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ACRST-1448

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the matter of:

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

Combined Meeting of Subcommittees on Structural Engineering, Seismic Design of Piping, and Metal Components

Docket No.

Location: Washington, D. C.
Date: Tuesday, September 24, 1985

Pages: 328 - 522



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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

COMBINED MEETING OF SUBCOMMITTEES ON STRUCTURAL ENGINEERING, SEISMIC DESIGN OF PIPING, AND METAL COMPONENTS

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PUBLIC MEETING

Room 1046

1717 H Street, N.W.

Washington, D.C.

Tuesday, September 24, 1985

The Subcommittees met, pursuant to notice, at 8:30 a.m.

ACRS MEMBERS PRESENT:

C. Siess, Chairman

P. Shewmon, Chairman

J. Ebersole, Member

J.C. Mark, Member

E. Rodabaugh, Consultant

M. Bender, Consultant

FEDERAL DESIGNATED EMPLOYEE:

A. Igne

SPEAKERS:

J. Richardson

J. Costello

H. Ashar

J. Burns

R. Cloud

G. Kurtz

B. Romer

B. Bosnak

* * *

P R O C E E D I N G S

MR. SIESS: This is the second day of the Combined Meeting of the ACRS Subcommittees on Structural Engineering, Seismic Design of Piping and Metal Components.

The two major items on the agenda for today, one is the containment integrity program, and the other is really not a research area, is it, Paul? It is an application of the results of research on a leak before break situation. That portion of the meeting may start before noon, and we can do that with the people here because it is a continuing meeting, and that will be chaired by Paul Shewmon as Chairman of the Metal Components Subcommittee.

Who is going to start?

MR. RICHARDSON. I am just going to say a few words, Chet. I would like to have you refer back to the front of the package that we handed out yesterday, and this morning we are going to talk about our Containment Integrity Research Program.

The third sheet in is the budget sheet for this program, and if you will notice, in 1985 our budget, including containment buckling, which is not a real integral part of this program but it is in the containment area, is about $3.9 million. In 1986 we are going to $3.7 million and staying level in 1987 for $3.7 million.

The program has three major elements: experiments on

containment models, containment integrity, which is really the analytical portion of the program, and the third element is integrity of containment penetrations.

MR. SIESS: As I said, I don't want to get too involved in budget figures, but how firm is your 1986?

MR. RICHARDSON: I have no idea. The budget is as firm as Congress will make it firm.

MR. SIESS: Let's see. 1986 is at what stage in Congress. Have you got an appropriation?

MR. RICHARDSON: No. We have a Senate mark and a House mark, and they are vastly different.

MR. SIESS: Okay. The House mark was a whopping cut.

MR. RICHARDSON: A big cut. And the Senate version was the OMB mark plus $8 million to cover the demanded salary cut that never came about.

MR. SIESS: Okay.

MR. RICHARDSON: So the Senate is full budget and the high version is --

MR. SIESS: Well, where do you stand internally?

MR. RICHARDSON: Internally, with the House budget, if the House budget were to prevail, the contingency plans, then, would be to substantially cut severe accident research. That would be one of the plan areas for cut. If that were to come about, then, our Containment Research Program would be

also severely cut, probably at least in half.

MR. SIESS: All right. Now, if this is cut in half, what are you going to do, just postpone that concrete containment?

MR. RICHARDSON: We will probably postpone the concrete containment. It will probably bring it to a halt. We put a hiatus on it this summer when we heard the House budget number. We put a hiatus on the construction. However, about the 1st of August we released that and allowed the contractor to proceed because it was becoming -- we were at a cost impact point, whereas if we did not proceed, it would start costing us a great deal of money.

The judgment of Bob Minogue and others was that the program would probably survive. It was not a made gamble to go ahead.

MR. SIESS: Personally, I would agree with that priority in terms of the research needs, not in terms of the dollars because I can understand that it may cost you more to defer something than it does to do it. But of all the things we have heard about, I think that one is least likely to affect regulation in the forseeable future.

That is just a personal opinion, for what it's worth.

MR. MARK: What does this mean? We -- the committee, that is, have been making noises for a little while

about the need of a containment performance term in the safety goals. Is that directly connected with what we are just talking of here?

MR. SIESS: Can I put an intermediate question in? Do you know what we mean by --

MR. MARK: You can rephrase my question, if you want?

MR. SIESS: No, I just want to ask them if they know what we mean by containment performance criteria.

MR. RICHARDSON: No.

MR. BENDER: Is a consultant allowed to express an opinion?

MR. SIESS: Well, I don't know what we mean by it either, and I'm hoping somebody can explain it to me.

MR. RICHARDSON: I turn to my colleagues if they have any --

MR. COSTELLO: Jim Costello from the NRC Staff. Since I have been just made a member of a task force to come up with a plan for possibly implementing or examining the options for implementing a containment performance part in the safety goal, the best I could offer is the guidance that we have in the internal staff exercise, which is to examine options which would add or permit the addition of some implementable requirement to the safety goal prescription which would reflect a defense in depth concept.

MR. SIESS: Okay. Well, there have been figures in one of our letters that said -- maybe it's a letter that never got sent out, I'm not sure -- that there should be at least a one in ten probability that the containment will function as assumed, on top of the 10 to the minus 5 core melt probability, you see.

Now, that I understand, but the function of the containment varies tremendously, depending on what containment you are talking about and what accident sequence you are talking about. It might be a basemat melt-through, it might be a steam explosion, and now we are still talking about a conditional probability of one in ten on the containment performance, which is quite a different thing. If you are talking about a steam explosion, then you are talking about flow overpressure; right?

MR. RICHARDSON: Oh, yeah.

MR. SIESS: Now, I think we know that if you have flow overpressure from basemat melt-through or sitting there and boiling off water, the containment will fail unless it leaks enough or you open a hole in it. Okay? If you are going to open a hole, deliberately vent, there is some advantage in knowing at what point it would fail, although how precisely you need to know that, I don't have the slightest idea.

You know, when are you going to vent? You don't

want to vent too early because everybody is going to be uncomfortable. This is, presumably, one reason we are doing ultimate load capacity tests on containments. Now, you look at the steel containment and what do you say you learn? You want a fairly good, sure point that it won't burst before you start venting. I think we know how to do it for steel ones. Yield. General yield, if you want. First yield isn't positive, but if it is going to leak, none of this has any application.

So even if I look at that, I would put this as a bottom priority because -- you have heard me say it -- that test is going to ask questions, not answer them, and I think we have got enough questions now that we don't need to spend $2 million to ask more if we haven't got the $2 million. That's why I just said I would agree with your priorities.

MR. BENDER: Well, I think you said most of it, but it seems to me that for the existing containments, which is really the severe accident policy that you are talking about here, a few kinds of containments that are more vulnerable than others, and I think Chet made the point properly that it is largely the steel containments that are the issues in the safety goal policy if you are going to implement it. And knowing the modes of failure concerning those, the ones that have most influence on what the overall consequences might be.

Everything I have seen shows that the concrete containments, reinforced or prestressed either one, have so much extra reserve strength in them that you don't have to worry about them getting up too high.

MR. EBERSOLE: May I ask a question? I see a piece of money in here for buckling, which recalls an old issue of about 19 years ago. We found that in steel containments, fairly thin, that buckling, it's autocatalytic, it's unstable. You know, if it buckles, it bursts real quick. The issue came up, should you test the hypothetical buckling pressure with some margin over that since structural catastrophe would result if you really buckle?

We had cold water we were spraying containments with, and you really cooled it down. As a matter of fact, some of our plants had to have the water warmed to keep the containment from buckling. So the question I would ask you here 19 years later is do you think you should require a proof test of buckling strength?

We did it much against the objection of the hieararchy.

MR. SIESS: You can't do it on the containment, Jesse.

MR. EBERSOLE: Yes, we did. We pulled a vacuum on it.

MR. SIESS: You mean build one and test it --

MR. EBERSOLE: No, no, no. I'm talking about in situ.

MR. SIESS: Well, you can test a containment up to 115 percent of LOCA load, but there is no way of testing a containment up to severe accident load.

MR. EBERSOLE: I'm talking about negative pressure.

MR. SIESS: Oh, negative pressure. Oh.

MR. EBERSOLE: Buckling. You see, that thin ice condenser containment is like a paper bag.

MR. SIESS: Oh, yeah. No, they are not looking at negative pressure at all.

MR. RICHARDSON: Buckling is from overpressure in the knuckle region.

MR. EBERSOLE: Well, what about the negative pressure aspect? You can certainly wreck a plant if you spray too cold water in it.

MR. SIESS: I assume somebody is looking at it because in the severe accident, if your sprays come on at the wrong time, you could develop a negative pressure.

MR. RICHARDSON: Yes. We are not working at it, but Jack, why don't you --

MR. BURNS: Jack Burns from the Staff. I think you might say about the only area we are looking at the negative pressure in steel containments was the reinforcements around the cutouts to see what kind of knockdown factors and so on

would be required to at least bring the cutouts up to the normal pressure strength of the cylinder itself.

MR. SIESS: But it seems to me I have heard recently in the severe accident the same kind of thing you got in the BWR. When you turn the sprays on, you can condense a lot of steam in there and pull a negative pressure. And I thought I heard some talk about vacuum breaker valves or something.

MR. EBERSOLE: That includes whether they perform or not. Sure.

MR. BURNS: No, we had not looked at that in our program. We had nothing giving that literally as a need from our user office.

MR. SIESS: Well, can you follow that up and see if the Containment Performance Working Group -- who was on that? You, Jim?

MR. COSTELLO: I am not really on the working group, but I was on one of the advisory committees.

MR. SIESS: Well, what they are looking here is with the nonhemispherical heads.

MR. EBERSOLE: I understand that. I just jumped to that.

MR. SIESS: Remember we went through it on GESSAR.

MR. EBERSOLE: Yes, I understand, but this other thing has -- you know, if you get a sticky vacuum release, it can get messy.

MR. SIESS: Well, somewhere you have looked to buckling due to earthquake loads, haven't you?

MR. BURNS: Yes, that is part of the program now. At the moment, or coming on the heading buckling problem, that was not an underpressure. That was really an overpressure condition we were looking at for the shallow heads. If you pressurize, you can develop a shear knuckle buckling.

MR. SIESS: Yes, that was a toroidal.

MR. EBERSOLE: Of course, this was the first time we ever saw a vessel that had substantial catastrophic potential if it buckled in the inward direction and busted the pipes and things.

MR. SIESS: Well, previously the only -- containments have been looked at for something like 2 or 3 psi negative. From what -- I can't remember. What is the source of that?

MR. BURNS: Spring of cold water. Probably a spray condition.

MR. SIESS: In the LOCA condition?

MR. EBERSOLE: Anything that steams it up, and especially the --

MR. SIESS: I'm talking about what they have done in the design, not what we are looking at now for severe accident.

MR. RICHARDSON: Are there any steel containments

that maintain a subatmospheric --

MR. SIESS: No, no. No, that's all the concrete.

MR. EBERSOLE: There is another thing. If you have lost the component atmosphere which is in there and you have, say, 100 percent steam --

MR. SIESS: Oh, yes, I know the circumstances. I'm trying to talk about what has been the design basis because I have been -- Hans, what is the design basis now for containment for negative pressure?

MR. ASHAR: Generally for the vacuum due to the tornado loading, some steel containment had been designed for 3 psi or so.

MR. SIESS: Tornado loading produces a negative pressure outside.

MR. ASHAR: Outside, yes, correct. Tornado pressure outside of 3 or 4 psi and then there are vacuum breakers.

MR. SIESS: But what would -- something that will produce an external pressure.

MR. ASHAR: But they are only in the range of 3 psi or 4 psi, not more than that.

MR. SIESS: If a containment is designed for 50 or 60 psi gauge inside, you mean they have just added 2 or 3 psi to that from the vacuum?

MR. ASHAR: Oh, no. I'm talking about negative pressure.

MR. SIESS: How do you get a negative pressure inside from a tornado? A tornado produces a pressure drop outside, and if you are atmospheric inside, that is a positive pressure inside gauge.

MR. ASHAR: Chet, there is the pressure from outside and the pressure from inside. On the other side there is --

MR. SIESS: I still don't understand.

MR. EBERSOLE: I don't understand how you can get a positive pressure from a tornado unless you vent it.

MR. BENDER: You can get some negative pressure on the downstream side of the wind.

MR. BURNS: That is just an unbalanced pressure around the cylinder.

MR. SIESS: But there is a design basis. I know it becauase I have seen it in FSARs for 2 or 3 psi negative, but that's rot --

MR. EBERSOLE: Let me set the stage for the real hairy thing. You have depressurization from someplace. You have the purge valves open. You blow out a substantial fraction of the atmosphere. I am making it bad. Then they succeed in closing, and then you hit it with real cold water, and then, if you want to compound it, the vacuum breakers don't all work.

You have available 15 psi. Hot containment. How much will you get and when will you collapse, and what is the

margin?

MR. SIESS: This has to be looked at in the severe accident thing.

MR. BURNS: Keep in mind, though, that a buckle itself may not be a failure of the containment. It has to be large enough to impact on something inside or to crack the containment in one form or another through a buckle or through distortions of the penetrations.

MR. EBERSOLE: Right, but if it starts to buckle, as I understand it, it's unstable and it will rapidly get worse.

MR. SIESS: It depends on whether the load is --

MR. EBERSOLE: Yes. It may just implode.

MR. MARK: Chet, when we were at Sandia, they were doing some very small-scale looks at buckling features of this dome.

MR. SIESS: They were looking at two things. One is they were looking at the code reinforcement formulas to see if that adequately took care of buckling due to overturning vertical compressions in the shell due to seismic loads overturning, and then they were looking at buckling in the knuckle region of those torispherical heads. I believe with the hemispherical heads, you don't run into the problem.

MR. BURNS: That was our conclusion from the test, including a large test at Chicago Bridge and Iron.

MR. SIESS: Those were the two things they were

looking at, and one was due to overturning from earthquake-type loadings, and the other was due to internal pressure. If you remember, GESSAR went through this complicated analysis because they have got the torispherical head and -- but the internal vacuum pressure -- I think we ought to have Al look at it with the NRR people and try to find out what the situation is, and you can follow it up and see if there is a problem there and whether somebody is thinking about it.

MR. EBERSOLE: Chet, I want to ask you this. I never have personally been able to rationalize where there isn't a very conservative relief valve on containments.

MR. SIESS: Well, there are a number of us looking at -- we see figures now saying that if you have a 10 square inch opening, you can never overpressure the containment unless you have something like a steam spike.

MR. EBERSOLE: You can back it up with a valve that closes by motor.

MR. SIESS: The question of deliberately venting, which the BWRs are proposing, hasn't been seriously considered -- well, it has for the PWRs. I know EPRI looked at it in their studies. But what people have come up with is that the slow overpressure that you could relieve with a modestly small valve takes a week to burst the containment, and by then the fission products are bound to a low level. You could have

evacuated people. And the consequences become negligible.

MR. RICHARDSON: Unless you get a catastrophic failure of containment where you might reintroduce aerosols that have plated out.

MR. SIESS: The first thing, it isn't a nice idea, let's face it, but neither is a deliberate release.

Now, the near-term operating license requirement is that they provide an opening in the containment, equivalent 3-foot diameter hole for possible vented filtered containment. Three foot diameter.

MR. EBERSOLE: With no intention of really using the hole.

MR. SIESS: Well, the idea someday that they might run a pipe through there to 20,000 tons of gravel; not to a lake, to gravel and all of this stuff. The vented filtered containment has been looked at. Even what they call a simple cheap filter. But now the boilers are proposing to vent into cooler water and take a terrific benefit from scrubbing, and if you don't want to overpressure this thing, it looks now from the scenarios that have developed that a 3 or 4-inch hole will take it out.

Now, somebody has looked at this for me and said that some of the containments with the double containment in the annulus and a filter system on the annulus can take a fair discharge right there. If you could discharge it under water

into your cooling tower basin, into your ultimate heat sink and take some credit for scrubbing --

MR. EBERSOLE: You can scrub the annulus if you want to.

MR. SIESS: What about the spent fuel pool?

MR. EBERSOLE: There are all sorts of ways of doing this.

MR. SIESS: But on Indian Point -- and I talked to Herschel about it -- they say, you know, that is so far down the line you are preventing something where the consequences are negligible, and if you have had the core melt, you have already done the public relations damage. You haven't hurt anybody yet, you know.

MR. BENDER: Well, just so it doesn't get too distorted, a lot depends on when the venting occurs. The Indian Point concept is based on the integrity of the containment being fully assured up to some pressure point, but it doesn't allow for the potential of a leak early in the event.

MR. SIESS: Oh, yes. They have made analyses. Studies have been made as to what the doses are if you have a leak early. Specter sent me a copy of a paper -- I don't know whether anybody else has gotten it. Los Alamos, I think, made a parametric study of early leakage and mentioned the Containment Performance Group.

It's not simple, obviously, but if you do have the leakage early, you won't overpressure but you will release early, and now you have got the trade-offs. If the late release due to rupture of the containment doesn't hurt anybody because everything is settled out and it doesn't resuspend, then early venting or early inadvertent venting or leakage may not be good.

MR. BENDER: They may have been able to make that case. The analysis may be correct, but they had a very prescriptive way of defining the accident. You have to accept their prescription.

MR. SIESS: You are talking about Indian Point?

MR. BENDER: Yes, I'm talking about Indian Point.

The other areas that have to be thought about, this big, 3-foot diameter opening that was put in way back when, I think there is no defensible filter system that goes with that particular scheme.

MR. SIESS: Well, somebody had one in mind.

MR. BENDER: They just don't have enough information about it. But the smaller systems where you vent with a 10-inch pipe or thereabouts, they can be bubbled through water or anything and they will do most of the decontamination that is needed.

MR. SIESS: Yes, but the BWRs just haven't looked at that seriously. As I said, EPRI looked at it and their

cost-effectiveness is poor. Because the dose reduction was negligible, there wasn't any dose there to speak of, so they couldn't afford to spend more than $50,000 to prevent rupture of the containment seven days down the line. That was the kind of calculation that was -- I said EPRI. IDCOR. Excuse me.

And if you have an early steam spike or a hydrogen detonation, that is not going to help you anyway.

Jim?

MR. COSTELLO: As far as I know in the matter of practice overseas, the Swedes are, I am virtually certain, going to do something with a PWR that is similar to their BWR venting scheme. I don't know what that is yet.

MR. SIESS: Oh, but it involves a huge gravel filter.

MR. COSTELLO: That is the BWR. Are they going to use the same system on the PWR?

MR. SIESS: Yes. But the Swedes came to that solution before they had the benefit of the severe accident sequence analyses. You know, I think their decision to go to vented filters was almost a political one without the engineering basis that we might now have for it, but the RDA studies on vented filters, you have seen those, and they come up with one that is fairly cheap looking. It's a separate building sitting over here that is hardly passive. It has got

fans. One of them even uses ice condensers. They just go on condenser steam. I thought that was interesting.

But I just can't see why the PWR doesn't fall somewhere in the same ballpark as the BWR. The BWR is not going to vent through a 3-foot hole.

Now, the other point, though, is, whether or not you deliberately vent, there may be enough leakage; but again, so far, looking at what we have looked at, you are not going to get an awful lot of leakage until you get up fairly high in pressure compared to the design pressure; right? That's what everything seems to be telling us so far.

And if it takes three days to get up to where you have significant leakage and you start looking at dose calculations, you don't see too much benefit. If you look at defense in depth, you see something else, I think.

MR. COSTELLO: I could also offer from my understanding of what I have heard about the French thinking. For one thing, they feel -- double containment is unlined, so they feel they can handle leakage through the inner containment into the anular region and clean it up. Or so they say.

MR. SIESS: Well, how much can they handle?

MR. COSTELLO: I have never seen a clear number on that, but they say enough.

As far as the PWR, their 900 megawatt PWR with the

similar containment and the liner, I have heard talk over there about venting schemes, gravel pit, that kind of stuff, although I have never seen any indications they are implementing that.

MR. SHEWMON: The last time the group was over here a year or two ago, they said they had decided to go to a vented, filtered containment. That was a decision. The building people didn't like it.

MR. SIESS: One problem I have is I can't tie numbers together. Some people are talking about leakage and the terms we use for leak testing, percent of the volume per day. Then I see filtered systems described as so many cubic feet per minute capacity, and then somebody else tells me from the severe accident study that a whole 10 square inches -- and I can't relate 10 square inches to cubic feet per minute to percent per day and get any feeling as to whether what goes out of a hole 10 square inches can be handled by the annulus filter system or not. You see?

Hans, did you do some looking up on this for me? Was it you?

MR. ASHAR: This is Hans Ashar, NRC Staff. Some work has been done, and the way we are going, for testing purposes, is by cubic centimeter or centimeter or length, parameter of penetration, four second, that kind of a parameter, because we are going to integrate a lot of leakages

from a lot of penetrations, but as far as the 10-inch diameter or 6-inch diameter, in my own opinion I think it all depends upon the flow rate between the outside and the inside, and depending upon what kind of flow you assume.

That's the reason it's not very definite that this diameter hole is going to depressurize containment to the extent that it won't pressurize and rupture the containment. This is an uncertainty that is always there.

MR. SIESS: Yes, but then the containment performance working group has got curves in their report showing various size openings, and it depends on a number of things, I will admit; but the simple question -- take a specific plant with an annulus, a 6-foot annulus with a filter system in it, and tell me -- take the filter capacity and feed it back into one of the accident sequences and tell me what it does.

This is a filtered vented release through an existing sytem, which I think is Category I if necessary.

MR. EBERSOLE: Chet, may I ask a question?

MR. SIESS: And you can't get the answers to that.

MR. EBERSOLE: I would like to know, and I think some pressure should be put on the industry to determine what the real leakage rate is under design conditions. My impression is the leakage tests are done like the old general's visit to the Army post. You knew he was coming ten

days in advance and you fixed it.

MR. RICHARDSON: Well, with the modification that we are in the process of rulemaking right now to modify Appendix J, the integrated leak rate test procedure, and in fact, we are trying to plug that loophole. The Staff has never considered that the applicant had or the utility had the privilege of fixing up before the test. However, some utilities disagree with us. We are going to make that very clear in the revision to Appendix J, that they can't do that.

MR. SIESS: But you have been getting some reaction from CRGR on that.

MR. RICHARDSON: Oh, yes.

MR. SIESS: This is under review.

MR. RICHARDSON: I might say the CRGR is now -- we have now gotten resolution of CRGR and it is ready to go now.

MR. EBERSOLE: Great. What does this mean, that there will be a SWAT team show up at your front door some day and it won't impact on their running condition?

MR. RICHARDSON: No. It just says that any time you make repairs to valves, you have to count that in the tally of leak rates.

MR. EBERSOLE: Oh, well that's not what I mean. I'm talking about a black hat team shows up at 2 a.m. in the morning and says: We are going to do a leak test.

MR. SIESS: You can't do it, Jesse.

MR. RICHARDSON: No, because that involves shutdown.

MR. EBERSOLE: No, I am talking about a careful program that would not impact on generation.

MR. BENDER: What do you want to know, whether it leaks at .1 percent --

MR. EBERSOLE: I want to know whether it leaks before they fix it. I just want to find out what it leaks, Mike.

MR. SIESS: Well, their procedure would not tell you at any point in time what the leak was because a valve could be open for 12 hours before somebody --

MR. EBERSOLE: Well, I'm talking about the automatic closure of the system by punching a button. That's the way it works.

MR. SIESS: I don't know if it can be done the way you say without --

MR. EBERSOLE: Well, how does it work at all?

MR. SIESS: Well, give me a couple hours sometime or the next time we look at Appendix J. But there are other ways the Staff is looking at it. You are going to hear a lot from Jim Costello about what they are doing on seals and penetrations and so forth, but what they are not doing in the research program is looking at what they refer to as pre-existing leakage. They have said that can be handled administratively. Well, obviously you can't do anything in

terms of research on it, and there are a couple of approaches. One of them, Conn Yankee, for example, operates, or at least one of the plants operates under 2 or 3 psi.

Now, with their recording that they have, it takes them about a week to detect one-tenth of one percent leakage and two-tenths of one percent leakage, whatever their tech spec leakage is. But we are not worried about one or two-tenths percent a day leakage. When you get up to one percent a day or something like that, I'm sure they could detect it a lot earlier.

The subatmospheric plants, which have to pull about 6 psi vacuum -- that's about what it is -- they operate at 9 or 10, don't they? Well, somewhere in that range. They pull a few psi vacuum. Now, that is leakage in the other direction, but it would catch the open valve. There they are giving them credit for pretty good control because the leakage can't be greater than the capacity of their pumps that are keeping the air pressure down. So there are ways of looking at that.

There is another approach, called a blunder test, which is every time you have had an outage and you close things back up, you run a test to be sure that somebody didn't leave something open. But that is the pre-existing leakage, and you won't hear anything from Research on that because it's not a physical research-type problem, and I believe that

administrative controls are being handled in NRR somewhere.

Don't you have Pacific Northwest or somebody looking at --

MR. COSTELLO: No, that's an NRR program.

MR. SIESS: Oh, they've got a technical assistance program.

MR. COSTELLO: But I guess I could say also on the question of the inerted BWRs, there is also a monitoring there, because nitrogen costs money, and the utilities find leakage.

MR. SIESS: And inerted BWRs have also got a control, but you are going to hear from Jim about leakage studies, and there are two aspects about leakage.

One is, if it leaks enough, it won't overpressure, which is good if you don't want the containment to fail. And what it does to doses is something else, and if it leaks early, you get doses.

Now our whole thinking about leakage has been LOCA, and we don't want leakage more than 1/10th of 1 percent, because combining that with the source term and the meteorology exceeds 25 rem. You know, that rigamarole we have gone through.

So the research is trying to get some numbers, but the thinking about what to do about it is supposed to be coming out of the severe accident program. And I haven't seen

that much thought being given to it, frankly.

MR. RICHARDSON: I have just a couple of words for those that may not be intimately familiar with our containment integrity program.

The overall objective, of course, is to study, evaluate and assess the structural and leak behavior of containments up to and including severe accidents, and we are doing this experimentally to validate, improve analytical models and predictions, so that we can then take this methodology into all the various containments that exist.

The program consists of three basic elements. That is, the large model testing of steel and concrete containments, and the only concrete that we are testing is a reinforced concrete. We have made a conscious decision not to test prestressed concrete.

MR. SIESS: On the basis that it no longer exists? The British are going to test one.

MR. RICHARDSON: And it still looks like the British are going to test one. That's the word we are getting from NII.

The CEBG doesn't want to do it, but it looks like NII is going to force them to do it. And, of course, our penetrations program, which is a separate effects program, looking at the seal and gasket materials and testing a few penetrations by themselves, using the data from the large

model tests as boundary conditions, and then an analytical effort that puts it all together and develops an analytical process that can be used to assess containments.

That, coupled with some supporting programs in the research areas that are feeding into this program, such as the electrical penetrations, are being evaluated under the electrical equipment qualification program and the containment isolation valves being evaluated in the mechanical equipment qualification program.

MR. EBERSOLE: How come these programs are mixed up like this? How come the programs are mixed up like this? Who really runs the show? We do.

Well, let me call out then, as late as on GESSAR II, I saw a line that says electrical penetrations not carrying 1E loads won't need 1E overcurrent protection. That's a flat wrong statement, because these penetrations carry fault loads under accident conditions. If you don't clear them, more often than not, they are the fuses in the circuit and they'll blow up.

MR. RICHARDSON: Well, maybe I answered too quickly who has control. The control of the research program of containment integrity rests with this branch, and we guide the research in the electrical penetrations area, in that we specify what we want.

MR. SIESS: But does the research on electrical

penetrations look at electrical overloads as a way of disintegrating --

MR. RICHARDSON: No. It is looking at pressure, pressure, temperature, radiation.

MR. EBERSOLE: Well, you know the conductors that go through those, that's the pinch point.

MR. COSTELLO: They are measuring fault currents and things like that in these.

MR. EBERSOLE: And what clears them?

MR. COSTELLO: That I couldn't tell you.

MR. EBERSOLE: That's what keeps them from being sustained and melting.

MR. RICHARDSON: Perhaps Hans can --

MR. ASHAR: The last electrical penetration they tested, what they saw was under pressure and temperature, after aging for so many days -- I don't remember how many days -- the radiation and temperature, they subjected to temperature and pressure, simulating an accident, and what they observed was there was no leakage from inboard or from outboard.

MR. EBERSOLE: That's not the point.

MR. ASHAR: But let me say -- go further. But there was a -- to the conductors, and the conclusion -- not conclusion, some kind of a decision was that some of the instrumentation depending upon penetration would not be

functioning, because of the heavy damage to the insulation. But --

MR. SIESS: I'm sorry, but the point Jesse is making is that electrical overload could damage that penetration and reduce its ability to resist pressure or temperature in the subsequent stages of the accident.

MR. EBERSOLE: No. It could just fully blow it out.

MR. SIESS: Well, I don't think that's a part of the research program. I think it should be looked at.

MR. COSTELLO: Okay.

MR. RICHARDSON: You have a good point.

MR. EBERSOLE: Well, it's an old, old issue, you know. For instance, the main coolant pumps, they have been typically protected by a single circuit breaker out in the yard and on seismic 1E or whatever, with a battery that has no pedigree, and so when you have a LOCA, these big pumps go to fault current conditions, and the circuit design almost always causes the penetration to be the pinch point of current-carrying ability, so it will simply blow like a big fuse. Physically. I am talking about explosive. Unless you clear it in micro-milliseconds. That has to be done by a big breaker.

MR. SIESS: There are some penetrations that may not be protected from overload because the circuits are not needed, but if the penetration fails --

MR. RICHARDSON: Yes, you may develop a leak.

MR. SIESS: Let me supplement what you said. Two things, Jim:

One thing that's very important to these large containment tests, the one that they have tested and the one that they propose to test, we all realize that there are probably 50 or 60 different containment designs out there, if not 90 or 120, when you really get to looking at them, and there is no hope of ever testing all of them, or even testing parts of all of them.

So the whole process here is we think we can analyze containments for their ultimate pressure-carrying capacity, and we are going to test a couple and test out our analysis, and then try to set limits on the analysis, that we can use analysis to handle all these different varieties.

Now that is an extremely important assumption, and the results are still going to have "uncertainties."

The other point I want to make is that even those tests, failure of a containment is defined now not as structural failure, but as leakage beyond some appropriate limit. The function of a containment is to contain, and when it no longer contains, it has failed.

So the emphasis is not on structural failure, but they are integral tests, they are separate effect tests, and they are analyses of the integral tests intended to verify or

validate the analyses and the separate effects tests are intended to provide input, too.

I think this is very important, because there's a very basic philosophy behind this, and it's not one that guarantees an answer, by any means.

MR. EBERSOLE: Chet, I want to make one comment. You are sort of the chairman of the containment integrity program -- this is an old issue that goes way back again, at least 15 years, and a lot of patch work and compromises have been done on it, but I for one don't know how it was really wrapped up, especially with regard to old plants, because all of them were found to be deficient in this matter of trip integrity. And so it might be worth an overview.

MR. RICHARDSON: We will certainly look into it.

Well, that's all I have, and I am going to turn it over to our two project managers, Hans Ashar and Jim Costello, who will describe the program.

[Slide.]

MR. COSTELLO: I am James Costello from the NRC Staff.

To get you to the right page in the handout, I have put up here the cover page.

As has been discussed previously, we have a large effort concentrated on three areas. As Prof. Siess pointed out, the underlying hypothesis behind these efforts is that

the state-of-the-art analytical methods, intelligently applied, will give answers that are good enough to make inferences about containment leakage and behaviour near failure.

Of course, the question of how good the analyses really turn out to be has to be checked experimentally and, indeed, we will find out, as we get into the history of the steel model test, the iterative process of pre-test prediction, post-test analyses and an assessment of how good the state of the art is.

The three activities listed up there are followed by, in your package, a bunch of format pre-'85 activity, '85 activity, '86 and '87 activity.

MR. SIESS: This is all Sandia, right?

MR. COSTELLO: All three of these activities are being performed at Sandia Laboratories.

We have in '85 sliced things up into three FINs, mainly for programmatic and management reasons. We have found in the past that leaving the analysis efforts in the same FIN with the model construction led to insufficient attention being devoted to the analytical methods.

I mean it is a simple fact of life, that getting a large experiment designed is a very ticklish undertaking, and attention gets devoted to the most difficult task.

So we have attempted to break things out this way.

It somehow makes it difficult when we come for a presentation, when we compartmentalize things this way, but we will do our best to give you presentations on the highlights. And since we are doing it all in the same morning, I trust you can see how they hang together.

MR. EBERSOLE: May I ask a question in sort of an overview? I would have thought this test would include severe accident potential capability of the containment, which goes whole-hog down the road.

MR. COSTELLO: It does, yes, sir.

MR. EBERSOLE: Well, then, for instance --

MR. SIESS: Except temperature.

MR. EBERSOLE: Well, there I go.

MR. SIESS: I know. Temperature doesn't have any effect on the steel itself. It's mainly on the penetration.

MR. EBERSOLE: Well, let's say the hypothesis is we melt the core and the vessel fails and it falls down into something, and I think the rationale has to be it is concluding now whatever the heck we're going to do under those circumstances, we will never fail to try to drive water to the core, we'll do it anyway. We don't know what else to do.

So this says if I can't drive water, I'll surely be in trouble. If I can, I might be. And this automatically leads to the thesis that a containment might be optimized by having a pre-existing pool of water into which the residual of

the vessel and fuel would progressively descend.

I'm talking about a hypothetical model, not -- we've got, as Chet says, maybe a hundred models, but I'm talking about one that you hope would work.

What is being done about any sort of thing like this?

MR. COSTELLO: This program? Literally nothing. The focus of this program is developing reliable predictions of the pressure and temperature conditions.

MR. EBERSOLE: In the field of containments we have?

MR. COSTELLO: Yes. Under which leakage or significant leakage will begin.

MR. EBERSOLE: There's no attempt then to really devolve a containment --

MR. COSTELLO: No, sir, this is just establishing facts.

MR. BENDER: It just seems to me that based on the discretion here, that you would be way ahead if you just wrote down a few scenarios and related the experiment to the few scenarios that you are using. They exist somewhere, and it seems to me that if they were just tied together a little bit --

MR. SIESS: Mike, what do you mean?

MR. BENDER: For the purpose of showing what these containment tests tell you. You have to have some reference

accident condition that you are relating to, and I think it is still quite abstract.

MR. SIESS: You mean the rate of pressure increase?

MR. BENDER: No, I am talking about the conditions including rate of pressure increase that have to be considered.

MR. SIESS: In the penetration studies, as you will hear, the pressure temperature from accident scenarios is being involved, or being considered. In the model containment test, there is no way they could get the temperatures on there, and they would have no effect on the basis shell. That couldn't be predicted. And the idea is to verify or validate analysis, so they are simply applying a pressure.

Now the time rate would be the only variable there, and they can't really do anything about it, because they have got to stop and take readings and so forth.

MR. BENDER: I am not trying to argue that the experiment should simulate the event. I am trying to get --

MR. RICHARDSON: What is it going to address?

MR. BENDER: Yes, what event? Not what event, but what events?

MR. SIESS: Well, that's covered. Containment loads working group has come up with scenarios and they are summarized in 956, or whatever it is, in the appendix, and they are all in their report, and they have taken various

scenarios, Mike, at various leak rates and various kinds of containments.

MR. BENDER: I don't disagree with the point you're making, Chet. All I'm saying is that if it is put into context, it will make it a lot easier to understand why the experiments have meaning.

MR. SIESS: Well, the thing is, it's going to be hard for them to put it into context here when we have spent several days in meetings on the Class 9 accidents, looking at the scenarios.

I think there is a problem here for the consultants who haven't been sitting in those meetings.

MR. RICHARDSON: It probably would have improved the presentation if we would have shown some bounding curves, showing the range of accidents that are being considered and how this fits into what we are addressing.

MR. SIESS: Yes. Well, Mike and Rodabaugh are at a disadvantage there. I have seen them, I think Carlton has seen them from Class 9 meetings, and Jesse, and this is not being done in a vacuum, I can assure you.

MR. RICHARDSON: We confess that we were probably under -- having worked with Chet pretty closely at this, we made the assumption that we weren't going to give much background. But your point is well taken.

MR. BENDER: I'm not all that uncomfortable with

that myself.

MR. SIESS: Mike, what we should get to you is that discussion -- I forget what chapter it is of 9.56 that came out of the containment loads working group, where they take the five or six plants and take the various scenarios and take the various containment failure possibilities, and they build up the scenarios very well in that. It is very well written. And it will give you exactly the picture you want. And what is in 9.56 is the executive summary I think from that report, and it is very good and we'll get a copy of that for you because I think it will help you a lot.

MR. COSTELLO: But your point is well taken, and it might not hurt for us to start off the first 10 minutes with a perspective of that type. We will make note of that. Thank you.

But as has been pointed out, in the large model tests we are proceeding -- oh, and by the way, I suppose the order in which the FIN activities are listed here are in increasing order of expenditure. The analytical efforts are relatively modest; the penetration experiments which are done in separate effects are more costly, and the construction of large models is most costly.

Going from the bottom up, the large model tests, it became apparent that (1) pressure effects are the predominant factor leading to leakage with temperature effects being

clearly secondary as the conventional wisdom has it for steel containment and likely to be more important than steel but not likely to be dominant in concrete containments.

So we have focused the large model tests on behavior under increasing pressure up to total failure, and it attempts to correlate how well state of the art predictive methods could predict what is going to happen.

The penetration tests are focused on possibilities for generating local leakage, and here temperature, time of temperature are likely to be very important. And consequently, accident scenario temperature and pressure histories are used in the penetration experiments.

MR. EBERSOLE: Let me ask you about the penetration experience and then the findings that you might make. You come to a conclusion pretty quick that the penetration ought to have a very robust margin in current-carrying capacity relative to the conductors that enter it and leave it. That when you started out, you should have designed it as not the weak point but the strong point in the circuit.

But you're going to find real quickly -- this is just a random combination of this, but to go back to what it ought to be might be worth considering, which says electrically speaking, from the time/temperature standpoint carrying overloads and current, the penetration ought to be the best thing in the whole circuit.

MR. COSTELLO: That's something we will convey to the electrical engineering research people when we talk to them. But we are also focusing on the mechanical penetrations which have great potential for leakage -- the larger diameter ones being the most likely.

MR. SIESS: Jim, you didn't mention that the large containment tests emphasized deformation measurements that would be input to the penetration tests.

MR. COSTELLO: That's correct.

MR. SIESS: Not just the failure.

MR. EBERSOLE: In that latter thing, mechanical penetrations, I hear that flued fittings are getting out of style now because you can't look at them. You know, the double-walled flued fittings that fire the broken pipe contents back into the containment? Is that true, that we won't be using anymore flued fittings?

MR. COSTELLO: I can't speak to that.

MR. SIESS: Jesse, this whole thing is directed at existing plants.

MR. EBERSOLE: Oh, they have flued fittings.

MR. BENDER: I just want to get a point clear in my mind. The tests that you're doing are directed not to the organic materials that provide the sealing devices for the electrical fittings, are they? They are directed to the structural -- to the main structure?

MR. COSTELLO: No. The effort on electrical penetrations actually are full-sized tests. We're not talking about these here today, but the electrical penetration tests are actual full-sized electrical penetrations subjected to these constructed severe accidents -- the histories.

MR. BENDER: Well, that's all right but I guess I am pre-supposing something that may not be correct. But the verification that the seals themselves have the capability to withstand the structural loadings is done in some other way, then, in these tests. That would be just incidental if they failed here due to something, I would guess.

MR. COSTELLO: In the separate effects tests? No, the pressure and temperature histories.

MR. BENDER: No, the organic materials that are used to make sure that --

MR. SIESS: Are aged and subject to pressure and temperature.

MR. BENDER: Are they pre-conditioned to establish their historical --

MR. COSTELLO: Yes, sir. Temperature and radiation aging, yes. And also, in some of the separate seal and gasket materials tests that are being performed in this program, my colleague, Hans Ashar will talk about it later on the agenda but we will give you a little rundown on what's done.

MR. SIESS: We're not going to cover the electrical

penetrations?

MR. COSTELLO: No, sir, not today.

MR. SHEWMON: Well, the penetrations tests then consisted of heating it up, putting pressure on it and seeing if it will move; is that it?

MR. COSTELLO: The electrical penetrations test, yes.

MR. SHEWMON: Is that what penetration means here?

MR. COSTELLO: No. Here we will be talking about the efforts looking at the mechanical penetrations and potential leakage.

MR. SIESS: These guys are not doing the electrical penetration tests.

MR. SHEWMON: Well, they are doing structural integrity of the containment and I'm trying to find out what structures they're talking about. So there's a lot of penetrations, and you're talking about doors and hatches more?

MR. SIESS: I think it might help if we would let them tell us.

MR. SHEWMON: Well, we won't find it on what was given out as a handout, so maybe he has a separate slide.

MR. SIESS: Well, he will explain it.

MR. COSTELLO: Again, corresponding to the agenda, we will run through the activities which are currently going on and will be going on in 1987, and give some historical

background on what went on in the past to try and put a picture together.

MR. RICHARDSON: Can I interrupt because I think it is such a simple thing. The containment, of course, is made up of the shell and many types of penetrations. We have the large mechanical penetrations such as airlocks and equipment hatches and large pipe penetrations with bellows. There are valves on those pipes that represent penetrations and electrical penetrations. Those are the four classes of penetrations of the containment.

Within this program, we are evaluating the large equipment hatches, airlocks and pipe bellows. In two other programs, in the equipment qualification area we are looking at the electrical penetration and the valves. So what you will not hear today is the leak integrity investigation of electrical penetrations and valves. What you will hear today are hatches and pipe penetrations.

MR. SHEWMON: Thank you.

MR. COSTELLO: And in the order of the presentations that we have today we will first talk about the planned concrete model tests that my colleague, Hans Ashar, will now speak to. And then I will be back to talk to you a bit about what went on in the large steel model series, and summarize that and what we learned in the way of pre-test analysis, post-test evaluation.

Then I guess -- and the problem of making models. And Bob Kassawara is not here and I would leave it up to you, Mr. Siess, to decide how would you best like us to speak to, or when you would like us to speak to EPRI's undertakings.

MR. SIESS: I think, Jim, about all we can do there is to have -- is for you to assume that I know what they are doing and not take the time to try to explain to everybody else because I think that's too much of a burden to put on you. And to take a few minutes to tell me what you think it will help you do. Okay?

MR. COSTELLO: And I will speak to that when I come back to talk to you again about pre- and post-test analyses, in the next go-around.

Then we will pass over the EPRI part of the agenda, and then my colleague, Hans Ashar, will be back to talk to you about what is ongoing and planned in the efforts on penetration experiments, and then I will finish up by talking about what we sense as the likely scope of the effort on the seismic question and ask for your advice on how -- any input you may to help in proceeding in 1987 and beyond on the seismic question.

MR. SIESS: Jim, this is an area where I am particularly unhappy that EPRI is not here because one thing that concerns me is where their containment program, which is all concrete containments, fits in, in the event that your

model test has to be deferred because of budgetary reasons. Because that then becomes the only work on concrete containments.

MR. COSTELLO: Well, if I can defer it I will speak to that when we get into the pre and post-tests. Okay.

MR. SIESS: Well, I think that was particularly important because that may be all that gets done on concrete containments for a couple of years if the budget gets whacked.

MR. COSTELLO: Thank you. I guess with that in mind, then, I guess I will have Hans Ashar come and talk about the concrete model experiments for which the initial construction has begun on the model right now.

MR. ASHAR: The first part of this presentation will be just a boilerplate format in which I will talk about the overview and budget requirements in a very generic way; what is the issue, objective and integration, et cetera.

In the second part I will show you some of the slides on what is going on in the reinforced concrete model testing.

[Slide.]

The contract is with Sandia National Lab and the budget requirement in 1985 going on, there was $2,060,000. For FY86 we have earmarked about $2 million. For 1987 we are estimating about $2,400,000, and in that one there will be completion of reinforced concrete model as well as some of the

needed separate effects test, such as we are thinking it all depends on how the evaluation by Sandia turns out as to the temperature effect on concrete containment. If needed, we might perform some separate effects tests for temperature on liner-concrete interaction.

And another thing that is an issue is: is there a different behavior of pre-stressed versus the reinforced. This is the one which we'll be talking of in the near future and work out if we need any separate effects to get the idea about the behavior of pre-stressed, if it is different from the reinforced concrete containment for overall pressure capacity.

[Slide.]

MR. RODABAUGH: Are you going to be using air as the test pressure medium? Are you going to be using for test pressure?

MR. ASHAR: For test pressure?

MR. COSTELLO: No. Nitrogen.

MR. ASHAR: Nitrogen will be the medium.

MR. SIESS: Why nitrogen instead of air?

MR. COSTELLO: The principal reason is it turns out to be cheaper. Considerable effort was done in scoping it out back when the initial steel model tests were done. The question of the size of pump you needed and the power requirements when compared against the easy availability of

nitrogen with oil field trucks and the like pointed to nitrogen.

MR. SIESS: And the leakage through a crack would be or would cost you about the same?

MR. COSTELLO: There was an old scoping calculation and it was felt that with the level of accuracy we're going to get, that would not be a problem.

MR. ASHAR: Okay. The issue is well known to you. You have discussed it here for about 45 minutes, which is to have some kind of idea as to the analytical prediction of containment failure modes by experimental means. We can find out as to what would be the failure capacities of various types of containments. That is the aim. For steel containment we know we learned a lot, and it will be transferred.

The objective -- perform experiments on containment models that will produce failure data under extreme loading conditions and permit an evaluation of the capability of state-of-the-art calculational methods.

As it was discussed, the pressure that we are putting in is a steady pressure at a particular rate of pressurization. It may not completely simulate pressure during the severe accident, but analyses and evaluations as to the effect on the containment itself show that it won't make any difference at what rate we pressurize the containment.

The temperature effect will be separately evaluated for steel as well as concrete containment, if there is any temperature effect.

MR. RODABAUGH: Do you anticipate building the pressure up and then dropping it to make inspections?

MR. ASHAR: For reinforced concrete containment the way the pressurization will be done is first it will be done at peak calculated pressure. That means, containment design pressure. It will be stopped and the readings will be taken for the deformations, et cetera. Then it will be stopped again at structural integrated test pressure, which is about 1.15 the design pressure.

MR. RODABAUGH: My question was are you ever going to drop the pressure before you get to your final pressure stage?

MR. COSTELLO: Not intentionally.

MR. SIESS: Hans, what did you say about temperature?

MR. ASHAR: For reinforced concrete containments? What I said was you might be aware of the discussion on including the temperature into the model, but what has happened is that there are more problems with including temperature than deriving any benefit we can get out of it.

So we have decided is that Sandia is going to make an evaluation based on the expert advice on temperature

effects on concrete containment. They are going to come out with a recommendation as to do we need any separate effects test to see that we can superimpose some of the effects in the discontinuity areas.

MR. SIESS: The effect you're considering is that the increased temperature puts the liner in compression.

MR. ASHAR: That's correct. But in the discontinuity area that effect might be a little different than in some areas. This is what Sandia is evaluating, and they have a letter report to us --

MR. SIESS: I don't care what they come up with; you're going to need separate effects test, I think.

MR. ASHAR: Probably you are right.

MR. SIESS: It will depend somewhat on how it fails, you know.

MR. RODABAUGH: When I run tests with nitrogen coming out of compressed nitrogen bottles I ended up with quite a cooling effect. Have you worried any about -- that you may be running your tests at lower temperature than you want to?

MR. COSTELLO: Well, on the steel tests that was compensated for to some extent by the fact that we actually had heaters in the containment, primarily to try and keep constant temperature during the diurnal cycle. And that had the effect also of --

MR. RODABAUGH: Okay, very good.

MR. ASHAR: The integration. As pointed out by Jim, this project has been integrated together with the containment penetration as well as the analytical pretest analysis and post-stress analysis, as well as with the wall testing program and the electrical penetration program.

In 1985 what we have done is the facility, as you all might have seen, the facility at Sandia National Lab, probably, tests the failure of three small steam models, and in '85 the large steel model also was tested, as you must be aware. Prior to 1985 was the site selection and three small steel model testing, and in '85 we completed the large steel model, one-eighth scale steel model testing, and completed design and started construction of the concrete model.

In '86 what we have planned is the complete construction and instrumentation of the concrete model and initiating testing. In 1987, complete testing to failure of concrete model, performing necessary supplementary tasks, what I was talking about today, the separate effects test; initiate experiments in seismic performance, that is, after the planning stages are over in that area. That is what Jim will talk about a little more later.

Regulatory use. Confirmatory assessment of severe accident policy statement that the containments are safe, probably, and the basis for possible addition of containment

performance requirements for safety goal implementation.

Now, the practical usage has been made in quite a number of areas, like in preparing NUREG-1037 for containment performance working group. They have taken the analyses done by Argonne National Lab on penetration, and they are finding out if their penetrations are the weak points at Sequoyah or at Brown's Ferry or at Peach Bottom, whichever containments they were looking into.

So they made extensive use of the survey and of the analyses of Argonne and Sandia National Lab. Also in the regulatory use, in addition to this very generic regulatory use, there will be code development as part of the computer code developments. These will be useful to a lot of people in conforming their nonlinear codes or to make sure that they modify their codes to suit certain data being available in this particular test.

MR. SIESS: Hans, are the analyses, the pretest analyses, far enough along on this to give you a prediction of what will happen?

MR. COSTELLO: I guess I could speak to that. There has been a modest effort at Sandia to do at least an axisymmetric modeling of the specimen to help in deciding where to put instrumentation, and the axisymmetric modeling again points to the basemat-wall intersection as an area of exceptional interest.

MR. SIESS: All right. That's where the concrete will be most highly stressed. Is it predicted that the liner will fail at that location?

MR. COSTELLO: What happens in this axisymmetric modeling at the level of detail that's done is the same that has happened in other models of the same ilk, which is that the local loss of stiffness leads to numerical instability in the calculation, and the argument is whether that is a numerical concrete modeling problem or it actually is reflective of a large deformation in concrete liners.

The answer is the level of analysis done so far is indeterminant on that point.

MR. SIESS: Has anybody ever considered getting away from a finite element analysis and trying to make some calculations using statics?

MR. COSTELLO: Hand calculations? I believe we may have actually --

MR. SIESS: Nobody knows how anymore.

MR. COSTELLO: We may have actually come to that.

MR. SIESS: Well, once I get to a certain point, I could model this as a little angle here and then I am pushing it apart.

MR. RICHARDSON: Do they teach those simple techniques in college anymore?

MR. SIESS: I don't know whether they teach anybody

any more. We do because we don't use computers that much. We think people ought to know how to do things that computers are doing.

MR. ASHAR: Now I will concentrate on some of the details of the reinforced concrete model testing. First, let me give you the status of where we are in this particular area. As Jim Richardson pointed out before, we have stopped the work in between and restarted again after Mr. Minogue gave us the go-ahead. So there was a slight delay, but it appears that there won't be a schedule delay because of that.

Now, at this time they have already broken the ground. They are all ready to put the mud mat for the basemat and are ready to make the fabrication for reinforcing for the mat. That's where they are. They expect to start putting the reinforcing for the mat sometime in October. That's what I heard last from Sandia. So that's where we are.

But the one-sixth scale reinforced concrete containment, the contract was given to United Engineers in design and construction of the model. United will work with two subcontractors, Chicago Bridge and Iron for the liner fabrication and supplying the penetrations, and Wiss, Janney & Elstner will be doing some modeling and testing of the materials.

MR. RICHARDSON: Is there any problem with pouring concrete in the winter out in that desert?

MR. SIESS: None that they couldn't overcome. They could keep it heated.

MR. ASHAR: Well, there might be some, but I think there are enough precautions taken by Wiss, Janney in that area to make cold weather concreting a possibility. I don't think there should be a problem. Maybe they may have to delay some work once in a week or something like that, but there won't be a break, as far as I understand it.

MR. SHEWMON: A different question. I am confused, maybe, by the use of your word "model." Now, do you recall -- I take it you use the word "model" to describe the one-sixth scale reinforced concrete containment. The word "modeling" is often used to try to write a computer program or do something. So what this Janney & Elstner did was to design the one-sixth scale structure; is that right?

MR. ASHAR: Yes. Modeling includes quite a number of things, like making an assessment as to the size of the liner.

MR. SIESS: Excuse me. I think scaling would be a better word. And this was designed as a small containment. It was not scaled down from a full-scale design. They were told to design a containment of this size using the code. They didn't try to design something with No. 18 bars and scale everything down, but to keep things about right, and they used Wiss, Janney for scaling questions.

MR. BURNS: In particular, it does not represent any

single containment in existence.

MR. ASHAR: But it is a containment as such.

MR. SIESS: It is typical and will be analyzed.

MR. COSTELLO: I can't let the question about the weather in the winter go. The answer is fundamentally it depends an awful lot on the winter as to how much time might be lost.

MR. ASHAR: The model is designed to the Code, Section III, Division 1 and 2, and there won't be a requirement for an N-Stamp on this one.

MR. MARK: How many pounds extra would you expect if you did have an N-Stamp?

MR. ASHAR: Well, as a matter of fact, at this time NRC does not require an N-Stamp on regular containments even.

MR. SIESS: No, this thing would not be N-stamped.

[Slide.]

MR. ASHAR: The work with United Engineers has been divided into two phases. The first phase includes development of quailty assurance program, plans for support tests for concrete using reinforced steel and splices, et cetera, conduct the support tests, design the model, prepare fabrication drawings, report the results of the prefabrication test, and summarize the design work to Sandia in design review meetings.

The first one is completed and all the drawings are

available now. We are in Phase II right now, revise the design drawings and supporting specifications. I understand that has been done. Sandia has reviewed the comments. Site preparation has been done. Fabricate the model -- that will be done. Perform the post-fabrication support tests -- that will be done in fiscal year 1986.

[Slide.]

These are some of the features of the model testing. Its design accident pressure will be 46 psig. There will be two equipment hatches with three doors -- I think I have a slide to explain the three doors -- two personnel airlock representations, and two constrained penetrations. I will be explaining that to you later.

1/16th inch and 1/12th inch steel liner with studs. The 1/16th is for the cylinder part of the containment model, and the 1/12th inch will be for the dome area. That is why there are two sizes of steel liner. Piping penetrations will be there, simulated piping penetrations, and layers of major reinforcing just to simulate what would happen to various layers in the cracking because of the layering.

MR. RODABAUGH: What kind of material will that 1/16th inch steel lining be?

MR. ASHAR: I think I have something on it later that I will come to.

MR. RODABAUGH: Thank you.

[Slide.]

MR. ASHAR: The equipment hatches are two 40-inch diameter hatches. One is centered in the cylinder wall. It has two hatch covers. One is inside and one is outside. In the initial testing, up to a certain level, line 1.15, the design pressure, it will be used -- the inside cover will not be in. The outside will be in. So that we can know that unseating of the hatch cover, what will be done, will it leak, will anything happen to the seals and gaskets and that kind of thing.

MR. SIESS: The outside door will open out?

MR. ASHAR: We will try to open it. Whether it will open or not, we don't know. It is a pressure unseating.

MR. SIESS: Which is not the way we designed them.

MR. ASHAR: That's correct, yes. This is just to understand the behavior.

MR. SIESS: You are looking at seals, though, drywell seals, to see if drywell seals do open up. Drywell hatches, if I'm not mistaken, do open up.

MR. ASHAR: Unseating hatches uses a double-tongue and groove seal geometry. Pressure seating hatch uses a double gumdrop seal geometry. These are used in regular nuclear power plants. The other hatch projects out from the containment has one pressure seating cover and uses double gumdrop seal geometry.

MR. SIESS: These are not intended to be typical equipment hatches; they are intended to test doors.

MR. ASHAR: They test doors. Airlocks, all equipment hatches are not typical, but the equipment hatch is more or less simulated.

[Slide.]

The steel liner. It will be A414 grade D that will be used. Generally what is being used on concrete containments is A516 steel, but A516 cannot be available in these sizes, so they had to make some tests on the A414 grade, and they did testing to see if the properties of A516 and A414 are approximately the same as far as the use strength and ultimate strength. They have been reviewed by the expert committees, and it looks to be a promising one. It almost simulates the steel liner --

MR. SIESS: Does it have a flat yield?

MR. ASHAR: No, it is quite a curving yield. It isn't flat.

MR. SIESS: What is the ultimate strength?

MR. ASHAR: The ultimate strength is in the area -- guaranteed ultimate strength is about 60 ksi.

MR. SIESS: No, strain.

MR. ASHAR: Oh, strain? Twenty percent.

MR. SIESS: So that compares pretty well with the liners --

MR. ASHAR: Yes, that's correct.

MR. SIESS: And the typical liners don't have a flat yield either?

MR. ASHAR: No.

MR. SHEWMON: A curvy yield means there is a yield drop?

MR. ASHAR: It is a variation. It is some kind of variable plateau, and you weigh the yield strength at that .1 percent or .05 percent, what ever is defined as the yield point. 1/16th inch thick in the cylinder region, 1/12th inch thick in the hemispherical dome, thickened in discontinuity regions as required, and 3/4 inch and 1/2 inch long studs will be attached to the liner as designed in free field, one to one replacement near the penetrations.

Now, on start, I think there is a linear deviation from the scaling. In the general shell area, the spacing of the studs, attachment into the concrete liner, attachment to the concrete, is more spaced than what would be in the typical containment, but in the area of discontinuity like hatches and piping, it has been one to one scaling ratio.

There has been quite a long discussion on this as to whether we should spend money on buying hundreds of studs. It was decided by the peer review committee and all the other experts involved that it is not necessary to have one to one stud pacing for model testing, because we are doing it for

pressure and not for seismic or anything.

MR. SIESS: And you don't have a temperature?

MR. ASHAR: We don't have temperature in this.

MR. SIESS: The original stud spacing was based on buckling between studs?

MR. ASHAR: Between the studs, and under pressure only, there is no question of buckling as such, but in the area of penetrations there is some need for it, so you have the one to one ratio in that area.

MR. SIESS: And the one to one has nothing to do with the studs?

MR. ASHAR: No.

MR. SIESS: It's just confusing there.

MR. ASHAR: Yes. It means that it is simulated correctly in that area.

[Slide.]

Reinforcing steel. ASTM, A615, Grade 60. That is typically used in concrete containments. No. 4's are the major reinforcing which are available. Four layers of hoop steel, two layers of meridonial steel, two layers of diagonal steel. Diagonal steel will be for the shear reinforcing. Simulator seismic reinforcing, really. Nothing more than that.

MR. RODABAUGH: What kind of a space do you have between the liner and the concrete?

MR. SIESS: None.

MR. RODABAUGH: None at all.

MR. ASHAR: They are attached to each other by studs. Studs are connected to the liner.

MR. SIESS: There might be a space, but it isn't deliberate.

MR. RODABAUGH: Okay, thank you.

MR. SIESS: It is uniform.

MR. ASHAR: Additional layers of discontinuity regions, 6 millimeter, No. 3, No. 5 and No. 6 bars will be used, reinforcing bar splices, 4500 cold swaged bar splices, and 50 modified cadwelds. Now, there are some problems because what was happening was, generally in the typical containment, the cadwelds are No. 18 bars. No. 18 bar cadwelds slipped about yield strength or something, and No. 4 bar cadwelds don't slip. This was being discussed at length in our peer review meeting, and they have tried to define a cadweld that would slip for No. 4 bars. That is another way of getting around it.

MR. SIESS: Lots of luck. I have tried it with bigger ones.

MR. ASHAR: And the last I heard on this one was that they could slip it but then the ultimate capacity was reduced, and that we cannot tolerate. So probably we might use a few cadwelds for No. 4 bars, but without simulating the slip for the No. 18 bars.

MR. SIESS: I think you could do that with separate effects tests if you had to.

MR. ASHAR: That has been done. That has been done.

MR. SIESS: Are the small bars likely to end up a little stronger than the No. 8, and that you could take care of in your analysis?

MR. ASHAR: Yes, that is the intent, correct.

[Slide.]

Now, personnel airlocks. There are two of them. Both have a 1 foot, 8 inch diameter. One is used as an escape lock, which is not representative of an actual airlock because of the bulkhead door openings and the seals and everything. It is not simulating the actual airlock. The other has two bulkheads with a typical stiffener pattern.

As far as the shell penetration interaction, it simulates very well with the actual airlocks, but as far as the detail of the envelope itself, of the airlock itself, it still is not the right one because of the diameter.

MR. SIESS: As far as the structure is concerned, it is seeing a typical airlock, but as far as the doors are concerned, you are testing doors.

MR. ASHAR: That's correct.

Now, there are no operable airlock doors on that one, so we are going to have a separate test on airlocks, which I will talk about in the penetration presentation.

[Slide.]

Constrained penetrations. In our testing of the steel containment, the one-inch steel containment model, we also had one constrained penetration, and the results of that particular testing were quite interesting. We are going to do the same kind of testing, a little different than what we had in the steel containment, but the purpose of this one was to represent the constraint placed on the containment by major piping penetrations.

Basically, the supports for the main steamline and feedwater lines, et cetera are sometimes very near to the containment face, and in order to simulate how much restraint will be given by them -- this is only one of the parameters. There might be much more. But this is to simulate that kind of a constraint to the piping penetration as to will it yield faster, will it punch through. This is the thing we are trying to figure out.

MR. SIESS: Now, in the steel test, that didn't have any effect, did it?

MR. ASHAR: As far as we know, there was no effect because of the constraint placed, but the results around that penetration are very interesting. That is why the strained configuration.

MR. SIESS: Did the tie yield?

MR. ASHAR: No. It was not supposed to yield and it

didn't yield.

MR. SIESS: It wasn't a weak spot in the containment.

[Slide.]

MR. ASHAR: The final drawing shows you how the model looks. The concrete model will have --

MR. SIESS: Where is the ground surface?

MR. ASHAR: The ground surface is here [indicating].

MR. SIESS: I just wondered if you had any seismic instrumentation on this in case they had an earthquake.

[Laughter.]

MR. ASHAR: No, there is no provision for that, but one foot diameter is not correct now because after the preliminary analysis that was done between the wall and the mat, there was absolutely no convergence of the finite element analyses they are performing.

MR. SIESS: And you have got an interior concrete on top of the base?

MR. ASHAR: Yes. There is going to be fill concrete on top of the base, so this dimension is going to be 40 inches now, 3 feet 4 inches, am I correct, Jim?

MR. COSTELLO: Yes.

MR. SIESS: Does that line knuckle the same all the way around?

MR. ASHAR: You mean this one here? Yes.

MR. SIESS: Is any thought given to changing that around the periphery? They are different details if I'm not mistaken. Am I right?

MR. ASHAR: Well, there has been a code detail used on the sloping bottom part, but that is not dissimilar. All the recent reinforced concrete containments have a straight face, so --

MR. SIESS: I'm talking about the details of the steel liner. If that is the weak spot in the concrete and the liner sees large deformation, that might be where the liner ruptures if it does. And if it is, it is going to be a function of a detail, I would think.

MR. RODABAUGH: I would think so, too, and I wonder if there is a weld there.

MR. SIESS: There is a weld there, but that could be had by separate effects test. But I was thinking would it have been possible to take three arcs around and put a different detail in each one.

MR. COSTELLO: Frankly, we haven't thought of that.

MR. SIESS: At this stage I'm not about to suggest it.

MR. COSTELLO: We hadn't thought about that.

MR. ASHAR: What happened was this detail was a very typical one being used for the recent reinforced concrete containment, like Seabrook has the same detail.

MR. SIESS: After what happened to the steel one, I wouldn't use the word "typical" on anything.

MR. ASHAR: That is true.

MR. RODABAUGH: This is 1/16th inch steel liner, a 16th-inch thick?

MR. ASHAR: Yes. 1/16th inch.

MR. RODABAUGH: You are going to have the problem of welding 1/16th inch steel in a corner weld? Is that just a corner weld at that critical point here?

MR. ASHAR: Yes.

MR. SIESS: Is it just this?

MR. ASHAR: The way we are planning it is that up to some point here, this part will be welded outside -- on the fill, and then it will be placed on the site. This part will also be done in the same way, so that there is no grouting. It will be --

MR. SHEWMON: But the question is you have to match this up and it is very easy to burn through.

MR. ASHAR: That's correct, and CBI has developed a special procedure for the T liner welding. We hope it does simulate the way it should be done.

MR. SIESS: Those steel models, how thick were the small-scale steel models?

MR. COSTELLO: The small-scale steels were .056.

MR. SIESS: And they welded those.

MR. RICHARDSON: Is this just a fillet weld in the corner?

MR. ASHAR: No, it will be a groove weld.

MR. SIESS: This may be better than the typical ones by the time they get through.

MR. ASHAR: This is a diameter of 32 feet and a height up to the spring line of 32 feet, 3 inches, and it is a hemispherical dome.

MR. SIESS: Can I ask you a question about material properties? Do you know the NDT of the liner material? Is that a test that will be made?

MR. ASHAR: Yes. The test was going to be conducted on it to make sure that it is as per the ASME Code.

MR. SIESS: Do you know the NDT of the rebar?

MR. ASHAR: No, we don't know the NDT of the rebar, either in this model or in actual prototype containment.

MR. SIESS: I know what it is in ordinary rebar. It's about the temperature in here.

MR. ASHAR: Right.

MR. SHEWMON: You don't do a Sharpy bar on 1/16th inch steel.

MR. ASHAR: They are going to do some energy tests. Whether it's Sharpy or drop rate or what, I have no idea at this time, but I will let you know if you are interested.

MR. SIESS: I would save some rebar just in case you

wanted to know what the NDT is later.

MR. SHEWMON: I rebar you could do it, but none of those tests are done on 16th-inch sheet. They are all thick plate.

MR. ASHAR: That's right. They are at least half-inch specimens, yes. They plan to do -- I have not heard about the results and how they have done it, but I will find out for you.

MR. SHEWMON: Chet, the other thing is there is no Sharpy test on stuff thinner than half-inch or something because you can't get the thickness to make it relevant. It is all shear lift.

MR. ASHAR: Well, this is about the end of my presentation. If you have any question on details, maybe I have some slides I can show you.

MR. SIESS: And right now they have poured the mud mat.

MR. ASHAR: Yes, they are ready to pour the mud mat.

MR. RICHARDSON: How many channels of instrumentation do you anticipate?

MR. ASHAR: About 1500. There are more than in the steel model. The steel model had about 1100 or so.

MR. COSTELLO: About 7. We do have a graph where we have some of the --

MR. RICHARDSON: I was just after a rough order of

magnitude.

MR. COSTELLO: Around 1100, I think.

MR. SIESS: Let me ask a question. The reason for using a gas to test this -- of course, there are two reasons. One is you are interested in leakage and it is leakage of a gas, and the other is that the mode of ultimate rupture will be, presumably, different with a gas than with a liquid. But is it conceivable that you could get far enough in a gas test that the thing -- if it leaked, you would have called it a leakage failure and you could back off and make a final test with a liquid where you could observe things more easily.

MR. COSTELLO: I think that's possible if that is the outcome. If we do get a small stabilized tear in the liner which leads to depressurization and inability to add the pressure in the gas, then we are in mode 2 of what to do next.

MR. SIESS: Would it be possible? I mean are your gauges protected inside well enough that you could fill it with water?

MR. COSTELLO: I think with a bladder.

MR. SIESS: That would be pretty expensive. You know, a Canadian test was made with water and a bladder, and they learned quite a bit from that, but I'm not sure they couldn't have learned it with air, but they couldn't have used air at their site. You know, the pieces would be a lot easier

to find.

MR. COSTELLO: But I think, you know, we haven't gotten down to Phase II yet, but our thought in the steel model was to bring it up to pressure failure and then see where we were about the possibility of maybe finding the next failure mode up by repairing and raising pressure again. One of the thoughts there was -- you know, what you might find out depends an awful lot on how far you are out in strain.

MR. SIESS: Well, it is just a thought.

MR. EBERSOLE: May I ask a question? Chet, you said the Canadians did this with a bladder?

MR. SIESS: They build a model of prestressed concrete, a can-do type containment. They don't line their containments with steel. They had a rubber liner in it.

MR. EBERSOLE: Well, can't you do a test like this with a mixed environment inside which is mostly filled with water or with x percent in a pneumatic ball and diminish the terrible consequences but still get --

MR. SIESS: The tests have to be with gas because they are interested in leakage. It's a gas that is leaking. I was just trying to find some way to avoid the explosive type -- where you can't see what happens and you just hope your cameras and your strain gauges catch enough information.

This tends to be a one-shot test. You spend a lot of money on it and you would like to milk it for all it's

worth.

MR. EBERSOLE: Well, for a strength test, you could fill it 99 percent water and have the rest pneumatic.

MR. RODABAUGH: The problem with water, of course, is any inside instrumentation like strain gauges --

MR. SIESS: Yes, if they are not waterproofed, and that is quite a job. At that stage you may not be interested in strains anymore.

MR. RODABAUGH: It's very possible, but it might be worth keeping in mind.

MR. SIESS: I mean you expect it to do more with the steel.

MR. COSTELLO: Another possible desirable use for this model is we do get a localized tear in the liner and a leakage through the concrete would be the same as you might have used for the steel model as a vehicle for some nice thermalhydraulics test in a large volume.

MR. BURNS: Actually, I would hope this would not be a catastrophic failure but that we could use it for a test vehicle for testing other things, like other forms of penetration and such.

MR. EBERSOLE: What is the time interval for a catastrophic failure? How many milliseconds are we talking about?

MR. COSTELLO: Very few. I have a little something

to show you here later.

MR. EBERSOLE: Not time enough to detonate a member, though, or anything like that.

MR. SIESS: I don't think this one can go the same way, but then --

MR. RODABAUGH: Chet, for my information, what happened to the steel model?

MR. SIESS: They are going to show you. I think that is waht we have here up on the film.

MR. COSTELLO: We have a little summary --

MR. SIESS: Is that the failure test?

MR. COSTELLO: Yes, sir.

MR. SIESS: Okay. We will wait. They couldn't get all the pieces in one photograph, I will tell you that.

MR. RODABAUGH: It failed under gas pressure. How big was it? About the same size as the concrete one?

MR. COSTELLO: Just a little bit smaller, about a one-eighth size.

MR. RODABAUGH: I would guess you have got pieces around a radius of a mile, more or less.

MR. SIESS: No, not quite.

MR. COSTELLO: No, thank God.

MR. SIESS: No, they weren't that far away from it. A mile away would have put them over in the -- what is that mountain?

MR. RODABAUGH: There is a fair number of industrial accidents where a tank had a gas pressure break off and could go a mile.

MR. BURNS: If the pieces went a mile, I doubt if Sandia would allow us to test this particular model at this site.

MR. SIESS: This was at an isolated site, but not that isolated.

MR. RODABAUGH: Battelle had a site they thought was isolated. They broke windows within three miles.

MR. SIESS: Gentlemen, this is the time for a break, and then what are we going to hear, the steel one?

MR. COSTELLO: After the break, I will talk about pretest and post-test analyses, primarily with emphasis on the steel model series, and then some lead-in into the concrete.

[Recess.]

MR. SIESS: All right.

MR. COSTELLO: James Costello from NRC Staff again.

I would like to start talking about the pretest predictions and post-test analyses and attempts to make sense of it all, which activity we have more or less concentrated into a single FIN, and having the other two FINs that Hans Ashar was talking about concentrating on trying to get the experiments built and done, which is the major undertaking that we have.

I would like to give some indication about some of the cooperating organizations involved in pre and post-test analyses. We have had with KFK in Germany some collaboration on the steel model. We had somewhat hoped that they might be inclined to try to predict the large steel model tests bearing in mind that the containments that they have been looking at in their research program are spherical.

However, they thought about it and decided that they are better off putting their analytical money into spherical models. However, they are cooperating with us to the extent of testing, doing biaxial testing in a machine that they have of some of the materials that we had in the steel models.

We also expect that we may well have cooperation down the road in the seismic question in Germany. That is, we have not yet gotten to that, and I will talk some more about the seismic question later.

As far as the concrete experiment, we do have agreements with EPRI to provide pretest predictions for the model. We also have agreements with the Commisariat A L'Energie Atomique, CA, Ensacle and Fontaneeurs to perform pretest predictions. They now have copies of the drawings and are at work. The same with the Nuclear Installations Inspector in the United Kingdom. They are having a contractor doing a pretest prediction. I will talk a little more of that later.

MR. SIESS: What are they predicting, leakage or failure?

MR. COSTELLO: Deformation.

MR. RICHARDSON: I think there is an interesting contrast between these two organizations. CEA is going to do a very complex, three-dimensional, sophisticated analysis, kind of representing the people that are enamored with computers and 3D finite element approaches, where NII is going to take a very simple approach, not quite back of the envelope, but a very simple approach, and I think it will give us a chance to see the sensitivity of complex versus simple methods and models.

MR. COSTELLO: Yes. The whole idea here is to try to get some handle on how well state of the art techniques can work and what do you have to model and how well to get predictions that are viable.

[Slide.]

I think at this time I would like to give a quick summary of where we were. In fact, in talking about the pretest predictions on the steel model series, I have to say that is one place where I bet on the wrong horse. I had the mistaken belief that self-interest, enlightened self-interest would have A&Es and/or computational mechanics firms want to show off how well their calculational techniques could predict the outcome of these experiments.

It all went along fairly well. We did invest some money in mailings and winnowing lists, asking people would they be interested. The answers of a great number were yes, and apparently when it required only a 20 cent stamp, they are willing to say yes. We sent out some drawings and responses began to flag, and in fact, no A&E firm or computational mechanics outfit actually went through the in-house expense of doing the calculation. Perhaps they just didn't see the market for it in the aftermath, but that is one place where I --

MR. SIESS: Are you assuming that they knew how? I mean it's a lot different calculating when something will fail and calculating when something will stand up, which is what design is.

MR. COSTELLO: I believe that all these firms had the same tools that were available to the people who did the calculations at Sandia.

MR. SIESS: Inelastic?

MR. COSTELLO: Yes, sir.

MR. SIESS: Yes, but how much experience did they have using them?

MR. COSTELLO: More, I think, than some of the people at Sandia who actually did the calculation in some firms.

MR. SIESS: You mean the AEs had made inelastic

calculations of containment behavior?

MR. COSTELLO: These have not, to my knowledge, made much more than the capability prediction kind of calculation.

MR. SIESS: Some of those just say calculate the yield strength and that's it. That's not really inelastic.

MR. COSTELLO: Or one percent --

MR. SIESS: That's still elastic.

MR. COSTELLO: But I think the people are there. Certainly the A&E firms have garnered a large number of the graduates of major universities over the last 10 to 15 years, and all of these fellows, many of them have been engaged in those kinds of calculations. Certainly the computational mechanics firms have that as their stock in trade, but I guess they simply didn't see the market and didn't want to make the in-house investment.

The activities currently going on I will talk about on pretest predictions of the model tests at the end.

I would like to go down to 1986 and 1987 a bit with you and then go back.

As Jim mentioned before, we made a conscious decision some years ago after discussions with our peer review panel and other members of the NRC Staff that a single model test of a reinforced concrete model, given that it was about all we could afford, was also the most likely vehicle to give us enough understanding to try and predict prestress behavior.

We had as background the fact that there had been the Canadian model test, albeit on line, at 1/14th size of a prestressed containment. There had been in the past, albeit it at much greater wall thicknesses, PCRV test to failure, and the prospect that there might be a prestressed model test of something representing the SNPPS type containment undertaken in the U.K.

That's an off and on -- as Jim reports from last August, it looks more on than off, but things might change by October. Nonetheless, we had that for background, and we also had the belief that, given that the cracking phenomena are the hardest to model and the effects of the cracking phenomena on the liner are the hardest to model, the reinforced concrete model would be a harder test of the ability to model behavior near failure.

Further, or taking the belief that you could reliably predict failure in a reinforced concrete model, extensions to prestressed where you have much less cracking along the path would be easier done. We still believe that. We now have to prove it. We will begin that in '86.

We also have to look seriously at the question of what do we need to do, if anything, to look at the question of degradation of containment capability under large seismic loading. Is it possible that you might lose containment capacity in a containment in an accident to follow?

MR. EBERSOLE: When you do this, are you hypothesizing that a coincident loss of coolant accident or a secondary failure will occur?

MR. COSTELLO: No, sir. I will get to that later, at the end. At the end I have to say a few words about where we are gonig to go there.

We will then in 1987 be going back to try and figure out what happened in the concrete model test, and I, frankly, am not as optimistic about that as I was about the outcome in the steel experiments. In the steel experiments, I stood here cheerfully four years ago and said it will all come out, not to worry, we will figure out rather easily what happened. I think we did and I will talk about that a little later.

In the concrete model, the state of the art of large deformation modeling is not anywhere near as vast and tried and true as in other applications in steel, and I expect we will have, in Professor Siess' phrase, a good deal more questions after the experiment than we had in the steel.

With that, I would like to spend about 10 minutes or so on the videotape machine giving you a little precis of what went on in the steel experiments. Now, this is not a very elaborate production. It is not, shall we say, of the caliber of those produced by KFK on the HTR experiments. It is simply a splicing together of pictures, graphs and the like collected over time in the series of steel model experiments, with

admittedly a little bit of music and some file footage taken in, but I think it does rather neatly summarize what went on in the steel experiments area.

[A videotape was shown.]

MR. SIESS: Jim, have you got an explanation for why those cracks did not run in the first two steel models?

MR. COSTELLO: We have a pretty strong hypothesis which is being checked now in the closeout. The answer is most likely extreme thinning, and we have measurements on that done by the grinding wheel at --

MR. SIESS: Yes, but why didn't it run?

MR. COSTELLO: The primary suspicion is that the material was so thin that even --

MR. SIESS: The stresses outside of --

MR. COSTELLO: Yes, it was confined by the material.

MR. SIESS: In both cases?

MR. COSTELLO: In both cases. And that is one of the things that we are going to check out. The fundamental thing, in the words of Dr. Von Reisman, his observation was that grinding wheels don't scale very well.

MR. SIESS: You know, I'm going to make a semi-facetious comment that maybe that is the way we ought to build them. You know, just put a thin spot in there so that when they do fail, it will just be a nice, good-sized leak and they won't end up in pieces around the countryside.

MR. EBERSOLE: That notion of programmed failure, Chet, that's what you are talking about, isn't it, programmed failure?

MR. SIESS: This is leak before break.

MR. EBERSOLE: Yes. I never really had heard that treated as a design thesis. I don't know why.

MR. SIESS: I mean it's just like a rupture disk.

MR. RICHARDSON: What would be the difference between that and a relief valve?

MR. SIESS: Well, somebody has got to decide to open that relief valve.

MR. RICHARDSON: Well, it could be set at some pressure.

MR. SIESS: Well, they will debate that for five years.

MR. SHEWMON: I was going to ask the question a different way, and that is, how do you think the NRC is going to approach what they will have for the limit on this. There is a decision of, okay, when do you recommend opening it so it doesn't blow?

MR. EBERSOLE: Well, it certainly doesn't seem rational to build it like the wonderful one-horse shay.

MR. SIESS: Paul, your question is great because, if that question could be answered now, we would probably end up saying that we want to be sure that it doesn't rupture, and we

want to open a valve or have a rupture disk or something in it. We would probably choose a pressure that could be predicted with a great deal of confidence, and we wouldn't need these kind of tests. But nobody has answered that question. In fact, they haven't even asked it properly. So we go ahead and try to get all the answers. You know, whatever anybody decides to do, we will be able to tell them how this thing will behave.

MR. COSTELLO: I think that, you know, an outcome of a series of steel experiments was to pretty strongly reinforce the suggestion that if you picked -- and some other penetration experiments that Hans is going to talk about next -- is to suggest that if you picked something like general membrane yielding, you would be quite sure that you were well below onset leakage from penetrations and that you are well below likely gross failure.

MR. SHEWMON: What was the pressure for general membrane strain on this one?

MR. COSTELLO: I don't have the Vu-graph -- well, it was around 160.

MR. SIESS: Your post-test analysis, you can probably explain why that thing failed, the big one that failed when it did.

MR. COSTELLO: Yes, sir.

MR. RICHARDSON: But that doesn't mean you could

predict it because it was sort of a localized effect of the people going back looking at had they accounted for the eccentricity Sure. And they debated it at the time when they made their pretest predictions. They debated whether they should model that eccentricity or not. They erroneously concluded that it was a never-mind.

MR. SIESS: But how many places would they be in a typical containment where somebody would have to make that decision, you see.

MR. RICHARDSON: Probably a lot.

MR. SIESS: And yet, to make a decision to take a general membrane yielding or smeared -- you know, you have established you can smear the stiffness.

MR. SHEWMON: That is four times design. You know, one shouldn't be greedy.

MR. SIESS: Yes, but it's four times LOCA design, but it's not four times what the severe accident predicts at certain stages, and you get peaks at early stages. In some containments those peaks are within the uncertainty range on the ultimate capacity.

MR. COSTELLO: Yes. TMLB sequences and things like that.

MR. BENDER: In these tests that you have run, somehow or other they have to be put in relation to the leakage characteristics of the closures that some people are

arguing will occur before the failure of the vessel itself happens. Do we have any feeling yet for what the relative capability of the sealed closures is?

MR. COSTELLO: Hans is going to talk to that in his summary of the penetration work, but it simply comes down on the steel model test to this. The ovalization of the equipment hatch, which was suspected to be the most likely failure mode of leakage through that equipment hatch, was predicted very accurately.

MR. BENDER: That is not quite what I'm asking, but it may be around it. If the burst pressure of this vessel is four times the design pressure or whatever it is, and the leakage capability of the gaskets is 2.5 times the pressure -- I don't know really what it is. I'm just picking a couple of numbers.

MR. COSTELLO: It was substantiall more than 4.5 because the leakage did not occur.

MR. SIESS: This one did not leak.

MR. BENDER: Well, this one did not leak, but I don't know whether this is representative of the gaskets --

MR. COSTELLO: Let me speak to that question. One of the exercises we went through in the post-test analysis, which I have not reported here, is to ask the "What if?" question, to say, what if, instead of this equipment hatch reinforcement configuration, another one or two which

are typical of the population were put in?

It was easy to examine that question because one had great confidence about the finite element model's ability to predict the ovalization having been benchmarked against the test data. I think five were examined that spanned the population. The outcome was that two of them would surely not have leaked in this experiment. The one that was in there didn't, and two others would almost surely have leaked earlier.

MR. BENDER: Well, there are a couple of ways to deal with Paul's point. One obviously is to put in a rupture disk. Really. Another is to have some weakened structural capability, and the third is to select the kind of sealing for the closure that would assure that leakage does occur in sufficient quantities so that the bursting never occurs.

Now, all those remedies are out there and they are all within the limits of the present regulatory system. The only one that is not in there, maybe, is that nobody wants to be in the position of saying, well, I'm going to be the guy that is going to press the button. That's not exactly rational, but that is the way it is.

MR. COSTELLO: Again, as Professor Siess pointed out, there is that question of how much more is really there that might be of benefit to you. If, indeed, you believed that the pressure in an accident was going to peak at 165 or

170, you would not have wanted to push the button at 160 given that this thing was going to ride out until nearly 200.

MR. BENDER: Well, if that is the game you want to play. But if you really would prefer to be in the position of saying I want to have an assured capability up to some level, and when that level occurs, I want to direct whatever comes out in a certain way, you would be far better off to select some mechanism and say, I'm going to work on the reliability of that failure mechanism happening.

MR. SIESS: Mike, what you are bringing up, it would be very nice to know at this point just how somebody is going to use these results, and that is what I was stressing. In contrast to some of the stuff we heard yesterday, the severe accident business has not been carried far enough yet that anybody knows how they are going to use it.

Now, we have had that trouble with the whole severe accident program, that people could not tell us what they were going to do with it when they got through; they were just going to learn everything about everything. The severe accident program hasn't really addressed the possible uses of this. Until some of this work was brought in, the people that were calculating containment loads, containment pressures were assuming it wasn't going to leak at all. They were drawing curves that just went on up. You know, the idea of containment leak never entered their minds.

And then their attention was gotten and they started calculating containment loading as if it might leak, and they are just beginning to think about these things.

MR. EBERSOLE: Well, Chet, it must surely be true that nobody contemplates that we will ever allow a containment to approach a burst pressure.

MR. SIESS: They haven't even thought about it yet, Jesse.

MR. EBERSOLE: Well, it has been around for 20 or 30 years.

MR. SIESS: I know, but in addressing a policy on severe accidents, this has not been addressed except to talk about vented filtered containment.

MR. EBERSOLE: I would rather have a big cannon out there on the site to open it up if I had to.

MR. SHEWMON: Well, that is part of why you are here, you know.

MR. SIESS: We are not so sure that the burst of this thing seven days down the line makes that much difference.

MR. EBERSOLE: Well, if it bursts violently and re-entrainment occurs, that is something else.

MR. SIESS: That is something they are just beginning to think about. As far as I can see --

MR. EBERSOLE: I can't see by any stretch of the

imagination that we would ever approach a burst pressure; that we would take violent means to preclude that.

MR. MARK: Well, this is at leat telling you that you have a good chance to know where that burst pressure is.

MR. EBERSOLE: Right. That is all I see here, is that you are finding the margin at which point you would deliberately open it.

MR. SIESS: Well, if somebody would say that they wanted a highly reliable, conservatively-established burst pressure below which they could vent, I don't think we would need that test.

MR. EBERSOLE: That is the point.

MR. RICHARDSON: Except you may need it to establish the validity of your models that predict that burst pressure.

MR. EBERSOLE: But you could put margins in the strength.

MR. SIESS: But I think on the steel ones -- maybe it took the big one. I'm not sure. I said to predict a highly reliable lower bound, and if somebody says, okay, we will accept yield as that, we don't really need a lot of model tests.

MR. RICHARDSON: But that may be so low that it would --

MR. SIESS: It may be too low, but you see, you have got to think about it.

MR. SHEWMON: We are talking about concrete now.

MR. SIESS: I'm talking about either one.

MR. SHEWMON: Well, but the steel, if that was four times the design pressure --

MR. SIESS: I know, but it's not four times the accident pressure. Design pressure doesn't mean anything when you are talking severe accident.

MR. BENDER: It only sets an upper bound on what the pressure is --

MR. SHEWMON: When you say a highly conservative lower bound, the design pressure is that, and that is much too low.

MR. SIESS: Well, no, 115 percent of design pressure is a highly conservative lower bound, but the higher you go, the greater the uncertainty is, obviously.

MR. EBERSOLE: Chet, let me ask you. With the concrete vessel, I understand that at least for the primary concrete vessels for gas, they have an intrinsic phenomenon that the reinforcement will stretch, the concrete will crack, and it will become its own permeable relief system.

Will that apply to this containment?

MR. SIESS: The liner has to fail. The concrete is not leak-resistant material. The liner is.

MR. SHEWMON: But the concrete limits the strain on the liner so that you may well have -- well, you certainly

will have a limited rupture.

MR. SIESS: Yes, that's right, but the cracks in the concrete can get pretty large before the liner fails. We don't know. The reason for testing the concrete containment, in my mind, is to see if there are some questions we haven't thought about.

MR. EBERSOLE: If the liner failed and it pressurizes the concrete inner surface, then the concrete is pressurized, and will it not then act as its own relievable structural --

MR. SIESS: Oh, yes. Unlined concrete, you can probably get enough cracks so if the stuff would leak out, it would go out through cracks, and then you have the question of how much deposition there is and aerosols in the cracks. You know, the devious path and so forth. But again, the unlined concrete one would not work for a LOCA, which has always governed our design.

Now, in a prestressed concrete containment, they are designed not to crack under LOCA load, and the Canadian prestressed containments, the French prestressed containments -- no, the French have liners, I believe, although they have looked -- well, anyway, the Canadian one, I know, is not lined. It has an epoxy paint that will take care of --

MR. EBERSOLE: It will stretch.

MR. SIESS: But it is prestressed, so at LOCA loads

it is not cracked, and nobody has looked beyond LOCA loads because that is what they were designed for. But a reinforced concrete one would not stand the LOCA. You could not get one-tenth percent leakage at LOCA loads on a reinforced one because you would have enough stress to get some cracks and you would get some leakage. I don't know whether anybody has even tried to calculate it.

But now we are talking about accident loads. At Indian Point, for example, TMLB' gets you up within a few psi of the predicted yield capacity, I think, in a coupe of hours, if I am not mistaken, and then it drops off a little bit and then a slow overpressurization comes and it keeps on going. But at that first stage where there is a lot of fission products in containment, it is within a range where you might like to know it better. In some others, you would be a mile off.

You see, you remember the trouble we went to on Sequoyah trying to get the capacity -- you know, we had four different answers and we sat around a table one day. You take the same design, essentially, for McGuire, where they didn't reduce the thickness of the liner as they went up. Remember, Sequoyah had the liner getting thinner and thinner as it went up; McGuire didn't. So McGuire had something like, what, 50 or 60 percent more capacity. And this was just the designer's choice of trying to save steel as he went up on this thing

because of vertical load. Remember that? So you have to look at those things. It makes a difference.

But if somebody would tell us what they wanted -- they were really going to vent these things and they wanted, you know, a 99 percent probability that they would vent below --

MR. EBERSOLE: Well, who is that somebody and why don't we find him?

MR. BENDER: It seems to me if we were doing it in a rational way, you would lay out all the strategies, and if you had a good probabilistic risk analyst, he would make the arguments for the various data --

MR. SHEWMON: We would submerge him in severe accident codes and he would never be seen again.

MR. BENDER: Well, that's probably right.

MR. SIESS: Well, if you believe the severe accident codes, which, you know, takes a certain amount of faith, you could be at that point right now. But as I pointed out, IDCOR looked at this venting thing; but on a cost-benefit type thing, venting to prevent rupture of the containment seven days down the line isn't worth anything in terms of dose release.

Now, they didn't talk about the resuspension.

MR. RICHARDSON: Yes, with catastrophic failure.

MR. EBERSOLE: That is what would be a key effect.

MR. BENDER: You won't have it if you will accept the argument of gasket leak --

MR. SIESS: But Jesse, the severe accident research has placed -- I am prejudiced -- has placed 99 percent of its emphasis on source term, and what is in the containment, all the scenarios and how it gets there and so forth, and on containment loading phenomena, and have not really been thinking about the things we are asking questions about. I have tried to get their attention on it.

MR. EBERSOLE: The cart is always before the horse, then.

MR. BENDER: No, that's not quite right.

MR. SIESS: The people that were doing the work got absolutely fascinated with this suite of codes, and they are going to get answers to what people thought were unanswerable questions, and now we are doing it, you know, and we are doing research on core-concrete interaction.

MR. EBERSOLE: The war is being won by the patrols.

MR. SIESS: Yes, it's the old question, Jesse. The ACRS has been asking it ever since they started. What are you going to do with this? What are you going to use it for?

MR. EBERSOLE: Yes. If you had already done it, what would it be worth?

MR. SIESS: If I told you this, what would you do with it?

MR. EBERSOLE: Yes. Well, I think every research program has all this. Suppose you are already done? What have you got?

MR. SIESS: Yes. What they did on severe accident -- I said it and I will say it again. Their approach was we are going to learn everything about everything, and when we get through, we will know what to do about it. And they are still trying to learn everything about everything. And here we tried to learn everything about everything because nobody has told us what they might do about it. And you can't ask the structural engineers what to do about it.

MR. COSTELLO: Well, I can't say that we are so immodest as to try to learn everything about everything.

MR. SIESS: No, I didn't say you are doing that, but again, you may be learning more than you have any use for if somebody could tell you what they wanted to do with it.

MR. COSTELLO: Yes, but one has to look at the prospect that a high degree of confidence of when and where it's going to fail is something in the end game that will be important.

MR. SIESS: You heard me state one of my famous generalities that one of my old professors taught me, and it has been borne out by my own experience. It says tests on full-sized structures never answer questions, they only ask questions. And this is about as close to a full-sized

structure as you are going to get.

Take the steel one. Did it ask any questions?

MR. COSTELLO: I would say it asked three questions, two of which were easy to answer, one of which was a little harder, and I think we have got the answers to them. And the net outcome I say is this: that the capability exists within the A&E firms and/or some of their consultants on behalf of utilities to go back and look at the steel containments they designed and built, use available technology and come up with very good estimates of when and where the containment is going to fail if they choose or the utility chooses to put the money into it.

MR. BENDER: I wonder if I could make a point that develops something Dr. Siess said a moment ago. When the Sequoyah vessel was looked at, there were four methods of analyzing them and they gave four different pressures.

MR. COSTELLO: I think it was closer to ten.

MR. BENDER: Well, I'm not sure how many there are, but four is enough for my argument. I am not clear right now which of the four was near to the right answer based on the experimental program that you did here, but it might be useful to be able -- to make that comparison just for the purpose of showing --

MR. SIESS: Well, one thing they established clearly in the small scale was that smearing works. You can smear the

stiffness, and that was an issue in the Sequoyah thing. Somebody assumed it, What's-His-Name with Westinghouse, with Ops, made the finite element type thing and supported it, and that came out very clear.

MR. BENDER: But I guess th> point I am really trying to make is that, yes, all the architect engineers can predict these capabilities. The question is which of the several methods that is out there is the one that you want to give preference to for this purpose. That's the most useful part of this program.

MR. COSTELLO: I will give two answers to the question. The answer to Problem 1 is, as I tended to call it over the years, that is a not unreasonable lower bound estimate. I believe there is sufficient evidence for steel containments that membrane yield quite suffices, and the outcome of the attempts to get leakage around these penetrations and some of the other experiments that Hans will talk about, if I ever give him a chance, at temperature will support that hypothesis.

The second one is Problem 2. Do you really have to know when and where it is going to fail? I say that the outcome of these experiments has been reasonably conclusive that the state of the art will do it if someone wants to model it in the kind of detail that's required.

MR. SIESS: I think Mike may not be aware of how

that steel containment failed and why.

[Slide.]

MR. COSTELLO: Oh, yes. May I wrap up?

Here we go with the picture. Up here you have a formed stiffener, a formed horizontal. There are eight such details like this.

[Slide.]

The design had what amounted to a half-inch of eccentricity. That is in the lower picture. Why? In order to make the weld, I guess. The belief by the fabricator was that that is the common thing to do. The judgment was made, after some agonizing early on in the pretest prediction, to model it as if there was no eccentricity.

MR. SIESS: Now, here you mean mathematical model and analyze that?

MR. COSTELLO: Yes. The analyzing pretest analysis. Let's not try and bring in a little bit of bending in here because tradition says that's not really important. Again, in yielding, things will -- et cetera. So they went with this model [indicating].

The outcome of the experiment was that at around 165 psi, a crack was noticed in the formed stiffener. The crack was spotted by an operator. One continued to raise the pressure in the programmed fashion. On the way from 192.5 to 195, there was the outcome.

This, as I say, was the third question, the hard question that was harder to explain, but it turned out to be not that hard. They went back -- you know, no curve fitting, no derivation of constants. Just went back in and did a finite element model, which included that eccentricity.

[Slide.]

MR. SIESS: Would the model predict the crack running?

MR. COSTELLO: Yes.

MR. SHEWMON: No, you don't really get into fracture mechanics in your model, do you?

MR. SIESS: No, but you get into propagation. Was the crack a brittle crack?

MR. COSTELLO: Oh, no. It's ductile.

What happened at predicted strain in the cylinder right next to that juncture in the pretest analysis, the membrane yielding roughly at 160, things beginning to happen, but nothing that would lead you to believe that you would have a catastrophic failure. And the predictions went out somewhere up here, around 220.

The other predictions for deformations around the hatch in ovalization suggested that you really would have lost metal-to-metal contact around 210. You would expect leakage, but it never got there.

MR. SIESS: Jim, the knee in the curve at 165 could

be predicted without a finite element analysis?

MR. COSTELLO: Yes.

MR. SIESS: That could be just membrane-type.

MR. BENDER: Well, the point that I was trying to make, and I will try to make it again, is if I can establish that 165 psi, or 160, whatever it is, is predictable by the methods of analysis that are available to me right now, and I don't have to worry about the sophisticated details that come with having to predict the rest of the behavioral pattern, I probably know enough to say if I can make the case for that 160 pounds being an acceptable upper limit and I can design the vessel so it relieves before that point, I have got a better case for accident control than I had with any of these things based on ultimate failure.

MR. SIESS: Right.

MR. COSTELLO: That is certainly a more robust argument if that is the one you want to make.

MR. BENDER: That's the one I ought to be trying to make, and that's the one you ought to be trying to make.

MR. SIESS: I think that's the one they are about ready to make on the steel containment. I think they are satisfied now that if somebody will look at the details, which conceivably could affect you even lower, but if they would look at the details, that you could predict that level with a high degree of reliability and you could probably predict some

other level with somewhat less reliability because there is always the question of completeness; right? And they don't propose to do any more tests on steel containment.

MR. COSTELLO: No. As far as we are concerned, the ballgame is over from a research point of view.

MR. SIESS: Now for concrete containments, what you would hope to get out of the test is some similar surprises or details or -- I hate to use the word "outliers" or something of that sort. But that can be overcome by a suitable analysis and end up on the same state with the concrete containment.

MR. BENDER: Let me go back to the other point that I was trying to make. Sequoyah had an analysis. If I were to take one of these analytical methods and relate it to Sequoyah, what answer would I get?

MR. SIESS: Oh, you could predict 165 --

MR. BENDER: For that particular vessel, in comparison to what they did get. Do you understand what I'm trying to say?

MR. COSTELLO: Sure.

MR. BENDER: Let's get a real case and compare it with a model so we have something that exists, that we can make a case with.

MR. COSTELLO: Well, let me tell you how we are going to close this thing out. We are going to have -- it is part of this question. We are going to examine the question

of how different details in the population might lead you to something like this. Just as we examined previously how different penetration designs -- as part of doing that examination, we are going to be looking at what kinds of modeling would have to be done for real penetration, and real details in reinforcement. And those kinds of calculations will be done on a sampling basis.

The real answer is, to my thinking, that the persons most capable of giving a good analysis of the containment are the people who designed them.

MR. SIESS: But, Jim, you take the Sequoyah analysis and use the smeared stiffeners, ignored the penetrations, except for looking at the capacity for buckling and so forth. The prediction that that analysis made of the general yield -- if you tested the model of Sequoyah, if you tested Sequoyah, don't you think there's a very high probability that it would reach that pressure --

MR. COSTELLO: I would say virtually certain, yes, sir. And in fact Gryman has done that calculation already.

MR. RICHARDSON: It seems to me Mike is asking, look, a few years ago in an atmosphere of a lot of ignorance, they made some predictions. Doesn't it make sense now to go back and revisit how well they did, using today's technology?

MR. SIESS: I don't think you have to go back, because all they did was look at free field, smeared the

stiffeners and --

MR. RICHARDSON: It seems to me, though, it may not be a big deal to do, but an interesting --

MR. BENDER: My reason for wanting to do is pragmatic. It says, look, here is a case we had out here, here is how the research would have influenced that action. If you did what Jim did later and looked at all the variations that have to be thought about, I think that is a constructive thing to do.

MR. SIESS: But, Mike, I think it has already been done.

MR. BENDER: I know, but they haven't put it out there where people can see it.

MR. RICHARDSON: But it would lend credibility to what we have done.

MR. SIESS: This shall reach general yielding, which is all the Sequoyah analysis was.

MR. BENDER: I think it would show that one of those methods was the right one to use.

MR. SIESS: To predict general yielding. That it wouldn't fail --

MR. BENDER: That was enough for them at the time.

MR. SHEWMON: Mr. Chairman, are we at 9:30 or 10:30?

MR. SIESS: Well, we are closer than you think.

I have suggested to Jim Richardson that we will skip

seismic performance of containments, which is clearly in the future, and pick it up at some other time. But I think we should have you -- can we go on now to penetrations, and then we will take a few minutes and see what time it is and talk a little bit about the EPRI stuff.

MR. COSTELLO: I guess if I could say I'd like to get the last word in on the steel models. Basically we are not prepared to declare total victory yet, but we are having this one set of closeout calculations in which someone else will try different but equivalent code to see if they reproduce those effects, and also look at the question of, if you look at something like Sequoyah -- which in fact this person has looked at before, and look at some of the details, would you come to the conclusion that you would get the membrane yielding, or is it something you would have to model?

And I think at the end of that we can claim that the game will be over and the good guys have won.

MR. SIESS: But in the meantime, would you try to convince some of these people that they ought to decide what they are going to do with this?

Okay, let's go on to Hans, and he will describe what Sandia is doing on large hatches, small hatches, and pipe penetrations.

MR. EBERSOLE: Chet, while he is getting ready, it always bothers me that if a failure occurs prior to core

damage, which can be a sequence of events, if the failure occurs in the regressive context, that it blows into the aux buildings of that region where the penetrations generally are, that will virtually guarantee core failure and disaster.

If it can be made to fail some place into open atmosphere, you have still got a chance.

MR. SIESS: Well, we could probably arrange that.

MR. ASHAR: Before I start on penetrations, let me make a little remark on Sequoyah.

Sequoyah has been looked at quite closely in NUREG 1037 on leak rate estimates in which, as far as I remember, at a peak pressure or peak acceleration pressure for the worst case scenario, they are predicting the pressures which does not prove the leak-before-break hypothesis.

The leakage is so small for penetrations in all the other areas that they have examined, they figured that if the pressure was any higher than what they had predicted, it would rupture the containment rather than leakage.

MR. RICHARDSON: Hans will discuss this later. But Mike's point is, it is in essence a PR -- an excellent one.

MR. SIESS: NUREG 1037 chose Sequoyah, and you would have gotten a different answer if you had chose McGuire, which is the same design of plant but a different design of containment.

[Slide.]

MR. ASHAR: I am going to show first the boiler plate slides on the project, and then I will show you some of the work that has been done in the past, and what will be done in the future, and then some of the sketches of the pressure chambers.

This is with Sandia National Lab, and the budget for '85 was 900K. For '86, it has been earmarked for 900K. For '87, it has been marked down to 600K.

We wish to complete most of the seal and gasket testing and probably most of the needed tests for the bellows for the fixed penetrations.

[Slide.]

The issue, I think it has been pointed out quite a number of times by the ACRS members, that leak-before-break is the one that we should examine more closely than anything else, and this is the attempt to do that. As to whether the containment will rupture first, or there will be leakage enough through the various penetrations in the containment that that will start depressurizing the containment.

So the issue is basically the analytical prediction of the containment failure modes -- that is what will be the failure mode, will there be leak-before-break or break of the containment.

The objective is to determine the major characteristics of operable and fixed containment penetrations

that could contribute to leakage during severe accidents.

The effect of pressure, temperature and deformation must be studied.

Now let me define for you, if there are some who are not aware of it, what our operable and fixed penetrations are. There are obvious terms, but still operable penetrations which are likely to be opened and closed during the operating years.

MR. SIESS: Other than valves?

MR. ASHAR: Other than valves. Valves are operable, but they are not included in this project.

What comes out are equipment hatches, air locks, escape hatches, drywell of the BWR head, and maybe in some cases fuel transfer tubes which are blind flanged, but they are operable, they can be opened and closed.

So these are the operable penetrations. The others are piping penetrations which are considered fixed penetrations.

MR. RODABAUGH: When you use the term leak-before-break, are you thinking of gasket leakage or mechanical?

MR. ASHAR: We are thinking of gasket and seal leakage.

Integration. It has been pointed out before that the three projects are closely integrated. In addition, the

valve leakage program, as well as the electrical penetration and assembly program, they are all integrated to assess the containment capacity.

MR. SIESS: The term leak-before-break here is different. It means anything that happens before the containment ruptures.

MR. BENDER: Yes, it is a different kind of leakage.

MR. SIESS: Yes. But they just adopted the term here.

MR. BENDER: They ought to fight not to use it, because it confuses people.

[Slide.]

MR. ASHAR: This project was initiated in 1984. The first thing that has been done was to survey penetrations. We really didn't know what type of penetrations exist, what type of seals and gaskets are used in penetrations, what are their configurations and sizes, their types, and the materials, et cetera.

So the first thing that was done was a survey of the existing operating plants to see as to what are the parameters that we ought to look into as far as testing was concerned.

I will go more into detail along with the survey results.

That was done prior to FY '85.

In '85, basically what has been done is testing of

seals and gaskets. Seal and gasket tests have been done. Some of them have been done at Sandia National Lab in the pressure chamber. Some of the tests have been done at Argonne National Lab, and by a subcontractor.

In '86, we plan to complete the seal and gasket tests and complete the air lock tests.

I pointed out during the presentation of containment model tests that air lock in the model does not represent the real air lock. It doesn't have an opening in the bulkheads required, et cetera. That's why we are going to test one air lock which we have procured at a bargain price. I will show you the schedule later.

Procurement of bellows and development of test plans. This will be done in 1986 so we can test the bellows in 1987.

[Slide.]

In '87, the evaluation of the air lock test and performance of bellows test. The regulatory use in a generic way, it is the same as before. Confirmatory assessment of severe accident policy statement, and the basis for possible addition of containment performance requirement for safety goal implementation.

But in detail, there are quite a number of uses. The first thing, it has been used in preparing NUREG 1037, which is going to be a part of the severe accident reporting.

Also, we are making a move to have some of the results used for the standards committees, such as the replacement of gaskets and seals. Right now there are no set requirements that people have to replace certain gaskets.

We will try to push that kind of idea into the ASME Section 11 committees, and there are a lot of details which have been learned from this testing which we will be transferring to the code committees which would be of use for modifying the codes and standards.

MR. SIESS: Hans, who has the job of looking at pre-existing leakage? NRR?

MR. ASHAR: That particular project is under John Wang in Containment Systems, NRR. BNL has looked at it. And he has some of the results.

MR. SIESS: And they don't call that research?

MR. ASHAR: They call it technical assistance, because it helps them in assessing as to what is available.

[Slide.]

Now I am going to give some details of what has been done. A survey of mechanical penetrations. The survey was conducted by Argonne National Lab under subcontract from Sandia National Lab.

A preliminary analysis of some of the structural analyses was done by Argonne and later on by Sandia National Lab.

Tests on penetrations are being performed by Sandia, and Idaho National Lab.

An investigation of electrical penetration assemblies is being conducted in another program, which I pointed out before.

[Slide.]

MR. SIESS: That is in another program because it started out under qualifications.

MR. ASHAR: That is correct.

[Slide.]

Program steps are: survey of penetration types and designs performed by ANL on 48 U.S. plants. 48 plants, I think, is a good sample. It's about half the available sampling, and attempts were made to make sure that there is enough PWRs, enough BWRs, enough steel in the prestress and reinforced concrete containment, because the inside is different in each of those cases.

MR. SIESS: There is a report out on that.

MR. ASHAR: There is a report out on it, and it is available, yes. If anybody is interested, I can send it to them.

Qualitative figures of merit developed. Figures of merit is a matter of finding out which are the parameters in the operable penetration assembly. As to how the sleeve length, how the diameter, how the thickness of the collar or

thickness of the reinforcing plate around the sleeve would affect the potential performance.

These are figures of merit according to what is considered as more important than the other. So that we can figure out what we should do and what we should keep in our minds. And that also is in that particular report. If any of you are interested, I can send these reports.

MR. SIESS: I think what you omitted was those 48 plants yielded about several hundred different types of penetrations.

MR. ASHAR: Oh, absolutely, yes, they did.

Preliminary analyses were conducted based on the survey. They came out with some typical design for analysis purposes as to what a typical -- really, it's not typical, but just for the purpose of analyses, to get an idea about what is predominating. The preliminary analysis -- there is a report on those analyses, too. So if anybody is interested, I will be able to transmit the reports to them.

Program plan developed and conduct the program. I will be getting more details on those.

[Slide.]

Experiments and analyses of penetrations. The shell structure interaction, equipment hatch and personnel air lock. They were all tested on a 1/32nd scale, 1/8th scale steel model, as well as they will be presented in a 1/6th

scale concrete model.

The equipment hatch with seal, 1-to-8 scale steel model, had one type of seal there. The equipment hatches, two pressure seating and one unseating in 1/6th scale reinforced concrete model, I showed you before in the concrete model.

[Slide.]

MR. SIESS: Excuse me. Is it clear to everybody that what we are looking for there is deformation, such that the two metal surfaces separate far enough that the elastomeric seals are no longer sealing?

MR. RODABAUGH: I was about to ask a question on that.

MR. SIESS: There are two issues. One is the deformation that occurs, and the other is the elasticity of the integrity of the seal material which might degrade with temperature.

MR. RODABAUGH: Can you scale -- I was wondering about that 1/8th and even smaller scales. Assuming the elastomer seals.

MR. SIESS: Those were the tests you just saw. And all they used those for were to get the effect of the shell behavior in the deformations. The other tests are not being scaled.

MR. RODABAUGH: Okay. The ones that I was just looking at are not --

MR. ASHAR: They were performed separately, and will be integrated together when the final reports come out. So as Dr. Siess pointed out, the deformation is how the structure in general will affect the deformation on the sleeves, on the penetration.

MR. SIESS: They have seals in there, but they don't expect to get definitive answers with those particular seals. It's just illustrative.

MR. ASHAR: A full sized personnel air lock will be tested in '86.

Expansion of bellows in '86, '87, and drywell head for BWR Mark I and Mark II analyis did not indicate a need for experiment.

I will have a little bit on the drywell head later.

MR. SIESS: That was interesting. It started out being pretty bad.

MR. ASHAR: Yes, it did.

[Slide.]

MR. SIESS: Can you get to pressure without the temperature?

MR. ASHAR: Well, in the Limerick study done on NUREG 1037, they predict leakage at very low pressure, around 86 psig or something for Mark II containment, only considering the pressure, and if the temperature is included, then it just so happens that it sinks back, and there is no leakage until

up to 130 psi. I will be elaborating on that a little later.

Pressure seating equipment hatches. Models for predicting the deformation and leakage for pressure seating hatches in the steel containment were verified by the 1/8th scale steel model test. Jim showed some of the slides and they have been discussed before.

Significant interaction between the cylinder and the penetration sleeve occurs. That is quite a legitimate concern.

Average membrane strength from 2.3 percent up to 5 percent must arrive before the sleeve deformation is sufficient to cause a mismatch that results in leakage. We are up to 2.3 to 5 percent, and they do occur in the discontinuity areas in some places.

MR. BENDER: When you talk about membrane strains in this case, what are you talking about? What part of the membrane?

MR. COSTELLO: Free field. That's one of the back calculations I referred to. The range was a factor of two, looking at existing typical penetration geometries, and in that experiment, some of the low end would surely have leaked before we had the rupture, and some of the high end surely would not have.

MR. BENDER: Can you generalize, tell me that is typical of all shells?

MR. COSTELLO: Of steel models, it certainly -- you can generalize that one of the population would leak before they break, and some would break before they leak.

MR. BENDER: Until I get the 2.3 percent strain, none of them would leak?

MR. COSTELLO: I would be hesitant to do that without looking at the penetration design itself. But of the population they found, the one that had the thinnest or skimpiest reinforcing still took that kind of free field strain before --

MR. SIESS: Jim, you had a couple of small scale models that ballooned. What kind of strains did they reach?

MR. COSTELLO: I believe it was around 15 or 16 percent.

MR. SIESS: Now you could generalize, I think -- or could you generalize and say that a real containment with hatches in it could not reach 15 percent without leaking?

MR. COSTELLO: Absolutely. That one I will go for.

MR. SIESS: Okay. Every little bit helps.

MR. BENDER: I've got even more of an axe to grind. I would like to be selective in the seals that I want to leak, and if I am selective, I can make the leak go where I want it to go, and when you're doing something like this, that's part of what you want to be able to display.

MR. COSTELLO: I think it is fair to generalize that

if your choice is the large diameter equipment hatch and you are willing to take the leakage there, then that should be rather easy to arrange.

MR. BENDER: But that's not where I want it. That thing is too big, and I can't --

MR. SIESS: Suppose you used a metal O ring on the equipment hatch. Would it keep the local leakage down if you still have regulations on that? And about what membrane strain would that start to leak?

MR. COSTELLO: I'm afraid that's too complex a question for me to try and wing off the top of my head.

MR. ASHAR: Let me address that question. If PWR conditions, as I will show you later on, probably you would not need to go that far to use the metal rings --

MR. SIESS: I'm talking about an equipment hatch.

MR. ASHAR: Even for an equipment hatch in a PWR, it won't be necessary. I will show you by the seal and gasket test we have performed. For a PWR, that is one of the possibilities that we should look into.

MR. SIESS: You said the BWR drywell head wouldn't?

MR. ASHAR: Oh, yes, BWR is a different thing we should think about, I'm saying.

MR. SIESS: All right. Now I was talking about the equipment hatch for dry containment. 14 to 20 foot hatch.

MR. ASHAR: Yes, okay. For that, I don't think it

will be necessary to go to that type of failure break. It is an elaborate system, but I'll show you that it is not of concern.

[Slide.]

Now back to the drywell head analyses. The CPWG, which is essentially NUREG 1037, shows that there will be unseating of drywell head due to internal pressurization at, as I pointed out, approximate 86 psig or something. And then substantial amount of leakage in the Mark I and Mark II containments.

However, the conclusion is based on analysis that did not take into account the effect of elevated temperatures which are also present in the accident.

Argonne National Lab and Sandia have conducted independent analyses to show that these elevated temperatures inside the containment are considered in the analysis. Metal-to-metal contact will be maintained between the sealing surfaces, thereby precluding leakage.

Differential thermal expansion between the drywell head flanges, which house the seal, and the bolts which attach the drywell head to the lower part of the containment, have the effect of additional preload on the bolts, thereby substantially increasing the pressure needed to unseat drywell heads.

I will show you some of the sketches on this --

MR. SIESS: I don't think you need to go into that.

MR. EBERSOLE: Is this due to the thermal gradient across the metal?

MR. ASHAR: Yes. Basically this is due to the difference between the flange of the drywell and the bolt outside.

MR. EBERSOLE: It's like a fin?

MR. ASHAR: Yes. There is a fin going out there, and then there is a bolting on top of it. The bolt tension keeps it compressed because comparatively it is in compression.

MR. SIESS: Are there any scenarios which would give you the pressure without the temperature?

MR. ASHAR: That also I will look into.

MR. EBERSOLE: Well, surely ATWS does.

MR. SIESS: No, you've got to have a coremelt to get anything in there.

MR. ASHAR: There is one scenario in a BWR that I recall.

MR. SIESS: Inside the vessel, the drywell head, not the vessel head.

MR. EBERSOLE: I'm offbase, yeah.

MR. SIESS: This drywell head.

[Slide.]

MR. SIESS: The drywell equipment hatch is pressure

unseating?

MR. ASHAR: You mean the BWR equipment hatch? No, they are pressure seating, most of them.

MR. SIESS: On the inside?

MR. ASHAR: From the inside. Now a little more in drywell head analyses. Argonne National Lab used a sophisticated finite element approach, whereas Sandia derived closed form solutions based on the strength of materials approach.

Sandia analyzed the response of drywell heads in eight containments. There were significant differences in the drywell head diameter, flange thickness, number of bolts, bolt diameter and bolt preload, which is quite important, within this group.

Only one of the eight unseated at the maximum accident pressure of 120 psig, and the gap was less than 2 mils, which would most likely be closed by the seal material.

There are significant conservatisms in Sandia's analysis, and the actual separation pressure is probably higher.

Based on the analysis, the test of the drywell head was not felt to be necessary, so we have been able to eliminate that elaborate test.

[Slide.]

Pressure unseating equipment hatches. A pressure

unseating equipment hatch will be tested in the 1-to-6 scale reinforced concrete model. I have shown you there will be one equipment hatch model in the reinforced concrete model which will have two, an inner cover and an outer cover.

The outer cover will be tested first as a pressure unseating type of cover. The same methodology used to analyze drywell heads will be used to analyze the pressure unseating hatch.

Data from the test, gap measurements, compression in the flanges, will be used to assess the method.

[Slide.]

Personnel air locks. Tests will be conducted in FY '86. The air lock has been procured. The RFQ will be going out to the public somewhere next month or the month after, as I understand, for test facility, where the testing will be conducted.

The preliminary analyses suggest that no significant interaction occurs between the shell and sleeve, and the door and bulkhead will undergo locked deformations associated with bending.

That is the basic reason for conducting a separate test for the air locks.

The first thing, there is no significant interaction between the shell and the sleeve of the air lock, because the air lock sleeve is quite a bit protruding out of the shell

liner or in the steel containment and steel face.

MR. SIESS: It seems to me there has to be an interaction between the shell and the sleeve, but the effect on the sleeve doesn't carry out to where the doors are.

MR. ASHAR: That is what it is, yes.

Finite element analyses will be performed with the actual material properties and a leakage criterion will be proposed prior to the test.

MR. SIESS: So it is just the bending of the door.

MR. ASHAR: And the bulkheads, yes.

[Slide.]

MR. SIESS: What about the doors that have -- I don't know what you call it, a mechanical lock where it actually rotates and slides in and locks it tight? Are those considered?

MR. ASHAR: In the personnel air lock?

MR. SIESS: Yes, in the personnel locks.

MR. ASHAR: All these personnel locks have a hinge on one side and they have been bolted on the other side by bolts.

MR. SIESS: Yes, and what holds them shut? What squeezes that seal?

MR. ASHAR: I will show you the sketch of the air lock later.

MR. SIESS: Okay.

MR. ASHAR: Test on seals' materials. As a result of the survey that was done on the 48 containments, these are the four materials of importance, but the most used materials are the silicon rubber and the EPI/EPDM material, which is -- I don't remember the whole name. It's a polymer, some kind of a polymer material, with specific material properties on it. Viton has been used on a few plants in some of the penetrations, and unspecified rubber or neoprene has been used on some of the older plants.

We will be doing some tests, trying to get samples from those plants.

MR. SIESS: These are for both kinds of locks?

MR. ASHAR: All types of operable penetrations.

MR. SIESS: I thought some had inflatable seals.

MR. ASHAR: Yes, that I have not shown, but that is a different configuration. But the material will still be in the same range.

Cross section geometry. There are O rings, dog ears and gumdrop and tongue-in-groove type.

I might show some of them. I might have some slides to show them.

MR. BENDER: Some of these seal materials are more temperature-sensitive than others?

MR. ASHAR: That is correct. I will show you some slides on how bad they are.

[Slide.]

Tests on seals. Environment. The seals will be aged and unaged. Both will be tested. Aging will be thermal and radiation exposure before test.

Now on the tests that have been performed at Sandia, they will undergo both types of aging, radiation and thermal, but the tests which are being performed at Argonne National Lab will only undergo thermal aging, because they don't have the facility to do the radiation. But we will be able to get a simulated comparison as to what the effect of various aging is.

Pressures will be up to 160 psia. I will be showing you the sketches on the pressure and temperature later on.

[Slide.]

The test set-up pressure chamber. I will be showing you the pressure chamber.

Saturated or superheated steam, heated air or nitrogen.

Sandia in all cases will be superheated steam. Sometimes they might use saturated steam just to get the comparison as how it will influence the material properties.

At Argonne National Lab, they are only using nitrogen, heated nitrogen.

The mating surfaces, metal-to-metal contact, prescribed gap, rotational surface, machine-inclined

Metal-to-metal contact, there will be another prescribed gap, but the gap will depend upon 48 mil or 10 mil, and the rotational one-surface.

This is to simulate the potential rotation that that particular mating surface would undergo because of the shell deformation.

There will be three rotations that we will be examining.

MR. SIESS: On the door deformation? Not just the shell? On equipment hatches it is door deformation, isn't it?

MR. ASHAR: Yes. Yes, that is correct.

[Slide.]

Future work. Complete tests on seals, investigate effect of aerosols on leakage, test personnel air lock, equipment hatch, test reinforced concrete model. These are the things I already mentioned.

[Slide.]

Let me show you some of the sketches which might be of interest to you.

This is the test chamber at Sandia National Lab. This is the whole chamber, and these are the three lengths of fixtures in the seal stage. I will show you a separate sketch of this particular assembly, but this will be exposed to the severe accident pressures and temperatures inside, like a pressure seating kind of condition.

MR. SIESS: And leakage will be measured?

MR. ASHAR: The leakages will be measured.

[Slide.]

Let me show you the profiles under which the seal tests are conducted. This is a PWR accident scenario. The pressures will be going from here to here (indicating) at 155 psia, will be PWR conditions, temperature will start from 293 or something and 361 degrees will be the highest temperature maintained for PWR conditions. And these are enveloped --

MR. BENDER: With regard to the air locks, somebody pointed out once that the way these air locks are designed, the outer air lock -- there is a chamber between the inner air lock and the outer air lock which reaches a temperature barrier. Does that influence what is up there?

MR. ASHAR: These temperature-pressure profiles are containment air profiles. They are not even at the site of the containment, which is lower than what they are shown here.

MR. SIESS: That's what the inside door will see, and what the outside door will see if the inside door failed.

MR. BENDER: Well, if it failed -- even if you get a leak there, if it's stagnant, they'll have a big insulator there. I am just asking because it may have an influence --

MR. SIESS: You could get the pressure on the outside door, but you are not likely to get temperature.

MR. EBERSOLE: I would like to raise a question

about these air locks, including both the equipment as well as personnel. I think they are an anachronism.

MR. SIESS: They are there, Jesse.

MR. EBERSOLE: I know, but they look like submarine air locks, and we have long since departed from the thesis that we don't have a moment in time to exposure ourselves to an open containment. As a matter of fact, containments for years ran with open purge valves that you couldn't even shut. 32 inch butterflies. They couldn't even shut them against an inflow from a LOCA. There had to be revolution that had to be imposed on NRC to get those things fixed.

So we have run, therefore, in the presence of wide open containments blowing air through them that didn't have a ghost of a chance of shutting up for a LOCA. In the meantime, we go to the ridiculous opposite extreme of having to double ourselves through this lock, thus saying I can't expose myself to an open containment for five minutes while I go through.

MR. SHEWMON: When the Westinghouse advanced reactor subcommittee chairman gets through with that, I hope they have something in it about better containments that don't have these problems.

MR. EBERSOLE: Well, I just want to recognize the curious contradictions in our logic.

MR. SIESS: Well, there's a proposal from RDA for an unpressurized containment. It just vents out through a

system. You would like that one.

[Slide.]

MR. ASHAR: This is a BWR profile for pressure, which the maximum is 135 degrees.

[Slide.]

This is a BWR profile for temperature, which some people say is not conservative enough. Some of the studies have shown the temperatures as high as 1000 degrees, but the consensus showed that.

MR. BENDER: Did you say that's not conservative enough?

MR. ASHAR: Yes. We heard from the IDCOR study using some code, I don't remember, and Oak Ridge did some studies which showed that the temperatures could be much higher in certain severe accident sequences than 700 degrees.

MR. SIESS: Is this hydrogen burning?

MR. ASHAR: No, there's no hydrogen burning; just core-concrete interaction giving very high amount of energies and temperatures.

MR. SIESS: Because there is an issue, isn't there, about hydrogen coming out of the wetwell and burning as it escapes, in the MARK III?

MR. ASHAR: Yes. I don't know the exact reasons, but some people do think the temperatures will be higher in certain BWR severe accident scenarios.

But we had modified this particular chamber from 500 degrees to 700, and we are not ready to do 700 to 1200 degrees because it is quite a job to change the chamber from one to another. And everyone said that this would give us enough idea about the material properties. And we will see from the results that it does.

[Slide.]

MR. RICHARDSON: But Hans, how will you eventually answer the question of these people that are claiming 1000 degrees? That would not be an acceptable answer, that our test fixture wasn't high enough to get it.

MR. SIESS: Have to look at the probabilities, Jim.

MR. ASHAR: You will see in some of the results on seals and gasket that by 700 degrees, those things deteriorate to such an extent, it doesn't matter 800 degrees or 1000 degrees.

MR. SIESS: Yes, but at 1000 degrees I'd start worrying about the steel.

MR. ASHAR: That's correct. Yes.

[Slide.]

These are the assemblies for the three parameters. We wanted to see the scale effect as to the parameter is larger, is the leak rate larger. That's why we've got three separate diameters here. And these are the channels through which the leakage will be monitored. It gets into one

particular place and --

MR. SIESS: Where is the test specimen? Where are the seals you're testing.

MR. ASHAR: The seals are here in the top set.

MR. RODABAUGH: How long are you going to run these tests? How many hours? The length of time?

MR. SIESS: You saw the curves.

MR. RODABAUGH: But I didn't make a note of it. Twelve hours or something like that?

MR. ASHAR: They will be going for around 12 hours or so at the highest temperature. First, at the PWR pressure and temperature, they will be maintained at 12 hours, and then it will be raised to BWR temperatures.

MR. RODABAUGH: Okay. So at 700F in 12 hours you wouldn't expect, for example, neoprene to be anything but a piece of liquid.

MR. ASHAR: That's correct.

MR. SIESS: Incidentally, there arer test data available on seal materials, independent of these tests that they're using I think to decide on those lengths. Am I right? I remember seeing great big sets of curves on seal materials.

MR. COSTELLO: Oh, yes. They are basic supplier material tests.

MR. SIESS: So you know this is long enough.

Mr. Rodabaugh says it's probably much longer than it needs to be.

MR. RODABAUGH: Yes. I was just wondering what you are going to get. I was trying to imagine. If you've got something like neoprene in there at 700F for 12 hours, that would be a liquid.

MR. COSTELLO: The real question here is, are there, in the whole panoply of geometries and material combinations, the first question is are there any surprises about the seal behavior beyond handbook kind of stuff.

The second question is, can you account for size effect in the different diameters and different perimeters. That's the second question.

MR. RODABAUGH: Okay. In that test setup, were you able to measure leakage in between -- it looked like you had four rights on that top set.

[Slide.]

MR. ASHAR: There are two rings in each of the sections.

MR. RODABAUGH: Okay. And on what pair -- are you going to measure leakage across pair rings?

MR. ASHAR: They will represent something like a double dog ear, or --

MR. SIESS: Where are you going to measure leakage? You've got two rings. Are you going to measure both --

MR. ASHAR: In between channels; after the first seal, there is a channel. After the second seal there is another channel, so both will be measured to see what goes from first to second, and then how it transpires.

MR. RODABAUGH: What I'm thinking is some of those materials at 700F the gas will be pushing through this liquid gasket --

MR. ASHAR: I'll be telling you some of the results. I don't have the slide for some of the results we have seen so far.

MR. EBERSOLE: May I ask, can the outboard door be justified on the basis it will be out in a cooler environment? That's the only reason I could justify it.

MR. ASHAR: For BWR you are thinking about?

MR. EBERSOLE: Well, any containment.

MR. SIESS: Two-door personnel hatch.

MR. ASHAR: Yes, okay.

MR. SIESS: The outside door will not see the same temperature. It's the same problem you went through with the electrical penetrations.

MR. ASHAR: Absolutely, that's correct.

MR. EBERSOLE: Well, in that case it is useful. Otherwise, it isn't.

MR. SIESS: It just may turn out to be.

MR. BENDER: It's a way of getting some use out of

it.

MR. ASHAR: Now let me give you some of the results just from what I remember. For silicone rubber material --

MR. SIESS: Let's don't get into results. The main purpose here is to talk about what you're doing and why. We'll explore the results at another meeting.

MR. ASHAR: Okay, very good.

MR. SIESS: What about the bellows, the pipe penetrations?

MR. ASHAR: They are being studied at this time.

MR. SIESS: And the mode of failure that you're looking for?

MR. ASHAR: In the bellows? Is the excessive compression or twisting.

MR. EBERSOLE: What about the big purge valves? Those are big things.

MR. SIESS: That's another program.

MR. ASHAR: There's another program where purge valves are being tested.

MR. SIESS: And we ought to look at that sometime but that's not in Research and it's under the cognizance of, I guess, the Containment Performance Working Group, isn't it?

MR. ASHAR: Purge valves are under the research.

MR. RICHARDSON: That is under our Equipment Qualification program. They are being tested at --

MR. SIESS: I'm talking about the whole problem of pre-existing leakage. Are the big valves a part of that? If they open, they open.

MR. RICHARDSON: Yes, right.

MR. SIESS: And how much they leak under pressure is something else. But purge valves are the prime suspect because they open at both ends, don't they? Containment atmosphere at one end and --

MR. RICHARDSON: You mean normally open?

MR. SIESS: No. The other so-called isolation valves that don't open at containment and don't open into the atsmophere. Those valves open at containment atmosphere at one end and the aux building at the other --

MR. EBERSOLE: I hope it isn't the aux building.

MR. SHEWMON: Who is responsible for that program?

MR. RICHARDSON: For the valve penetration? That is under our branch and it is in our Equipment Qualification Program. But we're also going up to severe accident conditions.

MR. EBERSOLE: By the way, what Chet said is certainly not true, is it? Those purge valves don't ever open into the aux building, do they?

MR. SIESS: I don't know where they open to.

MR. RICHARDSON: I don't know.

MR. EBERSOLE: If they do, that ought to be hammered

out right now and fixed. I hope they open into the annulus or the outdoors or something. If they open into the aux building --

MR. SIESS: Don't they open into some filtered area, or do they purge directly --

MR. EBERSOLE: I think they open into the filtered -- the secondary system. Secondary filtrated, you know, secondary containment. But if they open into the aux building, Chet, we have got a regressive consequence instantly.

MR. SIESS: Jim, could we talk about the EPRI work in a very short length of time? Let me introduce it and tell the other people what I think they ought to know about it. And correct me if I leave something out.

EPRI is having some tests made at the Construction Technology Laboratory, the Portland Cement Association. They built a testing rig that can suggest or subject a slab of concrete of full containment thickness to biaxial in-plane tensions like it would see under pressure, and to a transverse load that it could see on a penetration, and can measure leakage.

In other words, it can stretch it in two directions with reinforcement in it with a liner on it, and it could be full scale. So they are going to be making tests on sections of a containment wall to look at what might happen through the

wall or through the penetration; they can imbed penetrations. Now, is that reasonably correct?

MR. COSTELLO: I think that's a fair estimate, yes.

MR. SIESS: And there's no modeling. They have done some work on smaller-scale models in another area and some in this area, but this is their potential.

Now, are you involved? You are following this, I'm sure.

MR. COSTELLO: Yes, we follow it. We are also involved to the extent that usually, Dr. Tang from EPRI or Dr. Wahl from EPRI does appear at our meetings of our peer review panel.

MR. EBERSOLE: Is this the Dr. Tang that used to be up here?

MR. COSTELLO: No, it's H.T. Tang, used to be G.E., I believe. But EPRI does come and chat with our peer review panel and lets them know of progress and that way, fill in ourselves and the Sandia staff.

We have a rough idea of their test plan and in the last iteration they have been taking the benefit of comment from our peer review panels to help them think about what they're going to do in the outyear.

But their basic approach is to focus on the possibility of premature liner failure, the so-called, as I call it, the Rashid hypothesis.

MR. SIESS: Okay. That's really what they're looking at; to see when the liner will fail in relation to the concrete behavior.

MR. COSTELLO: Yes. With the suspicion that --

MR. SIESS: So that if you developed a premature liner failure in your concrete model, that work could be used to expand it into looking at how the anchors might have affected it and so forth.

MR. COSTELLO: Yes, sir.

MR. SIESS: If you don't develop anything in your concrete model and they do in their full scale model --

MR. COSTELLO: It should be interesting, yes.

MR. SIESS: Okay. And if neither one of you develops it, we quit.

MR. COSTELLO: Maybe.

Now the other thing that they are attempting to do and it's rather difficult and it's not clear yet that they will pull it off, is to do a modeling of the basemat-wall intersection that we talked about as being so interesting before.

MR. SIESS: And the same kind of answers go.

MR. COSTELLO: With something less than a complete wall with a segment. They have had difficulty -- and with loading by a bladder. They have had difficulty in getting the loading on in a couple of tries, but that should give us some

insight --

MR. SIESS: [Inaudible.]

MR. COSTELLO: That's something I haven't explored with them.

MR. SIESS: There was something said about possibly testing a 360 degree ring of something. What's that supposed to show?

MR. COSTELLO: I am not sure that that's an EPRI proposal or a PCA proposal.

MR. SIESS: I saw it in a report that EPRI distributed.

MR. COSTELLO: We have certain difficulty in getting EPRI plans in the same frame as we are. You see, we're talking about the 1987 budget. As of now, EPRI is just firming up their 1986 budget, so we have a timescale difference. But we hope that they are able to bring off this basemat wall test and get something out of there that will be beneficial to us in the model.

MR. SIESS: You had questions about scaling of your shear connectors, and that is not unrelated, I guess, to Rashid's problem and what they are looking at there. Will they do anything, varying the shear connector spacing?

MR. COSTELLO: I believe the series of tests they have do have different shear connector spacings and different imbedments, both studs and channels.

MR. SIESS: Okay.

MR. BENDER: Jim, there is another variable of this thing that probably they should look at if they haven't. And that is that the conformance of that shell basemat connection to the concrete backup or whatever it is they've got there varies all over the map, depending upon who has designed and who built it and when it was built.

And I wonder if just one model without some understanding of what the performance is going to be of the steel shell and the concrete will wind up being all that meaningful.

MR. COSTELLO: I think in many cases, the liner was used as one of the forms, right?

MR. BENDER: In some cases. But even when it was I think you will find that there is some uncertainty about whether the concrete really was up against the steel liner.

MR. COSTELLO: That's one of the things we're going to be looking at in our tests.

MR. BENDER: They may have a very good setup for their tests but the real skills may be a lot different.

MR. EBERSOLE: I thought that had to have about an inch or so of some sort of flexible membrane because of the differential expansion suddenly occurring, the suddenly-occurring thermal profile when you swell up the liner against the concrete, and you had to leave room for it or

otherwise it will surely buckle before the concrete heats up.

MR. SIESS: No, the stud spacing is based on buckling.

MR. EBERSOLE: Isn't there an insulation pack in there, though?

MR. BENDER: There are all sorts of variations in that connection.

MR. SIESS: Has anybody looked at, you know -- has anybody looked at the variation of details in those corners?

MR. COSTELLO: I don't know for sure. I do know that the design was chosen based on being representative, but I think we would be well advised to go back and look.

MR. SIESS: Yes, I think somebody ought to look.

MR. EBERSOLE: I know one containment has insulation and I'm not so sure that it isn't Sequoyah.

MR. SIESS: That is a steel shell.

MR. EBERSOLE: Well, it's not that then. But I remember one, they had trouble with it, Chet, this insulation.

MR. SIESS: That's another problem, you see. We tested a steel shell with a steel bottom to it and the steel shell sitting out there anchored down to a concrete base and that's quite a different story.

MR. EBERSOLE: Well, there's some containment that has this flexible, thick liner.

MR. SIESS: Well, some of the steel ones do because

they had to allow --

MR. EBERSOLE: There was a lot of trouble about it not always being, you know, fully cleared of concrete, too.

MR. SIESS: Well, steel shells have got some flexibility, they will come away from the concrete but that's not the concrete liner; that is the steel shell. And that concerned me because I thought the steel one was going to fail at the base.

Your steel one didn't have a bottom head, it had a flat bottom, didn't it?

MR. COSTELLO: No, it had an elliptical head.

MR. SIESS: The steel ones vary quite a bit in that detail where the steel and the concrete connect. There's a concrete floor in there and I figured that was going to be the weak spot and then we were going to have another problem.

But you know, I don't see why, in the reinforced concrete containment, the phenomenon is a local bending in that joint. I don't think it is three-dimensional even. And if you are going to explore it, I don't know why they just can't do that -- they can't look for leakage but they could look for the mechanics of how the thing fails. At some point, you've got to quit worrying about leakage and just look for cracks in the steel and assume if it cracks it's going to leak through it.

MR. EBERSOLE: I recall a detail, Chet, where at one

point the steel actually was poured against the concrete but as it turned vertical is where the insulation tore. So there was a joint where a transition took place.

MR. SIESS: I think you're thinking about what some people call the hybrids; the steel containment on a concrete base. It's got a steel bottom to it and that is for leaktightness, and it is not a code vessel. And those are the ones that have a problem.

Gentlemen, I think it is time for lunch. I will let the Chairman after lunch tell you what time to be back.

MR. SHEWMON: How about 50 minutes. 1:30.

[Whereupon, at 12:43 p.m. a lunch recess was taken, the meeting to resume at 1:30 p.m. the same day.]

AFTERNOON SESSION

MR. SHEWMON: This afternoon we will hear about containments of concrete, steel and piping. As I understand it, gentlemen, this will deal with the extension of the leak before break ideas into other parts of the primary system. Without any other introduction I will turn it over to Gene Kurtz to talk to us.

MR. KURTZ: Thank you. I would like to thank the subcommittee for giving us this opportunity to speak this afternoon. We would like to keep the subcommittee abreast of an effort that we have ongoing right now with NRR staff, which has currently been received quite well by the staff and

management of NRR. I am referring to the Whipjet program which we are pursuing which we believe will improve plant safety while reducing plant costs not only during the construction phase but also continue to reduce costs throughout the plant life. And to explain the technical aspects of it, I'd like to let Bob Cloud discuss the issues.

MR. SHEWMON: What is the name of the program?

MR. KURTZ: Whipjet is the name of the program that Bob Cloud has blessed the endeavor with.

MR. CLOUD: Thanks, Gene. I was doing some work at the Beaver Valley Power Plant last winter in a review mode looking at the methods and the approaches being taken by Stone & Webster in the conduct of the engineering qualification of the piping systems.

As part of that, I realized following the trends that were going on in the industry, I realized that Beaver Valley would be in the situation in a year or 18 months where they would be installing their whip restraints just about the time that the industry decided that they weren't necessary at all, which struck me as an unhealthy situation.

MR. MARK: Are you implying that Beaver Valley has never had them?

MR. CLOUD: No, they have always had them, but they are building them, they are welding them in.

MR. SIESS: Is this Beaver Valley 2?

MR. CLOUD: Two, I'm sorry. I should have said Beaver Valley 2. It's a plant under construction.

MR. MARK: Oh, I was just wandering in my mind.

MR. CLOUD: Well, that's quite all right.

So to that end, we thought that it should be possible to put together an engineering approach to the problem of pipe break protection that would hopefully be an improvement on the way it was planned to be done. And that's what we have done and that's what I would like to explain to you today.

[Slide.]

Our program -- this is a contraction of the terms whip restraints and jet shields. And we have labled it that to give us a reference point.

Fundamentally, what we are proposing, we are proposing an alternative approach to the engineering for the pipe break protection. And very specifically, we wanted to do two things. The first is -- in the first place, I should mention that the leak before break -- the fracture mechanics technology -- has advanced in the last ten years from the elastic fracture mechanics or the so-called linear elastic fracture mechanics to the point where now it works very well, quite adequately in the elastic plastic regime. And I think it is non-controversial to say that that is accepted on a technical basis, that the method works when it's applied in

applicable situations.

Our approach is to through an engineering program, a program of analysis and testing, to determine those places where the leak before break approach is appropriate for the balance of plant systems. When I say balance of plant, I am talking about those systems other than the primary system.

Now also I should mention that Beaver Valley 2 has requested, as have many others, relief from the so-called arbitrary intermediate breaks, and I believe that this is in the works and we'll talk about those some more in just a moment.

In those places where the leak before break approach can be shown to be appropriate, then we will implement it. That is to say we will perform those analyses and that testing that's required to prove that the pipes will leak before they will break and that they will leak in a detectable manner, and then we will review the leak detection capabilities as well.

An extremely important aspect of our program and our approach is that in those areas where the leak before break doesn't work or for some reason it's inapplicable or inappropriate, we'll do the work in the conventional way. In those cases where -- let's see, I guess I should mention that most of those areas would be related to reasons that are delineated in the recent Reg Guide 1061; they are laid out in Volume 3.

Further, in the second --

MR. SHEWMON: Is that a NUREG or a Reg Guide?

MR. CLOUD: I'm sorry, NUREG. My mistake.

Another very important aspect of our work is that we are attacking the issue of the dynamic effects on the pipes and protecting the plant from that phenomenon alone, and all those other aspects of the plant design that are related to or based upon the assumptions of the double-ended break we are leaving unaltered. In no way, for example, are we re-examining any of the equipment qualification, nor compartment pressures, nor containment pressure, nor ECCS assumptions, nor any of those other aspects of plant design related to or based upon the assumptions of the double-ended breaks.

I wanted to go over this very slowly and very carefully because we talked with the staff about this two weeks ago and we got a lot of questions that suggested to us that we went over this slide perhaps a little too fast.

MR. EBERSOLE: Is this to say that the only thing you intend to do physically then is to take off some pipe whip restraints?

MR. CLOUD: I'm sorry?

MR. EBERSOLE: Take off some pipe whip restraints, is that the objective?

MR. CLOUD: Our objective is to show that the leak

before break analysis will work in the balance of plant. Assume pipe breaks, then apply that approach and do not install whip restraints wherever the leak before break approach works. Yes.

MR. EBERSOLE: But is it just in the context of removing the pipe restraints?

MR. CLOUD: That's exactly correct.

MR. EBERSOLE: If you squirt water across 15 feet and hit an electrical box you will retain that thesis? Is that a leak?

MR. CLOUD: We have two kinds of break protection that we are addressing here. The whip restraints which are supposed to physically restrain the pipe, and the second means of protection are the so-called jet shields which are protective covers placed over presumably vulnerable equipment. Those two features are being addressed in our program.

MR. EBERSOLE: And is this for just primary piping?

MR. CLOUD: No; for everything except primary piping. Primary piping is already being addressed --

MR. EBERSOLE: Oh, this is for everything except primary?

MR. CLOUD: That's exactly correct; for the balance of plant systems. Everywhere else in the plant where we have high energy lines and whip restraints related to them.

MR. BENDER: Bob, I think you ought to reiterate again that it's where you can show that this concept is justifiable that you are arguing for the elimination. Not proposing universal elimination at this stage.

MR. CLOUD: Yes, exactly. I want to emphasize that. I want to reiterate it. I want it absolutely clear that we are not asking for any favors, we're not asking for any relief, we are not asking for any exemptions. But instead what we are proposing to do is to do a serious job of looking at the engineering involved in the postulated breaks, and when it's possible, to apply the leak before break which we think is a technologically improved means. Then we want to change away from the old-fashioned, well, blindly installing whip restraints in the hopes that it will do something.

MR. RODABAUGH: Bob, I would like to follow up on Jesse's question. I think it's a key point here. Your analysis will say that it's going to leak before it breaks. It could be a very big leak. Now you don't have the shields anymore. Just how big a leak is a leak?

MR. CLOUD: Yes, I understand that. Please know that we have not completed our program; we are just talking about doing it. We are here talking with you today, and we are not proposing to develop a situation that will expose sensitive equipment and then increase the risk of hazard.

So if we have that situation, then that would

definitely fall in the category of a jet shield that we know does some good, in which case we would leave it.

MR. RODABAUGH: Well, let me phrase it in terms of a regulatory guide or SRP's. Right now, you have in a sense postulated that you are going to get a split everywhere, for the purpose of equipment qualification, spraying on cabinets and so forth. Is your program -- or do you anticipate that you will change that part of it?

MR. CLOUD: I tried to say it before and I'm glad you asked the question because I want it to be crystal clear. Any equipment qualification that is required to be done before our program will be done after our program. Our program in no way, manner, shape or form affects the qualification of equipment, whether it does or not.

MR. RODABAUGH: So you would assume in the case of Jesse's question that yes, you will have a leak, that it will spray on an electrical cabinet nearby.

MR. CLOUD: If that cabinet is presumed to be sprayed on today, or before our program, it will be presumed to be sprayed on after our program, whether it will be or not.

MR. RODABAUGH: Okay, thank you.

MR. EBERSOLE: That's whether it's got a shield or not.

MR. CLOUD: Yes.

MR. SHEWMON: Why don't we assume you have covered

that slide, and we may return to it but let's go on. Maybe you can show us what you're doing.

MR. CLOUD: Okay, splended.

The other thing is this. I want everybody to be aware of a problem that we have and we are talking with the NRR about it, and Mr. Bosnak is here and he can elaborate on it. But we do have a bit of a licensing issue in the sense that Beaver Valley 2 will come up for their license at what, early 1987, and in order for us to do this program -- we can do it, we can begin now, we can do it in the next 18 months or 16 months, 14 months, whatever. But then we will come into a situation where it will be time for Beaver Valley to have their license awarded and they will be -- there will be some whip restraints that may not be installed because we are not going to know which ones need to be installed until our program is done.

We think, as a matter of actual fact, that there will be very, very few that will be required. But still and all, the situation will be that there will be time to load fuel and operate the plant and there will be some whip restraints not installed, and it will be necessary for the power company to get some assurance that it will be okay to install those in the refueling outages that follow.

We feel that that is a perfectly justified -- the position to be in. In fact, we think it is a preferable

position to be in than the alternative. The alternative being to close our eyes and blindly install the whip restraints. We feel that there will be very few whip restraints required.

In the second place, we feel that there will be very low risk of operating in the first cycle or two or three early in life with whip restraints absent because the initiation and growth of cracks does, in fact, require time.

Secondly, any construction errors we think will have been uncovered during the shakeout; that is to say, in the testing before the plant goes online. And in the third place, I think events have shown pretty well that in general, whip restraints don't work anyway.

And so that's basically where we stand. Excuse my bluntness on this point.

[Slide.]

MR. MARK: You said whip restraints don't work. Is that what you really mean, or is that you mean they are not necessary or they have nothing to do?

MR. CLOUD: Well, I meant what I said but I think what you said is also true.

MR. MARK: What? We have been putting these in and they just don't hang onto a pipe, or what?

MR. CLOUD: Well, I'm thinking, for example, specifically, we had an instance in a fossile plant of a major pipe rupture which, by the way, we wouldn't have had in a

nuclear plant, at the Mojave Station out in California three or four months ago. A number of us went down and looked at that. Mr. Bedoin from my group went down to see it and Mr. Bosnak went down to see it.

And if that line had had whip restraints on it at both ends, it wouldn't have helped any. All those people that were injured would have been injured. The line would have broken and everything would have been the same as in fact actually happened. Whip restraints wouldn't have done anything for us.

And I think in general what happens is if we are going to get a crack, if we're going to get a leak, it's going to happen in some way that we didn't think of anyway, in some location that we didn't think of, for reasons that we didn't think of.

MR. BENDER: Bob, in that instance it was not a double-ended guillotine break?

MR. CLOUD: That one was a split.

MR. BENDER: It was a split, and so it didn't follow the same mechanism that pipe whip restraints would be expected to resist.

MR. CLOUD: That's right. That's exactly right because the pipe didn't break the way it was supposed to. That's right.

What I'll be talking about today is this is the work

that we're going to be doing, and first I'll begin with the scope of the problem.

[Slide.]

At Beaver Valley 2 --

MR. EBERSOLE: I can't remember, what is Beaver Valley? Is it a PWR?

MR. CLOUD: Beaver Valley 2 is a pressurized water reactor, Westinghouse primary system, three-loop plant, and there are two units. One of them is now operating and one is presumed or hopefully will start in a couple of years.

On the whip restraints and jet shields, where the NRC has said that they are not needed on the primary system, we have about nine. We have also said that we need no longer consider the arbitrary intermediate breaks; there's about 127. In the balance of plant, those which we are talking about today, there's about 136, and it is a sheer coincidence that these turn out to be exactly half. So these are the ones we're talking about [indicating].

MR. RODABAUGH: Bob, by primary system, does that include the surge line to the pressurizer?

MR. CLOUD: No. The main coolant system --

MR. RODABAUGH: Not the whole primary system.

MR. CLOUD: Yes. The main coolant loop, right.

[Slide.]

Our first jobs are to demonstrate the applicability

of the technical approach, and there are four major tasks involved in doing that. We will talk about each of them in detail.

Secondly, after it is shown that it is applicable, then the performance of the work itself to show that it works.

MR. EBERSOLE: In respect to the size range of pipes, do you go clear down right on to the instrument lines?

MR. CLOUD: That's a very good question. At the moment, and a priori, we are making no distinction as to size. We know that there has been some discussion in learned circles that perhaps bigger pipes -- that the approach works better, and it doesn't work so well on small pipes. And we understand that, and we take that as a caveat.

We feel that it's wrong for us to tie our hands before our back before we ever get started with the program. We noticed that a high energy line -- there has been an instance very recently of a high energy line rupture in a nuclear plant of a one-inch line at Rancho Seco, which is well known to you people, I'm sure. That was a one-inch line and I think it was detected very, very early and very easily and very readily.

MR. EBERSOLE: Well, there have been others. They blow out at the welder let. I've heard of others where they blow out at the welder let. You know, where they weld it in.

MR. CLOUD: Well, you're ahead of me on that one. I

don't know which one you are referring to.

MR. EBERSOLE: There was one on a turbine, I think at Sequoyah. I'm not sure. It came out where it was attached to the primary pipes.

MR. CLOUD: But specifically to answer your question, we propose to study the entire range of sizes involved, and if we find that we can't show that a detectable leak will occur in the smaller lines, then we will continue in the old-fashioned way.

[Slide.]

Our first task is the stress corrosion review. Of course, it's a major problem in some plants, the business of the stress corrosion cracking, and it is much less of a problem in the pressurized water plants, although we feel that in some instances it could be a problem. And our task involves a specific review on a system-by-system basis where we are assessing the causative factors for stress corrosion cracking including stress levels, material, the environment, and putting the whole picture together.

If we see either from the point of view of history or for other reasons, we think that we have a place where we can have stress corrosion cracking in a higher energy line, then that would be a cause for us perhaps to have second thoughts about taking the new approach.

MR. BENDER: Bob, I guess just speaking personally,

I don't know that much about the materials that are involved in the balance of plant to know whether stress corrosion cracking is a big problem or a little problem or one that hasn't been thought about much. Is there some set of materials or references that are around that you are using as the basis for judgment, or are you going to create these?

MR. CLOUD: Fundamentally, Mike, we have three --

MR. BENDER: If I'm getting ahead of you I'll wait.

MR. CLOUD: No, it's quite all right, we can discuss it. Basically, we're talking about three materials. We are talking about carbon steel, A106, Grade B, and perhaps there may be some Grade C. The carbon steels, as you know, are essentially immune to stress corrosion cracking except in severe caustic environments. So we will look for that.

The second class of materials is the austenitic stainless 304 and the stabilized grade, 316. Those materials, as is well known, in the right circumstances are liable to stress corrosion cracking. The water has to be hot, there has to be a chloride or other causative agent and there has to be enough temperature and there has to be some stress. So we are going to watch for those situations.

And further, we will review the history of stress corrosion cracking in plants of this nature. We think that -- in fact, if my memory is correct, there have been instances of stress corrosion cracking in pressurized water plants. If my

memory is correct, they were not in high energy systems; they were, in fact, in stagnant, low energy systems.

But as best I can, that is the stress corrosion picture.

MR. BENDER: What is the third material?

MR. CLOUD: 304, 316 and 106.

MR. BENDER: The high pressure steam lines are what?

MR. CLOUD: They are 106 carbon steel.

MR. SHEWMON: Bob, there has been work on stress corrosion cracking of ferritic steels in BWR environments, and there was a paper given at a conference in Monterey a week or two ago by a man whose name I'll think of in a minute who used to work for a Swiss turbine manufacturer, Brown-Bravera, and he started off talking about what happens in rotor steels but then had also done work in waters for other carbon steels and found that indeed, he could get stress corrosion cracking above the threshold in water, again with about the same kinetics as the other, as the turbine steel.

So I agree with you, it's not normally looked upon as a problem but there are well-documented cases of it showing up.

MR. CLOUD: Yes. Now, I want to be clear on what you said. Did you say boiling water reactors or pressurized water reactors?

MR. SHEWMON: I said boiling water reactors because

they have a higher oxygen content and that's what it got blamed on. But he, I don't think, found that it varied much or at all with the variation of water composition, but he had not gone to extremely low oxygen, as I recall. It was not a highly caustic solution, which is what you mentioned earlier as a well-documented example.

MR. CLOUD: Right. By the way, I should mention that I have Bob Romer from Stone & Webster here today, as well as Ron Bedoin from my group, and hopefully they are taking notes on these questions.

MR. SHEWMON. Marcus Fidel was the author. He used to be in charge of materials for Brown-Bravera in the research area and is now a professor in a university in Switzerland.

MR. CLOUD: I think one of our people was at the conference, so hopefully we will have that information.

[Slide.]

Our second task, from a technical viewpoint, is the assessment of water hammer analyses. What we are doing here basically is following the guidance in NUREG-1061, which lists the series of caveats that the writers of those reports were concerned about from the point of view of applying leak before break. And water hammer or lines that are susceptible to water hammer was one of them.

So what we will be doing is making a specific review of the transients, also the history of water hammer and assess

its potential for water hammer on a system by system basis, and we will provide the technical justification to show that we don't have a water hammer problem in the high energy lines that we are addressing ourselves to.

If we can't show that, then we will, as I said, follow the old-fashioned way.

[Slide.]

MR. SHEWMON: Let me go back to stress corrosion cracking again. There has been this work of finding of cracks in the joints in steam generators. Indian Point and, I guess, Surry was the other, some Vepco plant. These may well have had cracks in them, but that is the secondary side. Are you talking primarily in the steam lines or water lines?

MR. CLOUD: We're talking about -- first I would say this. Your concern about the stress corrosion cracking in the steam generator is a legitimate concern, it's one of our concerns. We're talking about the high energy lines in the balance of plant. This does include the main steam lines and it does include a number of other lines pressurized with high pressure water. And certainly, the steam generator experience is applicable experience that I feel we will have to address head on.

[Slide.]

Another concern that the framers of the NUREG had was the concern about lines which might have an overly high

fatigue usage. It's an important question for the lines that we are working with because normally, these high energy lines do not have -- except the Class 1 lines -- do not receive a full-fledged fatigue analysis.

So what we will have the job of doing is to characterize the fatigue loading and the fatigue resistance and the fatigue capability of our lines, which we will do when we work out an approach to do that. And we will do straightforward ASME fatigue analysis on a certain representative number of them.

MR. SHEWMON: Does the fatigue come only from power cycles, or do some of these lines attach to pumps?

MR. CLOUD: Undoubtedly, there will be lines attached to pumps, and undoubtedly we will have to consider that form of loading.

MR. SHEWMON: I remember some outfit, it wasn't Beaver Valley, that the LER or whatever it was said this is the third time in a year that that line off a pump had broken. One wonders what kind of a clown was applying what kind of codes to keep doing the damn thing back again -- but that's enough. Go ahead.

MR. BENDER: It's the feedwater lines primarily that you're going to be looking at, I guess.

MR. CLOUD: Right.

MR. MARK: You have spoken of high energy lines;

those are the only lines I suppose which have whip restraints.

MR. CLOUD: That's right. That's what we're talking about.

MR. MARK: And there are lines in pipes which are not high energy lines.

MR. CLOUD: That's correct.

MR. MARK: And what is the rate point between the two?

MR. CLOUD: 200 degrees F and 270 pounds per square inch, either/or.

[Slide.]

MR. CLOUD: Another concern that has been raised -- and this is mainly much more of a concern in the primary system than in the balance of plant, but nevertheless we are going to consider it -- is the potential for the failure of a high energy line as the secondary or as an ancillary event to the failure of the supports for major equipment.

I think the original concern grew out of the potential or the concern that the steam generator supports in some plants might be vulnerable to a brittle failure, and might precipitate the failure of the primary coolant system, and so this is sort of a carryover concern, if you will, into the balance of plant.

Nevertheless, we will make a systematic adjustment of the potential for this problem to occur.

[Slide.]

What I have just described to you is the work that will be performed to show that the fracture mechanics analysis and the leak-before-break methods will be applicable to the lines in question.

If any of the systems that we are talking about or any of the postulated breaks fail the test that they will be subjected to as a result of this work then, as I mentioned, the whip restraints will be installed or at least earmarked for installation.

MR. MARK: You have had it on the slide, but you didn't say much about it. It is necessary if it leaks before break that you are in a position to detect the leak. There must be situations when there's a little difficult to assure yourself.

MR. CLOUD: That's correct. Yes, indeed, that is exactly correct. And, in fact, that is the part that comes into when we implement the program itself. We start assessing detection capability so we will be talking about that.

MR. SHEWMON: That is one reason why small lines get harder to be detected, too.

MR. CLOUD: That is exactly right.

[Slide.]

I will go fairly quickly through the specific technical analyses that are earmarked for the

leak-before-break analyses.

Basically we have three components. First, some of these materials, we have to be sure of their properties, so we are going to get left-over pieces of pipe from the plant and do the materials testing of the actual materials of the plant.

And the second are the two kinds of analyses that are very well and exhaustively described in the NUREG, the stability analysis for a throughwall crack and the crack growth rate analysis of a postulated flaw consistent with the tenets of Section 11.

MR. RODABAUGH: Before you leave the materials testing, how about all these hundreds and hundreds of welds, and what are you going to do about --

MR. CLOUD: We are going to do some testing. In fact, I am going to talk about that right now. Why don't I just --

[Slide.]

We hope -- it's a good question. We hope to, as I mentioned, get actual material and we anticipate the need to actually construct some welds, using the weld procedures that are in force at the plant and the weld materials, the welding rods in place at the plant, and characterize the properties of those welds.

MR. BENDER: Bob, every now and then you hear people with stories about whether the right materials are installed

in the right lines, and while A106 pipe is very good material and it is highly ductile and probably the right stuff to make this argument for, how are you going to make an argument for being sure that the right material is there?

MR. CLOUD: Well, I might ask for some help in answering that question, but I think what we would do -- and certainly my right-out-of-the-barrel answer would be that we do feel that -- and I'm sure that Stone & Webster feels very strongly about their quality assurance and their quality control programs, but we believe, and particularly for the high energy lines in safety-related systems, that those programs are adequate to ensure that we have the right material in the right place.

MR. BENDER: Well, the points that need to be considered, I think, are first of all that you are dealing with a chemistry range that you have to worry about, and that you have got a legitimate sample of the materials, of the various types that are used in the plant, and I don't know who is going to vouch for that, but that is often difficult.

MR. CLOUD: Yes.

Bob, do you want to add anything to what I said?

MR. ROMER: Robert Romer, Stone & Webster.

What we had talked about doing -- and we are interested in exactly the same concern -- was doing a detailed review of the CMTRs, material characteristics that came in for

those three materials and determine that we do have a representative sample, and work back to particular material samples that will undergo the fracture mechanics test.

MR. BENDER: Well, that helps some. Do you have any residual pieces off the pipe that's actually in there?

MR. ROMER: Yes, and that was the intent, to take actual residual marked pieces of piping from the plant and use them in the actual testing program.

MR. BENDER: Thank you.

MR. EBERSOLE: May I ask a question about this pipe?

Is there such a phenomenon as tight cracks or cracks that have been filled by corrosion products or crud? You know, that conceal the fact that you have lost structural strength until you lose too much of it?

MR. CLOUD: Excuse me, I'm not sure I heard you right. I tried to understand you, but I'm not sure I heard you.

MR. EBERSOLE: All right. I'll give you what I gave them yesterday, the old corn meal treatment to the Model T. I can fill up cracks with crud so you never know they are there. I don't know whether such materials are generated in these loops you are talking about or not, to fill up a crack and obscure the fact that you have lost structural strength, but it is not leaking.

MR. CLOUD: We used to do it with oatmeal, as I

recall.

MR. EBERSOLE: Well, call it oatmeal.

MR. CLOUD: In the transmissions, yes.

Well, our program does not depend upon a pipe crack inspection. Our work is based upon the presumption that there will be a priori the largest crack that would be acceptable under the ASME Section 11, on the one hand; and on the other hand, the analysis that we are talking about requires the postulation of a throughwall crack in the pipe to prove that the pipe will remain stable in the presence of that crack.

So whereas it is conceivable that we might have cracks in the piping that would be concealed by the presence of the corn meal, that would in no way either affect our conclusions or our program.

MR. EBERSOLE: Plain old rust makes a pretty good crack filler.

MR. CLOUD: That is correct.

MR. EBERSOLE: It swells up. So how do I know you haven't got a cracked pipe that is waiting for that next impulse to break it?

MR. CLOUD: You don't, but -- you do not know. However, what we will prove to you, if we continue with our program, we will prove that the result that concealed crack which just is getting ripe and springs open will produce a leak that will be detected, rather than a catastrophic break.

MR. EBERSOLE: You mean if I hit it with a hammer or a jolt or water hammer or whatever, it will then spring into a leak rather than a break?

MR. CLOUD: That is correct.

MR. RODABAUGH: Supposing you have a crack in a -- well, let's take a steam pipe 24 inches diameter by 1 inch thick, and following up Jesse's point, there happens to be a longitudinal seam in this pipe, and that is the point where the crack is developing.

It now, under Jesse's postulant, might grow to be seven feet long. Now when that pops through, that is an unstable crack. You are not going to show by fracture mechanics, unless we are talking of a different definition of break. To me, that would break. It will be an unstable failure.

MR. CLOUD: I think what you are saying is that you are visualizing that there will be some circumstances where it will not be possible to show that there will be a leak before break; is that what you are telling me?

MR. RODABAUGH: Depending a bit on just what you mean by a break. Circumferential breaks are one thing I think you could almost rule out, and longitudinal braks are something else.

Yes, there may be longitudinal breaks where you are going to have a hard time showing that it can occur.

MR. CLOUD: That's right. And we said we anticipated that circumstance, and we have said at the very outset -- and I am glad, in fact, that you brought it up, because I don't want to lose the opportunity to become repetitive on this point.

[Slide.]

But I want to bring back my first slide again, to say that we are going to retain the rupture restraint in the areas where the leak-before-break is not applicable.

So I am going to keep this one handy, and I want to say that we definitely have what we hope -- we hope that we have got -- for lack of a better term, I will say a more intelligent approach to the pipe break protection by using -- by making use of the program that we have, which envisions several different ways.

MR. RODABAUGH: Is it not true that a longitudinal split requires much less in the way of pipe whip restraints?

MR. CLOUD: As far as I am concerned, a longitudinal split -- a pipe whip restraint doesn't do any good on the longitudinal split, anyway. And so probably they wouldn't be there. But it might be that there would be some jet shields nearby because of that.

MR. RODABAUGH: Yes.

MR. BENDER: Bob, you stated that you are going to make your argument around the Section 11 inspection limit, and

I guess I am not all that comfortable with the assurance we have that inspection process under Section 11 for this raft of piping we have got out there necessarily will give you the confidence that you have exposed all the cracks that are within the limits.

I think in a statistical sense they find most of them, but how much does the argument hinge on Section 11 inspections?

MR. CLOUD: Well, not really at all. It really doesn't hinge on the Section 11 inspections at all, because part of our methodology is to assume that --

[Slide.]

-- this is the testing, this is the crack stability analysis, and this is the crack growth rate analysis. This is an entire class of analyses which is based on beginning with the assumption that you have a throughwall crack, a complete throughwall crack of a certain size that of and by itself would be significantly larger than Section 11 would ever permit.

And then we need to prove that pipe will remain stable in the presence of that crack.

The Section 11 comes in where we are basically following the methodology or, I guess, the practice, really, that has been formulated by NRR and others who have gone before me in saying okay, well, what kinds of crack growth

rates am I to anticipate in this circumstance, and to assume that we will have the largest crack that will pass through Section 11, and see how fast they would grow.

But we still need to show that a very large crack, much larger than Section 11 cracks, would remain stable and with detectable leaks.

MR. EBERSOLE: If I can take as an example the main steam lines from the steam generators to wherever, you know, the turbine, would you allow these to lay on top of the control room roof if it was say a four inch concrete slab?

MR. CLOUD: I don't know. I think -- I intended to say of course not.

MR. SHEWMON: What is your point, Jesse?

MR. EBERSOLE: The point is if he says it is not going to break before it leaks, that would be perfectly all right.

MR. CLOUD: Yes. If the leakage is acceptable in that location --

MR. EBERSOLE: Yes, but a big split would not.

MR. CLOUD: And then we get into the situation that would in fact we be vulnerable to a big split or not. And the important thing, I think, today is that we are in a position with the improvements in our knowledge, the analysis procedures, we are in a position to say whether or not we are vulnerable or we are not vulnerable.

[Slide.]

Just to briefly wrap it up, these are the -- filling in the blanks on the types and kinds of analyses. Once this is done --

MR. MARK: Excuse me. Are materials testing -- you have mentioned several kinds of material, like 106, whatever it is, steel. You only have to test a sample of that from one of these residual pipe ends. You don't have to go around and sample the metal at which whip restraint location, do you?

MR. CLOUD: No, sir, I don't believe we do. I believe that if we could characterize -- one of the things we have to do is see how many heats of this material we are dealing with.

MR. MARK: So you might go with taking a sample of each heat?

MR. CLOUD: That's the kind of thing that we are presently engaging in.

MR. MARK: Or each weld type, perhaps?

MR. CLOUD: Yes. And there are certain numbers of types of welds that would be permitted, and weld materials that would be permitted, and procedures that would be permitted. So we would sort through all of that to make sure that we have characterized the welding adequately, and similarly with the materials themselves.

[Slide.]

Now we have got a situation where we have come this far, we have gotten our postulated breaks, and we have seen that at these break locations we can be sure that we will get a significant leak prior to the catastrophic failure.

So now we have to go through an assessment of our leak detection capability to ensure that we have the -- that we have the ability to detect the leakage, and the most important thing is that we believe that there are several different ways to detect leakage, and we feel that a good and a sound leak detection program will incorporate several techniques.

In particular, it will have the instruments that are presently available. We will do a good study, a thorough study of the plant instrumentation in the sense that we believe that there is a tremendous amount of leakage that could be detected by a study of the pressure drops and liquid levels and other instrumentation that we have in place at the moment.

And the outcome of this study would result in instructions to the plant operators and alarms and things of that nature.

In addition, we have physical inspections that we could impose upon the plant operators and we believe that there are various other features. So we visualize a comprehensive leak detection program specifically for each of

the -- and we will show the path for leak detection for each of the postulated breaks that has the whip restraint eliminated.

[Slide.]

MR. BENDER: This leak detection concept is a two-edged sword. I think you might be able to make the case. The constraints put on the operation may have to be kept in mind, just as has been the case in the primary system. If you specify leaks requiring action that are too small, you may find the plant being shut down more than you would like, because you can't be sure you know where the leak is coming from.

It seems to me that side of it must be included when you make your major case.

MR. CLOUD: Yes, I guess I couldn't agree with you more, Mike. We definitely don't want to get into a situation where we are shutting the plant down for every valve leak. That's exactly right.

MR. SHEWMON: The current tech specs talk in terms of five gallons a minute for Beaver Valley 1?

MR. KURTZ: I believe it's one gallon per minute and 10 gallons per minute; one being unidentified and 10 being identified.

MR. RODABAUGH: To get back to Jesse's example, which I think is a good one since we're talking about balance

of plant, is the steam line. You have a fairly healthy steam leakage from the valve stems. What leakage method, other than going outside of the containment -- you could go look at the steam line. But inside the containment, would you depend then on your existing in-containment leakage system?

MR. CLOUD: Well, you're asking me questions that I'll be better able to answer when I'm done with the work. I believe that there are humidity indicators inside containment.

MR. RODABAUGH: Well, I was thinking of the valve house in the steam line in particular, which is moist, it's got steam.

MR. CLOUD: Yes.

MR. SHEWMON: How much lower than this one gallon a minute do you think you'll have to get, or are you aiming for? Are you talking about factors of 10 percent or 2 or an order of magnitude, or do you know at this point?

MR. CLOUD: No, sir, I don't know at this point.

I will point out to you, though, that the Rancho Seco line was a one-inch line, it was a very small line, and it developed a crack. Behaved, by the way, as we anticipated it would have behaved even though it was improperly supported. And I believe that that crack produced a leak of some 30 gallons a minute. So that the high energy lines leak a lot. Once they start leaking, well, it comes pretty good.

[Slide.]

I'd like to talk briefly about what we visualize some of the benefits. I'm going to talk about the benefits from a technical point of view, and the benefits from a cost point of view.

We think that just getting rid of the whip restraints, of and by itself, will be of benefit to the plant by improving the accessibility, minimizing restrictions on the inservice inspection, and we feel that there is additional radiation exposure that is incurred as a result of having a congested plant.

By focusing the plant operation on the detection of leakage, we feel that we are running the plant in a more intelligent way. It is known that it is possible to get binding with the whip restraints whenever there's a problem, so we visualize that there are unanticipated events that will be eliminated.

We are clearly, clearly, clearly going to have a much better understanding of the behavior of our high energy piping than we do using the current technology. The current technology doesn't do anything; very little engineering on the high energy piping. So we're talking about very serious study of exactly how that piping behaves, and we feel that that, of and by itself, will be a major contributor to improved safety of the plant.

MR. EBERSOLE: How does this interface with the

other hoped-for advantage in getting rid of most of the snubbers?

MR. CLOUD: I'm sorry?

MR. EBERSOLE: How do you interface this effort for getting rid of the pipe restraints with the other ongoing effort to get rid of the snubbers?

MR. CLOUD: Well, getting rid of the snubbers is -- those are essentially independent efforts. We have no snubbers, for example, that serve as whip restraints. And the snubbers are a part of the pipe support system, whereas the whip restraints --

MR. EBERSOLE: They are? I didn't understand that. I thought pipe supports were independent from snubbers.

MR. CLOUD: Well, yes and no. It depends on what you consider to be independent. But the snubbers --

MR. SIESS: They are unbroken pipe supports as opposed to broken pipe restraints.

MR. CLOUD: In any event, we believe that by addressing ourselves and doing the engineering work on the high energy lines, that we have got to end up with a better plant.

MR. RODABAUGH: Bob, before you leave that slide, I think Jesse and I keep running into the same confusion with yesterday's program. An improved understanding of piping failure modes. Yesterday, we were discussing the difference

between collapsed failure mode and fatigue failure mode.

Now ordinarily, a pipe whip restraint, if properly designed, never touches the pipe.

MR. CLOUD: That's right.

MR. RODABAUGH: So in your program, how are you improving the understanding of piping failure modes?

MR. CLOUD: Okay. We are improving the understanding of the high energy piping failure modes because of the fact that we will know, for example, about the susceptibility of our high energy lines to stress corrosion cracking.

MR. RODABAUGH: Okay. You're using the words "failure mode" in a different term than it was being used yesterday.

MR. CLOUD: I'm using it in the general sense.

MR. RODABAUGH: All right, fine.

[Slide.]

MR. CLOUD: We're talking about significant amounts of cost, too, which is what got me started thinking about it in the first place. I want to talk about two kinds of costs. What we are going to call the quantitative costs. Quantitative costs are costs that we can estimate reasonably well, and we have two kinds of costs that we are going to be talking about today.

The first are these quantitative costs that we can

estimate reasonably well, and the second is a whole lot of other costs that we know about, we know we are going to incur, but we cannot estimate them nearly so well as these quantitative costs. In the quantitative costs we have the analysis, design, fabrication, installation and the indirect costs of designing and installing the whip restraints. We're looking at about $8 million for Beaver Valley, considering the work that has already been done.

[Slide.]

The more difficult to estimate costs are the construction sequence frequently gets seriously screwed up because of the presence of congestion. We have a major gap adjustment verification program that must be conducted just before -- after all the whip restraints are in and just before the plant goes into operation. And this is a big program and it varies a lot.

Structural changes that we know will be required which will be due to the rupture restraint loads, -- big loads get calculated out of these whip restraints.

Another congestion cost [indicating].

And subsequently, in our outages we feel that we are going to save, or make major savings, once again due to congestion. And then there is the heat loss. The fact that we have the insulation off of the pipe at the rupture restraints, we will be able to insulate the whole pipe. So we

lose a lot of heat in the operation of the plant.

[Slide.]

Taken all together for this particular plant, we have costs that will save somewhere in the range of $12 to $16 million.

[Slide.]

And we felt that those are savings that are very definitely worth going after, particularly in the present situation where we have the leak before break technology that we have developed over the years.

Secondly, from the questionable validity or the questionable practicability of the rupture restraints anyway.

Thirdly, we feel that by doing this additional engineering work that we de facto, on the face of it, will end up with a safer, better plant.

[Slide.]

So taken all together, what we are doing is we are proposing to provide for the pipe break protection using the state-of-the-art today. We are not asking for any exemptions, we are proposing to provide for the protection in a different way. We want to use the ability to successfully detect pipe leaks. We believe, as I mentioned, that this will be a major improvement in plant safety and design, both during operation and during the outages.

Second, it's a strong industry initiative. We are

here offering, I think, to do more than -- we are giving for what we get on this one.

That is the conclusion of my presentation. Thank you very much for taking the time to hear it through. And understand the complexities of the licensing process which will require some assurance be given Duquesne Light that if this approach is followed, that there won't be a glitch at the licensing -- at the time for licensing, and that the license of the plant will not be jeopardized.

Thanks again, and I'll be glad to answer any further questions if there are any.

MR. RODABAUGH: A couple of details on what you, at this stage, think you may be addressing. There is a flange joint, several flange joints, for example, off the safety relief valve. Are you going to address in any way flange joints?

MR. CLOUD: We have to consider the geometry of the pipe as it is, so definitely we will consider the flange joints.

MR. RODABAUGH: Well, I asked the question because nobody that I'm aware of has done any leak before break on flange joints -- analysis and tests.

I guess my second curiosity is the leak before break technology is fairly well advanced for straight pipe and welds in straight pipe, but I've seen essentially nothing on

application of the leak before break technology to elbows, reducers, branch connections, which you run into a lot of.

MR. CLOUD: You're talking about -- when you say -- in the question you're asking, are you referring to the calculation of the growth of cracks and the stability of cracks?

MR. RODABAUGH: The stability, primarily. What is the stable crack size, an approximation?

MR. CLOUD: Oh, yes. Well, we feel that whereas in the case of straight pipes, for example, where we might have very exact solutions for the various different kinds of cracks, nevertheless, in the fundamental mechanics of the behavior of a crack it's the same regardless of anything else. It is only complicated by the geometry of the material and the geometry of the crack.

And we believe that, like any other analysis problem, we are entirely confident that it will be possible for those cases where we do not have exact solutions to have approximate conservative solutions like we do in so many other analysis areas.

MR. RODABAUGH: Well, I certainly want to encourage work along these lines.

MR. CLOUD: You are in a position to do so, I might point out.

MR. RODABAUGH: Well, I'm not sure if I am or not,

but I think it's a very worthwhile thing to attempt to do.

MR. CLOUD: I couldn't agree with you more.

MR. SHEWMON: Let me ask a simple question. A branch is a T-joint of dissimilar diameter points?

MR. RODABAUGH: Yes.

MR. BENDER: Like Ev, I am a supporter of this idea. I think it is constructive for a number of reasons, not the least of which is that you get rid of pipe whip restraints.

But there are some things that I think ought to be done as a preliminary, and that the regulatory staff will have to do in order to give you any assurance that what you are proposing will be acceptable after you do all the work. I think really you have to be somewhat more quantitative than you have been about the size breaks, or size of crack that you are going to have as the initiator, from which you are going to extrapolate growth rates. And I'm not at all sure that I want to accept the Section 11 limits as being the starting point.

But you probably don't have to start that small. I think you probably could start with something somewhat bigger because the A106 pipe in particular has good fracture properties, and you probably have a long way to go.

The second thing I want to say again, I think you may be letting yourselves in for more than you know when you

commit yourself to do something if you have a leak of a certain size, recognizing the fact that finding out where the leak is is sometimes a difficult job in a primary steam system. And that that may influence, to some degree, what parts of the system you want to defend.

The third point is the one which Ev has I think articulated well enough, and that is that the fittings are a separate case.

Now, the regulatory staff had difficulty dealing with the fitting question for the primary system, as you know, and stayed with the straight pipe. Whether they will get the fittings in the picture or not later, I don't know but I think that in view of that precedent, you ought to think about what your case for fittings is going to be, and whether it fits with the other arguments.

That's all I have.

MR. CLOUD: I would like to reply to those points becasue they are all three important ones. The first thing, the most obvious and most important aspect of the reply is that everything you say in every aspect of your remarks is in fact true. Everything that you pointed out in every aspect of the things in our program that you discussed are things that are completely ignored with the conventional approach.

So that just by virtue of the fact that we are in and poking around trying to understand how the systems behave

to protect against the potential breaks in an intelligent way is almost, de facto, of and by itself, I think an advance.

And I agree, we certainly don't know all of our answers in advance, but we believe that we can develop them as we go along, and we believe that the state-of-the-art is advanced to the point where we can develop workable, satisfactorily conservative answers as we go through.

Another thing I'd like to point out with respect to the discussion related to the primary system is that the primary system piping in the pressurized water plants, that is all cast material. That is the least tough material in the plant, and that's the part that we've accepted the leak before break on.

We have all the rod material in the balance of plant is much tougher, much more fracture resistant. Mr. Mark?

MR. MARK: I am certainly favorably impressed with the direction of things here. You have mentioned that the state-of-the-art is advanced, and that was particularly with respect to fracture mechanics and crack growth calculations. How is it with respect to leak calculations?

MR. CLOUD: That is not my field and I'm not sure.

[Laughter.]

I'm not in the fluid mechanics business, but I believe we can calculate the amount of leak once we have a given --

MR. MARK: Well, once you have a through-wall crack and it's big enough that the pressure will probably pry things apart slightly, then I could understand some leaking must go on but I'm not sure that that's the way things always happen. Nor am I sure that you are necessarily so good at calculating the opening of the crack as you may be at the progress of the crack.

MR. SHEWMON: The opening should be elastic, and if you assume it's elastic then it gets down to a question of, you know, how rough it is. And they can calculate smooth cracks -- smooth-walled cracks, I understand it, or you can do tests on that. And they can talk about, with a given pressure, given two surfaces, if we now make a cut through here, how much will it open up.

My impression is it gets worse as you start talking about how much --

MR. MARK: Zig-zag, yes.

MR. RODABAUGH: There is a good deal of test data, Carson, on leak rates and small cracks.

MR. MARK: It was a question; it was not an assertion of doubt.

MR. RODABAUGH: Well, your doubt is well taken, and I think Jesse's point enters here, too. Crud stoppage of cracks. But the research work is mostly on a piece of straight pipe. I know of very little on leakage rates in a

crack in branch connections, for example. So your question is a good one.

MR. EBERSOLE: Paul, I was just going to renew that question I discussed with you about the wide range of material properties you can get within the context of A106, B. Are you going to sharpen that up? I recall having --

MR. SHEWMON: He said that they knew what heats were in the plant and thought they could get samples from that.

MR. EBERSOLE: Right. I'd like to know what that range of property is which is under the cover of A106-B. I've heard stories ranging from almost brittle at 40 degrees to stuff that you could forage around and bend into duplex bends.

MR. CLOUD: Well I'll tell you what. Give us the go-ahead on this program and we will tell you what the range is.

MR. EBERSOLE: 106B, I think that's something that needs --

MR. SHEWMON: And also hot pipes at 200 or 270.

MR. EBERSOLE: Well, I'm interested in the cold pipes, too, that service water.

MR. CLOUD: That's an excellent question, Mr. Ebersole, and I'd like to reply in the same way I did to Mike and that is that the questions you are asking you will get the answer to if we could go ahead with the program. But you're not going to know nothing if you don't, if we don't.

MR. SHEWMON: Let me ask one more simpleminded question. Would you list the systems that you will be looking at -- steam systems, certainly. Feedwater.

MR. CLOUD: Those systms are listed and well defined, and they are the so-called high energy line systems. I don't have it right now, but it's the main steam lines, the feedwater lines, and all the other lines that are higher than 275.

MR. EBERSOLE: Service water is about maybe 200 or 300 pounds at 40 degrees.

MR. SHEWMON: I see a violent shaking of the head back there.

MR. CLOUD: Bob, can you help me out informally with anymore of the lines, anymore of the hydrogen systems?

MR. ROMER: Steam generator blowdown lines, low pressure injection, other injection lines. Of course, we mentioned feedwater, main steam, aux steam, charging. It definitely doesn't cover service water.

MR. EBERSOLE: Component cooling? It doesn't cover that?

MR. ROMER: I don't believe so. In some cases we have postulated breaks in lines and the effects are virtually non-existent.

MR. EBERSOLE: So really you're looking at just the elimination of pipe whip.

MR. CLOUD: In general, that's correct.

MR. EBERSOLE: You're not looking at the loss of service function due to breaks.

MR. CLOUD: That's exactly right.

MR. SHEWMON: So these are steam lines and feed lines. Okay.

Any other questions for Bob before we go on to the other Bob?

[No response.]

MR. SHEWMON: Okay. Thank you very much.

MR. BOSNAK: The staff has had several informal meetings with the people from Beaver Valley, Duquesne Light, and I would characterize the staff right now as being sympathetic particularly to the removal of these items of hardware that are in there to protect against postulated pipe breaks. And we are also sympathetic to the approach that is being proposed.

We are also I think -- in preface, we are pleased that Duquesne has chosen to do these kinds of analyses and testing. I want to stress that testing is an important part of this thing because we believe that the broad scope rule change which is in preparation now through GDC-4, I think will be aided. It has to be helped by this program.

Now, what are some of the problems that we see? We expect that within a couple of weeks we will get a formal

transmission with all of the meat on the skeleton that Duquesne is able to come up with at the present time. But certainly, identification of systems to which fracture mechanics techniques may not apply -- that is going to be quite important.

I think Bob said that the method works when applied in appliable situations, and we quite agree. So we don't want to be down at the last minute arguing about whether or not this system is subject to stress corrosion cracking, or this one has large dynamic loads which we don't know how to analyze. So we want to be sure that they go through, at least now, a preliminary screening and eliminate or kick out the systems which we will be arguing about. So in particular, Bob did mention the large dynamic loads, stress corrosion cracking and the fatigue situations.

From a legal and administrative point of view, we have talked several times with the staff counsel, and I think originally they felt that the broad scope rule had to be in place before they were able to go ahead with this. That has changed now.

I think the caveats that they have are that the broad scope rule is proceeding on track. In other words, there have been no hangups identified. And of course, we and they would be hopeful that there wouldn't be too many systems for which these analyses and testing techniques cannot be

applied.

Now what they see happening and what we would see happening is that there may be one or two systems at the end -- and this is at the point at which the license has to be issued, and I guess we're talking about the end of 1986 or early 87 -- if that is the case, then we would handle that -- and this is what's being proposed now -- by a schedular exemption that would be similar to what we are doing with the narrow scope rule for the main loop.

By that I mean that they have gotten to the point now where they are ready for the license and there is this one system which we believe we need to install the hardware that we have been used to. And if that is the case, an exemption schedule or an exemption, if you will, will be granted for perhaps one or two refueling outages, and after that period the hardware would have to be installed.

So that's the way we look at it. Obviously, if there are many, many such systems when we get down to the end, that will be bad news, and it would have to delay the licensing. We hope that there won't be such a situation. And that is why right now we believe that preliminary work, going through and screening the number of systems, is very, very important.

MR. SIESS: Bob, if Beaver Valley 2 were allowed to operate without all these pipe whip restraints in place, would

they be the only plant operating without pipe whip restraints?

MR. BOSNAK: Other than the primary loop which we have been talking about, they would be the only plant recently licensed --

MR. SIESS: That wasn't my question. Could you say yes or no and then elaborate?

MR. BOSNAK: If you go back to the very old plants -- and there are those plants that were never designed for these kinds of situations.

MR. SIESS: There are plants -- what do you call very old? Dresden?

MR. BOSNAK: I'm not sure whether Dresden --. Maine Yankee -- well Connecticut Yankee perhaps. Maine Yankee may have --

MR. SIESS: SEP plants?

MR. BOSNAK: Essentially, the SEP plants, but again, those have been looked at from a consequence point of view and during the recent SEP exercises. So even though they may not have the hardware in there, they have been reviewed from a systems and consequence point of view.

MR. SIESS: Okay. I was just trying to get some perspective in terms of risk, of this plant operating, say, for two years without these restraints versus the sum total of risk. You know. Not a regulatory approach; strictly a safety view of it, without consulting a lawyer.

MR. BOSNAK: Staff, at least in the Division of Engineering, feels that these, particularly the pipe whip restraints, really don't contribute to safety and may actually detract from safety because you can have an interaction between a whip restraint and a system in normal operation, and over the years these things can settle and change position. And that may, in fact, under certain situations, lead to a bad situation.

MR. SIESS: So your problem was simply a legal one of some way to defer this until the whole issue is settled by the rulemaking.

MR. BOSNAK: Well, even if --

MR. SIESS: You don't have a real safety concern.

MR. BOSNAK: That's right, because we are not changing -- I think what Bob pointed out, even though some of the letters that have come in on the narrow scope rule have indicated we should go further, we are not making any changes with respect to equipment qualification.

When you are talking about balance of plant, that is the important thing. That is not being changed.

MR. MARK: On one of the slides we saw there were 136 pipe whip restraints in the balance of plant.

MR. BOSNAK: Items of hardware. Perhaps pipe whip restraints, jet shields.

MR. MARK: Yes. Is that the total number that are

out there, some of which might later be decided were not --.

MR. BOSNAK: I think that comes from about 400 or so breaks and those are the only things for which they have necessity to have this kind of break protection. In other words, for the other breaks they expect that they don't need these kinds of hardware.

MR. CLOUD: It is the total number. The numbers I presented on the pie chart were the total numbers.

MR. MARK: So some of those probably won't be relieved in this way, since you will find that they are subject to corrosion or fatigue or something.

MR. CLOUD: That's exactly correct.

MR. RODABAUGH: Bob, in terms of your MEB 36.2, right now you have this requirement for longitudinal pipe breaks which are more of a vigorous crack. What are your plans regarding that part? Is that involved at all here?

MR. BOSNAK: Well, if you go into the fracture mechanics approach, both the longitudinal and circumferential breaks go away.

MR. RODABAUGH: I guess 36.2 requires the longitudinal breaks even in a moderate energy piping.

MR. BOSNAK: Well, certain locations might have longitudinal. It depends on the stress ratio.

MR. RODABAUGH: Maybe I'm confusing this with through wall leakage cracks.

MR. BOSNAK: Through wall leakage cracks are there in moderate energy situations, and you know if you don't have a postulated pipe break in those areas, then you go into the through wall leakage crack which --

MR. RODABAUGH: I am trying to explore this equipment qualification bit -- maybe it wouldn't make any difference.

MR. BOSNAK: Right now from what the equipment people tell me, the difficult area is not the large break; it's the smaller break in which they can get some superheated steam.

MR. RODABAUGH: That's exactly the point I'm trying to follow. Would this impact how you evaluate --

MR. BOSNAK: It wouldn't impact that at all. Not at the present time at least. But we do have all of these suggestions that say we should go further but we are not intending to do that now.

MR. SHEWMON: Any other questions? I think the sense of the consultants and the members here is positive and encouraging. Now, do you want anything other than warm feelings out of us at this time?

MR. BOSNAK: I think that's what we were looking for. That you don't see reasons that this program should not proceed. That's what we wanted to know; if you had any doubts at all. But if you have warm feelings --

MR. SHEWMON: I have a note from Jesse. He says, "Sounds like a really worthwhile program," and I think that tends to be the sense of the meeting. So I think on that, unless I am misquoting anybody, -- any other questions or discussion? If not, the meeting is adjourned.

[Whereupon, at 3:03 p.m., the subcommittee meeting was adjourned.]

# 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 Subcommittees on Structural Engineering, Seismic Design of Piping, and Metal Components

Docket No.:

Place: Washington, D. C.

Date: Tuesday, September 24, 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.

Jim Richardson
9-23-24/85
(1)

MECHANICAL-STRUCTURAL ENGINEERING BRANCH

PRESENTATION TO ACRS SUBCOMMITTEE ON

STRUCTURAL ENGINEERING

SEISMIC DESIGN OF PIPING

METAL COMPONENTS

SEISMIC, STRUCTURES, AND CONTAINMENT INTEGRITY RESEARCH PROGRAM

SEPTEMBER 23 AND 24, 1985

## MSEB BUDGET FOR STRUCTURES AND SEISMIC RESEARCH

| TITLE | FY 1985 | BUDGET FY 1986 | FY 1987 |
|---|---|---|---|
| SEISMIC MARGINS STUDIES | $650K | $600K | $900K |
| VALIDATION OF SEISMIC RESPONSE PREDICTIONS | 1100 | 1750 | 1900 |
| COMPONENT FRAGILITY DATA ACQUISITION AND EVALUATION | 240 | 1100 | 1000 |
| SEISMIC CATEGORY I STRUCTURES | 820 | 1200 | 1500 |
| RELIABILITY ANALYSIS OF NONLINEAR BEHAVIOR OF CONCRETE STRUCTURES (BNL) | 0 | 200 - | 400 - |
| STRUCTURAL DEGRADATION | 0 | 0 | 300 |
| STRUCTURAL COMPUTER CODE BENCHMARKS | 300 | 200 | 200 |
| NRC/EPRI PROGRAMS ON PIPING DYNAMIC LOAD CAPACITY | 200 | 700 | 900 |
| OTHER NRC PIPING RESEARCH | 333 | 375 | 600 |
| PARAMETERS INFLUENCING DAMPING IN PIPING SYSTEMS | 230 | 200 | 0 |
| | $3873K | $6325K | $7700K |
| PROGRAMS THAT TERMINATE IN FY 1985 | 1,418 | | |
| | $5291K | | |

primarily
improving data base
fragility

## MSEB BUDGET FOR CONTAINMENT INTEGRITY RESEARCH

| TITLE | BUDGET FY 1985 | FY 1986 | FY 1987 |
|---|---|---|---|
| EXPERIMENTS ON CONTAINMENT MODELS UNDER EXTREME LOADING CONDITIONS | $2,060K | $2,000K | $2,400K |
| CONTAINMENT INTEGRITY UNDER EXTREME LOADS | 740 | 600 | 700 |
| INTEGRITY OF CONTAINMENT PENETRATION UNDER SEVERE ACCIDENT CONDITIONS | 900 | 900 | 600 |
| CONTAINMENT BUCKLING | 250 | 200 | 0 |
| | $3950K | $3700K | $3700K |

EFFECTS OF EARTHQUAKES ON OPERATING PLANTS

## ISSUE

SOME OPERATING PLANTS MAY BE REQUIRED TO WITHSTAND EARTHQUAKES LARGER THAN THEIR ORIGINAL DESIGN BASIS BECAUSE OF NEW SEISMOLOGICAL INFORMATION. IT IS IMPORTANT TO ESTIMATE AVAILABLE DESIGN MARGINS OF PLANTS TO WITHSTAND THESE LARGER EARTHQUAKES TO PROVIDE THE BASIS FOR REGULATORY DECISIONS AND AVOID UNNECESSARY SHUTDOWNS.

some plants in the near future some plants need higher seismic design levels. ... Eastern seism. study to provide seism. design level. (DBE may go up!)

## OBJECTIVE

TO EXPERIMENTALLY VALIDATE COMPLEX METHODS USED TO PREDICT SEISMIC BEHAVIOR OF THE PLANT; IMPROVE AND REDUCE UNCERTAINTIES IN COMPONENT FRAGILITY DATA BASE USED TO ESTIMATE MARGINS; DEVELOP PROCEDURES FOR ESTIMATING SEISMIC DESIGN MARGINS; AND ELIMINATE EXCESSIVE USE OF SNUBBERS TO PROVIDE BETTER BALANCE OF SAFETY.

## ELEMENTS

- CONDUCT EXPERIMENTS USING LARGE SCALE INTEGRATED FACILITIES TO VALIDATE COMPLEX PREDICTIVE METHODS.
  - 1986 HDR (FRG) vib w/eccentric shaker whole Bldgs (opera. react. next door)
  - Jap. shaker ... negotiation on-going: PWR BWR loop 1/3 - 1/2 scale & contain. stl & concrete
- ASSEMBLE EXISTING COMPONENT FRAGILITY DATA AND CONDUCT FRAGILITY TESTS TO IMPROVE THE DATA BASE.
- DEVELOP AND DEMONSTRATE PROCEDURES FOR ESTIMATING SEISMIC DESIGN MARGINS AND PROVIDE BASIS FOR REDUCING THE NUMBER OF SNUBBERS + pipe supports USED IN SEISMIC DESIGN.

up to design basis Earthquake only ... not larger .. NRC wants to go to failure. Japs now agree ... prob w/ financ[illegible]

## INTEGRATION

PROGRAM INVOLVES COOPERATION AND COORDINATION WITH EPRI, INDUSTRY, GERMANY AND JAPAN.

## REGULATORY USE

METHODS, DATA BASE AND REVIEW PROCEDURES WILL BE USED BY THE REGULATORY STAFF TO EVALUATE LICENSEE SUBMITTALS, PROBABILISTIC RISK ANALYSES, AND ESTIMATE SEISMIC MARGINS.

# EFFECTS OF EARTHQUAKES ON OPERATING PLANTS (OMB presentation ma...)

## ISSUE:

NEW SEISMOLOGICAL INFORMATION INDICATES THAT SOME OPERATING PLANTS MAY EXPERIENCE EARTHQUAKES LARGER THAN WHAT THEY WERE ORIGINALLY DESIGNED FOR (E.G., THE USGS HAS STATED THAT AN EARTHQUAKE SIMILAR TO THE 1886 CHARLESTON, S.C., EARTHQUAKE MAY OCCUR OVER A WIDER AREA THAN ORIGINALLY THOUGHT). IT IS IMPORTANT TO UNDERSTAND THE BEHAVIOR AND CAPACITY OF NUCLEAR POWER PLANTS TO WITHSTAND EARTHQUAKES LARGER THAN THEIR ORIGINAL DESIGN BASIS TO MAKE REGULATORY DECISIONS AND NOT IMPOSE UNNECESSARY MODIFICATIONS OR SHUTDOWNS. EXCESSIVE USE OF SNUBBERS HAVE LED TO OVERLY STIFF PIPING SYSTEMS WHICH MAY DIMINISH OVERALL SAFETY.

## OBJECTIVE:

1. TO EXPERIMENTALLY VALIDATE COMPLEX METHODS USED TO PREDICT THE BEHAVIOR OF STRUCTURES, SYSTEMS AND COMPONENTS UNDER VERY LARGE EARTHQUAKE LOADS THAT WOULD CAUSE RESPONSES INTO THE NON-LINEAR RANGE. THESE COMPLEX METHODS WILL THEN BE USED TO BENCHMARK SIMPLIFIED APPROACHES TO BE USED TO MAKE REGULATORY DECISIONS FOR INDIVIDUAL PLANTS WHOSE DESIGN EARTHQUAKE HAS BEEN INCREASED.
2. TO IMPROVE AND REDUCE THE LARGE UNCERTAINTIES IN THE DATA BASE THAT DESCRIBES THE FRAGILITY (FUNCTIONAL CAPACITY) OF CRITICAL COMPONENTS TO BE USED TO QUANTIFY THE SEISMIC MARGIN OF A NUCLEAR PLANT AND PERFORM PROBABILISTIC RISK ANALYSES.
3. TO DEVELOP AND DEMONSTRATE PROCEDURES TO ESTIMATE THE SEISMIC DESIGN MARGINS OF NUCLEAR POWER PLANTS.
4. TO DEVELOP CRITERIA FOR REDUCING THE NUMBER OF PIPING AND COMPONENT SNUBBERS USED WHICH WILL PROVIDE BETTER BALANCE IN SAFETY BETWEEN NORMAL OPERATING AND ACCIDENT CONDITIONS AND REDUCE RADIATION EXPOSURE TO WORKERS.

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# EFFECTS OF EARTHQUAKES ON OPERATING PLANTS (CONTINUED)

## PROGRAM ELEMENTS:

1. VALIDATION OF METHODS - IN FY 1986 AND FY 1987, PARTICIPATE IN HIGH LEVEL VIBRATION EXPERIMENTS AT THE HEISSDAMPFREAKTOR (HDR) IN COOPERATION WITH THE FEDERAL REPUBLIC OF GERMANY TO PARTIALLY VALIDATE SEISMIC CODES. ALSO COOPERATE WITH EPRI IN A SOIL-STRUCTURE INTERACTION EXPERIMENT BEING BUILT IN AN ACTIVE EARTHQUAKE REGION IN TAIWAN (FY 1986-1988). PARTICIPATE IN FY 1987 IN VIBRATION EXPERIMENTS IN COOPERATION WITH THE JAPANESE ON LARGE INTEGRATED PIPING SYSTEM AT TADOTSU FACILITY (WORLD'S LARGEST SHAKER TABLE) TO VALIDATE NON-LINEAR PIPING COMPUTER CODES. VALIDATION EFFORT WILL BE COMPLETED IN FY 1987.

2. IMPROVED FRAGILITY DATA BASE - IN FY 1986, WILL COMPLETE GATHERING OF COMPONENT FRAGILITY (FAILURE) DATA IN COOPERATION WITH EPRI AND INDUSTRY (SEISMIC QUALIFICATION USERS GROUP) AND IDENTIFYING WHAT SPECIFIC FRAGILITY DATA IS NEEDED. IN FY 1987, WILL COMPLETE FRAGILITY TESTING OF SELECTED COMPONENTS. CONTINUE IN FY 1986 AND COMPLETE IN FY 1988, EXPERIMENTS ON SMALL SCALE CONCRETE SHEAR WALL STRUCTURES TO INVESTIGATE THEIR BEHAVIOR UNDER SEISMIC LOADS EXCEEDING THE DESIGN BASIS TO DETERMINE THE MODE AND LEVEL OF FAILURE. THE COMPONENT AND STRUCTURAL FRAGILITY EFFORT WILL BE COMPLETED IN FY 1988.

3. SEISMIC DESIGN MARGINS - IN FY 1986, COMPLETE DEVELOPMENT OF PROCEDURES AND REVIEW GUIDELINES TO ESTIMATE THE SEISMIC MARGINS FOR PWR PLANTS AND CONDUCT A TRIAL PLANT REVIEW TO DEMONSTRATE AND IMPROVE THE PROCEDURES. IN FY 1987, SIMILAR PROCEDURES AND PLANT REVIEW WILL BE COMPLETED FOR A BWR AND WILL COMPLETE THIS EFFORT.

## INTEGRATION

1. COOPERATING WITH THE FRG AT HDR FACILITY TO VALIDATE SEISMIC METHODS. (FRG-$10M, NRC-$500K)
2. NEGOTIATING WITH JAPANESE (MITI) TO COOPERATE ON TADOTSU SHAKER TABLE TO VALIDATE NUCLEAR PIPE CODES. (MITI-$12M, NRC-$700K)
3. COOPERATING WITH EPRI ON SOIL-STRUCTURE INTERACTION EXPERIMENTS IN TAIWAN. (EPRI-$1M, NRC-$200K)
4. COOPERATING WITH EPRI AND INDUSTRY (SEISMIC QUALIFICATION UTILITY GROUP) TO GATHER FRAGILITY DATA. (INDUSTRY-$50M, NRC-$500K)
5. COOPERATING WITH EPRI ON SEISMIC DESIGN MARGINS. (EPRI-$1M, NRC-$1.2M)

NRC RESEARCH IS FOCUSED ON DEVELOPING THE TECHNICAL BASIS FOR LICENSING DECISIONS AND ESTABLISHING REGULATORY CRITERIA USING RESULTS OF INDUSTRY RESEARCH WHERE POSSIBLE.

## REGULATORY USE

1. VALIDATED SIMPLIFIED METHODS WILL BE USED TO EVALUATE LICENSEE SUBMITTALS.
2. IMPROVED FRAGILITY DATA BASE WILL BE USED TO EVALUATE AVAILABLE SEISMIC MARGINS AND PROVIDE IMPROVED PROBABILISTIC RISK ASSESSMENTS.
3. SEISMIC DESIGN MARGIN PROCEDURES WILL BE USED TO ASSESS CAPACITY OF NUCLEAR PLANTS TO WITHSTAND LARGER EARTHQUAKES AND MAKE SOUND REGULATORY DECISIONS WITHOUT UNNECESSARY MODIFICATIONS OR SHUTDOWNS.
4. ASME CODE, REGULATORY GUIDES, AND STANDARD REVIEW PLAN MODIFIED TO PERMIT REMOVAL OF SNUBBERS TO MAKE PIPE SYSTEMS MORE FLEXIBLE AND PROVIDE IMPROVED BALANCE OF OVERALL SAFETY.

## FOREIGN AND DOMESTIC RELATED PROGRAMS

### SEISMIC HAZARD

- o EPRI and Industry Probabilistic Seismic Hazard Program
- o USGS Ground Motion Studies
- o National Earthquake Hazard Reduction Prog. (USGS, NSF, FEMA, NBS)
- o Corps of Engineers Seismic Soils Settlement Program

### VALIDATION OF SEISMIC METHODS

- o Germany - KfK HDR Program
- o EPRI - Taiwan SSI Experiments
- o Japan - MITI/NUPEC Seismic Experiments

### FRAGILITIES AND RESPONSE

- o EPRI Piping Program
- o EPRI Equipment Qualification Program
- o NRC Equipment Qualification Program
- o NRC Aging Program
- o Seismic Qualification Utility Group Data

### SEISMIC MARGINS

- o EPRI Seismic Margins Research Program
- o Industry Probabilistic Risk Analyses

## NRC SEISMIC SAFETY RESEARCH PROGRAM

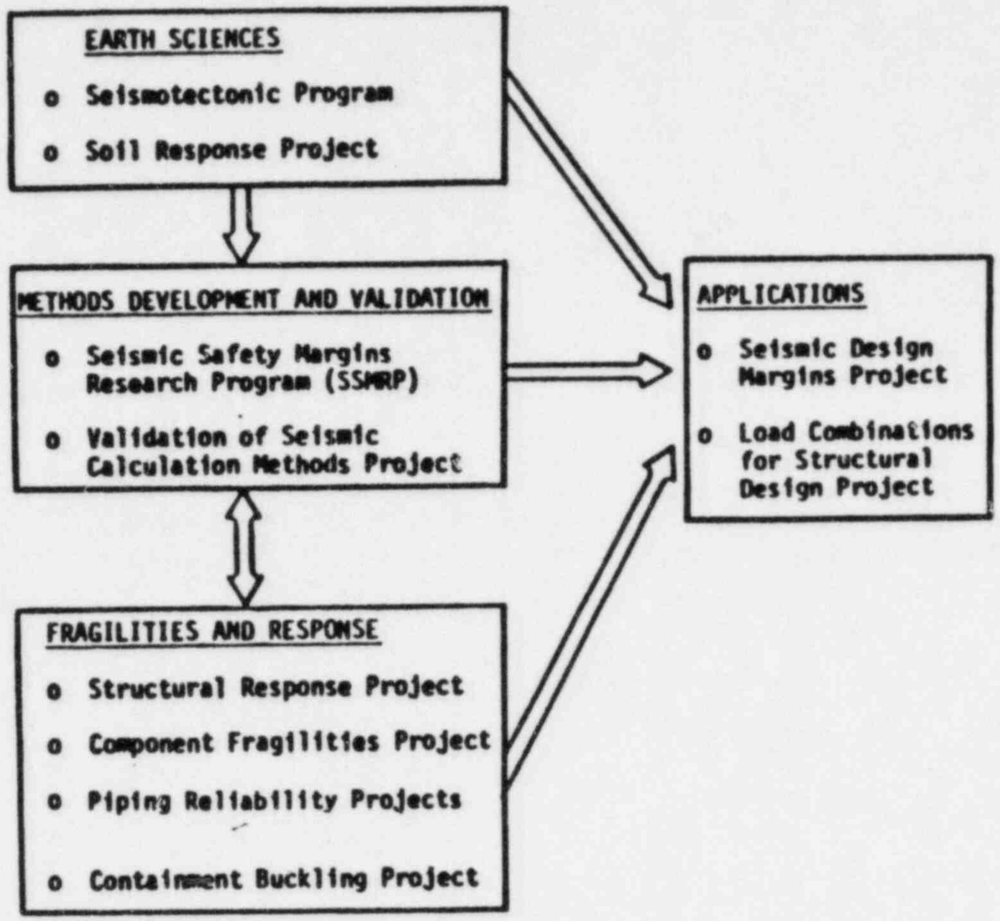



Figure 1 Project Interrelationships and Regulatory Applications

## REGULATORY APPLICATIONS

### SEISM C HAZARD

- o Charl ston Earthquake
- o New B unswick Earthquake
- o Site- pecific Spectra

### SEISMIC RISK

- o Licensee PRAs
- o Integrated Safety Assessment Program
- o Risk Methodology Integration & Evaluation Program

### SEISMIC MARGINS

- o NTOL Seismic Issues
- o Pipe Damping (R.G. 1.61)
- o Floor Spectra (R.G. 1.122
- o ASME Code-Piping & Structures
- o Equipment Qualification
- o Structural Damping (R.G. 1.61)
- o Independent Pipe Support Motion

RES pays about 25% of Research Budget

## SEISMIC RESEARCH INTEGRATION

progress = [illegible] also operational

| ELEMENT | RES CONTRACTOR | OTHER SOURCES | RELATIONSHIP |
|---|---|---|---|
| BUILDING BEHAVIOR | | | |
| SOIL-BUILDING INTERACTION | BNL | EPRI, TAIWAN | JOINT |
| BUILDING FAILURE | LANL, SNL | JAPAN | COMPLEMENTARY |
| BUILDING RESPONSE | LANL | TAIWAN, FRG, JAPAN | COMPLEMENTARY |
| PIPING BEHAVIOR | | | |
| PIPING-BUILDING INTERACTION | LANL | - | |
| PIPING FAILURE | ETEC, ANCO | EPRI | JOINT |
| PIPING RESPONSE | HEDL, INEL, BNL | EPRI, JAPAN, FRG | JOINT & COMPLEMENTARY |
| PIPING CRITERIA CHANGES | INEL, BNL, ORNL, LLNL | ASME, PVRC, EPRI | JOINT |
| EQUIPMENT BEHAVIOR | | | |
| EQUIPMENT-BUILDING INTERACTION | LANL | - | |
| EQUIPMENT FAILURE | LLNL, BNL | EPRI, SQUG | JOINT & COMPLEMENTARY |
| EQUIPMENT RESPONSE | INEL | FRG | JOINT |
| VALIDATION OF SEISMIC CALCULATIONAL METHODS | | | |
| SOIL-BUILDING INTERACTION | BNL | EPRI, TAIWAN | JOINT |
| BUILDING-EQUIPMENT/PIPING INTERACTION | ANL, ANCO, INEL | FRG | JOINT |
| EQUIPMENT RESPONSE | BNL, INEL | JAPAN | JOINT |
| SEISMIC DESIGN MARGINS | | | |
| DEVELOP REVIEW PROCEDURES FOR ESTIMATING MARGIN | LLNL/EXPERT PANEL | EPRI | JOINT |
| DEVELOP FRAGILITY DATA BASE | LANL, LLNL, BNL | EPRI, SQUG INDUSTRY EQUIPMENT TEST LABS (I.E.,WYLE) | JOINT & COMPLEMENTARY |
| CONDUCT TRIAL PLAN REVIEWS | LLNL | EPRI | JOINT |

8

# ADEQUACY OF SAFETY EQUIPMENT UNDER ABNORMAL CONDITIONS
## CONTAINMENT INTEGRITY

### ISSUE

CONTAINMENT BUILDING IS THE FINAL BARRIER TO RELEASE OF RADIOACTIVE MATERIAL TO THE ENVIRONMENT FROM SEVERE ACCIDENT. IT IS IMPORTANT TO UNDERSTAND THE STRUCTURAL INTEGRITY AND LEAK BEHAVIOR OF CONTAINMENTS UNDER SEVERE ACCIDENT CONDITIONS.

### OBJECTIVE

OBJECTIVE IS TO EXPERIMENTALLY VALIDATE METHODS USED TO PREDICT STRUCTURAL AND LEAK BEHAVIOR OF STEEL AND CONCRETE CONTAINMENTS UNDER SEVERE ACCIDENT LOADS THAT ARE BEYOND THE DESIGN BASIS.

### ELEMENTS

PROGRAM CONSISTS OF SCALE MODEL EXPERIMENTS OF STEEL AND REINFORCED CONCRETE CONTAINMENT BUILDINGS AS WELL AS SEPARATE EFFECTS EXPERIMENTS ON LARGE CONTAINMENT PENETRATIONS AND SEAL AND GASKET MATERIALS TO VALIDATE STRUCTURAL AND LEAK BEHAVIOR PREDICTIVE METHODS.

### INTEGRATION

PROGRAM INVOLVES COOPERATION AND COORDINATION WITH EPRI, ENGLAND, FRANCE, AND GERMANY.

### REGULATORY USE

VALIDATED METHODS WILL BE USED BY LICENSING STAFF TO MAKE REGULATORY DECISIONS REGARDING LEAK BEHAVIOR OF CONTAINMENTS UNDER SEVERE ACCIDENT CONDITIONS. RESULTS OF PROGRAM WILL ALSO SUPPORT COMMISSION POLICYMAKING ON SEVERE ACCIDENTS.

# ADEQUACY OF SAFETY EQUIPMENT UNDER ABNORMAL CONDITIONS

## CONTAINMENT INTEGRITY

ISSUE:

IN ORDER TO EVALUATE THE EFFECTS ON PUBLIC HEALTH AND SAFETY RESULTING FROM POSTULATED SEVERE ACCIDENTS, THE ABILITY OF THE CONTAINMENT BUILDING TO PROVIDE A LEAK TIGHT BARRIER AGAINST THE RELEASE OF RADIO-ACTIVE MATERIAL TO THE ENVIRONMENT MUST BE KNOWN. THERE ARE LARGE UNCERTAINTIES IN PREDICTING THE LEAK AND STRUCTURAL BEHAVIOR OF THE CONTAINMENT SYSTEM UNDER SEVERE ACCIDENT CONDITIONS (PRESSURES AND TEMPERATURES LARGER THAN THE DESIGN BASIS).

OBJECTIVE:

1. DEVELOP AND CARRY OUT EXPERIMENTS ON SCALE MODEL STEEL AND CONCRETE CONTAINMENTS TO SUPPORT DEVELOPMENT AND VALIDATION OF METHODS FOR ESTIMATING THE LEAK AND STRUCTURAL BEHAVIOR OF CONTAINMENT BUILDINGS UNDER SEVERE ACCIDENT CONDITIONS THAT EXCEED THEIR DESIGN BASIS.
2. DEVELOP RELIABLE METHODS FOR ASSESSING THE INTERACTION BETWEEN CONTAINMENT PENETRATIONS (E.G., HATCHES, AIRLOCKS, VALVES, ELECTRICAL PENETRATIONS) AND CONTAINMENT STRUCTURES TO PREDICT LEAK BEHAVIOR UNDER SEVERE ACCIDENT CONDITIONS THAT EXCEED THE DESIGN BASIS. VALIDATE THE METHODS EXPERIMENTALLY.

# ADEQUACY OF SAFETY EQUIPMENT UNDER ABNORMAL CONDITIONS
## CONTAINMENT INTEGRITY (CONTINUED)

PROGRAM ELEMENTS:

1. COMPLETED IN FY 1985, EXPERIMENTS ON A 1/8 SCALE STEEL CONTAINMENT THAT VERIFIED THE ADEQUACY OF THE ASME BOILER AND PRESSURE VESSEL CODE USED TO DESIGN STEEL CONTAINMENTS. IN FY 1986, THE EXPERIMENTAL RESULTS WILL BE USED TO VALIDATE THE PREDICTIVE METHODS USED TO EVALUATE STEEL CONTAINMENTS.

2. IN FY 1986, A 1/6 SCALE REINFORCED CONCRETE CONTAINMENT BUILDING, INCLUDING SOME PENETRATIONS, WILL BE CONSTRUCTED. IN FY 1987, EXPERIMENTS WILL BE CONDUCTED ON THIS BUILDING TO INVESTIGATE ITS BEHAVIOR UNDER SEVERE ACCIDENT CONDITIONS AND VALIDATE THE PREDICTIVE METHODS.

3. IN FY 1986, EXPERIMENTS ON VARIOUS PENETRATION SEAL AND GASKET MATERIALS UNDER SEVERE ACCIDENT CONDITIONS WILL BE COMPLETED. IN FY 1986, EXPERIMENTS WILL BE COMPLETED ON ELECTRICAL PENETRATIONS.

4. IN FY 1987, EXPERIMENTS WILL BE COMPLETED ON LARGE PENETRATIONS (E.G., AIRLOCK, PIPE BELLOWS) TO INVESTIGATE THEIR LEAK BEHAVIOR UNDER SEVERE ACCIDENT CONDITIONS.

5. IN FY 1988, THE PROGRAM WILL BE COMPLETED WITH VALIDATION OF ANALYTICAL METHODS USING THE EXPERIMENTAL DATA AND INVESTIGATING THE BEHAVIOR OF CONTAINMENTS UNDER VERY LARGE EARTHQUAKE LOADS.

INTEGRATION:

1. EPRI IS CONDUCTING SEPARATE INVESTIGATIONS OF CONCRETE WALL ELEMENTS AND WALL-BASEMAT INTERACTIONS THAT WILL PROVIDE INPUT TO THE NRC PROGRAM. (EPRI-$2M, NRC-0)

2. EPRI WILL PROVIDE PRETEST PREDICTIONS TO EVALUATE METHODS FOR CONCRETE MODEL EXPERIMENTS. (EPRI-$200K, NRC-0)

3. UK-NII WILL PROVIDE PRETEST PREDICTIONS TO EVALUATE METHODS FOR CONCRETE MODEL EXPERIMENTS. (UK-$200K, NRC-0)

4. FRANCE-CEA WILL PROVIDE PRETEST PREDICTIONS TO EVALUATE METHODS FOR CONCRETE MODEL EXPERIMENTS. (CEA-$200K, NRC-0)

5. FRG-KFK IS CONDUCTING EXPERIMENTS ON STEEL VESSEL MATERIAL TO INVESTIGATE BIAXIAL EFFECTS AND WILL ALSO PROVIDE ANALYSIS AND INSIGHTS ON STEEL CONTAINMENT UNDER LARGE EARTHQUAKE LOADS. (KFK-$500K, NRC-0)

NRC RESEARCH EFFORT IS FOCUSED ON BEHAVIOR AND LEAKAGE OF CONTAINMENT BEYOND THE DESIGN BASIS (SEVERE ACCIDENTS). INDUSTRY EFFORT IS FOCUSED ON BEHAVIOR OF CONTAINMENTS FOR DESIGN BASIS ACCIDENTS.

REGULATORY USE:

RESULTS FROM THE SCALE MODEL CONTAINMENT AND PENETRATION EXPERIMENTS WILL PROVIDE THE BASIS FOR VALIDATING ANALYTICAL PREDICTIVE METHODS. THESE METHODS WILL BE USED BY THE NRC LICENSING STAFF TO MAKE REGULATORY DECISIONS REGARDING THE INTEGRITY AND LEAK BEHAVIOR OF CONTAINMENTS UNDER SEVERE ACCIDENT CONDITIONS. THE RESULTS FROM THIS PROGRAM WILL ALSO SUPPORT THE COMMISSION POLICYMAKING ON SEVERE ACCIDENTS.

//

CONTAINMENT INTEGRITY RESEARCH PROGRAM

| ELEMENT | RES PROGRAM CONTRACTOR/SUB-CONTRACTOR | OTHER SOURCES | RELATIONSHIP |
|---|---|---|---|
| EXPERIMENTAL EVALUATION OF OF CONTAINMENT MODELS UNDER EXTREME LOADING | SNL/UNITED ENGINEERS<br>SNL/CHICAGO BRIDGE & IRON | EPRI, FRG | COMPLEMENTARY |
| CONTAINMENT INTEGRITY UNDER EXTREME LOADING | SNL | EPRI, FRANCE, UK | JOINT |
| INTEGRITY OF CONTAINMENT PENETRATIONS UNDER SEVERE ACCIDENT LOADS | SNL/INEL | EPRI | COMPLEMENTARY |
| CONTAINMENT MARGINS TO FAILURE - CONTAINMENT BUCKLING | LANL | PVRC | COMPLEMENTARY |

134
(2)

TITLE:

SEISMIC MARGINS STUDIES

FIN;

A 0398

CONTRACTOR:

LLNL
EXPERT PANEL: R. BUDNITZ, P. AMICO, A. CORNELL, W. HALL, R. KENNEDY, J. REED, M. SHINOZUKA

BUDGET:

| FY 1985 | FY 1986 | FY 1987 |
|---|---|---|
| $650K | $600K | $1100K |

ISSUE:

NEED TO DETERMINE THE CAPABILITY OF NUCLEAR PLANTS TO WITHSTAND EARTHQUAKES LARGER THAN THE DESIGN LEVEL. ✓

OBJECTIVE:

DEVELOP THE BASES FOR EVALUATING NUCLEAR PLANT SEISMIC MARGINS.

- O ASSESS EXISTING MARGINS INFORMATION (EXPERIENCE DATA, TESTS, PRA'S)
- O DEVELOP MARGINS REVIEW PROCEDURES
- O IDENTIFY INFORMATION NEEDS

NUREG/CR-4334
An approach to the
Quantification of
Seismic Margins in
Nuclear Power Plants

Aug '85 / 4

SCOPE/ACCOMPLISHMENTS:

FY 1985

0 NRC SEISMIC DESIGN MARGINS PROGRAM PLAN EXPERIMENTS.

0 EXPERT PANEL REPORT ON "AN APPROACH TO THE QUANTIFICATION OF SEISMIC MARGINS IN NUCLEAR POWER PLANTS" (NUREG/CR-4334).

- ASSESSMENT OF EXISTING MARGINS INFORMATION
- DEVELOPMENT OF THE HCLPF CONCEPT AND SCREENING APPROACH
- OUTLINE OF REVIEW PROCEDURES

hi confidence low probability failure

0 EXPERT PANEL REPORT ON GUIDELINES FOR SEISMIC MARGINS REVIEWS. ✓

0 FY 1986

- SEISMIC MARGINS REVIEW GUIDELINES REVIEWED BY NRC WORKING GROUP AND FINALIZED AS A NUREG.
- TRIAL SEISMIC MARGINS REVIEWS OF A PWR.
- MULTILEVEL EARTHQUAKE "TARGETS". (g levels)
- EXPERT PANEL TO MONITOR TRIAL REVIEWS.

0 FY 1987

- REVIEW GUIDELINES FOR PWRS UPDATED BASED ON REVIEW EXPERIENCE AND NEW RESEARCH.
- BWR REVIEW GUIDELINES DEVELOPED.
- TRIAL SEISMIC MARGINS REVIEW(S) OF A BWR.
- PROCEDURE FOR POST-OBE EVALUATION DEVELOPED.

REGULATORY USE:

- O SEISMIC MARGINS REVIEW GUIDELINES WILL PROVIDE AN EFFICIENT AND COST EFFECTIVE WAY TO ADDRESS THE SIGNIFICANCE OF PERCEIVED CHANGES IN SEISMIC HAZARD.

- O SEISMIC MARGINS REVIEW GUIDELINES CAN BE USED TO IDENTIFY PLANT-SPECIFIC "WEAK-LINKS" AND THE NEED TO UPGRADE SEISMIC DESIGN PROCEDURES.

Costello
(4)

TITLE:

VALIDATION OF SEISMIC RESPONSE PREDICTIONS (experimental & analytical)
→ floor motion
ground spectra

FIN:

[How good the method is ... & not how to improve it.]

A 2251, B 5702, D 1603

CONTRACTOR:

ARGONNE NATIONAL LABORATORY
BROOKHAVEN NATIONAL LABORATORY
NATIONAL BUREAU OF STANDARDS

COOPERATING ORGANIZATIONS:

✓ELECTRIC POWER RESEARCH INSTITUTE
KERNFORSCHUNGSZENTRUM KARLSRUHE (FRG)
MINISTRY FOR INTERNATIONAL TRADE AND INDUSTRY (MITI) (JAPAN)

BUDGET:

| FY 1985 | FY 1986 | FY 1987 |
|---|---|---|
| $1100K | $1750K | $1900K |

ISSUE:

ANALYTICAL METHODS THAT ARE, ESSENTIALLY, LINEAR ARE USED TO PREDICT SEISMIC RESPONSE OF STRUCTURES AND COMPONENTS. THERE IS LITTLE DATA TO INDICATE HOW WELL THESE METHODS CAN BE USED TO PREDICT BEHAVIOR NEAR FAILURE. NOR IS THERE A CLEAR PICTURE OF HOW GOOD PREDICTIONS HAVE TO BE FOR SOUND DECISIONS ABOUT PLANT SAFETY.

large uncertainties in:
- hazards
- fragilities

OBJECTIVE:

OBTAIN INFORMATION THAT CAN BE USED TO DEVELOP ACCEPTANCE CRITERIA FOR PREDICTIONS OF THE BEHAVIOR OF NUCLEAR POWER PLANTS SUBJECTED TO LARGE EARTHQUAKES.

INTEGRATION:

O THE QUESTION OF ADEQUACY OF PREDICTIVE METHODS HAS A STRONG CONNECTION WITH EFFORTS TO DETERMINE SEISMIC SAFETY MARGINS.

O ONGOING NRC-SPONSORED EXPERIMENTAL PROGRAMS ON CONTAINMENTS AND OTHER CATEGORY I STRUCTURES ARE AN INTEGRAL PART OF THE VALIDATION EFFORT.

SCOPE/ACCOMPLISHMENTS:

0 FY 1985

- DEFINE SCOPE OF COLLABORATION IN HDR SEISMIC TESTS.
- LOW LEVEL EXCITATION OF EPRI MODEL IN TAIWAN.
- EXPLORATION OF INFORMATION EXCHANGE POSSIBILITIES WITH MITI.
- SCOPING CALCULATIONS FOR EXTENDING JAPANESE TESTS AT TADOTSU FACILITY INTO THE INELASTIC RANGE.

0 FY 1986

- PARTICIPATION IN LARGE SHAKER TESTS AT HDR.
- PRE-EARTHQUAKE PREDICTIONS OF RESPONSE OF EPRI MODEL. (Taiwan)
- IMPLEMENTATION OF INFORMATION EXCHANGE AGREEMENT WITH MITI.

0 FY 1987

- PARTICIPATION IN LOCAL PLASTIFICATION TESTS AT HDR.
- CONTINUATION OF INFORMATION EXCHANGE AGREEMENT WITH MITI.
- ASSESSMENT OF PREDICTIVE MODELS FOR EPRI MODEL RESPONSE. (Taiwan)

- 2 EQ. in Fukushima's plant ... real earthquakes, data forthcoming
  rocking - torsion soil struct. interaction ... not obtained.

TADOTSU - $20-25,000/day cost to operate facility.

20

REGULATORY USE:

0 ASSESSMENT OF SEISMIC MARGINS AT EXISTING PLANTS.

0 JUDGEMENT ON THE RELIABILITY OF PROBABILISTIC RISK ANALYSES FOR EARTHQUAKES.

J. O'Brien

TITLE:

COMPONENT FRAGILITY DATA ACQUISITION AND EVALUATION

FIN:

A 3278

CONTRACTOR:

BROOKHAVEN NATIONAL LABORATORY (BNL)
PROJECT MANAGER: C. H. HOFMAYER

BUDGET:

| FY 1985 | FY 1986 | FY 1987 |
| --- | --- | --- |
| $240K | $1100K | $1000K |

ISSUE:

MORE RELIABLE AND REALISTIC COMPONENT FRAGILITY INFORMATION IS NEEDED FOR SEISMIC MARGIN STUDIES AND PROBABILISTIC RISK ASSESSMENTS. IT IS NOW BELIEVED THAT PESSIMISTIC ESTIMATES OF THE SEISMIC THREAT TO NUCLEAR POWER PLANTS HAVE DEVELOPED BECAUSE OF UNDUE CONSERVATISM IN THE INPUT COMPONENT FRAGILITIES.

... all electrical components
... mechanical is very rugged.
- by Wylie Sales re EPRI.
- utilities have run shake tables for fragility tests
- these confirmed values to to used for more realistic PRA analyses.

OBJECTIVES:

FY 1985

0 TO INITIATE COOPERATION WITH DOMESTIC AND FOREIGN INSTITUTIONS TO OBTAIN ALREADY EXISTING COMPONENT FRAGILITY DATA.

0 TO ASSEMBLE, ANALYZE AND INTERPRET EXISTING COMPONENT FRAGILITY DATA AND COMPARE WITH INFORMATION CURRENTLY BEING USED.

0 TO DEVELOP A SCHEME FOR PRIORITIZING AND GROUPING COMPONENTS FOR FRAGILITY TESTING AND TO DEMONSTRATE A PROCEDURE FOR PERFORMING COMPONENT FRAGILITY TESTS WHICH WILL PROVIDE A BASIS FOR COMPREHENSIVE TESTING IN FUTURE YEARS AND USEFUL FRAGILITY DATA IN FY 1985. (LLNL OBJECTIVE UNDER A DIFFERENT FIN).

OBJECTIVES: (CONTINUED)

FY 1986 AND 1987

- O TO REDUCE BY ADDITIONAL DATA ACQUISITION AND SOME LIMITED LABORATORY TESTING THE INADEQUACIES OF THE PRESENT COMPONENT FRAGILITY DATA BASE.

- O TO IMPROVE SEISMIC PRAs AND OBTAIN BETTER ESTIMATES OF SEISMIC MARGINS BY USING MORE REALISTIC TEST BASED COMPONENT FRAGILITIES WHICH CHARACTERIZE ACTUAL FAILURE MODES.

SCOPE:

SCOPE INCLUDES ELECTRICAL AND MECHANICAL COMPONENTS AT NUCLEAR POWER PLANTS WITH EMPHASIS ON ELECTRICAL COMPONENTS SINCE THEY ARE MAJOR RISK CONTRIBUTORS ACCORDING TO PRESENT VIEWS. (MECHANICAL COMPONENTS ARE INHERENTLY RUGGED SINCE THEY MUST, IN GENERAL, BE DESIGNED FOR TEMPERATURE AND PRESSURE LOADS). ONLY ACTIVE MECHANICAL COMPONENTS TREATED, BUT BOTH ACTIVE AND PASSIVE ELECTRICAL COMPONENTS ARE CONSIDERED. PIPING IS EXCLUDED FROM THIS PROGRAM.

SCOPE: (CONTINUED)

EMPHASIS IS ON SEISMIC LOADS, BUT CONCURRENT OPERATING LOADS INCLUDED. NO OTHER SEVERE ENVIRONMENTAL OR ACCIDENT LOADS TREATED; ALSO SEVERE ENVIRONMENTAL EFFECTS EXCLUDED. AGING, SCALING AND ANCHORAGE VARIABILITY INCLUDED. NOT NECESSARILY DEVOTED TO OBTAINING FRAGILITY LEVELS; HOWEVER, TESTING OR DATA ACQUISITION MUST DEMONSTRATE THAT FRAGILITIES ARE GREATER THAN PRESENTLY ASSUMED BEFORE BEING DISCONTINUED.

ACCOMPLISHMENTS: (SINCE NOVEMBER 1984)

0 OBTAINED FRAGILITY INFORMATION FROM GE, WPPSS, BROWN-BOVERI, GOULD, SDRC, FARWELL & HENDRICKS, ANCO AND OTHER SOURCES. EVALUATION OF TEST RESULTS UNDERWAY.

0 ESTABLISHED COOPERATIVE AGREEMENT FOR INFORMATION EXCHANGE WITH EPRI. TWO-WAY INFORMATION TRANSFER IN PROGRESS.

0 HOSTED THREE DAY WORKSHOP AT BNL WHERE CRITICAL ISSUES WERE DISCUSSED AND TEST RESULTS WERE REVEALED. (SEVENTY-FIVE ATTENDEES AND TWENTY-TWO PRESENTATIONS). → NUREG DUE OUT! within week.

0 DEVELOPED PRIORITIZATION SCHEME AND IMPORTANCE CLASSIFICATION FOR COMPONENTS.

ACCOMLISHMENTS: (CONTINUED)

0 DEVELOPED STANDARDIZED COMPONENT FRAGILITY TEST PROCEDURES; EXECUTION OF TEST PROCEDURES BEGINS ON SEPTEMBER 24, 1985, FOR APPROXIMATELY TWO MONTHS USING A THREE BAY MCC LOADED WITH ELECTRICAL COMPONENTS TO BE TESTED FOR BOTH STRUCTURAL AND FUNCTIONAL FRAGILITY.

FUTURE PRODUCTS:

FY 1986

0 RECOMMENDED LIST OF COMPONENT FOR TESTING BASED ON PRIORITIZATION AND GROUPING.

0 TEST PLANS AND TEST RESULTS FOR FRAGILITY TESTS ON ELECTRICAL COMPONENTS MOUNTED IN A THREE BAY MOTOR CONTROL CENTER OF VARYING STRUCTURAL STIFFNESS AND VARYING ANCHORAGE.

0 SUMMARY OF CURRENT UNDERSTANDING OF COMPONENT FRAGILITY IN NUCLEAR POWER PLANTS.

FUTURE PRODUCTS: (CONTINUED)

FY 1987

O RECOMMENDATIONS FOR COMPONENT FRAGILITY LEVELS AND MODES OF SELECTED COMPONENTS FOR SEISMIC MARGIN AND PRA STUDIES.

REGULATORY GUIDES OR STANDARD REVIEW PLAN SECTIONS AFFECTED:

NONE; HOWEVER, COULD LEAD TO THE ESTABLISHMENT OF A COMPONENT FRAGILITY DATA BANK AT ONE OF THE NATIONAL LABORATORIES.

REGULATORY USE:

RESPONDS TO QUESTIONS RELATING TO EAST COAST SEISMICITY, PARTICULARLY THE CHARLESTON AND NEW BRUNSWICK EARTHQUAKE ISSUES. INTENDED TO PROVIDE A RATIONAL BASIS FOR DECISION SHOULD THESE ISSUES IMPOSE NEW LICENSING REQUIREMENTS ON EAST COAST OPERATORS.

Kenneally

TITLE:

SEISMIC CATEGORY I STRUCTURES PROGRAM
reinforced cat I struct. not containment

FIN;

A 7221

CONTRACTOR:

LOS ALAMOS NATIONAL LABORATORY

BUDGET:

| FY 1985 | FY 1986 | FY 1987 |
|---|---|---|
| $820K | $1200K | $1500K |

ISSUE:

ABILITY OF CURRENT LIGHT WATER REACTOR PLANTS TO ACCOMODATE LARGER EARTHQUAKES THAN THOSE CONSIDERED IN THEIR INITIAL DESIGN.

OBJECTIVE:

REDUCE UNCERTAINTIES IN METHODS USED TO PREDICT HOW THE INCREASED EARTHQUAKE LOADS ARE TRANSMITTED BY THE PLANT BUILDINGS TO THE SAFETY SYSTEMS AND COMPONENTS NEEDED TO OPERATE AND SHUTDOWN THE PLANT.

- EXPERIMENTAL DATA ON THE SENSITIVITY OF STRUCTURAL BEHAVIOR TO VARIATIONS IN CONFIGURATION AND EARTHQUAKE LOAD.

- CHANGES IN FLOOR RESPONSE SPECTRA RESULTING FROM INCREASED EARTHQUAKE LOADS.

- EXPERIMENTAL DATA TO VALIDATE COMPUTER PROGRAMS USED TO PREDICT STRUCTURAL BEHAVIOR IN THE ELASTIC AND INELASTIC RANGES.

INTEGRATION:

- 0 STRUCTURAL BEHAVIOR INFORMATION WILL BE PROVIDED TO:
  - VALIDATION OF SEISMIC CALCULATIONAL METHODS PROJECT
  - SEISMIC DESIGN MARGINS PROJECT
- 0 FLOOR RESPONSE SPECTRA INFORMATION WILL BE PROVIDED TO:
  - PIPING RELIABILITY PROJECTS
  - COMPONENT FRAGILITY PROJECT

SCOPE/ACCOMPLISHMENTS:

O PRIOR TO FY 1985

- STATIC OR SEISMIC TESTING OF 23 DIFFERENT MODELS REPRESENTING TWO TYPES OF STRUCTURES.

- MODELS BUILT TO TWO DIFFERENT SCALES (ONE INCH AND THREE INCH WALL THICKNESS).

- NUMBER OF FLOORS IN THE MODELS VARIED FROM ONE TO THREE. aux bldg - 3 floors / diesel gen Bldg - 1.2 floors

- STIFFNESS OF THE MODEL WAS LOWER THAN THE COMPUTER UNCRACKED CROSS-SECTION VALUES BY A FACTOR OF 4.

- SCALEABILITY OF RESULTS ILLUSTRATED IN THE ELASTIC AND INELASTIC RANGE, HOWEVER, ALL MODELS WERE FABRICATED USING MICROCONCRETE.

- anti-mass system to get necessary freq.

SCOPE/ACCOMPLISHMENTS (CONTINUED)

0 FY 1985

- WITH THE AID OF THE PROGRAM TECHNICAL REVIEW GROUP A MODEL WAS DESIGNED TO HELP RESOLVE THE STIFFNESS DIFFERENCE ISSUE AND PROVIDE CREDIBILITY FOR SCALE MODEL EXPERIMENTAL DATA. $f_n$ = 30 hertz seismic & static ld

- TEST TWO 1/4 SCALE MODELS OF THE TRG (technical review group) STRUCTURE. THESE MODELS WERE FABRICATED WITH MICROCONCRETE AND SIMULATED REBAR.

- START FABRICATION OF THE FIRST TRG STRUCTURE. THIS MODEL WILL BE FABRICATED WITH PROTOTYPICAL CONCRETE (4000 psi) AND REBAR. Test in Nov 85 — they'll keep us inform

SCOPE/ACCOMPLISHMENTS (CONTINUED)

0 FY 1986

- TEST TWO TRG STRUCTURES; THE FIRST ONE WILL BE SUBJECTED TO LOW LEVEL STATIC THAN INCREASED SEISMIC EXCITATION TO FAILURE (NOVEMBER 1985); THE SECOND ONE WILL BE TESTED QUASISTATICALLY TO FAILURE (MARCH 1986).

El Centro Earthquake input through shaker properly timed.

- CONTINGENCY PLANS HAVE BEEN DEVELOPED FOR SCENARIOS IDENTIFIED AS LIKELY POSSIBLE OUTCOMES OF THE TRG EXPERIMENT.

- PENDING RESOLUTION OF THE STIFFNESS AND SCALEABILITY ISSUES INITIATE A LIMITED NUMBER OF EXPERIMENTS TO MEET PROGRAM OBJECTIVES AND AID IN BENCHMARKING THE ANALYTICAL MODEL DEVELOPMENT.

- A STATISTICIAN, KNOWLEDGEABLE IN EXPERIMENT DESIGN, WILL BE USED TO INSURE THAT CONTROLLED AND UNCONTROLLED VARIABLES ARE INCORPORATED INTO A COST-EFFECTIVE TEST MATRIX TO MEET PROGRAM OBJECTIVES.

(Test to compare to analysis)

SCOPE/ACCOMPLISHMENTS (CONTINUED)

0 FY 1987

- ENHANCED ANALYTICAL EFFORT TO REDUCE THE NUMBER OF TESTS AND BENCHMARK ANALYTICAL METHODS.

- SEISMIC TESTS ON 1 FLOOR MODELS WITH 1 INCH THICK WALLS (IF FY 1986 RESULTS ALLOW) TO DETERMINE THE AFFECTS OF WALL ARRANGEMENTS AND EARTHQUAKE INPUT.

- SEISMIC TESTS ON 2 FLOOR MODELS WITH DIFFERENT WALL CONFIGURATIONS ON THE FIRST AND SECOND FLOORS (3 OR 4 INCH WALL THICKNESS). (thk. wall models very expensive)

REGULATORY USE:

- O PROVIDE EXPERIMENTAL DATA AND ANALYTICAL METHODS TO DETERMINE THE BEHAVIOR OF REINFORCED CONCRETE BUILDINGS SUBJECTED TO EARTHQUAKES LARGER THAN THE DESIGN BASIS.
- O RECOMMEND IMPROVEMENTS AND REDUCE UNCERTAINTIES IN REGULATORY GUIDES (E.G., 1.61, 1.122) AND STANDARD REVIEW PLANS (E.G., SECTIONS 3.7, 3.8, 3.9 AND 3.10).
- O ESTABLISH NEW REGULATORY CRITERIA CONSIDERING NONLINEAR RESPONSE EFFECTS.
- O WHEN COUPLED WITH COMPONENT AND PIPING RESEARCH HELP DETERMINE SEISMIC DESIGN MARGINS IN OPERATING PLANTS.

TITLE:

RELIABILITY ANALYSIS OF NONLINEAR BEHAVIOR OF CONCRETE STRUCTURES

FIN;

A 3292

CONTRACTOR:

BROOKHAVEN NATIONAL LABORATORY

BUDGET:

struct. ld Combination → Reliability analysis .. nonlinear .. concrete struct. | Beyond design load.

- higher loads, principally seismic

| FY 1985 | FY 1986 | FY 1987 |
|---|---|---|
| $0 K | $200K | $400K |

BNL: wrap-up report in preparation (linear)

OBJECTIVES:

- O DEVELOP STOCHASTIC, PROBABILISTIC, NONLINEAR ANALYSIS METHOD FOR MORE RIGOROUS STRUCTURAL CAPACITY ESTIMATES FOR USE IN PROBABILISTIC RELIABILITY ANALYSES AND STRUCTURAL SEISMIC MARGIN STUDIES.

- O DEFINE WHEN APPROPRIATE TO USE THIS NONLINEAR METHOD OR SIMPLIFIED METHOD BY SAMPLE PROBLEM COMPARISONS.

- O VERIFY THE APPROXIMATE NONLINEAR LIMIT STATES DEVELOPED FOR CONCRETE STRUCTURES UNDER FIN A3802, "FRAGILITIES OF CONCRETE STRUCTURES".

SCOPE: FY '86

TASK 1. DEVELOP STOCHASTIC, PROBABILISTIC, NONLINEAR STRUCTURAL ANALYSIS METHODS FOR CATEGORY I STRUCTURES. DEVELOP A STOCHASTIC EQUIVALENT LINEARIZATION METHOD IDEALIZED IN TERMS OF STICK MODELS. COMPARE RESULTS OBTAINED WITH RESULTS FROM MONTE-CARLO SIMULATION TECHNIQUES.

TASK 2. VERIFY ANALYTICAL RESULTS BY INITIATING PSEUDODYNAMIC TESTS ON STICK MODELS OF IDEALIZED STRUCTURES. REPRODUCE NONLINEAR DYNAMIC BEHAVIOR UNDER SEISMIC LOADING ON A DECELERATED TIME SCALE, AND ESTABLISH A RELATIONSHIP BETWEEN THE MAXIMUM NONLINEAR RESPONSE AND PEAK GROUND ACCELERATION.

TASK 3. INITIATE EXTENSION OF THE RELIABILITY ANALYSIS METHOD TO INCLUDE NONLINEAR STRUCTURAL RESPONSE.

varying random variation

TASK 4. COMPLETE REPORT ON STOCHASTIC EQUIVALENT LINEARIZATION TECHNIQUE FOR CATEGORY I STRUCTURES.

nonlinear behavior into a more manageable technique, an approx.

'87 about same as '86
except complete program.

--- containment performance criteria (in ACRS letter)

ACRS
--- staff wants (w/BNL) to review program with us.

--- is Ellingwood still involved? don't know
... if not involved get as ACRS consultant!

REGULATORY USE:

- O DEVELOP MORE RIGOROUS STRUCTURAL FRAGILITY ESTIMATES FOR USE IN PRAs AND SEISMIC MARGIN STUDIES.
- O EVALUATION OF EXISTING STRUCTURAL CAPACITIES AND PRAs FOR OPERATING REACTORS.
- O EXTEND BNL-DEVELOPED PROBABILITY-BASED LOAD COMBINATION METHODOLOGY TO INCLUDE NONLINEAR BEHAVIOR.

Cvr

TITLE:

STRUCTURAL DEGRADATION

FIN;

TO BE ASSIGNED

CONTRACTOR:

TO BE SELECTED

BUDGET:

| FY 1985 | FY 1986 | FY 1987 |
| --- | --- | --- |
| $0 K | $0 K | $300K |

proposal for 1987

not hi priority item yet!

OBJECTIVE:

PREPARE NRC STAFF TO BE ABLE TO IDENTIFY:

- O STRUCTURAL ADEQUACY UNDER EXTENSIONS OF PLANT DESIGN LIFE.
- O POST-LOCA ENVIRONMENTAL EFFECTS ON STRUCTURAL RELIABILITY.
- O HOW TO ADJUST STRUCTURAL CAPACITIES AFFECTED BY DEGRADATION WHEN PERFORMING SEVERE ACCIDENT ANALYSES.
- O WHAT SECONDARY EFFECTS RESULT FROM DETERIORATION OF MATERIALS UNDER OPERATING OR POST-LOCA CONDITIONS.

SCOPE:

- O BEGIN INVESTIGATIONS INTO LONG-TERM CHEMICAL REACTIVITY BETWEEN SPECIFIC TYPES OF CONCRETE AGGREGATES, ADDITIVES (SUCH AS FLYASH), AND CEMENTS OF DIFFERENT ALKALINITIES.
- O MORE ADVANCED UNDERSTANDING OF HOW DIFFERENT CONCRETES BEHAVE UNDER LONG-TERM CONDITIONS OF LOCALLY HOT (150°F - 300°F) TEMPERATURES SUCH AS THOSE AT PENETRATIONS.

- EXAMINE AND DEFINE UNIQUE ENVIRONMENTAL CONDITIONS THAT EXIST POST-LOCA IN THE CONTAINMENT AND THEIR EFFECTS ON STRUCTURAL MATERIALS OF UNFORESEEN STRESS OR CORROSION EFFECTS, AT A TIME WHEN FUNCTIONAL RELIABILITY IS ESSENTIAL BUT ACCESS FOR INSPECTION AND MAINTENANCE IS NOT PRACTICAL.

REGULATORY USES:

- IMPROVED PREDICTIONS OF LONG TERM MATERIAL DETERIORATION
- LIMITS ON HOSTILE OPERATING ENVIRONMENTAL EXPOSURES
- REDUCTION OF LICENSING RELIANCE PURELY ON INSPECTION AND SURVEILLANCE
- IMPROVEMENTS IN DAMAGE INSPECTION AND INCORPORATION INTO SRP-REFERENCED NATIONAL DESIGN STANDARDS

WILL ENABLE NRC STAFF TO:

- BETTER ACCEPT MATERIAL SELECTIONS
- REQUIRE APPROPRIATE DESIGN PROVISIONS
- PERMIT CONTINUED OPERATION NEAR, AT, OR BEYOND 40-YR DESIGN LIFE

- O DETERMINE POST-LOCA CONTAINMENT ENVIRONMENT (THERMAL, RADIATION, CHEMICAL) SHORT AND LONG TERM IMPACTS ON STRUCTURAL MATERIALS

- O ASK LICENSEES THE RIGHT QUESTIONS WHEN REVIEWING REQUESTS FOR EXTENSIONS OF PLANT DESIGN LIFE

<u>EXAMPLES</u>:

- O MICRO/SHRINKAGE CRACKING STIFFNESS DEGRADATION IN LANL SHEAR WALL TESTS

- O USE AT SEABROOK OF AGGREGATE SHOWING ALKALI-SILICA REACTION AT PEASE AFB RUNWAY

- O CHEMICAL REACTIVITY IN ONTARIO-HYDRO CONTAINMENT BLDG

- O TENDON FAILURES IN ORNL MODEL PCRV, PERHAPS DUE TO THERMAL DECOMPOSITION OF TENDON GREASE

- O W. R. GRACE & CO. EVIDENCE THAT HALOGENS, ESP. PVC, DECOMPOSE LINEARLY VS. AT SOME THRESHOLD LEVEL OF ENERGY INPUT

- O LONG TMI-2 CONTAINMENT INACCESSIBILITY, W/MOISTURE, RADIATION, BORON, $H_2$ BURN EFFECTS ON RELIABILITY
- O WOLSUNG 1 (KOREA) CONCRETE BASEMAT SWELLING, DUE TO ALKALINE CEMENT REACTION W/VOLCANIC AGGREGATE
- O DEGRADATION OF SONGS-1 EQUIPMENT SUPPORTS DUE TO PLANT ENVIRONMENT
- O 9 MILE PT.-1 REACTOR BLDG WALL CRACK, POSSIBLY DUE TO THERMAL GRADIENT

CTS: not a very fruitful endeavor ... lots of info on concrete degradation. (or narrow the questions)

JRichardson: Program to develop important questions to ask for licensing, in order to extend plant licensing.

MB: need a mail list

Herman Graves

TITLE:

STANDARD PROBLEMS FOR STRUCTURAL COMPUTER CODES

FIN:

A 3242

CONTRACTOR:

BROOKHAVEN NATIONAL LABORATORY (BNL)

BUDGET:

| FY 1985 | FY 1986 | FY 1987 |
|---|---|---|
| $300K | $200K | $200K |

ISSUE:

VARIOUS ANALYTICAL APPROACHES WITH DIFFERENT DEGREES OF APPROXIMATION HAVE BEEN DEVELOPED AND USED TO DETERMINE STRUCTURAL RESPONSE AND SOIL-STRUCTURE INTERACTION OF NUCLEAR STRUCTURES TO SEISMIC AND DYNAMIC LOADS. APPROXIMATIONS USED MAY OR MAY NOT REPRESENT THE PHYSICAL BEHAVIOR OF THE STRUCTURE, THUS, THERE IS A NEED TO ESTABLISH BENCHMARKS SOLUTIONS TO DETERMINE THE VALIDITY AND ACCURACY OF ANALYTICAL METHODS PRESENTLY USED.

OBJECTIVE:

TO ESTABLISH PROBLEMS WITH EXPERIMENTALLY KNOWN SOLUTIONS (BENCHMARKS) FOR USE BY THE LICENSING STAFF TO VALIDATE MAJOR PARTS OF LICENSEE METHODS USED TO CALCULATE STRUCTURAL RESPONSE AND SSI OF SAFETY-RELATED BUILDINGS, SYSTEMS AND COMPONENTS.

INTEGRATION:

- 0 THE FINDINGS OF THIS PROGRAM CAN BE USED IN EFFORTS TO DETERMINE SEISMIC SAFETY MARGINS.
- 0 EXPERIMENTAL RESULTS FROM VARIOUS STUDIES CURRENTLY BEING PERFORMED FOR THE NRC AT SNL (CONTAINMENTS), WCC (E.Q. CHARACTERIZATION) AND LANL CATEGORY I STRUCTURES) WILL COMPLEMENT THIS PROGRAM. ALSO WORK FUNDED BY EPRI (SIMQUAKE) HAS BEEN USED.
- 0 DATA HAS ALSO BEEN OBTAINED THROUGH COOPERATIVE AGREEMENTS (FUKUSHIMA)

SCOPE/ACCOMPLISHMENTS:

0 FY 1985

- WORK WAS CONCENTRATED IN THE SSI AREA; SPECIFICALLY, WITH DETERMINING THE EFFECTS OF FOUNDATION LIFTOFF, HIGH GROUND WATER TABLE, AND SOIL LAYERING ON SSI ANALYTICAL METHODS.

0 FY 1986

at the waterford nucl. Plant

- COMPLETE FY 85 EFFORTS (WATER TABLE)
- INITIATION OF A STRUCTURAL DATA SURVEY AND EVALUATION OF DATA
  bldg response - reinforce concrete struct.
- WORKSHOP ON SSI.
  ps notify the ACRS.

0 FY 1987

- DEVELOP SSI BENCHMARK PROBLEMS — shear wall type struct
- DEVELOP STRUCTURAL (CONCRETE) BENCHMARK PROBLEMS
- EVALUATE AVAILABLE NEW DATA WITH THE AIM OF IMPROVING BENCHMARKS

CPS- was Humboltd by data used ... not enough instrumentation

- to find out how good your codes are.

REGULATORY USE:

Struct. Geotech. Eng Branch

0 PRELIMINARY FINDINGS HAVE BEEN USED BY BNL TO HELP NRR (SGEB) RESOLVE SSI ISSUES ON BYRON, BEAVER VALLEY 2, AND DIABLO CANYON NUCLEAR PLANTS.

0 BENCHMARKS WILL BE USED TO ASSESS THE ACCURACY OF LICENSEE METHODS USED TO PREDICT THE BEHAVIOR OF SAFETY RELATED STRUCTURES UNDER SEISMIC LOADS.

develope new analytical methods.

0 BENCHMARKS AND OTHER DATA DEVELOPED WILL BE USED TO [EVALUATE/REVISE AND WHERE NECESSARY ESTABLISH NEW SEISMIC DESIGN CRITERIA (I.E., SRP, REG. GUIDES).]

<u>REPORTS</u>:

S. SHARMA, M. REICH, AND TY CHANG, BROOKHAVEN NATIONAL LABORATORY, "REVIEW OF CURRENT ANALYSIS METHODOLOGY FOR REINFORCED CONCRETE STRUCTURAL EVALUATIONS," USNRC REPORT NUREG/CR-3284, APRIL 1983.

C. A. MILLR, C. J. COSTANTINO, A. J. PHILIPPACOPOULOS, AND M. REICH, BROOKHAVEN NATIONAL LABORATORY," VERIFICATION OF SOIL-STRUCTURE INTERACTION METHODS," USNRC REPORT NUREG/CR-4128, MAY 1985.

50

NUREG -1061 vol 2 & 4 ] Based on IRC reports

TITLE: [12 ticket items

NRC/EPRI PROGRAMS ON PIPING DYNAMIC LOAD CAPACITY

- 0 EPRI/NRC COOPERATIVE PROGRAM "PIPING AND FITTING DYNAMIC RELIABILITY" (FIN D1157) ← main effort. [elbows & systems.]
- 0 ETEC DEMONSTRATION SEISMIC FRAGILITY PIPE TEST (FIN B3052)
- next yr & '87 [ 0 INDEPENDENT ASSESSMENT OF PROPOSED ASME PIPING RULE CHANGES ... eg. 9
- 0 INTEGRATION WITH NRC DEGRADED PIPING PROGRAM
- 0 PIPING FRAGILITY REDEFINITION FOR PRA USE

CONTRACTOR:

GE (THROUGH EPRI), ETEC, ANCO, OTHERS

MSEB BUDGET:

| FY 1985 | FY 1986 | FY 1987 |
|---|---|---|
| $200K | $700K | $900K |

$800K NRC — EPRI adding $2×10^6

Cons.
Cloud
Kennedy
Bosnak
Jantes

Expert panel recommendations

design & construction

51

ISSUES:

- O ASME CODE DESIGN RULES FOR PIPING OF UNDER DYNAMIC LOADS MAY HAVE AN UNREALISTIC (OVERALLY CONSERVATIVE) BASIS. ... e.g. 9
- O PRA PIPING FRAGILITY ESTIMATES NEED VALIDATION.

OBJECTIVES:

- O EXPERIMENTALLY DETERMINE DYNAMIC FAILURE LEVELS AND MECHANISMS (FATIGUE/RATCHETTING, OR COLLAPSE) FOR PIPING SYSTEMS AND COMPONENTS. L cycles
- O DEVELOP NEW DESIGN RULES FOR ASME CLASS 1, 2, AND 3 PIPING.
- O ASSESS THE IMPACT OF THESE PROPOSED CHANGES.
- O IMPROVE PRA PIPING FRAGILITY ESTIMATES.
- O BENCHMARK NONLINEAR BEHAVIOR IN THE PIPE FAILURE RANGE.

why dynamic test: pipe nonlinear response (and effects), not mat'l changes due to strain rate effects.

SCOPE/ACCOMPLISHMENTS:

0 FY 1985

- NRC/EPRI COOPERATIVE AGREEMENT ESTABLISHED
- PROGRAM PLANNING COMPLETED
- ANCO COMPONENT TESTS INITIATED (FIRST 12 OF 40 TESTS)
- ETEC DEMONSTRATION TEST INITIATED

0 FY 1986

- COMPONENT TESTING CONTINUES
- SEISMIC PIPING SYSTEMS TESTS (SEISMIC) ... also waterhammer
- FATIGUE/RATCHETTING SPECIMEN TESTS

0 FY 1987

- COMPONENT TESTS COMPLETED
- HYDRODYNAMIC LOAD & WATERHAMMER PIPING SYSTEMS TESTS
- FATIGUE/RATCHETTING TESTS COMPLETED
- DEVELOPMENT OF PROPOSED CODE CHANGES
- ASSESSMENT OF THESE CODE CHANGES
- RESULTS OF TESTS INTEGRATED WITH RESULTS OF THE DEGRADED PIPING PROGRAM
- PRA FRAGILITY MODELS VALIDATED/IMPROVED

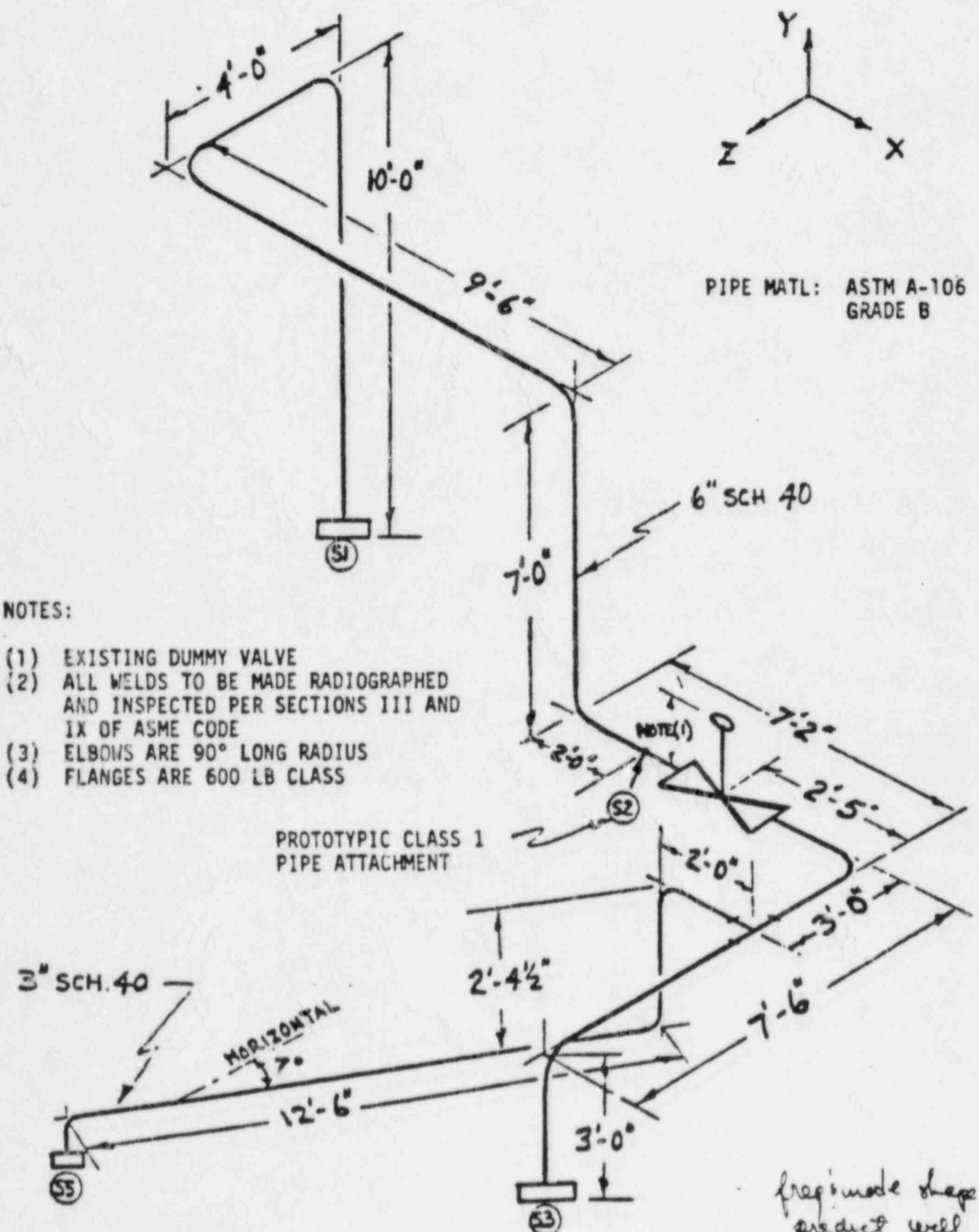
REGULATORY USE:

- O PROVIDES THE BASES TO ENDORSE CHANGES TO ASME CODE RULES (SECTION III, SUBSECTIONS NB/NC/ND 3600).
- O PROVIDE FURTHER JUSTIFICATION FOR SNUBBER MINIMIZATION.
- O ESTABLISH PIPING FAILURE MECHANISMS AND MARGINS.

- code predicts we fails by collapse
- should fail by fatigue/racheting instead. ] justify dynamic tests ... CBS questions why not static tests.

if it true we change rule in code.

# TEST ARTICLE PIPING SYSTEM




PIPE MATL: ASTM A-106
GRADE B

NOTES:

(1) EXISTING DUMMY VALVE
(2) ALL WELDS TO BE MADE RADIOGRAPHED AND INSPECTED PER SECTIONS III AND IX OF ASME CODE
(3) ELBOWS ARE 90° LONG RADIUS
(4) FLANGES ARE 600 LB CLASS

- freq. mode shape can predict well
- amplitude a deflect is difficult to analyze

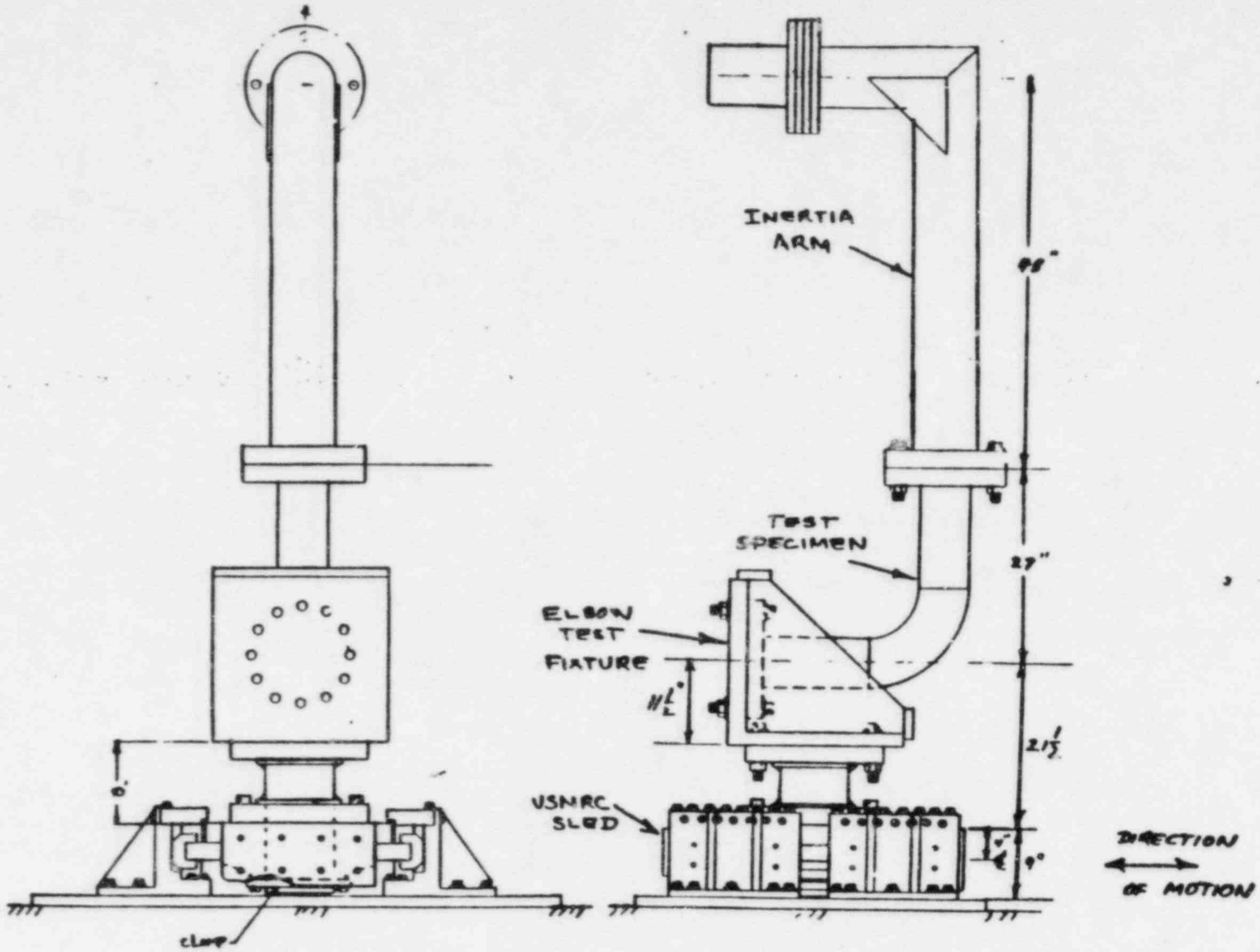



Figure 3.1: Elbow Test Setup

57

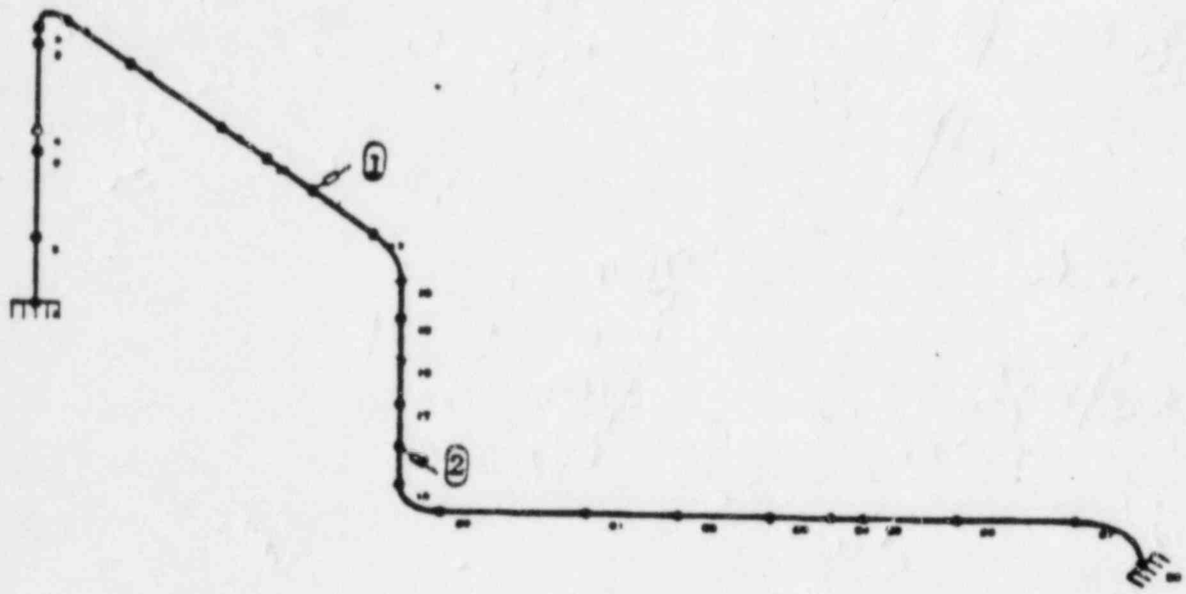
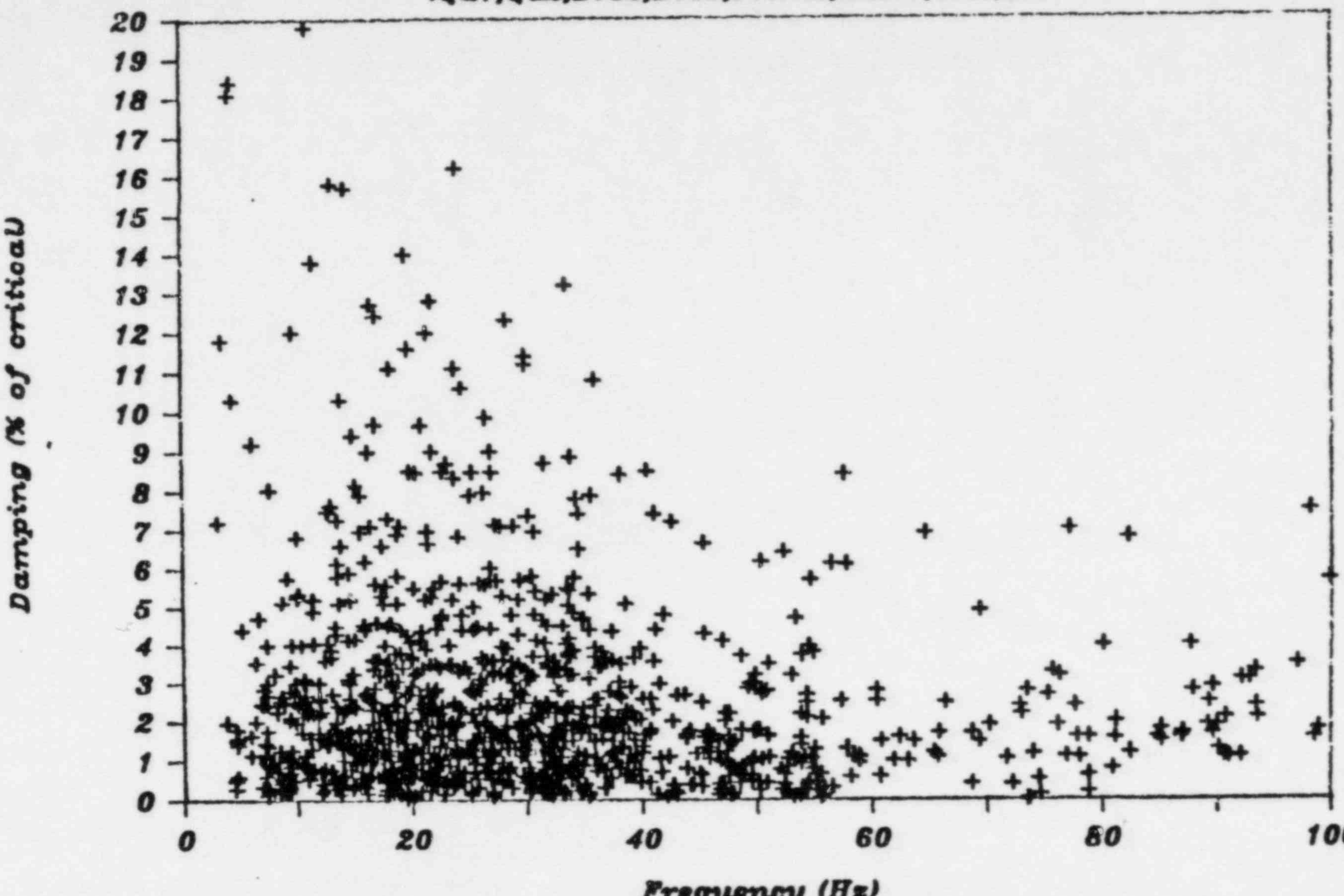



Figure 1. Typical 5-in. pipe arrangement.

| | 5-in. System (Fig. 1) | 3-in. System (Fig. 2) |
|---|---|---|
| End supports only | no supports | no supports |
| Hydraulic snubber | 1 | |
| Mechanical snubber | 1 | 1 |
| Rigid strut | 1 | 2 |
| Combination strut and snubber | 1,2 | 1,2 |
| Strut combination | 1,2 | |

# Listed Reactors

(Qd1,Qd2,Drs2,Drs3,Frmi2,Zmr1,Kuo,Lsl1)




July

58

low level hammer

TITLE:

OTHER NRC PIPING RESEARCH (low priority items except nozzle.)

- NOZZLE DESIGN GUIDANCE (ORNL FIN B0474)
- COMBINATIONAL PROCEDURES FOR PIPING RESPONSE SPECTRA ANALYSIS (BNL FIN A3287)
- NONLINEAR PIPING RESPONSE PREDICTIONS (HEDL FIN D1611)
- ASSESSMENT AND IMPROVEMENT OF SPECTRUM-BROADENING PROCEDURES (LLNL FIN A0453)
- TIME HISTORY PIPE DAMPING (UNDESIGNATED)
- ADDITIONAL STUDIES OF COMBINED EFFECTS (UNDESIGNATED) → · PVRC + independent support point motion
  · loss of conservatism

BUDGET:

| FY 1985 | FY 1986 | FY 1987 |
|---|---|---|
| $333K | $375K | $600K |

ISSUES:

0 NEED TO IMPROVE PIPING RESPONSE PREDICTION TECHNIQUES, AS ITEMIZED IN NUREG 1061 (PIPING REVIEW COMMITTEE RECOMMENDATIONS)

0 NEED TO ADDRESS COMBINED EFFECTS OF PRC RECOMMENDATIONS ON PIPING DESIGN

- ISM METHOD IN COMBINATION WITH PVRC DAMPING
- RECLASSIFICATION OF SEISMIC STRESSES
- SUPPORT DESIGN

SCOPE/ACCOMPLISHMENTS:

0 FY 1985 AND 1986

0 IMPROVE NOZZLE DESIGN GUIDANCE

0 EVALUATE ISM METHOD IN COMBINATION WITH PVRC DAMPING

0 IMPROVE MODEL COMBINATION METHODS

- ISM WITH KNOWN PHASE CORRELATION
- CLOSELY SPACED MODES
- HIGH FREQUENCY MODES

- 0 EVALUATION (AND VALIDATION) OF SIMPLE NONLINEAR RESPONSE PREDICTION TECHNIQUES
- 0 EVALUATION OF APPROPRIATENESS OF R.G. ±1.122 PEAK BROADENING RANGE
- 0 DEVELOPMENT OF BASES FOR "FLATTENED AND BROADENED" SPECTRA
- 0 RECOMMENDATIONS FOR DAMPING VALUES TO BE USED IN TIME-HISTORY ANALYSIS
- 0 FY 1987
- 0 INVESTIGATION OF COMBINED EFFECTS OF NEW PIPING DESIGN CRITERIA
  - DAMPING
  - NEW ASME DESIGN RULES
  - NEW NOZZLE DESIGN CRITERIA
  - PIPING SUPPORT DESIGN RULES

TITLE:

PARAMETERS INFLUENCING DAMPING IN PIPING SYSTEMS (cont. of INEL program)

FIN:

A 6316

CONTRACTOR:

INEL

BUDGET:

| FY 1985 | FY 1986 | FY 1987 |
|---|---|---|
| $230K | $200K | $0 K |

ISSUES:

- 0 OVERALLY STIFF PIPING DESIGNS HAVE RESULTED FROM USE OF R.G. 1.61 DAMPING VALUES.
- 0 DATA AND GUIDANCE IS LACKING FOR HIGH FREQUENCY MODAL RESPONSE CAUSED BY NONSEISMIC LOADS.

OBJECTIVES:

- 0 COMPILE AND EVALUATE EXISTING DAMPING DATA
- 0 TEST SIMPLE SYSTEMS, VARYING RESPONSE AND DESIGN PARAMETERS

SCOPE/ACCOMPLISHMENTS:

- 0 FY 1985
- 0 ESTABLISHED WORLD DATA BASE ON PIPE DAMPING

- 0 TESTING OF 3-DIMENSIONAL SYSTEM
  - LOW STRAIN AMPLITUDES
  - DIFFERENT SUPPORT CONFIGURATIONS
  - PRESSURIZED AND UNPRESSURIZED
  - DIFFERENT FORCING FUNCTIONS
- 0 REVIEW OF EXISTING HIGH FREQUENCY DAMPING DATA
- 0 FY 1986
- 0 CONTINUED TESTING OF 3-DIMENSIONAL SYSTEM
  - HIGH FREQUENCY LOADS
  - INSULATION
  - HIGH STRAIN SEISMIC LOADS
- 0 TESTING OF 1-DIMENSIONAL SYSTEM AT HIGH FREQUENCY
- 0 FINAL REPORT

PVRC and N-411

[illegible] only

REGULATORY USE:

0 PROVIDE BASIS FOR ENDORSING ASME CODE CASE N-411 ) 0-33 hz range

0 PROVIDE BASIS FOR REVISING R.G. 1.61 AND SRP

## CONTAINMENT INTEGRITY PROGRAM ACTIVITIES

### FIN A-1401 ANALYSIS AND EVALUATION

- PLANNING OF EXPERIMENTS
- PRETEST PREDICTIONS
- POST TEST EVALUATIONS
- DEVELOPMENT OF PREDICTIVE METHODS
- INTERACTION WITH PEER REVIEW PANEL

### FIN A-1375 PENETRATION TESTS

- PROCUREMENT OF SPECIMENS
- DETAILED DESIGN OF TEST FIXTURES AND INSTRUMENTATION
- CONDUCT OF EXPERIMENTS
- COMPILATION OF TEST REPORTS

### FIN A-1249 LARGE MODEL TESTS

- DESIGN AND CONSTRUCTION OF MODELS
- INSTALLATION OF INSTRUMENTATION
- EXPERIMENTAL PLAN AND SAFETY ANALYSES
- CONDUCT OF EXPERIMENTS
- COMPILATION OF TEST REPORTS

TITLE:

CONTAINMENT INTEGRITY UNDER EXTREME LOADS

FIN;

A 1401

CONTRACTOR:

SANDIA NATIONAL LABORATORY

COOPERATING ORGANIZATIONS

KERNFORSCHUNGSZENTRUM KARLSRUHE (FRG)
ELECTRIC POWER RESEARCH INSTITUTE (EPRI)
COMMISARIAT A L'ENERGIE ATOMIQUE (FRANCE)
NUCLEAR INSTALLATIONS INSPECTORATE (UK)

BUDGET:

| FY 1985 | FY 1986 | FY 1987 |
|---|---|---|
| \$740K | \$600K | \$700K |

ISSUE:

THE CONSEQUENCES OF A SEVERE ACCIDENT WOULD BE SIGNIFICANTLY AFFECTED BY THE PERFORMANCE OF THE CONTAINMENT. ANALYTICAL PREDICTIONS OF CONTAINMENT FAILURE MODES REQUIRE EXPERIMENTAL VALIDATION.

OBJECTIVE:

DEVELOP A METHODOLOGY THAT CAN BE USED TO PREDICT THE PERFORMANCE OF CONTAINMENT BUILDINGS DURING SEVERE ACCIDENTS.

INTEGRATION:

- LARGE MODEL TESTS PERFORMED UNDER FIN A1249 PROVIDE THE DATA FOR BENCHMARKING ANALYTICAL PREDICTIONS OF STRUCTURAL DEFORMATIONS.

- PENETRATION TESTS PERFORMED UNDER FIN A1375 PROVIDE DATA FOR ANALYTICAL PREDICTIONS OF LEAKAGE.

SCOPE/ACCOMPLISHMENTS:

0 PRIOR TO FY 1985

- PRE TEST PREDICTIONS AND POST TEST ANALYSES FOR SMALL STEEL MODEL SERIES.

0 FY 1985

- POST TEST ANALYSIS OF LARGE STEEL MODEL TEST.
- PRE TEST PREDICTIONS FOR CONCRETE MODEL TEST.

0 FY 1986

- DEVELOP A BASIS FOR EXTENDING CONCRETE MODEL TEST INSIGHTS TO PRESTRESSED CONTAINMENTS.
- DETERMINE EXPERIMENTS NECESSARY TO VERIFY PREDICTIONS OF PERFORMANCE UNDER SEISMIC LOADS.

0 FY 1987

- POST TEST ANALYSES FOR CONCRETE MODEL.
- PRE TEST PREDICTIONS FOR SEISMIC EXPERIMENTS.
- DEVELOPMENT OF A LEAKAGE METHODOLOGY BASED ON PENETRATION EXPERIMENTS.

REGULATORY USE:

0 CONFIRMATORY ASSESSMENT OF SEVERE ACCIDENT POLICY STATEMENT.

0 BASIS FOR POSSIBLE ADDITION OF CONTAINMENT PERFORMANCE REQURIEMENT FOR SAFETY GOAL IMPLEMENTATION.

TITLE:

INTEGRITY OF CONTAINMENT PENETRATIONS UNDER SEVERE ACCIDENT CONDITIONS

FIN;

A 1375

CONTRACTOR:

SANDIA NATIONAL LABORATORY

BUDGET:

| FY 1985 | FY 1986 | FY 1987 |
|---|---|---|
| $900K | $900K | $600K |

ISSUE:

THE CONSEQUENCES OF A SEVERE ACCIDENT WOULD BE SIGNIFICANTLY AFFECTED BY THE PERFORMANCE OF THE CONTAINMENT. ANALYTICAL PREDICTIONS OF CONTAINMENT FAILURE MODES REQUIRE EXPERIMENTAL VALIDATION.

OBJECTIVE:

DETERMINE THE MAJOR CHARACTERISTICS OF OPERABLE AND FIXED CONTAINMENT PENETRATIONS THAT COULD CONTRIBUTE TO LEAKAGE DURING SEVERE ACCIDENTS. THE EFFECT OF PRESSURE, TEMPERATURE AND DEFORMATION MUST BE STUDIED.

INTEGRATION:

- THE PREDICTIVE METHODS TO BE DEVELOPED UNDER FIN A1401 WILL RELY IN LARGE MEASURE ON THE PENETRATION EXPERIMENTS.
- TESTS OF LARGE DIAMETER PENETRATIONS UNDER PRESSURE LOADING ARE INTEGRATED INTO THE LARGE MODEL TESTS PERFORMED UNDER FIN A1249.

SCOPE/ACCOMPLISHMENTS:

0 PRIOR TO FY 1985

- SURVEY OF PENETRATION TYPES, GEOMETRIES, AND MATERIALS TO IDENTIFY MOST LIKELY CANDIDATES FOR LEAKAGE TESTS.
- DESIGN OF TEST MATRIX FOR SEAL AND GASKET GEOMETRIES AND MATERIALS.

0 FY 1985

- INITIATION OF SEAL AND GASKET TESTS.
- PROCUREMENT OF A FULL SCALE AIR LOCK AND SELECTION OF A TEST FACILITY.
- DESIGN DETAILS COMPLETED FOR AIR LOCK AND EQUIPMENT HATCHES IN CONCRETE MODEL.

0 FY 1986

- COMPLETTION OF SEAL AND GASKET TESTS.
- COMPLETION OF AIR LOCK TEST.
- PROCUREMENT OF BELLOWS AND DEVELOPEMENT OF TEST PLAN.

O FY 1987

- EVALUATION OF AIR LOCK TEST.
- PERFORMANCE OF BELLOWS TEST.

REGULATORY USE:

O CONFIRMATORY ASSESSMENT OF SEVERE ACCIDENT POLICY STATEMENT.

O BASIS FOR POSSIBLE ADDITION OF CONTAINMENT PERFORMANCE REQURIEMENT FOR SAFETY GOAL IMPLEMENTATION.

TITLE:

EXPERIMENTS ON CONTAINMENT MODELS UNDER EXTREME LOADING CONDITIONS

FIN;

A 1249

CONTRACTOR:

SANDIA NATIONAL LABORATORY

BUDGET:

| FY 1985 | FY 1986 | FY 1987 |
|---|---|---|
| $2060 | $2000K | $2400K |

ISSUE:

THE CONSEQUENCES OF A SEVERE ACCIDENT WOULD BE SIGNIFICANTLY AFFECTED BY THE PERFORMANCE OF THE CONTAINMENT. ANALYTICAL PREDICTIONS OF CONTAINMENT FAILURE MODES REQUIRE EXPERIMENTAL VALIDATION.

OBJECTIVE:

PERFORM EXPERIMENTS ON CONTAINMENT MODELS THAT WILL PRODUCE FAILURE DATA UNDER EXTREME LOADING CONDITIONS AND PERMIT AN EVALUATION OF THE CAPABILITY OF STATE-OF-THE-ART CALCULATIONAL METHODS TO PREDICT CONTAINMENT FAILURE UNDER SEVERE ACCIDENT CONDITIONS.

INTEGRATION:

- O THE MODEL EXPERIMENTS ARE COORDINATED WITH THE ANALYTICAL PREDICTION EFFORT PERFORMED UNDER FIN A1401.
- O THE LARGE DIAMETER PENETRATIONS INCLUDED IN THE MODELS PROVIDE DEFORMATION DATA USED IN THE PENETRATION EXPERIMENTS PERFORMED UNDER FIN A1375.

SCOPE/ACCOMPLISHMENTS:

0 PRIOR TO FY 1985

- DEVELOPMENT OF A REMOTE TESTING FACILITY FOR HIGH PRESSURE EXPERIMENTS.
- TESTS TO FAILURE OF A SERIES OF THREE SMALL STEEL MODELS TO VERIFY THE ABILITY OF LARGE DEFORMATION COMPUTER CODES TO MODEL STIFFENER BEHAVIOR AND BEHAVIOR AT PENETRATION DISCONTIUITIES.
- DESIGN, CONSTRUCTION, AND INSTRUMENTATION OF A LARGE STEEL MODEL.

0 FY 1985

- COMPLETED TESTING TO FAILURE OF A LARGE STEEL MODEL.
- COMPLETED DESIGN AND STARTED CONSTRUCTION OF CONCRETE MODEL.

0 FY 1986

- COMPLETE CONSTRUCTION AND INSTRUMENTATION OF CONCRETE MODEL AND INITIATE TESTING.

0 FY 1987

- COMPLETE TESTING TO FAILURE OF CONCRETE MODEL
- PERFORM ANY NECESSARY SUPPLEMENTARY TESTS
- INITIATE EXPERIMENTS ON SEISMIC PERFORMANCE

REGULATORY USE:

- O CONFIRMATORY ASSESSMENT OF SEVERE ACCIDENT POLICY STATEMENT.
- O BASIS FOR POSSIBLE ADDITION OF CONTAINMENT PERFORMANCE REQURIEMENT FOR SAFETY GOAL IMPLEMENTATION.

# POST–TEST ANALYSIS OF FAILURE

The failure mechanism and capacity of the model were not predicted correctly. Metallurgical investigations showed that the failure was ductile, and no degradation or defects in the materials or welds were detected.

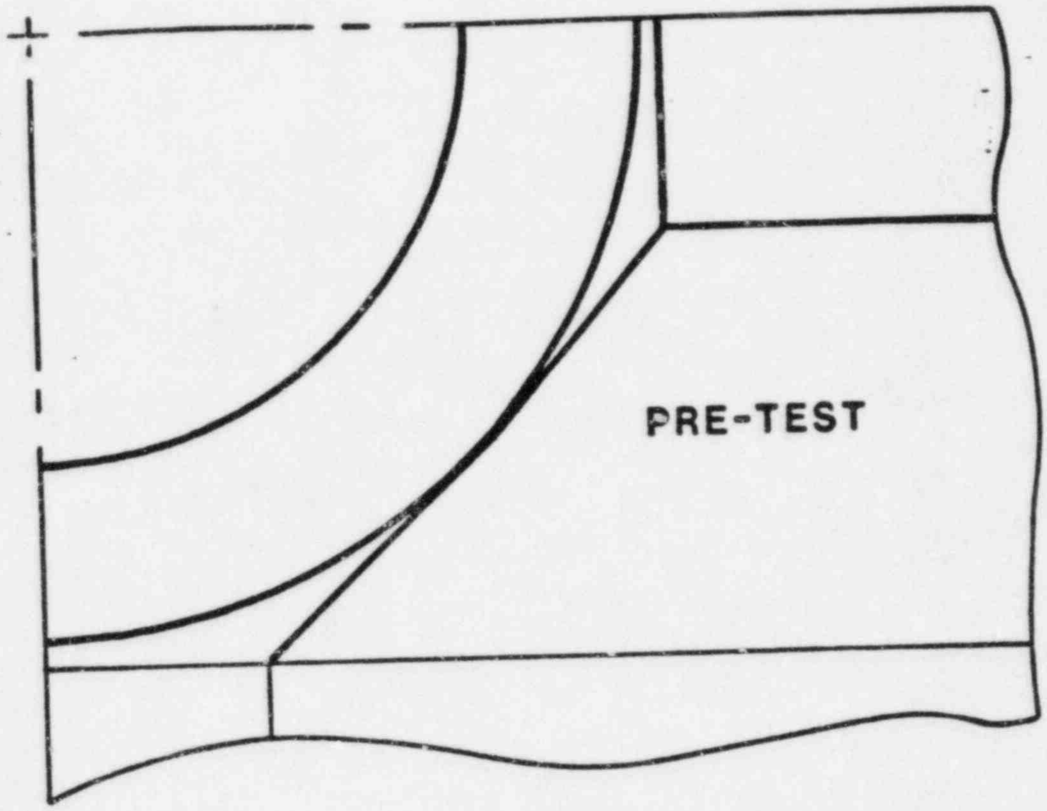
A crack in the formed stiffener around EH1 was observed during the test (first reported at 165 psig). A post–test analysis was conducted to investigate: (1) what caused the initial crack in the formed stiffener, and (2) how a crack in the stiffener would affect the response of the containment wall.

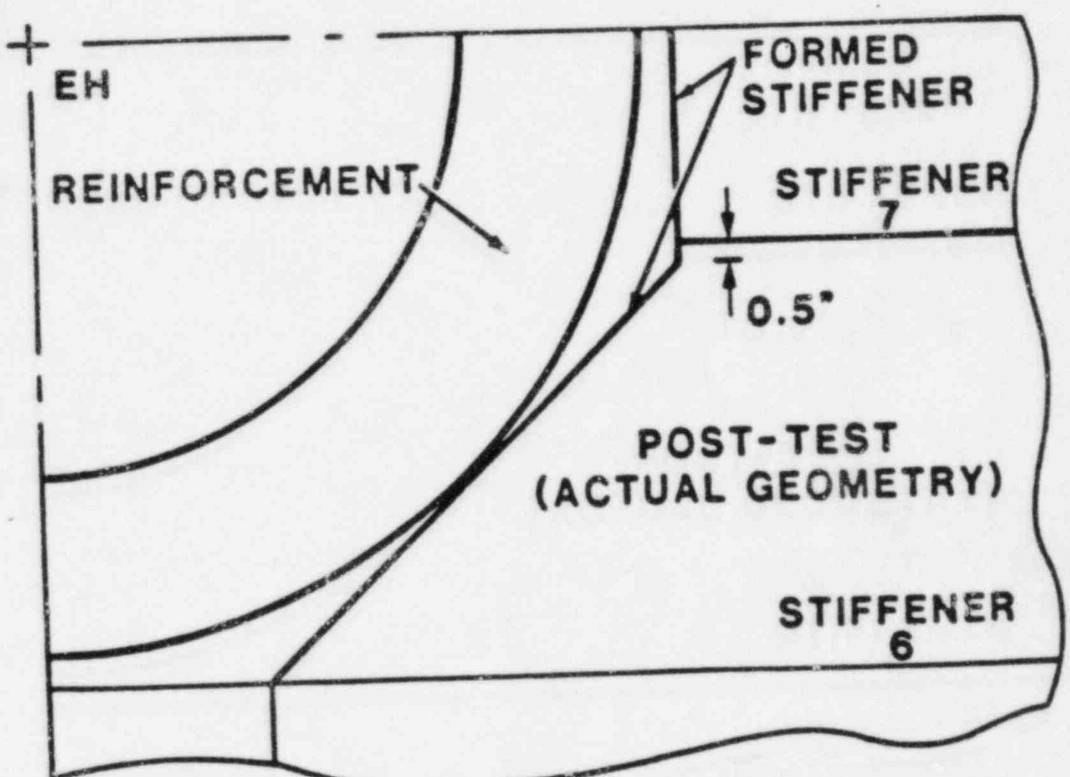
The model was similar to that used for the pretest analyses, except for an "eccentricity" at the junctures between the formed stiffeners and circumferential stiffeners.

# POST–TEST ANALYSIS – RESULTS

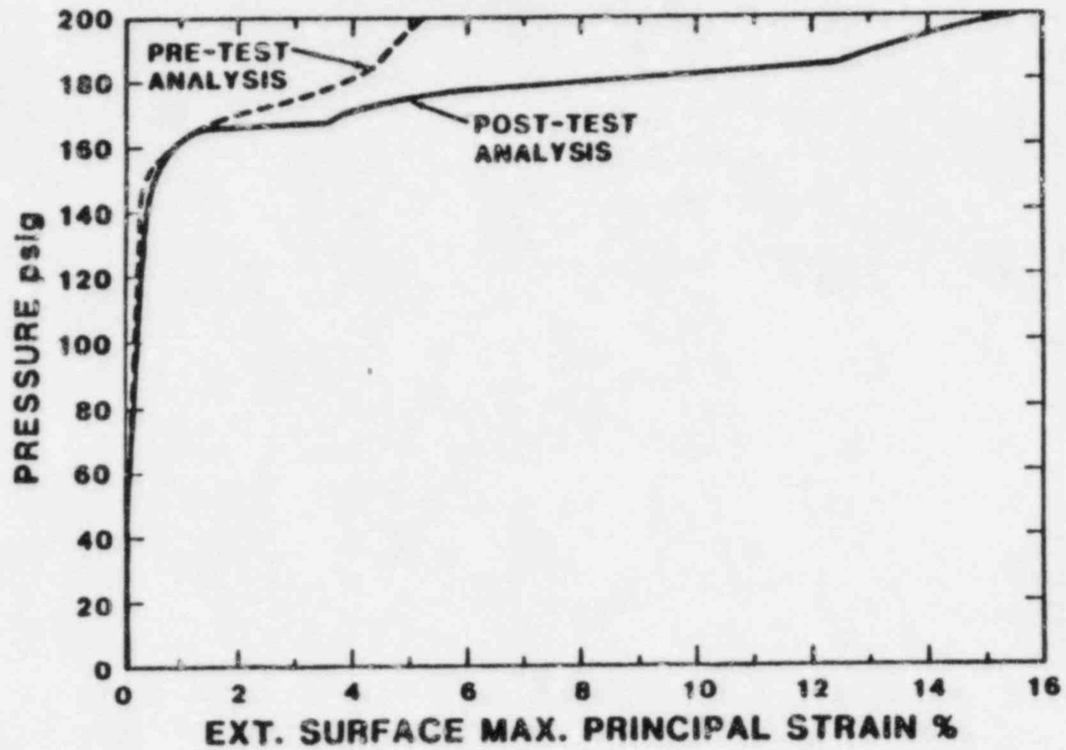
At 165 psig, the max. principal strain was 16% at the outer fibers of the formed stiffener where it intersected the circumferential stiffener. This is consistent with the observed crack. With the introduction of the eccentricity, equilibrium at the juncture could not be satisfied with membrane forces only, thereby resulting in bending moments and high shear.

A strain concentration occurred in the cylinder near the stiffener's juncture, with the maximum principal strain (primarily hoop) exceeding 14% at 195 psig. Again, the calculated strain in conjunction with the rupture criterion is consistent with the experiment. This strain concentration is a direct result of the redistribution of load from the stiffener (after it has cracked) into the shell wall.


PRE-TEST


EH
REINFORCEMENT
FORMED STIFFENER
STIFFENER 7
0.5"
POST-TEST (ACTUAL GEOMETRY)
STIFFENER 6

STRAIN IN CYLINDER NEAR THE JUNCTURE OF THE FORMED STIFFENER WITH STIFFENER 7



# PROGRAM ACTIVITIES

- Survey of Mechanical Penetrations (Argonne National Laboratory)
- Preliminary Analysis (ANL, Sandia)
- Tests on Penetrations (Sandia)
- Tests on Seals (Sandia, Idaho National Engineering Laboratory)

Note - Investigation of Electrical Penetration Assemblies is being conducted in another program

# PROGRAM STEPS

- SURVEY OF PENETRATION TYPES AND DESIGNS PERFORMED BY ANL ON 48 U.S. PLANTS
- QUALITATIVE FIGURES OF MERIT DEVELOPED
- PRELIMINARY ANALYSES CONDUCTED
- PROGRAM PLAN DEVELOPED
- CONDUCT PROGRAM

# EXPERIMENTS/ANALYSIS OF PENETRATIONS

| | |
|---|---|
| PERSONNEL AIR LOCK (FULL SIZE) | 1986 |
| EXPANSION BELLOWS | 1986-87 |
| DRYWELL HEAD FOR BWR MK I OR MK II | ANALYSES DO NOT INDICATE NEED FOR EXPERIMENT |

# PRESSURE SEATING EQUIPMENT HATCHES

Models for predicting the deformation and leakage for pressure seating hatches in a steel containment were verified by the 1:8–scale steel model test

Significant interaction between the cylinder (shell) and the penetration sleeve occurs.

Average membrane strains from 2.3% up to 5% must arise before the sleeve deformation is sufficient to cause a mismatch with the cover that results in leakage.

Two additional pressure seating equipment hatches will be tested in the 1:6–scale reinforced concrete model.

# DRYWELL HEAD ANALYSES

CPWG cites unseating of drywell head due to internal pressurization as a major contributor to leakage in Mk I and Mk II containments in a severe accident. However, the conclusion is based on analysis that did not take into account the effect of elevated temperatures, which are also present in the accident.

ANL and Sandia have conducted independent analyses that show that if elevated temperatures inside the containment are considered in the analysis, metal to metal contact will be maintained between the sealing surfaces, thereby precluding leakage.

Differential thermal expansion between the drywell head flanges, which house the seal, and the bolts, which attach the drywell head to the lower part of the containment, has the effect of additional preload on the bolts, thereby substantially increasing the pressure needed to unseat the drywell head.

# DRYWELL HEAD ANALYSES

ANL used a sophisticated finite element approach, whereas Sandia derived closed form solutions based on a strength of materials approach.

Sandia analyzed the response of drywell heads in eight containments. There were significant differences in the drywell head diameter, flange thickness, number of bolts, bolt diameter, and bolt preload within this group. Only one of the eight unseated at the maximum accident pressure (120 psig), and the gap was less than 2 mils, which would most likely be closed by the seal material. There are significant conservatisms in Sandia's analyses, and the actual separation pressure is probably higher.

Based on the analyses, a test of a drywell head was not felt to be necessary.

# PRESSURE UNSEATING EQUIPMENT HATCHES

A pressure unseating equipment hatch will be tested in the 1:6–scale reinforced concrete model

The same methodology used to analyze drywell heads will be used to analyze the pressure unseating hatch.

Data from the test (gap measurements, compression in the flanges) will be used to assess the method.

# PERSONNEL AIRLOCKS

Test will be conducted in FY 86

Preliminary analyses suggest that: (1) no significant interaction occurs between the shell and sleeve, and (2) the door and bulkhead will undergo large deformations associated with bending.

Finite element analyses will be performed with the actual material properties, and a leakage criterion will be proposed prior to the test.

# TESTS ON SEALS

| | |
|---|---|
| **Materials -** | **Silicone Rubber**<br>**EPM/EPDM**<br>**VITON (FKM)**<br>**Neoprene** |
| **Cross-Section Geometry -** | **"O" Ring**<br>**Dog Ear**<br>**Gum Drop**<br>**Tongue-and-Groove** |

# TESTS ON SEALS

ENVIRONMENT - SEALS AGED AND UNAGED AGING (THERMAL AND RADIATION EXPOSURE BEFORE TEST)

PRESSURE - UP TO 160 PSIA (1100 KPA)

TEMPERATURE - UP TO 700°F (370°C)

# TESTS ON SEALS

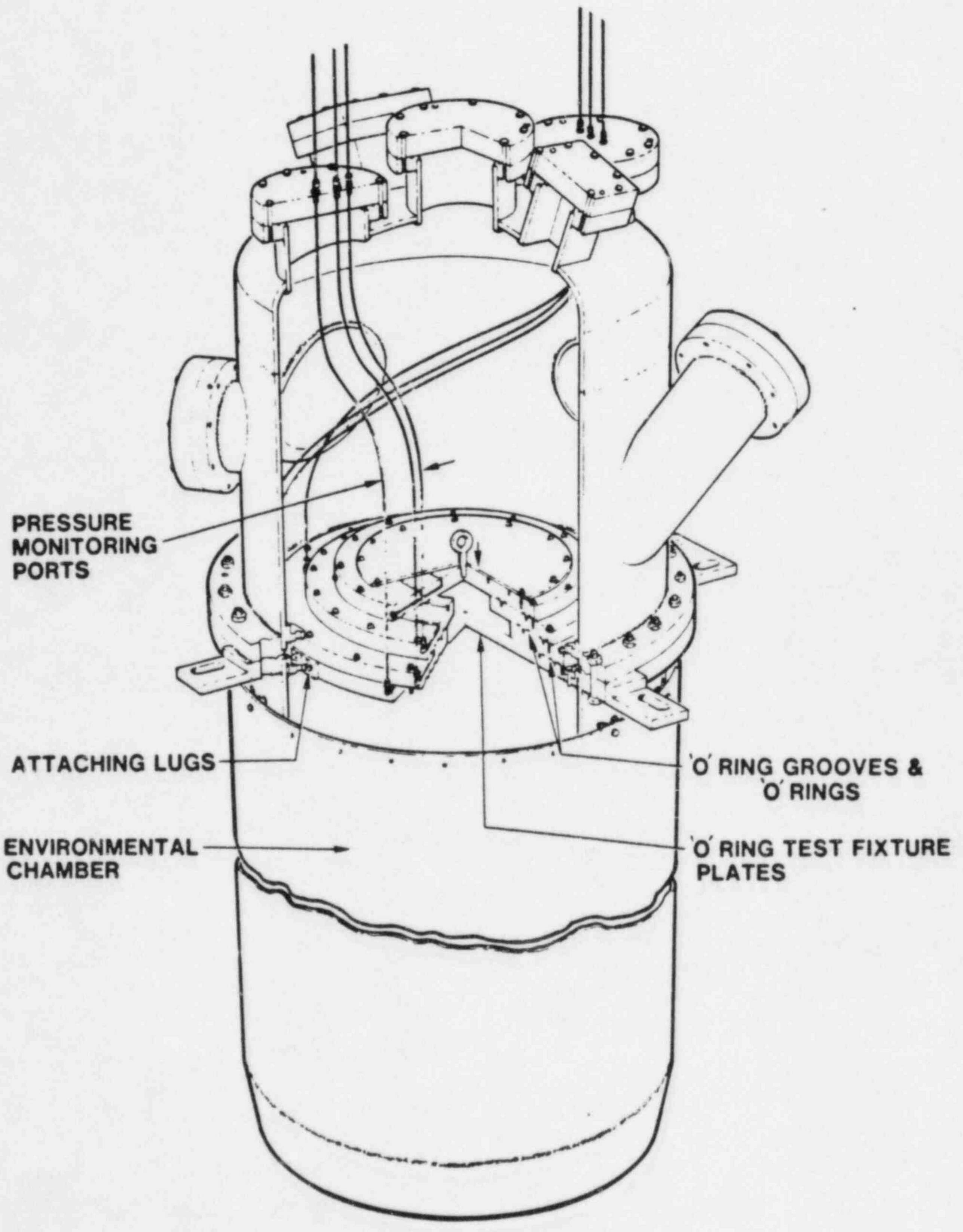
| | |
|---|---|
| TEST SET-UP - | PRESSURE CHAMBER (SATURATED OR SUPERHEATED STEAM, HEATED AIR, OR NITROGEN) |
| MATING SURFACES - | METAL-TO-METAL CONTACT PRESCRIBED GAP ROTATION OF ONE SURFACE (MACHINED INCLINE) |

# EXPERIMENTS/ANALYSES OF PENETRATIONS

| | |
|---|---|
| SHELL-STRUCTURE INTERACTION<br>EQUIPMENT HATCH<br>PERSONNEL AIR LOCK | TESTS ON 1:32 SCALE STEEL, 1:8 SCALE STEEL, & 1:6 SCALE CONCRETE MODELS |
| EQUIPMENT HATCH WITH SEAL | 1:8 SCALE STEEL MODEL |
| EQUIPMENT HATCHES<br>2 PRESSURE SEATING<br>1 PRESSURE UNSEATING | 1:6 SCALE REINFORCED CONCRETE MODEL, 1987 |

# FUTURE WORK

- COMPLETE TESTS ON SEALS
- INVESTIGATE EFFECT OF AEROSOLS ON LEAKAGE (PLUGGING)
- TEST PERSONNEL AIR LOCK (THERMAL AND STRUCTURAL)
- EQUIPMENT HATCH TEST IN REINFORCED CONCRETE MODEL




SEALS AND GASKET TEST ASSEMBLY

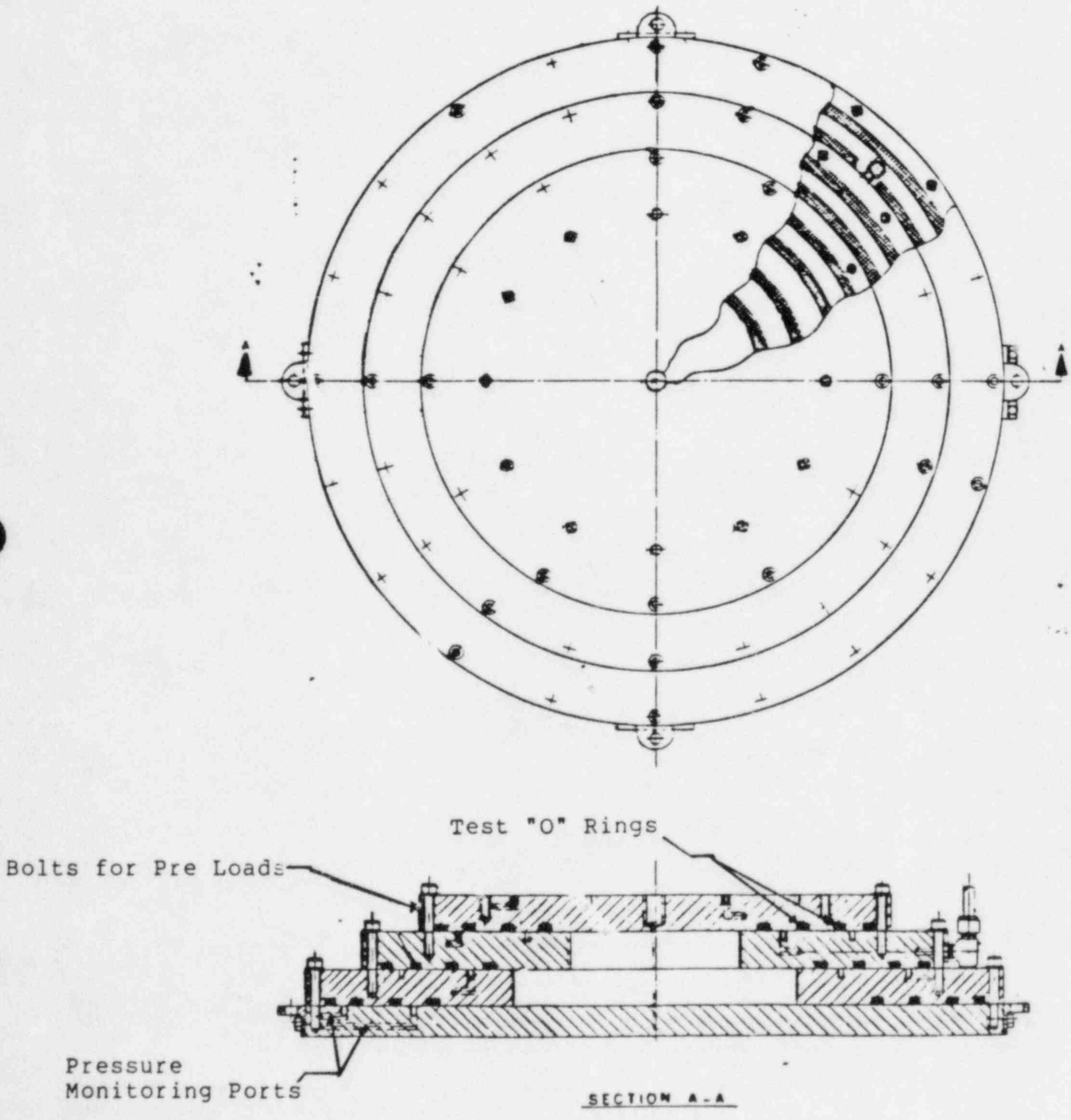



FIG. 6.0: FLANGE ASSEMBLY FOR DOUBLE "O" RINGS TEST

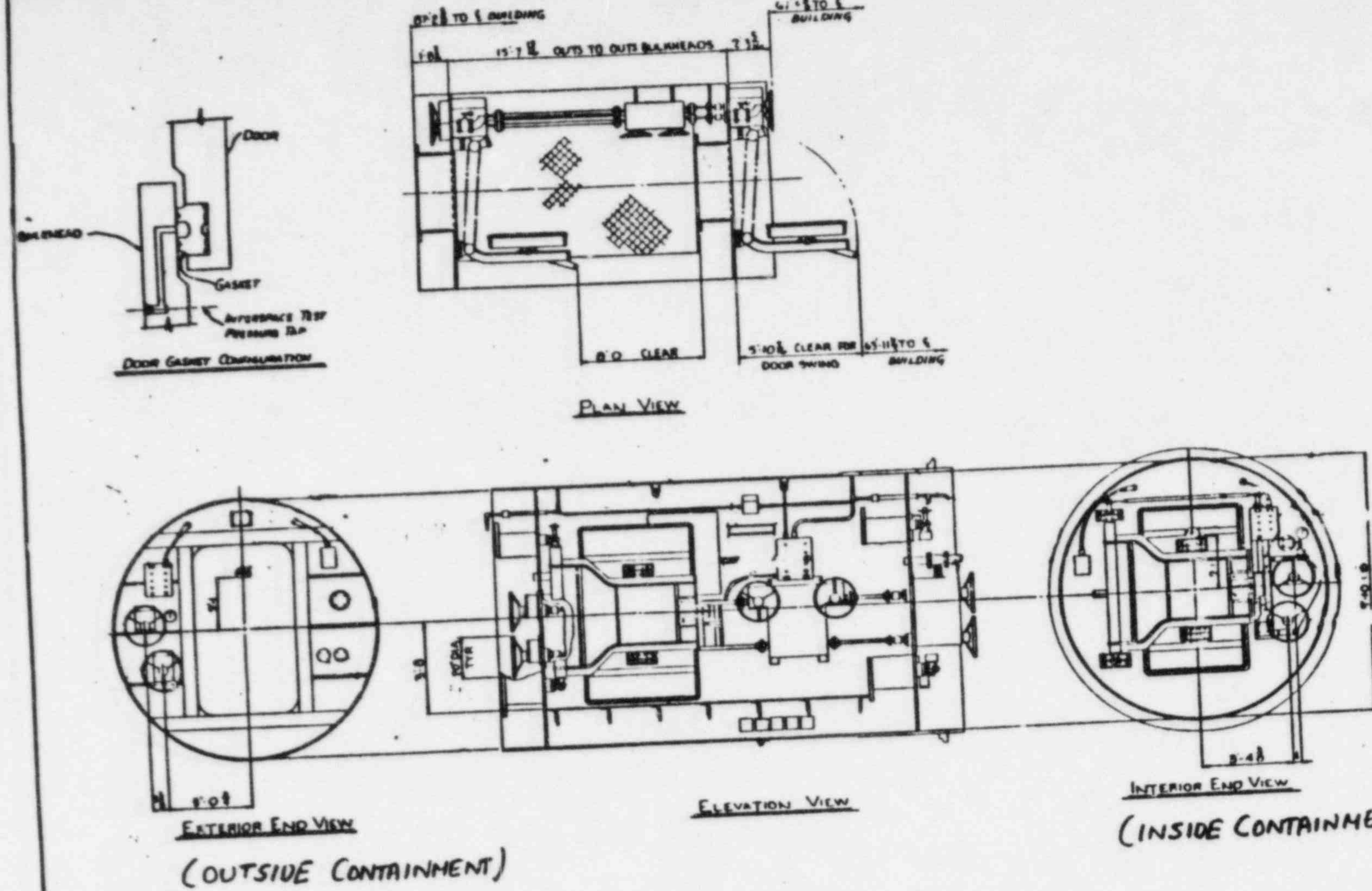



Figure 1.
General Arrangement
For
3'-6 x 6'-8 Personnel Lock

(For Dimensional Info. Only)

Cloud
12-16

# WHIPJET PROGRAM

DUQUESNE LIGHT COMPANY

BEAVER VALLEY POWER STATION - UNIT 2

# WHIPJET PROGRAM

AN ALTERNATIVE ENGINEERING METHOD FOR PIPE BREAK PROTECTION

- PERFORM TEST & ANALYSIS TO SHOW LBB APPROACH IS APPROPRIATE FOR B.O.P. SYSTEMS

- IMPLEMENT THE LBB APPROACH
  - o DEMONSTRATE LEAKS OCCUR FIRST
  - o DEVELOP LEAK DETECTION PROGRAM

RETAIN RUPTURE RESTRAINTS IN AREAS LBB IS NOT APPLICABLE OR ECONOMICAL

RETAIN DEGB ASSUMPTION FOR ECCS, CONTAINMENT DESIGN, ETC.

# PROGRAM

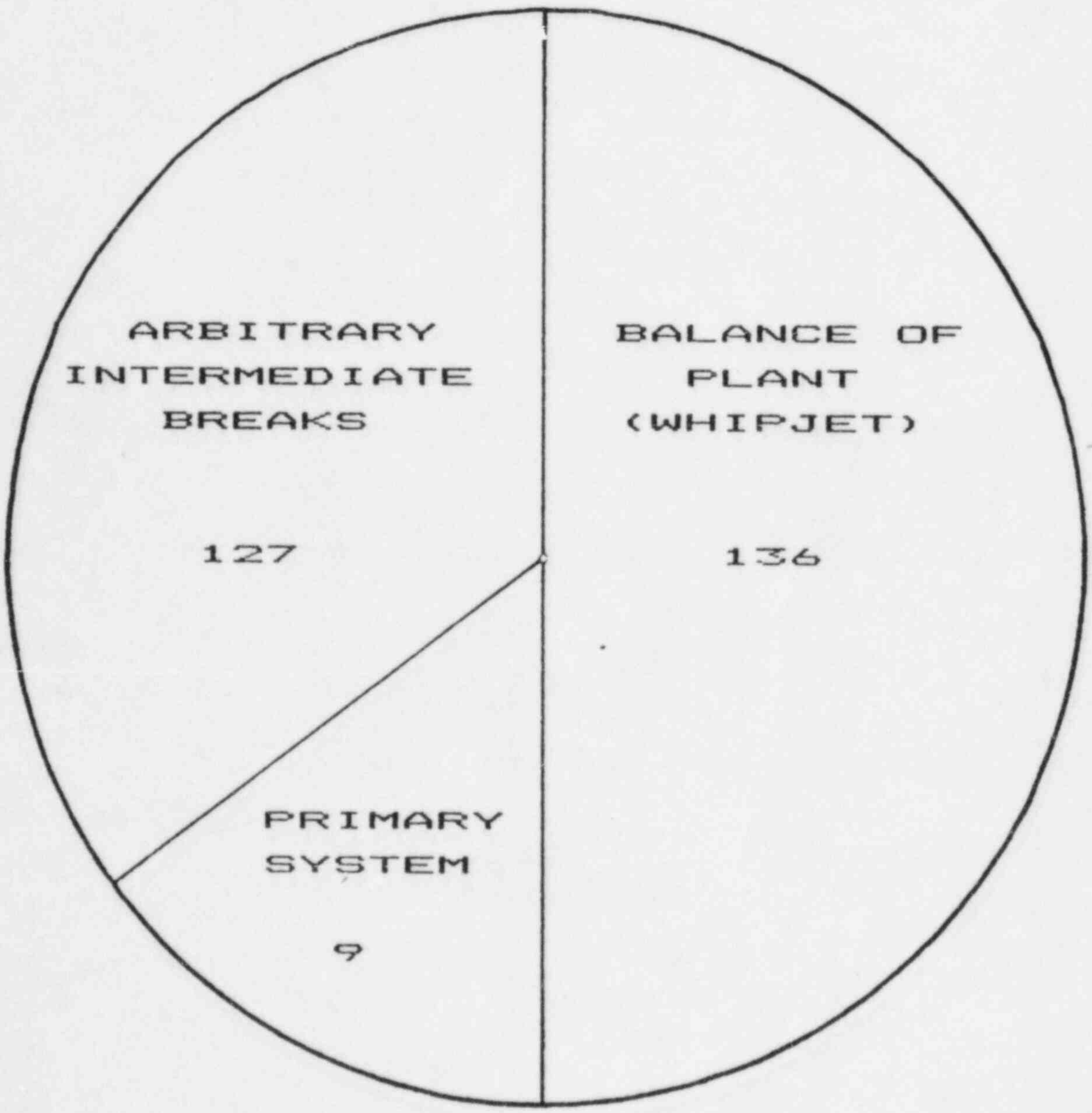
- o SCOPE

- o ACTIVITIES
  - — STRESS CORROSION REVIEW
  - — WATER HAMMER ANALYSES
  - — FATIGUE EVALUATION
  - — EQUIPMENT SUPPORT EVALUATION
  - — LBB ANALYSES
  - — LEAK DETECTION PROGRAM
  - — COST BENEFIT ANALYSIS

- o SUMMARY AND CONCLUSIONS

SCOPE

RUPTURE MITIGATION HARDWARE




THE NUMBERS REFER TO BVPS-2 RESTRAINTS AND JET SHIELDS

# ACTIVITIES

DEMONSTRATE APPLICABILITY OF LBB

- o STRESS CORROSION REVIEW
- o WATER HAMMER ANALYSES
- o FATIGUE EVALUATION
- o EQUIPMENT SUPPORT EVALUATION

IMPLEMENTATION OF LBB PROGRAM

- o LBB ANALYSES
- o LEAK DETECTION PROGRAM
- o COST BENEFIT ANALYSIS

# STRESS CORROSION REVIEW

- CONDUCT A SPECIFIC STRESS CORROSION REVIEW ON A SYSTEM-BY-SYSTEM BASIS

- ASSESS COMBINATION OF STRESS LEVELS, MATERIAL, AND CORROSIVE FLUID ENVIRONMENT FOR EACH CLASS OF PIPING

- ASSESS THE POTENTIAL FOR STRESS CORROSION CRACKING AND FORMULATE A CONCLUSION FOR B.O.P. SYSTEMS

## WATER HAMMER ANALYSES

- o REVIEW TRANSIENTS CONSIDERED APPLICABLE TO BVPS-2 WATER HAMMER ANALYSES
- o ASSESS THE POTENTIAL FOR HARMFUL WATER HAMMER ON A SYSTEM-BY-SYSTEM BASIS
- o PROVIDE TECHNICAL JUSTIFICATION TO SHOW WATER HAMMER IS ADEQUATELY CONTROLLED
- o DOCUMENT TREATMENT OF FLOW TRANSIENTS FOUND APPLICABLE TO BVPS-2

# FATIGUE EVALUATION

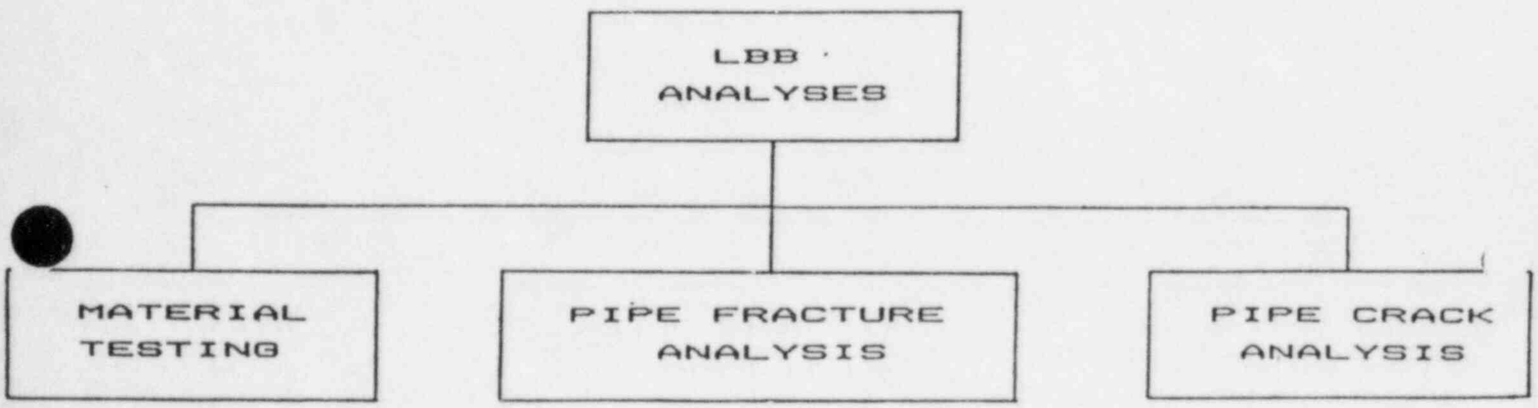
- o THERMAL FATIGUE EFFECTS PREDICTED BY USING:
  - NUMBER OF THERMAL CYCLES
  - ALLOWABLE STRESS LEVELS TO OBTAIN CUMULATIVE USAGE FACTORS (CUF)

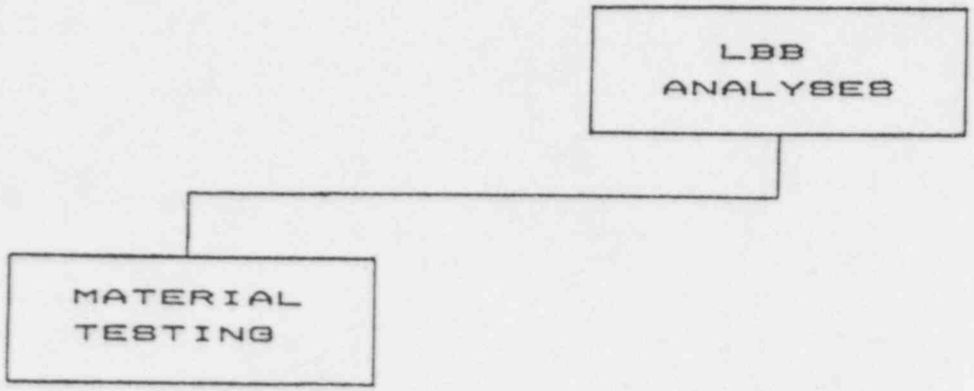
- o PERFORM MORE FATIGUE EVALUATION FOR LINES WITH CUF GREATER THAN 0.1

# EQUIPMENT SUPPORT EVALUATION

- ESTABLISH CRITERIA TO EXAMINE EQUIPMENT SUPPORTS AFFECTING B.O.P. PIPING

- SUPPORT FAILURE POTENTIAL MUST BE EXAMINED TO ENSURE PLANT SAFETY IS NOT COMPROMISED


LBB
ANALYSES
MATERIAL
TESTING
PIPE FRACTURE
ANALYSIS
PIPE CRACK
ANALYSIS

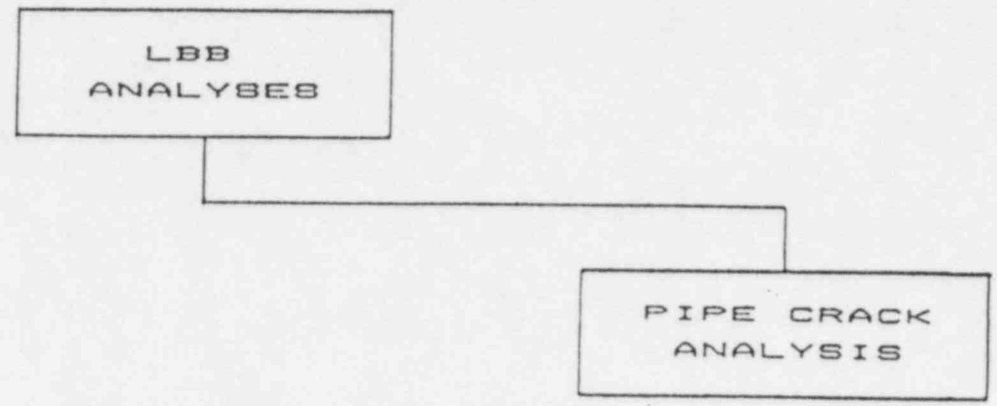



- BVPS-2 MATL
- STRESS-STRAIN
- J-R CURVES
- PLANT SPECIFIC

LBB ANALYSES

PIPE FRACTURE ANALYSIS

- CONSERVATIVE
- CIRCUMFERENTIAL CRACKS
- CRITICAL CRACK LENGTH
- LEAK RATES




- J-T APPROACH
- LOAD SAFETY MARGIN
- STABLE GROWTH

## LBB ANALYSES

### MATERIAL TESTING

- BVPS-2 MATL
- STRESS-STRAIN
- J-R CURVES
- PLANT SPECIFIC

### PIPE FRACTURE ANALYSIS

- CONSERVATIVE
- CIRCUMFERENTIAL CRACKS
- CRITICAL CRACK LENGTH
- LEAK RATES

### PIPE CRACK ANALYSIS

- J-T APPROACH
- LOAD SAFETY MARGIN
- STABLE GROWTH

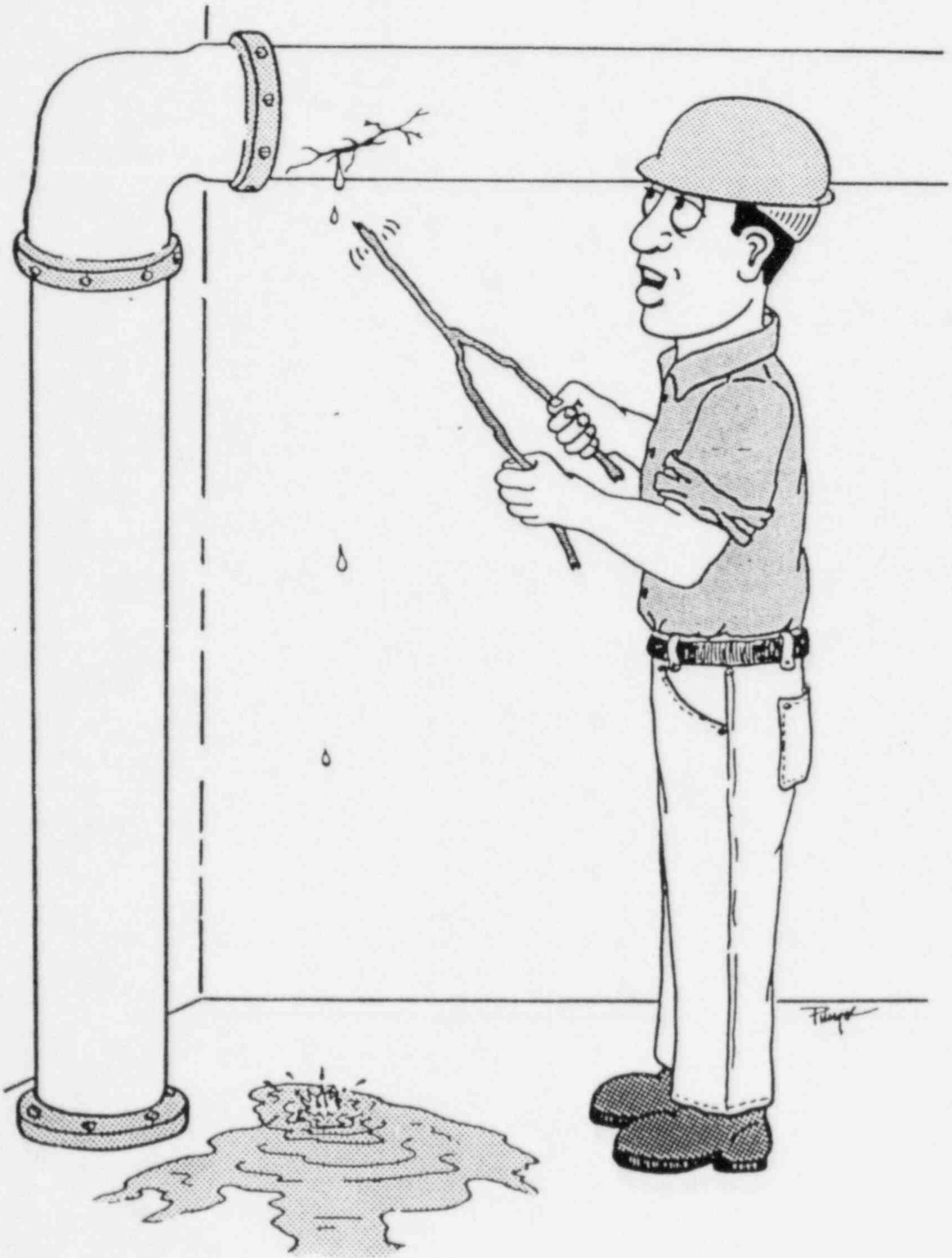
# LEAK DETECTION

- PROVIDE CAPABILITY TO DETERMINE, LOCATE, AND QUANTIFY PIPE CRACK LEAKAGE

- OPTIMUM LEAK DETECTION TECHNIQUE IS A COMBINATION OF MORE THAN ONE METHOD

- EXAMINE LEAK DETECTION RATES OF EXISTING AND/OR ADDITIONAL INSTRUMENTATION

- ESTABLISH OVERALL LEAK DETECTION STRATEGY



# BENEFITS

- IMPROVE ACCESSIBILITY TO MINIMIZE RESTRICTIONS TO ISI AND REDUCE PERSONNEL RADIATION EXPOSURE

- TIMELY AWARENESS OF LEAKAGE

- MINIMIZE UNANTICIPATED THERMAL EXPANSION STRESS DUE TO INTERFERENCE

- IMPROVE UNDERSTANDING OF PIPING FAILURE MODES

- REDUCE PLANT COST

QUANTITATIVE COST SAVINGS (NET)

| | |
|---|---|
| HAZARDS ANALYSIS | $1,420,000 |
| DESIGN | 330,000 |
| FABRICATION | 2,980,000 |
| INSTALLATION | 1,890,000 |
| INDIRECT COSTS | 1,400,000 |
| | ----------- |
| TOTAL QUANTIFIABLE COST SAVINGS (NET) | $8,020,000 |

QUALITATIVE COST SAVINGS

- INCREASED FLEXIBILITY IN THE CONSTRUCTION SEQUENCE
- ELIMINATION OF GAP ADJUSTMENT VERIFICATIONS DURING START-UP AND POWER ASCENSION WALKDOWNS
- ELIMINATION OF STRUCTURAL CHANGES WHICH ARE DUE TO PIPE RUPTURE RESTRAINT LOADS
- REDUCTION OF ENGINEERING AND CONSTRUCTION COSTS WHICH ARE DUE TO DESIGN AND CONSTRUCTION IN CONGESTED AREAS
- DECREASED OUTAGE COSTS DUE TO ISI DIFFICULTIES AND CONGESTION
- REDUCTION IN HEAT LOSS FROM PIPING TO ADJACENT PIPE RUPTURE RESTRAINTS.

## COST BENEFIT

| | |
|---|---|
| DIRECT COST SAVINGS IN DESIGN, ANALYSIS, FABRICATION, AND INSTALLATION | 8M |
| INDIRECT COST SAVINGS DUE TO BETTER SCHEDULE AND AN IMPROVED PHYSICAL PLANT | 4M TO 8M |
| TOTAL COST SAVINGS | 12M TO 16M |

# SUMMARY AND CONCLUSIONS

- PROVIDE PIPE BREAK PROTECTION USING STATE-OF-THE-ART ENGINEERING TECHNOLOGY

- USE THE ABILITY TO SUCCESSFULLY DETECT PIPE LEAKS

- IMPROVE PLANT SAFETY AND DESIGN DURING OPERATIONAL PERIODS AND OUTAGES

- SHOWS REASONABLE, AGGRESSIVE INDUSTRY INITIATIVE TO IMPROVE SAFETY AND LOWER COSTS

# SCHEDULE

| | |
|---|---|
| NRC GRANTS SCHEDULAR EXEMPTION FOR B.O.P. WHIP RESTRAINTS | SEPT. 1985 |
| DLC COMPLETES WHIPJET PROGRAM | DEC. 1986 |
| INSTALL WHIP RESTRAINTS, IF ANY ARE REQUIRED | REFUELING OUTAGES |