraphs.

MR. SHEWMON: Milt Vagan keeps saying no in my ear, but maybe I can do that -- maybe we can cover that with Ray later.

MR. LIAW: Later on we can cover that.

MR. SHEWMON: Now we go to seismic.

MR. HOU: I am Shou-Nien Hou, staff of NRR, and the Chairman of the Task Group on Seismic Design, NRC Piping Review Committee.

The task group consists of five NRC members and five consultants. The end product is in NUREG-1061 Volume 2 and addenda to the Volume 2.

[Slide.]

For years, the seismic design criteria required by NRC have been developed one at a time without overview of

integrated effects. And sometimes, because without data and an adequate data base. So because of the uncertainty, we add conservatism in each step of the criteria development. Then also at times, we tend to believe if we put the conservatisms together they will enhance the overall safety.

Today, we have the piping systems that get a lot of seismic support and snubbers, and the piping systems become very stiff and with high thermal stress and the nozzle loads, and more adversely affected by the errors of construction, operation, maintenance and inspections. And we have more snubber problems; for instance, lost snubber function due to degradation or aging of the hydraulic snubbers. And we have increased pipe stresses due to snubber lock-up of mechanical snubbers.

So the problem is we have spent so much effort in the seismic design, the design is getting so complicated and costly; and yet, results in piping which is less reliable in normal operation.

[Slide.]

So the objective of the task group is to try to achieve immediate improvement in piping reliability on normal operations. What we do is to review the seismic information and recommend changes in NRC requirements and identify the future actions.

[Slide.]

Here is a list of the technical issues. I'm going to present them to you one by one. The problems and our recommendations.

[Slide.]

The first issue is about OBE and SSE. Now, the design pretty much follows the industry practice at two earthquake levels. According to the requirement of 10 CFR 100, Appendix A, it says shall be designed to both OBE and SSE. Now, by definition, the OBE is an earthquake having a reasonable probability to occur in the plant life. Again, we also have it saying the OBE shall be at least one-half of the SSE.

See, we are so safety conscious, and OBE and SSE is such a level you won't have great uncertainty. So in the plan review, usually the SSE has been very, very high. But because of the relationship of OBE and SSE, the OBE is also getting very high at such a level that it's no more here than the earthquake having a reasonable probability to occur. In fact, it becomes an earthquake which reasonably has probability not to occur. So here you can see the inconsistency by the definition.

Again, according to the Reg Guide 1.61, there's a requirement that the damping has different values for the OBE and SSE. And that makes the OBE control the design.

Now, OBE actually is a matter of a level to protect

the investment. It's for the utility to decide -- of course, we don't want it to be too low. However, if OBE set the level of OBE that would make the systems overly stiff, and that's not what we like to see.

Also, because of the importance of 1.61, there are different damping values for OBE and SSE.

In piping seismic analysis, we need two separate analyses for OBE and SSE. At the present state of art, all analyses are linear elastic, just because of different damping and you have doubled the effort because it sounds reasonable.

Now also, the ASME Code does not address the relative anchor motion to the level of stress level E, which is SSE level. And I'm going to address that issue later on.

I will show you the piping response we've observed. We found out the rate of anchor motion, which is very important and ought to be considered. So those are the problems and the current issues related to OBE and SSE.

[Slide.]

These are our recommendations. We're asking for decoupling of OBE and SSE by rulemaking to be undertaken to change the OBE definition in 10 CFR 100, Appendix A. For your information, in fact, they already have -- half the OBE is less than one-half the SSE level. Now, a noticeable one is Diablo Canyon.

The second recommendation is to investigate the

feasibility of a single seismic analysis. For that, we feel that to have an NRC internal review on using the uniform structure damping for both OBE and SSE, uniform piping dampings for both OBE and SSE. If that can be done thoroughly, it will be feasible; just one analysis. And then by scaling to together with one OBE and SSE.

Another recommendation is request ASME to consider the anchor motion at SSE.

MR. BENDER: What does that mean? When you ask ASME to consider the anchor movement at SSE, you're asking them to look at a stress condition that really isn't covered in the Code. What are you trying to get them to do?

MR. HOU: Well, we call their attention to various avenues. The one possible avenue is for the co-chairman to write a letter to them informing them of the findings. Matter of fact, they've already been informed about our findings when we mailed our report to them.

MR. BENDER: I think you're not quite clear on what the question is. I understand that you can ask them to do it. What kind of response do you want from them? What do you want them to put in the Code?

MR. HOU: To change the Code rules.

MR. BENDER: Well, that's not enough for me.

MR. BOSNAK: I'm Bob Bosnak, Division of Engineering. What is really being asked for is a

reconsideration of how we look at seismic inertia stresses and also, the sam stresses. Those now in piping are secondary; they're secondary stresses, they're not included once you go beyond the upset condition.

So we're asking for -- and I think this will not take place until some of the research work that EPRI is doing has been completed. And that will get into how does piping really fail under earthquake loads. So again, we're talking about two things here. Not only -- not this by itself, but we're talking about seismic inertia stresses as well.

MR. HOU: According to the current state of art for coupling the piping response, they couple it in two parts. One is the initial response, the other is the relative anchor motion.

Now, for the OBE level currently we do consider both parts and add them together. But in SSE, not. But currently it's not that critical because OBE controls the design. But in future when we have the rule come out and decouple OBE and SSE that will be critical. That's why we'd like to call their attention to it.

MR. BENDER: Okay, that's a better explanation. Thank you.

[Slide.]

The last issue is about damping values. Damping is a very hypothetical parameter. It represents the energy

dissipation of a piping system under dynamic loads. And it involves a lot of things that can affect damping. In the past, because we are not aware, not very clear about the effect of the individual parameters, that's why when the Reg Guide 1.61 came out it just used a lower bound value.

But because it used a lower bound value it added conservatism in there and it contributes to the stiff piping system.

Currently, the damping values proposed by the PVRC are based on experimental data from the plant, from the lab, domestic and foreign, large piping, small piping with various support conditions and based on that we make our recommendation.

[Slide.]

And there are the damping values. Originally, Reg Guide 1.61, the damping is different for the SSE and OBE. And also, --

MR. SIESS: Excuse me, what's the abscissa on that plot?

MR. HOU: These are frequency. This is percentage of damping.

MR. SIESS: No, the abscissa. That's percent, I understand. That's the ordinate. But the abscissa.

MR. HOU: This is frequency.

MR. SIESS: Calculated frequency?

MR. HOU: This is the frequency of the piping system.

MR. SIESS: The calculated frequency of the piping system, assuming whatever you assume.

MR. HOU: Yes, we performed a spectral analysis of the piping. The piping frequency based on the mode of frequency to pick up damping values on this curve.

Now, the Reg Guide damping is related with parameters and also related with the level of the earthquake. But here [indicating] it's not. But there is a new parameter in here, the only parameter that -- piping frequency.

Now, we have looked at a lot of data. We know that damping can be affected by a lot of things. For instance, the type of support, how to space it, how much insulation, whether there's a gap. All kinds of things. It's very complicated.

MR. SIESS: You didn't mention stress level.

MR. HOU: Yes, I mentioned the stress level. OBE and SSE designed to differ the stress limit. And here it's not dependent on the stress level.

MR. SIESS: The new proposal doesn't?

MR. HOU: The new proposal does not. The reason is even though SSE stress is higher, but however, essentially the piping system still responds elastically, even at level D which is not really making much different to cause a big difference in damping.

MR. SIESS: Are you assuming elastic response in all cases?

MR. HOU: Yes. We do not yet have the -- damping data.

MR. SIESS: Okay, thank you.

MR. SHEWMON: So you know there's still a very large conservatism in this because the stuff will go plastic before it fails.

MR. HOU: Right.

[Slide.]

The reason we chose frequency as a parameter is we go through that regression analysis to find out which parameter really has the more dominant effect. And this is based on the nice work of the PVRC.

MR. SIESS: You said that this was based on plant experience. So this was then all at displacements which people who own plants will let you run experiments at. So that gets also back to the all totally elastic range. Is that right?

MR. HOU: It's not that they let us run experiments. It's we just get the data from various sources. They contribute to this.

MR. SHEWMON: But this is on plants.

MR. HOU: Yes, some is in plants; some is in the lab testing. It was all kinds of conditions.

MR. ETHERINGTON: I missed something. Are the ordinates multiples of the OBE or are they percent damping? Percent of critical damping? What are the ordinates in this figure?

MR. HOU: This is damping.

MR. SHAO: The abscissa is frequency.

MR. HOU: This is damping value.

MR. EBERSOLE: When you get rid of all these restraints, are you going to change the damping values? When you remove the restraints are you going to raise the damping values? Do these damping values -- are they based on the present restraints?

MR. HOU: It's based on all the data. It's on various conditions; some with very little restraints; some with a lot of restraints. In other words, the PVRC is not intending to precisely point out what damping -- under what kind of parameters. And especially in a mathematical accurate fashion. But here, just kind of general conclusions. These are all kinds of conditions, with some margin such that we feel confident.

So to answer your question, that considers also the situation with less restraints.

MR. SHEWMON: Let me answer his questions and you grade me, then. My impression is that he's saying that this bounds the data they have and the data is on a lot of

different systms with and without -- with varying degrees of constraints.

MR. EBERSOLE: But I thought these constraints -- they all had to meet current requirements, and therefore, your damping values wouldn't have been --

MR. SIESS: If you remove the restraints you're going to change the frequency because you can increase the spans. But then frequency is a variable in here.

MR. HOU: Right, exactly. That's why the frequency becomes such a powerful parameter, because if you change the weight you change the frequency, if you change the spacing of the support you change the frequency. All kinds of things are reflected in the frequency.

MR. SIESS: And the non-linear effects from gaps aren't counted in here anyway.

MR. BOSNAK: That's a different animal. That's been looked at. When you go into that aspect, the damping values, then you're talking about more like 10 to 20 percent at least.

MR. SIESS: Yes. That's why I said you haven't taken any credit for those.

MR. BOSNAK: No credit whatsoever for that aspect.

MR. SHEWMON: Let's go on.

MR. SHAO: Before you go to the next viewgraph, I think we never answered Mike Bender's previous question. Let me try to crack at it. Related to the anchor movement.

MR. BENDER: I'm willing to accept the previous answer which was a lot better than the three previous ones to that. But if you think you can improve it, go ahead.

MR. SHAO: Okay, briefly. The ASME Code. When the earthquakes comes, it produces two types of stresses; one called inertial stresses and one is called anchor movement stresses. The ASME Code tried to classify the inertia stresses as primary and the anchor movement as secondary.

Because the ASME Code treats SSE as so-called faulted condition, the faulted condition never worries about secondary stresses; only worry about primary stresses.

MR. BENDER: Well, to the extent that they limit the approach to yield, they do take account of it. But go ahead.

MR. SHAO: For faulted condition, ASME Code only requires you to worry about primary stresses; you don't have to worry about secondary stresses. And for that reason, for SSE you don't have to worry about anchor movement. But according to actual earthquake data, the anchor movement is really causing all the failures.

So we say maybe, ASME Code, you should take a second look. You cannot neglect this anchor movement because we treat it as secondary stress. All our failures are coming from anchor movement.

MR. BENDER: I'll take that as a supplement to what's been told.

MR. HOU: Later on I'm going to provide you more information about why we say so.

MR. SHAO: I don't know whether I made it clear or not.

MR. SHEWMON: You've made it very clear. Let's go on.

MR. SIESS: Only the Code and the analysts make that distinction. The structure doesn't know the difference.

MR. SHAO: Yes, but the trouble is the ASME Code says secondary stress you don't have to worry about.

MR. HOU: On the damping I'd like to mention that it's been endorsed by the ASME as the Code Case N-411. And we have done some independent assessment of how much response can be reduced when new damping be used. And the figure is about 20 to 40 percent.

[Slide.]

Now let's turn to the next subject about spectral modifications. In the Reg Guide 1.122 for the floor response spectra which are used for input to the piping, when there is a peak that causes uncertainty of the material, of the soils and also of the soil-structure interactions, and also uncertainty about the response of the structures. There's all these uncertainties. So in the past the Reg Guide 1.122 arbitrarily widened it plus or minus 15 percent.

[Slide.]

This is the floor response spectra, widened plus or minus 13 percent.

As we know, because of this, the input a lot more energies to the piping seismic response calculations. Because there is only one peak in this uncertainty range, not all the frequency in this range have the level to the peak.

So the PVRC recommendation is still recognize the uncertainty range but however, perform more than one analysis. First, assume the peak is in this place, and then move the peak -- piping frequency happen in that range and shift the peak, and then shift the peak to the right extreme of that.

In this way, the number of calculations is increased, however, the response can be reduced. The amount is just about 10 percent in reduction, which is not an awful lot. If we look at the seismic conservatisms embedded.

MR. SIESS: In the basis for the peak broadening to begin with, you mentioned some uncertainties. They're the uncertainties in determining that frequency of vibration of the structure that supports the pipe under the earthquake excitation, right? How did you arrive at that 15 percent? Is that based on experiments, analyses?

MR. HOU: I think for the 15 percent -- I didn't participate in that edition of the reg guide. I heard some people -- just based on the best estimated engineering

judgment. Does not have an adequate data base.

But later on, we have information indicating that the range, in fact, is not 15 percent -- could be wide.

MR. SIESS: For example, the Category 1 structure's research at Los Alamos, working with I'll admit models right now, suggests that the shear wall type structures are cracked almost from the beginning. How much difference does it make in the frequency in the spectra if I assume those walls to be cracked, or I assume them to be uncracked? Does the 15 percent cover that?

MR. HOU: No, not enough. Actually, as I recall from that paper, it's much wider than the 15 percent. But this is a separate issue. In those, it's the peak shifting procedure.

MR. SIESS: I agree it's a separate issue, but I'm just trying to understand the original issue, which is the peak broadening. Is it true that analyses are made assuming those shear wall structures to be uncracked and the equipment is then qualified on the basis of those spectra?

MR. HOU: I think in this we need more study to look at more cases. We cannot just base it on the one case.

MR. SIESS: That wasn't my question. I'm asking what is practice in design? To assume one stiffness for the structure, or to take a range of stiffness for the structures? To assume the structure is cracked, to assume

it's not cracked and get the range?

MR. SHAO: I think in practice, they assume stiffness in the structure. However, we need to do soil-structure interaction analysis. The stiffness of structure is only one stiffness. But in the soil-structure interaction analysis, the NRC position is you have to look at a different range of soils.

MR. SIESS: I don't know how much effect that has.

MR. SHAO: It does have some effect. This floor response spectra is coming from soil --

MR. SIESS: Oh, yes. But I'm just looking at the one aspect of it because cracking in a concrete shear wall can reduce its stiffness by a tremendous factor. I don't know what it does to --

MR. SHAO: In this case they would not be covered by the 15 percent.

MR. HOU: So this 15 percent is not adequate. And that issue, we put in the recommendation.

MR. SIESS: Incidentally, with your revised proposal, an increased broadening would have less of an impact.

MR. HOU: What you're saying is right. Now, because you use peak shifting, the impact will be much less. Otherwise, if you widen 30 percent, then there will be a lot more extra energy to put into.

MR. BUSH: But from a different perspective, this change if it were implemented has a relatively minor impact from the point of view of piping. It's almost a second order effect.

MR. SHAO: Yes, a very small impact.

MR. HOU: This peak shifting is being endorsed by ASME as a Code Case N-397. And as you see, the drawback of performing peak shifting, you have to do a lot more analysis. Especially when you have more than just one peak. And also, when you have more than one support into motion.

So the ASME put in the Code Case to consider that as an alternative method. So our recommendation is to accept the the peak shifting for licensing and immediately endorse the ASME Code Case N-397. And also, we hope eventually to incorporate the peak shifting to the revised Reg Guide 1.122 and put into the Standard Review Plan. And we're going to look at the adequacy of the 15 percent. And we feel that the range is uncertain. Need more studies.

And also, we feel that probably broadening the spectra still is a good way to go, except that you should account for equivalent energy input. We feel that we need more study to find out.

[Slide.]

This is just for your information. For the new damping, there are 14 plants already use -- four plants use

the PVRC recommendation.

[Slide.]

The next subject is nozzle flexibility and the nozzle loads. The piping systems generally terminate at the nozzles. They connect to either the vessel or to another pipe or to the rotating equipment. Generally, the nozzles in the piping seismic analysis are treated as a rigid anchor. In that way, that means you get a calculation and get higher stress than actually you were experiencing. In the meantime, because of overly precaution because the industry doesn't know about the nozzle load, so we put a very low allowable.

So the combined effects of the rigid anchor motion -- rigid anchor and low allowable, that means you need more support to the piping system. So this is one of the factors contributing to the stiff system.

If we look at the NRC Standard Revie Plan 3.7 or 3.9, both sections, we have not really addressed nozzle flexibility and the nozzle loads. But industry guidance is also far from adequate. So we feel that this is an area we should pay more attention to.

So our recommendation is to revise the standard review plan 3.9.2 to consider nozzle flexibility in the NRC position. And also, again we're going to ask ASME to pay attention to develop enough guidance about nozzles. And also, we need a research program to develop more guidance about

nozzle stress limits and flexibilities.

MR. EBERSOLE: When you do that, will you be accounting for the fact that this is dynamic machinery and slight misalignments will cause it to malfunction?

MR. HOU: Yes. That's the nozzle connecting to the rotating equipment. Here is just one more factor, as you say. Operability of equipment. And that's one reason why they put a very low allowable.

MR. BENDER: I wanted to expand on Mr. Ebersole's question a little bit. I think there's a lot of merit to the industry's prior position that nozzle loads be kept low. I mean, there are a lot of things that we don't know about how those stresses affect the component.

Is this approach which you're using going to aim in the direction of letting those loads go up higher?

MR. HOU: Well actually, we say we don't know. Actually, we say we don't know enough about this. We want to know better. And now, for connecting to the rotating equipment, yes, we consider equipment operability. But connecting to a vessel, may not have that concern. And on the branch line, do not have that concern. So someplace, maybe we should allow them to have a higher allowable.

MR. BENDER: I see. So you're saying where the structures are passive, you might be more relaxed about what the stress levels will be.

MR. HOU: Right.

MR. BUSH: Maybe I can expand on this a little bit. There's a program that was just completed for EPRI, not published and not released yet, that looks at this problem explicitly. There is no bridge program that looks at the combination of loads flexibility. And one of the tasks of the task group on dynamic effects in the technical committee on piping in PVRC is to look at this explicitly with the idea of coming up with a Code position.

But first, you need the information. And supposedly, the study for EPRI and the Oak Ridge study will supply us some of the information. Obviously, you do not want to let your loads get out of line. You may be able to accept a higher level but you want to be able to justify a higher level.

MR. SHEWMON: Spence, would you drop back two layers in complexity and explain what we are talking about? What is flexibility to a mechanical engineer? Apparently it's not you take a rigid member, move the pipe and ask how much it flexes. Because you guys are talking about the loads that get applied someplace.

MR. BUSH: The man you should ask is right there; he's the expert.

MR. RODABAUGH: Here is a vessel tank heat exchanger, someplace coming out of it is a branch pipe, and

this we are generally talking about as the nozzle. If you put a load out here for a moment, or a moment out here, you can calculate what that rotation is due to just the rotation of this piece of pipe.

You run tests, though, and you find that this is going to moment that way [indicating]. It will do this sort of thing, it will dimple. You can't see it, but tests will show that instead of, say, rotating .001 radiant, because of this local effect, it will rotate 100 times that much.

Now, when you do your piping system analysis and you assume this is rigid, then you very much over-estimate the load that's going on here because in fact it can rotate. So that's the flexibi ity aspect as to what happens in here to affect how the pipe will rotate. Is that sufficient?

MR. SHEWMON: Is that rotation particularly bad because it's a larger strain, and thus fatigue is more of a problem?

MR. RODABAUGH: It has both effects. It's good because it permits the pipe to take up the displacements imposed on them much easier. But it's bad because yes, you have local strains here that you have to account for.

MR. SHEWMON: Okay, that's probably enough for now. Thank you.

MR. BENDER: Paul, I want to deal with the other half of it, because you asked about this what I call a passive

member. The question may not have anything to do with the stress level, but just deformation of the shell that may affect its operability, and that's the point Jess was making.

MR. RODABAUGH: Well, let me say a couple of words about pumps and compressors and turbines. There are industrial standards, of course, to look at. PVRC has a program to check with users as to what experience they have had trying to find out just what is behind these industrial standards.

In many cases it turns out that the critical element is the coupling between, say, the motor and the pump. It turns out, interestingly enough, that you can allow a larger nozzle load by specifying a more rigid -- so there are aspects like that that need looking at. But there's been a lot of improvement; we now have the industrial standards but they still need looking at.

MR. EBERSOLE: What about valves that are left into their seats with zero clearance and can't take any deflection so they'll bind up?

MR. RODABAUGH: The valve manufacturers will generally say that their valve bodies will take the load that the pipe can put on them. But they -- I've never gotten a valve manufacturer to say that the valve will operate with those loads on it.

MR. EBERSOLE: Well, that's the critical part of it

-- the operation.

MR. RODABAUGH: You're absolutely right.

MR. EBERSOLE: That's why they wouldn't say it.

MR. HOU: You see the kind of problem here? It's the buyer that says what kind of loads he wants to see. And then negotiates with the seller. And then, they set out the allowables, which sometimes you don't know what the basis is. And generally, the allowable is very low. And of course, low doesn't matter, but what is the reason is unclear.

And actually, there's ongoing work by the PVRC subcommittee on the pipe, valve and pump. They are working on the problem and hopefully in the near future we'll have something from them.

So now let's go to the next subject.

[Slide.]

Inelastic analysis. We know that SSE is an event with very low probability, and it's appropriate when designing pipings to let it have more deformation and absorb more energy, and utilize the good properties of the material.

But currently, the design criteria uses linear elastic analysis, and also, the current acceptance criteria is all based on stress in the ASME Code. It does not have the strain or deformation criteria.

So the acceptance criteria not even saying in the ASME Code to allow for inelastic analysis. But people would

not get benefit from it because lack of strain or deformation criteria.

And naturally, we feel that this is a place where we should have more study.

Also, we have seen that the piping, the actual capability to absorb energy, the potential is very, very high. We have seen some actual observed conditions of behaviors of the piping under the earthquake conditions. Later on I will address that. But we feel this is an area with potential and we should have more study.

[Slide.]

To set a guidance for the inelastic analysis is not an easy matter. And because in addition to the stress allowables, and also, you have the stabilities, the functioning parts and all this is case by case.

But anyhow, we feel that we will be able to say go ahead to perform the inelastic analysis as long as you are able to justify that and you are able to resist the failure with margin.

Also we feel that more study needs to be done to develop a method. The reason people have objection about inelastic analysis is because that's so time consuming and very costly. If we can develop some pseudo-linear-elastic analysis to account for inelastic effects, that would be a much simpler procedure and a very nice thing to do.

MR. BENDER: Been arguing about this inelastic business for at least 10 years, maybe longer than that, but the argument always turns out to be that we don't have any criteria for acceptability.

If you introduce a research program that develops something that you call pseudo-linear-elastic, it may not be much different than the old piping stress analysis that people used to do and develop very high stresses. What is it that you think this new method will provide for you?

MR. HOU: This new method first, of course, has to be simple and practical. And also, account for the energy and susceptibility of the piping. Now, the model may be a bilinear type, not very complicated. And also, maybe still use some -- in the framework of the ASME Code, use the current allowables, but be able to account for the similar effect.

MR. BENDER: Well, will it have stress limits, strain limits or what? What are you looking for?

MR. HOU: Actually now, it's looking for the energy absorption. But you account for the energy absorbing effect.

At this time we cannot say totally without any method -- there are some methods being developed. We have to look at that but now they are not good enough.

MR. BENDER: I have enough, thank you.

[Slide.]

The next subject is seismic spectral input. We know

the piping systems may be supported by the restraints or supports in different elevations, in different floors. And their spectral input could be quite different. But in the past, what we've used in general, like in the Standard Review Plan, is to envelope the response spectra and end up with a uniform envelope of spectra. Certainly it's very conservative and contributes to the system.

And as we mentioned earlier, the piping response is calculated by two parts; one is an inertia response, one is seismic anchor motion. And we put it all together. Now all of this at the current time does not have guidance as to how to combine them -- well, how to allow for the input, however does not have the guidance to specify how to combine the modal and directional response. And also, how to combine these two components, and also, it varies from one AE to another.

So here, NRC funded a Brookhaven study. It has completed NUREG/CR-3811. In there it provides guidance to perform this innovative spectral input. We feel this is important for the seismic design. We recommend to encourage the use of this kind of analysis because that's more realistic and also can reduce unnecessary conservatism.

[Slide.]

The next subject, supports and snubbers. We know a number of snubbers per plant was increased significant in the past decade. That's because of increase in plant seismic

level and stringent regulatory requirements and also, because the seismic design is such a complicated issue, and the manpower in AE and inexperienced designers and they put more suports into the design than there should be.

So now, also in the piping design, the type, number and locations of the supports and snubbers are not optimized. And we know there's a lot of snubbers used in plants, and maintenance of the snubbers is costly, and also, the snubbers need maintenance, inspection and all these added exposures to the personnel. And also, if it malfunctions, a lock-up of mechanical snubbers will cause the piping stresswise and add a higher probability of a piping failure.

However, there's also some bright spots. For the past decade from 1973 to 83 there are 25 cases of snubber lock-up reported, however, none of them led to a piping failure.

And also, because we pay attention to the snubbers, there's a lot of NRC effort like Generic Issue A-13 for improved snubber operability and reliability. And results in NUREG-0731 for guidance for the design and testing. And also, in the Standard Review Plan 3.9.2, we have paid attention to the snubbers.

So from 1973 to 1983 the number of snubber failures actually gets per population, it's decreasing.

MR. SHEWMON: We're coming close to the end of your

time, if you'd try to get through your recommendations and move a little faster I'd appreciate it.

[Slide.]

MR. HOU: So we feel that because snubbers cause a lot of problems we should try to limit the use of snubbers. By the way, the recommendation is non mandatory snubber reassessment program to reduce the number.

MR. EBERSOLE: In the design of a snubber, is the snubber designed so that if it hangs up it will deform before damaging the pipe?

MR. BUSH: The answer is no.

MR. EBERSOLE: Should it be?

MR. BUSH: Not necessarily. But there have been dynamic events where they've torn all the snubbers off. The longest one I recall was about 200 feet of piping. Every support was torn loose.

MR. EBERSOLE: Well, that's the way you would have it rather than hurt the pipe.

MR. BUSH: But what they've done since then is they've gone to thicker embedment base and --

[Laughter.]

MR. SIESS: Wasn't it the snubber deformed and usually pulled the supports out of the concrete.

MR. EBERSOLE: But do you think that's been a good thing?

MR. SIESS: Well, yes. I've been a little concerned about the factor of safety on the supports. I think it's a little bit high. I get a lot of comfort when they fail before the pipe does.

MR. EBERSOLE: Seems like it should be done deliberately, not accidentally.

MR. BUSH: I can't disagree. I felt that way a long time ago.

MR. HOU: For all the events with locked-up snubbers there are no piping failures.

[Slide.]

Now the last issue is about overall design margins. The design margins by definition is the ultimate locating capability of the piping system in comparison with its design capability.

MR. SHEWMON: Why don't you let us read it and move on to your recommendation and we can ask questions. High a high point if you want to.

MR. HOU: Okay. The recommendation is what all the information indicated, we don't feel we know enough about the seismic margins. Because piping design is based on the ASME Code, we put so much emphasis on inertial load -- however, look and observe the failure.

Also, the SSE level does not consider the relative anchor motion which is so important to the piping failure

mechanism. And we feel that we should have more study and more information about the failure mechanisms. And also, we have to determine what a design philosophy is.

Now, shall we design piping such that it's more flexible and special design support and make a support as a kind of mechanical -- so that in case of a dynamic event absorb some energy. But piping if it has multiple support failure, the piping will still be able to sustain.

So we have to be thinking about the philosophy. Cert nly, we're not going to take it and put a lot of supports and restraints.

MR. SHEWMON: You have a recommendation there. How do you expect that recommendation to be carried out? There's a lot of assessing to be done.

MR. HOU: There's a compilation of -- there is some testing been done by some industry -- for instance like NRC and the PVRC and the piping testing at INCO. Now, when you test it to the full SSE the piping still does not fail. That means something wrong with the pipings in the ASME Code.

Now also, --

MR. SHEWMON: Is the answer to my question that other organizations will do it and you will watch?

MR. HOU: Exactly.

MR. SHEWMON: Okay, thank you.

MR. HOU: We point out the problem, then others do

it and we're going to watch it and assess it, and hopefully we'll learn some guidance.

MR. SHAO: Let me clarify this. There is a cooperative program between EPRI, NRC and INCO to try to find out what is the failure mode of piping.

MR. SHEWMON: Okay. Mike?

MR. BENDER: Well, it seems to me that this can only be done by experimenting with piping systems. You're going to have to look at deformation characteristics and how the structure responds over the length of piping from one support to another. And then by varying the support arrangement, you can see what might happen to the deformation characteristics and where the strains are absorbed.

Is that the kind of program that's in place?

MR. SHAO: Yes. No. Let me say why we need this kind of program. There was one consultant who is sitting at the table --

[Laughter.]

He recommends -- so far the ASME Code says earthquake cause two type of stresses; one is primary and the secondary. And this data says this stress is all secondary like thermal stresses. We didn't take his recommendation this time because of lack of experimental data.

If that position is adopted, there will be a tremendous relaxation in the criteria. But in actual

earthquake experience, they don't fail by inertial stresses; they fail by anchor movement which is secondary in nature. So I think this kind of test would help us to answer that kind of question.

MR. BENDER: Well, I was asking a different question which is: is a program in place to do that, or are you hoping that industry will pick up and develop that program?

MR. SHAO: It's already in place to do that.

MR. BENDER: Whose is it? Is it EPRI's?

MR. SHAO: EPRI and NRC.

MR. BENDER: Joint sponsor and jointly funded.

MR. SHEWMON: Where is it going to be done?

MR. SHAO: At Anco.

MR. SHEWMON: Where is Anco and who are they?

MR. SHAO: Anco is in Los Angeles.

SPEAKER: The main contract will be GE's. Anco is doing a piece of the test, the component test. There will be systems testing which has not been awarded yet.

MR. SHEWMON: Is that over and above the one you had at Livermore, or is the Livermore phased out?

SPEAKER: We had a previous program at Anco for systems tests.

MR. SHEWMON: Well, you've been spending many millions of dollars a year while Livermore calculates how fast a crack grows and other things. That's the program I'm

talking about.

SPEAKER: That's an analytic program.

MR. SHEWMON: And it's going on.

SPEAKER: No, that's winding down. I think this is the last year.

MR. SHEWMON: Okay.

MR. HOU: I'd like to have just a couple minutes to present to you interesting informations. We have to know how the piping really behaves under an actual earthquake. This is a study in Addendum 2, Addendum 1 and 2. This industry piping is non-nuclear piping. However, we can see the similarity.

We found very few piping failures, less than .01 percent. And also, the failure mechanism in most cases due to insufficient flexibility to accomodate large anchor motions.

And also, there's testing result of Anco in tests with the SSE, the piping results failure.

So with this information we know we have to have a new approach to the seismic design of piping systems.

MR. MICHELSON: I would like to ask a question. In addition to worrying about pressure boundary failure as a consequence of an earthquake, one also has to worry about equipment operability. This question was brought up earlier, and it's not clear to me how you are factoring in -- when you start to remove snubbers and anchors and so forth -- how you factor in the fact that valves must still function, pumps must

still function and so forth. How are you weighing these two together to decide, you know, in the process of removing supports.

MR. HOU: For the equipment operability, it's based on the testing. But testing similar to actual earthquake input to the realistic level. So we can --

MR. MICHELSON: By input you mean nozzle loads or what?

MR. HOU: Nozzle load is one of the functions. Also, the amplitude, the directions, all this have simulated the earthquake environment. And equipment has been tested under operating conditions to see whether it still can function. So it's not the piping stress limit that can solve the problem.

MR. MICHELSON: You're going to establish, then, certain nozzle loading limits that must not be exceeded and still assure operability, and then you're going to see what you can do to the piping to the extent that it will not now exceed these nozzle loads.

MR. HOU: Nozzle loads is only one of the considerations

MR. MICHELSON: Yes, it's one of them. But you will use the operability assurance on the components as a major consideration in all of this, I hope, and not just pressure boundaries.

MR. HOU: That's right. The seismic condition.

Now, for the pressure boundary -- there is NRC research. We have pipe to pipe impact. The pipings in very large degree, the pressure boundary will still be able to maintain.

MR. SHEWMON: Good. Let's stop there. Bob?

MR. BOSNAK: I'm going to share with you the little bit that we know that is going on abroad. Most of it we know has been covered by informal context of meetings, particularly. I am going to ask Spence and Jack Burns, who is sitting in for Jim Richardson, to add to anything I can tell you.

I am going to read the statement that you have in the agenda. There are really two parts here. As I understand what you are looking for, you want to know whether the rest of the world thinks flexible piping systems are the way to go, and from our context, particularly with the Federal Republic of Germany, they are going to 4 percent damping across the board, and they are handling the OBE-SSE question by raising the limits on the OBE.

You heard what Dr. Hou told you about changing the regulations. So that OBE does not control the design and make things stiff, they are going to jack up the allowable limit from what they have now to essentially the yield area.

MR. SHEWMON: Jack up what limit?

MR. BOSNAK: The allowable limit. There is an allowable limit for the piping system analysis, and --

MR. SHEWMON: "Allowable'' is not an adjective; it is a noun in that case, or something. It is what the mechanical engineers use someplace; is that right?

MR. BOSNAK: Well, it's what is specified in their standards. It's what is specified in our ASME code.

The Japanese -- and if you will recall the slide that Shou-Nien had here -- the Japanese, I understand, now are going to be using 2.5 percent instead of 3 percent. The proposal was that they use the 3 percent. The regulatory group decided that they were going to accept 2.5 instead of 3 percent. So, as you see here, the Germans across the board are using 4 percent.

MR. BENDER: What table are you looking at?

MR. BOSNAK: I'm looking at the previous handout. That was the one without the label. But the other thing that you have to recall is that most of the foreign countries have not coupled the accident loads -- in other words, pipe break and seismic factor. So that they have had in the past less stiff systems. Their systems generally were more flexible, and they are now going to decrease the flexibility.

Again, what we are trying to do, we are trying to remove as many of the supports that we can and yet keep the components operating, the ones that Mr. Michaelson mentioned,

and we are interested, obviously, that valves and pumps function. But we have had an excessive amount of snubbers installed on systems.

When we started, we had probably 200 to 300 snubbers, and now we have 1500 to 2000 snubbers. So all of that affects reliability. I just got the final project report. This was done by Livermore, NUREG-CR-4263. It is the reliability analysis of stiff versus flexible piping.

Generally, their conclusions are that a flexible piping system has more reliability than a stiff system, and again, we are comparing the performance of the system for normal operation. Albeit you might reduce the margin for these extreme events, you do, in fact, in a small amount reduce the margin that you have.

In other words, you are at stresses which are higher than they were previously for these postulated events. But again, you want the system to be more reliable for the day-to-day operation.

Well, that is about all I can tell you with respect to the --

MR. EBERSOLE: Can I comment on that? Isn't that just basically due to overdesign of these anchors that we just talked about, that they will damage the pipe? And if you have a program coordinated design, that wouldn't be true.

MR. BOSNAK: When you say optimization, that is

correct. In other words, these systems were never optimized. But even if they were optimized, you require our limits to meet the allowable limits. If you have to put in more supports than you really would have to, then again, you are increasing the probability that you are going to have something occur during normal operation that you don't want to happen.

MR. SIESS: What Jesse is saying, I think, is if you designed a snubber or restraint so that it had to fail before the pipe did, would that design be acceptable for seismic design or would you find it wouldn't meet your seismic design criteria?

MR. BOSNAK: Well, it would not meet the seismic design criteria if, in fact, the support failed. The current criteria that we have does not permit an item to fail under the loads that it is required --

MR. SIESS: I know that, but the question is how do you determine the loads? Jesse would say determine the load that would cause the pipe to fail, which is not necessarily the load that you get as the seismic excitation. So I said, suppose you put a limit on your snubber capacity that it could not cause the pipe to fail under either seismic or thermal movement. Would you be able to get a pipe support that would meet the seismic criteria? I don't know how these loads compare.

MR. BUSH: How does the designer come up with this value? I think that is the closest thing to possible for a designer to establish. You are asking an awful lot of the designers.

MR. SIESS: I'm asking them to design a load that would cause the pipe to fail.

MR. BUSH: Well, you've got a whole series of modes of failure. They will vary from location to location so it's going to be location-specific, and system-specific. You are asking them an awful lot, I think.

MR. SIESS: So you can't really answer the first part of the question as to what that load would be, and we wouldn't know whether that is greater or smaller than the seismic load.

MR. BENDER: Well, it seems to me that where we have seen these snubber failures, they have been malfunctions, they have been mistakes, and none of them have been the result of earthquakes. So really what we are dealing with --

MR. SIESS: Well, there was some result of water hammer. The ones out at TMI-2, the snubbers went to pieces.

MR. BENDER: Well, I don't know how to design for that particular problem.

MR. BUSH: I am aware of several cases where you couldn't even go back into the records and establish their was a water hammer, but the evidence is very convincing that there

had to be one because every snubber in the system, even the mechanicals, were locked up. So it is pretty conclusive that you have some type of a dynamic event, not enough to shake the building to the point that it woke up the operator or something, but certainly enough to end up with every one of those snubbers in a locked position, which is not the way you want it.

MR. SIESS: But we do have instances where snubbers have failed. We have no instances where pipe has failed.

MR. BUSH: I am unaware of any instances, with the possible exception that they do put snubbers on lines that are down to half-inch or three-quarter inch in size, and there might have been one that failed later and hasn't made it, but I have looked pretty carefully at the records.

MR. SIESS: So the presumptionis on that evidence that snubbers are weaker than the pipe.

MR. BUSH: They originally were, although I must confess they are going the wrong way.

MR. SIESS: Well, I know the recommendation on the study on the snubbers out at TMI-2 was don't go in and put bigger snubbers in.

MR. BUSH: Well, that is not the answer.

MR. SIESS: Well, I don't know how far they got with that recommendation.

MR. BUSH: Well, to put it in perspective, I have

been working on a problem recently on a system, and they are doing all the wrong things. Snubbers were put in to control vibration, to damp the vibration. They put hydraulics in originally and then they switched to mechanicals. The mechanicals have high amplitude vibration field and have effective lives of $50 to $100, and then they lock up. You end up with a pile of little shavings underneath the thing and that's it, that's the end of the snubber.

If you put a new one in, it goes through the same thing. Obviously, the answer is not to put mechanical snubbers in those locations. All you are doing is spending a lot of money for no purpose. There are other solutions to this that people unfortunately have not been using. You can use sway braces, you can use loaded springs and things of that nature, all of which are conventional.

MR. SHEWMON: Is there one other comment from the Staff over here?

MR. HOU: Just a while ago I had information about design philosophy. Now, are we going to design the support and restraint and snubbers in the mechanical fields? That is exactly the thinking Dr. Siess is talking about. I think we need more study. This is good thinking.

MR. BOSNAK: Earlier, Spence mentioned the group that is getting under way under the sponsorship of PVRC to look at supports in general. Piping supports probably should

be designed differently than component supports, and by component, I mean things like steam generator vessels, heat exchangers. So all of that is going to be looked at, and I think the things that Professor Siess mentioned will also be thought about because a lot of people feel that if a support fails, it is going to protect the piping system.

MR. BENDER: I would like to add one point to the discussion. The things we have seen that have failed in snubbers and the like are really in the smaller systems. Even where we have seen --. It hasn't been in those instances where the system is large, but the real concern is with the really big snubbers, where in order to put them in, you have to have a massive structure to support them. We don't really know what the capacity of the support is or the piping.

To develop some kind of design approach that permits those big snubbers to work, you have got to have some massive structure behind them, and to me, the argument the Staff is making right now is we have probably gone too far in that direction. If we take a different design approach on which stresses are computed, we won't need those massive snubbers and that will enhance reliability, and I think that is a legitimate argument.

MR. BOSNAK: Tomorrow morning in the lead-off, I want to discuss this particular area again, and also to go back to your letter, the letter that you wrote back in June of

1983. We need to get your thoughts and input on this particular matter, so we are going to return to it tomorrow.

MR. EBERSOLE: I have a comment on the small pipe business. It has been only recently, hasn't it, that we found out that this counter-current hot and cold fluid flow and some of these great big pipes has pulled the anchors out of even great big pipes? How big were they, 16 inch?

MR. RODABAUGH: At least 16.

MR. EBERSOLE: You know what I mean? There's a case in point where the anchors came out rather than the pipe.

MR. BUSH: On the replaceable piping, maybe I can add a little bit more to what Bob had to say. We deliberately in the PVRC Steering Committee have representation from Italy, France, Germany, and United Kingdom, and at our last meeting a few weeks ago, the CEGB discussed for the first time -- because I have asked the question before what their philosophy is on piping, which I think is interesting. They do not intend -- well, obviously this depends on the nuclear installation inspection and final approval, but the current intent is no OBE. That's one aspect.

The other one is that they would tend to go the flexible piping route, higher damping route, that they are using the data that's available in there. So here is one for Sizewell-B, that's the case we're talking about where they are tending to take these particular steps.

Now, this is interesting because here is a new design. In other words, this is one of the very few reactors that I would say is on the design boards now, and they are looking a this very carefully. They expect to have difficulty in some of these areas in selling the nuclear installation inspector, but they do intend to pursue very actively the use of the higher damping values.

MR. SHEWMON: How high is higher? Five percent?

MR. BUSH: Five percent in what I call the bare pipe. I am sure in insulated pipe or in stand-off installation where you can easily justify higher, they may well do it; but for right now, that is where they are pursuing. And of course, if they go the no-OBE route, that introduces another substantial factor with regard to the design aspects.

MR. SHEWMON: What is the no-OBE route?

MR. BUSH: They are planning on one type of earthquake, the SSE load. I would mention in passing that in the others -- Bob mentioned briefly, I think, the German. Now, the Italians have had four years of experimental work. Unfortunately, most of this hasn't hit the streets yes. They are willing to make the information available. This was the basis for their coming up with the position essentially more relevant to what Ray is talking about, leak before break, but they are moving in that same general direction for use of

higher damping values, removal of restraints and things of this nature, much of it based on their own experimental program supported by ENEL and ENEA.

MR. SIESS: The British would have trouble using an OBE anyway. That would just confuse people.

MR. BUSH: I know what you mean.

MR. BOSNAK: The second part of the item that you had here -- if we are through with foreign practice on flexible versus stiff piping systems -- gets into the Japanese reasons or possible reasons for higher reliability of snubbers in nuclear plants in Japan.

We have very little in NRR -- and Jack Burns may have a little bit more, but we are aware of two companies that manufacture mechanical snubbers; NHK and Sanwatekki. The experience that we have gotten indirectly from NHK is that they have had some problems as well, and they have had to go to a redesign. Sanwatekki supposedly has had a better operating experience because they initially qualified some of their designs to a more strict standard than some of their competitors. But those are the only two that we're aware of.

We're not so sure, if you compare the U.S. manufacturers as a whole, perhaps that's the reason for looking at lower reliabilities, but there are some certain manufacturers, not necessarily mechanical but several of the hydraulic snubber manufacturers, who have had fairly decent

results on reliability. So it's not a completely black picture, as far as U.S. suppliers are concerned.

MR. SIESS: Was there a figure I saw that said the failure rate on snubbers is down to one in 1000?

MR. BOSNAK: I haven't seen that.

MR. SIESS: Except the number now has gone up to 100,000 snubbers or something, so the number of failures go up although the rate goes down. But one in 1000 isn't bad, that's true.

MR. SHEWMON: Well, we've got 40,000 snubbers.

MR. SIESS: Yes, 40,000 snubbers now, so we get 40, I guess it's a year or something, isn't it?

MR. BUSH: I just finished a statistical analysis of snubbers. I admit I don't have the 1985 data; I only have into early 1984, and I would say that that tends to be a little on the optimistic side. It depends on how you define failure and a few other things, because I have -- if you look at the figures, the numbers are a little too large per plant to come up with that.

MR. SIESS: Well, a lot of the hydraulic snubber failures are maintenance and installation errors.

MR. BUSH: That's true.

MR. SIESS: Bob, did you address why the Japanese allegedly have stiff piping?

MR. SHEWMON: Or do you feel they do?

MR. BOSNAK: We don't feel they do. They started out, if you recall, their damping values were a half percent, but their loads, their seismic loads and also, the dynamic loads which they add to the seismic loads are much less than we have here.

MR. SIESS: What would be your measure of stiffness of piping? How many snubbers, how many supports, or a calculation of frequency?

MR. BOSNAK: That would be one measure. Also, natural frequency.

MR. SIESS: Have you got data on that?

MR. BOSNAK: I don't have any data here today, no.

MR. SIESS: Because the allegation has been made that they have stiff piping and we're going away from it. And I don't know what it was based on or how it was measured.

MR. BOSNAK: But again, their spectra is the Housner spectra, which was considerably lower as far as input is concerned than what we use here. So I think when you compare their half percent damping, and now they're going to 3 percent or 2 1/2, with their input, you're kind of comparing an apple and an orange.

MR. SIESS: So you think that although you don't know how stiff it is, that their criteria is such that it shouldn't be as stiff as ours.

MR. BOSNAK: That's correct.

MR. SHEWMON: Now, you said that the loads they got were less just because they don't have LOCA loads superimposed on their --

MR. BOSNAK: No, because their seismic spectra is less than ours.

MR. SHEWMON: That's the Housner spectra. But before that you said the loads they get are less, or the stresses are less.

MR. BOSNAK: Well, as far as LOCA loads are concerned, they have two levels of earthquake. I don't believe and I'm not sure that they have an OBE. They have an S-1 I think, and if anybody in the audience knows --

MR. SHAO: They have S-1 and S-2. Also, I think, Dr. Shewmon, you're right. They don't combine LOCA with SSE.

MR. BOSNAK: Which would be more severe, again, for the BWR than the PWR.

MR. SHEWMON: Okay. Harold?

MR. ETHERINGTON: Removal of constraints on the big piping will impose greater displacements on the branch piping. Does that look as though it's any kind of a problem?

MR. BOSNAK: Well, as far as removing supports is concerned, when one does that you have to look at all of the displacements that are associated. You've got to go through a whole new re-analysis, make sure that your clearances are adequate, do you have any line mounted equipment, the

accelerations may increase. All of that has to be taken into account.

MR. MICHELSON: What will be your data base for getting information on snubber failures in the future? Or will they be reported?

MR. BOSNAK: You mean in this country?

MR. MICHELSON: Yes, yes.

MR. BOSNAK: They're still in the --

MR. MICHELSON: Are they in the new LER rule, though? I don't think, unless it's an unusual kind of failure that is generic and indicating a safety issue, a single snubber failure would not be reported. I don't think it's reported to NPRDS either, but I'm not sure of that.

MR. BOSNAK: The Tech Specs do require a change in the -- if they have a snubber failure they are required to increase the frequency of surveillance.

MR. MICHELSON: Oh, they are.

MR. BOSNAK: So I think there will be some --

MR. MICHELSON: I'm not sure that it still picks it up, though.

MR. BUSH: The only thing it would do there is you shorten your interval and increase your sample until you get down to the -- the bottom line is six weeks, which of course is a short period. But you could be right.

MR. MICHELSON: But that wouldn't make it reportable

under LER necessarily.

MR. BUSH: Probably where it might be would be INPO.

MR. MICHELSON: Yes, except the NPRDS data base I don't think picks it up either, but I'm not sure.

MR. BUSH: That's something I can't say.

MR. MICHELSON: Somebody ought to look into it, though, and find out.

MR. BOSNAK: Also, the regions are aware of the frequency of inspection of the snubbers. In other words, that's a function of the failure rate.

MR. SHEWMON: Bob, can we get a commitment out of the staff to see where there is -- how that is recorded if anyplace?

MR. BOSNAK: Yes, we will check into that and report back to you.

MR. SHEWMON: Can we adjourn for lunch now? Okay. We'll see you at 1:30.

[Whereupon, at 12:30 p.m., the meeting was recessed for lunch, to reconvene at 1:30 p.m.

AFTERNOON SESSION

1:35 p.m.

MR. SHEWMON: All right, let's reconvene.

MR. KLECKER: My name is Ray Klecker, I'm from NRR, and the slides I have are in the handout so you can follow along.

First of all, I thought we would define what we're talking about here when we're talking of leak before break, and I might add based on some of the questions that arose this morning as to how we got here, just a little bit of history, not to regurgitate it all. But this started out as a problem as far as loads both on the internals and the externals of reactor vessels. And it was found that if one postulates a full double-ended break at the support systems for the reactor vessel, that some of the older facilities would not accomodate it. And in the process of seeing what could be done about it, it was found that to fix it mechanically would be awful difficult.

So at that time, people started doing analyses, postulating flaws in pipes and so forth, less than a full double-ended break, to see at what limit they could live with. And they found, indeed, this was a viable approach.

So that's where it originated. It wasn't called leak before break in those days, but it really is the application of fracture mechanics technology and the licensing

process to demonstrate the integrity of nuclear facility high energy piping systems, in lieu of requiring non-mechanistic double-ended guillotine breaks. Because as soon as one postulates these non-mechanistic breaks, then restraint systems are required, and in the case of these older vessels, different supports both for the vessel itself and then there's also the question of the reaction loads on the internals of the vessel itself.

So in that case then, we are limiting the application against the dynamic effects as addressed in General Design Criteria No. 4.

[Slide.]

MR. MICHELSON: Well, it's my understanding that the loads on the internals in the vessel are going to be there, irrespective of whether or not you postulate the intermediate type breaks because you still have to postulate the terminal pipe breaks. And even in a blowdown I thought changed the loads. So I don't think it has anything to do with internal loads in vessels.

MR. KLECKER: Well, what we're saying, however, is we do not have to postulate the terminal end breaks if one can justify the approach --

MR. MICHELSON: Well, that's a different statement, though, than you had in your slide. The non-mechanistic breaks are I thought the intermediate breaks.

MR. KLECKER: No.

MR. MICHELSON: You're defining mechanistic now to include the terminal breaks as well?

MR. SHAO: Because the break was -- even though the stress was lower, we still had to posit two intermediate breaks and two other breaks.

MR. KLECKER: Well, the intermediate breaks will be discussed a little separate from this. When I get to the final recommendations of the Piping Review Committee, yes, we did recommend eliminating those breaks as well. But we don't do it by the same route. We don't necessarily do it by leak before break approach.

We are looking at, in a sense, the terminal end breaks, primarily those that -- wherever you have welds and so forth. I will get into exactly what we do in a future slide here.

The question has come up a number of times, why don't we limit it to the dynamic effects. Well, there are a number of reasons; one is that we have done a lot of our homework looking at the various analyses performed against dynamic effects, primarily for the large primary coolant system piping in PWR's.

We do not include the effects of ECCS on containment in this case simply because as we mentioned this morning, you fail some bolts and stuff like that somewhere in the system,

you could have valves leak and so forth. So one still needs containment for those purposes. And perhaps sometime in the future, say 5 or 10 years downstream, both the industry and the staff may be looking at eliminating some of those effects, too.

But for the time being, the immediate payoff is in eliminating these big breaks and getting rid of the dynamic effects, which allows then the eliminating of pipe whip restraints, jet impingement shields and a whole lot of other peripheral situations which I will discuss later.

I guess I already mentioned that these malfunctions -- there are sources of load, so you still need containment.

Now, from an administrative or legalistic point of view, to allow for the dynamic effects requires only a revision of General Design Criterion Number 4, whereas, if we were to address ECCS in containment, we'd essentially be addressing the full book of regulations as affecting nuclear power. So it's considerably different, an order of magnitude different degree of work.

[Slide.]

Now, dynamic effects -- I have listed the main ones -- are the pipe whip and other pipe break reaction forces. The jet impingement forces -- the vessel cavity and subcompartment pressurization, including the asymmetric transient effects which is the effect on the internals of the

vessel, and pipe break-associated transient loadings and functional systems or portions thereof whose pressure retaining integrity remains intact. That is reaction forces that reflect down the pipes and so forth.

Now, I put down here the final conclusion of the Piping Review Committee. This has been digested out of Volume 5. The Piping Review Committee recommends that the NRC consider granting exemptions to GDC-4 during the rulemaking process. Now, you will hear a lot more about where we stand on the rulemaking process later in this program.

The benefits to be gained are significantly great to warrant -- and again, the lawyers inserted the words "schedular treatment" -- in order to achieve the in-plant objective of implementing the exclusion of consideration of the above dynamic effects at the earliest possible date.

Now schedular exemption in this case means for a period of, say, several refueling outages. And that will be discussed a little more later on.

MR. MICHELSON: Excuse me, could you clear up for me one point? In GDC-4 you're really dealing with two conditions; the environmental condition, which is the first sentence of the GDC, and then the second sentence which deals with so-called dynamic effects. Why is pressure a dynamic effect instead of -- well, certain aspects of it clearly are dynamic effects, but why is pressure not an environmental

instead of a dynamic effect?

MR. KLECKER: I'm not sure I understand the question.

MR. MICHELSON: Okay. Subcompartment pressure. If I break a pipe in a room, that room pressurizes. Is that an environmental condition of that room, or is that a dynamic effect in that room?

MR. KLECKER: Well, from an instantaneous double-ended guillotine break, the pressure rises as a spike very rapidly so you get differential pressures across the wall, for instance, just due to that effect. Whereas, if I have a small leak, the pressure can equilibrate between the two sides of the compartment walls. So an environmental effect is still there; the dynamic effect is gone.

MR. MICHELSON: Well, when you say you're eliminating dynamic effects, are you still including, though, the final peak pressure in the subcompartment as an environmental effect?

MR. KLECKER: Well, I'm not sure. If we eliminate the double-ended break there are other sources of pressurization of that compartment. for instance, smaller lines that may be --

MR. MICHELSON: What I'm getting to is I have been reassured on everal occasions that you're not changing any of the environmental qualification requirements. And one of

them, of course, is pressure.

MR. KLECKER: Well, obviously, environmental effects will be lessened if we eliminate the full double-ended break. So we're handling that on a case-by-case basis.

MR. MICHELSON: Well, I haven't found that discussed anywhere. I hope we get to that discussion because that's quite a bit different than I have heard, and I would like a real clarification on whether or not you're considering environmental effects of pressure or not.

MR. SHEWMON: Well, the pressures will be reduced if you reduce the break size. Are you concerned about whether they would completely eliminate pressure?

MR. MICHELSON: Yeah, right.

MR. SHEWMON: Okay. But --

MR. MICHELSON: Because if you leak before break and so forth, you're not going to get any pressure anymore, you're not going to get any temperature, by the way, to speak of anymore either. You're not going to worry about a number of things and you don't need ECCS either, but they said, well, ECCS we're not going to touch; we're going to keep it.

But I was told in the environmental subcommittee they were going to keep environmental.

MR. BOSNAK: If I could interject here, that's correct. The environmetal effects are not changing. What we're talking about, if you want to call it, is static

pressure effect rather than a dynamic pressure effect. That's still there.

MR. MICHELSON: Yes, that doesn't come through in any of the rulemaking material I've been reading. I can't figure out -- it clearly says --

MR. BOSNAK: I think in the rulemaking it speaks to not changing the environmental qualifications.

MR. MICHELSON: I can't even find that.

MR. BOSNAK: That's in there, I'm sure of it.

MR. MICHELSON: But clearly, you did you're eliminating pressure now because pressure was deemed to be a dynamic effect. And I think you need a clarification of what the dynamic aspects --

MR. BOSNAK: We're eliminating the dynamic effects.

MR. MICHELSON: The shock wave effects, that sort of thing. That needs to be cleared up. I thought that's what you were doing.

MR. SHEWMON: Jesse?

MR. EBERSOLE: Early on I deliberately asked about the matter of the equivalent split but not the double-ended break. You qualified this by calling it the double-ended break. The industry will interpret that explicitly, I think, and -- that is, what you've got up here -- and thus, not allow for the equivalent split. And that will permit them to do -- and I'll just arbitrarily give you a configuration -- that

will let them lay up a 28-inch steam line against a control room which will have a split equivalent to double-ended break and carve its way right in there and kill all the operators and blow out the plant. What is going to prevent them from doing that?

MR. KLECKER: Well, when we get to our detailed criteria for the application of leak before break we do include a requirement to look at other orientations of flaws. Not only the longitudinal split but possibly elbows. We may have to look at diagonal splits at some angle between --

MR. SIESS: Yes, but in these general words you have eliminated jet impingement as a generic context.

MR. KLECKER: Well, if we eliminate the splits, -- you see, we do also look at the longitudinal splits in pipes when we do the fracture mechanics. It turns out for the cases -- especially the ones we have looked at -- they are not limiting because the tendency for the driving force to open them is merely pressure and so the stresses are fairly low. Whereas in the large pipes, the bending moment is the dominant load on these pipes.

MR. ETHERINGTON: Isn't it the words that are incomplete? The report did specifically cover all kinds of breaks equivalent to double-ended breaks.

MR. KLECKER: I believe in Volume 3 we tried to be much more explicit than what I have in some of these slides.

These are not legal words.

MR. MICHELSON: When you say you are not going to consider subcompartment pressurization yet you will consider the maximum pressure that is reached in terms of the environmental qualification of equipment, does this mean also that you use that same maximum pressure for qualifying structural walls and so forth?

MR. BOSNAK: The answer to that is yes, that would be used if there is a way for the pressure to decay. Generally they would use the heat pressure as a conservative way of designing it.

MR. MICHELSON: So, what does it mean now that you are not going to consider subcompartment pressurization? What aren't you going to consider besides shock waves?

MR. BOSNAK: What we are really talking about is the assymetric pressurization effects.

MR. MICHELSON: Yes, and I don't have a problem with that, but I have a problem when I start reading the words because it sounds like you are no longer considering compartment pressurizations due to breaks, whether they be pipe breaks, component breaks or whatever. And that is a different matter entirely. So maybe it is just a clarification of the words, eventually.

MR. KLECKER: Let me have one more try at it. If we have, let's say, a relatively slow leak or, let's say, a leak

from a smaller line such that the dynamic effects -- that is, the differential of pressure across the wall -- is more or less uniform because they are all vented from one to the other, and if you look at the structural effects of that, it is very minimal compared to, let's say, if I have a double-ended break or equivalent longitudinal split in a great bit line, or I can for the first instance have a tremendous force on one side of the wall as contrasted with the other.

But we stil: have to live with the equilibrium pressure. That is why we go back to the containment design. We do not want to touch that. So the containment will still be designed for the equivalent of a double-ended guillotine break.

MR. EBERSOLE: Well, how does that do any good if the compartment blows up.

MR. KLECKER: What we are saying is if we eliminate the double-ended guillotine break, it won't.

MR. EBERSOLE: Well, suppose we know there's a split on the 25 degree --

MR. KLECKER: Well again, that would be a relatively small leakage size crack rather than, say, a very large one.

MR. EBERSOLE: Well, earlier on I think we said it was twice the area, an equivalent split.

MR. KLECKER: Well, that is the present requirement, but we have done away with that.

MR. EBERSOLE: You are going to eliminate the split?

MR. KLECKER: Yes.

MR. MICHELSON: What he said, I think, is that he isn't going to have any breaks in compartments.

MR. EBERSOLE: Just leaks.

MR. MICHELSON: That gives me a problem because things in compartments besides a pipe might cause a leak, like a valve bonnet will blow off, and if it does, you are going to blow the room apart if you don't design for it.

MR. EBERSOLE: And you won't have any substantial breaks next to critical support equipment.

MR. BUSH: But Carlisle, how do you think what he has proposed now is going to change that situation? It is going to change nothing.

MR. MICHELSON: Well, what is being done today is to design for the double-ended rupture relative to the pressurization of the compartment.

MR. BUSH: But who is designing any plants these days. This isn't going to change anything.

MR. MICHELSON: I think you are right in terms of today, sure. If that was the case, then it would be different, and this ought to not be allowed on new plants. But it is written for new plants as well. The rulemaking is written for new plants. That's the way I was looking at it.

MR. EBERSOLE: I presume that GE and Westinghouse

will ride this train right down the middle.

MR. SHEWMON: Well, if they ever sell any new plants, let's keep in mind to review it again, but I don't want to hold this up any more. Let's go.

MR. KLECKER: Well, I have listed here some of the other effects.

[Slide]

I am not going to spend a great deal of time on them. They are in your handout and you can read them at your leisure. But there are a lot of supplemental effects, too, that come into play if you eliminate the large double-ended break.

[Slide]

MR. EBERSOLE: You mean the large break, period.

MR. KLECKER: The large break, period.

Now, some of the advantages that go in the leak before break are listed here in this slide and some of the subsequent ones. This information is contained in the value impact analyses that were done for the rule change. I'm not sure whether you folks have seen that yet, but eventually you will. In the back of the handout that I gave you, there is some supplementary information, which I don't intend to get into unless you want to. I don't have the slides.

You will find here, let's say, for the primary coolant system, both for PWR and BWR facilities. These

numbers are based for the PWRs on a total of 85 facilities. These numbers are based for the PWRs on a total of 85 facilities, and in the case of a BWR, about 38 facilities, by various combinations of operation, in the process of being built or under design.

Here you see you have got roughly a $2 million saving per facility, taking this number and dividing it by 85, or the best estimate and divided it by 85, and down here it is roughly $1 million per facility with a primary coolant system.

In terms of man rem, these are these are the values that are saved. Here again, this is some 34,000, and if I add this 8,000, it's over 40,000 man rem that are saved. Now, the negative effect of man rem hardly shows in these numbers. It's down on the order of a few man rem. So there is a tremendous gain in terms of man rem, which is one of the main objectives, as well as dollars.

MR. BUSH: I think for the record, since it is being taped, I believe that slide doesn't say $2 million. I think it says over $200 million.

MR. KLECKER: What did I say?

MR. BUSH: Oh, you made the division. I'm sorry.

MR. KLECKER: Right. Was trying to get it on a per facility basis, which is the basis for this next slide here.

[Slide]

If we look at other than the primary coolant system

-- well, then you have a lot of other restraints that can be removed, so this includes now a Westinghouse-designed plant in operation, a Westinghouse plant in final licensing stage, a B&W plant in the same stage, and GESSAR. Of the total -- these are the full pipe whip restraints that are now in these plants, say an average of 153, and the amount that could be removed if we eliminate, let's say, the large breaks on all piping systems that they choose to eliminate them on, then they would eliminate approximately half of the pipe whip restraints.

Now, there is some reason for not removing them all because when you get down to the smaller lines, the economics are not necessarily in favor of removing them. Also, some of those restraints also serve as supports, and to redesign them, they just said it is not worth it.

So the main dollars and cents accrue to the larger pipes.

Now, as far as jet impingement shields, there is a similar ratio that you would remove approximately one-half of them.

Now, the total estimated cost savings for pipe systems other than the primary reactor coolant system is something on the order of $90 million per facility, and about two-thirds of this number is essentially the cost of downtime to take this equipment out for inspection and so forth. The

other installation costs.

MR. SHEWMON: There was some talk this morning about Class 2 and Class 3 piping systems. Once you are out of the primary system, where does all this money come from for all the pipe whip restraints? What systems are these?

MR. KLECKER: These are supposed to be all the systems in the facility.

MR. SHEWMON: The bottom line there that you said was non-primary.

MR. KLECKER: Oh. The piping that is not the main coolant piping of the PWR or BWR because there are a lot of branch lines and so forth that run off of it. Pressure surge line and so forth.

MR. SIESS: Is this both inside and outside containment?

MR. KLECKER: Yes.

MR. SHEWMON: The piping to the pressurizer is not primary reactor coolant piping?

MR. KLECKER: Well, it's connected to it. I consider it a branch line, but --

MR. SHEWMON: When you say other than primary, you are talking about things that are still the primary pressure boundary, but the way you counted there --

MR. KLECKER: Other than the main loop piping, the large diameter piping.

MR. EBERSOLE: I wanted to ask you. The general effects of this would be to eliminate that sturdy wall that has been put between the turbine hall and the critical auxiliary building and its facilities internal to it because, by virtue of eliminating the turbine missile problem, that has gone away, by the main steamline failures and the reaction and jet forces and so on, that has gone away, so you could put up a brick wall there now and say, well, I want more money than this.

You are looking into a radical reduction in physical strength of the structures.

MR. KLECKER: I'm not sure those effects were taken into account when they did this analysis. Do you happen to know? I assume it is mainly the pipe whip restraints and so forth. We do have an application in house that is now on hold to review, let's say, piping systems in the turbine building. We have not done so to date, primarily for administrative reasons until the rule change is made. We have not addressed that.

We would, of course, if we get applications of that nature in the future, would have to look at it on a case-by-case basis.

MR. EBERSOLE: What I am saying is you are basically eliminating energetic effects from pipe failures wherever you go.

MR. KLECKER: For every pipe we redo, that's correct.

MR. MICHELSON: Yet the decision is based on the idea of knowing that pipes can break and nothing else can break and cause such energetic effects like pressurization, so they don't need to put in these heavy walled compartments anymore except for shielding if shielding happens to be a consideration.

MR. SHEWMON: But if there is something else that could break there, presumably they would look at it.

MR. MICHELSON: Well, that's not clear.

MR. EBERSOLE: One can run emergency feedwater lines parallel to each other virtually along one route. Is this correct?

MR. MICHELSON: Right.

MR. EBERSOLE: You know, it is far-reaching, what you are doing. Is that correct?

MR. KLECKER: That is right. Well, we are not there yet. We have not reviewed all of these situations. I want to make that clear.

MR. EBERSOLE: Well, the generality of the language, though, will almost always result in the cheapest run.

MR. SHEWMON: Unless there's some reason for redundancy or separation. There are other reasons for parallel trains in opposite sides of the plant than pipe

whip.

MR. EBERSOLE: Well, you will be troubled to find very many.

MR. SHEWMON: Well, one is sabotage. Another is fire, and certainly fire considerations aren't going to go away.

MR. EBERSOLE: Fire never does bother pipes.

MR. MICHELSON: It bothers what is on the end of the valves. If you go back historically and look at the pipe situation in 1972, '73 or '74 when this was brought to the attention of everybody in these letters, the solution was to go back and do an analysis, breaking pipes one at a time. Well, questions at that time were even raised about, well, how about other things that can cause leakage, pressurization, adverse temperature effects and so forth?

Well, the answer was then, well, these are all bounded by the pipe breaks, and that's why they even picked these arbitrary intermediate pipe breaks, to be sure to bound the kinds of breaks that would otherwise have to be considered.

If you eliminate pipes now as breaking, then you have to also either go back and eliminate valve bonnets, check valve cover plates, manhole covers. You have to eliminate these kinds of things also or you have to go back and start considering them as the environmental challenge to the plant.

We haven't done that.

MR. SIESS: Well, I am confused. They are talking about removing physical restraints, whip and jet impingements to the pipes. Are you talking about physical restraints on valve bonnets or are you talking about environmental effectgs of a break?

MR. MICHELSON: Environmental effects.

MR. SIESS: So the question is does removing the physical restraints of pipe whip and jet impingement change the environmental conditions you would assume in a particular room for a qualification of environmental equipment?

MR. MICHELSON: Precisely. And the answer I got a little while back from somebody else was no, you still have to use the same environmental conditions. Now, I'm not sure I hear that answer today, and I keep hearing caveats on it, and I'm really wondering now. Nothing in the rulemaking comes out and clearly says that for purposes of environmental conditions, you still pick an arbitrary --

MR. SIESS: You don't have to have a double-ended pipe break and a whipping pipe to get the steam out.

MR. MICHELSON: That's right. So it's a different issue. But the question is, if they aren't using a double-ended rupture for the environment, what are they using?

MR. KLECKER: I think in a lot of the literature that we have written on this, we do have to consider these

valve bonnets coming off and so forth. The other sources of leakage have to be considered. We are not eliminating that.

MR. SIESS: Even leakage from the pipe you are talking about.

MR. KLECKER: That's right.

MR. SIESS: Because you're not saying the pipe won't leak; you're saying it won't break.

MR. KLECKER: That's correct.

MR. BOSNAK: Again, the environmental conditions aren't going to change. What we are saying is that the dynamic effects -- and the pressure obviously will change because of the dynamic effects being eliminated.

MR. MICHELSON: That is an environmental condition, very definitely.

MR. BOSNAK: But you will have a steady state pressure, and that would be the environmental design condition.

MR. MICHELSON: And with that, I would agree. But where is the basis now? Somewhere you have to make this clear to the user --

MR. SIESS: What GDC addresses the environmental effects?

MR. MICHELSON: GDC-4. It's the first sentence of that GDC. If you like, I can read it.

MR. SIESS: And the Staff thinks that the word

"dynamic" covers it? The Staff thinks that dynamic effects means a certain break as well as the whipping of the pipe as far as the environmental conditions.

MR. BOSNAK: Right.

MR. MICHELSON: And they also think that pressurization is a dynamic effect.

MR. SIESS: Rapid pressurization.

MR. MICHELSON: No, it doesn't say rapid. It just says "and pressurization in cavities, compartments and subcompartments."

MR. BUSH: Well, one reason that the Germans established an upper bound size was that if you stay below a certain pole size -- I will use that word rather than crack size -- then essentially jet loads are not a parameter. So what you have is the condition that Bob has been talking about.

You have something that is not a steady state, it is certainly not a dynamic pressure, and I think that is what he is really talking about here.

MR. MICHELSON: Well, somewhere there must be a rule on how you calculate pressure for environmental qualification purposes -- what break size do you assume and so forth for that purpose?

MR. SHEWMON: Let's file that as one of the things that we ought to consider later.

MR. SIESS: But what were you quoting from?

MR. MICHELSON: I was reading from the rulemaking. I was looking at the proposed broad scope rule, page 3, bottom of the page, scope of rulemaking.

MR. SIESS: Okay. I've got it now.

MR. MICHELSON: And the second sentence of that is what I was reading. There it points out two things. The jet impingement, the decompression waves, and the pressurizatio. in cavities, subcompartments and compartments.

[Slide]

MR. KLECKER: I thought I would tell you where we stand as far as A-2, but so far no action has been taken on it. There has been no response from the remaining 13 facilities. However, I understand that our Division of Licensing is on a push for some activity in that respect.

The CESSAR review. There was a letter to Combustion Engineering last October, and we are about halfway through the review of a new B&W report at this time.

MR. EBERSOLE: Let me ask a question again about the far-reaching effects of this. There is a big effort going on now to qualify valves but so far no action has been taken on it. There has been no response from the remaining 13 facilities. However, I understand that our Division of Licensing is on a push for some activity in that respect.

The CESSAR review. There was a letter to Combustion

Engineering last October, and we are about halfway through the review of a new B&W report at this time.

MR. EBERSOLE: Let me ask a question again about the far-reaching effects of this. There is a big effort going on now to qualify valve functions, to see that the valves do what they are supposed to do. The hypothesis has in general been that they must intercept flows derived from full size pipe failures. This takes a considerable dynamic capacity to do this. Are you going to wipe that requirement out?

MR. KLECKER: That would be a dynamic effect.

MR. EBERSOLE: Of course it is. I mean if you wanted to slice through that right this instant.

MR. SHEWMON: Well, if we conclude that those effects were incredible in the plant, then why not eliminate them through the testing of the valve?

MR. EBERSOLE: Well, I am saying: is this a spin-off from this process? But then, of course, the environmental conditions that we are predicting can't exist either because they are only caused by these big breaks. 'f you postulated smaller breaks, the environmental effects are no where near as severe.

MR. SHEWMON: That may be true.

MR. MICHELSON: So what I think Jesse and I are trying to say is what are we intending here?

MR. SHEWMON: That message has come through. We

have heard it three times. It is on the record. We will look after it.

MR. MICHELSON: Okay.

MR. KLECKER: As far as the near-term operating licenses, there is a total of 22 units that we have reviewed to date. They are all listed in here. I won't bother to read them off. There have been exemptions granted at Unit 1 of Comanche Peak for jet impingement shields only simply because they already had the restraints in. The Vogtle unit was blessed, say, for its lifetime, and at Catawba they were given a schedular exemption.

MR. SHEWMON: On those, what do you do for the cast stainless steel components? At least the B&W has nothing in there at all on that data.

MR. KLECKER: I am going to discuss that in a little while. We do look at it.

On Wolf Creek they did not get an exemption simply because they asked for only a very limited benefit from the leak before break approach. That is, they wanted to replace the water bags in the shielding adjacent to the vessel with permanent concrete plugs, and that was approved.

Now, there are several of these that need to be updated. We have had a number of applications, one on Prairie Island, which we now have under review, and Indian Point 3, which we also have under review.

I might say a word here about Indian Point 3 because the analyses were done by fracture-proof design on that one, which includes Paul Parris as well as other people. In our review of that, he originally came in with his large break requirement, and after some discussion with both Indian Point 3 folks and Parris and company, it was agreed that they would also look at it the way we wanted them to look at it, that is, look for leakage size cracks, so they are stable, which they have done. So they have essentially agreed with us on that.

Now, these other ones we have not reviewed to date simply because it was decided administratively we would wait for the rule change on that.

Now, these are secondary lines, and the Nine Mile Point 1 is even outside.

MR. MICHELSON: I would like to ask you about Seabrook since I have read a little correspondence about it. In your letter dated April 12, 1985, they asked for elimination of arbitrary intermediate pipe breaks in feedwater systems, and that is all they asked for, yet. Then they submitted at the same time an amendment to their FSAR, but in writing their amendment, they made no mention of feedwater, but the amendment is good for the whole plant.

MR. KLECKER: Well, there probably are two letters. Now, Bob Bosnak and his group reviewed the arbitrary and

intermediate breaks, and they respond separately from us, so that would not necessarily be a leak before break application.

MR. BOSNAK: We will cover the arbitrary and intermediate breaks tomorrow.

MR. MICHELSON: There is a difference?

MR. BOSNAK: Very definitely, because one is based on fracture mechanics and the other are arbitrary.

MR. MICHELSON: So you mean they submitted a separate one for the rest of the breaks? They submitted with this the FSAR amendment, which covers all breaks. It eliminates all breaks.

MR. BOSNAK: These are handled differently. The arbitrary intermediate breaks are a separate submission on the part of the utility, and a separate answer is given. There is no extension required in GDC-4 for arbitrary and intermediate breaks. All it is is a deviation from the Standard Review Plan, and that's the way letters have gone out.

The first one was on Catawba that went out early in 1984.

MR. MICHELSON: Well, that's interesting. Thank you.

[Slide]

MR. KLECKER: Well, now we are finally getting to our report. I don't intend to discuss all of these because at a meeting we had with Paul Shewmon's subcommittee last

November 8, I believe it was, we pretty much went through that report. I will try and touch just the highlights of it.

In general, look at, let's say, Chapter 5, which are the acceptance criteria. The value impact we have already disscussed something of, and then we will have to try our hand at a few fracture mechanics comments that were raised this morning here.

[Slide]

Now, I have used this slide before as sort of a digest of the way we look at our requirements, and rather than getting into all the details, which you will find in the report, I am just going to highlight the steps that we go through in a typical analysis.

We ask that they take the largest flaw that could be missed during in-service inspection or which would be permitted by Code and review that, a peak analysis to show that it will not grow significantly during the service of the plant for the normal loads that are applied on that, and we find in general that this rose insignificantly. You would have possibly a fairly deep crack and fairly long in order for it to go through the wall during the plant life.

There are also some limitations on the use of fracture mechanics, and that, I guess, was alluded to a little bit this morning also. The main reason -- if you have thermal fatigue or stress corrosion cracking, rather than having a

flaw, let's say, at one side of the pipe, these flaws could be distributed around the pipe. And we showed the slide where indeed they were due to stress corrosion cracking.

In this case, this procedure is not used. We stick with pipes where the predominant loads are generally bending, in which case the flaws, if any, in the pipe are going to originate and grow primarily on one side of the pipe. Experience has shown that to be the case.

Then, even though you have shown that this crack isn't going to grow, we ask that you postulate the throughwall flaw of sufficient size such that the leakage can be detected with assurance with the installed leak detection equipment, and then, if undetected prior to an earthquake, show that that flaw will take the earthquake loads without growing.

MR. SHEWMON: Now, you say equipment. Do you also have practice in there, that is, whether they check it once a week, once a day or once a shift?

MR. KLECKER: Well, actually, the tech specs have requirements. They design the systems in the plant to Reg Guide 145, and the technical specification or the tech specs for the plant will tell you how often you have to review it. What we are saying is this crack, even in a period of weeks or a month, will not grow significantly.

MR. SHEWMON: No, that's not the question. The comment was that the equipment there for detecting leaks will

detect, but you say nothing about their procedures, yet in the recommendations that came out of Spence's talk earlier, there was a recommendation that they go to more frequent monitoring.

MR. KLECKER: That was on the BWRs. On the PWRs which we have reviewed to date, they are supposed to be able to detect one gallon per minute -- or one hour.

MR. SHEWMON: With their current procedures?

MR. KLECKER: With their current procedures, and that is reviewed by another branch. So it is reviewed. Then we take that particular crack and test it in two different ways. One, we say how far away from the critical crack size is that crack? And we ask that a margin -- and I have added the value of 2 in here, which was not on one of our original slides, because this is a consequence of the deliberations of our Piping Review Committee.

So we say that this crack must be less than one-half the critical crack size of that pipe. The other way we test it is we ask that you increase the loads on that pipe arbitrarily by a factor of the square root of 2 and show that this crack, the original crack, now, is still stable. So we test it both in terms of crack size and in terms of loads.

[Slide]

Now I'm going to speak a little bit about some of the uncertainties we have in these analyses and so forth. Again, this is a slide I used once before, and just to put it

into perspective --

MR. SHEWMON: Before you leave that last one, the LBL approach shall not be considered after a high energy fluid system piping or portions thereof that operating experience has shown susceptible to failure from the effects of corrosion, e.g., IGSCC. The reason for this is self-evident, it says. It's not self-evident to me. Could you explain why?

MR. KLECKER: Well, maybe the words were a little hard, but in stress corrosion cracking, since the dominant stresses generally are due to pressure and, let's say, the residual welding stresses, which I are distributed evenly around the circumference of the pipe, that if a crack grows at all, it could grow almost 360 degrees or intermittently 360 degrees around the pipe, in which case, if it grew, let's say, a significant depth there, the leak before break approach would not necessarily apply simply because you have no real guarantee it will break out at one corner of the pipe.

However, in a real case -- we will go back to Dwayne Arnold a number of years ago, where it was approximately 75 percent throughwall most of the way around, and it did break out to one side because there was some bending moment on that pipe.

MR. SHEWMON: But that's the basis, the fact that it could go 360 degrees.

MR. KLECKER: Yes. But if the dominant loads are

bending, that is not the case.

MR. SHEWMON: Okay, thank you.

MR. ETHERINGTON: Along the same lines, though, suddenly it would break through geometrically at the point but it would be unstable, and the crack will immediately grow to some fraction of the inside length. So the way in which the crack grows is important. I think Westinghouse at one time had what they called a two-crack criteria in which the crack could grow lengthwise or depthwise.

I notice in one of the sketches you show the crack as going deep with very little increase in length. Can you say anything about the variation around the perimeter or what determined whether it goes long or deep?

MR. KLECKER: Yes. Based on both analyses and experience, say if this is a pipe wall, and let's say we have a throughwall parallel crack. As this grows, the J applied -- you see, my loads are now dominantly bending. The J at this peak of the crack is much greater than it is out here at the surface.

MR. ETHERINGTON: Well, when there is a growing crack, we are talking K rather than J, aren't we?

MR. KLECKER: It goes something like this, and eventually it will break through. Now, it won't be a nice, clean crack. That is an idealization. But generally speaking, it will grow something like this.

MR. ETHERINGTON: This is a fatigue crack, is it?

MR. KLECKER: Yes.

MR. SHEWMON: So could we substitute K for J in what you just said, your last paragraph, without offending you?

MR. KLECKER: For the loads we are talking about, yes, if it helps you understand.

MR. SHEWMON: Well, one usually talks K.

MR. KLECKER: Well, we usually do fatigue crack growth in terms of K, yes.

I want to talk a little about some of the uncertainties so we don't go away from here leaving you thinking that we have everything 100 percent under control.

[Slide]

This is not a science at this time. This is still an art, and we have some things to learn. However, if we put things in perspective, the slide I used last time is the same as this one except now I have put on some of the uncertainty margins that might accrue. This was the experimental point [indicating]. In this case it was an actual pipe test. There were three different approaches used to calculate the failure of that pipe, which would be this line here in terms of J. The more optimistic one fell short by about 13 percent. In other words, they predicted it would fail about 90 percent less than where it did fail. On the other extreme, the NUREG approach is about 18 percent the other way. So that is

roughly, let's say, plus or minus --

MR. SIESS: Excuse me. You said optimistic? Maybe I didn't understand.

MR. KLECKER: The optimistic approach said that the pipe would fail before it actually did fail.

MR. SIESS: That doesn't sound very optimistic to me. That sounds pessimistic.

MR. SHEWMON: Unconservative, anyway.

MR. SIESS: Well, you predicted it fails at 1000. That's conservative.

MR. KLECKER: Yes. All right, I agree with you.

MR. SIESS: Okay.

MR. KLECKER: If this were a real pipe -- now, this was an 8-inch diameter pipe, but if this were a real pipe, normally the loads associated with -- relative, say, to the predicted failure point are less than, oh, say, a third to one-half of that value. So we do have a margin to take care of these uncertainties. But that is not to say we are not going to try and reduce these uncertainties. In fact, that is a major effort as part of Mel Vagan's program.

MR. SIESS: You mean the EPRI curve is really on the conservative side of the NRC curve?

MR. KLECKER: Yes, quite so.

MR. SIESS: I think we ought to mark that one up.

MR. KLECKER: Well we have discussed it with them

and they think they should continue using it.

[Slide]

Now, this is one of the same things I showed before to show where we have a number of them plotted on the same diagram. This, instead of absolute values, is in terms of, let's say, the limit moment, which would be 1. In this case the failure occurred, generally speaking, about 7 percent less than that, on the average. There was a spread, and the experimental results are about 4 percent. And here the EPRI estimation scheme was 16 percent below. The NUREG approach was 24 percent above.

In general, the approach that the NRC is using in our estimation scheme, we have it pretty well except for this point out here.

[Slide]

And now, if I may, I will say a few words about how we have been treating this problem of cast stainless. I know it is a subject that you are very interested in, and I thought I would try and do that by going through our thinking on that.

This is the trends due to thermal aging, and thermal aging means going from a solid line to a dotted line. One usually starts by getting material data based on compact tension specimens or some fracture mechanic specimen to arrive at what we call a J-R curve. That is a material property, J

versus the crack extension in this particular specimen.

If we go from here to here, we have to go via analysis because I don't think the experimenters have designed a J meter as yet. The other bit of experimental data that we have to have is the stress strain diagram.

Now, the last time in our presentation, Warren Banford of Westinghouse showed that as the material aged, it went from a curve something like this back to a much steeper curve. In other words, the material hardened. And taking these two effects into account, we can now go back to the pipe, and again, going from the pipe to, let's say, a J versus an applied load, or I could also have plotted this J versus some increase in crack angular, if you wish, the Delta A. The curve would look the same, and I would expect this to be so [indicating].

In other words, as the material toughness comes down and the strength goes up, the calculated J goes down as well. Now, when we have applied it to date, I think we have been quite conservative. We have done a number of things. First of all, we put a limit of 3000 ksi -- excuse me -- in pounds per inch squared up here simply because that is where we pretty much run out of data. That crack extension is roughly a quarter-inch.

So we have taken the available material data even though they expect it to go much beyond that and put an

arbitrary limit for the time being on that.

MR. SHEWMON: What was the limit you put on it?

MR. KLECKER: 3000 inch pounds per inch squared.

Now, if I superimpose this diagram with this one on a J-a digram, where "a" starts out as a0, which is initial crack size, or, if you wish, the initial crack angle, this would be the material curve here. The load curve, say, if that were J versus Delta A, for example, would be this, and I reach this point here, and that is the J for a particular loading on that plant. In this case we would be below J-1c, which is roughly at the bend of that curve.

Now, as the material ages, both the material properties decrease -- that is, the toughness goes down, which is this curve here -- and the calculated J goes down. So in reality, I could move down to point B. But to be conservative, since we don't know these data too well yet, we have said we will keep the original calculated J, and we will take the degraded property J, and that then moves us over to point A.

So we are penalizing them in two ways: by putting a ceiling on there, plus looking at it conservatively in a J Delta A space.

MR. SHEWMON: Now, the properties depend on how much the ferrite ages and also how much ferrite you have got. It also depends probably on whether it is static casting or

dynamic casting, and the elbows and pump casing and those things will be static castings with a bunch of weld metals to set up residual stresses and plug holes. And the piping may or may not be lower in ferrite, but probably you will have better properties.

How much of that spectrum do you have data on?

MR. KLECKER: Well, we don't have a great deal, but what we are using is what we believe to be the worst case. Dr. Johnson is going to talk about that in more detail later.

MR. SHEWMON: So B&W had no data in their report that someplace before you complete that review, you are going to get data from someplace that you think is germane, is that right?

MR. KLECKER: Well, if we don't get any other data, we will apply the same limits for the cast stainless.

MR. SHEWMON: And where does that limit come from?

MR. KLECKER: Again, Dr. Johnson has some story on that. You might wait until that presentation.

There is a series of reports. One is a proprietary report by Westinghouse, plus there are some non-proprietary reports.

MR. SHEWMON: The highest I have ever heard from Westinghouse is a 17 pecent ferrite that they got from the French, and there is a lot higher ferrite than that in the field, I have been told.

MR. KLECKER: Not in the facilities we have looked at. They generally have been -- in fact, 17 percent was the highest one.

MR. SHEWMON: How did they get that number? Did they actually go over each piece with a ferrite meter or did they take a composition and guess at the nitrogen?

MR. ELLIOT: The answer is they use a Schoefer diagram to calculate the ferrite.

MR. SHEWMON: So you take the composition and you don't do any field measurements at all, then?

MR. ELLIOT: No.

MR. SHEWMON: And they haven't either?

MR. ELLIOT: No.

MR. SHEWMON: Well, the Schoefer diagram is good within uncertainty limits that are far from zero, and I understand the nitrogen gets superimposed on that and that can vary it again.

MR. ELLIOT: We include what we considered a typical nitrogen value to be for the material in the calculation.

MR. SHEWMON: Okay. And this, then, says that the stronger it gets, the better it is on a J kind of calculation, except you don't give them credit for all of it, is that it?

MR. KLECKER: That is it. Until we, let say, get further data to substantiate the exact quantitative amount

this chages. We have very limited data. We know intuitively that's where it goes. We have some data to substantiate it but not enough, really, to reach a quantitative conclusion at this time. So we try to be very conservative in our final approach.

MR. SHEWMON: One of the things that is bothersome to an old-fashioned engineer is the fact that the Charpy energy of this just goes to zilch. Is any of this stuff done at a high enough strain rate to know whether indeed in a rapid test you get a different kind of fracture than you get at a nice, slow, leisurely test like, I assume, those J integrals are taken in?

MR. KLECKER: I will have to beg off to the metallurgist on that, I'm afraid. My understanding is that these are not necessarily rapid.

MR. ELLIOT: We have recently seen data from Westinghouse in which the dynamic toughness is greater than the static toughness.

MR. SHEWMON: And was that nice stuff like 10 percent ferrite or was it other stuff like 25 percent ferrite?

MR. ELLIOT: I believe it was about 17 percent ferrite, what we are talking about here.

MR. SHEWMON: But there is a range of ferrites in the field. So what do you do to get a spectrum on it? If you go to a percolation argument it's sort of the ferrite gets

continuous at about 20 percent.

MR. ELLIOT: We were talking to Westinghouse about that. That is different. There are a couple of plants that are in that situation, and we don't have criteria for that yet. We are still talking to Westinghouse about that particular criteria.

MR. SHEWMON: Now, does this ferrite come in on a per-component basis or do they give you an average number for the whole plant?

MR. ELLIOT: No. We get it per heatup material.

MR. SHEWMON: And is it always on piping or does this include elbows?

MR. ELLIOT: Piping and elbows.

MR. SHEWMON: You get different numbers for elbows and pipes, I presume.

MR. ELLIOT: Right.

MR. SHEWMON: But each elbow and each casing for a valve is a different heat?

MR. ELLIOT: I want to make sure you understand this. We don't look at valves and we don't look at pump casings.

MR. SHEWMON: But you do look at elbows and Ts, and they are also static cast.

MR. ELLIOT: Yes.

MR. SHEWMON: And you don't look at the pump casings

or whatever those other things are because they are so much thicker that you feel that must be okay.

MR. ELLIOT: Yes.

MR. SHEWMON: But the elbows and Ts are thinner, but are some of them the same material?

MR. ELLIOT: Yes.

MR. SHEWMON: Now, they are also pressure tested before they are put into service, like the pump?

MR. ELLIOT: All fittings and pipes get pressure tested, yes.

MR. SHEWMON: I am told that the static stuff, the quality you get depends on how much time you spend welding over holes.

MR. ELLIOT: We heard about this question. We talked to Westinghouse on this particular issue. The have the equipment specification. Depending upon the amount of weld repairs, it determines upon what kind of heat treatment they do. If they have a minor weld repair, they will not do any additional heat treatment. If they have a major weld repair, weld for repair, they will re-solution or quench the pipe.

MR. SHEWMON: I am not talking about pipe; I am talking about elbows and Ts.

MR. ELLIOT: Well, elbows and Ts. That is part of their equipment specification. They apply it to all static --

MR. SHEWMON: It is the static that I am the most

concerned about, but their story is that --

MR. ELLIOT: For major repairs they re-solution the component.

MR. SHEWMON: And that will take the residual stresses out and does what to the ferrite?

MR. ELLIOT: I don't think it changes the ferrite very much. The ferrite will still form at the grain boundaries.

MR. SHEWMON: How high do they anneal it?

MR. ELLIOT: I think it's 2000 or 2100 degrees Fahrenheit. This is a quench into water.

MR. SHEWMON: Some 2000 Fahrenheit? Why do they want to heat it so high? That has to do things to the ferrite. If they just want to stress relieve, 1000 or 1200 would do it. Someplace in there, it starts to sag out of shape.

MR. ELLIOT: That is the standard, 1050 C.

MR. ETHERINGTON: Is it water quenched or air cooled?

MR. ELLIOT: Yes, it is water quenched.

MR. ETHERINGTON: That is standard for quenching temperature.

MR. ELLIOT: They never wanted to see anything that looks like sigma. The idea is not to let it cool slowly through a region.

MR. SHACK: Bill Shack, Argonne National Laboratory. The rational, as I understand, is just to quench it quickly so it never goes to a region where you have a possibility of sigma formation.

MR. ETHERINGTON: What do you do with complex casting, though?

MR. SHACK: I am a researcher, not a fabricator. I sort of wondered about that myself. I suspect you do a lot of machining touchup after you are all done, but I don't know.

MR. SHEWMON: The answer is they distort.

MR. ETHERINGTON: But you still quench. Is that the position?

MR. SHACK: That is my understanding.

MR. ELLIOT: That is my understanding, too.

MR. SHEWMON: So, on the pump casings, independent of how much repair work they do, they don't heat treat it again; is that --

MR. ELLIOT: No, I said for minor weld repairs.

MR. SHEWMON: But a minute ago you said you weren't talking about pump casings, you were only talking about Ts and elbows.

MR. ELLIOT: Let me say one more thing, too. We are talking about the primary loop here.

MR. SHEWMON: Yes, there are pumps in the primary loop last time I heard.

MR. ELLIOT: Yes, but there aren't Ts.

MR. SHEWMON: But there are probably elbows.

MR. ELLIOT: Okay. That we are talking about. We are talking about elbows and pipe, and as they told me, for weld repairs, static or centrifugal cast material. For minor repairs, there is no re-solution treatment. For major repairs, there would be a re-solution treatment.

MR. SHEWMON: And that is for elbows and pumps?

MR. ELLIOT: Yes.

MR. BENDER: Well, every now and then we have to think about different kinds of piping besides elbows.

MR. SHEWMON: Go ahead.

MR. KLECKER: I have listed here the various areas in which we still have uncertainties. Now, that includes both the loads, where we do accept the stress analysis of record, so supposedly, this is taken as gospel and being correct.

Material properties, as the metallurgists know, do have variations from heat to heat and so forth. Fracture mechanics analysis -- on the previous slide I showed some of the uncertainties in that.

Leakage analyses. Also in fracture mechanics we calculate the crack opening area, and for very small cracks, yes, this can have a very large uncertainty, but when one gets to reasonably-sized cracks where you get up to 5 or 10 gpm or more, we feel that the effects are minimal, and hopefully we

calculate that conservatively.

We have gone back to the data wherever it exists to more or less correlate our analysis with what we are using.

And then, why we look for margins. In each one of these steps when we do a review we also rely on some engineering judgment for the overall conservatism of a leak before break approach. What we try to do is, for instance, if they are a little short in one area and long in the other, we would by judgment give them the credit for it, again realizing that we still have to fine tune some of these various analysis numbers.

Now, I am going to propose in the interest of saving time that perhaps I skip some of the next slides here, which we covered at our previous meeting, the limitations for application of leak before break, and let's say some discussion of the detailed criteria, which are all in our report, if this is all right with you, Mr. Chairman, and I will jump to just a final slide I have here, which is the recommendations of our task group.

That is, we still have to look at the leakage detection systems, and that came up in a number of questions here, to assure ourselves that indeed we have a margin of approximately 10 on detection of leakage. Deterministic analysis, the fracture mechanic analysis, should permit elimination of pipe whip restraints, et cetera, as we

discussed in scme detail.

I mentioned earlier that we indeed recommend that arbitrary intermediate breaks should be eliminated as a requirement, that there should be updating of Regulatory Guides, Standard Review Plans, and whatever else needs to be changed to address some of these peripheral issues. Admittedly, what we have in Volume 3 is more or less a general overview, and we recognize that there has to be a lot more meat put on those bones over the next few years before we can apply it for every pipe in the plant.

We recommended expedited rulemaking, which you will hear more about later, and we also specifically recommended at that time that indeed, if the BWR piping systems are changed out to be nuclear grade material, that we would recommend the leak before break approach for BWRs as well as PWRs. And as I mentioned earlier, we do have an application on GESSAR in house right now.

Thank you.

MR. MICHELSON: On that slide, you mentioned only the arbitrary intermediate breaks. Did the task group make a recommendation on the other break locations that would normally be determined under the existing regulations?

MR. KLECKER: Well, the other breaks -- this is an option, now, allowed the user here or the applicant or licensee. He can retain those other breaks if he wishes, and

he may on some smaller lines because it may be more economical to put in the restraint systems, or he can go the leak before break route, in which case he has to give us a lot of information and prove or demonstrate that he will not have these big breaks at these other locations.

MR. MICHELSON: But he can eliminate all breaks if he can so show.

MR. KLECKER: That is correct.

MR. MICHELSON: Now, you remain silent in this slide on the environmental qualification aspects. What did the task group recommend?

MR. KLECKER: The task group recommendation I believe was stated in Volume 3, and I'm not sure of the exact page number, but we recommended that --

MR. SHAO: That is on page 20 of Volume 5.

MR. MICHELSON: And on page 20 it points out pressurization and environmental effects due to leakage must be evaluated. Did the task group somewhere identify what they meant by leakage? Is this the amount of leakage on the leak before break detection, or what leakage is this?

SPEAKER: Yes. This is the leakage due to the postulated fault for that particular piping system when leak before break has been applied. If leak before break hasn't been applied, then you would take whatever breaks, postulated breaks --

MR. MICHELSON: If it hasn't been applied, such as the case that we have been discussing here, what leakage then would be used for environmental qualification?

SPEAKER: For the environmental qualification purposes, you would still take the equivalent static pressure of a flow break area. For environmental qualification, remember, now, in GDC-4 there are two parts to GDC-4. We are only changing that portion of GDC-4 having to do with dynamic effects. We are not touching the environmental portion.

MR. SHAO: Read the sentence just before this.

MR. MICHELSON: Well, I didn't take it out of the sentence. I took it out of item 3 on page 20.

MR. SHEWMON: Why don't you read it out loud?

MR. MICHELSON: The concern is on page 20 of Volume 5. It says, "Vessel cavity or subcompartment pressurization, including asymmetric transients and effects, is one of the items that will be excluded." Then there is an asterisk that says, "Pressurization and environmental effects due to leakage must be evaluated."

My question was: What do you mean by leakage in this case since it is not clear in the report?

SPEAKER: Remember the context of what we are talking about. It is put in the dynamic effects. We are talking about elimination of dynamic effects only.

MR. MICHELSON: Wouldn't it be easier, though, and

much clearer if you just say you have still got to take the double-ended rupture for the purpsoses of environmental qualification? Then I think everybody would understand it, instead of these funny words.

SPEAKER: I think this is clear.

MR. MICHELSON: I don't want to take the time now, but I will go into your rulemaking document and it has exactly the same problem.

SPEAKER: We are not changing the environmental qualification --

MR. MICHELSON: And that is what I want to hear clearly and unequivocally, and I don't find it.

SPEAKER: But it is obvious from the rule change.

MR. SHEWMON: We will get into GDC-4 in a little bit.

MR. SIESS: Well, I want to say this. I am in agreement completely with Carl Michelson. Before I knew what size leak to assume for compartment pressures, temperatures and so forth, and now I don't. You ought to be very specific, open it up and let it out both ends of the pipe. Now I hear the words "postulated leakage," and I haven't the slightest idea what postulated leakage means. I had expected to see it defined in a Reg Guide or a Standard Review Plan. But to me, postulated leakage does not mean double-ended pipe break.

I wouldn't postulate it, not if I was using leak

before break.

MR. KLECKER: Well, I was going to refer to the postulated leak as that one where, let's say we size a leakage-type flaw. It's one you are sure you can detect. Now, in the case of the large pipes, it's about 10 gpm.

MR. SIESS: Now, that disagrees with what the gentleman over here says because he said it would be the double-ended pipe break.

MR. KLECKER: No. This is not for environmental qualification. This is the leakage that we would expect from that pipe.

MR. SIESS: I'm sorry. The question was raised in the context of environmental qualification, and I had to assume that the answer was to the question. For environmental qualification, it is not clear what size break you assumed.

MR. KLECKER: The equivalent of a double-ended break.

MR. SHAO: It should still be based on double-ended pipe break.

MR. KLECKER: We say the equivalent of rather than saying double-ended break, but it's the same.

MR. ARLOTTL: Mr. Chairman, we are not changing the definition of a LOCA. LOCA is still in the General Design Criteria a complete range of a very small break up to equivalent to the area of the double-ended pipe break. I

think that that is still true.

MR. SIESS: That is not in GDC-4, is it?

MR. ARLOTTL: GDC-4 is not the place that that's in, but if you look at GDC-50, when we talk about internal compartments in containment, we do talk about that being designed for a loss of coolant accident, which gives us a continuing entire range of breaks.

MR. SIESS: But that is subcompartment pressure, and that is what you are leaving in. That was not only double-ended; that was instantaneous double-ended.

MR. ARLOTTO: That's right, but not by definition of LOCA.

MR. SIESS: Okay.

MR. EBERSOLE: From the standpoint of jet impingement effects, I want you to answer this question for me. I am talking about sabotage. I could literally strap the main and aux feedwater systems together in a bundle and sell them to the Palo Verde boilers; am I correct? They have to have feedwater? According to your general rules and guidelines, I could strap all the feedwater lines together in a bundle; am I correct? I have bundled all the feedwater lines together into one bundle.

MR. SHEWMON: Couldn't we write them that or do it sometime else? These hypothetical questions --

MR. EBERSOLE: It's not hypothetical.

MR. SHEWMON: Yes, it is. It is very hypothetical because you are changing the design of the plant.

MR. EBERSOLE: You'd better believe we're changing it, we're changing it like you can't believe.

MR. KLECKER: Theoretically I guess you could, but practically I don't think it would.

MR. EBERSOLE: I just wanted to hear the theory.

MR. SHEWMON: Okay, fine. You have got an answer. Let's go on.

MR. ETHERINGTON: I have a slightly irrelevant question that has been bothering me. Could we take one minute to ask the question and then perhaps you can decide whether I can take advantage of the specialists here to respond? Can I go ahead?

MR. SHEWMON: Yes.

MR. ETHERINGTON: In the Charpy transition curve, we have a change from 100 percent cleavage to 100 percent shear, and along with that we have the energy change. When we get to 100 percent shear, the energy reaches a maximum because you can't get any better.

I think we have plausible explanations of why we had to change the mode of the fracture. I am told that in the K1C transition curve, we had cleavage throughout the transition in the temperature, and shear only on the upper shell. Is there some kind of physical explanation of how you get an abrupt

change of that kind? Is it correct that you have only cleavage in the transition?

MR. SHEWMON: I doubt very much that the nature of the failure changes, but I don't know. Are you saying what people say they observe?

MR. ETHERINGTON: I am just questioning. We nave been informed that you only have cleavage in the transition zone. Is it right, to begin with? And if it is, then of course my question stands.

MR. HUTCHINSON: I think most people would say that is not right, that it becomes mixed; but from what I have been reading, I don't think it is certain. I think it is very unclear. There are some wonderful experiments, ductility tests, going back to Hahn, Rosenfeld and Cohen in the fifties, where they also observed that right on through the tensile ductility change, that cleavage persisted right on through, and it was only once you hit the shelf that you start to see the other mode.

But I think most people in the fracture business are of the opinion, anyway, whether they are right or wrong, that the transition is occurring in the mode over the transition --

MR. ETHERINGTON: Well, that is entirely understandable, then. So shall I assume that we are misinformed?

MR. SHEWMON: Ray wants to say something here.

MR. KLECKER: I was going to try an elementary discussion of this. There is indeed a transition. If I would plot, let's say, the toughness material in terms of K against, let's say, temperature down here, you find when you go from the brutal regime -- and let's say the cryogenic temperature is out here -- and you go through the RDNDT, and finally you reach the upper shelf.

In this range down here, we look at cracks that look like this. You use linear elastic fracture mechanics. In fact, if you recall, under pressurized thermal shock review, we looked at this as sort of an idealized curve that looked like that, and we treated everything on this side here by LEFM, and then that's your elastic fracture mechanics.

When we get up to the operating temperatures of these pipes, now we are in a ductile regime. So now we have to go to elastic plastic fracture mechanics, which normally is J -- you probably saw the J-T approach which we discussed at our last meeting.

So in this region, even though the toughness comes down, say it were to age and come down here, it is still a crack that behaves something like a blunted tip. It has to be treated differently than when it is in the brittle range.

MR. ETHERINGTON: When you use the word "brittle," by brittle I presume you mean cleavage. But could we perhaps ask one of our experimentalists what the observation is?

MR. VAGANS: In a fracture specimen, the answer is not that simple. What you are seeing in a Charpy is an unconstrained specimen, and you are not really seeing a fracture specimen, and you can get mixed mode and you do get mixed mode all the way through the transition. In other words, you start with cleavage and you get more and more percent fibers until you get at the top and you get pure fibers.

In fracture, conditions of restraint, tri-axial constraint to the crack tip are of critical importance. We have experimental evidence that shows that if you have enough constraint, you wil; never get any fibers tearing until you are totally on the upper shelf temperature wise.

MR. ETHERINGTON: Does that mean a sudden change in the behavior, then?

MR. VAGANS: Almost, yes. I could actually say there would be a sudden change in behavior.

MR. ETHERINGTON: Then you don't have a physical picture that would explain --

MR. VAGANS: We are working on it.

MR. SHEWMON: Onward.

MR. SERPAN: I hope to give, hopefully, a brief overview of the research programs that are under way on in-service degradation of cast stainless steel. I would like to point out that the work that we do have under way is

relatively modest. It hasn't been going on very long, and it certainly is not a mature program. So we have as many questions, perhaps, as you have, too. So we do not have all the answers, by any stretch.

The objective of this work is to provide an independent assessment of the effect of long-time service at operating temperature on the toughness loss of cast austenitic stainless steel components for nuclear service, and to evaluate possible remedies to the embrittlement problem for existing and at future plants.

[Slide]

I think perhaps a good way to go would be to provide as much bacground kind of information. Oh, I'm sorry. This is the research program itself. I need to point that out.

The program is to characterize the microstructure of long-term in-service reactor components and low temperature laboratory-aged specimens. It is important because we are doing both laboratory specimens, where we are aging materials, but we are also looking at materials that we have taken from components in service.

The next step is to correlate the microstructural changes with loss in toughness, to identify the mechanism of embrittlement, and, very important, to validate the extrapolation of experimentally-observed embrittlement to the long-term aging at reactor operating temperatures.

Next, to characterize the loss of fracture toughness in terms of fracture mechanics parameters such as the J-1C and J-R curve. It will not be just Charpy curve. And finally, to provide an understanding of the effects of compositional and metallurgical variables on the kinetics and degree of embrittlement.

[Slide]

I am going to go about three Vu-graphs of background, which I certainly hope will set the scene for what we understand at this point. There are plenty of questions raised here and there are things that certainly are not definitive, but that is where we are, and I think it is useful to go through it.

The bulk of the data currently available are based on work by the Swiss and French. Their results show that low temperature aging of duplex stainless steels leads to the following: drastic reductions in room temperatures impact strength. For example, impact energy decreases from 280 to 40 joules after about 8 years at 300 degrees C. of cast steel containing greater than 25 percent ferrite.

Now, these are kind of examples of what goes on. There is a decrease in J-1C fracture toughness. There is little data available on tearing modulus, but it also appears to decrease.

Relatively small increases in hardness and tensile

strength. And one of the better things, there is little or no effect on fatigue crack propagation at low R.

Now, much of the data obtained on cast materials with ferrite levels, much of the data that has been obtained so far has been done by the Swiss and is with ferrite levels greater than 30 percent. The chemical compositions are outside the ASTM A-351 specs, and it has been done under accelerated aging conditions, typically around 400 degrees C.

MR. SHEWMON: Low R means that the mean stress is close to zero?

MR. SERPAN: No, it's the other way, isn't it? Yes, it's the other way.

MR. SHEWMON: So, if there are residual stresses comparable to the yield from having welded this thing in place, then you then had a stress variation superimposed on that; that is a low R test?

MR. SERPAN: No, that is high R.

MR. SHEWMON: So then the low R test isn't particularly germane to what happens in the system where you have got residual stresses from fabrication.

MR. SERPAN: Yes. Simply observing what we have found.

[Slide]

The time-temperature histories to produce equivalent aging are expressed by this equation with an activation energy

of about 24kCAl per mole. The degree of embrittlement at the end of life depends strongly on the ferrite level. That is certainly one of the stronger pieces of information about this.

The more ferrite there is, the more embrittlement one is likely to have. An extrapolation of laboratory data to reactor temperatures requires a satisfactory understanding of the aging process, and precipitation of chromium-rich phases like alpha prime in ferrite matrix is believed to cause embrittlement at temperatures below 500 degrees Centigrade.

There are three other precipitate phases in the low temperature aged material which have also been observed in recent studies, and they are being looked at with great care to decide what their effect is on the process.

[Slide]

Finally, the last one of the background slides. Microstructural information on aged cast duplex steels is insufficient to ascertain the actual mechanism of embrittlement or to validate the activation energy for the overall process of embrittlement.

The current estimates of activation energy are 24 kCal per mole, and that is lower than the solute bulk diffusion of 55 kCal per mole. That indicates that precipitation of the alpha prime occurs not with nucleation and growth but by other mechanisms like, perhaps, spindle

decomposition, or that processes other than a' precipitation contribute to embrittlement.

All I can say at this point is that is part of the problem we have and it is being worked on very diligently.

Finally, the influence of the ferrite morphology and the distribution and concentration of interstitial elements on aging adds uncertainty in predicting the long-term embrittlement of cast duplex steels.

MR. SHEWMON: Before you leave that, is it clear that it is the embrittlement of the ferrite that is the primary cause --

MR. SERPAN: At this point it certainly seems to be, yes.

[Slide]

Now, just to be sure we are all talking about the same thing, the specification for this steel is approximately the same as 304. The CF-3 has .03 power, CF-8 has .08, and the big difference here on the CF-8M is that it has 2 to 3 percent Moly.

[Slide]

Now, the heats of steel we have in the program are listed here, but the point of all this is to show that we do have a number of heats of steel from keel blocks, which are stepped, shaped blocks which have been made for laboratory purposes, and then we have components here that we have from

pipes and impellers and so forth.

In addition to this listing that you have, the one in your paper, be sure to note that we do have the pump cover from the KRB reactor, which was aged for about 12 years. That is not on that list, but it is important to know.

[Slide]

It is also, I think, interesting to look at some of the microstructures that we typically get in these things. At the low percentages of ferrite, one which is over here, it is 2.6 percent ferrite, we tend to get this globular stuff, just this little stuff. Then as one tends to get to the higher ferrites, then you start to get lacy, and this is what is called lacy ferrite. I have got some more examples of that.

[Slide]

Again, 10 percent and 29 percent. Here you can see the lacing. Now, here is acicular ferrite as well, and that typically shows up at the higher rate.

MR. SHEWMON: Presumably that stuff along the grain boundary was ferrite, too?

MR. SERPAN: It could be precipitates along the grain boundary. But this, then -- yes, this is the ferrite. Here is the ferrite [indicating].

[Slide]

And to show how different these things can be, this is the microstructure of the KRB pump casing, and this is the

ferrite, and this is the austenite. And here you can see almost a continuous decoration on the grain boundary of precipitates.

MR. SHEWMON: And the continuous phase there is ferrite?

MR. SERPAN: The continuous phase is ferrite, and this is austenite; that's correct.

MR. SHEWMON: And which fraction is that one?

MR. SERPAN: This is, I think, about 30 percent ferrite.

SPEAKER: It's more like 26 percent ferrite. When you do the quantitative metallography, it's more like 26.

MR. SERPAN: It looks like it's a lot more.

MR. ETHERINGTON: The ferrite must be separated out during the formation of the austenite grains, mustn't it?

MR. SERPAN: Well, it almost looks like the ferrites come out first.

MR. ETHERINGTON: How would it get around the grains like that, then?

MR. SERPAN: Mr. Etherington, I really do not know how that stuff formed. All I know is I was rather surprised to see that kind of a microstructure myself because it's quite different from the others.

MR. SHEWMON: You ought to have great toughness when the ferrite embrittles.

MR. SERPAN: Yes.

[Slide]

Now, to get back to the part of the program that we have at Argonne, the time and temperature of aging for cast materials that we have in the program will sharply impact tensile and J Integrals, and this is the time in hours that we will be aging and at these different temperatures, and the key down here tells you the Charpy specimens, impacts and the J Integrals. I think you can probably follow that if you are particularly interested.

But the idea here is to show the range of temperatures that we are looking at and the kinds of specimens that we are looking at.

[Slide]

Certainly an item of interest is the -- not just the Charpies, but the J-R curve and tensile tests which will be done with materials. This is the current matrix that we have of specimens, the numbers of specimens from the different components, unaged and aged, for different times and temperatures here, and then the number of specimens that will be tested.

These specimens have been machined and they have been sent to MEA right here outside of the Beltway in Washington, where the tests will get under way shortly, but they are not under way yet.

MR. HUTCHINSON: Are there any plans to do any dynamic J tests?

MR. SERPAN: I don't think so, no. No.

MR. SHEWMON: That, in a sense, gets back to the Charpy versus the J numbers, whether we are measuring different things, and then the question of whether we should be more comforted by the high J or concerned by the low Charpy.

MR. SERPAN: Yes. I don't think we have any plans for dynamic Js.

SPEAKER: The current plan is not for a high strain rate J type test. It's for a standard J test, at least to get a feel for what was happening.

[Slide]

MR. SERPAN: There is some information that we have generated so far on Charpy impact data for room temperature tests on thermally aged cast stainless steel, and here are the results. Going from the unaged material in this column to material that was aged at 350 degrees, which was closest, certainly, to the surface temperature, and then up here at 450 you can see there really is a drastic change at 450 degrees. So these tend to run in the neighborhood of 78 or 90 percent drop -- or I'm sorry, 70 to 90 percent of the original figure. But that is a fairly short period of time. That is the status of our Charpy data at this time.

[Slide]

This is kind of interesting. It shows the effect of thermal aging on room temperature impact properties, and up at the top is service time in years at two different kinds of temperatures to give a feel for how the properties fall off. These solid points here are from the KRB pump cover. They were done for about eight years worth of service by the utility itself.

We now have that pump cover at Argonne, and we have done some tests on those, and those are these points [indicating]. However, these points were from -- what -- higher temperature, weren't they?

SPEAKER: Ours were lower temperature. They took the higher temperature.

MR. SERPAN: Oh, that's right. They were from the low temperature region. So the combination of lower temperature aging plus the longer time puts them in roughly about the same range. So you can see that this material seems to be falling approximately on this curve, so there is some good validation of that curve.

[Slide]

Another way to look at in general the kinds of roperties one is going to get from Charpy impact energy, for aging at 280 degrees, after 70,000 hours, the curve is going to fall like so. After 300,000 hours, it will fall like so

[indicating.] For aging at 320 degrees, there is a 70,000 hour drop and a 300,000 hour drop. And these are the measured data points that correspond to these curves. So we think that they are reasonably good at this point from the small amount of data that we have.

[Slide]

Now we will just go to some summaries that we have. I have got summaries in here of information that Argonne has developed, as well as summaries from the Swiss, French and Westinghouse. I am not necessarily going to go through all of that stuff, in the interest of time.

At Argonne we are working on 26 experimental and six commercial heats. Ferrite contents range from 3 to 30 percent. Material characterizations of the various materials have been completed, and as you can see, mechanical test specimens are being aged at different temperatures, and Charpy tests have been completed also at a range of temperatures.

The initial data indicate the influence of interstitial content carbon and nitrogen and cast structure on the embrittlement behavior. That influence is that the higher the amount of ferrite in there is the worst amount of embrittlement that we get.

The J-R curve and tensile tests are in progress, as I told you. The microstructural characterization has been completed, or is in progress, really, on the Swiss material

and also on the KRB pump cover.

MR. ETHERINGTON: Would you explain what spinodal means?

MR. SERPAN: I wish I could. Maybe Bill Shack might be able to give us an idea, but I'm afraid to wade into spinodal.

MR. SHEWMON: When you quench yourself into a region where any small fluctuation in the composition tends to grow, so you get a negative diffusion coefficient, in effect, and it can break up. The solute-rich and solute-poor regions can develop on a very small scale, and thus it tends to go faster than the classical precipitation.

I would be pleased to explain more of that.

MR. SERPAN: I think these other comments here can be read. Here and there I have some of these items, I think, that are worth -- if I can remember which ones they are now. From the Swiss, the information that we have there is materials have been aged at 400. The room temperature impact energy decreases from 250 joules to about 15 joules for materials containing greater than 25 percent ferrite, and to about 40 joules for 12 percent ferrite, and to about 100 joules for 6 percent ferrite.

So you can see the range there. As you have less ferrite, why, you have much more of the original strength in the material. And here, the aging shifts the ductile to

brittle transition to higher temperatures and lowers the upper shelf energy. Just putting in words what those numbers show up there.

[Slide]

The French. Again, the first one is a summary of the different materials that have been looked at, a restatement of the fact that impact energy and J-1C values are lowered by the aging at these elevated temperatures. Fatigue crack propagation and low cycle fatigue propagation are not significantly modified.

Oh, here is an interesting one. The French have come to this conclusion, that for most cast steels used in French plants, the calculated Charpy impact energy values are at least greater than 30 joules per square centimeter at the end oflife. That is not terrific, but that's what they thought, that it was at least 30 joules. That is, what, 20 foot pounds or something like that. It is not too good, really.

They think that a conservative lower bound value of J-1C is expected to be at about 100 kilojoules per square meter, which also is not terribly high.

[Slide]

MR. SHEWMON: Now, the curve that Ray Klecker was using as a bounding curve before had 3000 and some units, that was pounds per inch squared? And the French are using

570 for theirs.

MR. KLECKER: But this is J-1C, where we allowed some crack extension.

MR. SHEWMON: You weren't quoting J-1C, you were quoting the upper bound as to where it went with some hardening.

MR. KLECKER: Yes.

MR. SHEWMON: And these numbers are consistent with your number, then, and could sextuple, that is, increase by a factor of 6, which means J-1C in the upper limit?

MR. SHACK: My guess is they are the same heat. You have to realize how little data there is. We just keep quoting the same data over and over again.

MR. SHEWMON: Okay.

MR. SERPAN: Some of the highlights out of the Westinghouse work is that they see significant reductions in Charpy V toughness, but changes in J-1C are not as severe. And again, the fatigue crack growth is not affected by aging. Aging leads to significant increase in Charpy V-notch transition temperature.

And finally, they apparently have done a test here which shows that Charpy -- and they have from this concluded -- and we are not quite sure how they have done this -- but the Charpy energy has little correlation with the failure mode in cast stainless steel. So the failure characteristics of

the piping are not significantly changed by the thermal aging process.

Now, this conclusion was based on results from a 4 point bond test on CF8M pipe containing throughwall flaws at mid-span and was pressurized to 2250 psi. The material had 13 percent ferrite and was aged for 2000 hours at 427 degrees C., which is equivalent to ten years at 300 C.

So that is at least one piece of information.

That concludes what I have to present from the Argonne program.

MR. SHEWMON: There is one EPRI report out in which their contractor said that the fatigue crack growth rate was affected at high Rs. Are we going to get a third data point on that so we can split the tie?

MR. SERPAN: Bill, that is in the program, isn't it?

MR. SHACK: Yes, we will be looking at that. Again, there may be much more an effect at high R than one would expect to see in low R tests.

MR. SERPAN: I guess the conclusion that I should make out of this is a restatement of what I started with. This always has been a small program, and it suffered a near-fatal cut a year ago, and now we have got it going again. But this is going to be a long-term kind of thing because we can't really rush the aging of these specimens because if we age them at much too high a temperature, then we

are concerned that we may not be getting the proper precipitation in the right phases coming down, and we may be looking at embrittlement from something that really will not be there in service.

So this represents kind of a start of what I hope is not too long a program, but it will necessarily have to extend for some years.

MR. SHEWMON: It has to go for at least 50,000 hours, if you believe the data.

MR. SERPAN: That's true. We will do the best we can, though, with looking at Shippingport components and the other component because they, indeed, have been aged for a long time, but we will milk those for all we can.

MR. SHEWMON: Any questions?

MR. ETHERINGTON: Your first summary sheet showed Charpy impact energy of 30 joules per square centimeter. Was that an error?

MR. SERPAN: I don't think so.

MR. SHACK: That is simply the way the Swiss report their data. They just normalize it to the specimens because all the Europeans used different-size Charpy specimens.

MR. ETHERINGTON: Then we can't just convert that into 20 foot pounds.

MR. SERPAN: No, that's correct. That converts to 5.9. Multiply it by 5.9. That will convert into Charpy-V.

MR. BUSH: About 30 years ago, this whole family was looked at rather extensively, and they went up to $100,000. There are a lot of higher temperatures and the like, but there is some of it where you still get this CFAMs and CFA-8's were just being developed basically then. Obviously there were no fracture mechanics taken, but there is lots of impact data buried away in the reports, which might serve as a cross-correlation. You are right, it is very hard to come by 50,000.

MR. SHEWMON: Actually, I was interested to see that one of the studies, that some EPRI or Westinghouse report quoted a fair amount was done by Frank, Beck and Marsh Fontana at Ohio State 20 years ago or something, and I suspect they were more interested in the corrosion, but they did the toughness work, also.

MR. BUSH: Yes, I have a pretty extensive collection of those papers, and I was interested mainly in the degradation of the impact properties. But there is that whole sequence there. But about all you could tell -- you could infer some things, and of course, you can make C-curve type corrections.

MR. SHEWMON: Two hours without a break is probably long enough. Why don't we take a break, and then we will come back and hear all about GDC-4 again.

[Recess]

MR. SHEWMON: Okay. Implementation of pipe break connections, GDC-4 modifications.

MR. O'BRIEN: My name is John O'Brien, from the Office of Research, and I want to begin today by very, very briefly describing the document which you never saw, which is our limited scope modifications in GDC-4.

The reason you never saw it is that it fell within the purview of the resolution of A-2, which you did see. And not only did we skip by you, we skipped by the CRGR. Miraculously, we were given authorization to begin the rulemaking in December and March without a rule to the Commission, which is something of a record, I think.

We have got two to five Commissioners to vote affirmatively without comment to date, and I want to begin today by talking about -- and I'm going to do it real fast. You watch me fly through this. And then I will get to the document where we need your help.

[Slide]

So, today I will talk about the limited scope rulemaking.

[Slide]

And the history of it goes something like this. The GDC-4 requires the postulation of pipe ruptures, primarily those of PWRs. We have got technology now that shows that these kind of double-ended guillotine breaks don't occur. One

consequence of the dynamic effects associated with these pipe breaks is a lot of pipe whip restraints and jet impingement barriers.

There are other consequences, by the way, like, for instance, snubbers are sometimes placed on steam generators to resist these dynamic effects. We have got evidence in a report that Bosnak waved in front of you this morning that these devices degrade reliability. They are no good. And we have given some exemptions to GDC-4. My slide shows 19. Ray said 22, and he knows better than I because he is in licensing.

To give you an idea of what we are talking about, all this black stuff here is a pipe whip restraint, massive pipe whip structures.

[Slide]

You are supposed to catch it right here. There is a very, very large pipe whip restraint.

[Slide]

MR. SHEWMON: What were those things you pointed out in the wall? The whats?

MR. O'BRIEN: These things here are connected to the pipe whip restraint. You see, they go around this section and catch the pipe whip restraint. This is the structure that holds the pipe in place.

MR. MICHELSON: What are we looking at in this case?

MR. O'BRIEN: I don't know what kind of piping that is.

MR. MICHELSON: Is that inside or outside of containment?

MR. O'BRIEN: I don't know. I think it's inside when you get to that diameter, but I'm not sure.

MR. SIESS: I have seen bigger ones.

MR. O'BRIEN: It is pretty huge, though, because look at the size of the structure and look at the man standing there. You are talking 30 or 40 tons of structure. And this is another nice picture.

[Slide]

It shows a smaller pipe whip restraint but illustrates clutter. Here, you can even see whip restraint. This is a whip restraint, this is a whip restraint, there is a whip restraint, there is another one, here, here, to catch this little line here. And how can you do in-service inspection with this kind of stuff?

MR. SIESS: You are going to put the structural engineers out of business.

[Slide]

MR. O'BRIEN: Originally the double-ended guillotine break was a maximum hypothetical accident. It becomes a design basis without any technical information to support it. The consequences are the pipe whip restraints and jet

impingement barriers occur, and also asymmetric LOCA, and these loads were identified in '75.

In response to their question, a lot of work outside and within the NRC was undertaken.

MR. MICHELSON: May I ask before you leave that slide, I think the inference here is that you are worried about double-ended ruptures. It is my understanding that even longitudinal splits will require restraints in many cases in jet impingement and whatever. So this isn't just because of the theoretical double-ended rupture of pipe -- these are required for many lesser cases, if I understand it correctly.

MR. O'BRIEN: It's hard to imagine a pipe whipping very much so don't --

MR. MICHELSON: No, jet impingement is also part of the argument, so longitudinal split creating a whip requires some other big shields and stuff.

MR. O'BRIEN: That's right, but isn't it also true that the double-ended guillotine break is more probable than the longitudinal split?

MR. MICHELSON: I don't know.

MR. O'BRIEN: Yes, that happens to be the case. So if you can exclude the double-ended guillotine break, then the longitudinal split becomes a "no, never mind."

MR. EBERSOLE: May I ask you a question? With that qualification of double-ended break, it certainly does lead to

the notion that you are not talking about splits or four cross-sectional area breaks, and I certainly would suggest you clean up the language and say that it does mean all of those less-descriptive breaks.

MR. O'BRIEN: Well --

MR. EBERSOLE: Well, you mean something more than double-ended breaks. A great deal more.

MR. O'BRIEN: I believe it is the double-ended breaks that trouble us because that is when you get highest whipping pipes. You know, you have to separate the two --

MR. EBERSOLE: Well, sometimes it tends to whip, I agree, but not from jet effects.

MR. MICHELSON: You said the double-ended rupture was the more probable. I thought I had read in places that nobody has seen such except in a couple of rare instances, whereas longitudinal splits have been observed. Is there something wrong with the logic?

I would expect them to have never seen a longitudinal split, or at least much less likely than a double-ended rupture.

MR. EBERSOLE: Well, GE had one position and Westinghouse had another.

MR. MICHELSON: I kind of think I wouldn't want to argue it on a probability basis.

MR. O'BRIEN: I'm sorry. Let me back off. I am

talking only about the limited scope rule, which is primary circuits of PWRs. Are there any longitudinal welds on that pipe? I think the answer is no.

MR. RODABAUGH: No. There have been many longitudinal breaks in pipe with longitudinal welds.

MR. O'BRIEN: Yes. You have got to have an initial crack to grow the crack. If you don't have the crack and all the cracks are in the weld, not in the base metal, so you are not going to grow a crack that is not there.

MR. MICHELSON: I thought some of the plants did have longitudinal in the primary piping. Maybe not.

MR. RODABAUGH: I think some of the elbows do, at least.

MR. BUSH: I think the Palisades plant. As I recall, the Palisades plant has a 42-inch carbon steel or ferritic primary-type plant.

There have been some -- under severe water hammer loads, there have been some axial splits that are not necessarily related, but it certainly helps sometimes to have welds there as well.

MR. O'BRIEN: I think our premise is all the cracks are in the welds and are induced by the welding. I have been told that all the cracks are in the welds, and you don't have to worry about cracks in the base metal too much.

MR. SIESS: What about the elbows that are two

pieces welded together?

MR. O'BRIEN: That's another story.

MR. BENDER: John, Jesse reminded me, the Germans decided on having some kind of arbitrary break size for the purpose of dealing with the kinds of issues he is talking about. Your decision not to have them does leave a no man's land. If you have got that thing out on the table, I'm not suggesting that you go change it at this stage, but you need to continue to think about how you are going to deal with that issue.

MR. O'BRIEN: Replacement criteria?

MR. BENDER: Yes.

MR. SIESS: It would help me to separate whip restraints from jet impingements. It seems fairly clear that if you don't have double-ended guillotine breaks, you don't have pipe whip. But it certainly is not clear from what I have just heard around the table that that also eliminates the jet impingement question.

MR. O'BRIEN: So you would have to --

MR. SIESS: The designers could tell us what kind of jet impingement protection they have to have for longitudinal splits, which I know are postulated in the pipe whip criteria.

MR. O'BRIEN: You would have to only move those jet impingement barriers that relate to type of pipe ruptures that you are excluding. We are saying right now in our rule that

longitudinal and circumferential breaks are -- there is enough evidence to say that these don't occur, and you can take all pipe whip restraints away from those two types of breaks.

MR. SHEWMON: See, the other part of this is that even though there is the longitudinal split of some kind, the postulate is that this will start as a small one and will increase, and before it gets big, it will leak. It seems to me that argument is as good for longitudinal split as it is for a circumferential crack.

MR. O'BRIEN: Oh, it is even more so because the stresses that drive -- that is, if you start to crack the section, you start to redistribute the load, which may not happen with the longitudinal split, it is kind of like bending loads, for instance.

MR. SIESS: You still have the jet impingement for the maximum crack you are willing to have before a break.

MR. O'BRIEN: Right.

MR. SIESS: But that might be manageable. I don't know.

MR. BUSH: We have two physical cases of this that have occurred at plants where we have generated fairly substantial longitudinal splits, but I never recall hearing any figures that the jet impingement therefrom was that substantial. In other words, you can have a fairly good-sized crack and still not have a substantial level of jet

impingement because it is a function of the crack opening.

MR. SIESS: Well, there was an instance at Indian Point of a feedwater pipe that cracked at 180 degrees around the circumference at the containment penetration, and the jet impingement, if you want to call it that, buckled a large area of containment liner completely away from the concrete. It did not rupture the liner. It was still leaktight, but it was an area about 20 by 40 feet, I think, that heated up from the hot feedwater and buckled out, but I don't believe there was a crack through the liner wall.

MR. BUSH: Maine Yankee was the other one.

MR. ETHERINGTON: You mean that was a thermal expansion effect?

MR. SIESS: Yes, it was thermal expansion. The upper half of the pipe broke. It just sprayed hot water right up the containment wall and buckled it out.

MR. EBERSOLE: Does the fossil plant experience bear this out?

MR. BUSH: Oh, yes. In fact, one goes back to the evidence of fossil plants, either in this country or, in fact, in looking at larger pipes, because our records aren't that good, you usually go to the German records because there you can get some several million operating years of experience to come to a basis of that.

Now, that doesn't say you don't have -- it just says

the probabilities are very good.

MR. SHEWMON: Onward, please.

MR. O'BRIEN: Okay. So we have troubles, legal troubles with the use of exemptions, and therefore we need rulemaking to continue to take pipe whip restraints and jet impingement barriers from the primary circuits of all three PWR manufactaurers. So this limited scope rule, which, again, you haven't seen, deals only with the pipe rupture and dynamic effects from pipe ruptures. And we say ECCS and containment will not be affected. It will still be based on the double-ended guillotine break.

We said equipment qualification was not affected, but that was taken away because they wanted to have environmental qualification on a case-by-case basis. But at one time we had environmental qualification also not impacted by this rule.

MR. EBERSOLE: What about the dynamic qualification of valves?

MR. O'BRIEN: There are no valves on the primary loop, right, on the primary loop? That means the --

MR. EBERSOLE: Yes, but you are going to extrapolate to the -- yes, some valves on the main pumps are generally sometimes isolated. But anyway, you are going to extrapolate this to all other systems eventually.

MR. O'BRIEN: I am going to talk about that in a

minute. There are no line-mounted valves.

MR. MICHELSON: I am assuming that the primary pressure boundary includes the appendages there to the second isolation valves. By general definition.

MR. SIESS: If you don't think there can be a double-ended break, you don't think there can be a double-ended break,, period.

MR. O'BRIEN: In the rule, we wanted to say that environmental qualification was not affected. The Staff backed off and said let's be silent because we want to do it on a case-by-case basis. Okay?

MR. EBERSOLE: Yes, but wait a minute. There is an ambiguous component to this. The environmental qualification comes under, you know, the change in the environment, and the other aspect of it is the dynamic capability of the valve to handle the full hydrodynamic load that you get with a cross-sectional break. Are you going to eliminate the second part?

MR. O'BRIEN: I think that the Staff -- and I'm not talking for NRR -- but my understanding is that NRR on a case-by-case basis wants to use environmental qualification.

MR. SIESS: But that's not environmental qualification, John.

MR. O'BRIEN: Dynamic equipment qualification.

MR. SIESS: It's equipment qualification, not

environmental.

MR. O'BRIEN: Yes. It's my understanding that NRR would like to use this rule on a case-by-case basis to apply to equipment qualification, and Bob Bosnak is going to answer that better than I.

MR. SIESS: Well, if you use it to eliminate dynamic effects on core internals, it makes equal sense to eliminate dynamic effects on valves.

MR. BOSNAK: Again, this is limited rulemaking, and we are talking about the main loop, and we are not getting into the branch lines because the branch lines still have breaks postulated in them. The terminal end of the branch lines are still break locations for the branch lines.

MR. SIESS: We are talking about the limited scope rule now, only the limited scope rule?

MR. BOSNAK: The limited scope rule.

MR. MICHELSON: It's not all Class 1, then.

MR. BOSNAK: Well, those,if you go beyond the point of code demarcation, become Class 2.

MR. MICHELSON: Yes, but you re saying that you are not including the Class 1 portion of branch lines?

MR. BOSNAK: The Class 1 portion of the branch lines are not a part of the loop. There is a break required in the Class 1 branch line right at its terminal end.

MR. SIESS: All right. But now looking down the

line, the broad scope rule comes next, right?

MR. BOSNAK: That's correct.

MR. SIESS: Okay. So right now we are only talking about the primary main loop piping, the primary system, the main loop piping on a PWR, limited scope rule.

MR. SHEWMON: I'm getting confused.

MR. BENDER: I just wanted to ask, John, can you provide a diagram with the rule that shows where the boundaries were? If you didn't, I suggest you get one together because you can just see from this conversation here there is a little bit of confusion.

MR. O'BRIEN: Some have two hot legs for every cold leg.

MR. BENDER: The idea is to be sure, if you are excluding branch lines, you need to be very explicit about them because you will find out --

MR. BOSNAK: In the Westinghouse PWR, there are 11 breaks. One of those is a longitudinal break. And those are the ones that are being eliminated. Branch lines are still there, the terminal ends of the branch lines.

MR. BENDER: I'm not trying to argue about it, Bob. I'm just saying if you guys will do something to define the things carefully, you will eliminate a lot of the problems later on.

MR. O'BRIEN: Okay. Some of the value impacts.

They are mentioned in tens of thousands of man rems, and cost savings on the order of hundreds of millions of dollars. In the limited scope rule, we did say with regard to pressurization of compartments that pipe rupture induced pressurization. I think that answers some of your concerns this morning. Every other pressurization of a compartment is still in the design basis. That is in the rule. Not in your rule. You have got the broad scope.

MR. MICHELSON: I don't know. I'm confused. I have two rules. One is issued on March 26th.

MR. O'BRIEN: Okay. That's the limited .cope.

MR. MICHELSON: Yes. And then I've got the broad scope one. I've got two.

MR. O'BRIEN: Okay. Well, we have two.

MR. MICHELSON: And you are talking about the March 26th rule. So we do have it.

MR. O'BRIEN: Okay. I'm glad you do.

If you look in the summary of the Federal Register notice in that rule, it says specifically, pipe rupture induced pressurizations. That means that every other pressurization is still in the design basis. The summary is on the first page on the bottom. It says, "Pipe ruptures induced pressurizations of compartments, subcompartments and cavities."

The reason we need that is that we can't get out of

the woods with A-2 unless we can eliminate the cavity pressurization. So in your acceptance of our resolution to A-2, you said it's okay to exclude that pressurization, and we just extended it to say any other compartment that is not part of a containment volume is excluded from the design basis. However, if that compartment could be pressurized by a valve, by a leaky seal, by the steam generator, then it is still in the design basis.

So I think that might make you feel a little better.

MR. SIESS: It will temporarily, but when we look at the broad scope, we will be back again.

MR. MICHELSON: Yes. It uses the same words.

MR. O'BRIEN: Well, anyway, when we looked at the legal recourses, we decided that we couldn't re-interpret the existing text of GDC-4 to achieve the design removal. We really wanted to get rid of these pipe whip restraints. They are really evil. For 15 years we have been interpreting it as necessary, so if you change the way you are doing business, you have to have a rule.

We couldn't use exemptions because this is effectively rulemaking without due process.

MR. SIESS: Is that true, that you can't introduce new engineering knowledge to change your interpretation? There is nothing in the present rule that defines a loss of coolant accident as a double-ended guillotine pipe break?

MR. O'BRIEN: Well, here is my lawyer.

MR. SHIELDS: We faced this question probably two years ago when we first started the GDC-4 question. It's true that GDC-4 is worded rather broadly. It does say that you have to consider the double-ended break up to and including the largest break --

MR. SIESS: I'm sorry. Where does it say that?

MR. SHIELDS: Well, it brings that in through the definition of LOCA.

MR. SIESS: Where is the definition of LOCA in the regulations?

MR. SHIELDS: I believe it's in the introductory portion.

MR. SIESS: All right. That is in the regulations.

MR. SHIELDS: Yes, in the introduction.

MR. SIESS: And a loss of coolant accident is defined as a double-ended guillotine break?

MR. SHIELDS: Well, it's defined, I think, as a break up to and including the largest pipe --

MR. SIESS: Then why can't you simply revise that part of the regulation without revising the GDC?

MR. SHIELDS: Well, if you revise the LOCA definition, then you would be revising that definition for all other purposes for which LOCA --

MR. SIESS: No, you have two sentences. I can write

them. For purposes of pipe width, et cetera, you do one thing, and --

MR. SHIELDS: I think that would rather baldly state the dichotomy that is already evidenced in some of this work.

MR. SIESS: How could it possibly be more confusing than what is being proposed?

MR. BENDER: Chet, you are not a lawyer and you are not supposed to make judgments.

MR. SHIELDS: I was trying to answer the question why we had to do a rulemaking, and the reason was that, however broadly the words are phrased, when you have a long-standing regulatory interpretation of those words which is quite specific and which is set out in the Standard Review Plan and other documents, certainly you can make minor changes to respond to technical developments, but when you make a major change in regulatory philosophy, which I think everyone would agree this is, and you really are taking a whole different direction or approach to this problem, we felt that rulemaking was really necessary to put the public and the regulated industry on notice that this change is being made.

So it really is a question of degree. You are right, you can make certain adjustments to your interpretations, but when it becomes a significant change in a long-standing practice interpretation -- .

MR. SIESS: I understand, legally.

MR. SHIELDS: That's the only way I can approach it.

MR. SHEWMON: Onward, John.

MR. O'BRIEN: Well, he has a master's degree from MIT, so watch out.

Our summary is that the Staff feels that there is enough evidence to accept the use of leak before break for the primary loops of PWRs, and although you can't apply this new technology except by extention, we feel that there are significant benefits to promote its use. It seems to be something that's good for every point of view in that it enhances safety, reduces radiation exposures, saves cost. There is absolutely no reason not to do it.

That is my formal presentation. I want to spend just a few minutes talking to you about our broad scope rule --

MR. MICHELSON: Before we leave the narrow scope, can I ask a question?

MR. O'BRIEN: Well, you will have to ask Paul Shewmon.

MR. SHEWMON: Be my guest.

MR. MICHELSON: On page 10 of the narrow scope rule, you make a statement here which I am wondering about. It says, "Second. Studies completed to date indicate that the only adverse safety implications associated with postulating pipe rupture are those resulting from consideration of the

dynamic effects associated with pipe rupture."

Now, you are saying that if it weren't for the dynamic effects, there would be no problem with pipes breaking. I just simply don't believe --

MR. O'BRIEN: No, no, no. What it says is that --

MR. MICHELSON: Oh, no adverse safety implications. That's what it says.

MR. O'BRIEN: The intent of that was that ECCS systems can meet the requirements of a double-ended guillotine break. Containments can meet the requirements of a double-ended guillotine break. However, whipping pipes and jet impingements are met with adverse safety implications.

MR. SIESS: What about environmental qualification?

MR. O'BRIEN: Okay.

MR. MICHELSON: I don't believe you can license a plant today if there are adverse implications from whipping pipes. They were supposed to have been taken care of by all those fancy restraints and whatever.

MR. O'BRIEN: Oh, no, no. Let me tell you an analogy. It's like a guy comes to put fertilizer on the lawn and he kills the grass because he overdoes it. What you are doing is bad engineering. You cannot be cavalier about it. We have got a safety feature in there that doesn't help; it hurts. We cannot be a good engineer like a guy gives you a bad haircut. What we are doing is we are ripping off the

public. That's the truth.

MR. MICHELSON: I don't think I agree with what you are saying at all.

MR. O'BRIEN: That's because you haven't read the evidence.

MR. MICHELSON: Well, I read your five volumes. I didn't read every page of it, I will admit.

MR. O'BRIEN: You didn't read the references.

MR. SHAO: I think what the sentence means is that these pipe whip restraints increase stiff piping systems. Stiff piping systems --

MR. O'BRIEN: No, that's not true. They don't increase the stiffness of the pipe.

MR. SHAO: Yes, but there is more dependence to cause maintenance and inspection areas.

MR. O'BRIEN: When improperly installed, these devices degrade safety.

MR. MICHELSON: I suggest you just read the sentence I cited on page 10 and explain to me what the basis is that you have for making that statement, and read the sentence first.

MR. O'BRIEN: The basis I will try to explain is the NUREG which Bob Bosnak waved at you this morning, NUREG 4263, which shows that pipe whip restraints can't degrade the reliability of piping.

MR. SIESS: That's not the sentence, John.

MR. SHEWMON: Read the sentence because not all of us have it memorized.

MR. MICHELSON: It says, "Studies completed to date indicate that the only adverse safety implications associated with postulating pipe rupture are those resulting from consideration of the dynamic effects associated with pipe rupture."

MR. SIESS: That's not true.

MR. MICHELSON: That's simply not true.

MR. SIESS: That does not take account of environmental effects at all.

MR. SHIELDS: Let me interject here. I think you are missing the point of that sentence. It may be in the wording. What they are saying is the adverse effects of postulating pipe rupture. They are not saying the adverse effects of pipe rupture. There is a difference between those two statements.

When you postulate the pipe rupture, then you lead to a certain series of steps.

MR. SIESS: No, no. The word that is missing is "arbitrarily" postulating pipe rupture, if you want to get fancy.

MR. SHIELDS: This is the only one, the only consequence of postulating pipe rupture which can be shown to

have an adverse effect on safety.

MR. SIESS: That's not what the sentence says, though.

MR. SHIELDS: Well, that is what it's intended to say.

MR. BENDER: At the risk of suggesting we stop arguing about the words and try to find out what Mr. Michelson's concern is, I think we ought to find out what it was that he is trying to get at.

Are you concerned about the words or are you concerned about --

MR. MICHELSON: No. In this particular case I was just concerned about the words. That sentence ought to be tailored up or something because it simply isn't quite right and it doesn't belong in rulemaking. This is the scope of the rulemaking section. It ought to be well engineered.

MR. BENDER: Well, the Staff has always been willing to take editorial suggestions.

MR. SHEWMON: Does that come to the end of what you had to say, John?

MR. O'BRIEN: I'm willing to end it if you are.

[Laughter.]

MR. SHEWMON: We have come to the end of the slides. Are there other questions?

MR. O'BRIEN: I should very briefly tell you that

the broad scope rule differs significantly from the small scope rule in that no analyses need to be submitted to take advantage of the limited scope rule, and that the Staff says that enough work has already been done on the primary circuit of the three major BWR vendors.

To go beyond the primary circuit, somebody has to do something. Most likely the applicant will have to undertake studies to show that he meets the Staff's leak before break criteria. So the broad scope rule is not a license to do anything except persuade us that you can apply leak before break to a new situation.

It is a very major difference because the limited scope rule says it's there for anybody who wants it -- take it -- and --

MR. SHEWMON: But only for the primary loop?

MR. O'BRIEN: The broad scope rule says that if you have evidence to support it, either tests, analyses, the like, present it to us and we will evaluate it. In other words, the Staff has not said anything except we will entertain now extended application leak before break.

MR. SHEWMON: Are you going to have this for GDC-4A and GDC-4B, or how do people know which one they can come in under?

MR. O'BRIEN: Well, as it was explained to me, the limited scope rule will go into effect very soon and go on the

books, and then the new rule replaces it and the old rule goes off the books.

MR. SIESS: John, what is there in the new rule that changes what they have to do to demonstrate it? The words seem to be identical.

MR. O'BRIEN: Well --

MR. SIESS: I've got the new rule in front of me. It says when analyses demonstrate that the probability of fluid system piping ruptures are extremely low under conditions consistent with design basis for piping. The words are identical.

MR. O'BRIEN: No, they are not. The first rule says pressurized water reactor piping.

MR. SIESS: Oh, yeah. One of them says primary coolant loop pressure in pressurized water reactors may be excluded. This says postulated pipe ruptures in light water reactors may be excluded. But from there on out, the words are the same. So how does that change the --

MR. O'BRIEN: Well, the Federal Register notice says that that sufficient evidence already exists to apply the rule to the primary circuits.

MR. SIESS: Well, both of them say when it can be demonstrated. I don't see any difference in the words.

MR. O'BRIEN: That's true in the rule itself.

MR. SIESS: Well, I'm a lawyer. I'm only reading

the rule itself.

MR. O'BRIEN: I know, but doesn't the Federal Register notice interpret the rule, Bill? No, it doesn't?

MR. SHIELDS: I guess the way to read that is that -- and we did have certain problems here, I must admit, in having to put out this interim rule and the broad scope rule. This was not our intent. Our intent was to put out one rule, which would essentially have been the broad scope rule that you have in front of you, where, for a variety of reasons, we were rushed into putting this interim rule together.

The idea would be, though, that although the words are the same, essentially we have already determined that analyses do show that this methodology applies to the primary loop PWRs. So all it means, really, is that the Staff has already accepted the application of this technology as outlined by the interim rule.

In the case of the broad scope rule, one would have to make further submittals in order to extend the application. So the words being identical really doesn't mean very much. The fact is the technical work has been done with regard to the interim rule, and it has not been done with regard to extension beyond that.

MR. SIESS: Well, that is the way the Staff will interpret "demonstrate."

MR. SHEWMON: Okay. Now, Ray had something to say?

MR. KLECKER: The only point I was going to add to that was that in Chapter 5 of Volume 3, we gave all the limitations and the criteria for application for leak before break for all piping systems, so those are the requirements we would review on any application. So they are identical in principle. Of course, the pipe sizes and loads and everything will change.

MR. SHEWMON: Okay. Any other questions?

[No response.]

Fine.

Part of this next session will be closed because we will be discussing proprietary information, and you will tell us when you want to take a five-minute break and close the meeting, is that right?

MR. MICHELSON: While he is getting ready, could you tell us what is the next step as far as commenting on the proposed broad scope and narrow scope in terms of GDC-4?

MR. SHEWMON: No, I can't tell you.

MR. MICHELSON: I was thinking from the subcommittee viewpoint, what is our next step? Are we going to write a letter on it or comment on it or wait for it to go out for public comment or what?

MR. SHEWMON: I can't say. What do you suggest?

MR. MICHELSON: Well, I think I would suggest waiting at least until it goes out for comment.

MR. SIESS: I am a little confused, too. What is the status of the interim rule or the short rule?

MR. O'BRIEN: It has already been in the Commission for two months and they are voting on it now. Two of the five have completed their --

MR. SIESS: If we want to comment on it, we can comment after it goes out for public comment.

It seems to me that what the committee has to decide is whether we accept the evidence of leak before break, and the basis for that conclusion. If we accept that evidence and agree with the Staff, then I think we pretty much have to agree with the proposed rule, the short rule, and then the broad scope rule follows the same way. That is, if the same kind of evidence can be brought forth for other piping, then it could be applied to other piping.

So I would think our issue is a technical issue of is there sufficient evidence of leak before break and what kind of data has to be developed to expand it beyond that if we look at the broad scope rule beyond that limited PWR thing.

MR. BENDER: I wanted to comment on --

MR. SHEWMON: Would you move that mike up half as close as Chet has?

MR. BENDER: The arguments that Mike made for other piping systems might not be the same type that are required for this one, and I think it would be dangerous to make an

interpretation which says the same type of information is needed for the secondary system as for the primary.

MR. SHEWMON: Well, let's not talk about the information. What Ray put up here was a procedure as to what should be postulated. Now, what sort of information might be needed to do that calculation might change and it might not, but it seems to me if we are going to comment, it ought to be on what we think of the procedure.

MR. SIESS: If the Staff does as good a job on that as they have done on this, that would be a criterion.

MR. BENDER: Well, I am saying that the kinds of arguments that are being made for the primary system are not the type that necessarily should be made for the secondary system or the service water system or all those other things out there that need to be considered. The criteria are different, and probably the reliability requirements are different, and the regulatory process should make sure it doesn't encourage a constrained approach like this one to deal with materials that have different kinds of problems in different kinds of systems.

MR. MICHELSON: I don't think we really discussed outside of containment today.

MR. BENDER: Or even systems inside containment.

MR. MICHELSON: And they're even getting into the non-seismic, high energy non-seismic systems out there under

these -- you know, what kind of rules if we are not going to postulate about their failure?

MR. SHEWMON: Well the rule was --

MR. MICHELSON: Leak before break on non-seismic, non --

MR. SHEWMON: You have to postulate a throughwall crack and see if it will take seismic, is what I heard. Seismic plus the applied load to it. And I guess I don't see why that isn't still a reasonable -- you know, if it's good for one, I don't see why being outside containment is going to change the fracture characteristics.

MR. BENDER: Well, there are a lot of reasons for making the point, but first of all, the leak detection approach is not very practical for a lot of others. Secondly, the material characteristics are different. Thirdly, the implications of failure are different. And consequently, all of these things have to be put together to make some sense out of the approach. I don't think we can get all of --

MR. SIESS: Is it going to get worse or better, Mike? I can't tell.

MR. BENDER: It will be different. Hopefully, it will be better, but I really think you have to sit down and look at each system and develop a set of logical criteria to deal with it.

MR. SHEWMON: Well, the leak detection certainly is

different. I will buy that one.

MR. BENDER: Well, that's the crux of this one. So if you decide you are not going to apply that kind of approach, you have to look at it entirely differently, and I think you really ought to.

MR. SHEWMON: Shall we ask Staff about the general rule covering that one?

MR. ARLOTTO: Let me just comment. Mr. Chairman, I think I agree with what Mr. Bender says. I think I would say it a little differently. Because we have done a considerable amount of research on the PWR primary loops, we have a reasonably good technical base, particularly probabilistically. The people in NRR have gotten submittals from Westinghouse doing topical reports, again on the primary loop. Therefore, I think we are in a different state regarding how much confidence we have to eliminate these breaks in the primary loop rather than everything else.

And I think that if we were going to relook at the broad scope rule -- and it may be, based on the discussion I am hearing around the table, that maybe we should have a two-step approach within the broad scope rule: one, addressing the non-need to postulate double-ended breaks for the primary system, and then crack the door open for the rest of the system whereby proof must be established, which again goes to the discussion around the table.

That might be quite different from what we have here, but principally because we have done a hell of a lot more work on the primary loop.

MR. MICHELSON: It is not clear that the cost-benefit study that was done on the primary system at all pertains outside of containment either, and I think you have to think about it carefully, whether there are significant benefits out there. We just didn't discuss any of this.

MR. SHEWMON: Well, let me bring up a separate question that will come at the end of the meeting, and that is: What do we want to try to bring before the full committee from this? It seems to me on the limited rule, that has gone a fair way and there is less concern about that than there is about the non-primary -- well, it is my impression that there is less concern about that than there is about the general one and what sort of a box we are opening. I won't call it Pandora's for now, but at least what sort of a box we are opening with the general one.

What is the feeling about -- do we have any time in the full committee meeting this month on this?

MR. IGNE: No, but we can easily put in a half-hour.

MR. AXTMANN: Five minutes would do it.

MR. SHEWMON: Better five minutes. Well, let's get comments on that later, but sometime towards the end of the day, I would also like to get your comments on where do we go

from here, on do we want to wait until it goes through the Commission. I guess in that sense it goes out for six weeks of comments?

MR. O'BRIEN: Sixty days.

MR. SHEWMON: Okay. So at Christmas time it will come back or something. No, this is the limited rule, because they want to get the limited rule out, and then 60 days after that.

Okay. Have I answered all your questions?

MR. MICHELSON: I assume it is going to be later and we will deal with it again.

MR. SHEWMON: I think so, and we have advised the Staff that we are more comfortable with the limited than the broad.

Okay, onward, then.

MR. JOHNSTON: Just peripherally, listening to this, this group has already discussed the limited rule twice before. We presented it to you more than a year and a half ago, and you approved it. It wasn't called a rule.

MR. SHEWMON: Yes, but when we get to implementing it, we would like to know more about it.

MR. JOHNSTON: Okay. Well, I have got something here that I know you will want to know more about, too. You asked us to come in and talk some more about the leak before break as it is applied to the cast stainless steel and the

fact that, as you have already heard, it ages due to precipitates appearing in the ferrite phase of the duplex material.

What I am going to do is in part repetitious of what Chuck Serpan did because I am going to also show information that says, yes, indeed, the mechanical properties are degraded, especially the Charpies. Much of the data that one has to deal with is trout line data, which is the source that is referred to in other people's work.

There is some additional work that has been done by the French, and Westinghouse has done some work of their own. Some of the French work was reported recently in the open literature. The pricipal author was Slama, and I will talk about some of that.

Unfortunately, my talks are proprietary when I get into some of the more specific information and data that we have.

The thrust of my talk is going to be that while Charpy is nice, what we really need for licensing is the J-R curve type of data, and tensile data, and I believe Ray Klecker indicated earlier that we have a criterion that he uses or that we use for the review, for the leak before break.

In line with the previous Westinghouse topical report, we know that there are certain maximum bending loads and total loads that can be placed on the piping, and if the

properties of the pipe aren't able to take or able to meet those criteria, then we conclude that it is an acceptable material.

Well, I believe Ray gave you the criteria this morning. We have such a criterion for the cast pipe. It is based upon fracture mechanics information. The thrust of my talk really is to try to emphasize what we know and perhaps what we don't know about the fracture mechanics area and the fact that we have taken a material that has minimum mechanical properties and used that as our criteria to show that it meets the criteria.

Therefore, any reviews that we get which give us material that has properties that exceed that minimum, we conclude that it meets the criteria and is therefore acceptable, and that is in essence what I will be showing you in my slides. So now you know what to shoot at, too.

[Slide.]

The first one, then, is merely to bring us up to date again. This is the summary. The effect on aging as far as the tensile properties are concerned. There is a slight increase in the yield strength and elongation, and a significant decrease in the reduction of area. Significant increase in the ultimate tensile strength. The stuff gets stronger.

MR. SHEWMON: And ductility goes up?

MR. JOHNSTON: But reduction in area goes down. This is a duplex material, and when you have the very ductile austenite with the ferrite mixed in, and you can see as a function of ferrite what the density of the ferrite is and what point they begin to be interconnected. I should also say that the material we are dealing with -- because I'm focusing on piping -- has not been presented to us, at least, with ferrite contents of above about 18 percent, and consequently, the pictures that you saw of 35 and 30 and 40 percent are a whole different material from the point of view of if you look at the microstructure. It's a matter of degree, I guess, but it's different.

MR. HUTCHINSON: Does elongation go up because the necking is delayed because of higher arcing?

MR. ELLIOT: I am reporting the data in the literature.

MR. HUTCHINSON: Well, what is meant by elongation here? Total elongation?

MR. ELLIOT: No.

MR. JOHNSTON: Two-tenths percent offset or what?

MR. SHEWMON: No. Elongation is changed in length over the entire gate section.

MR. HUTCHINSON: That's right. So it must be that necking is delayed.

MR. JOHNSTON: In the case of fatigue properties for

low R values -- and I didn't hear all of your discussion on the different R values -- but for low R values, the data we have shows no significant effect. The impact properties, as you have seen, have a significant decrease, as much as a factor of 10 or more, in absorbed energy. Fracture properties, the J-1C and the T decrease, but not as significantly as the impact properties. I want to show you some of that data.

MR. ETHERINGTON: Can you give us an idea of what they are starting with? You are giving us these increases and decreases.

MR. JOHNSTON: I will show you some graphs in a minute, and this is more just to give a general idea of what seems to happen.

We heard a lot more about the impact data. I wanted to present some additional information.

As far as weld metal is concerned, the yield strength, tensile strength, elongation reduction area and Charpy impacts vary only slightly with aging. And I will also show you that as far as the welds are concerned, they start out very low in properties, and they don't change much, and they are about the same as they are for the cast steel after it is aged, a rather small difference.

MR. BUSH: You have to be careful about that statement and say what kind of welding process because that

doesn't apply generally.

MR. JOHNSTON: I know. It is not -- this is stick weld. I'm talking stick weld, which is what we are using on our pipes.

[Slide.]

MR. JOHNSTON: This is the reference from Slama. It was at the Smirt 7 Post Conference in 1983.

[Slide.]

This is actually the French data, and this is the same kind of data that you already have seen. This is time. This is the change in the Charpy values. This is in decajoules per square centimeter, and that is the stuff you multiply roughly by 6 to come up with our English units.

Basically, at the low temperatures it takes a long time before anything happens. Here is 10,000 hours. But at the higher temperatures, it happens at much lower temperatures, reaching values down in here on the order of 4, 3, or something of that sort for, you might call it, fully aged material.

[Slide.]

MR. SHEWMON. It's interesting that they have the stuff going lower at 400 C than they do at 350 C.

MR. JOHNSTON: Yes. I don't understand the difference, but the mechanical property data never falls on top of itself.

[Slide.]

This is similar information plotted differently, but these are for the weld metal, E308L, that was also studied. This is still the Charpy numbers, but what we have now is a function of temperature, and it shows basically the same kind of drop-off with time. If you take a given temperature, it starts here, and goes to here [indicating] between the beginning and the 10,000 hour data. So it drops.

But look at the numbers we are talking about. We are talking something that is already down around 4, and it starts at 8 or something like that. So we are down in the bottom of the curve that I just showed you. This is for weld material.

MR. SHEWMON: Do we know whether the cast elbows sort of fall where the weld is or up where the rod is to begin with?

MR. JOHNSTON: To begin with?

MR. SHEWMON: Your point here is --

MR. JOHNSTON: Well, this is the kind of data that you get for the new material, the unaged, and I guess the cast in the rod must be similar.

MR. SHEWMON: No, I'm trying to distinguish between the centrifugally-cast and the statically-cast.

MR. JOHNSTON: The data that I have seen show very little di'ference between the statically-cast stainless and

the centrifigually-cast stainless if they are both cast in the sand. I have one piece of data where it is cast into a metal mold and there is a significant difference, but our understanding is that all the commercial pipe that is presently being used and has been used in the plants is cast into sand, and it therefore has the slower cooling rate.

The cooling rate is important in the details of the morphology of this material. It does affect the distribution of ferrite. It does not affect the grain size, but it does affect ferrite distribution.

[Slide.]

This is the J-R curve for cast stainless steel. This is the virgin, unaged material. You see the J-1C located here, and here are two different -- this is the same heat at age 3000 hours, and here is heat aged 7500 hours. And you see the drop down into this [indicating] where the J-1C is dropping well below 500. The lower point here is around 100, in the kilojoules per square meter units.

Also you will notice the way the toughness falls off with the aging.

This is the kind of curve that we would like to see more of.

[Slide.]

MR. SHEWMON: And it is one of those lower curves that you have used for your bounding values?

MR. JOHNSTON: Yes. This is the lowest. This is the one that we use as our lower bound, and we have shown that material with this property would meet our leak before break criteria, and the other material that is above it is acceptable.

MR. SHEWMON: That is the 20 percent circumference throughwall crack or something akin to that?

MR. JOHNSTON: It is 7-1/2 inch length, full throughwall crack, 7-1/2 inches in circumference. A minimum of 10 gpm.

MR. ETHERINGTON: Those are relatively high temperatures.

MR. JOHNSTON: These are ranged at 400, that's true.

[Slide.]

This is additional J-a curve data. One of the uses here -- this again is a plate, and here is J-a curves for welds, which gives you the same idea that the Charpy curves did. As far as the welds are concerned, they have very low J-a values as well. J-1C is 130 and 150 in these two particular heats. The value is 100 for the aged cast stainless that I showed on the previous slide. So this is slightly higher than the cast stainless, but not very much when you compare it with the data here.

MR. SHEWMON: Can somebody, just for the heck of it, get me a J-1C value for a pressure vessel that we put into

service 15 years ago?

MR. BUSH: You mean in the original state?

MR. JOHNSTON: Well, that wasn't stainless steel.

MR. SHEWMON: Well, I will take both. Let's take it on the upper shelf. I almost understand the units of foot pounds, but I sure don't know much about decajoules per something or other.

MR. JOHNSTON: Well, that is why I gave you a 5.9 conversion. It's about 17 foot pounds in the Charpy test. The lowest number for the Charpy in the French units corresponds to about 17-1/2 foot pounds.

MR. SHEWMON: Can 17 foot pounds -- you guys can convince yourself, with all your fancy fracture mechanics, that it's great for taking care of a 7-inch crack?

MR. JOHNSTON: Yes.

MR. SHEWMON: That is lower shelf energy.

MR. JOHNSTON: We are talking fracture mechanics.

MR. SHEWMON: But a minute ago you said 17 foot pounds.

MR. JOHNSTON: That's your equivalent Charpy number.

MR. SHEWMON: But we bless it all with fracture mechanics and it comes out looking good. Once we run it through the fracture mechanics.

MR. JOHNSTON: That's right, and that is just this kind of data.

MR. SHEWMON: Okay, I guess.

MR. JOHNSTON: Part of what I am trying to show is that we have been talking a great bit about tremendous loss in properties, and I am really trying to point out that the welds are already down there and they always have been, and we have been perfectly capable of reviewing them by use of fracture mechanics, and I'm showing you that it's acceptable. You see, this is not different in kind. It's different in numbers.

[Slide.]

This is -- I believe this is the same curve that wa shown this morning by Ray as part of his presentation. These are the properties in limiting loads that we have used to evaluate cast stainless steel piping that has been presented to us. The J-1C -- now again, we have got a unit problem, but this corresponds roughly to 100.

This is the same as the J-1C intercept on the previous curve, which I told you was 100 kilonewtons per meter in the European units. That is the same as this 570. T is your slope at 40, and the Jmax is 3000. The Charpy there has been an empirical correlation for this common composition which has been made that will give us a correlation between a Charpy measurement and a J-1C, and the Charpy in that correlation, then, that corresponds to this is 17.5 foot pounds that we just spoke about.

[Slide.]

Now, I have one more point. A comment we would like to make on the research program is that while we supported strongly and did support in the past couple of years the focus, we would like to see the focus somewhat more on questions of the sort that we are raising here. In other words, yes, indeed, we are interested in finding out what kind of material characteristics are going to be the kind of things that are going to affect this if we get stainless steel coming into us that is less than the reference number that I said we were presently using.

Suppose we get something that is worse than what we have. We would like to know how to deal with it, and we would appreciate more data that would be fracture mechanic type data. In other words, J-R curves and the true stress and true strain curves. In other words, a little more macro-metallurgy as opposed to the micro-metallurgy that they have been reporting on mostly at the present time.

We need more effective methods for in-service inspection of this type of material, too. There is work going on at Westinghouse and several of the NRC contractors are working on this, but this is one area that does trouble us.

MR. SHEWMON: You mean the UT inspection of looking for cracks?

MR. JOHNSTON: In cast pipe, yes, because of the difficulties of getting the signal to penetrate and get back.

But these are areas where we would like to see more emphasis on them in the research program, or perhaps I should say an augmentation is necessary to the research program in this area.

MR. SHEWMON: Are there questions?

MR. JOHNSTON: That completes the non-proprietary portion of the talk. What I have in the proprietary portion is to show you some actual data, to show you how we do an evaluation of an actual cast elbow in a plant and how that relates to the criteria we use.

MR. HUTCHINSON: I have a quick question. Are you worried about whether there might be considerably lower J values or J resistance curve values under dynamic conditions? Suppose it turned out to be the case. Would that be unsettling from the point of view of the design problems? Would it even matter?

MR. JOHNSTON: I am aware of the discussion that the business has been in over the difference between measuring static and dynamic properties, and I'm not an expert in that area and I really don't have an opinion on it. When I tried to think of the failure modes of it we might be dealing with in the plant, in the first place, we are postulating a 7-1/2 inch crack here to start the whole business off.

First you have to have some event that is going to cause you to get a crack in the first place. We have already

put the battleship in the desert, if you will, and we have shown that with it in the desert as it is, it meets our criteria.

MR. HUTCHINSON: That is assuming, though, that it is not a dynamic event.

MR. JOHNSTON: Assuming there is no large difference between what would we get in dynamic and static testing. And the next step would be to postulate what kind of a dynamic event might we get that would cause something like this, first to initiate, and secondly, to get beyond the point at which we could do something about it.

Again, the conservatisms are in here because the 7-1/2 inch leak guarantees that there is at least a 10 gallon per minute leak, and that gives us time to do something about it. I don't know whether we are talking about a crane falling down on the primary system or --

MR. HUTCHINSON: Well, would a water hammer be a sufficiently dynamic event?

MR. JOHNSTON: Not usually in the primary loop. In other parts of the plant, yes, but this is primary loop piping only, and I don't think that is one of the very feasible likelihood events.

MR. SHEWMON: You say yes, it would bother him if it occurs here, but he doesn't think it occurs here.

MR. BUSH: One thing I don't think -- well, you kind

of worked around it, but you mentioned the grain size tended to be the same, but I also know that in material of the current age group, that you can get relatively fine grains and you can get fairly coarse grain, and then if you work back through, you can get a redistribution of critical components, et cetera, et cetera. And I am wondering -- I am not particularly aware of information along this line as to the implications of such.

MR. JOHNSTON: Well, when we started to make our preparation for this talk, I was very interested in having that kind of information. It seemed to me at first that much of the data we saw was all taken on slabs, and they were all cast and they were all rather thick, and I wanted to know, is that the same as the pipe that we are dealing with? Is the cooling rate the same given that the compositions are about the same? What about things like cooling rate and all of that?

In the course of that, essentially the information that came to us is that it doesn't make a heck of a lot of difference. It turns out that the pipe that is actually being used, as I mentioned before, is currently sand cast rather than metal cast. The cooling rates turn out to be -- there are some data by Legar in which he did some effect of thickness. In other words, he varied the cooling rate.

For the kinds of thicknesses that we are talking

about, when it gets to be over 2 inches or more thick, it seems to make very little difference. The cooling rate is one or two degrees a second, and it doesn't make much difference. If it's up around 10 degrees of 12 degrees or something like that, then there is apparently a more significant difference. But it doesn't seem to be in the material that we are dealing with.

So he did do a study of the effect of composition on the grain size according to the temperature, where you quench it from, where you are in the phase diagram, whether you are in a liquid plus delta or whether you are in delta gamma phase range. These things do influence it. This literature I saw is indeed limited, but it suggests that actually there is a reverse -- it tends to saturate, it begins to wash it out because you also are in the relatively low ferrite side. You are getting a gamma phase back again.

MR. BUSH: Well, the reason I raised the question is I got to the last point you had on the one slide there, and that is that Westinghouse conveniently, for their NDE, the UT examinations, they have samples they use and they can show how they can actually examine them. They happened to be fine grain size. Whether that fine grain size material is typical or atypical, I cannot say. I do know that the ones that P&L had to do the Rob Robin were not -- you couldn't get a beam through it under any circumstances.

So there are obvious differences in this respect, and I, quite frankly, don't know which is correct, whether it is possible to get the fine grain or not; but they got fine grain because they were using it very conveniently for their ultrasonic testss.

MR. JOHNSTON: I understood the method in making the cracks was different between the two organizations, but that makes, apparently, a significant difference. We do know that the piping that is in the field has a variety of growth. That's true, but again, the understanding that I got, which is incomplete, is that those kinds of differences don't make a great deal of difference on major mechanical properties.

MR. SHEWMON: Is that it?

Since we have covered the Paul Parris point this morning, then we will have a closed session and that will be the end of the meeting. Why don't we take five minutes and clear the place of anybody who is not NRC or hasn't signed a waiver on protection or such things.

[Whereupon, at 4:40 p.m. the subcommittee meeting continued in closed session.]

CERTIFICATE OF OFFICIAL REPORTER

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of: Advisory Committee on Reactor Safeguards

Name of Proceeding: Combined Meeting of ACRS Subcommittees on Metal Components and Structural Engineering

Docket No.:

Place: Washington, D. C.

Date: Thursday, May 23, 1985

were held as herein appears and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission.

(Signature) Suzanne B. Young

(Typed Name of Reporter) Suzanne B. Young

Ann Riley & Associates, Ltd.

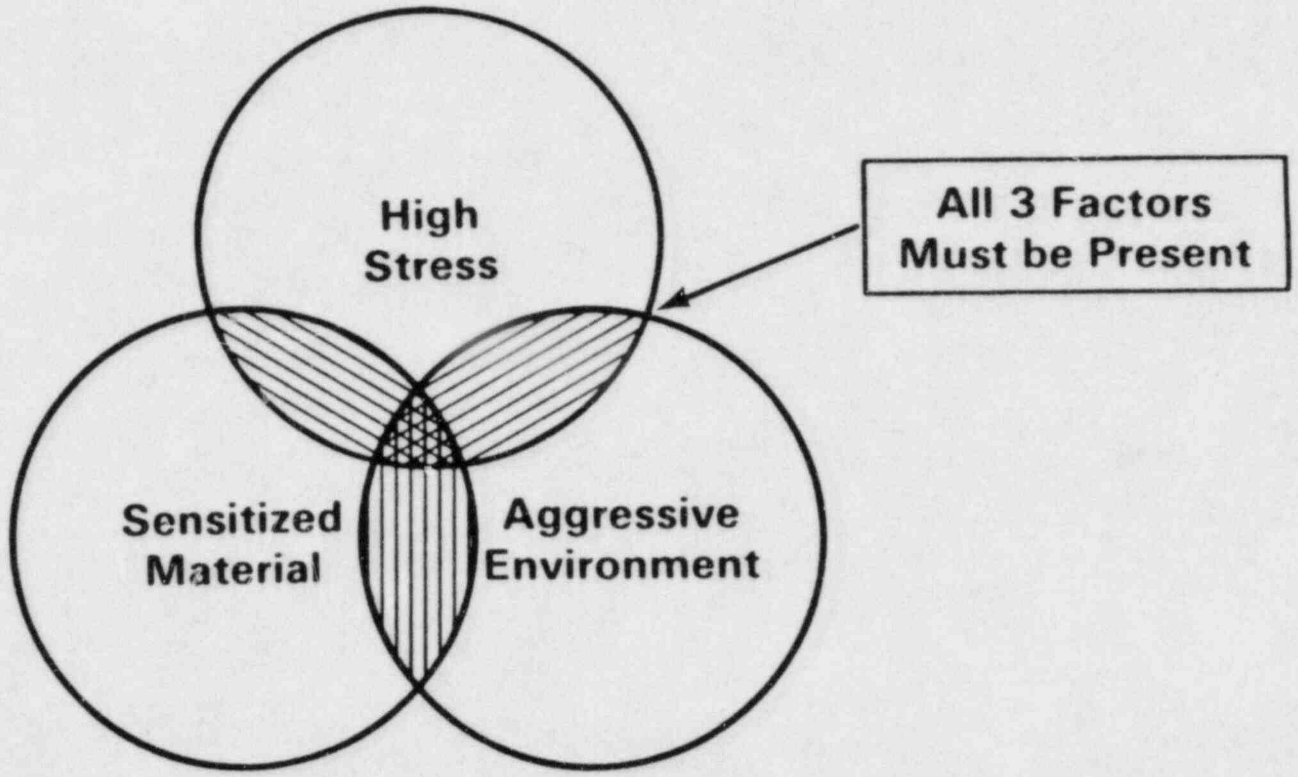
Summary of Inspection Findings on Large Piping in All Operating BWRs Inspected According to IEB 82-03 and 83-02

Plants	Extent of Inspection (% of Welds Inspected)		Inspection Results (No. of Cracked Welds)		No. Of Welds Overlay Repaired
	Recirculation	Reactor Heat Removal	Recirculation	Reactor Heat Removal	
Big Rock Point	20% (11/59)	N/A	0	-	0
Browns Ferry 1	98% (103/105)	90% (36/40)	33	14	42
Browns Ferry 2	27% (25/91)	28% (9/32)	2	0	0
Browns Ferry 3	98% (103/105)	28% (9/32)	0	0	0
Brunswick 1	25% (29/115)	75% (3/4)	3	0	3
Brunswick 2	100% (102/102)	100% (5/5)	15	1	8
Cooper	100% (108/108)	100% (7/7)	20	0	13
Dresden 2	47% (47/101)	10% (4/40)	10	0	7
Dresden 3	100% (115/115)	90% (45/50)	53*	11*	61
Duane Arnold	42% (49/117)	40% (2/5)	0	0	0
FitzPatrick	47% (49/106)	45% (5/11)	1	0	0
Hatch 1	47% (47/100)	100% (11/11)	5	2	6
Hatch 2	94% (97/103)	100% (11/11)	36	3	27
Millstone 1	11% (11/100)	0% (0/46)	0	0	0
Monticello	100% (106/106)	78% (18/23)	6	0	6
Nine Mile Pt. 1	82% (62/76)	N/A	53	0	0
Oyster Creek	39% (31/80)	N/A	0	0	0
Peach Bottom 2	100% (91/91)	91% (32/35)	19	7	21
Peach Bottom 3	91% (77/85)	92% (35/38)	10	5	15
Pilgram 1**					
Quad Cities 1	8% (9/110)	20% (9/44)	0	0	0
Quad Cities 2	100% (106/106)	90% (45/50)	20	2	9
Vermont Yankee	66% (58/88)	7% (2/30)	33	1	22

**After inspecting approximatly 7 welds, and finding cracks in 4 of them, the utility decided to replace the piping with Type 316 NG.

NA - Not Available

Conditions Leading to Stress Corrosion
(Intergranular Stress Corrosion Cracking (IGSCC) Is a Subset)



Stress Corrosion Possible

- Because mitigating actions addressing only one of the factors may not be fully effective under all anticipated operating conditions, mitigating actions should address two and preferably all three of the causative factors; e.g., material plus some control of water chemistry, or stress reversal plus controlled water chemistry

- BWR water chemistry controls should be modified to minimize IGSCC. These modifications should include both a substantial reduction in the levels of ionic species entering the primary coolant and a control of oxygen level. The current work on reduction of oxygen through hydrogen additions should be followed closely with the possibility that it may be employed to reduce further the electrochemical potential of the stainless steel to a level at which SCC, either IGSCC or TGSCC, will not occur. It appears that hydrogen water chemistry is an effective IGSCC countermeasure. However, ongoing work regarding potential adverse effects on other reactor components should be closely followed in order to confirm the acceptability of this countermeasure.

- IHSI is considered to be a more effective mitigating action for IGSCC than HSW and LPHSW in part because more data are available to demonstrate that the process does produce a more favorable residual stress state. All the residual stress improvement remedies are considered to be much more effective when applied to weldments with no reported cracking.

- The use of IHSI on weldments with detectable cracking must be considered on a case-by-case basis. However, for relatively short cracks (approximately 20% of the circumference in length), since even large errors in crack sizing or the prediction of flaw growth will lead only to small leakage, the decision on whether an additional repair is required can be determined by analysis. For longer cracks, repair will probably be required.

- Experience with materials to mitigate IGSCC, such as 347NG in Germany and 304NG and 316NG in Japan has been excellent. Other materials used in the U.S. include 304L and 316L. All of these alloys are more resistant to IGSCC than conventional Types 304 and 316 stainless steel. Based on U.S. data and prior use, Type 316NG stainless steel offers an additional margin of resistance to IGSCC and utilities that choose to replace pipe should be strongly encouraged to use it.

- **Although low-carbon stainless steels with nitrogen additions have been successfully fabricated and welded in Japan and Europe, U.S. experience with these materials is limited. It appears that greater care must be exercised in the control of composition and fabricaton variables to limit cracking during hot forming or welding.**

- Flaw evaluation criteria should limit the length of the cracks accepted for continued operation without repair. The limitation on acceptable crack length is primarily a result of the lack of confidence in flaw depth sizing capability, and is intended to ensure leak-before-break conditions. The maximum allowable throughwall crack length can be determined based on weld joint specific loads.

- On the basis of fracture mechanics evaluation for bounding and typical stress conditions and weld toughness properties, it is concluded the IWB-3640 provides an adequate basis for evaluating the majority of the weld connections in BWR recirculation piping. This is especially true because many of the cracks will be in higher toughness zones adjacent to the lower toughness welds.

- The maximum crack length allowable without repair for a specific weld joint should be the minimum of either 1) the throughwall crack length demonstrated by elastic-plastic fracture mechanics analyses to be stable under operating plus SSE loading conditions, 2) the throughwall crack length that would still permit the pipe to withstand normal operating plus SSE loading conditions as demonstrated by net section collapse (limit-load) analyses, or 3) the maximum crack length that would result in a leak rate greater than the plant's normal makeup capacity. Shorter cracks can be evaluated using the IWB-3640 criteria as modified by the NRC staff in SECY 83-267C. Calculations indicate that in the majority of cases the maximum crack length associated with the above criteria will be approximately 25% to 30% of the pipe circumference.

- For relatively short axial cracks, analysis can be used to justify long-term operation with weld overlays, since errors on crack depth measurement or flaw growth predictions for these cracks will lead at worst to relatively small leaks, which will be easily detectable long before the crack can grow long enough to cause failure. For circumferential cracks weld overlay is considered an acceptable repair procedure for a maximum of two refueling outages unless reliable techniques for the sizing of cracks through the overlay or for the monitoring of crack growth are developed.

- The Task Group also recommends that additional fracture mechanics analyses, material properties characterization, and large scale pipe tests be performed to understand further the implications of stainless steel weld and cast material fracture toughness properties in flawed pipe evaluations. Furthermore, in this regard, the Task Group recommends active NRC support of the ASME Task Group currently evaluating the concerns which have been raised regarding IWB-3640.

- Code minimum UT procedures result in totally inadequate IGSCC detection. Easily implementable modifications to these procedures have resulted in some improvement. These have been incorporated into Code Case N-335. Therefore, it is recommended that Code Case N-335 should be immediately mandatory for all augmented inspections until better procedures are developed.

- Although IGSCC detection has improved to the point that it is considered acceptable under optimum conditions and procedures, the detection reliability as impacted by variability in operator procedure and equipment performance along with field conditions needs further study and improvement. While length sizing of cracks is acceptable, depth sizing is currently inadequate. It is recommended that advanced techniques and procedures for crack detection and depth sizing continue to be developed and incorporated into Code requirements to provide data to reduce the need for extremely conservative fracture mechanics evaluation.

- The current activities in personnel and procedure qualification and performance demonstration represent steps in the right direction, and the resultant process that is being implemented is acceptable in the interim; however, they need further improvement. Therefore, it is recommended that ongoing industry and NRC activities to develop adequate criteria for qualification of the entire inspection process to achieve more reliable field inspection be completed and implemented on a high priority basis.

- **Inspection techniques should be developed for detection and dimensioning of flaws in pipes repaired by the weld overlay process.**

Recent laboratory research and field experience indicates that the need for improvement is still critical for both detection and characterization (dimensioning) for cracks. Specifically, the following inspection problems need to be addressed immediately:

- Develop and validate effective and reliable manual UT inspection methods to correctly interpret UT indications.
- Develop reliable automated UT equipment to detect, diagnose, and characterize cracks
- Develop ultrasonic techniques for dimensioning flaws in the through-wall plane
- Develop inspection techniques for detection and dimensioning of flaws in pipe repaired by the weld overlay process
- Determine the effect on detection and characterization of cracks in pipe that has had the induction heat stress improvement (IHSI), or last pass heat sink (LPHS) treatments
- Develop a practical means for implementing a "transfer method" to compensate for response differences between the calibration block and the piping material. This concept was recently eliminated from the Code requirements since no practical means existed for its implementation. However, the concept has merit, and a serious development effort is warranted.
- Develop inspection techniques for examination of austenitic butt welds through the weld metal (i.e., far side access which is typical for a pipe-to-component weld)
- Develop reliable inspection techniques for ID cladding and the welds in CCSS piping and for dissimilar welds
- Establish the reliability of advanced techniques

In order to upgrade the qualifications of UT operators for inservice inspection, it is recommended that:

- Every UT operator should be required to successfully complete a statistically based qualification demonstration for both detection and dimensioning of flaws. This recommendation is essential for optimizing the UT information to be used for fracture mechanics analysis.

- Every UT operator should be required to complete additional classroom training once a year to update the skills necessary for inservice inspection

- All UT procedures should specify the equipment to be used, and each procedure/equipment combination should be qualified by demonstration using representative flaws.

- The deficiencies in the ASME Code should be submitted to the appropriate Code Committees with recommendations for action.

Comments for Improving on Current ASME Code Requirements

- Calibration blocks - For austenitic stainless steels, the calibration blocks should contain welds and the calibration reflectors should be located either in the weld or on both sides of the weld. In addition, the calibration block and pipe should have the same nominal microstructure.
- Calibration Reflectors - When notches are used as calibration reflectors, compensation should be required for the sensitivity differences between notches and side-drilled holes.
- Search Units - In addition to the currently required 45° S-wave examination for welds, an additional 60° S-wave examination should be required. The potential advantages of the refracted L-wave technique for far side inspection should be recognized, and this technique should be required as a supplementary examination for austenitic stainless steel.
- Beam Spread - If beam spread corrections are made as permitted by the ASME Code, flat calibration blocks should be used for the corrections to crack and lack-of-fusion type indications.
- Angled Defects - A skewed scan should be required to detect defects oriented other than parallel or perpendicular to the weld.
- Crack Length Sizing - The 50% DAC method of crack length sizing should be revised to require that end points of a flaw be determined by loss of signal amplitude.

The results and conclusions drawn from the BMI-PNL pipe inspection round robin test were as follows:

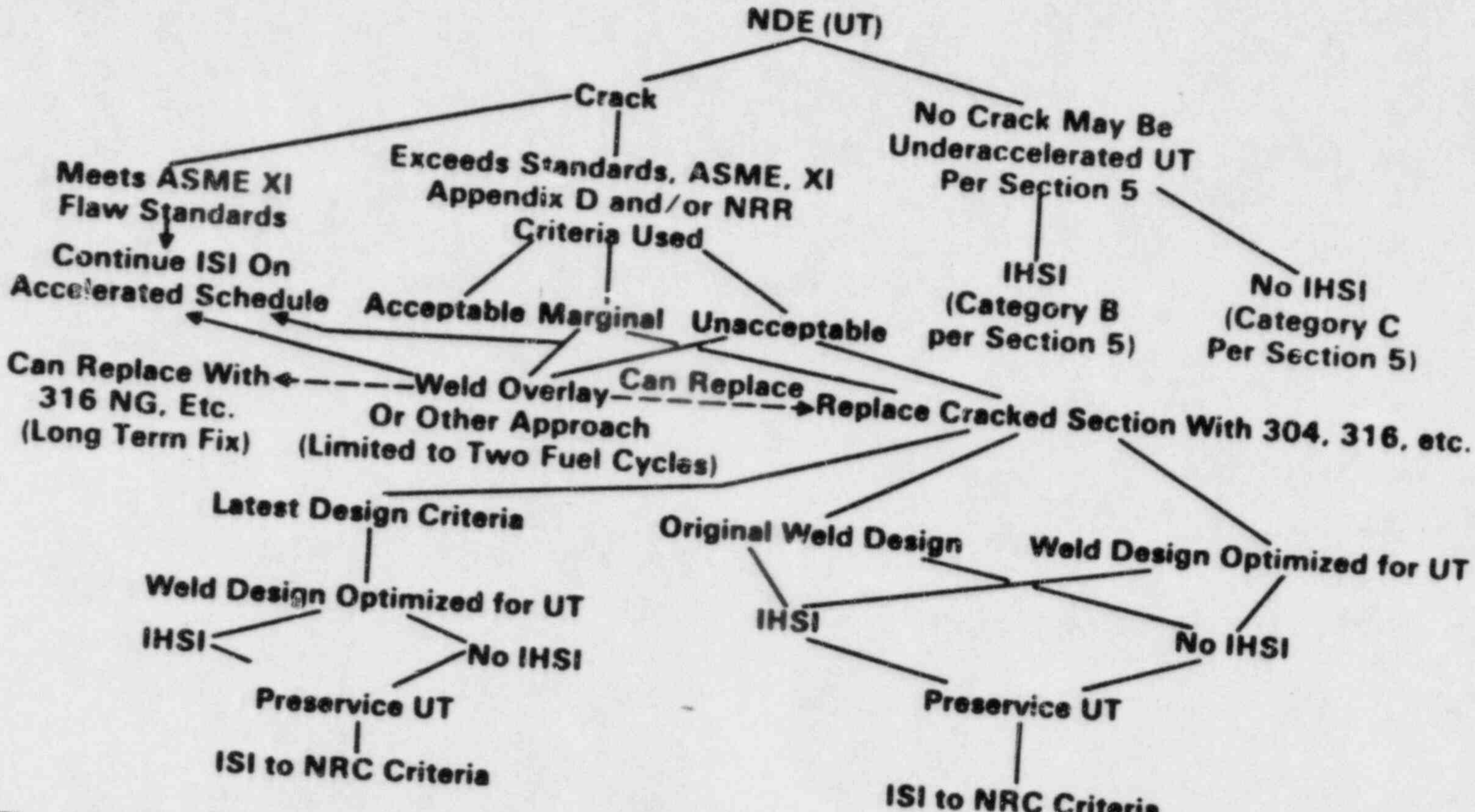
- UT detection of cracks in clad ferritic main coolant pipe can be 100% effective, if adequate sensitivity is used per ASME Code Case N-335. Section XI minimum sensitivity (50% of the notch amplitude) is not adequate
- Detection of cracks in clad ferritic pipe is almost equally effective with and without weld metal in the sound path
- UT detection of cracking centrifugally cast stainless steel (for PWRs) is ineffective using the conventional manual techniques currently applied in the field. The false call rate was almost identical to the probability of detection and correct interpretation (PODCI) rate
- Section XI minimum requirements do not provide effective inspection of wrought stainless steel pipe welds. Increased sensitivity and selection of optimized search units improves detection reliability. For both IGSC and thermal fatigue cracks in stainless steel, the six teams achieved an average PODCI of 50-60% when using their own procedures for cracks 15% throughwall or greater
- When the sound beam must pass through the butt weld in wrought stainless pipe, UT inspection using current field techniques is ineffective
- Variability in crack detection reliability is significant from operator to operator, even when identical equipment and procedures, are used
- Crack detection reliability in UT inspection of stainless steel pipe welds should be qualified by test
- Crack length measurements were in general quite good. There was a trend to oversize very small cracks and to undersize very long cracks by small amounts. a conservative approach would be to record length based on signal reduction to the background noise level
- Crack depth measurements by all the teams using the Code-advocated method of amplitude drop was totally ineffective

- Since operating experience and fracture mechanics evaluations indicate that leak-before-break is the most likely mode of piping failure, the Task Group recommends that actions be taken to ensure that as-good-as-reasonably-achievable leak detection procedures be in effect in operating plants. In addition, improved leak detection capabilities should be pursued. Current sump pump monitoring systems are sensitive enough to provide additional margin against leak-before-break if more stringent requirements on surveillance intervals and unidentified leakage are imposed (see Section 4.0). Therefore, the Task Group recommends that the limits on unidentified leakage in BWRs be decreased to 3 gpm and that the surveillance interval be decreased to 4 hours or less.

- For future plants or for replacement of existing piping systems, the material, design of pipe joints, and accessibility from both sides of the weld should be optimized for UT examinations; this requirement should be mandatory for all components with the exception of existing items such as pumps, valves and vessels in older plants. The uninspectable joints should be subjected to IHSI.

Short-term Solutions For Replacement, Repair or Continued Operation Without Repair

Event Tree*



*The following assumptions apply to the event tree:

- Repairs and replacements per original version of ASME construction Code or alternately updated to latest edition, or ASME XI in part
- Section 5 refers to this report (NUREG-1061)

Recommended Measures for Controlling IGSCC in BWR Piping

	Near Term			Long Term		Ultrasonic Exam.			
BWR Plant Status	Overlay Weld*	Replace with Similar Alloy	Residual Stress Improvement IHSI, HSW	Hydrogen Water chemistry	316 NG Piping.	New Base-line	Accel. UT	Norm. UT	Enhanced Leak Detection (moisture tapes, AE, etc.)
Design Stage			X	X	X			X	
NTOL or Recent Startup			X	X		X		X	
Operating >5(?) years									
No Cracks Detected			X	X		X	X------	-X#	X (maybe)
Only Limited Shallow Cracks			X	X		X	X+------	-X	X
Deeper Cracks -- Few or Many	X	X maybe	X**	X	X	X	X then	X (for 316NG)	X Prior to Replacement

*Limited to two cycles unless convincing evidence is presented

**Also suggested after replacement with 316 NG

Prior to mitigation, accelerated UT; thereafter normal UT

X Accelerated UT limited to cracked welds

+ With mitigation, accelerated UT limited to cracked welds

All welds in BWR systems should be categorized according to how likely they will be to crack. Three categories are recommended:

Category A - Welds very unlikely to have IGSCC, because the piping is made of resistant materials, or

Welds made with, or subjected to, two complementary mitigating processes

Category B - Welds with some degree of improved resistance to IGSCC, because, although the piping is not made of resistant material, welds are made with or subjected to a mitigating process.

Category C - Welds likely to be subject to IGSCC because they are neither made of resistant material nor subjected to a mitigating process.

- The Task Group recommends that the inspection schedule for welds be based on the resistance to IGSCC of the materials and the effectiveness of the mitigating processes applied to the welds. The materials which are considered resistant and the categories of countermeasures processes are:

Resistant Materials

(1) 304L, 316L, 316K, 304NG, 316NG, 347NG, 308L

(2) Low-strength carbon steels

(3) Approved nickel-based materials

(4) Cast low-carbon/high-ferrite austenitic stainless steels

(5) Welds solution heat-treated after fabication and welding

(6) Other, as approved by NRC

Treatment and Inspection Required for Piping Categories

Weld Category	Treatment	Inspection Required
A	Resistant material or countermeasure A	25% of the welds of each pipe size in 10 years. At least one-third of these should be inspected every 3 1/3 years
B	Nonresistant material or countermeasure B	50% of the welds of each pipe size in 10 years. At least one-third of these should be inspected every 3 1/3 years
C	Neither of the above	100% in 6 years. At least one-half of these should be inspected in 3 1/3 years. For plants older than 6 years, all uninspected Category C welds shall be inspected at the next outage.

INTRODUCTION AND BACKGROUND

NRC PIPING REVIEW COMMITTEE

MAY 23, 1985

Shao

NRC PIPING REVIEW COMMITTEE

EDO REQUEST OF PROPOSAL MAY, 1983

- o MAKE COMPREHENSIVE REVIEW OF CURRENT PIPING REGULATORY REQUIREMENTS
- o MAKE RECOMMENDATIONS, WHERE APPROPRIATE, FOR MODIFYING CURRENT REQUIREMENTS
- o SUGGEST WORK OR RESEARCH REQUIRED FOR ISSUES NOT YET RESOLVED

COMPREHENSIVE PROPOSAL PREPARED, JULY 1983

NRC PIPING REVIEW COMMITTEE INITIATED AUGUST 1983

BASIS FOR REASSESSMENT

- EARLY POSITIONS DEVELOPED WITHOUT SIGNIFICANT DATA
- GREATLY EXPANDED DATA BASE
- SERVICE EXPERIENCE
- NEW DEVELOPMENTS IN ANALYTICAL TECHNIQUES
  - FRACTURE MECHANICS
  - PRA
- RESULTS IN SOME CASES THOUGHT TO DIMINISH OVERALL SAFETY
- SOME POSITIONS NEED INCREASING REQUIREMENTS WHILE SOME NEED DECREASING REQUIREMENTS

REGULATORY ISSUES

FOUR GROUPS IDENTIFIED

1. PIPE CRACKING: INTERGRANULAR STRESS CORROSION IN LARGER-DIAMETER BWR PIPING. THE ISSUES RELATE TO INSERVICE INSPECTIONS, EVALUATION OF REPAIR AND REPLACEMENT TECHNIQUES AND BASES FOR ALLOWING CONTINUED OPERATION.

2. SEISMIC DESIGN: OPERATING BASIS EARTHQUAKE (OBE) USUALLY CONTROLS DESIGN. REQUIREMENT FOR DAMPING VALUES, PEAK BROADENING REQUIREMENT FOR FLOOR RESPONSE SPECTRA AND ENVELOPING SPECTRAL INPUT. EXCESSIVE NUMBER OF SNUBBERS. STIFF PIPING SYSTEM.

3. PIPE BREAK: PROTECTION AGAINST DYNAMIC EFFECTS DUE TO DOUBLE-ENDED GUILLOTINE BREAKS (DEGB).

REGULATORY ISSUES - CONTINUED

4. <u>LOAD COMBINATIONS:</u> CERTAIN LOAD COMBINATIONS UNREALISTIC.

   <u>OTHER DYNAMIC LOADS:</u> TREATMENT OF OTHER DYNAMIC LOADS SUCH AS WATER HAMMER AND VIBRATIONAL LOADS.

APPROACH

SET UP AN NRC PIPING REVIEW COMMITTEE WITH PARTICIPATION FROM NRR, RES, IE, REGIONAL OFFICES, AND CONSULTANTS.

SCOPE AND OBJECTIVES

- o REVIEW REGULATORY REQUIREMENTS FOR PWR AND BWR SAFETY-RELATED PIPING
- o REVIEW DOMESTIC AND FOREIGN INFORMATION
- o REVIEW OPERATING EXPERIENCE
- o MAKE RECOMMENDATION ON WHERE AND HOW THE REQUIREMENTS CAN BE MODIFIED
- o IDENTIFY AREAS WHERE FURTHER WORK IS NECESSARY

NRC PIPING REVIEW COMMITTEE

NRC Piping Review Committee Members

Richard H. Vollmer, Cochairman
Lawrence C. Shao, Cochairman
Spencer H. Bush, Vice Chairman
Alfred Taboada, Secretary
Robert J. Bosnak
John R. Fair
Shou-Nien Hou
Raymond W. Klecker
Gus C. Lainas
Boen-Dar Liaw
Phillip R. Matthews
John A. O'Brien

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Goutam Bagchi
Daniel J. Guzy
Kamal A. Manoly
John A. O'Brien

Pipe Break Task Group Members

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Shou-Nien Hou
Jack R. Strosnider
Keith R. Wichman

Other Dynamic Loads and Load Combinations Task Group Members

John A. O'Brien, Chairman
Goutam Bagchi
John R. Fair
Mark Hartzman
Aleck Serkiz

LIST OF CONSULTANTS FOR NCR PIPING REVIEW COMMITTEE

NAME	AFFILIATION
CONSULTANTS TO PIPE CRACK TASK GROUP	
S. H. BUSH (CHAIRMAN)	REVIEW & SYNTHESIS ASSOC.
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W. SHACK	ARGONNE NATIONAL LAB.
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E. C. RODABAUGH	E. R. AND ASSOCIATES
J. D. STEVENSON	STEVENSON AND ASSOCIATES

INDUSTRY COORDINATION

- o BWR PIPE CRACKS - BWR OWNER GROUP
  - EPRI
  - GENERAL ELECTRIC
  - ASME CODE SUBCOMMITTEE ON SECTION XI

- o SEISMIC DESIGN/LOAD COMBINATION/PIPE BREAK

  PVRC (PRESSURE VESSEL RESEARCH COMMITTEE)

  ASME CODE SUBCOMMITTEE ON SECTION III

  ASME CODE SUBCOMMITTEE ON SECTION XI

  AIF RELATED SUBCOMMITTEES

INTERNATIONAL REVIEW TEAM ON BWR PIPE CRACKS REPORT

ANDO OF JAPAN
de KAZINCZY OF SWEDEN
KUSSMAUL OF GERMANY
TOMKINS OF UNITED KINGDOM

CONCLUDING REMARKS

(1) IGSCC IN BWR PIPING SYSTEMS DESERVES STRINGENT ATTENTION TO BOTH THE INITIATION AND GROWTH OF CRACKS.

(2) ALTHOUGH IT IS ANTICIPATED THAT LEAK-BEFORE-BREAK IS INHERENT TO TOUGH, AUSTENITIC MATERIAL, IT IS NECESSARY TO BASE THE SAFETY ASSESSMENT FOR REPLACEMENT OF CRACKED SECTIONS AND THE CRITERION ON A LIMITATION OF CRACK LENGTH.

(3) CURRENT ULTRASONIC METHODS, PROPERLY APPLIED, ARE CAPABLE OF ASSURING THE CRITERION OF A LIMITING CRACK LENGTH.

(4) FOR WELDS WHICH ARE NOT ACCESSIBLE TO ULTRASONIC TESTING, FROM BOTH SIDES, IT IS NECESSARY TO CONSIDER REPLACEMENT OR AT LEAST TO APPLY ADEQUATE COUNTERMEASURES AGAINST DOUBLE-ENDED FAILURE.

(5) IMPROVED NUCLEAR GRADE MATERIALS SHOULD BE USED FOR ALL REPLACEMENTS AND ANY NEW CONSTRUCTION.

FOREIGN INFORMATION

- o BWR PIPE CRACK
  - REVIEW OF FOREIGN EXPERIENCE, RESEARCH AND POSITIONS
  - CSNI MEETING ON REGULATORY BASIS
    FOR ACTIONS ON BWR PIPE CRACKS
    (FEB. 1984)
  - FOREIGN EXPERTS' REVIEW OF DRAFT REPORT

- o SEISMIC DESIGN/LOAD COMBINATIONS/PIPE BREAKS
  - REVIEW OF FOREIGN EXPERIENCES, RESEARCH AND POSITIONS
  - QUESTIONNAIRE SENT TO FOREIGN COUNTRIES
  - INFORMATION FROM INTERNATIONAL CONFERENCES AND MEETINGS

REPORTS ISSUED

VOLUME 1 - INVESTIGATION AND EVALUATION OF STRESS CORROSION CRACKING IN PIPING OF BOILING WATER REACTOR PLANTS

VOLUME 2 - EVALUATION OF SEISMIC DESIGNS - A REVIEW OF SEISMIC DESIGN REQUIREMENTS FOR NUCLEAR POWER PLANT PIPING

VOLUME 3 - EVALUATION OF POTENTIAL FOR PIPE BREAKS

VOLUME 4 - EVALUATION OF OTHER DYNAMIC LOADS AND LOAD COMBINATIONS

VOLUME 5 - SUMMARY - PIPING REVIEW COMMITTEE CONCLUSIONS AND RECOMMENDATIONS

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

MAY 15 1985

MEMORANDUM FOR: W. J. Dircks
Executive Director for Operatons

FROM: R. H. Vollmer/L. C. Shao, Cochairmen
NRC Piping Review Committee

SUBJECT: NUREG 1061, "REPORT OF THE U. S. NUCLEAR REGULATORY COMMISSION PIPING REVIEW COMMITTEE"

Your memorandum of August 1, 1983 to H. R. Denton and R. B. Minogue initiated the formation of the NRC Piping Review Committee to conduct a comprehensive review of nuclear power plant piping and to make recommendations, where appropriate, for revising NRC requirements on this subject. Our memorandum of October 25, 1984 to you gave an interim status report and estimated that the Committee's final recommendations with supporting reports would be available in May 1985.

The Committee has completed its review and documented its findings in NUREG 1061, "Report of the U. S. Nuclear Regulatory Commission Piping Review Committee." This report, made up of five volumes, is enclosed. Volumes 1 through 4 contain individual task group reports on the four major topics reviewed: (1) Stress-Corrosion Cracking in Piping of Boiling Water Reactor Plants, (2) Evaluation of Seismic Designs, (3) Evaluation of the Potential for Pipe Breaks, and (4) Evaluation of Other Dynamic Loads and Load Combinations. Volume 5 is the Committee report which integrates the task group reports, summarizes the major issues and contains the Committee's conclusions and recommendations for changes in NRC requirements. Volume 5 also suggests research or other action that may be required to respond to issues not amenable to resolution at this time.

Each volume lists the members, consultants, and other participants that contributed to the document. Substantial use was made of the expert consultants who helped prepare position papers and assess data. The major position papers are included in the appendices to Volumes 1 through 4.

Significant information was also received from industrial groups such as the BWR Owners Group and AIF, and from foreign sources. In addition, an international review team was assembled to comment on the task group report on stress corrosion cracking. Their comments are included in Volume 1.

The suggested changes in NRC requirements are quite substantial. The collective judgement of the Committee is that implementation of the changes will have positive effects on both the licensing process and the safety and reliability of nuclear reactor power plants. Most of the

principal suggested changes should lead to a simplification of licensing, and, if implemented, plant piping would become more accessible and inspectable, thereby reducing occupational radiation exposures, costs, and the likelihood of undetected defects.

A summary of the six high priority recommended changes and the five high priority recommended research items is included in Enclosure 1. Lower priority recommendations may be found in Volume 5, the Committee summary report. The Committee believes that these high priority recommendations are highly significant in the context of regulatory requirements and research needs.

The first high priority item would relax the loss-of-coolant-accident (LOCA) criteria and apply leak-before-break (LBB) criteria instead when justified. The implementation of such an action would permit removal of pipe restraints and jet impingement barriers.

Changes in seismic damping values, the second high priority item, have been accepted by the NRC on a case-by-case basis. Broader implementation of these changes could substantially reduce the excessive number of piping supports, praticularly snubbers. Some NRC Regions have already questioned the need for snubbers where a rigid support would suffice.

The third high priority item, a change in operating basis earthquake (OBE) accelerations, would have a major impact on seismic design requirements of nuclear power plants and extend well beyond piping considerations. In this instance, a decision is necessary concerning what is an appropriate relationship of OBE to SSE (safe shutdown earthquake). The ultimate aim is that the OBE not control plant design, which can be achieved by decoupling the OBE from SSE.

In the case of BWR intergranular stress corrosion cracking (IGSCC), the fourth high priority item, the Committee suggests that the preferred action is to replace existing recirculation piping with materials known to be resistant to IGSCC. The procedures exist and have been used to implement such actions. It should be noted, however, as discussed in Volumes 1 and 5, that alternative fixes may be more appropriate and cost effective in specific cases.

The fifth high priority item permits decoupling the LOCA from seismic events when justified.

The sixth high priority item relates to improvement and modification of leak-detection systems.

It is the intent of this report that, wherever appropriate, these recommendations be applied to operating reactors, plants under construction, and future plant designs.

In addition to the technical recommendations in this report, the Committee also recommends that active participation by the NRC staff in the important standards writing national bodies such as ASME and PVRC be continued and fully supported by the NRC management.

We believe that the publication of these reports completes the Committee assignment and unless otherwise requested do not intend to take any additional formal Committee actions. It should be noted, however, that implementation of the recommendations will require changes in regulations, regulatory guides, and standard review plans, as well as important changes in the ASME Code. Implementing actions should begin as soon as possible because, in the absence of definitive value-impact studies, it is the judgment of the Committee that there will be major payoffs from the actions suggested for the high-priority category and substantial, albeit lesser, payoffs for the low priority categories.

R. H. Vollmer, Cochairman
NRC Piping Review Committee

L. C. Shao, Cochairman
NRC Piping Review Committee

Enclosure (1) as stated

Other Encls: (1) Volume 1 Investigation and Evaluation of Stress Corrosion Cracking in Piping of Boiling Water Reactor Plants
(2) Volume II Evaluation of Seismic Designs
(3) Volume III Evaluation of Potential for Pipe Breaks
(4) Volume IV Evaluation of Other Dynamic Loads and Load Combinations
(5) Summary - Piping Review Committee Conclusions and Recommendations

cc: V. Stello
H. Denton
R. Minogue
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Enclosure 1

The following is a summary of Category A recommendations for regulatory change in order of priority. Categories B and C are described in Section 10.

Category & Rank Order	Recommendation	Documents Requiring Change
A-1	Use LBB criteria rather than double-ended guillotine break criteria in design of piping so that terminal and intermediate breaks can be eliminated when certain acceptance criteria are met. This would lead to exclusion of dynamic effects such as pipe whip, jet impingement, and subcompartment pressurization. The major impact would be on General Design Criterion 4, Environmental and Missile Design Bases. The requirement to postulate arbitrary intermediate breaks should be eliminated.	10 CFR Part 50 (Appendix A, GDC-4, -30, -31, -32) SRP 3.6.2 R.G. 1.46
A-2	Modify seismic damping values currently used in seismic design. The suggested values have been incorporated into ASME-III and accepted by NRR on a case-by-case basis. This modification could lead to changes in support design and spacing and consideration of nozzle loads as well as reducing the number of snubbers.	R.G. 1.61 SRP 3.9.2
A-3	Decouple OBE from SSE.	10 CFR Part 100 (Appendix A)
A-4	Replace 316SS or 304SS in BWR recirculation piping with alloys resistant to IGSCC to eliminate this mode of pipe cracking. Possible types are 316NG, 304NG, 347NG.	10 CFR Part 50 (Appendix A, GDC-30 (possibly)) NUREG-0313 R.G. 1.44
A-5	Decouple seismic and LOCA events in systems where LBB is applicable.	SRP 3.9.3
A-6	Modify leak-detection requirements. This issue impacts BWR-IGSCC as well as Recommendation A-1.	NUREG-0313 Tech. Specs. R.G. 1.45

The following is a listing of Category A items for research in order of priority. Categories B and C are described in Section 9.

Category & Rank Order	Recommendation
A-1	The full-scale pipe fracture experiments of the NRC Degraded Piping Program should be completed. Of primary interest is the development and/or validation of fracture mechanics analysis techniques for ductile piping. Experimental variables should include flaw geometries, material toughness, axial-to-bending load ratios, and static/dynamic loads.
A-2	Advanced techniques and procedures for crack detection and depth sizing should continue to be developed and incorporated into Code requirements. Included should be analysis of the human factor, equipment qualification and certification, and inspection techniques for detection and dimensioning of flaws in pipes repaired by the weld overlay process.
A-3	Test programs (e.g., EPRI's piping capacity tests) for verifying seismic design margins and identifying failure modes for typical piping systems should be supported. Test results should be evaluated and recommendations provided for criteria changes (e.g., reclassification of seismic inertial stresses as "secondary"), as appropriate. Both cracked and uncracked piping systems should be tested.
A-4	Work under way at the Lawrence Livermore National Laboratory on Babcock and Wilcox and General Electric reactor coolant loop piping designs should be completed to learn whether earthquake in combination with reactor coolant loop double-ended guillotine break may be excluded for these designs.
A-5	Work should be performed to determine the reliability of methods to predict leak rate and validate the reliability of leak-detection systems.

B.D Liaw

PROFESSOR PARIS' CONCERNS

- ORIGINAL ASME SECTION XI IWB-3640 IS "DANGEROUS" BECAUSE IT DID NOT ACCOUNT FOR LOW TOUGHNESS WELDS. FAILURES COULD OCCUR BELOW LIMIT LOADS

- THERMAL STRESSES SHOULD BE INCLUDED IN ESTABLISHING THE ACCEPTANCE CRITERIA; WE AGREE AND THE NEW PROPOSED IWB-3640 WILL ADDRESS THIS.

- NEED TO DEMONSTRATE MATERIAL DUCTILITY

    . CONCEPTUALLY THE STAFF DID NOT DISAGREE

    . WE DISAGREE WITH PROF. PARIS IN THE EXTENT WE SHOULD REQUIRE THE UTILITIES TO POSTULATE SUPPORT FAILURES OR OTHER PHYSICAL LIMITS.

NRC PIPING REVIEW COMMITTEE

TASK GROUP ON SEISMIC DESIGN

PRESENTATION TO ACRS ON MAY 23, 1985

BY
SHOU-NIEN HOU

CHAIRMAN OF THE TASK GROUP

SEISMIC DESIGN TASK GROUP MEMBERS

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DANIEL GUZY	RES
KAMAL MANOLY	RI
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END PRODUCTS

NUREG-1061, VOLUME 2, "EVALUATION OF SEISMIC DESIGN - A REVIEW OF SEISMIC DESIGN REQUIREMENTS FOR NUCLEAR POWER PLANT PIPING"

NUREG-1061, VOLUME 2 ADDENDUM, " SUMMARY AND EVALUATION OF HISTORICAL STRONG-MOTION EARTHQUAKE SEISMIC RESPONSE AND DAMAGE TO ABOVE-GROUND INDUSTRIAL PIPING"

PROBLEMS IN CURRENT SEISMIC REQUIREMENTS

PROBLEMS

- NUMEROUS SEISMIC SUPPORTS & SNUBBERS USED
- STIFF PIPING SYSTEMS
  - HIGHER THERMAL STRESSES & NOZZLE LOADS
  - MORE ADVERSELY EFFECTED BY ERRORS OF CONSTRUCTION, OPERATION, MAINTENANCE & INSPECTION
- MORE SNUBBER PROBLEMS
  - LOST SNUBBER FUNCTION DUE TO DEGRADATION OR AGING
  - INCREASED PIPE STRESSES DUE TO SNUBBER LOCK-UP.

PROBLEM CAUSES

- YEARS OFTEN DISCRETE REGULATORY ACTIONS WITHOUT OVERALL ASSESSMENT OF COLLECTIVE EFFECTS ON PIPING
- CRITERIA WITH PREMISE THAT ADDED CONSERVATISM RESULTS IN INCREASED OVERALL SAFETY
- SOME CRITERIA WERE ESTABLISHED WITHOUT ADEAUATE DATA BASE

THE RESULTS

- PIPING SEISMIC DESIGN IS MORE COMPLICATED & COSTLY AND YET RESULTS IN LESS RELIABLE PIPING IN NORMAL OPERATION.

TASK GROUP OBJECTIVE

TO ACHIEVE IMMEDIATE IMPROVEMENT IN PIPING RELIABILITY DURING NORMAL OPERATION BY DOING THE FOLLOWING:

- REVIEW & EVALUATE CURRENT SEISMIC DESIGN REQUIREMENTS FOR LWR PLANT PIPING BASED ON AVAILABLE INFORMATION
- RECOMMEND CHANGES IN CURRENT NRC REQUIREMENTS
- IDENTIFY AREAS REQUIRING FURTHER RESEARCH OR NRC/ INDUSTRY ACTIONS

TECHNICAL ISSUES ON SEISMIC DESIGN

THE TASK GROUP HAS INVESTIGATED THE FOLLOWING SPECIFIC ISSUES:

- OBE & SSE
- DAMPING VALUES
- SPECTRAL MODIFICATIONS
- SUPPORTS & SNUBBERS
- COMPONENT NOZZLE FLEXIBILITY & NOZZLE LOADS
- SEISMIC SPECTRAL INPUT
- INELASTIC ANALYSIS
- OVERALL DESIGN MARGINS

OBE & SSE

BACKGROUND

- 10 CFR 100, APPENDIX A REQUIREMENTS TO PIPING:
  - (1) DESIGN TO BOTH OBE & SSE
  - (2) BY DEFINITION
    - OBE - THE EARTHQUAKE HAVING REASONABLE PROBABILITY TO OCCUR IN PLANT LIFE
    - SSE - THE LARGEST POTENTIAL EARTHQUAKE AT PLANT SITE
  - (3) OBE SHOULD BE AT LEAST ONE-HALF THE SSE
  - (4) DESIGN REQUIREMENT
    - UNDER OBE - STRUCTURALLY & FUNCTIONALLY INTACT
    - UNDER SSE - ONLY SAFETY FUNCTION TO BE MAINTAINED

- R G 1.61 REQUIRES DIFFERENT DAMPING FOR PIPING UNDER OBE & SSE

- ASME CODE DOES NOT REQUIRE CONSIDERATION OF RELATIVE ANCHOR MOVEMENT UNDER SSE.

THE ISSUE

- INCONSISTENCY IN DEFINING OBE

  THE EARTHQUAKE LEVEL REASONABLY EXPECTED TO OCCUR IN PLANT LIFE IS INCOMPATIBLE TO AND GENERALLY LOWER THAN ONE-HALF THE SSE.

- OBE CONTROLS PIPING SEISMIC DESIGN

  A CONTRIBUTOR TO OVERLY SUPPORTED & STIFF PIPING SYSTEM WITHOUT ENHANCING SAFETY. (DESIGN TO SSE IS SUFFICIENT TO ENSURE SAFETY)

- AT BOTH OBE AND SSE SHOULD BE EVALUATED

  SEISMIC ANALYTICAL EFFORT IS DOUBLED WITHOUT OBVIOUS REWARD.

- DEFICIENCY IN ASME PIPING CODE

  RELATIVE ANCHOR MOTIONS WAS FOUND TO BE AN ESSENTIAL MECHANISM TO CAUSE PIPING SEISMIC FAILURE AND IS NOT CONSIDERED UNDER SSE.

RECOMMENDATIONS

- **PERMIT DECOUPLING OF OBE & SSE**

  RULEMAKING BE UNDERTAKEN TO CHANGE THE OBE DEFINITION IN 10 CFR 100, APPENDIX A.

- **INVESTIGATE FEASIBILITY OF SINGLE SEISMIC ANALYSIS**

  INITIATE NRC INTERNAL REVIEW ON USING UNIFORM STRUCTURE AND PIPING DAMPING VALUES FOR EVALUATING BOTH THE OBE AND SSE AND THUS PERMIT SCALING OF A SINGLE ANALYSIS

- **CONSIDER ANCHOR MOVEMENT AT SSE**

  REQUEST ASME TO CONSIDER SUCH EFFECTS.

DAMPING VALUES

BACKGROUND

- DAMPING IS A HYPOTHETICAL FACTOR USED TO REPRESENT ENGERGY DISSIPATION IN DYNAMIC RESPONSE OF A SYSTEM

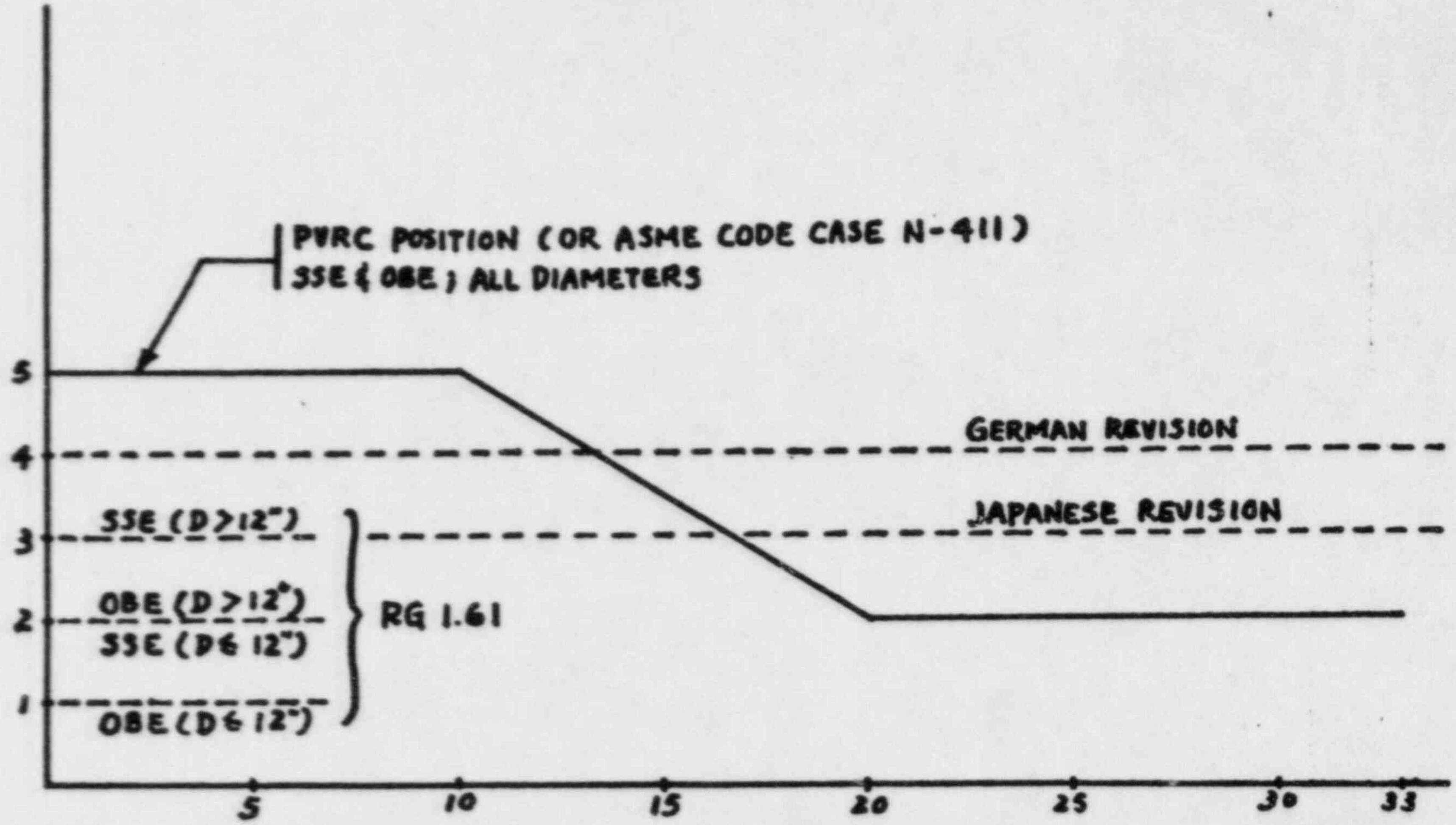
- DAMPING OF A PIPING SYSTEM IS COLLECTIVELY EFFECTED BY MANY PARAMETERS, SUCH AS
  - NO. & TYPE OF PIPE SUPPORTS
  - PIPE SIZE
  - LEVEL OF LOADING OR RESPONSE
  - PIPE WEIGHT
  - TYPE & THICKNESS OF INSULATION
  - PIPING CONFIGURATION
  - PIPING NATURE FREQUENCIES, ETC.

- DAMPING VALUES IN R. G. 1.61 ARE BASED ON LOWER-BOUND VALUES DUE TO LACK OF UNDERSTANDING OF PARAMETERS AFFECTING DAMPING AT THAT TIME
- NEW DAMPING VALUES PROPOSED BY PVRC
  - BASED ON EXPERIMENTAL EVIDENCE
  - REGRESSION ANALYSIS FOUND STRONG CORRELATION BETWEEN DAMPING AND FREQUENCY
  - ADOPTED BY ASME AS CODE CASE N-411
  - APPLIES ONLY TO SEISMIC DESIGN
  - 20 TO 40% REDUCTION IN PIPING SEISMIC RESPONSE

THE ISSUE

THE LOWER-BOUND DAMPING VALUES OF R. G. 1.61 WERE MANDATED FOR USE IN CURRENT SEISMIC DESIGN, WHICH IS ONE OF MAJOR CONTRIBUTORS TO CAUSE STIFF PIPING DUE TO OVERLY ESTIMATED SEISMIC RESPONSE.

DAMPING VALUES



RECOMMENDATIONS

- ACCEPT NEW DAMPING FOR LICENSING

  IMMEDIATELY ENDORSE ASME CODE CASE N-411 FOR CALCULATING SEISMIC RESPONSE USING SPECTRAL ANALYSIS METHODS.

- INCORPORATE NEW DAMPING INTO REGULATORY POSITION

  REVISE R G 1.61 AND SRP 3.9.2

- RESEARCH PROGRAMS

  - COMPLETE INEL DAMPING TESTS FOR VERIFYING THE DEPENDENCY OF DAMPING TO FREQUENCY
  - INVESTIGATE THE POSSIBILITY OF APPLYING PVRC DAMPING TO DYNAMIC LOADS OTHER THAN SEISMIC AND ADDRESS DAMPING FOR FREQUENCIES BEYOND SEISMIC RANGE (ABOVE 33 Hz)

ON-GOING EFFORT ON PIPE DAMPING

- PVRC PIPING COMMITTEE EFFORT TO EXTEND
  - DAMPING FOR NON-SEISMIC RESPONSE
  - DAMPING FOR HIGH FREQUENCY RESPONSE
  - DAMPING FOR HEAVILY INSULATED PIPING

- HEISSDAMPFREAKTOR PIPING TESTS
  - IN 1986 WITH U.S. PARTICIPATION
  - TEST AT HIGH AMPLITUDE LEVELS

- INEL TESTS USING HIGH FREQUENCY INPUTS
  - ON BOTH INSULATED & UNINSULATED PIPING

- POSSIBLE TESTS AT THE CANCELLED HARTSVILLE PLANT

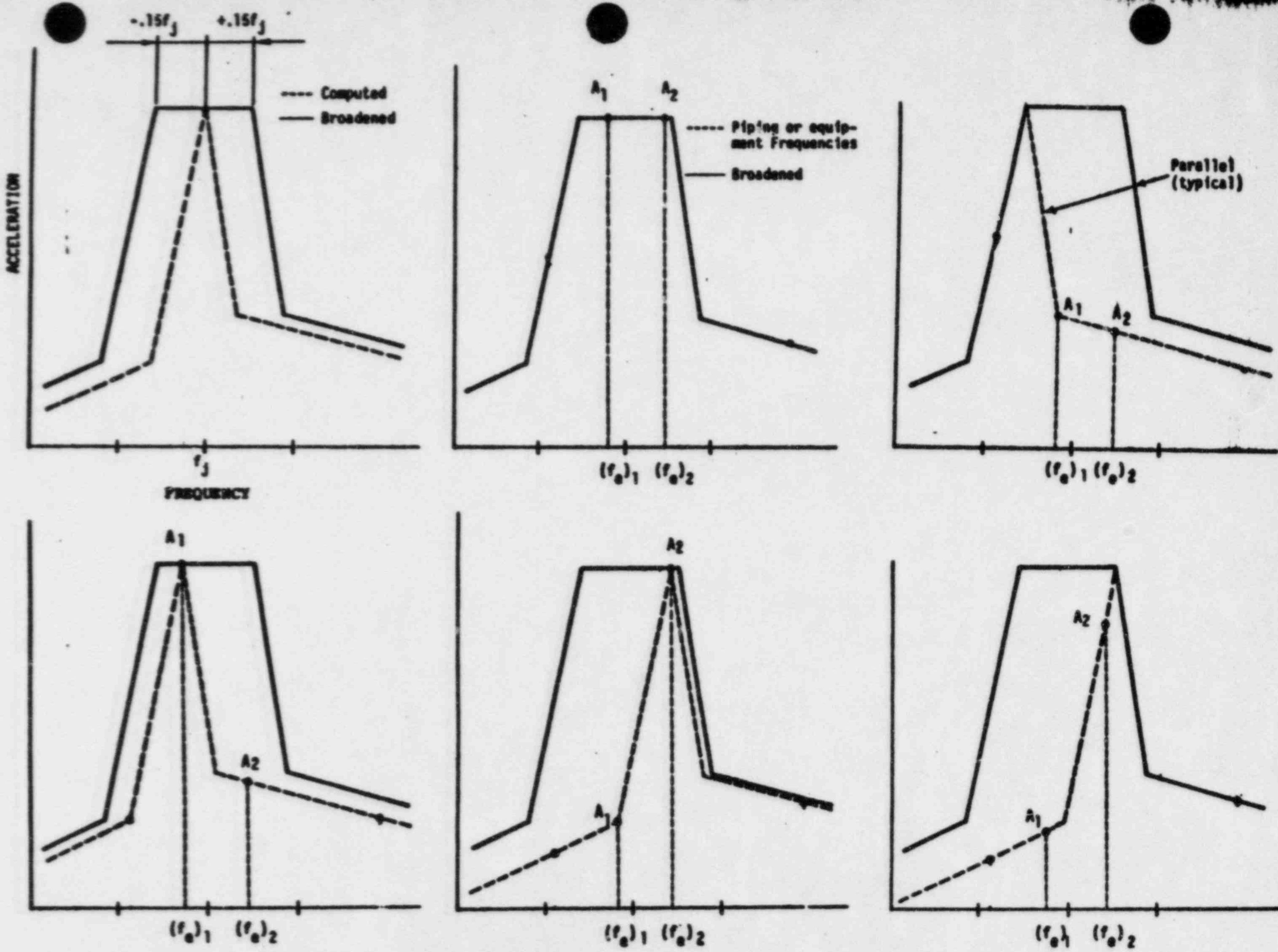
- ESTABLISHMENT OF WORLD DATA BANK ON PIPE DAMPING
  - AT INEL
  - WILL PERFORM VARIOUS PARAMETRIC STUDIES
  - JAPANESE DATA UNDER NEGOTIATION

- FURTHER BNL STUDIES ON MARGINS

SPECTRAL MODIFICATION

BACKGROUND

- R.G. 1.122 SPECIFIES THAT THE PEAK OF FLOOR RESPONSE SPECTRA USED FOR PIPING DESIGN INPUT BE BROADENED BY ± 15%
  - TO ACCOUNT FOR FREQUENCY UNCERTAINTY OF THE PEAK RESULTING FROM UNCERTAINTIES IN
    - MATERIAL PROPERTIES OF STRUCTURE & SOIL
    - ANALYSIS TECHNIQUES FOR SOIL-STRUCTURE INTERACTION
    - MODELING TECHNIQUES IN SEISMIC ANALYSIS
- IN REALITY, A PIPING SYSTEM WILL EXCITE ONLY AT THE PEAK FREQUENCY. NOT AT ALL FREQUENCIES IN THE ARTIFICALLY BROADENED RANGE.
- SPECTRAL PEAK SHIFTING METHOD PROPOSED BY PVRC
  - INSTEAD OF SINGLE ANALYSIS BROADENED SPECTRUM, PIPING RESPONSE TO SEVERAL PEAK-SHIFTED SEPCTRA SHOULD BE ANALYZED
  - FINAL PIPING DESIGN WOULD ENVELOPE RESULTS OF ALL ABOVE ANALYSES
  - UP TO 10% REDUCTION IN PIPING SEISMIC RESPONSE
  - MAY NOT BE PRACTICAL DUE TO INCREASED ANALYSIS COST FOR SOME CASES
  - ADOPTED BY ASME
    - AS CODE CASE N-397
    - AS ALTERNATIVE METHOD



SPECTRAL PEAK SHIFTING

THE ISSUE

THE PEAK BROADENING REQUIREMENT OF R. G. 1.22

- UNREALISTICALLY INCREASES ENERGY INPUT TO THE PIPING SYSTEM.
- INTRODUCE ADDITIONAL CONSERVATISM INTO PIPING SEISMIG DESIGN.

RECOMMENDATIONS

- ACCEPT PEAK-SHIFTING FOR LICENSING

  IMMEDIATELY ENDORSE ASME CODE CASE N-397

- INCORPORATE PEAK SHIFTING INTO REGULATORY POSITION

  REVISE R.G. 1.122 AND SRP 3.9.2 TO PERMIT PEAK SHIFTING AS AN ALTERNATIVE TO PEAK BROADENING

- INVESTIGATE UNCERTAINTY RANGE OF SPECTRAL FREQUENCY

  INITIATE NRC INTERNAL REVIEW ON ADEQUACY OF ± 15% RANGE USED IN R. G. 1.122.

- RESEARCH PROGRAMS

  - ASSESS UNCERTAINTY RANGE OF SPECTRAL FREQUENCY
  - DEVELOP A SIMPLE SPECTRAL-BROADENING PROCEDURE BASED ON EQUIVALENT ENERGY INPUT.

INPLEMENTATION STATUS
(5/2/85)

PLANT	ASME CODE CASE N-397	ASME CODE CASE N-411
SOUTH TEXAS 1 & 2		X
BEAVER VALLEY 2		X
DAVIS BESSE 1		X
CLINTON	X	X
NINE MILE POINT 2		X
SEABROOK 1 & 2		X
BYRON 1 & 2		X
BRAIDWOOD 1 & 2		X
McGUIRE 1 & 2	X	X
MILLSTONE 3		X
WATTS BAR	X	X
BELLEFONTE 1 & 2	X	X
VOGTLE 1 & 2		X
HATCH 1 & 2		X

NOZZLE FLEXIBILITY & NOZZLE LOADS

BACKGROUND

- PIPING SYSTEMS GENERALLY TERMINATE AT NOZZLES CONNECTED TO
  - PRESSURE VESSELS & TANKS
  - ROTATING EQUIPMENT (IE PUMPS OR TURBINES)
  - RUN PIPE
- GENERALLY THE NOZZLES ARE MODELED AS RIGID ANCHORS IN PIPING SYSTEM ANALYSIS AND USING LOW ALLOWABLES.
- NO NRC POSITION ADDRESSING NOZZLE FLEXIBILITY OR NOZZLE LOADS
- INDUSTRY GUIDANCE ON NOZZLE DESIGN
  - <u>NOZZLE IN VESSEL</u>

    WRC BULLETING 107 GIVES VESSEL STRESSES AT NOZZLE BUT NO GUIDANCE ON FLEXIBILITY OR STRESS LIMITS ON NOZZLES OF CONNECTING PIPE.
  - <u>NOZZLES ON ROTATING EQUIPMENT</u>

    LOW ALLOWABLES ARE GENERALLY USE (IE, NEMA SM 23 FOR STEAM TURBINES. API-610 FOR CENTRIFUGAL PUMPS). NO GUIDANCE ON NOZZLE FLEXIBILITY.
  - <u>NOZZLES IN PIPING</u>

    ASME CODE GIVES GUIDANCE ON STRESS LIMITS. HOWEVER, ONLY CLASS 1 HAS GUIDANCE ON NOZZLE FLEXIBILITY.

THE ISSUE

THE COMBINATION OF USING LOW ALLOWABLE NOZZLE LOADS AND IGNORING NOZZLE FLEXIBILITY MAY LEAD TO ADDITIONAL RESTRAINTS, WHICH MAY REALLY NOT BE NEEDED. THIS IS ANOTHER CONTRIBUTOR TO STIFF PIPING.

RECOMMENDATIONS

- CONSIDER NOZZLE FLEXIBILITY IN NRC POSITION
  REVISE SRP 3.9.2
- IMPROVE INDUSTRY GUIDANCE
  REQUEST ASME TO ADDRESS NOZZLE FLEXIBILITY CALCULATION (COMPLETED)
- RESEARCH PROGRAM
  DEVELOP IMPROVED DESIGN GUIDANCE ON NOZZLE STRESS LIMITS AND FLEXIBILITIES

INELASTIC ANALYSIS

BACKGROUND

- SSE IS A LOW-PROBABILITY EVENT. IT IS APPROPRIATE IN PIPING DESIGN TO ACCEPT SOME INELASTIC BEHAVIOR. IN FACT, PIPING IS CAPABLE OF ABSORBING A CONSIDERABLE AMOUNT OF ENERGY

- CURRENT DESIGN PRACTICE USES LINEAR-ELASTIC ANALYSIS, WHICH IS INCAPABLE OF ACCOUNTING FOR THE INELESTIC ENERGY ABSORPTION CAPACITY EVEN AT LEVEL D STRESS LIMIT

- CURRENT ASME PIPING CODE
  - ACCEPTANCE CRITERIA ARE BASED ON STRESS LIMITS
  - FOR INELASTIC ANALYSIS, ACCEPTANCE CRITERIA BASED ON STRAIN OR DEFORMATION ARE MORE APPROPRIATE WHICH HAVE NOT BEEN DEVELOPED
  - ALTHOUGH INELASTIC ANALYSIS IS PERMITTED BY CODE DUE TO LACK OF PROPER ACCEPTANCE CRITERIA. SUCH ANALYSIS ONLY RESULTS IN MOUNTING COST WITHOUT OBVIOUS BENEFIT.
  - UNREALISTIC OF EQUATION (9)
    - STRESS LIMIT BASED ON STATIC LOADS
    - NO INERTIA TYPE FAILURE
      - IN ACTUAL EARTHQUAKES (SEE ADDENDUM. VOL 2)
      - IN 4-SSE TESTS (BY ANCO)

- INELASTIC ANALYSIS ARE NOT ONLY COSTLY, BUT ALSO COMPLICATED BY ADDITIONAL CONSIDERATIONS OF
  - POTENTAIL LOCAL OR SYSTEM INSTABILITY
  - LARGE DEFORMATION INDUCED FATIGUE AND FUNCTIONAL FAILURE OF A PIPING SYSTEM AND ITS MOUNTED EQUIPMENT.

- SUCH CONSIDERATIONS ARE GENERALLY ON CASE BASIS.
  GENERIC GUIDANCE REMAINS TO BE DEVELOPED.

THE ISSUE

CURRENT DESIGN PRACTICE AND ACCEPTANCE CRITERIA ARE INADEQUATE FOR INELASTIC ANALYSIS. AS A RESULT, PIPING SYSTEMS ARE DESIGNED LINEARLY & ELASTICALLY, WHICH CONTRIBUTE TO STIFF SYSTEMS.

RECOMMENDATIONS

- SET NRC POSITION ON PERFORMANCE CRITERIA
  REVISE SRP 3.9.2 TO STATE GOAL OF INELASTIC ANALYSIS FOR SSE, WHICH WOULD ESTABLISH MARGIN AGAINST FAILURE OF
  - PLASTIC TENSILE INSTABILITY
  - LOW-CYCLE FATIGUE OR PLASTIC RATCHETTING
  - LOCAL OR SYSTEM BUCKLING
  - FLOW AREA REDUCTION BY DEFORMATION
  - FUNCTIONAL FAILURE OR PIPE MOUNTED EQUIPMENT

- RESEARCH PROGRAM
  - DEVELOP PSEUDO-LINEAR-ELASTIC ANALYTICAL METHODS AND DESIGN PROCEDURES TO ACCOUNT FOR INELASTIC RESPONSE.

SEISMIC SPECTRAL INPUT

BACKGROUND

- A PIPING SYSTEM MAY SUBJECT TO DIFFERENT SPECTRAL INPUTS IF SUPPORTS ARE LOCATED IN DIFFERENT FLOORS

- CURRENT PRACTICE IN SPECTRAL ANALYSIS
  - TOTAL RESPONSE IS A COMBINATION OF TWO SEPARATELY CALCULATED EFFECTS OF
    - MASS INERTIA RESPONSE (MI)
    - SEISMIC ANCHOR MOTION (SAM)
  - ENVELOPE SPECTRA INPUT (R.G. 1.60) ARE GENERALLY USED FOR MI CALCULATION
    - MODAL & DIRECTIONAL COMBINATION PER R.G. 1.92
  - PERFORM PSEUDOSTATIC ANALYSIS FOR SAM
  - COMBINE MI & SAM VIA ABSOLUTE SUM

- MULTIPLE-RESPONSE SPECTRA METHOD
  - DEVELOPED BY NRC FUNDED BNL STUDY (NUREG/CR-3811)
    - RULES FOR RESPONSE COMPONENT COBINATION AMONG
      - MODES
      - DIRECTIONS
      - SUPPORT GROUPS

      } SEE CHAP. 2, VOL. 4 OF NUREG-1061 FOR DETAILS
    - SPECTRAL ASSUMPTIONS ARE CLOSER TO REALITY
  - CAN REMOVE SOME CONSERVATISM OF DESIGN AND YET STILL PROVIDE ADEQUATE MARGIN

THE ISSUE

THE USE OF ENVELOPED SPECTRA AS A UNIFORM SEISMIC INPUT TO ALL PIPING SUPPORTS (INSTEAD OF REALISTIC CONSIDERATION OF INDIVIDUAL INPUT FOR DIFFERENT SUPPORTS) IS ANOTHER CONTRIBUTOR TO STIFF PIPING.

RECOMMENDATIONS

- SET NRC POSITION FOR NEW SPECTRAL INPUT

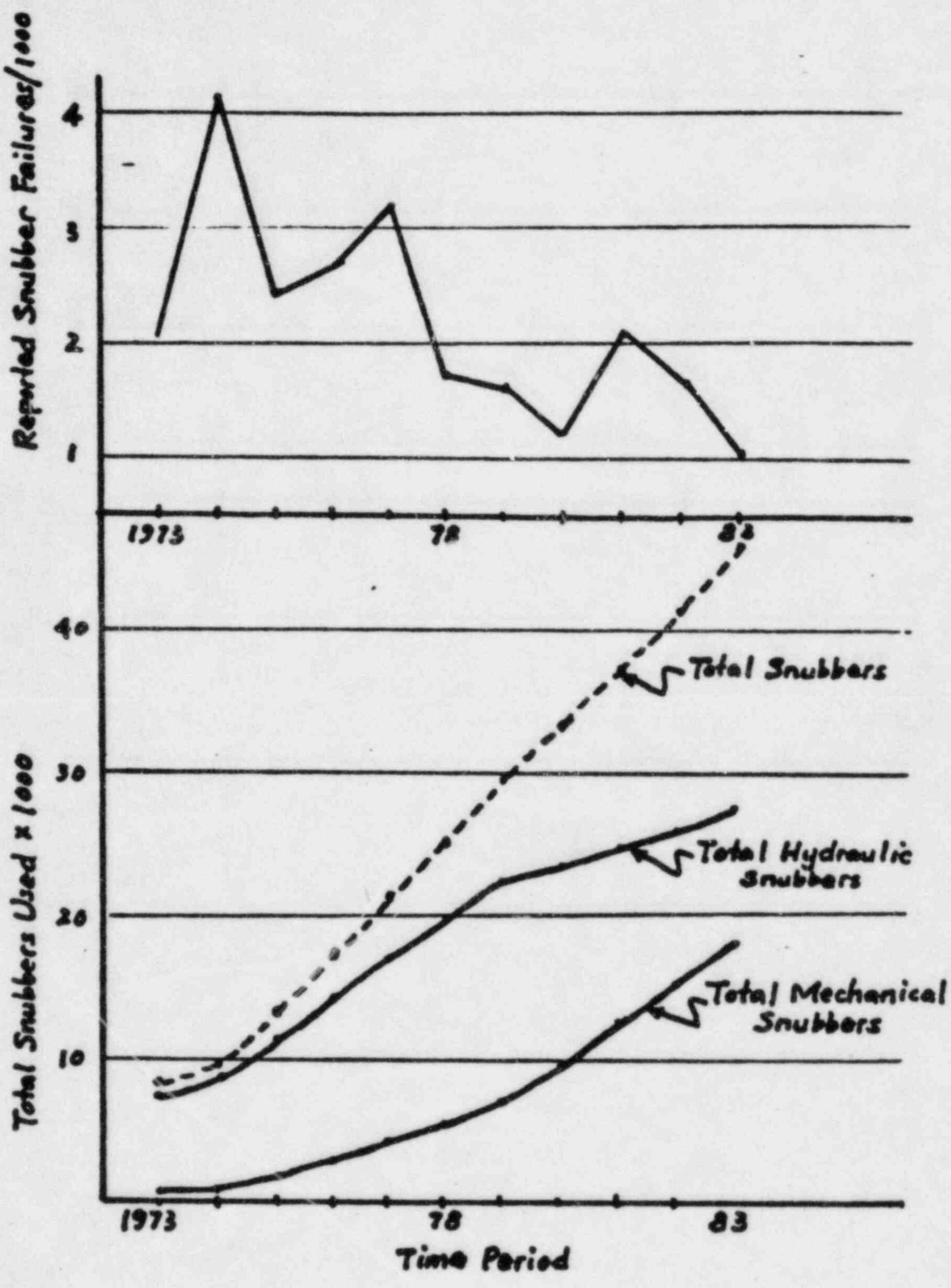
  REVISE SRP 3.9.2 TO PERMIT AND ENCOURAGE THE USE OF MULTIPLE-RESPONSE SPECTRA METHOD

SUPPORTS AND SNUBBERS

BACKGROUND

- NO. OF SUPPORTS & SNUBBERS PER PLANT WAS INCREASED SIGNIFICANTLY IN PAST DECADE DUE TO
  - INCREASE IN PLANT SEISMIC LEVEL
  - STRINGENT REGULATORY REQUIREMENTS
  - INEXPERIENCED PIPING DESIGNERS & ILL DESIGN PRACTICE
- CURRENT DESIGN CRITERIA ADDRESS PIPING, PIPE SUPPORTS & COMPONENT SUPPORTS INDEPENDENTLY, AND THEIR DESIGN MAY BE HANDLED BY SEPARATE ENGINEERING GROUPS.
- TYPE, NUMBER & LOCATION OF SUPPORTS & SNUBBERS ARE GENERALLY NOT OPTIMIZED IN DESIGN
- SNUBBER FAILURE REACHED AN ALARMING RATE IN EARLY 70.
  - SEAL LEAKAGE OF HYDRAULIC SNUBBERS
  - "LOCK UP" OF MECHANICAL SNUBBERS
  - MAINTENANCE OF SNUBBERS ARE COSTLY & INDUCE EXPOSURE
- SNUBBER FAILURE CONSEQUENCES
  - MAY LOSE SNUBBER FUNCTION
  - MAY ENHANCE PIPE FAILURE PROBABILITY
  - SO FAR, NO SNUBBER INDUCED PIPE FAILURE
- EFFORTS IN PAST DECADE HAVE IMPROVED SNUBBER PERFORMANCE
  - NRC GENERIC ISSUE A-13 FOR IMPROVED SNUBBER OPERABILITY & RELIABILITY
  - SRP 3.9.2 FOR CONSIDERATION OF SNUBBER PROBLEMS
  - NUREG-0371 FOR SNUBBER DESIGN & TESTING PRACTICE
  - DRAFT R.G. FOR SNUBBER OPERABILITY
  - FAILURE RATE WAS IMPROVED

(21)



<u>Snubber Population & Failure Rate</u>

THE ISSUE

THE USE OF SNUBBERS AND SUPPORTS SHOULD NOT ONLY MEET DESIGN REQUIREMENTS, BUT ALSO CONSIDER FOR IMPROVING OVERALL RELIABILITY OF PIPING SYSTEMS.

RECOMMENDATIONS

- NRC ACTION TO LIMIT THE USE OF SNUBBERS
  - INITIATE A NONMANDATORY SNUBBER REASSESSMENT PROGRAM FOR OPERATING PLANTS & PLANTS UNDER CONSIDERATION
- INDUSTRY EFFORT TO IMPROVE SUPPORT DESIGN
  - ENCOURAGE PURC & ASME TO REVIEW & IMPROVE PIPING SUPPORT DESIGN CRITERIA
- RESEARCH PROGRAMS
  - COMPLETE PNL EVALUATION OF LERS FOR SNUBBER PERFORMANCE
  - ENCOURAGE INDUSTRY TO INVESTIGATE
    - METHODS & PROCEDURES FOR LIMITING USE OF SNUBBERS
    - PROCEDURES TO OPTIMIZE SUPPORT PLACEMENT

OVERALL DESIGN MARGINS

BACKGROUND

- IDEAL WAY TO SET DESIGN MARGINS
  - BALANCED MARGINS AMONG EFFECTS OF VARIOUS LOADINGS
  - BASED ON REALISTIC FAILURE MODES
- DESIGN MARGINS OF ASME PIPING CODE
  - VARYING AMONG
    - SERVICE LEVELS
    - PIPING CLASSES & SUPPORTS
    - MATERIALS USED
    - CONSIDERATION OF
      - TENSILE ALLOWABLES
      - FATIGUE
      - BUCKLING
  - COMPLICATE & LACK OF CONSISTENT EXPERIMENTAL OR THEORETICAL JUSTIFICATION
  - GENERALLY SOUND FOR OPERATING LOADS DUE TO YEARS EXPERIENCE & PRACTICE, BUT POOR IN SEISMIC DESIGN
    - INERTIA RESPONSE MAY NOT BE THE REAL FAILURE MODE
- ADDITIONAL PROBLEMS
  - EXTRA MARGINS FOR LARGE UNCERTAINTIES
    - UNCERTAINTY OF SEISMIC HAZARD AT PLANT SITE
    - UNCERTAINTY IN CALCULATING SEISMIC INPUT TO PIPING
    - UNCERTAINTY IN CALCULATING PIPING RESPONSE
  - COMPLICATED AND COSTLY ANALYSES WITH NEGATIVE RESULTS IN STIFF PIPING

THE ISSUE

SEISMIC MERGINS MAY BE BASED ON WRONG ASSUMPTION OF FAILURE MODE AND WRONG PREMISE THAT ADDED CONSERVATISM WILL INCREASE OVERALL SAFETY.

RECOMMENDATIONS

- NRC ACTION TO ASCERTAIN SEISMIC FAILURE MODE & DESIGN PHILOSOPHY
  - ASSESS PIPING EXPERIENCE WHEN A SEISMIC EVENT OCCURS
  - MONITOR & ASSESS PVRC & ASME ACTIVITIES
  - SUPPORT TEST PROGRAMS FOR VERIFYING SEISMIC MARGINS AND FAILURE MODES

CONCLUSIONS

- CURRENT REGULATORY POSITIONS ON SEISMIC DESIGN OF PIPING SYSTEMS IN NUCLEAR POWER PLANTS WERE EVALUATED
- MAJOR FINDINGS
  - THERE IS INCONSISTENCY IN DEFINING THE OBE
  - SEISMIC DESIGN CRITERIA ARE GENERALLY OVERLY CONSERVATIVE
    - DUE TO INADEQUATE SUPPORTING DATA
    - DUE TO PERCEPTION THAT ADDED CONSERVATISM IN SEISMIC DESIGN IMPROVES SAFETY
  - SUCH CRITERIA HAVE LED TO
    - OVERLY STIFF PIPING
    - EXCESSIVE USE OF SNUBBERS AND SUPPORTS
    - LESS RELIABLE PIPING
- MAJOR RECOMMENDATIONS
  - RULEMAKING AMENDING APPENDIX A TO 10 CFR 100 BE UNDERTAKEN TO PERMIT DECOUPLING OF THE OBE AND SSE
  - ASME CODE CASES N-411, PERTAINING TO DAMPING VALUES AND N-397, PERTAINING TO SPECTRA MODIFICATION, AS DEVELOPED BY THE PVRC PIPING COMMITTEE AND CITED IN WRC BULLETIN 300, BE EXPEDITIOUSLY IMPLEMENTED. R.G. 1.61 AND 1.122 SHOULD BE REVISED TO BE CONSISTENT WITH THESE CODE CASES
  - SRP 3.9.2 BE REVISED:
    - TO ADDRESS COMPONENT NOZZLE FLEXIBILITY
    - TO INCORPORATE PERFORMANCE GOALS FOR CONDUCTING INELASTIC ANALYSIS
    - TO PERMIT THE USE OF THE MULTIPLE-SPECTRA METHOD
  - A NONMANDATORY SNUBBER REASSESSMENT PROGRAM BE INITIATED FOR ALL PLANTS TO LIMIT THE USE OF SNUBBERS
  - THE ASME CODE COMMITTEE BE REQUESTED TO DEVELOP GUIDANCE ON COMPONENT NOZZLE FLEXIBILITY

REPORT OF NRC PIPING REVIEW COMMITTEE

NUREG-1061, VOLUME 2, ADDENDUM

"SUMMARY & EVALUATION OF HISTORICAL STRONG-MOTION EARTHQUATE SEISMIC RESPONSE & DAMAGE TO ABOVE GROUND INDUSTRIAL PIPING"

MAJOR CONTRIBUTORS

JOHN STEVENSON	STEVENSON & ASSOCIATES, INC.
ROBERT L. CLOUD	ROBERT L. CLOUD ASSOCIATES
PETER YANEO	EARTHQUAKE ENGINEERING, INC.
HELSI SHILATOR	UNIVERSITY OF TOKYO

SCOPE OF INVESTIGATION

- COLLECT AND SUMMARIZE OBSERVED EARTHQUAKE DAMAGE TO ABOVE GROUND INDUSTRIAL PIPING

- COLLECT AND SUMMARIZE EXPERIENCE OF STRONG-MOTIVE PIPING TESTS

- EXPLAIN PIPING RESPONSE

- RECOMMEND FUTURE PIPING SEISMIC DESIGN

LIST OF EARTHQUAKES HAVING PIPING DAMAGE OBSERVED

EARTHQUAKE SITE	DATE	MAX GROUND ZPA (G)
LONG BEACH, CA	3/10/33	0.25
KERN COUNTY, CA	7/21/52	0.26
ANCHORAGE, AK	1964	0.3 ~ 0.5
SAN FERNANDO, CA	1971	0.2 ~ 0.4
MANAGUA, NICARAGUA	1972	0.39 ~ 0.6
FERNDALE, CA	1975	0.37
MIYAGI-KEN-OKI, JAPAN	1978	0.125 ~ 0.4
SCHWABISHE-ALB, W. GERMANY	1978	0.3 ~ 0.35
IMPERIAL VALLEY, CA	10/15/79	0.5 ~ 0.93
EUREKA, CA	1980	0.4
COALINGA, CA	1983	0.35 ~ 0.6
HILO, HAWAII	11/83	0.1 ~ 0.3

STRONG-MOTION PIPING TESTING

- JAPAN
  - DAMPING TEST BY UTILITIES (1978 - 82)
  - SNUBBER & SUPPORT TEST BY MITI (1982 - 83)
  - SHAKE TABLE PROOF TEST BY NUPEC AND MITI (1984-85)
- FRG
  - SMALL PIPING TESTS BY ANCO (USA) FOR KWU
  - 1:3 SCALE MODEL TESTS BY ANO (USA) FOR KWU
  - PIPING STRUCTURAL CAPABILITY TEST BY KWU
    - TEST LEVEL FAR EXCEEDS LEVEL D STRESS (3 ~ 4SSE)
    - NO PIPE LEAKAGE OR SUPPORT FAILURE HAD OCCURRED.
  - HIGH SEISMIC TESTING UP TO 5G BY HDR (SINCE 1983)
- USA
  - HIGH-LEVEL TESTING BY ANCO FOR EPRI/NRC (1984)
    - COMPLEX 3D PIPING TO WELL ABOVE YIELD
    - NO PIPE FAILURE REPORTED

CONCLUSIONS

- VERY FEW PIPING FAILURES (LESS THAN 0.01% OF EFFECTED PIPING)
- OBSERVED FAILURE CONDITIONS:
  - IN MOST CASES DUE TO INSUFFICIENT FLEXIBILITY TO ACCOMMODATE UNEXPECTED LARGE ANCHORE MOTIONS, SUCH AS
    - AT CONNECTION TO MASSIVE COMPONENT
    - AT CONNECTION OF SMALL BANCH LINE TO MAIN RUN.
  - AT PLACES SUSCEPTABLE TO FATIGUE CRACKING
  - AT REGION DEGRADED BY CORROSION OR EROSION
  - AT WORK JOINTS SUCH AS POOR WELDING.
- OBSERVED FAILURE MECHANISM:
  - USUALLY DUE TO EXCESSIVE SHEAR OR AXIAL LOAD RATHER THAN BENDING
  - INERTIA MASS RESPONSE HAS LITTLE EFFECT ON PIPING FAILURE
- LESSONS LEARNED
  - INERTIA (OR PRIMARY) LOADS MAY NOT CONTROL SEISMIC DESIGN
  - DESERVE MORE ATTENTION ON SEISMIC ANCHOR MOTIONS
  - AVOID OVERDESIGN OF PIPING SUPPORTS TO PERMIT SUPPORTS TO ACT AS MECHANICAL FUSES FOR PIPING.

NRR STAFF PRESENTATION TO THE
ACRS

10

SUBJECT: NRC PIPING REVIEW COMMITTEE PRESENTATION

POTENTIAL FOR PIPE BREAKS, NUREG-1061, VOL. 3

DATE: MAY 23, 24, 1985

PRESENTER: R. W. KLECKER

PRESENTER'S TITLE/BRANCH/DIV:

SECTION CHIEF, COMPONENT INTEGRITY SECTION,
MATERIALS ENGINEERING BRANCH,
DIVISION OF ENGINEERING

PRESENTER'S NRC TEL. NO.:

R. KLECKER (301) 492-8007

SUBCOMMITTEE:

COMBINED MEETING OF SUBCOMMITTEES ON METAL COMPONENTS AND
STRUCTURAL ENGINEERING

LEAK-BEFORE-BREAK

THE APPLICATION OF FRACTURE MECHANICS TECHNOLOGY IN THE LICENSING PROCESS TO DEMONSTRATE THE INTEGRITY OF NUCLEAR FACILITY HIGH ENERGY PIPING SYSTEMS IN LIEU OF REQUIRING NON-MECHANISTIC DOUBLE-ENDED GUILLOTINE BREAKS.

INITIAL APPLICATION RELATES TO REQUIREMENTS FOR PROTECTION AGAINST THE DYNAMIC EFFECTS OF POSTULATED PIPE RUPTURES (GDC 4).

REASONS FOR LIMITING LBB APPLICABILITY TO DYNAMIC EFFECTS

- IN-DEPTH TECHNICAL AND REGULATORY ANALYSES PERFORMED ONLY FOR PROTECTION AGAINST DYNAMIC EFFECTS FROM POSTULATED PIPE BREAKS - NOT ECCS, CONTAINMENT, ETC.

- IMMEDIATE "PAY OFF" IN ELIMINATING PIPE WHIP RESTRAINTS, JET IMPINGEMENT, SHIELDS, ETC., IN TERMS OF LARGE NET SAFETY BENEFITS (ORE) AND REDUCED IMPACTS (COSTS)

- LEAKS, VALVE MALFUNCTIONS AND OTHER SOURCES OF BLOWDOWN INDICATE NEED FOR ECCS & CONTAINMENT - IN-DEPTH STUDY NEEDED FOR ANY RELAXATION OF DESIGN REQUIREMENTS

- MAJOR CHANGES TO REGULATIONS REQUIRED TO ADDRESS ECCS & CONTAINMENT - RULEMAKING PROCESS INITIATED TO ADDRESS DYNAMIC EFFECTS ONLY INVOLVES A MODIFICATION TO GDC-4

DYNAMIC EFFECTS THAT MAY BE EXCLUDED

1. PIPE WHIP AND OTHER PIPE BREAK REACTION FORCES,
2. JET IMPINGEMENT FORCES,
3. VESSEL CAVITY OR SUBCOMPARTMENT PRESSURIZATION, INCLUDING ASYMMETRIC TRANSIENT EFFECTS, AND
4. PIPE-BREAK-ASSOCIATED TRANSIENT LOADINGS IN FUNCTIONAL SYSTEMS OR PORTIONS THEREOF WHOSE PRESSURE-RETAINING INTEGRITY REMAINS INTACT.

THE PIPING REVIEW COMMITTEE RECOMMENDS THAT THE NRC CONSIDER GRANTING EXEMPTIONS TO GDC-4 DURING THE RULEMAKING PROCESS. THE BENEFITS TO BE GAINED ARE SUFFICIENTLY GREAT TO WARRANT SCHEDULAR TREATMENT IN ORDER TO ACHIEVE THE IN-PLANT OBJECTIVE OF IMPLEMENTING THE EXCLUSION OF CONSIDERATION OF THE ABOVE DYNAMIC EFFECTS AT THE EARLIEST POSSIBLE TIME.

Table 1. Summary of Potential Impact Areas

Structures, Systems, Components Considered for Potential Impact	Potential Impact
Reactor Coolant Loop Pipe Whip Restraints	Delete from design (new plants); remove existing restraints (operating plants).
Jet Impingement Barriers	Elimination of jet impingement barriers. Reduced analysis of jet impingement loads.
RCL Tributary Piping, Control Element Drive Mechanisms, In-Core Instrumentation	Eliminate analysis of hydrodynamic loads and vibratory motion due to RCL pipe break.
Vessel Sub-Compartments	Eliminate analysis of mass and energy release due to RCL pipe break. No design changes.
Reactor Coolant System Piping	Eliminate analysis of hydrodynamic loads and vibratory motion due to RCL pipe break.
Reactor Internals and Fuel	Eliminate analysis of response to RCL pipe break loads.
Reactor Cavity, Reactor Vessel Supports	Eliminate analysis for asymmetric blowdown loads.
Neutron Streaming Shield[a]	Install permanent shield in plants not so equipped.
Refueling Pool Seal[a]	Install permanent seal in plants not so equipped. Reduce ORE and eliminate potential for seal damage due to handling.
RCL Component Supports	No change.
Emergency Core Cooling Systems	No change in performance requirements. Piping design may be affected as for "tributary piping" above.
Containment Design	No change.
Reactor Coolant Piping Leakage Detection Systems	No change.[b]

Notes:

(a) In certain older plants, a permanent component of this type capable of withstanding postulated asymmetric blowdown loads cannot be installed.

(b) Upgrading of leakage detection systems in certain plants may be necessary before exclusion of pipe breaks would be allowed.

SUMMARY OF VALUE-IMPACT ASSESSMENT
(PWR PRIMARY REACTOR COOLANT LOOP PIPING)
85 FACILITIES

	VALUE (MAN-REM)	IMPACT ($)	
		10%	5%
BEST ESTIMATE	3.4E+4	-186E+6	-186E+6
HIGH ESTIMATE	1.1E+5	-277E+6	-276E+6
LOW ESTIMATE	8.6E+3	-87E+6	-87E+6

SUMMARY OF VALUE-IMPACT ASSESSMENT
(BWR RECIRCULATION LOOP PIPING)
38 FACILITIES

	VALUE (MAN-REM)	IMPACT ($)	
		10%	5%
BEST ESTIMATE	8.6E+3	-30E+6	-30E+6
HIGH ESTIMATE	1.0E+4	-65E+6	-65E+6
LOW ESTIMATE	5.9E+3	-15E+6	-15E+6

VALUE-IMPACT ASSESSMENT OF LBB PER FACILITY

	PIPE WHIP RESTRAINTS		JET IMP. BARRIERS	
	TOTAL	REMOVED	TOTAL	REMOVED
PLANT A, W (IN OPERATION)	236	100	24	5
PLANT B, W (NTOL STAGE)	187	102	32	11
PLANT C, B&W (CP STAGE)	79	37	15	15
GESSAR 251 (STD BWR)	110	44	(NOT STATED)	
AVERAGE	153	71	24	10

TOTAL ESTIMATED COST SAVINGS FOR PIPING SYSTEMS OTHER THAN PRIMARY REACTOR COOLANT PIPING. $90,000,000(MIN.)

LBB REVIEW STATUS

OWNER'S GROUPS

W A-2 FACILITIES	REVIEW COMPLETE, GENERIC LETTER 84-04 (TECH REVIEW COMPLETE FOR COOK 1, 2 AND GINNA. NO RESPONSE FOR REMAINING 13 FACILITIES.)
CESSAR, SYS. 80	REVIEW COMPLETE, LTR TO CE 10/11/84
B&W	REVIEW UNDERWAY
GESSAR	REPORT RECEIVED

NTOL'S (22 UNITS, MAIN PCS PIPING ONLY)

FACILITIES	SER COMPLETE	EXEMPTION GRANTED
COMANCHE PEAK 1,2	05/25/84	08/28/84 (UNIT 1, IMP. SHIELDS)
VOGTLE 1, 2	08/20/84	02/05/85
CATAWBA 1, 2	09/20/84	04/23/85 (UNIT 2)
SOUTH TEXAS 1, 2	10/15/84	
PALO VERDE 1, 2, 3	10/31/84	
CALLAWAY/WOLF CREEK	12/11/84	03/11/85 (WOLF CREEK)
MILLSTONE 3	01/15/85	
BYRON 1, 2	01/15/85	
BRAIDWOOD 1, 2	01/15/85	
SEABROOK 1, 2	01/18/85	
BEAVER VALLEY 2	01/18/85	
SHEARON HARRIS 1	02/04/85	

OTHER APPLICATIONS

PRAIRIE ISLAND 1	REVIEW UNDERWAY
INDIAN POINT 3	REVIEW UNDERWAY

(NO ACTION ON THE FOLLOWING PENDING BROAD RULE CHANGE)

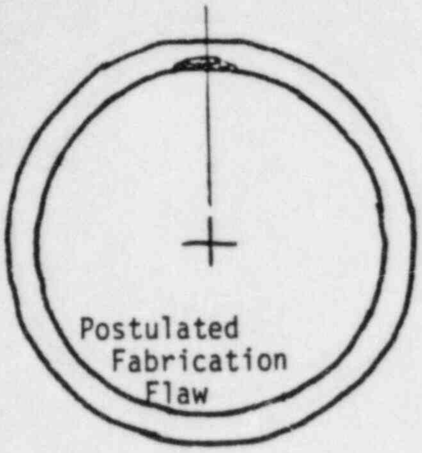
NINE MILE POINT 1	SUBMITTAL RECEIVED (SECONDARY LINES)
CATAWBA 1, 2	SUBMITTAL RECEIVED FOR RHR, PRESSURIZER SURGE AND ACCUMULATOR INJECTION LINES

EVALUATION OF POTENTIAL FOR PIPE BREAKS

NUREG-1061, VOL. 3: TABLE OF CONTENTS

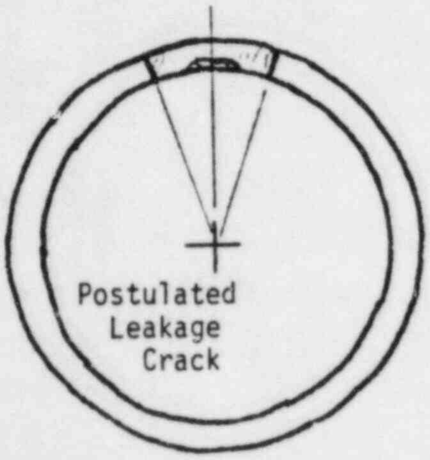
STEP-WISE APPROACH, LEAK-BEFORE-BREAK ANALYSIS

1.



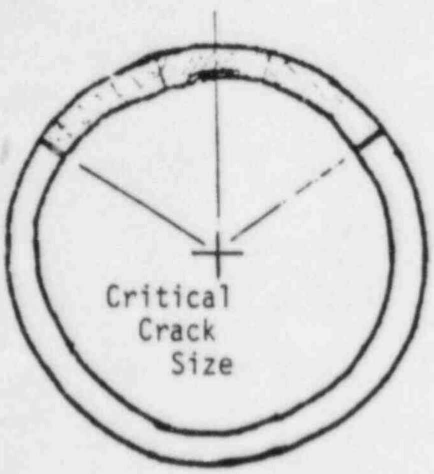
- Select highest stress, poorest material properties location in pipe under consideration.
- Postulate crack that may be missed during fabrication and preservice inspections or would be permitted by Code, whichever is larger.
- Demonstrate by analysis that crack will not grow significantly during service either by fatigue, corrosion or impact forces (water-hammer).

2.



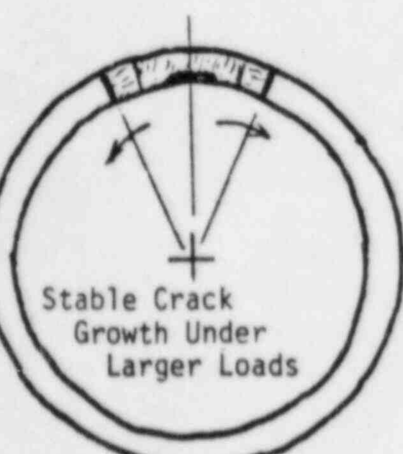
- Demonstrate that <u>even if</u> crack propagated through wall that:
  - Leakage through crack is significantly greater than minimum leak detection capability under normal operating loads so that detection of crack is assured and
  - <u>even if</u> undetected prior to an earthquake, crack is stable under normal plus earthquake loads (growth, if any, is minimal for long periods of time).

3.



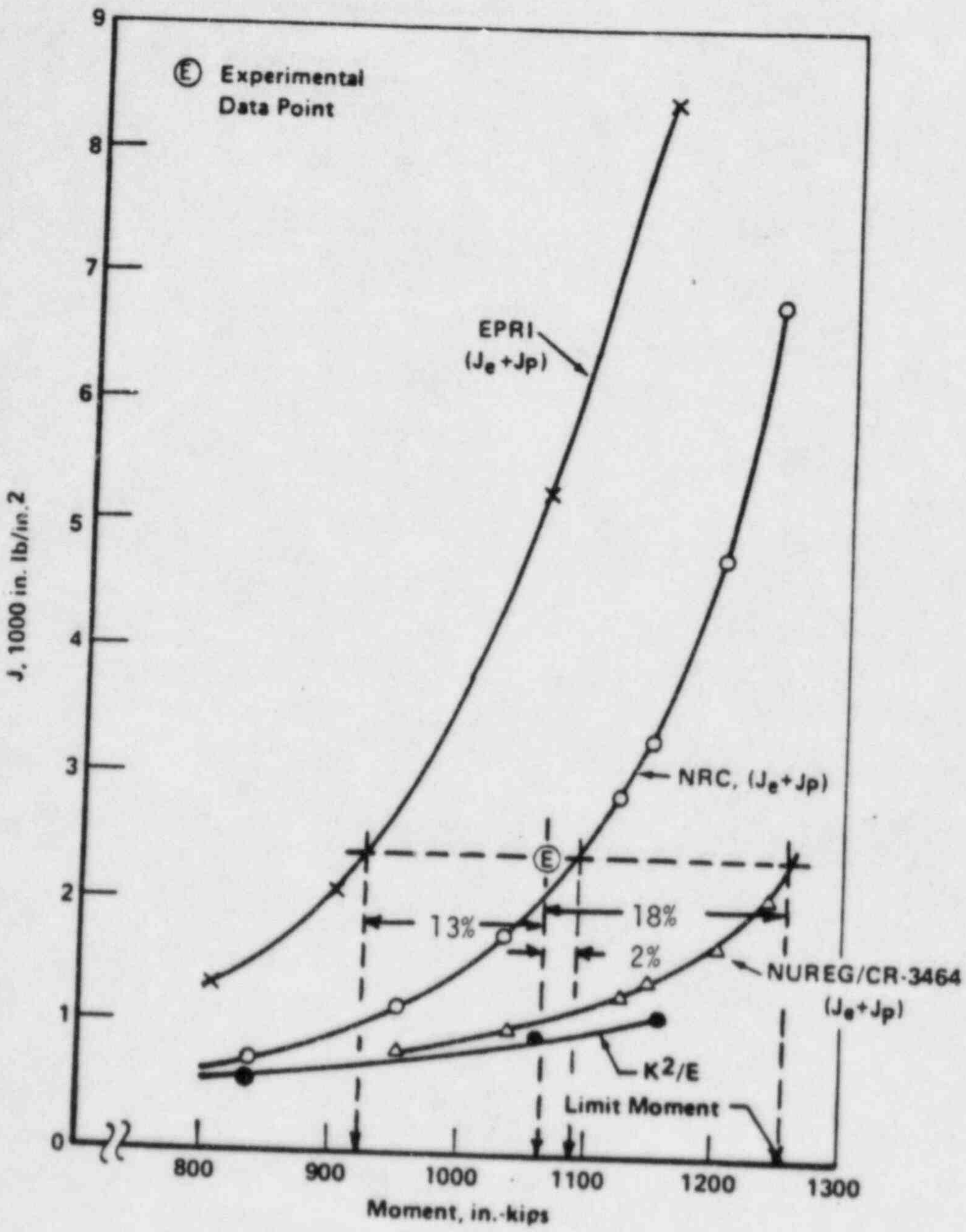
- Demonstrate margin of 2 via crack sizes
  - Compare leakage crack size to critical crack size under normal plus earthquake loads.
  - Demonstrate that there is adequate margin to account for uncertainties inherent in analyses and leak detection.

4.

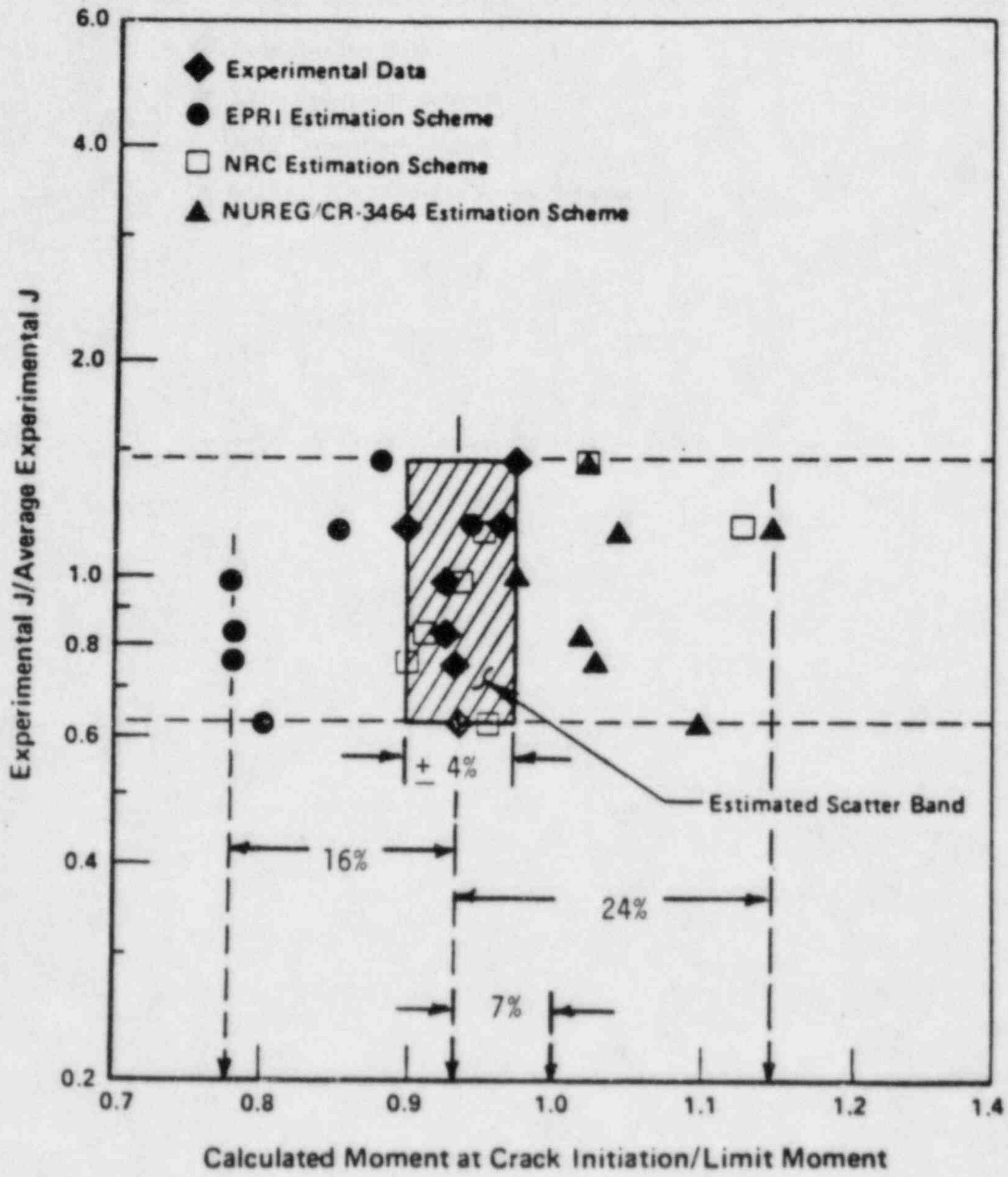


- Demonstrate margin of $\sqrt{2}$ via loads (3 if limit load analysis is used)
  - Demonstrate that leakage size cracks will not experience unstable crack growth <u>even if</u> larger loads are applied and that final crack size is limited (that is, a double-ended pipe break will not occur.

VERIFICATION PROCEDURE

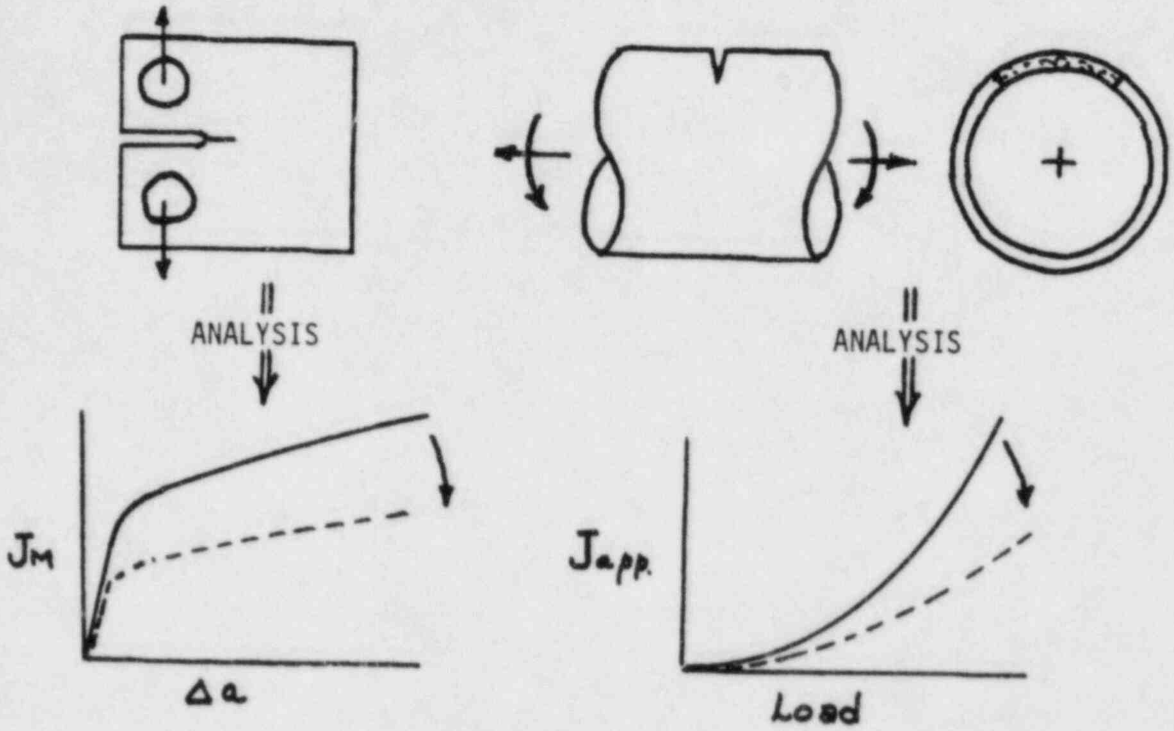


Comparison of Various J-Estimation Schemes to Average Values From DTNSRDC Ferritic Pipe Test Data at Crack Initiation

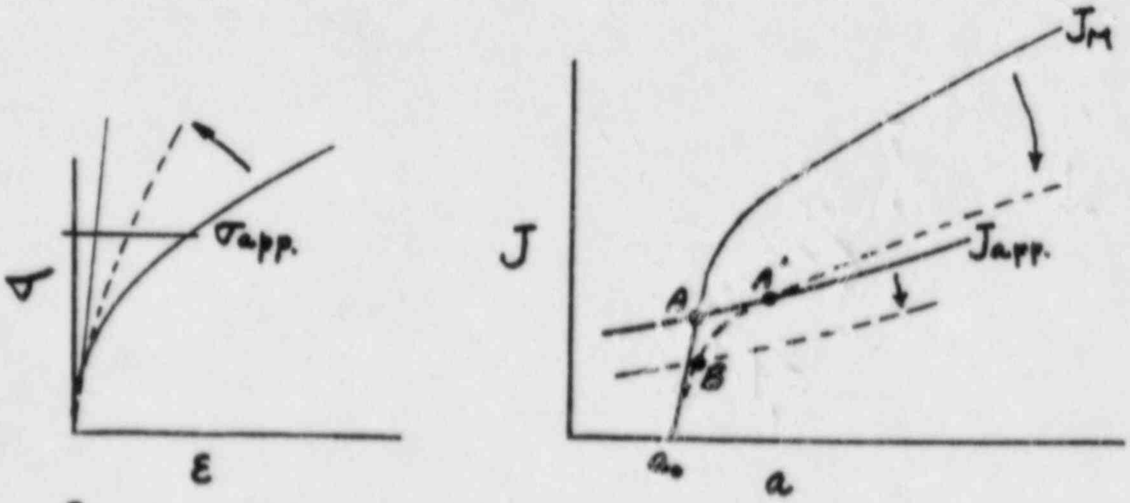


Comparison of Predicted to Experimental Maximum Moments for 8-in.-diameter Ferretic Piping Tests (A.25)

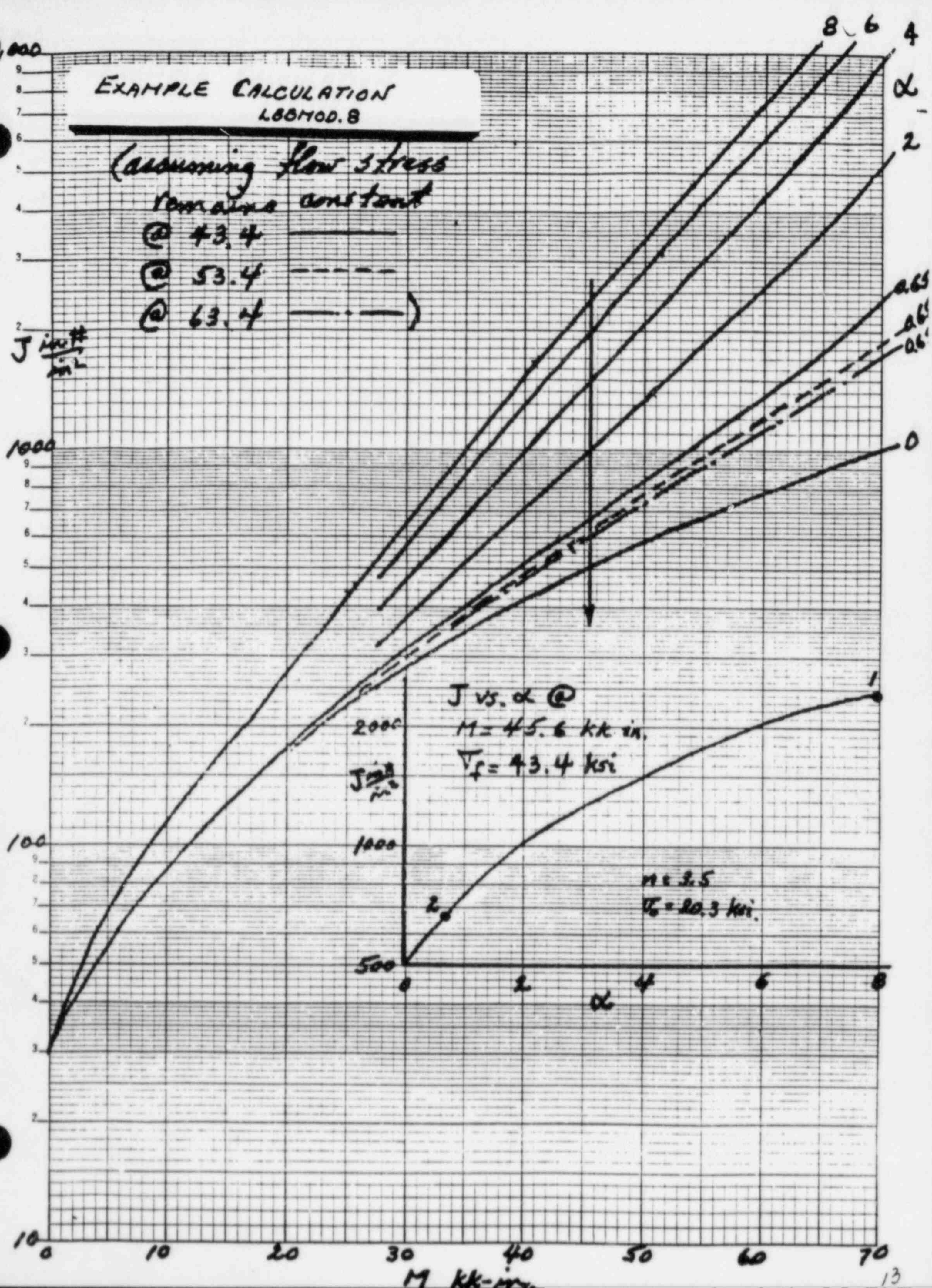
TRENDS DUE TO THERMAL AGING



J, A FUNCTION OF SPECIMEN GEOMETRY, CRACK SIZE, LOAD AND MATERIAL PROPERTIES (ARROWS REPRESENT TREND WITH AGING)



$$\frac{\varepsilon}{\varepsilon_0} = \frac{\sigma}{\sigma_0} + \alpha\left(\frac{\sigma}{\sigma_0}\right)^n, \quad \varepsilon_0 = \frac{\sigma_0}{E}$$



EXAMPLE CALCULATION
LBBMOD. 8
(assuming flow stress
remains constant
@ 43.4
@ 53.4
@ 63.4)
8
6
4
α
2
0
10,000
1000
100
10
J in#/in²
0
10
20
30
40
50
60
70
M kk-in.
J vs. α @
M = 45.6 kk in.
σf = 43.4 ksi
2000
1000
500
J in#/in²
n = 3.5
σ0 = 20.3 ksi
0
2
4
6
8
α
K+E SEMI-LOGARITHMIC 46 5493

LBB UNCERTAINTIES

- LOADS (STRESS ANALYSIS OF RECORD)
- MATERIAL PROPERTIES (J-R AND STRESS/STRAIN DATA)
- FRACTURE MECHANICS ANALYTICAL METHODS
- LEAKAGE ANALYSES (GPM/IN^2)

WHILE WE LOOK FOR SPECIFIC MARGINS AT EACH STEP, WE ALSO RELY ON ENGINEERING JUDGMENT FOR OVERALL CONSERVATISM IN LBB APPROACH.

LBB CAUSES INDUSTRY TO REEXAMINE DESIGN INTEGRITY OF PIPING SYSTEMS (INCLUDING LIMITATIONS ON USE OF LBB).

TO DATE, HAVE REVIEWED PWR MAIN COOLANT LINES. DETERMINISTIC AND PROBABILISTIC ANALYSES CONFIRM VIABILITY OF LBB.

SPECIFIED MARGINS FOR SMALLER LINES EXPECTED TO BE HARDER TO MEET - HOWEVER CONSEQUENCES OF A RUPTURE MAY DETERMINE MARGINS WE IMPOSE. (FOR SMALL LINES, IT PROBABLY WILL BE MORE PRACTICAL TO INSTALL RESTRAINTS THAN TO PURSUE THE LBB APPROACH.)

LIMITATIONS ON THE APPLICATION OF LBB FOR HIGH ENERGY FLUID SYSTEM PIPING

(A) EXISTING REGULATIONS GOVERN DESIGN FOR ECCS, CONTAINMENTS AND ESF; ENVIRONMENTAL EFFECTS SHOULD BE CONSIDERED ON A CASE-BY-CASE BASIS.

(B) LBB NOT APPLICABLE TO PIPING SUSCEPTIBLE TO IGSCC, FATIGUE OR WATER HAMMER FAILURES.

(C) FOR FACILITIES WITH CPs AND OLs, THERE SHOULD BE NO CHANGE IN SUPPORT MARGINS.

(D) LBB NOT APPLICABLE IF FAILURE OR DAMAGE LIKELY FROM INDIRECT CAUSES (FIRES, MISSILES, EQUIPMENT FAILURES, ETC.).

(E) LBB NOT APPLICABLE IF REQUIREMENTS OF IEB 79-14 HAVE NOT BEEN MET.

(F) LBB ONLY APPLICABLE IF PIPING MATERIALS NOT SUBJECT TO CLEAVAGE FRACTURE OVER TEMPERATURE RANGE WHERE RUPTURE HAS SERIOUS CONSEQUENCES.

GENERAL TECHNICAL GUIDANCE FOR LBB APPLICATION

(A) SHOW NONE OF THE LIMITATIONS FOR LBB APPLY TO PIPING RUN/SYSTEM UNDER CONSIDERATION.

(B) SPECIFY LOADS AND STRESSES (TYPE, MAGNITUDE, SOURCES AND COMBINATION METHOD). IDENTIFY LOCATION(S) WHERE HIGHEST STRESSES COINCIDENT WITH POOREST MATERIAL PROPERTIES OCCUR.

(C) IDENTIFY MATERIALS, THEIR SPECIFICATIONS AND PROPERTIES (TOUGHNESS AND TENSILE DATA, THERMAL AGING AND OTHER LIMITATIONS).

(D) POSTULATE LARGEST FLAW PERMITTED BY SECTION XI AT LOCATION(S) IN (B) ABOVE. SHOW BY FATIGUE CRACK GROWTH ANALYSIS THAT SIGNIFICANT GROWTH DOESN'T OCCUR FOR CLASS 1 PIPING.

(E) POSTULATE THROUGHWALL FLAW SIZE SO THAT LEAKAGE IS DETECTED WITH MARGIN UNDER NORMAL LOADS AT LOCATION(S) IN (B) ABOVE.

(F) CONSIDER PERFORMANCE OF A SYSTEM EVALUATION FOR GEOMETRICALLY COMPLEX SYSTEMS.

(G) APPLY N+SSE LOADS TO SHOW POSTULATED THROUGHWALL FLAW IS STABLE (I.E., CRACK GROWTH MINIMAL FOR LONG PERIOD).

(H) APPLY N+SSE LOADS TO SHOW A MARGIN ≥ 2 BETWEEN POSTULATED THROUGHWALL FLAW AND CRITICAL SIZE CRACK.

(I) Show that postulated throughwall flaws are stable in terms of crack growth when applying loads $\geq \sqrt{2}$ times N+SSE loads.

(J) J-R and tensile curves should be provided for temperatures near upper range of normal operation and should show ductile behavior.

(K) Ideally, J-R curves obtained from specimen thicknesses $\geq$ pipe wall.

- Specimen sized to obtain crack extensions consistent with J/T condition.

- If specimen size limitations exist, extrapolation if appropriate may be used (Section A2.4.3, App. A).

(L) Provide tensile curves from proportional limit to max load.

(M) Ideally, materials tests (both base and weld metals) should be conducted using archival material. If archival material unavailable, substitute specimens from 3 heats having same material specification.

(N) Two tensile and J-R curves should be obtained from each of 3 heats with same material specifications, thermal and fabrication histories as piping material.

- From archival material, 3 tensile and J-R curves is sufficient.

- TESTING TEMPERATURES SHOULD BE NEAR UPPER RANGE OF NORMAL OPERATION (E.G., 550°F).

- ONE TENSILE AND J-R CURVE SHOULD BE OBTAINED AT LOWER TEMPERATURE (E.G., HOT STANDBY) TO DETERMINE DEPENDENCE OF TOUGHNESS ON TEMPERATURE.

(O) SUBJECT TO GENERIC RESTRICTIONS (SECTION 5.9.1) LIMIT LOAD ANALYSIS ACCEPTABLE IF LIMIT MOMENT ≥ 3 TIMES N+SSE MOMENT.

OTHER T.G. RECOMMENDATIONS

- LEAKAGE DETECTION SYSTEMS SHOULD BE SUFFICIENTLY RELIABLE, REDUNDANT, DIVERSE AND SENSITIVE SO THAT A MARGIN $\geq$ 10 ON DETECTION OF UNIDENTIFIED LEAKAGE FROM THROUGHWALL FLAW EXISTS.

- DETERMINISTIC FM SHOULD PERMIT ELIMINATION OF PIPE WHIP RESTRAINTS AND JET IMPINGEMENT SHIELDS AS A DESIGN REQUIREMENT (INCLUDING ASYMMETRIC LOADS IN PWRS).

- ARBITRARY INTERMEDIATE BREAKS SHOULD BE ELIMINATED AS A DESIGN REQUIREMENT.

- CHANGES SHOULD BE MADE TO REG. GUIDES, SRPS, GENERIC ISSUES AND CODES AND STANDARDS TO FACILITATE FM TECHNOLOGY IN REGULATORY PROCESS.

- RULEMAKING SHOULD BE EXPEDITED (E.G., GDC-4).

- APPLICATION OF LBB SHOULD BE PERMITTED FOR BWR PIPING SYSTEMS WITH MATERIAL (E.G., 316 NG) RESISTANT TO IGSCC.

Table 16. Summary of Piping Systems Affected by GDC-4 Modification
(Plant A: Westinghouse PWR, In Operation)

Piping System	Pipe Whip Restraints Total[1]	Pipe Whip Restraints To be removed[2]	Jet Impingement Barriers Total[1]	Jet Impingement Barriers To be removed[2]
Reactor Coolant Loops	20	16	4	4
Residual Heat Removal	1	1	0	0
Main Steam	50	32	12	0
Main Feedwater	43	10	2	0
Auxiliary Feedwater	21	0	1	0
Chemical Volume Control	16	0	0	0
Safety Injection	12	10	0	0
Steam Generator Blowdown	25	0	0	0
Upper Head Injection	31	14	4	0
Pressurizer Surge Line	17	17	1	1
Totals	236	100	24	5

Notes:

(1) Total number of restraints or barriers in system, i.e., number that would be affected if removal were required.

(2) Number of restraints or barriers that would be affected if removal were optional. Only those devices (restraints or barriers) to which none of the following criteria applied were considered "candidates" for removal:
- (a) The piping system was not seismically qualifed.
- (b) The piping is less than six inches in diameter.
- (c) The device is required for "special protection".
- (d) The device also acts as a pipe support.
- (e) Pipe supports are attached to the device
- (f) The device protects against feedwater line breaks at steam generator nozzles.

20

Table 17. Summary of Piping Systems Affected by GDC-4 Modification (Plant B: Westinghouse PWR, NTOL Stage)

Piping System	Pipe Whip Restraints Total[1]	Pipe Whip Restraints To be removed[2]	Jet Impingement Barriers Total[1]	Jet Impingement Barriers To be removed[2]
Reactor Coolant Loops	20	16	0	0
Residual Heat Removal	8	8	1	1
Main Steam	57	33	14	4
Main Feedwater	42	14	0	0
Auxiliary Feedwater	11	10	8	1
Chemical Volume Control	1	1	0	0
Feedwater Bypass	3	0	0	0
Safety Injection	8	8	0	0
Steam Generator Blowdown	27	2	0	0
Pressurizer Surge Line	6	6	5	5
Upper Head Injection	4	4	4	0
Totals	187	102	32	11

Notes:

(1) Total number of restraints or barriers in system, i.e., number that would be affected if removal were required.

(2) Number of restraints or barriers that would be affected if removal were optional. Only those devices (restraints or barriers) to which none of the following criteria applied were considered "candidates" for removal:
- (a) The piping system was not seismically qualifed.
- (b) The piping is less than six inches in diameter.
- (c) The device is required for "special protection".
- (d) The device also acts as a pipe support.
- (e) Pipe supports are attached to the device
- (f) The device protects against feedwater line breaks at steam generator nozzles.

Table 18. Summary of Piping Systems Affected by GDC-4 Modification (Plant C: Babcock & Wilcox PWR, Construction Permit Stage)

Piping System	Pipe Whip Restraints		Jet Impingement Barriers	
	Total[1]	To be removed[2]	Total[1]	To be removed[2]
Reactor Coolant Loops	10	10	8	8
Residual Heat Removal	13	11	0	0
Main Steam	25	8	0	0
Main Feedwater	14	8	0	0
Pressurizer Surge Line	0	0	7	7
Make-Up and Purification	17	0	0	0
Totals	79	37	15	15

Notes:

(1) Total number of restraints or barriers in system, i.e., number that would be affected if removal were required.

(2) Number of restraints or barriers that would be affected if removal were optional. Only those devices (restraints or barriers) to which none of the following criteria applied were considered "candidates" for removal:
- (a) The piping system was not seismically qualifed.
- (b) The piping is less than six inches in diameter.
- (c) The device is required for "special protection".
- (d) The device also acts as a pipe support.
- (e) Pipe supports are attached to the device
- (f) The device protects against feedwater line breaks at steam generator nozzles.

22

Table 20. Summary of Piping Systems Affected by GDC-4 Modification (GESSAR 251 Standard BWR Plant)

Piping System	Pipe Whip Restraints[a]
Recirculation Loops	28
Main Steam	48
Feedwater	18
Residual Heat Removal	1
High Pressure Core Spray	2
Low Pressure Coolant Injection	8
Reactor Core Insulation Cooling	3
Total	110

Notes:

(a) Total per plant. General Electric has indicated that removal of approximately 40 percent of pipe whip restraints would be considered under the proposed rule change.

23

Table 2. Value-Impact Summary, PWR Reactor Coolant Loop Piping (Total for 85 Plants)[a]

Factors	Best Estimate	High Estimate	Low Estimate
Values (man-rem)			
Public Health	-2.8E-4	-1.8E+1	0
Occupational Exposure (Accidental)	-2.2E-3	-9.9	0
Occupational Exposure (Routine)	3.4E+4	1.1E+5	8.6E+3
Values Sub-Total	3.4E+4	1.1E+5	8.6E+3
Impacts ($)			
Industry Implementation Cost[b]	-1.1E+8	-1.7E+8	-5.6E+7
Industry Operating Cost	-1.6E+7	-1.8E+7	-1.4E+6
NRC Develop. & Implementation Cost	2.0E+5	3.0E+5	1.0E+5
NRC Operating Cost	0	0	0
Power Replacement Cost[c]	-6.0E+7	-9.0E+7	-3.0E+7
Offsite Property[d]	4.9E+1	7.6E+5	0
Onsite Property[d]	3.2E+1	1.3E+5	0
Impact Sub-Total	-186E+6	-277E+6	-87E+6
(w/o replacement power)	(-126E+6)	(-187E+6)	(-57E+6)

Notes:

(a) Primary reactor coolant loop piping only.
(b) Does not include industry costs expended to date to prepare plant fracture mechanics analyses.
(c) A-2 plants only.
(d) 10% discount factor.

24

Table 3. Value-Impact Summary, BWR Recirculation Loop Piping (Total for 38 Plants)[a]

Factors	Best Estimate	High Estimate	Low Estimate
Values (man-rem)			
Public Health	-1.7E-1	-8.3E+2	0
Occupational Exposure (Accidental)	-9.6E-4	-4.3	0
Occupational Exposure (Routine)	8.6E+3	1.1E+4	5.9E+3
Values Sub-Total	8.6E+3	1.0E+4	5.9E+3
Impacts ($)			
Industry Implementation Cost[b]	-1.5E+7	-2.8E+7	-9.5E+6
Industry Operating Cost	-4.3E+6	-7.4E+6	-2.6E+6
NRC Develop. & Implementation Cost		included in PWR summary	
NRC Operating Cost	0	0	0
Power Replacement Cost[c]	-8.1E+6	-3.0E+7	-2.4E+6
Offsite Property[d]	2.2E+1	3.4E+5	0
Onsite Property[d]	1.5E+1	6.1E+4	0
Impact Sub-Total	-30E+6	-65E+6	-15E+6
(w/o replacement power)	(-22E+6)	(-35E+6)	(-12E+6)

Notes:

(a) Reactor recirculation loop piping only.
(b) Does not include industry costs expended to date to prepare plant fracture mechanics analyses.
(c) Plants currently replacing or planning to replace recirculation piping.
(d) 10% discount factor.

25

T. 14

RESEARCH PROGRAMS ON

IN-SERVICE DEGRADATION OF CAST STAINLESS STEEL

MATERIALS ENGINEERING BRANCH
DIVISION OF ENGINEERING TECHNOLOGY

ACRS
MAY 23, 1985

Serpan

IN-SERVICE DEGRADATION OF CAST STAINLESS STEEL

OBJECTIVE:

PROVIDE AN INDEPENDENT ASSESSMENT OF THE EFFECT OF LONG-TIME SERVICE AT OPERATING TEMPERATURE ON TOUGHNESS LOSS OF CAST AUSTENITIC STAINLESS STEEL COMPONENTS FOR NUCLEAR SERVICE, AND EVALUATE POSSIBLE REMEDIES TO THE EMBRITTLEMENT PROBLEM FOR EXISTING AND FUTURE PLANTS.

Current NRC Research Program Seeks To:

- Characterize the microstructure of long–term in–service reactor components and low–temperature laboratory–aged specimens.
- Correlate the microstructural changes with loss in toughness.
  - Identify the mechanism of embrittlement.
  - Validate the extrapolation of experimentally observed embrittlement to long–term aging at reactor operating temperatures.
- Characterize the loss of fracture toughness in terms of fracture mechanics parameters such as the J_{IC} and J_R curves.
- Provide understanding of the effects of compositional and metallurgical variables on the kinetics and degree of embrittlement.

Background

- Bulk of data currently available are based on work by Swiss and French. Their results show that low–temperature aging of duplex stainless steels leads to:
  - Drastic reductions in room–temperatures impact strength (e.g., impact energy decreases from 280 to 40 J after ~ 8 y at 300°C of cast steel containing > 25% ferrite).
  - Decrease in J_{IC} fracture toughness; little data available on tearing modulus, but it also appears to decrease.
  - Relatively small increases in hardness and tensile strength.
  - Little or no effect on fatique crack propagation at low R.

- Much of the data obtained on cast materials with ferrite levels > 30%, chemical compositions outside the ASTM A–351 specifications, under accelerated aging conditions (i.e. temperature ~ 400°C).

Background (Continued)

- Time–temperature histories to produce equivalent aging expressed by

$$\text{Time} = 10^{P}\left[\exp\frac{U}{R}\left(\frac{1}{T}-\frac{1}{673}\right)\right]$$

  Where activation energy $U \simeq 24$ kCal/mole and 10^{P} is time in hours at 400°C.
- Degree of embrittlement at end of life depends strongly on ferrite level.
- Extrapolation of laboratory data to reactor temperatures requires a satisfactory understanding of the aging process.
- Precipitation of chromiun–rich phase (α') in ferrite matrix is believed to cause embrittlement at temperatures below 500°C. Three other precipitate phases in low–temperature aged material have also been observed in recent studies.

Background (Continued)

- Microstructural information on aged cast duplex steels is insufficient to ascertain the actual mechanism of embrittlement or to validate the activation energy for the overall process of embrittlement.

- Current estimates of activation energy (~ 24 kCal/mole) are lower than solute bulk diffusion (55 kCal/mole); indicates that precipitation of α' occurs not via nucleation and growth but by other mechanisms (e.g., spindol decomposition), or that processes other than α' precipitation contribute to embrittlement.

- Influence of ferrite morphology and distribution and the concentration of interstitial elements on aging adds uncertainty in predicting the long-term embrittlement of cast duplex steels.

ASTM Specification A-351 for Austenitic Steel Casting[a]

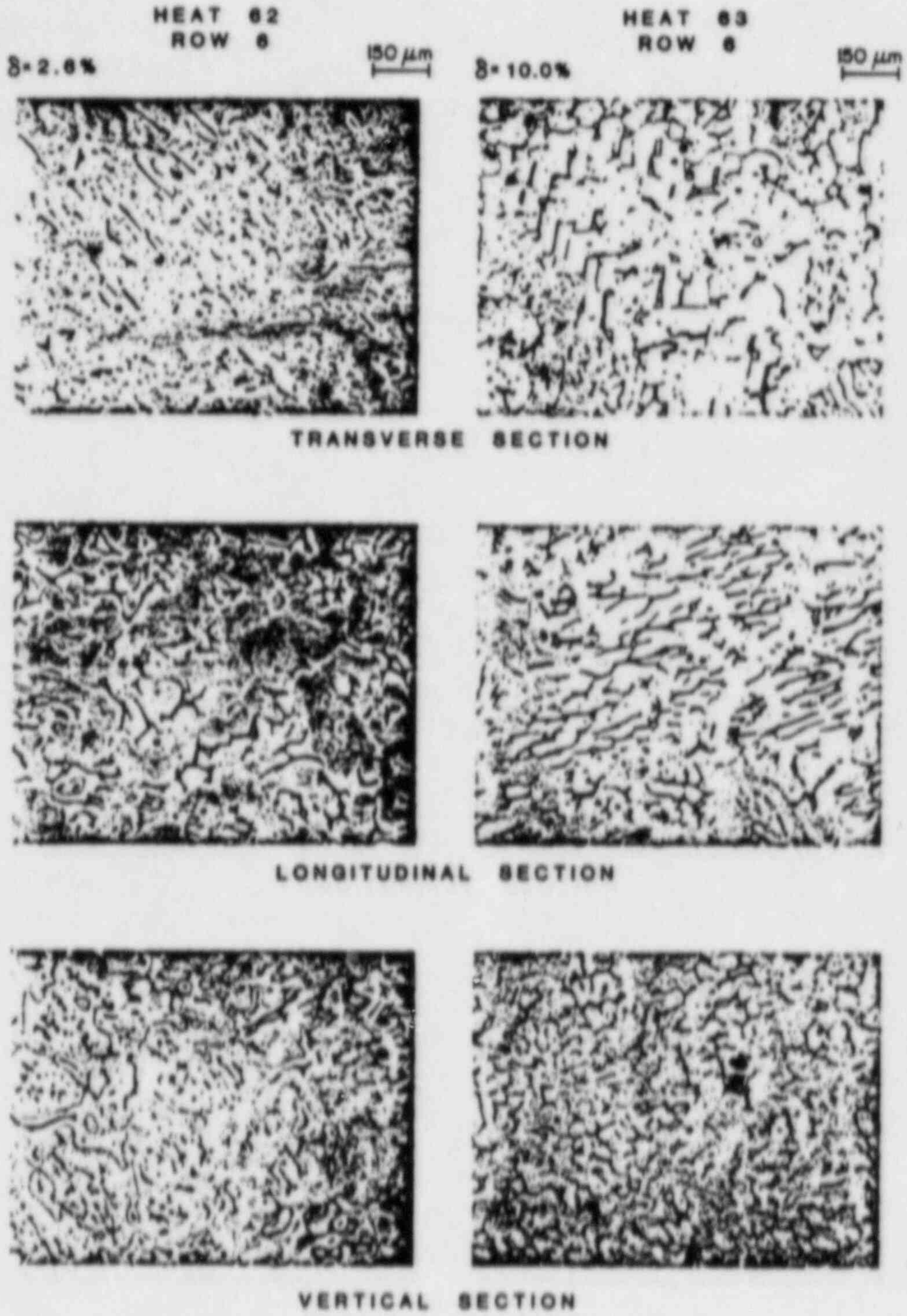
Grade	Chemical Composition (%)								Mechanical Properties, min		
	C	Mn	Si	S	P	Cr	Ni	Mo	Tensile (MPa)	Yield (MPa)	Elongation (%)
CF-3	0.03	1.50	2.00	0.04	0.04	17–21	8–12	–	483	207	35
CF-8	0.08	1.50	2.00	0.04	0.04	18–21	8–11	–	483	207	35
CF-8M	0.08	1.50	1.50	0.04	0.04	18–21	9–12	2–3	483	207	30

[a] Furnished in solution-treated condition.

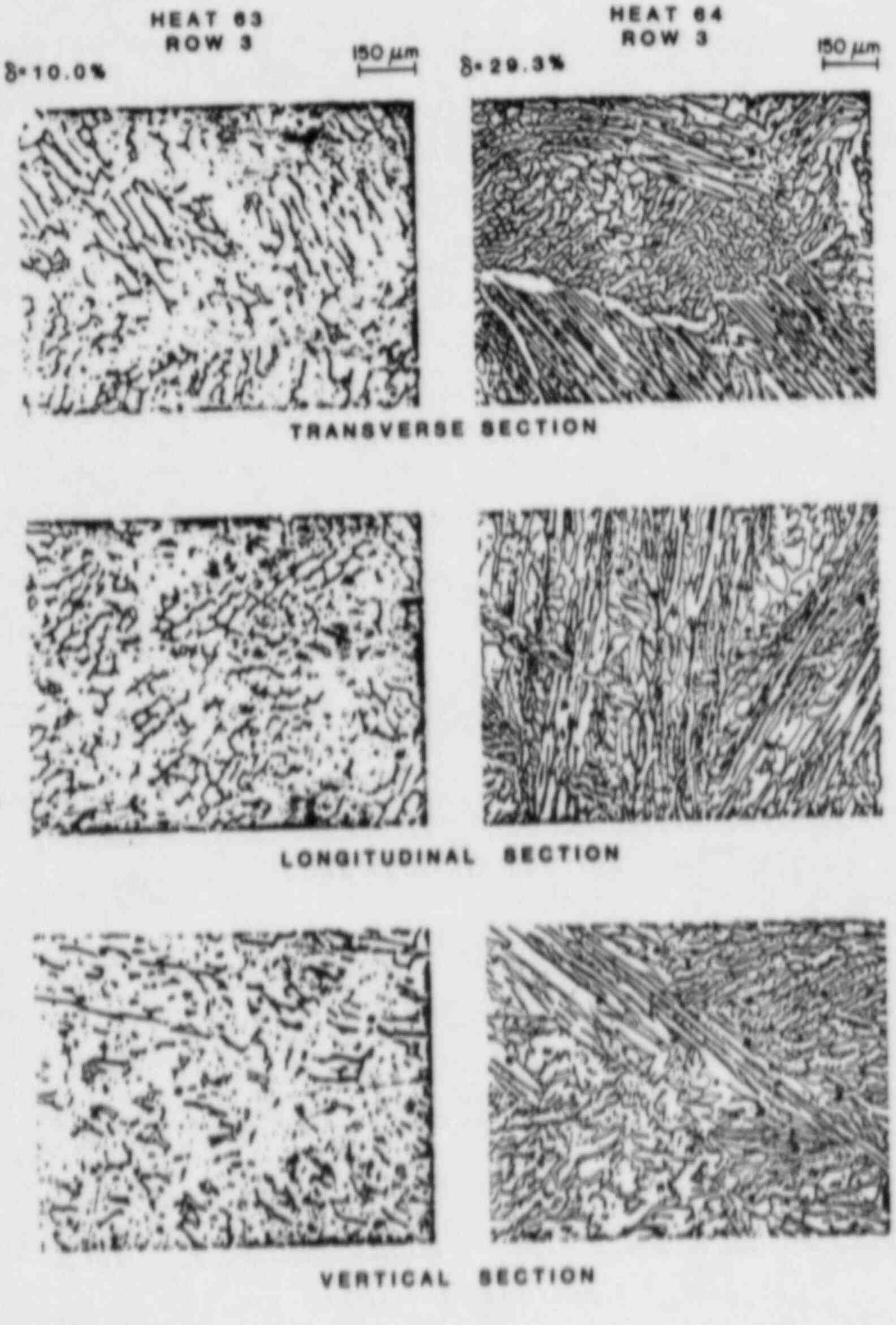
Chemical Composition and Ferrite Content of Various Heats of Cast Stainless Steel

Heat	Location	Grade	Composition, wt.%									Ferrite Content, %	
			Mn	Si	P	S	Mo	Cr	Ni	N	C	Measured[a]	Calculated[b]
							Cast Keel Blocks						
58	Row 6	CF-8	0.62	1.12	0.010	0.005	0.33	19.53	10.89	0.040	0.056	2.1	3.2
57			0.62	1.08	0.009	0.004	0.34	18.68	9.27	0.047	0.056	2.8	4.4
54			0.55	1.03	0.011	0.005	0.35	19.31	9.17	0.084	0.063	2.3	4.1
53			0.64	1.16	0.012	0.009	0.39	19.53	9.23	0.049	0.065	7.8	6.3
56			0.57	1.05	0.007	0.007	0.34	19.65	9.28	0.030	0.066	8.2	7.3
59			0.60	1.08	0.008	0.007	0.32	20.33	9.34	0.045	0.062	12.7	8.8
61			0.65	1.01	0.007	0.007	0.32	20.65	8.86	0.080	0.054	13.1	10.0
60			0.67	0.95	0.008	0.006	0.31	21.05	8.38	0.058	0.064	21.7	15.2
50		CF-3	0.60	1.10	0.016	0.007	0.33	17.89	9.14	0.080	0.034	3.7	3.0
49			0.60	0.95	0.010	0.007	0.32	19.41	10.69	0.065	0.010	6.3	4.4
48			0.60	1.08	0.009	0.006	0.30	19.55	10.46	0.072	0.011	8.5	5.0
47			0.60	1.06	0.007	0.006	0.59	19.81	10.63	0.028	0.018	16.2	8.7
52			0.57	0.92	0.012	0.005	0.35	19.49	9.40	0.052	0.009	16.7	10.3
51			0.63	0.86	0.014	0.005	0.32	20.13	9.06	0.058	0.010	18.0	14.3
62		CF-8M	0.72	0.56	0.007	0.005	2.57	18.29	12.39	0.030	0.063	2.6	2.8
63			0.61	0.58	0.007	0.006	2.57	19.37	11.85	0.031	0.055	10.0	6.4
66			0.60	0.49	0.012	0.007	2.39	19.45	9.28	0.029	0.047	20.5	19.6
65			0.50	0.48	0.012	0.007	2.57	20.78	9.63	0.064	0.049	25.4	20.9
64			0.60	0.63	0.006	0.005	2.46	20.76	9.40	0.038	0.038	29.3	29.0
							Cast Components						
C1	O.D.	CF-8	1.22	1.19	0.036	0.008	0.64	19.10	9.32	0.041	0.036	2.3	8.6
	I.D.		1.22	1.17	0.030	0.008	0.65	18.89	9.42	0.040	0.041	1.7	7.1
P1	O.D.		0.56	1.07	0.028	0.014	0.04	20.38	8.00	0.053	0.032	27.6	18.9
	I.D.		0.61	1.17	0.024	0.012	0.04	20.60	8.20	0.060	0.040	19.5	16.5
P3	O.D.	CF-3	1.04	0.86	0.014	0.015	0.01	18.93	8.33	0.159	0.020	2.5	3.3
	I.D.		1.08	0.89	0.020	0.012	0.01	18.85	8.56	0.176	0.022	0.9	2.4
P2	O.D.		0.72	0.92	0.019	0.005	0.16	20.20	[illegible].24	0.041	0.020	15.9	13.0
	I.D.		0.75	0.95	0.018	0.006	0.16	20.20	[illegible].51	0.040	0.019	13.2	11.8
I	Vane 3		0.46	0.80	0.021	0.012	0.44	20.08	8.50	0.030	0.016	20.2	22.3
	Vane 1		0.48	0.85	0.029	0.009	0.46	20.20	8.80	0.035	0.022	14.3	18.6
	Shroud		0.47	0.82	0.036	0.012	0.44	20.34	8.64	0.029	0.021	16.9	21.9
P4	O.D.	CF-8M	1.07	1.02	0.022	0.015	2.06	19.63	10.00	0.153	0.039	11.1	5.9
	I.D.		1.06	1.01	0.016	0.014	2.04	19.65	9.99	0.149	0.041	9.8	6.0

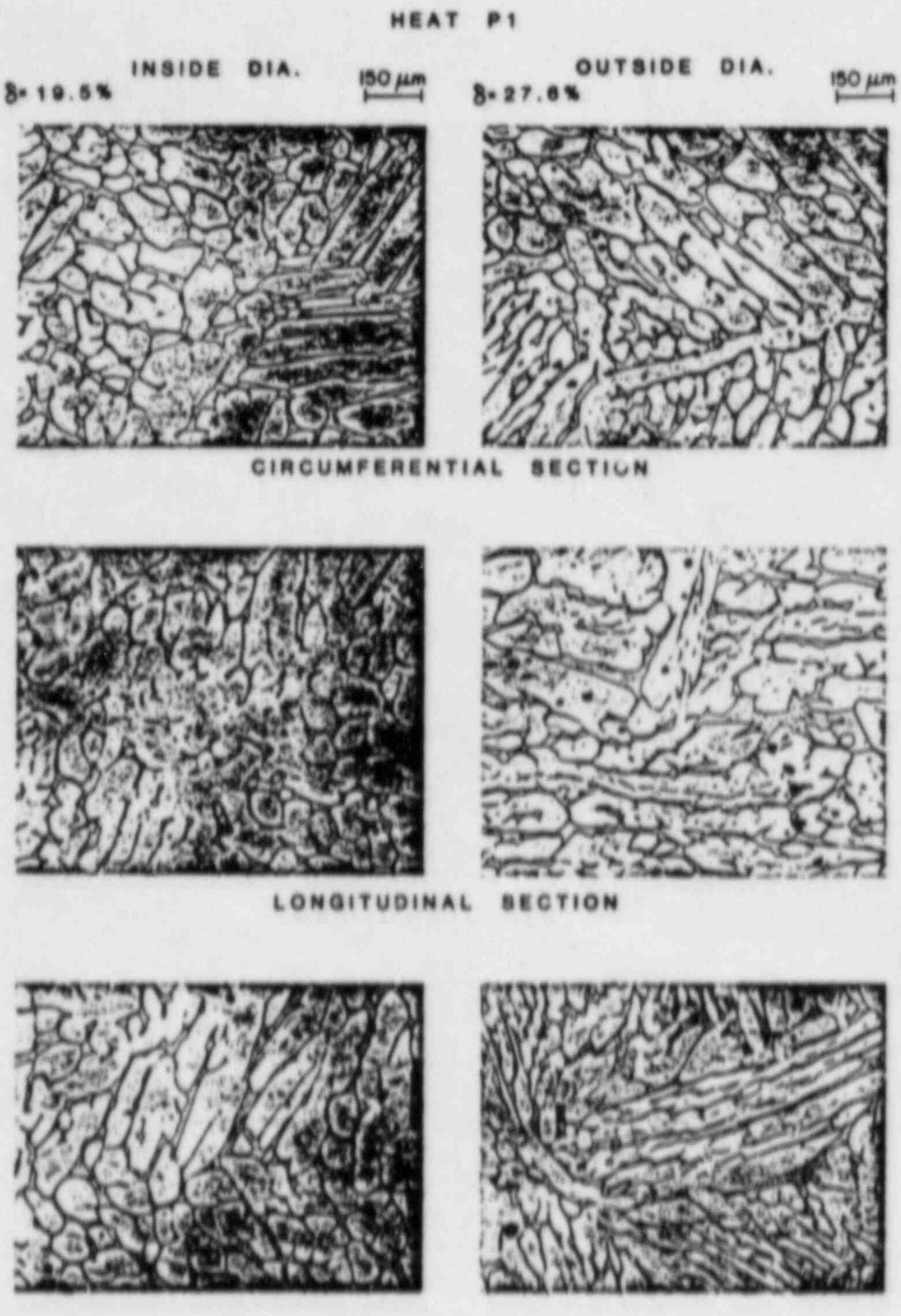
[a] Ferrite content measured by Ferrite Scope, Auto Test FE, Probe Type FSP-1.
[b] Calculated from the composition using Hull's equivalent factor.



Globular and lacy ferrite in static cast CF-8M steel.

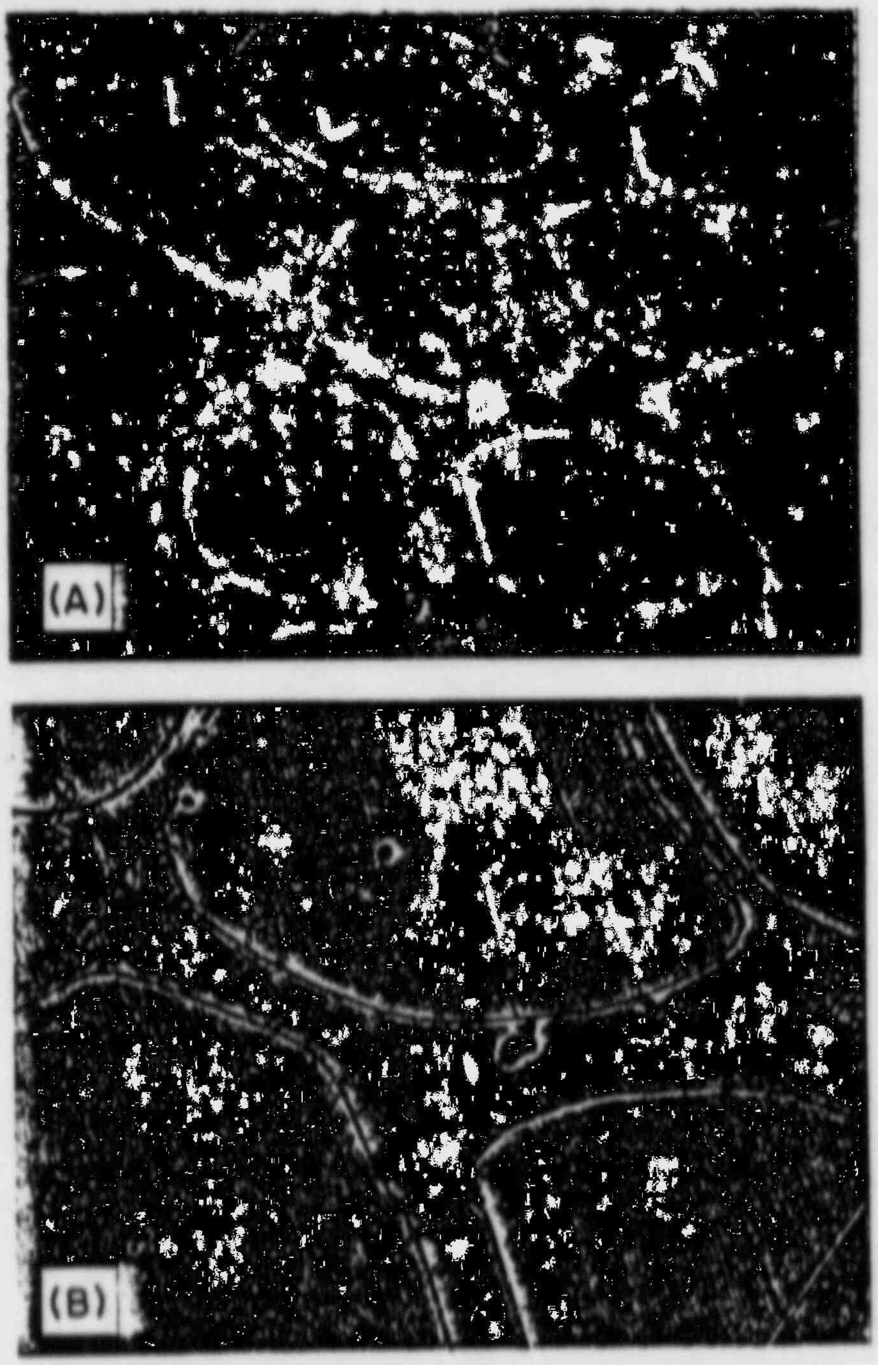


Lacy ferrite (Heat 63) and mixture of lacy and acicular ferrite in static cast CF-8M steel.



Lacy ferrite in centrifugally cast pipe of CF-8 steel.

SIGNIFICANT RESULTS (CONT'D)



Optical micrographs of the KRB BWR pump casing material showing (A) the morphology of ferrite surrounding the austenite grains, (B)nearly continuous precipitates on the austenite-ferrite grain boundaries.

Time and Temperature for Aging+ of the Cast Material for Charpy Impact, Tensile and J–Integral Tests

Time, h	Temperature, °C				
	450	400	350	320	290
100	A	A			
300	A	A	A		
1,000	A	A	A	A	
3,000	A,B	A,B	A,B	A	A
10,000	A	A,B	A,B,C	A,B,C	A
30,000	A	A	A,B,C	A,B,C	A,B,C
>50,000		A	A,B,C	A,B,C	A,B

+Aging time completed for the small experimental heats and reactor components = 12,000 h and for large experimental heats = 5,000 h.

A = Charpy impact test at room temperature.

B = Charpy impact test at different temperatures (DBTT) and J–integral (1–T specimens) and tensile tests at room temperature and 290°C.

C = J–integral (2–T specimens) tests at room temperature or 290°C.

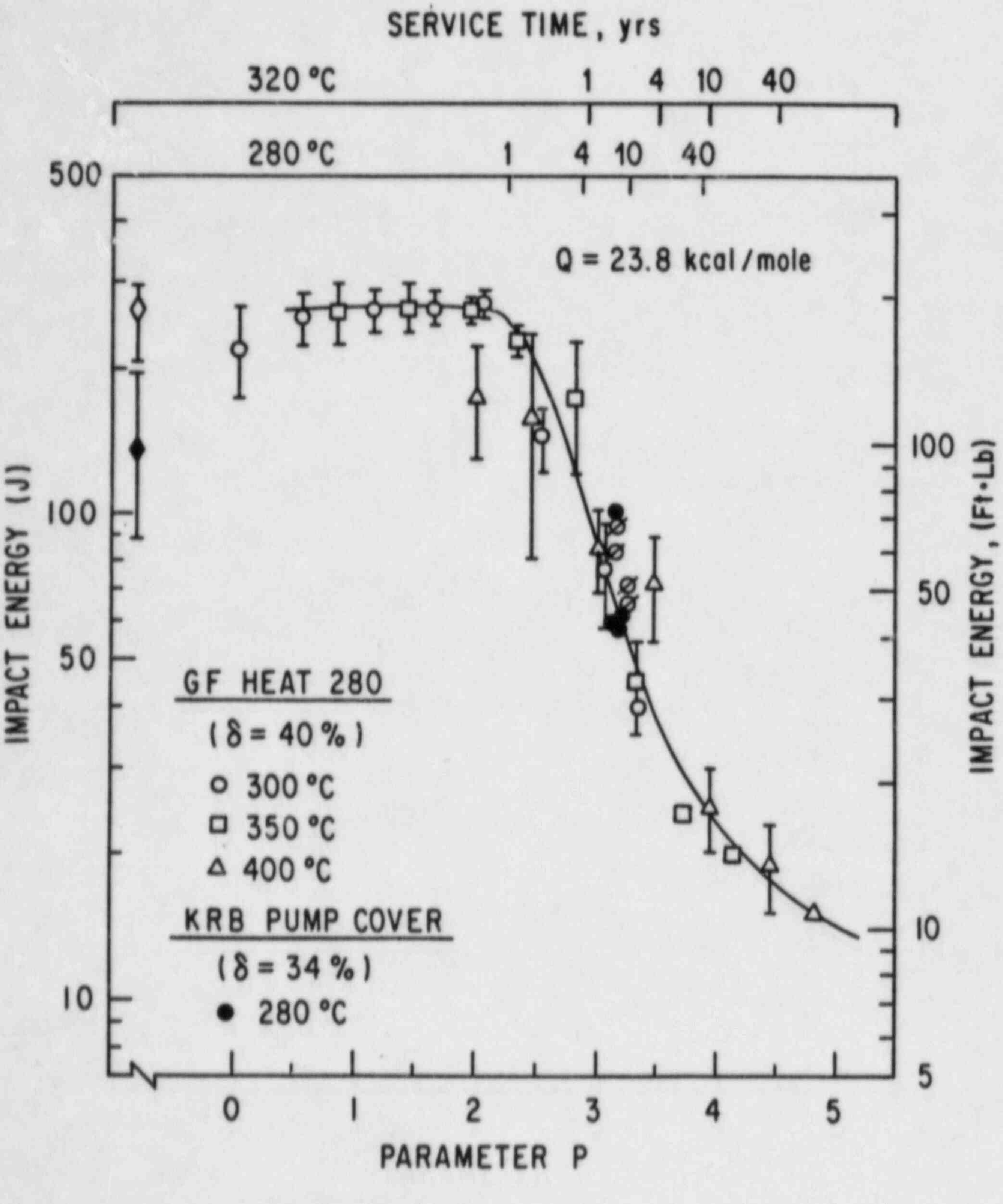
Test Matrix for J-R Curve and Tensile Tests at MEA

Heat	Grade	Product Form	Process	Ferrite Content (%)	Aging Condition		Mechanical Tests			
					Temp. (°C)	Time (h)	J-R Curve		Tensile	
							RT	290°C	RT	290°C
P1	CF-8	Pipe	Centr.	24	Unaged		3	2	4	4
					350	10,000	3	2	4	4
					350	10,000	2	1	2	2
P2	CF-3	Pipe	Centr.	16	Unaged		3	2	4	4
					350	3,000	2	1	2	2
					350	10,000	2	1	2	2
					400	10,000	2	1	2	2
I	CF-3	Pump Impeller	Static	18	Unaged		3	2	5	5
					350	10,000	3	2	3	3

Charpy Impact Data Obtained at Room Temperature for Thermally Aged Cast Stainless Steel

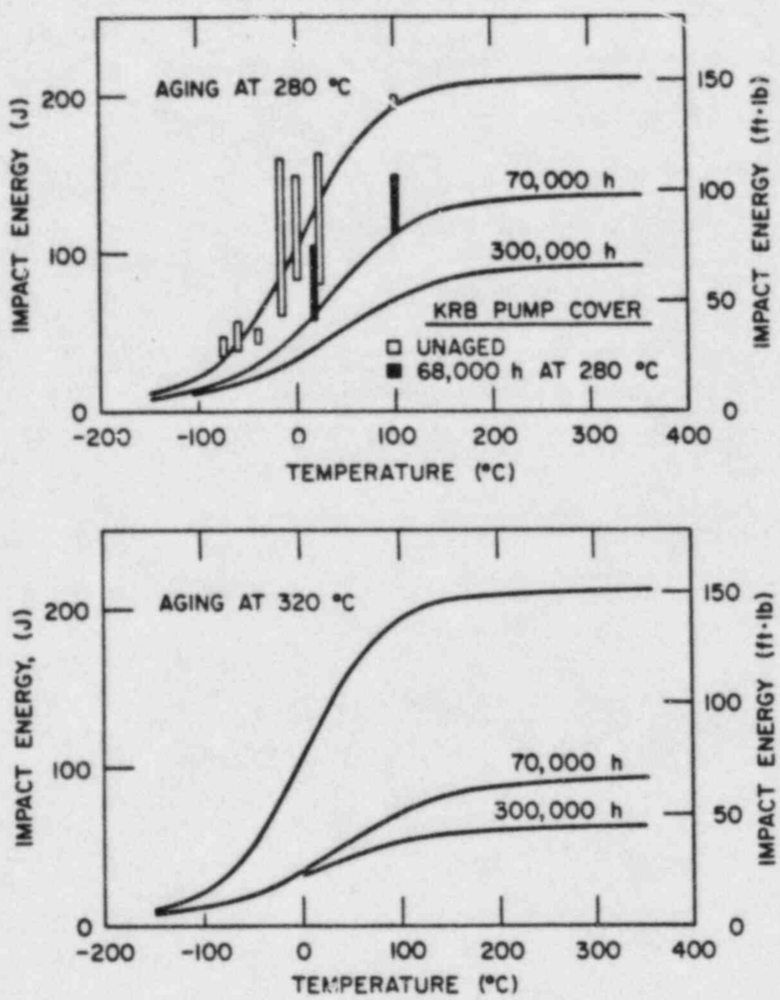
Heat	Ferrite Content, %	Impact Energy,* J			
		Unaged	Aged for 3000 h at 350°C	400°C	450°C
		CF-8			
56	10.1	181	158	146	114
59	13.5	201	146	143	103
61	13.1	222	165	161	108
60	21.1	173	162	69	50
C1	2.2	49	44	49	50
P1	24.1	201	164	48	55
		CF-3			
47	16.3	203	196	165	152
52	13.5	219	207	191	169
51	18.0	177	179	142	136
P3	1.9	264	247	324	348
P2	15.6	335	278	232	164
I	17.6	167	168	–	112
		CF-8M			
63	10.4	220	180	136	137
66	19.9	195	181	121	95
65	23.4	196	152	54	53
64	28.4	176	129	42	44
P4	10.4	184	115	78	37

*Impact tests performed on instrumented drop-weight impact machine using V-notch impact bars (ASTM specification E-23).



Effect of thermal aging on the room-temperature impact energy of cast CF-8 stainless steel containing >30% ferrite. Slashed symbols represent tests for material from the flange of the cover plate.

7-7



Predicted DBTT curves for CF8 steel aged at 280 and 320°C. Thermal aging effects are assumed to be the same as for the G. Fisher Heat 280N.

- Actual mechanism of embrittlement still unclear.

- Microstructural changes are not observed under TEM examination during the early stages of embrittlement (i.e., when RT impact energy starts to decrease).

- Status of the present understanding of the embrittlement of ferrite phase may be summarized as follows:

	Phase	Possible Mechanism of Formation	Effects of Deformation
α'	BCC, Cr-rich	Spinodal	Unlikely to influence in the early stages of formation
M	FCC, rich in Ni & Si	Nucleation & growth	Pinning of dislocations
X	Unknown	Nucleation & growth forms preferentially on dislocations	"

- Atom probe, small angle neutron scattering, or neutron diffraction techniques can provide additional information.

- Fracture behavior of the duplex cast structure depends on the morphology and distribution of the "embrittled" ferrite phase.

- Influence of additional precipitates at the ferrite/austenite boundaries is not known.

T.15

SUMMARY

Argonne National Laboratory

- Data being obtained on 26 experimental and 6 commercial heats as well as reactor aged material of CF-3, -8, and -8M cast duplex stainless steels. Ferrite contents range from 3 to 30%.
- Material characterization of the various materials has been completed.
- Mechanical test specimens being aged at 290, 320, 350, 400, and 450°C.
- RT Charpy tests completed for materials aged up to 3000 h at 320, 350, 400, and 450°C.
- Initial data indicate the influence of interstitial content (C,N) and cast structure on the embrittlement behavior.
- J-R curve and tensile tests are in progress on 3 commercial heats of material aged for 3,000 and 10,000 h at 350 and 400°C.
- Microstructural characterization performed on 3 heats of thermally aged material from Swiss study and the KRB pump cover material.
    - All low-temperature aged materials show Type M and X precipitates.
    - α' phase observed in KRB material but not in the Swiss specimens. The predominance of α' phase probably depends on the Ni/Cr ratio in the ferrite phase.
    - The ferrite phase shows cleavage fracture for RT Charpy specimens aged for ~8 y at 300°C or >1.2 y at 400°C. Amount of cleavage fracture is more than the ferrite content in the steel (e.g., ~60% cleavage fracture for KRB material with ~26% ferrite).

SUMMARY

SWISS

- Data obtained on 18 heats of static cast CF8 and CF8M cast duplex steels (ferrite content $\sim$40% for 7 heats, $\sim$30% for 6 heats, 10-15% for 3 heats, and 6 and 22% for 1 heat each) aged up to 70,000 h at 300, 350, and 400°C.

- For materials aged at 400°C, RT impact energy decreases from $\sim$250 J to $\sim$15 J for >25% ferrite; to $\sim$40 J for $\sim$12% ferrite; to $\sim$100 J for 6% ferrite.

- At temperatures between 300-400°C, embrittlement behavior is uniform and represented by an activation energy of $\sim$24 kcal/mole.

- Aging shifts the ductile to brittle transition to higher temperatures and lowers the upper shelf energy.

SUMMARY

FRENCH

- Data obtained on 8 static cast and 4 centrifugally cast CF8 and CF8M cast duplex steels (ferrite content ∿22% for 3 heats, 14-18% for 6 heats, 12% for 1 heat, and ∿8% for 2 heats) and 8 stainless steel welds (ferrite numbers 6 to 18) aged up to 28,000 h at 300, 350, and 400°C.

- Impact energy and J_{IC} values are significantly lowered by aging (J curve data from 7,500 h at 400°C or 3,000 h at 427°C.

- Fatigue crack propagation and low-cycle fatigue properties not significantly modified.

- Developed correlations (using Swiss data) to predict end-of-life Charpy impact toughness for a component of given chemical composition and ferrite content. Kinetic data indicate that

  40 y at 290°C $\simeq$ 10,000 h at 400°C - cold leg

  and

  40 y at 320°C $\simeq$ 30,000 h at 400°C - hot leg.

  NOTE: Predictions are based on 400°C data.

- For most cast steels used in French plants the calculated Charpy impact energy values are >30 J/cm^2 at end of life.

- A conservative lower bound value of J_{IC} is expected to be 100 kJ/m^2 (570 in.-lb/in.^{2}).

SUMMARY

WESTINGHOUSE

- Data obtained on 3 heats of centrifugally cast pipe of CF8M cast duplex steel (ferrite contents 13, 14 and 21%) aged up to 3000 h at 427°C.

- Significant reductions in Charpy-V toughness but changes in J_{IC} not as severe.

- Fatigue crack growth not affected by aging.

- Aging leads to significant increase in Charpy V-notch transition temperature.

- Charpy energy has little correlation with the failure mode in cast stainless steels. Failure characteristics of the piping are not significantly changed by thermal aging process.

  NOTE: This conclusion based on results from 4 point bond test on CF8M pipe containing throughwall flaws at mid-span and pressurized to 2250 psi. Material contained 13% ferrite and aged 2000 h at 427°C (~10 y at 300°C).

PRESENTATION OUTLINE

O'Brien

1. NATURE OF ISSUE
2. TECHNICAL DEVELOPMENTS
3. TECHNICAL AND LEGAL REMARKS
4. RECOMMENDATIONS
5. SUMMARY

NATURE OF ISSUE

- O GDC-4 REQUIRES POSTULATION OF PIPE RUPTURES IN PRIMARY LOOPS OF PWRS; THIS REQUIREMENT HAS CONSERVATIVELY BEEN INTERPRETED AS A DOUBLE-ENDED GUILLOTINE BREAK (DEGB).
- O VALIDATED NEW TECHNOLOGY DEMONSTRATES THAT SUCH DEGBS ARE EXTREMELY UNLIKELY.
- O DYNAMIC EFFECTS ASSOCIATED WITH POSTULATED DEGBS REQUIRE PIPE WHIP RESTRAINTS AND JET IMPINGEMENT BARRIERS.
- O INSTALLATION OF THESE PROTECTIVE DEVICES MAY DEGRADE OVERALL SAFETY IF IMPROPERLY INSTALLED.
- O EXEMPTIONS TO GDC-4 HAVE BEEN GRANTED FOR COMANCHE PEAK, UNIT 1, AND VOGTLE, UNITS 1 AND 2.
- O APPLICANTS/LICENSEES FOR NINETEEN NTOL UNITS AND FOUR OPERATING UNITS HAVE REQUESTED EXEMPTIONS. THIS IS IN ADDITION TO THE THREE UNITS WHICH HAVE BEEN GRANTED EXEMPTIONS.

TECHNICAL DEVELOPMENTS

- O DOUBLE ENDED GUILLOTINE BREAK OF PRIMARY LOOP PIPING IN LWRS ORIGINALLY POSTULATED AS "MAXIMUM HYPOTHETICAL ACCIDENT".

- O MAXIMUM HYPOTHETICAL ACCIDENT BECOMES DESIGN BASIS ACCIDENT. THIS IS BELIEVED TO BE CONSERVATIVE, BUT IS NOT BASED ON TECHNICAL INFORMATION.

- O CONSEQUENCES OF THE PRESUMED REALITY OF DOUBLE ENDED PIPE RUPTURE ARE PLACEMENT OF MASSIVE PIPE WHIP RESTRAINTS AND JET IMPINGEMENT BARRIERS. ALSO, ASYMMETRIC BLOWDOWN LOADS ON REACTOR PRESSURE VESSEL AND OTHER STRUCTURES AND COMPONENTS RESULT. THESE NEW LOADS WERE FIRST RECOGNIZED IN 1975.

- O IN RESPONSE TO THE ASYMMETRIC BLOWDOWN PROBLEM, INVESTIGATIONS WERE UNDERTAKEN BY INDUSTRY AND THE NRC TO DETERMINE THE LIKELIHOOD OF PIPE RUPTURES IN PRIMARY LOOPS OF PWRS. RESULTS OF INDUSTRY AND NRC STUDIES PROVIDE STRONG EVIDENCE THAT SUCH PIPE RUPTURES ARE EXTREMELY IMPROBABLE.

TECHNICAL DEVELOPMENTS (CONTINUED)

- O BOTH DETERMINISTIC AND PROBABILISTIC METHODS OF ADVANCED FRACTURE MECHANICS ARE USED IN THE INVESTIGATIONS. STUDIES OF POTENTIAL INDIRECT FAILURE MECHANISMS WHICH COULD LEAD TO PIPE RUPTURE ARE INCLUDED.

- O GENERAL ACCEPTANCE OF FINDINGS HAS LED TO AN ALTERNATE METHOD FOR RESOLVING THE ASYMMETRIC LOADS PROBLEM AND THE ISSUANCE OF GENERIC LETTER 84-04 WHICH ADVISED UTILITIES THAT EXEMPTIONS FROM GDC-4 WOULD BE NEEDED TO REMOVE PROTECTIVE DEVICES. ALL BREAK LOCATIONS ON ALL PWR PRIMARY LOOPS ARE COVERED BY GENERIC LETTER 84-04.

- O USE OF EXEMPTIONS PRESENTS LEGAL PROBLEMS, THEREFORE NECESSITATING THIS RULEMAKING.

TECHNICAL AND LEGAL REMARKS

- O ONLY DYNAMIC EFFECTS FROM PIPE RUPTURE ARE EXCLUDED BY THIS RULEMAKING, ECCS PERFORMANCE AND CONTAINMENT DESIGN WILL STILL BE BASED ON THE EQUIVALENT OF A DOUBLE ENDED PIPE RUPTURE OF PRIMARY LOOP PIPING. PRESENT SCOPE IS LIMITED TO REACTOR COOLANT LOOPS OF PWRS.

- O THIS RULEMAKING COULD REDUCE OCCUPATIONAL RADIATION EXPOSURES BY AMOUNTS MEASURED IN TENS OF THOUSANDS OF MAN-REM. ALSO, EFFECTIVENESS OF INSERVICE INSPECTION IS INCREASED, LEADING TO GREATER ASSURANCES THAT SAFETY WILL BE MAINTAINED.

- O COST SAVINGS EXCEED $100 MILLION DUE TO REDUCED CONSTRUCTION AND MAINTENANCE EXPENDITURES.

RECOMMENDATIONS

- O A REINTERPRETATION OF THE EXISTING TEXT OF GDC-4 TO ACHIEVE THE REMOVAL OF PIPE WHIP RESTRAINTS AND JET IMPINGEMENT BARRIERS WOULD BE INAPPROPRIATE BECAUSE RULEMAKING IS NECESSARY TO JUSTIFY THE DEPARTURE FROM LONG-STANDING PAST PRACTICES.

- O CONTINUED USE OF EXEMPTIONS IS LEGALLY UNACCEPTABLE AND THE USE OF PLANT SPECIFIC EXEMPTIONS TO THE REGULATIONS ENTAILS SIGNIFICANT ALLOCATION OF NRC RESOURCES.

- O APPROVAL OF THIS RULEMAKING SECURES THE LEGAL BASIS FOR STAFF ACTIONS, REMOVES IMPEDIMENTS TO THE APPLICATION OF NEW TECHNOLOGY IN THE LICENSING ARENA AND PROMOTES INVESTIGATIONS ON THE SCOPE OF AFFECTED PIPING.

SUMMARY

- O SUFFICIENT TECHNICAL EVIDENCE HAS BEEN ACCUMULATED TO PROMOTE WIDESPREAD ACCEPTANCE AND INCREASING CONFIDENCE IN THE APPLICABILITY OF THE TECHNOLOGY SUPPORTING ELIMINATION OF DEGB.

- O ALTHOUGH NOT PERMITTED EXCEPT BY EXEMPTION, THIS NEW TECHNOLOGY REFLECTS AN ENGINEERING ADVANCE WHICH ALLOWS SIMULTANEOUSLY AN INCREASE IN SAFETY, REDUCED WORKER RADIATION EXPOSURES AND LOWER CONSTRUCTION AND MAINTENANCE COSTS.

NRR STAFF PRESENTATION TO THE ACRS

17+18

SUBJECT: AGED CAST STAINLESS STEEL

DATE: MAY 23, 1985

PRESENTER: Dr. William V. Johnston

PRESENTER'S TITLE/BRANCH/DIV: Assistant Director for Materials, Chemical & Environmental Technology
Division of Engineering

PRESENTER'S NRC TEL. NO.: 492-7331

SUBCOMMITTEE: Metals Components and Structural Engineering

AGING OF CAST STAINLESS STEEL

PROCESS - PRECIPITATION OF CHROMIUM RICH ALPHA PRIME (α') IN THE FERRITE PHASE OF THE DUPLEX STRUCTURED (AUSTENITE AND FERRITE) MATERIAL

SUMMARY

EFFECT OF AGING ON MECHANICAL PROPERTIES OF CAST STAINLESS STEEL AND WELD METAL

EFFECT OF AGING:

ON TENSILE PROPERTIES OF CAST STAINLESS STEEL

- SLIGHT INCREASE IN YIELD STRENGTH AND ELONGATION
- SIGNIFICANT DECREASE IN REDUCTION OF AREA
- SIGNIFICANT INCREASE IN ULTIMATE TENSILE STRENGTH

ON FATIGUE PROPERTIES OF CAST STAINLESS STEEL

- NO SIGNIFICANT EFFECT

ON IMPACT PROPERTIES OF CAST STAINLESS STEEL

- SIGNIFICANT DECREASE IN ABSORBED ENERGY

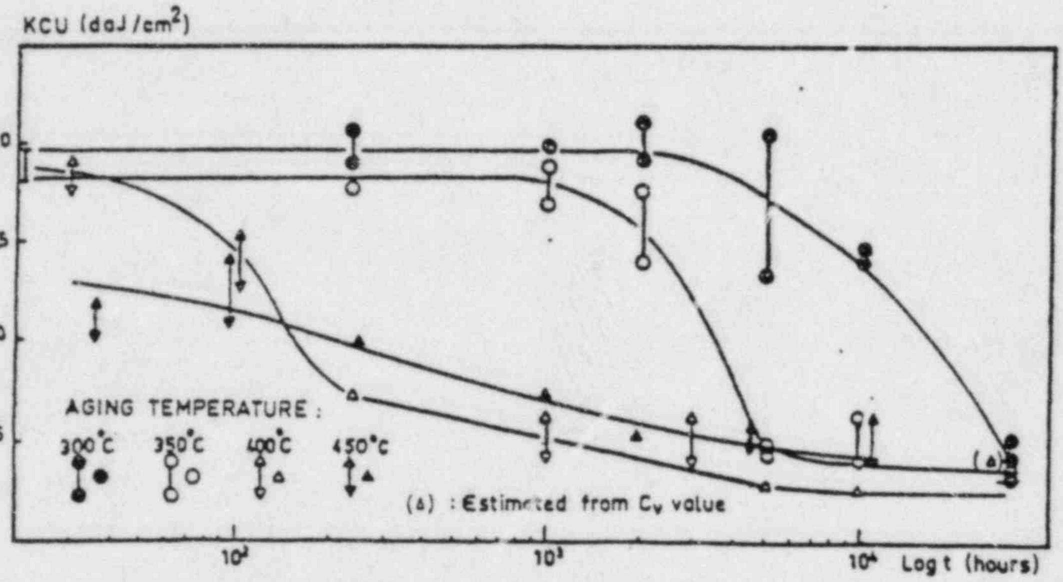
ON FRACTURE PROPERTIES OF CAST STAINLESS STEEL

- J_{IC} AND T DECREASES, BUT NOT AS SIGNIFICANTLY AS IMPACT PROPERTIES

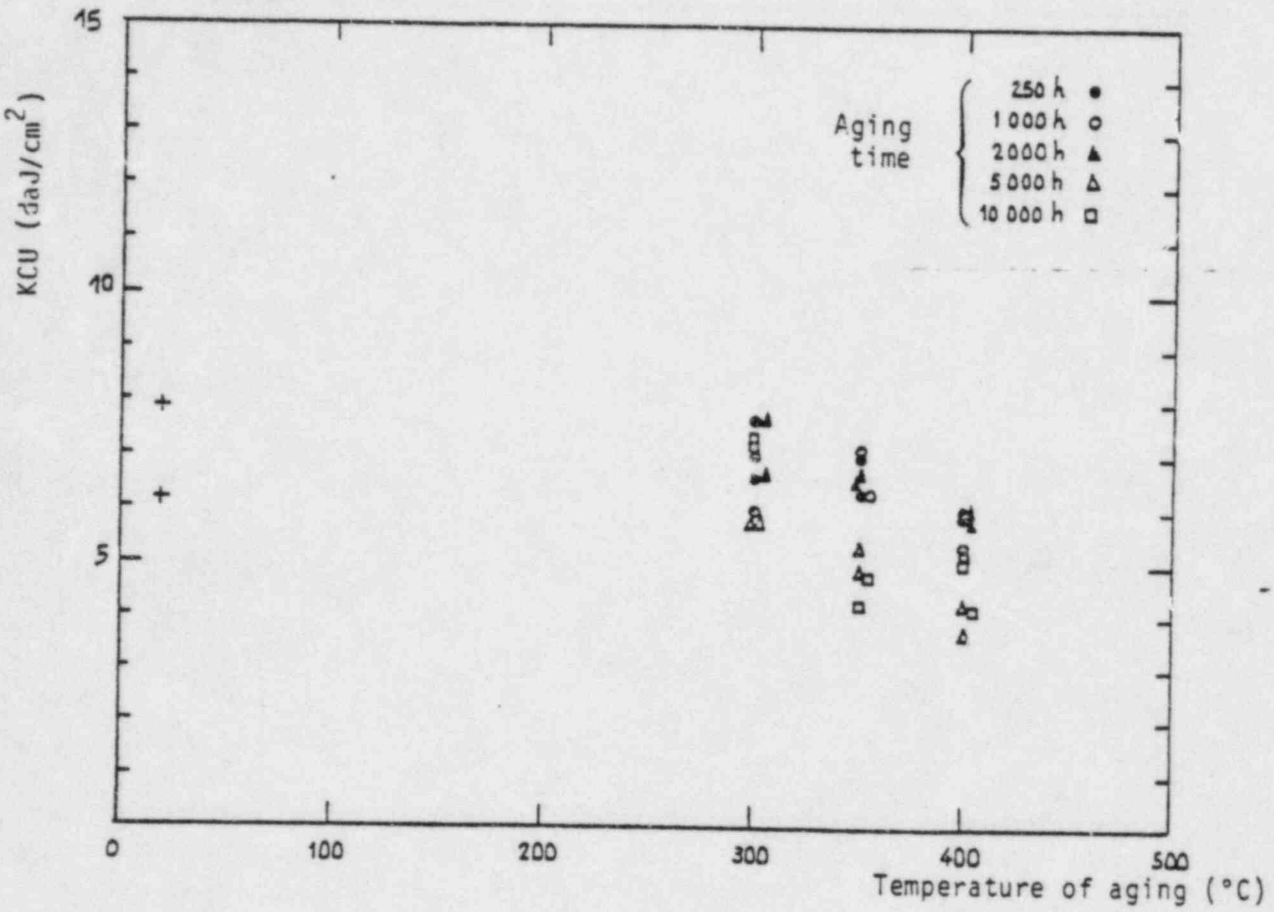
ON WELD METAL

- YIELD STRENGTH, TENSILE STRENGTH, ELONGATION, REDUCTION IN AREA AND CHARPY IMPACT TOUGHNESS VARY SLIGHTLY

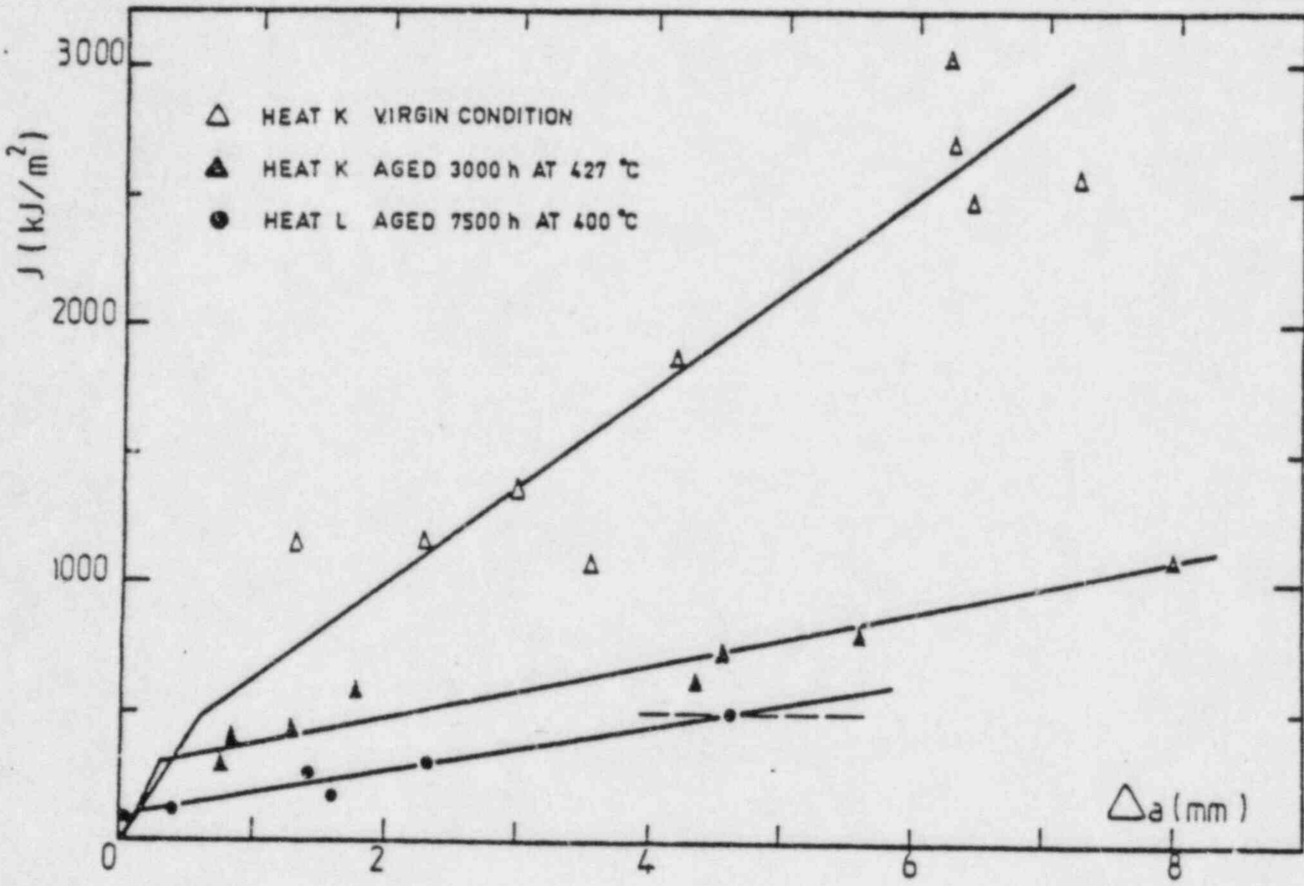
G. SLAMA, P. PETREQUIN, S. H. MASSON AND T. R. MAGER, "EFFECT OF AGING ON MECHANICAL PROPERTIES OF AUSTENITIC STAINLESS STEEL CASTING AND WELDS," - PRESENTED AT SMIRT 7 POST CONFERENCE SEMINAR 6 - ASSURING STRUCTURAL INTEGRITY OF STEEL REACTOR PRESSURE BOUNDARY COMPONENTS, AUGUST 29/30, 1983, MONTEREY, CA.



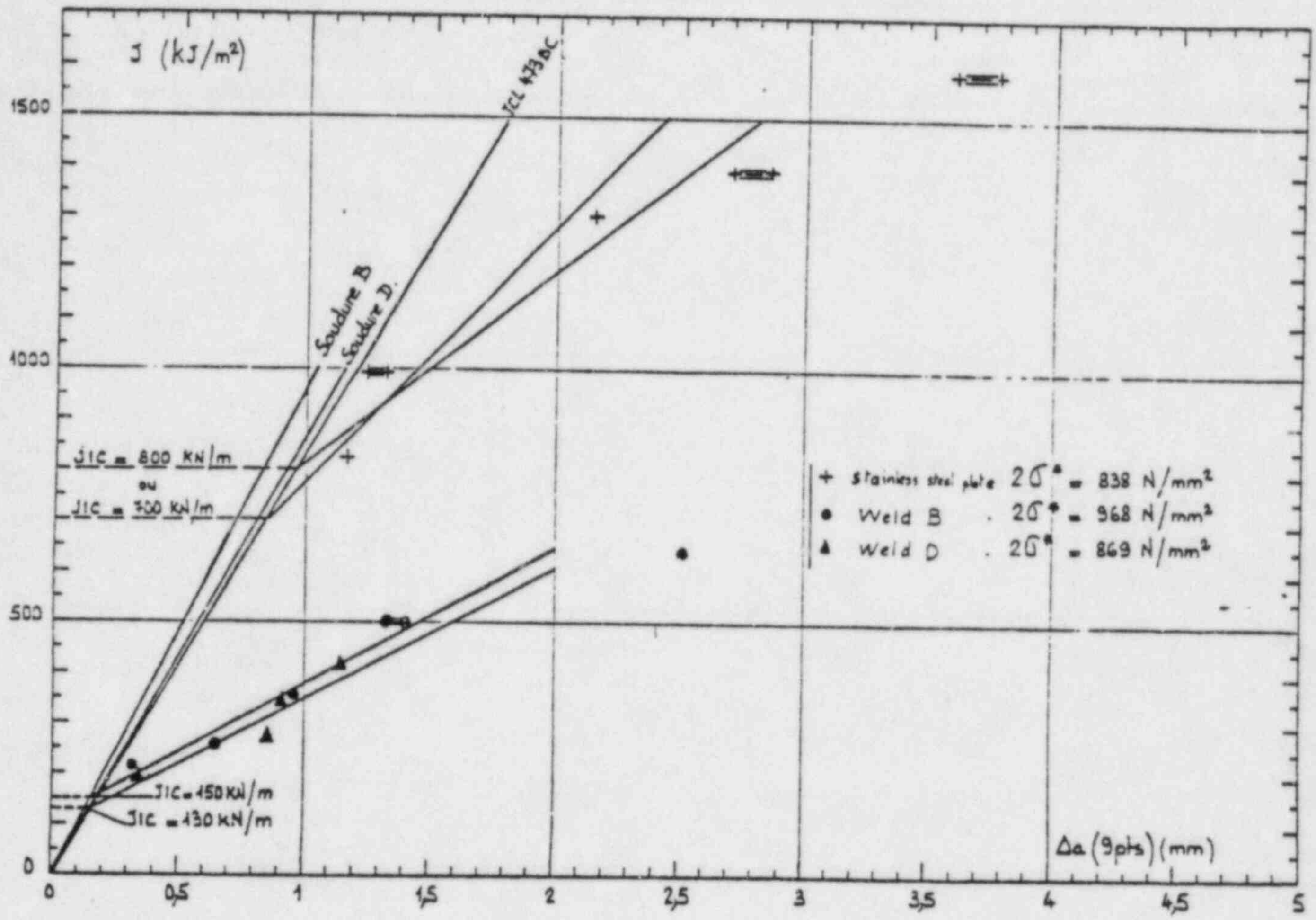
INFLUENCE OF AGING ON IMPACT CHARPY TOUGHNESS (KCU) OF CAST STAINLESS STEEL, HEAT B



INFLUENCE OF AGING ON IMPACT CHARPY TOUGHNESS (KCU) OF WELD METAL (E308L)



J-Δa Curves for virgin and aged cast stainless steels.



J-Δa Curves for welds B and D.

Room temperature (interrupted tests)

MATERIAL PROPERTIES AND LIMITING LOAD USED BY THE STAFF TO EVALUATE AGED CAST STAINLESS STEEL PIPING

- J_{MAX} = 3000 IN-LBS/IN^2
- T = 40
- J_{1C} = 570 IN-LBS/IN^2
- IMPACT PROPERTIES ARE USED AS A MEASURE OF RELATIVE EMBRITTLEMENT

WESTINGHOUSE PROPRIETARY

EVALUATION OF LEAK-BEFORE-BREAK FOR WESTINGHOUSE
CENTRIFUGALLY CAST STAINLESS STEEL

References:

Ref. 1 - WCAP-10456, "The Effects of Thermal Aging on the Structural Integrity of Cast Stainless Steel Piping for Westinghouse Nuclear Steam Supply Systems," Nov. 1983.

Ref. 2 - WCAP-10699, "Technical Bases for Eliminating Large Primary Loop Pipe Rupture as a Structural Design Bases for Shearon Harris Unit 1,", Sept. 1984.

Ref. 3 - WCAP-9558, Rev. 2, "Mechanistic Fracture Evaluation of Reactor Coolant Pipe Containing a Postulated Circumferential Through-Wall Crack," June 1981.

Ref. 4 - NUREG/CR-3464, "The Application of Fracture Proof Design Methods Using Tearing Instability Theory to Nuclear Piping Postulating Circumferential Through-Wall Cracks, June 1981.

ANSWERS EXPECTED OF OUR RESEARCH
PROGRAM ON CENTRIFUGALLY CAST STAINLESS STEEL PIPE

- WHAT MATERIAL CHARACTERISTICS (% FERRITE AND COMPOSITION), AND HEAT TREATMENT WILL CAUSE THE FRACTURE PROPERTIES FOR AGED (32 SERVICE YEARS AT 320°C) CAST STAINLESS STEEL TO BE LESS THAN THAT OF THE WESTINGHOUSE REFERENCE MATERIAL.

- WHAT ARE LOWER BOUND END-OF-LIFE FRACTURE PROPERTIES (J_{1C}, T AND J_{MAX}) AND TENSILE TEST DATA (TRUE STRESS AND TRUE STRAIN) FOR THE MATERIALS IDENTIFIED ABOVE.

- PROVIDE AN EFFECTIVE METHOD FOR IN-SERVICE NDE.