NUCLEAR REGULATORY COMMISSION

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

IN THE MATTER OF:

SUBCOMMITTEE MEETING

on

METAL COMPONENTS

Place - Washington, D. C.

Date - Tuesday, 10 July 1979

Pages 1 - 346

546 144

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

Tuesday, 10 July 1979

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546 145

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBCOMMITTEE MEETING

on

METAL COMPONENTS

Room 1046
1717 H Street, N. W.
Washington, D. C.

Tuesday, 10 July 1979

The ACRS Subcommittee on Metal Components met, pursuant to notice, at 8:35 a.m., Dr. Paul G. Shewmon, chairman of the subcommittee, presiding.

PRESENT:

DR. PAUL G. SHEWMON, Chairman

MR. MYER BENDER, Member

MR. HAROLD ETHERINGTON, Member

P R O C E E D I N G S

DR. SHEWMON: This is a meeting of the Advisory Committee on Reactor Safeguards, Subcommittee on Metal Components. I am Paul Shewmon, Subcommittee Chairman.

Tomorrow we will meet also with the Extreme External Phenomena Subcommittee. That is why you will see a bunch of extra seats around. And also, the Combination of Dynamic Load Subcommittee.

The other ACRS members present are Myer Bender and Harold Etherington, and Carson Mark may be here.

We have in attendance the following consultants: Warren Berry, John Moteff, Monroe Wechsler and Zenons Zudans.

The purpose of this meeting is to review the NRC research sponsored by the General and Water Reactor Safety Research Offices. After tomorrow, we will get into the activities that have shut down five plants because of loading combinations. We will also discuss feedwater cracking.

The meeting is being held in accordance with the provisions of the Federal Advisory Committee Act and the Government in the Sunshine Act. We are fortunate to have Mr. El Igne on my right as the designated federal employee for this portion of the meeting.

The rules for participation have been announced as part of the notice of the meeting previously published in the Federal Register on June 25 and 26.

A transcript of the meeting is being kept and will be made available, as stated in the Federal Register notice. It is requested that each speaker first identify himself and speak with sufficient clarity and volume so that he can be readily heard.

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

Let me scope things for a minute here, if I can find my agenda.

(Pause.)

As most of you know, the original purpose and main purpose today was to go over the research and technical assistance programs that are funded by the NRC, in preparation for a report to Congress which the ACRS must write annually. At the latter -- since the research program that the NRC does is to be set in a context of a broader need, we will have representatives from EPRI and the vendors here to talk about their research programs in this area of metal components.

Metal components has become such a popular and exciting program these days that they have squeezed us all down into one day from what had been a two-day meeting, by superimposing or preempting the second day, first with combined loads, which I acquiesced to, and now I see external phenomena, which I don't remember acquiescing to. But it is conceivable that I did.

So why don't we -- if there are any gen ral questions or comments at this point, I would be pleased to hear them. And if not, we will get on with Dr. Serpan.

MR. BENDER: It wasn't obvious to me that we were going to combine this with the external load business either. How did that happen?

MR. IGNE: What we are going to do, because of the fact that it is coming from the same group -- Larry Shao, Larry Shao's branch -- there are a couple of related sections here. We are going to cover the mechanical engineering section anyway. And since the structural engineering area is intermediate between the seismic part and the mechanical part, in looking at the structural aspects of it --

DR. SHEWMON: But you gave them a half day and that's too much.

MR. IGNE: It might be, depending upon how it goes. We can modify that.

MR. BENDER: My impression is, Mr. Chairman, that we ought to modify it. That is just a personal opinion.

DR. SHEWMON: Do you have any idea -- the earlier draft of the agenda had the vendor programs on the second day, or do we have any idea whether those people can stay over?

MR. IGNE: I can request it, but I don't know if they can or not. They did have some flexibility in their schedule when I talked to them.

DR. SHEWMON: My thought was that we would run behind schedule through the first half, up to the break. At least from last year, Vince Noonan didn't take an hour to talk, and Jim Knight may or may not, depending on how many questions we ask him. So let's start and not spend too much for questions for Chuck. We don't want him to feel left out. We will see where it goes from there.

(Slide.)

MR. SERPAN: I am chief of the Metallurgy and Materials Research Branch in the Office of Water Reactor Safety Research.

This morning I intend to review the activities that we have under way for primary system activity in this branch. The research of the branch is conducted in four major areas. Those are: vessel and fracture mechanics; irradiation tests and dosimetry; steam generator tube integrity and stress corrosion; and nondestructive examination.

I have been specifically asked to give extended discussions in three separate areas this morning. So I will do that as they appear when I go through the program for these separate areas.

(Slide.)

The area of vessel and piping fracture mechanics has as an overall purpose to establish validated fundamentals of fracture and fracture analysis for vessels and piping, to assure safe design and operation. The specific objectives -- the overall objectives, I should say, that we have for this piece of work are to develop and validate elastic, plastic and tearing instability criteria for the licensing staff, for application in both vessels and piping.

We are working on validating thermal shock and steam line break evaluation methods. We are quite well down the way on thermal shock, and we are plunging into the steam line break, which could be also construed as a pressurized thermal shock. We are pushing hard on that, trying to get that going.

The next objective is to establish the integrity of vessel having low shelf material. The problem surfaced with the B&W low shelf weld metals, and we are working hard to determine the toughness of those weld metals. But we have concluded that it is necessary to show that this low shelf weld metal in a vessel either will or will not maintain the integrity of the vessel.

So we are planning an intermediate vessel test with low shelf material in it, to prove the integrity of such a material.

DR. ZUDANS: You mentioned this came from B&W. That is with the weld that they use, metal that they use?

MR. SERPAN: Yes.

DR. ZUDANS: I thought they were do'ng all of that research on it. Why would you do that research?

MR. SERPAN: We were specifically requested by the licensing staff to determine the toughness of that low shelf material, so that the licensing staff would have a basis to understand, based on the Sharpe numbers that come in from the surveillance programs, whether the toughness is adequate or not. We have been getting a great deal of help from B&W. They have been supplying materials for us. Admittedly, we are doing an extensive job in testing and irradiation. But without the materials, we could not do it either. But we are doing this in direct result of a request from the licensing staff for this information.

DR. ZUDANS: The only question I really had was, how much of the work is really parallel to what B&W is doing?

MR. SERPAN: B&W is not irradiating any material. So the crucial thing that we are doing is the irradiation of this material, including specimens up to four-inch thickness, and developing the size effect transition in the irradiated as well as the mechanical properties.

DR. ZUDANS: How do you get four inch thick metals? This is the welding that we are talking about.

MR. SERPAN: The specimens are made from -- the weld runs right through there. But the specimens themselves are four inches thick.

DR. ZUDANS: Thank you.

DR. SHEWMON: You are giving them accelerated radiation tests?

MR. SERPAN: Yes.

DR. SHEWMON: Where is that being done?

MR. SERPAN: At Oak Ridge.

Two irradiations have been conducted with these large specimens, and we are planning a third one.

The next step is, we are working to update the ASME 'e curves for crack growth rate. We have work under way at NRL and through the HSST program at Westinghouse, and we have an international program under way where we have about a dozen countries throughout the world who are also, hopefully, contributing their data.

DR. SHEWMON: How much of that is in environmental effects, and why are we doing any of it?

MR. SERPAN: A great deal is environmental effects. We are watching the water chemistry very carefully. It is being done mostly at 550 degrees Fahrenheit and 2100 or 2200 pounds pressure, and it is being done in reactor-grade water, with the chemistry being very carefully controlled, to try at this point with pressurized water reactor chemistry. But we are trying to duplicate PWR water chemistry as closely as we can.

DR. SHEWMON: Does anyone really know what kinds of excursions in pH or other things come about in LWRs? One theory, that is, in the BWRs it is the high oxygen on startup that bothers you.

Do you know whether or not it is, for example, pH excursions in LWRs that may give you most of your problems?

MR. SERPAN: No, we don't know that. We think we have the most severe conditions that are reasonable. But no, we don't know the answer to that one.

DR. SHEWMON: We don't know where the problem is scoped and we aren't doing anything to find out?

MR. SERPAN: From that standpoint, as far as the water chemistry standpoint, it's correct, yes, that's true.

MR. BENDER: I don't understand your answer quite as well as I ought to, Chuck. Are you saying that we don't know the factors that influence pH control?

MR. SERPAN: I don't think we know them well enough -- wait a minute. The factors that influence pH control?

MR. BENDER: I think the PWRs have a position which says they know what the pH ought to be, they are regulating it, and so if pH is a problem, then it has to be, because we don't know where to set it.

MR. SERPAN: I don't think that's the case.

MR. BENDER: What is the case?

MR. SERPAN: I think what Dr. Shewmon was talking about was excursions and going off chemistry.

DR. ZUDANS: Irradiation levels are not known in actual plants. If they do the tests precisely and control pH, it may not represent the real situation.

MR. BENDER: You mean we may not have taken enough samples to know what it is; is that what you're saying?

DR. ZUDANS: Yes.

MR. BENDER: I am not comfortable with that answer. I suspect that we know a lot more about it than might be inferred by that answer.

MR. SERPAN: What I was saying was that I do not know that much about the excursions in there.

MR. BENDER: That is a different answer than saying that --

DR. SHEWMON: Is there anybody in the NRC who is likely to know what the excursions are?

MR. SERPAN: I think that information probably is much more available to the licensing staff.

DR. ZUDANS: How closely do the licensees control pH and what kinds of records do they have on that? What is the meaning of the test and this strict control that you will be doing?

MR. SERPAN: We have representatives from the vendors who come to the meetings periodically where we discuss this. I guess at this point I am assuming that the vendors and utilities who are interested are paying attention to this and trying to give us some of that input. If we are not getting it, we will certainly look into it from now on.

Pedro Albrecht is responsible for this area, and I think you are listening and I certainly hope you take this --

DR. SHEWMON: Is this the water chemistry area?

MR. SERPAN: The cyclic crack growth rate. We will certainly look into it.

MR. ETHERINGTON: The range of boric acid concentrations in BWRs, I would suppose that the pH would vary over a very wide range. It probably isn't even controlled.

DR. SHEWMON: I hear things about lithium additions. Is that done to control pH some?

MR. ETHERINGTON: I don't know if that is standard practice or not.

DR. SHEWMON: I don't know if there are any regs on it or not.

MR. BERRY: They do add lithium for pH control. As you increase the temperature, boric acid really doesn't change pH much, so that by adding just a fraction of lithium, the lithium is very effective in maintaining a more or less neutral pH at operating temperatures.

DR. SHEWMON: Is it your impression that the pH is controlled within reasonably narrow limits, then?

MR. BERRY: It is controlled, yes, to the best of their ability. You can't measure a high-temperature pH. It is added for that purpose, to try to get a neutral pH or close to neutral.

DR. SHEWMON: What concerns me is that we are blissfully going on at one pH, and it is possible it doesn't make any difference where it is. But we certainly do know that the vendors don't always control their chemistries particularly well, as witness steam generator problems. And although that is not primary, I grant -- and it bothers me somewhat that we don't seem to even be doing anything to scope the problem, to know if we are in the least conservative part of it.

e-1

MR. BENDER: They have a range that claims to be the range at which crack propagation is minimized. That was my impression. You metallurgists know more than I do.

DR. SHEWMON: Some work out of Westinghouse, their theory is it is hydrogen deposition at the crack as -- that is indeed helping propagate the crack. I don't think they did anything with pH variations in water.

MR. BENDER: I won't argue that point. They don't think the crack propagation rate is of great importance.

DR. SHEWMON: Their views may be changing on that.

MR. SERPAN: I do not know the exact answer for you on this, but we have been working on it for quite a while and pH is well known. We do have to take care for it. I will not say that we are operating in the absolute proper range for it. I would be surprised if we were not.

DR. SHEWMON: I am sure your advisers tell you you're in the best range.

Are you doing anything to find out if pH does affect it?

MR. SERPAN: I am pretty sure that we are not. pH as such is not one of the primary variables.

DR. SHEWMON: Why is it one of your responsibilities to help the vendors redesign the ASME code curve?

MR. SERPAN: Information has come out that says that the crack growth rates are considerably higher than the allowable curves in the code.

DR. SHEWMON: The environmental code?

MR. SERPAN: Both in water and in air, yes. And as a result, the staff has asked us to please get with it and find out what the data really are. They are going to have to recommend a new curve and they want to be sure that it is proper and conservative.

DR. SHEWMON: This is what the Marshall report suggested several years ago.

MR. SERPAN: We were working on it at the time. We have been working on it.

MR. BENDER: How far off are they?

MR. SERPAN: What is it, Pedro? Maybe an order of magnitude?

MR. ALBRECHT: About a factor of 1.5 to 2 in the range of about 10 ksi, a delta K range of the stress intensity factor of 10 ksi to about 40.

MR. BENDER: Is the argument that the crack size is detectible, is such that that 1.5 factor is important? Or is it just that the number --

MR. SERPAN: We are talking about crack growth rate.

MR. BENDER: I understand. But you start with some specified crack size and you postulate a crack growth rate that is a function of the initial size. If I am looking at a crack growth rate of 1.5 times something and I am starting with a very small crack, then the importance of making -- whether it grows at 1.5 times the old rate or not may or may not be moot.

MR. SERPAN: Now you are talking about the actual imposed stress intensity on the crack, and that crack might be in a low stress field or in a high. I don't think that just the size of the cracks -- I guess they are independent.

MR. BENDER: The code limits the stress level.

DR. ZUDANS: The size of the crack determines a range of stress intensity and the crack rate depends on the range of changes of stress intensity during the cycle. The crack growth rates are very small numbers. In other words, it is inches per cycle.

1.5 may not mean much. But what surprises me is, you said even in the air environment the curves are not correct in the ASME code. Those were represented by the lower bounds of all the tests available at that time.

And what is the new evidence that says -- or is it the testing methods that have changed since?

MR. ALBRECHT: The largest differences come in the environment. That is what we are observing.

DR. ZUDANS: You also said in air environment.

MR. ALBRECHT: Yes. There the effect is smaller. The important thing is, it is a change in the test done in the environment, the BWR.

DR. ZUDANS: Does this have anything to do with the methods of testing that are changing from static to dynamic?

MR. ALBRECHT: In the environment, yes. We know the old time cycle to have an effect on the cyclic crack growth rates.

MR. SERPAN: And the slower frequency of testing.

DR. SHEWMON: Let me come back. This 1.5 to 2 that you spoke of is the lack of conservatism in the air data?

MR. ALBRECHT: In the environment.

DR. SHEWMON: You and I ought to compare, because it is very easy to find published papers that talk about up to a factor of 10. I don't know where you get your 1.5. The Westinghouse work, for example, in certain ranges of delta K has been a lot more than 1.5. And if you are right, I would be interested in seeing the discussion of the published literature that reinterprets that I have been looking at.

MR. ALBRECHT: Yes, I will dig out this information.

DR. SHEWMON: All right.

MR. SERPAN: The next area is, we are working to establish a crack arrest toughness analysis and have that worked into the overall pressure vessel integrity analysis scheme.

The last three items have to do with piping, and I will discuss them in more detail. They include reevaluation of the cold leg break criteria, reevaluation of the criteria for pipe breaks and pipe whip, and establishing a piping analysis method and proposal of updated licensing criteria.

(Slide.)

The scheme that we tried to follow in the piping programs in our branch and also in Jim Richardson's branch to some extent, start this way, kind of simplistically; but I think it follows through. We assume that in the reliability of the piping system we have to worry about stresses and loads, material properties and flows.

The stresses and loads we are working on -- and I will describe programs that we have in these areas in more detail following, but I want to try to go through this scheme. We are looking at seismic loads, primarily with the load combination program that we are doing with Jim Richardson's branch.

And we are also looking at the --

DR. WECHSLER: What branch?

MR. SERPAN: Mechanical Engineering Branch, Jim Richardson's operation.

DR. WECHSLER: Thank you.

MR. SERPAN: We are looking at design stress and loads versus the real ones. From this kind of information, we are trying to get out a better idea of where break locations can really occur.

Moving to material properties, we have found that we have little information available, especially the piping materials, on the crack growth rates, their fracture toughness and stress corrosion cracking information. We have separate work under way to get that information, although I must confess that the amount of stress corrosion cracking information we have under way is extremely small to almost vanishing at this point. We simply have not had the money or we have not had the request to do it.

From a flaw size, flaw work, we need to determine what size of a flaw could become a critical flaw and what is the distribution of flaws by different sizes and components, and what is the reliability of detection of those flaws. We are working on that with a separate contract at Battell Northwest.

The material properties on the flaw sizes feed into the fracture analysis method. The stress of loads also comes in and we try to get out the piping reliability, try to get a number for the piping reliability itself.

Again, as I say, this is all quite simplistic, how we are looking at it.

From the break locations now, we try to determine what the consequences are of those breaks in terms of both pipe whip and, for example, double-ended cold leg break, from the reliability consequences, break locations and all, and then we try to update and revise the design and operating criteria for the piping systems.

We have this charge from the licensing staff, to completely review all of their piping, the rules, regulations and their criteria. What we hope to do from that eventually -- and this amounts to a proposal for future work that we are trying to get funded in 1981 -- we want to come up with an interactive piping analysis system whereby the entire piping system can be reviewed on an interactive display system. The man in licensing can simply take the deck from that particular plant and put it onto the computer and punch up any place that he wants on that system.

If he thinks there is a hanger out of place, he can call up that system and he can say: What is the stresses and loads on that hanger? Is it in the right place, the wrong place? What if we took it out? What if there was a break there?

DR. SHEWMON: Is it where the drawing says it is?

MR. SERPAN: Exactly. That is exactly right. That kind of a code, as it turns out, would be marvelous for determining the as-built versus the design, and to see if in fact the as-built was as good as the design. That is the proposal for the future.

MR. BENDER: Don't take that out. There are a couple of things I want to ask you about.

First, I am a little concerned about the idea that a computer code is going to become the panacea for curing our problems. I wouldn't want to be overwhelmed by the idea. I think it is idealistic.

How does this program relate to what Larry Shao is having done in his program on combined loads and the work that is generally being sponsored out of Livermore?

MR. SERPAN: We are working parallel with Larry on this, and in fact this, up here in the corner, this thing that says, seismic stress and loads, is jointly funded between his branch, between his office and my branch.

The piping reliability, the methodology, coming up with the piping reliability, is actually being done, part of that contract, and we are having part of it done at Battelle Columbus. So we are really working hand in glove with him on it.

MR. BENDER: When we listen to Larry's program, we have to think in terms of this.

MR. SERPAN: Yes, sir.

The materials properties, for example, they are not

546 164

thinking about getting the material properties, because we are getting them. A lot of the fracture analysis method, the basis for it, has already been done by Professor Paris at Washington University. They are using that. They are going into the seismic load, that area, much more heavily than we are, and we are taking input from them.

But these programs really are coming together, and we are going to come up with one piping reliability number, not one from his operation and one from mine. We are going to come up with one.

MR. BENDER: I don't know what the term "one piping reliability number" -- I guess it is one piping reliability curve.

MR. SERPAN: What I mean is, his office is not going to come up with one set of data and we are not going to come up with another set.

MR. BENDER: Do you have an input concerning the reliability of hangers somewhere in that, that thing? Where is it in that program?

MR. SERPAN: Yes. Well, I think it tends to come out more here, in the pipe whip area, and it doesn't show up too much there. But when I talk about that program, I think you will find -- you will see where it comes in. In that particular program, what we tried to do is get the loads on a piping system and then determine what is the consequences of that load, how is the pipe going to whip around. So if it is contrained, then. one can tell what the effect is, if the constraint is in the right place, if it is enough, if there are enough of them, or if one needs one and if one is not there.

MR. BENDER: The kinds of things that have been of concern to me are, first, the possibility of a constraint locking up at the wrong time, which is not unlikely; or the possibility that a constraint has not held well in the anchor, whatever it is that is holding the constraint, and it breaks out and the pipe is unconstrained for a longer span.

Are those kinds of things being considered in this?

MR. SERPAN: No. The only way that I can consider that is to have an analysis that will permit one to see what the consequence is if that hanger pulled out. But I am not looking after the reliability of hangers locking up or of hangers pulling out of the wall. I haven't been given that charge. That really is Larry Shao's operation, I think.

DR. SHEWMON: The comment was the consequences, not the probability here.

MR. SERPAN: Yes. I am talking about the consequences. If it does pull out and there is no more constraint on that pipe, then I am attempting to find out what the consequences will be of that. But I am not working on making sure that that constraint does not pull out or that it does not lock up. That has not been my charge.

If it does lock up, then all I can say is, I can tell you what the consequences will be.

MR. BENDER: That is a useful piece of information. I didn't interpret what you had said originally as being that answer. That would be hêlpful.

DR. ZUDANS: I have a couple of questions.

DR. SHEWMON: Is it on piping reliability, on the top line there?

DR. ZUDANS: Yes.

You mentioned that you would look at design loads and real loads. Can you clarify? How are you going to get to real loads?

MR. SERPAN: By looking at the actual records of how the piping systems operate and deduce the loads from that.

DR. ZUDANS: In other words, you plan to put some instrumentation in the systems that will tell you how the piping systems operate?

MR. SERPAN: I would rather have Pedro describe as close as we are going to get to the actual load.

DR. ZUDANS: All right. I believe that you have trouble getting actual loads.

Then, break locations. There was a fairly long discussion. Is it ever considered to postulate break locations and test runs?

MR. SERPAN: Yes.

MR. ALBRECHT: The ASME, the reg guides, require that the breaks be postulated at points where there are stress concentrations.

DR. ZUDANS: Always at the end?

MR. ALBRECHT: Nozzles, elbows.

DR. ZUDANS: So it is likely you could have several thousands of feet str.ight run and there is no break postulated?

MR. ALBRECHT: That is correct.

DR. ZUDANS: What comes to my mind is, you can't really tell where the material differences may show up, and it is not unlikely -- or at least very difficult to argue -- that the break will never occur in a straight line. That might open the whole question of breaks in a completely different light, and maybe it is worth thinking about.

e-2

MR. BENDER: That's not a new question. It has been around a long time. The problem has to do with the likelihood of the event occurring there ahe kinds of constaint that you might put on it to avoid it.

If you have a break in the straight run, forces might still show up where the constraints are.

DR. ZUDANS: That is correct. I wouldn't be concerned about pipe strains or potential pipe whip. I would be concerned about what that break would see in terms of other equipment in terms of jet impingement.

DR. SHEWMON: This is an instantaneous double-ended pipe break, the type that the analysts like to have, but the metallurgists never find.

DR. ZUDANS: I am more concerned about longitudinal breaks, washing out piping, the cables and instruments.

MR. SERPAN: I guess the incidence of flaws that have been discovered in pipes that could initiate that kind of a break are so few that the probability -- I don't know if it is a real probability. I am afraid to use that word. But the likelihood of that kind of a break happening is low enough that we have concluded to not work on it, or not put a great deal of emphasis on it, let us say.

We are looking at longitudinal breaks. We are trying to determine the likelihood [illegible]. We are trying to fracture mechanic solutions [illegible] effect of longitudinal breaks for the critical length of them. But the primary concentration is on the circumferential-type break and the possibility of breaks at the welds, joints, elbows.

DR. SHEWMON: Let me come up with a different question on the break location.

You have the stresses and loads going to break locations going to consequences. From reading the reg guide, I don't remember offhand that stresses and loads hardly ever come into it. It is more you will postulate breaks at locations.

MR. SERPAN: Yes.

DR. SHEWMON: Is it likely that anything will come out of this, anything that would have to do with where breaks --

MR. SERPAN: Really would occur? Yes.

DR. SHEWMON: And when?

MR. SERPAN: That is part of the plan. That is what we wish to determine. It has been arbitrarily stated where you will assume breaks based upon really kind of an arbitrary stress load.

We are trying to get at the validity of those rules by doing that very thing, so that when, at the end of this, we may say, yes, that is exactly right. That is exactly where you should postulate those breaks because that is where the stresses are. We may come around and be able to say, no.

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that is wrong. Those stresses —

DR. SHEWMON: This is going to be done analytically?

MR. SERPAN: Yes. Quite a bit of it is going to be done analytically, but we will ultimately have to get into some test work.

DR. SHEWMON: What does piping reliability mean?

MR. SERPAN: It means a number on a piping component, whatever it be, that gives you an idea of the likelihood of it failing.

DR. SHEWMON: And this is related to what? Stress relative to yield? How does somebody establish the probability of its failing?

MR. SERPAN: I would like to have Pedro talk about that.

MR. ALBRECHT. We are going to come back to that in a later slide that he will have, in essence -- have a fracture mechanics model of crack propagation.

MR. SERPAN: We will walk to that, how we will get to that number, if you want a few viewgraphs.

DR. SHEWMON: Fine.

MR. BENDER: I hate to prolong the conversation, but I can't stand not to ask this question: Is the approach you are taking going to allow for the fact that the stresses change, as the crack propagates, that the stresses change as a break opens and the pressures are relieved, that the stresses

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change as a function of the kind of seismic loadings that are applied?

MR. SERPAN: Yes.

MR. BENDER: All of those things are going to be put into your reliability curve?

MR. SERPAN: Yes.

MR. ETHERINGTON: In your top left-hand box, stress and loads -- is your concern that we are overdesigning or underdesigning?

MR. SERPAN: I think that there is a concern that we are overdesigning and putting in too many hangers and supports which, in fact, then, make it, for some reason or other, unsafe.

(Slide.)

What I am going to try to do now -- this is quickly a review of the contractors that we have working in the area. I hope it is not controversial. The cold leg integrity work is being done by Battelle Columbus, under re-evaluation of the criteria for pipe breaks and pipe whip.

Work is underway at Sandia on two-phase jet loads, at Berkeley on dynamic analysis of pipe whip, and a very new program on the reliability of piping systems at SAI.

Support programs that I mentioned are the material properties of the piping steels at Naval Research Lab, and that is the Naval Ship Research and Development Center in

546 172

Annapolis and then non-destructive examination work is at PNL.

I will take -- I hope to get through them. The cold leg integrity work, the purpose of it is to determine if the safety margin against the large break in the PWR cold leg during its 40-year life is large enough to make the postulation of a break overly conservative.

The way that we are going through this piece of work is to get plant and load descriptions. And we have typical plans from B&W, Westinghouse, and CE, Arkansas, St. Luci, Farley, review the stress analysis results of the primary piping system, determine the fracture mechanics model for crack growth rate, determine material properties for the actual piping materials in these plants which we have the actual materials, and then get data on crack characteristics, including the size, shape, location, the largest missed flaw, analysis of cyclic crack growth and final instability, and from that information, re-evaluation and need to actually postulate the large break in the cold leg.

DR. SHEWMON: Are you going to let them cut their teeth on the feedwater nozzle cracking on the secondary side, see if they know what they are doing?

MR. SERPAN: That would be a good thing to work into it.

DR. SHEWMON: It would be interesting to see if they gsn

predicted it would last for 50 years.

MR. SERPAN: Yes. I would like to point out that this particular piece of work is being done pretty much from the literature, or what they can come up with in a plant with loaded descriptions from the plants themselves.

The material properties we are trying to get out, but we will have very little available to Battelle Columbus this year.

What they are trying to do is go back and come up with a more solid literature theoretical basis for the postulated cold leg break which was laid out rather arbitrarily a long time ago.

DR. ZUDANS: It is with some distant future objective to eventually agree and not postulate a break in the cold leg?

MR. SERPAN: If the data showed that that cold leg break need not be postulated, then yes.

DR. SHEWMON: It will be a very cold day around that leg, I think.

MR. SERPAN: In any event, we need to have the background data so that we can understand how close what the margin is, and that is the purpose of that program.

MR. BENDER: What is the reason for concentrating on the cold leg, as opposed to something else?

MR. SERPAN: Dr. Tong said that you will concentrate on the cold leg because that is a more serious break for a

546 174

gsh

large break rather than the hot leg.

MR. BENDER: That is troublesome because I think most of us intuitively believe that the largest break is not anywhere near to being the break that we have to be concerned about. And fairly small breaks obviously have become a very important issue in --

MR. SERPAN: They certainly have.

MR. BENDER: For some reason, I find the rationale for selecting the cold break as being the thing on which to focus. It doesn't lend itself to our immediate concerns.

MR. SERPAN: No. But this program was started a couple of years ago.

MR. BENDER: I understand that. And that is the reason for not going in that direction. But, nevertheless, I think someone has to be given --

MR. SERPAN: It was chosen because at least -- I am not a thermohydrologist. I don't know. I go to my boss and he tells me what the serious problem is.

And he told me that the cold leg break was by far and away a more serious one because of the counter-current than the counter-flow that one has to worry about in the core.

MR. BENDER: Given the size break and specific location, no one argues that point.

I think the point I am trying to make is that we are gsn

concentrating on trying to find out whether we can eliminate the largest break in the worst place.

Maybe that is a good way to go at it. Maybe we ought to be thinking about what size breaks we ought to be postulating in the primary system.

And for some reason or other, that doesn't come out of this approach. But perhaps it could.

(Slide.)

MR. SERPAN: The first contract that we have underway that is leading to the piping reliability work is the program at Sandia on two-phase jet loads.

The purpose here is to establish an accurate, simply applied, predictive methodology for load determination of jets eminating from cracks or breaks in nuclear piping systems.

The objectives of the work here is to evaluate the available two-phase flow analysis computer codes that are already existing, such as BEACON/MOD 2, TRAC, and so forth, select one of them, or more, if need be, that are best suited for characterizing the two-phase jets that eminate from breaks or cracks in the typical PWR systems, modify those codes as necessary, and coordinate with the Germans and the Japanese on their ongoing two-phase jet experimental program.

I should point out that we are doing the analytical work here. We are getting experimental data from the Germans

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and Japanese. And we are coordinating with them to be sure that we get the data that we need to validate the code work.

DR. SHEWMON: Is the Japanese program producing results now?

MR. SERPAN: Yes. It is a fairly small pipe. It is less than four inches in diameter, but they have had a blowdown. And we have the results and we are working to try to analyze those results.

We got a package of information, but it turned out that we needed a little bit more than what they had given us, so we have gone back to them asking for it. And we will attempt to evaluate that data with what we know.

That is the next point — to use the existing experimental data from both the Germans and the Japanese to validate the code, and then from that to develop a simplified mathematical model to be used in the licensing process for the evaluation of jet loads.

One of the things we want to improve on in this area is to improve the Moody model, which is now, I guess, for the basis for it.

Are there any questions on that?

(No response.)

(Slide.)

Once we have established the loads, we move to the dynamic analysis of pipe whip. And here the purpose is to

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develop a special purpose computer program for the dynamic response analysis of the nuclear piping system subjected to the jet loads and to impact with adjacent structures.

The idea is to modify the existing codes, such as ANSR to allow pipe whip analysis capable of describing the effects of those things listed -- gaps, geometrical and material nonlinearities, large displacements, elastic plastic response of restraints, impact with adjacent structures, and local deformation and rebound.

What we need is a large displacement of elastic plastic codes, the structural analysis code. Quite a bit of it is already developed using ANSR as the basis. But now we have got to put it together so that it makes sense and will run this operation for us.

MR. BENDER: I am not clear on what you are trying to -- what the code will do for you.

MR. SERPAN: It will take a load from either -- from a jet or from a break and it will tell us what the deflection, the deformation is in that pipe, how much the reaction force will cause it to whip, how it will smash into another pipe.

MR. BENDER: What is wrong with what we are doing now?

MR. SERPAN: Apparently, there isn't a good enough code system to do that.

MR. BENDER: I will agree, but I am not overly

546 178

optimistic that you will get all of the information that is needed to make this code any better.

So you are talking about a fairly refined kind of analytical approach involving a lot of materials information, combined in some unpredictable ways.

It looks to me like the code will require you to constrain the way in which the loadings are applied and accepted.

I guess I am skeptical that a code of this sort would ever be useful because you wouldn't find very many places where you could fit all of the parameters in it.

Dr. Zudans might be better able to comment than I am.

DR. ZUDANS: I would like to only add that each AE today has its own code that identifies whip analysis. And mos conclusions are that you don't need a complicated code because the energy absorption capability of the pipe itself is negligible compared to any of the absorbing anchors.

The one-dimensional analysis predicts bounds the loads that you would introduce and it supports very nicely.

You could do today exactly what you described on this list with a sophisticated element code. A code exists that can do these things, but you wouldn't be able to exercise it. It takes too much time and too much money.

It is very likely that you would not be able to get

5A 79

gsh

all of the input needed for it.

So what is the purpose of analyzing a simplistic pipe whip with a jet load at the end which impacts an anchor with the capability of absorbing energy to account for 10 percent additional energy absorption in the pipe, or maybe not even that much?

MR. ALBRECHT: To some degree, it is a question of modelling. We can model about any structure using finite elements and elastic plastic material response laws.

We are now planning to come up with a code for a piping system where we model everything in the piping system with finite elements.

You want to develop a matrices to relate displacement and loads elastically and inelastically for elements. for linear elements based on data that we can find in the literature and where that is lacking, or in supplement to that based on detailed analysis of individual components.

But as we use the code, we will have the matrices which describe the relationships for the linear elements.

Now where there is a need, licensing has been requesting it very much that we can assess the effect of a pipe impacting adjacent structure.

So we will have the ability with that to model the piping system with linear elements, except for that region of the pipe that will actually impact a wall, for example. And

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then we can break down that small region into finite elements where we put the finite elements around the circumference and along the length of an elbow.

But the remainder of the plant would be modelled with linear elements. And there exists relationships where we can connect the node displacement at the end of a two-node to the displacements around the circumference of the connecting portions.

DR. ZUDANS: All you say is correct. And yet, I feel that, if I read this description, it is nothing more than to generate another sophisticated code such as ANSR, or many others that could do the job, if you are willing to make up the input. Whose code is this? The ANSR.

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MR. ALBRECHT: That was developed at the University of California at Berkeley.

DR. SHEWMON: Is this one contract being done at Berkeley?

MR. SERPAN: Yes.

DR. SHEWMON: Tell me how this gets coupled back to NRR and great decisions. Jim Knight has written you a request saying he really needs all this?

MR. SERPAN: That's right. This has grown out of a user's request that we got several years ago from Jim Knight, where he wanted all of the piping criteria re-evaluated all of the break locations, are they in the right place?

What is the effect of pipe whip? They have applications in there where pipes impact upon one another and they have their rules which say that a small pipe cannot take out a large pipe, but a large pipe can take out a small pipe.

That is not good enough and they want those rules validated, updated, changes, or whatever. So they wrote us this request and asked us to re-evaluate all of that criteria.

This is the tool that we are developing in order to be able to do that.

The output, then, part of the output from the work that we are doing will be to have the code capability to be able to evaluate all of these rules that they have, and we

546 182

will be able to determine if, in fact, one pipe can take out another one and under what conditions, so that we can at least bound that for them, so that when they look at an application, they can understand whether it is real or whether they are getting something that is not accurate. Or if they don't want to take that risk.

Right now they can't do that and this will be a tool that will permit them to do that. And they claim that they are in trouble to be able to evaluate that.

MR. BENDER: I think they are in trouble in order to be able to evaluate whether a pipe will be taken out or not. They are in more trouble if they try to use a code like this to get the answer.

And I think you really need to think about that. I think you will generate an unbelievable amount of computational capability that you can use.

DR. SHEWMON: Why don't we hold that until Jim comes. Is he going to show up today?

MR. ALBRECHT: Yes.

VOICE: He is planning to later in the morning.

DR. SHEWMON: Someone is on the program up there. Is that you or him?

VOICE: Someone from the mechanical engineering branch.

MR. SERPAN: The rest of what we have here I think we pretty much talked about. We talked about implementing it, validating it with experimental data from the Germans and then developing the models to be used in the licensing process.

We have essentially gone through that.

MR. ZUDANS: May I make one more remarks?

Sometime ago, when General Electric made extensive presentations, they generated their pipe whip calculations, which are simplistic but based on many, many tests. Those were actually blowdown tests with pipes of different lengths, elbows impacting different configurations, and so forth.

Isn't that package of information that is available already from GE tests pretty descriptive and maybe more than you need to make a decision on pipe whip design, because if you want to do what you describe on those matrices in combining them, I grant you that you can do it with the linear portion very good, package them and keep them somewhere stored.

As soon as you couple them to non-linear portions, they will change, not only because of physical dimension differences in the systems, but also because of the load process. The material will have memory and you cannot store in Your computer such information unless you really model it by finite elements locally. Every history will require a different set of matrices. I don't understand how you will do it.

I understand that you can take an existing program now and analyse what you describe here in an expensive process, but I don't see what really you are trying to develop because how can you say, for example, impact on adjacent structures? How can you determine the impact on adjacent structures unless you model the adjacent structures?

There is no single set for you to pre-model. Every structure would be different. Short of a complete, non-linear, inelastic computer program which uses finite elements, you cannot do what you describe here.

If that is the case, you already have programs like that. MARK is a program like that, ANSR, and many others.

DR. SHEWMON: Why don't we postpone it until someone from DSS is here to talk about their end of it?

DR. ZUDANS: Fine.

(Slide.)

MR. SERPAN: This is the work that we have underway in cooperation with Jim Richardson's branch on reliability of piping systems. The purpose is to determine the reliability of typical piping systems, both inside and outside the containment and program a sound technical basis for defining the criteria for postulating breaks.

From this work, we hope to revise reg guide 1.46 as necessary. The objectives, and this is kind of a flow chart through here, to begin with, the deterministic fracture mechanics model of crack growth and intability. And add the stochastic inputs for the initial flaw size, crack detection probability, loading and material properties, and then compute the probability of a piping system failing by the leak, break before leak, or break following a leak. And then determine the effect of in-service inspection and leak detectors on the pipe failure probabilities.

DR. SHEWMON: What type of cracks do you assume here?

MR. SERPAN: What kind of cracks?

DR. SHERMON: Circumferential? 360 degrees, or nice penny-shape cracks?

MR. SERPAN: Pedro, do you know what they are going to use?

MR. ALBRECHT: I guess you are asking about the information on the distribution of cracks and the crack sizes. There is some information available in the literature on the distribution, the direction of the thickness of the wall.

There is very limited information available on the -- what I meant before was the dimension compared to the thickness of the wall. There is very little information available about the dimension L, the length of the crack along the surface of the pipe.

The only study of such information is one done by Wilson at General Electric.

546 186

gsh

DR. SHEWMON: You haven't heard from Duane Arnold?

MR. ALBRECHT: Yes.

DR. SHEWMON: Isn't that data 0.2?

MR. ALBRECHT: In the Duane Arnold case, the crack stress corrosion cracking was around the circumference. Eventually, it appears that the mode of growth, changing from stress corrosion cracking to corrosion fatigue. Now there is no information on — we have models for calculating the growth of cracks on the fatigue and corrosion fatigue. We don't have any good models to calculate the growth of cracks in the mode stress corrosion cracking.

DR. SHEWMON: There is an interesting after-dinner joke about the guy looking for his wallet under the streetlight They ask, did you think you lost it here, and he said, no, but it is the only place where there is enough light to look.

(Laughter.)

I don't know if you are telling me that we are doing calculations where there is enough light to look or whether I am misunderstanding.

What my particular hang-up is that the leaks, which seem to be found in reactor plants these days, seem to be circumferential and seem to be environmentally assisted.

What I see here is what mechanical engineers who have worked on fracture mechanics love to do. And I am not sure — on what they can do well. And it is whether the two are

546 187

gsh

related to each other is what is of concern to me.

MR. SERPAN: We are aware of the problem of the stress corrosion and cracking. And we do not have any significant work underway to work on it.

We have been trying to get work underway. We have been requesting funding for it and have not been successful.

DR. SHEWMON: There is partly the impact if circumferential cracks are the ones that are likely to get you in trouble. Are you using the tools that you are using the way you should be, or the way that it is likely to show up in the reactors?

MR. ALBRECHT: We are analyzing circumferential cracks, in what direction they grow, whether it is longitudinal or circumferential. That depends on the stress field.

So that is being considered.

I think the only point that -- maybe I have mislead on the question you asked. I think you are leading to the question as to how can we predict as to what kind of a stress corrosion crack might exist in the structure?

I think that there is no way of predicting that.

MR. SERPAN: At least we don't know how to predict how fast that stress corrosion crack will grow and exactly the conditions that will grow it. But the work that we are doing will find out for us the critical size of that crack and under what conditions, then, it will either leak, break,

546 188

or it will come apart, or it will stay there.

So at least we have that part of it.

MR. BENDER: Is there some — we have had techniques for a long time for predicting critical size of a crack. We may not have had the data that goes with it to determine what the properties were that were to be used.

What is different about this than the techniques that have been used before?

MR. SERPAN: For one thing, we are looking at these materials in the elastic plastic regime, not brittle. If it were a linear elastic regime, I would agree with you that we could, indeed, predict those critical flaw sizes. But not so much in the elastic plastic regimes.

MR. BENDER: It is the plasticity aspect that makes the difference.

MR. SERPAN: Yes, sir. We are assuming that we have to worry about the failure of these pipes when they are hot, when they are at their ductile shelf temperatures.

MR. ETHERINGTON: Is there a problem in defining the length of a crack that goes all the way around?

MR. SERPAN: You mean a critical flaw that would go all the way around? Yes, we are working on that.

MR. ETHERINGTON: Once it has gone all the way all around.

MR. SERPAN: Once it has gone all the way around. Wait

546 189

gsh

a minute now. I am not sure if I understand.

MR. ETHERINGTON: The fracture mechanics. Have you applied that for a crack that goes all the way around?

MR. SERPAN: You are worried mostly about the depth. The Duane Arnold crack can be analyzed. And Professor Paris of Washington —

MR. ETHERINGTON: Was that all the way around?

MR. SERPAN: No. It was through 90 degrees and then it was part through the other 270 degrees.

MR. ETHERINGTON: It was all the way around —

MR. SERPAN: Part way. It was all the way around. That is correct.

DR. SHEWMON: Part of the way through it was all the way around.

MR. SERPAN: Yes. About 90 degress. It was all the way. It was completely through. But that crack, that flaw has been analyzed.

We can't understand it. We can't predict something from it.

DR. ZUDANS: On this reliability assessment program, how do you plan to determine what is your ultimate objective. By considering a variety of pipe diameters, variety of pipe configurations?

MR. SERPAN: Yes.

DR. ZUDANS: You will have to limit your scope very

546 190

dramatically because there are hundreds and hundreds of different sizes.

MR. SERPAN: We will try to bound it.

DR. ZUDANS: Bound the whole field?

MR. SERPAN: Yes. We appreciate that it is a tough job, but we are doing the very best that we can on it. And think we have a very capable contractor working on it. Dave Harris at SAI has been on it quite a bit.

DR. ZUDANS: I have no doubt about the credentials of the investigators. I guess I would like to return back to the previous comment.

If you look at the actual experience in power plants and all the cracks that have occurred so far, what would be the fraction of -- other than stress corrosion cracking, other than due to the environment? Are there any cracks developed due to mechanical loads that these systems, these piping systems have seen?

MR. SERPAN: I think there is a question about the cracks. I think the KRB last year in Germany could very well have been a design problem.

DR. ZUDANS: D.C. Cooke, the large pipes.

DR. SHEWMON: Everything I have read says environmentally assisted propogation.

DR. ZUDANS: I wanted to comment on this. There is no load, really, that you can postulate. There was one

546 191

gsh

possibility that maybe the snubber froze, the vertical snubber. And then by thermal expansion, induced a load. But there is no such observation.

It seems like it is really not a mechanically-induced fracture. If all the fracs that have occurred in power plants are not of a mechanical origin, then your study is directed to something essentially academic.

The other aspect of crack propagation growth is very much more important.

MR. SERPAN: I think what we are looking at is given that a flaw is there, what is the severity of that flaw and what would be its critical size? And do we have to worry about it failing the component.

And what we are hearing today from the ACRS is that you want us to work very hard on finding out how that crack gets there in the first place and what are the environmental conditions for that crack to grow?

DR. SHEWMON: If what you are studying never happens in plants —

MR. SERPAN: No, we're not. We are not studying arbitrary cracks. We are studying the cracks that occur in things like the Duane Arnold crack. We are aware that it is there.

That certainly is one of the kinds of cracks that we are worrying about to try to determine what is the severity of

546 192

it.

Now maybe it doesn't show up there. Maybe it doesn't say that on the third line that this is aimed directly at Duane Arnold, but it certainly is.

We are trying to get together the methodology so we can understand those cracks and predict them and figure out what they are doing.

MR. ALBRECHT: Maybe I should say a few more things that would clarify that.

The impression seems to arise that there is a study of fictitious things, which is not the case at all. I think there is also a misunderstanding about the mechanical versus the environmental conditions.

I think D.C. Cooke is very much a mechanical stress that caused the crack to initiate. There is a transition from an elbow which is a Schedule 80 elbow into a Schedule 60 nozzle.

There is a very large difference in thickness. It was ground out on the side of the elbow. And the crack does start at the point of discontinuity, where they have ground out the portion of the elbow to make a proper transition.

I shouldn't say "proper." I should say make the transition. That part of the discontinuity has an ankle that varies from 15 to 30 degrees. There are grinding marks. There is a stress effect and the crack did start from there. That

546 193

gsh

is the carbon steel side on the elbow. It is not in the transition piece in the nozzle and there is no indication that I have seen so far that -- to show that it is a stress corrosion cracking carbon steel.

So it is a mechanically induced failure, if you so like.

DR. SHEWMON: Do you distinguish between stress-assisted crack growth or environmental-assisted crack growth and stress-assisted cracking?

MR. ALBRECHT: You have to distinguish between stress corrosion cracking --

DR. SHEWMON: You say it could be corrosion fatigue, but it wasn't stress corrosion cracking or it wasn't either.

DR. SHEWMON: Was it corrosion-assisted fatigue? Have you seen any evidence it was that?

MR. ALBRECHT: No metallurgical evidence, but it appears to be corrosion fatigue.

DR. SHEWMON: Thank you.

MR. BENDER: Let me make one comment about this business. It seems to me the usefulness stems from the fact that the regulations are based on these kind of phenomena. So it is necessary to work on them.

The question is whet er the regulations are founded on the right kind of metallurgical phenomenon. I think that is a matter that doesn't come out of this discussion so far, except to the point that Dr. Shewmon has brought it up.

DR. ZUDANS: I think what you do will determine the reliability of the piping systems once the crack is there. But in this program, you don't care how it got there to begin with.

MR. SERPANS: That is correct.

DR. ZUDANS: From that point of view, you need to know what happens if you happen to have that crack, for whatever reasons it is there.

MR. ALBRECHT: You are referring to the crack data. There are two parts of that. The outline -- there, under the stochastic inputs for the initial flaw size and the crack detection probability, you need to know these two things. The information on distribution on what is the probability of

546 195

detecting a crack, given that it exists, information of that type is being developed by the program that we have at PNL, and Chuck will speak about later on.

Now, information on what is the initial flaw size distribution within a component after fabrication, such information -- there is very little available on that.

Other aspects which I think are extremely important in this program is -- take, for example, the Duane Arnold crack, in which the calculations show, based on the information of the material property information that we have, that that crack was stable under the that it existed.

We can think of the problem, working, if you so like, from the final crack on backwards. Mathematically, we can reverse the model, so we can look at the largest cracks, that it's so stable. Then, using the models of corrosion fatigue crack growth, we can integrate backward and see from the crack, how long does it take, how many years of operation or weeks or whatever it takes to bring that crack back to the point where it just breaks with the wall where the leak begins. And then we can continue to calculate back, how many years of operation would it take to make the crack smaller and smaller.

So we get, in this manner, an estimate of the life from any initial crack size to a leak, and also to that crack size for which final instability will occur. And it allows us to impose the effects of in-service inspection and also of leak detection in the system. We can make statements at the end about relative probabilities of getting a leak versus a break, relative effect of in-service inspections on probabilities of failure.

MR. BENDER: But it is based on an anticipated set of phenomena that cause crack propagation. At the moment, fatigue, I would think, is the premise. But corrosion-assisted fatigue is not yet in this set of data, as I understand it.

MR. ALBRECHT: The material properties that we are measuring are for crack growth in a PWR environment.

MR. BENDER: Corrosion fatigue, if you wish, yes. And in a PWR environment. But which environment? I mean, just the fact that it is water and it has a certain pH so it doesn't necessarily mean that it is an environment which causes corrosion fatigue.

MR. SERPAN: It gets back to the first question that we haggled with, and that is, do we have the most severe environment going. And I don't know the answer to that. We get back to the pH. I think so, but I don't know.

I don't want you to think that this is the first time that -- that this is a novel discussion for us. We have talked about stress corrosion cracking, the influence of it, in the branch many times. We have struggled with it, trying to figure out what to do.

Where we get hung up is that the code has rules for design which will prevent stress corrosion cracking kinds of things. There is a reg guide out which talks about prevention of sensitization in stainless steel. There are rules for how you fit up the plants so that you don't induce all kinds of extra stresses.

If the rules that were in place were followed, most of these cracks, if not all of them, for that matter, probably wouldn't occur. So I find myself in a quandary knowing what it is that we should try to do, when we know a lot of the things that are out there that are calling these cracks, and if they weren't done in the fabrication of a plant or the fabrication of materials, the cracks wouldn't be there.

So we can study and say, this is the range of variables of oxygen, of pH, of carbon content, of chrome or whatever, and the heat treatment. But if it is not done, then what good does it do you? It is still going to happen in the plant. That is the frustration that we feel.

DR. SHEWMON: We haven't even got a regulation that speaks to oxygen content in water yet.

MR. SERPAN: It is well known.

DR. SHEWMON: It's well known, but the NRC doesn't know it yet in the form of its regulations.

MR. SERPAN: That may be.

DR. SHEWMON: I am not sure the problem is just the people who make the plants.

MR. SERPAN: My frustration is that I know the oxygen concentration and the reg staff knows the oxygen concentration --

DR. SHEWMON: No, they don't. They can't write a reg. It wasn't even in the first reg they put out. The only thing they put out was chlorine. It got bounced. And now they are considering to see if they know oxygen has an effect.

You go look and find out who's writing that reg and whose desk it's stuck on.

MR. SERPAN: I don't know.

(Slide.)

Very quickly, this talks about the material properties that we are getting from the piping steels. We have already talked about that. We are getting the crack growth rates in the PWR environment, reactor-grade water and getting J-R curves at room temperature and 350 degrees Fahrenheit.

Naval Research Laboratory and Naval Research Development Center in Annapolis.

DR. ZUDANS: The pressure is what?

MR. SERPAN: 2100 psi.

(Slide.)

The last topic in the piping has to do with the determination of the flaw size and the reliability of ultrasonic inspection. This is under way at Battelle Northwest, the purpose of which is to determine the reliability of ultrasonic NDE applied to primary systems, primary systems, and its impact

nte 6

on fracture mechanics analysis.

The objectives are: to prepare plate and pipe samples containing service-induced type flaws fabricated from A106, A516, type 304 SS and SA 351 steels; determine the significance of flaw roughness aspect ratio and flaw depth on detection; and, using those variables and the flaw location, tightness, geometry, orientation, and the inspection team who made the inspection as a variable, and then try to determine the probability of detecting given flaws in piping systems.

DR. ZUDANS: Last November, when you made presentations, I thought there was discussion of an instrument that was being made, that would cost about $100, that you could go into the field and do the crack detection testing. Was that the instrument for in-service inspection?

MR. SERPAN: That doesn't ring a bell.

DR. ZUDANS: Doesn't ring a bell?

MR. SERPAN: No.

DR. ZUDANS: Someone was developing this.

DR. SHEWMON: That was for whether or not stainless steel was sensitized.

DR. ZUDANS: That was one of the instruments.

DR. SHEWMON: That was the only one I heard of.

MR. SERPAN: Any questions on this?

MR. BENDER: This UT program has been going on for some time.

546 200

nte 7

MR. SERPAN: This is a new program.

MR. BENDER: But other people have pursued it, maybe not in piping, but probably in piping, too.

Are you doing this because you think you are about at the point of having a technique that is useable?

MR. SERPAN: You mean an ultrasonic technique?

MR. BENDER: Yes.

MR. SERPAN: This program will actually be looking at current techniques as well as advanced techniques. We don't have a good number on reliability of NDE detection using current techniques, and this will give us that reliability number. And then we will go on with the same kinds of flaws, the same samples, and come up with improved -- use of the improved NDE techniques.

MR. BENDER: This is really just an attempt to assess--

MR. SERPAN: Quantify where we are.

MR. BENDER: -- adequacy of the current -- that is the wrong term -- to determine just how good the current technique is.

MR. SERPAN: Yes, sir; and then try to improve it.

MR. BENDER: Fine. Probably a good idea.

MR. SERPAN: Any other questions.

DR. SHEWMON: Where is that on your budget? You say that is at PNL?

MR. SERPAN: Yes.

DR. SHEWMON: There is nothing from PNL -- it must be one of the undesignated --

MR. SERPAN: No, integrate NDE and fracture mechanics. It is the fifth from the bottom on the nondestructive.

DR. SHEWMON: You now skipped over to the nondestructive?

MR. SERPAN: That is nondestructive, but we put it in because this particular program will be feeding in the flaw detection reliability and the flaw size estimates into this program, into the overall piping program. I guess I didn't explain that. We are getting that input from that program.

(Slide.)

Moving into the second area of the overall branch program of irradiation effects on dosimetry, the purpose of this subtask area is to establish valid irradiation effects trends and methods to predict fluence and embrittlement in reactors. General objectives are listed, and I will go into a more detailed discussion on the dosimetry aspects at the end. The more metallurgically oriented things are to establish the ductile shelf toughness of weld metals, primarily the B&W irradiated at Oak Ridge; reevaluate the 10 CFR 50 rules on CHARPY-V's 50 foot-pound toughness criteria that will come directly out of that effort; support fracture mechanics technologies and crack arrest and crack growth rate; establish criteria for cyclic irradiation and annealing of pressure

546 202

vessels.

And then the last two is, to validate pressure vessel surveillance dosimetry procedures and evaluate the validity of embrittlemen saturation. The last two I will talk in more detail about.

Any questions on the first, the top ones?

(No response.)

DR. SHEWMON: What does the second one mean? Is that alternate criteria for licensing, in case you don't have 50 foot-pounds?

MR. SERPAN: Yes, but primarily to find out what CHARPY-V 50 foot-pounds means with regard to a fracture toughness number. Right now the correlation is not good. The licensing staff needs to have that cleaned up a lot. If we have these weld metals with a low shelf toughness -- that is, 50 foot-pounds or below -- we must determine what that really means in toughness in full-section material.

So we have four inch thick compact tension specimens with that same kind of weld metal, and they will be irradiated to give us approximately the equivalent of a CHARPY-V 50 foot-pound. So we can break the CHARPYs, find out that they are essentially 50 foot-pounds, and then determine what the equivalent real fracture toughness is.

DR. SHEWMON: This is a "J"?

MR. SERPAN: Yes, using the J-R curve techniques.

nte 10

This will be elevated temperature. This is not linear elastic. It will be ductile shelf maximum toughness. When we have the toughness number, we can go back to a vessel analysis and determine if that is sufficient toughness for safety under thermal shock or any kind of accident.

DR. WECHSLER: Why was 50 foot-pounds chosen as the criterion?

MR. SERPAN: That is in the Code of Federal Regulations.

DR. WECHSLER: Why?

DR. SHEWMON: Don't ask us why; it's our policy.

(Laughter.)

MR. SERPAN: There were a lot of reasons, and it was, I guess, as much a compromise as anything else.

DR. WECHSLER: Somewhat arbitrary, then?

MR. SERPAN: Somewhat arbitrary. But that went in in the early 70s. I think it has gone back to 30 now, because the shelf drops can get to 50 and below, and if your criterion is 50 then you have no idea what the shift is from a legal standpoint. So we have gone back to 50.

e-5

(Slide.)

MR. SERPAN: I will talk now about the dosimetry program. I think perhaps I will start with this, which is -- I think it is one viewgraph over. The entire dosimetry program is trying to update dosimetry and embrittlement projections

546 204

for pressure vessel surveillance, and this is probably as good a way to talk about it.

What we expect to come out of this is a series of standards, and these are the titles of standard procedures and standard methods. Up at top is probably the big umbrella for the whole thing, which is analysis and interpretation of nuclear reactor surveillance results. It is a brand-new practice. We still have to write it yet.

Then we have these four at the top, which probably cover the main areas: surveillance tests for nuclear reactor vessels, exactly what you put into the surveillance capsule, the specimens as well as the dosimeters.

Surveillance dosimetry extrapolation. Once you have the dosimetry, how you actually extrapolate it from your measurement point to inside the pressure vessel.

Displaced atoms, DPA exposure unit. The concept of flux or fluence greater than one Mev has been show to be not accurate enough. We think that displacement per atom is a better one. This will be a procedure for how you actually calculate that and use it.

DR. SHEWMON: Since no one can measure a displacement per atom, why do you pick that somewhat -- you figure it is better than what you have now, even though it is unmeasurable?

MR. SERPAN: Yes. It comes from some theoretical work on the knock-ons of the atoms. It has been correlated and been shown to work quite well in fast reactor work. And we are bringing it into line for a slightly different spectrum for the light water reactor. It seems to correlate better.

DR. SHEWMON: It is purely an empirical correlation?

MR. SERPANS: Yes, you can't measure it.

And the last one on the top right is damage correlation. That gets to the correlation of the embrittlement between a power reactor and a test reactor.

The others below that are much more detailed, the methods to how to get to the others, and I am not sure it is necessary to talk about those today.

The actual calculation, the transport methods, for example, the spectrum unfolding methods, updated cross-sections, damage monitors and so forth -- this gives you an overall --

MR. BENDER: What are we using right now, Chuck?

MR. SERPAN: What are we using right now?

MR. BENDER: What you have here suggests that we don't have much.

MR. SERPAN: That's right. What we have now is 1-B up here, surveillance tests for nuclear reactors. Those are ASTM practices 185 and 184. That tells you specimens to put in and dosimeters to put in. 560 is a first cut at how to extrapolate surveillance dosimetry. It needs considerably more work.

So what you are seeing here is the fact that we have a dirth of information as to how to do this as far as standards and guides are concerned. It is being done and there are other ASTM standards that help. But the reason for starting this whole program was the errors were not acceptable, they were higher than we wanted, but the procedures were not standardized amongst all of the vendors.

DR. SHEWMON: Errors detected how? And what errors? You said the errors were unacceptable.

MR. SERPAN: Measured versus calculated on dosimetry.

DR. SHEWMON: That gets down to 10-D, or did you have some experiments on 1-C?

MR. SERPAN: On 1-C? Well, I don't know how they calculate those errors, I really don't. I know that there are errors in there. They put plus or minus 30 percent on them right now, a great deal of them. I can't tell you how they calculate those errors.

MR. BENDER: Where in the life of a vessel would it be urgent to have these procedures in place? It is obviously not urgent today, because you don't have them.

MR. SERPAN: Closer to the end of the life.

MR. BENDER: The last 5 years of a 40-year life, or the last 10 years of a 20-year life? I am not sure what the number is.

MR. SERPAN: Part of the urgency for this program is that the low shelf weld metals are dropping fast enough, that there is concern about the toughness of those materials, and the licensing staff would like to have this information within a year or two, because they want to be able to evaluate those pressure vessels based on the surveillance data with a lot more accuracy than we can right now.

MR. BENDER: That is the immediate urgency?

MR. SERPAN: Yes, sir.

MR. BENDER: Further on down the road, what will be the urgency?

MR. SERPAN: Further down the line, I would say the last third of a vessel's life, ordinarily the last third of its life.

MR. BENDER: Thank you.

(Slide.)

MR. SERPAN: The three programs that we have in place on the irradiation effects and surveillance dosimetry are at HEDL, Oak Ridge and NBS. The general scope of work for the HEDL work is shown here. They perform flux and spectrum calculations of surveillance locations and other reactor locations. They assemble, irradiate and count the very carefully selected neutron flux monitors which were irradiated in those reactors.

They formulate models for radiation damage and development of predictive damage functions, and they write standards for measuring and interpreting neutron flux spectrum and embrittlement. Again, these are simple, but that scopes what they do.

Oak Ridge, on the other hand, is concerned with the hardware part, the large hardware part of this program. They are constructing and operating two benchmark facilities, one of which is for direct spectrometry of the neutron spectrum and for dosimetry and embrittlement, which is the PSF. The direct spectrometry is called the PCA. It is pool-critical assembly.

The PSF is pool side facility, which is a dosimetry experiment. I will show a picture of that in a minute.

And then Oak Ridge is deeply involved in writing of a standard method for the transport theory of flux spectrum calculations. Transport theory turns out to be the basis for most of what we plan to do and what most people are doing for the spectrum calculations.

Bureau of Standards provides unique and valuable service for standardization for all of the laboratories involved in this work. They make what amount to absolute flux measurements in benchmark test facilities. They have a clever system for getting absolute measurements of the flux in facilities. I don't know if I have a picture to show that. I guess I don't.

What I would like to show you --

D SHEWMON: Before you take that off, can you tell me what the funding is for the last two items for HEDL?

MR. SERPAN: HEDL is, overall, about 500,000. And the last two are about 125,000 of that.

DR. SHEWMON: That is not much, but they have been doing it for ten years, and I don't know -- ten years ago they were doing it. Nichikowa was doing it instead of somebody else.

MR. SERPAN: That line is the people working on the DPA and getting DPA validated for light water reactors.

DR. SHEWMON: Validated, whatever that means. And isn't it entirely a calculation procedure that nobody can check?

MR. SERPAN: It has to be, that's true.

DR. SHEWMON: I hope it doesn't go on for another ten years.

MR. SERPAN: It will not.

(Slide.)

To give you an idea of some of the laboratories and some of the facilities that are involved in this, we have three primary areas that are at work here. The first one is the benchmark in callibration, the second one is the benchmarks for transport calculation validation, and the third one appears on the next viewgraph.

But we have facilities for the callibration benchmark at NBS. The 252 Californium, U-235 fission, there is another U-235 at CEN/SCK in Belgium. We have a great deal of input from Belgium.

We have another standard at NBS, and the CMR CRMF facility at Idaho.

The transport calculation benchmarks include the iron shells in Belgium and the PCA at Oak Ridge. The test fields in reactors that we are using include the BSR at Oak Ridge, the light water and heavy water test reactors at KFA-Julich in Germany, University of Buffalo test reactor, University of Virginia test reactor, BR-3 small power reactor, Arkansas Power & Light No. 1, Garigliano in Italy, Brown's Ferry 3 and McGuire 1.

So we have radiations in the core, in the cavity, or wherever, in all of these different facilities.

The primary test facility that we have, wherein we think that we will get it all together, as it were, in this piece of work is this experiment at Oak Ridge. This is the PSF experiment. The reactor core will have a mockup of a thermal shield, and this is an eight-inch thick pressure vessel wall, and it is almost three feet square.

This chunk right here is an experimental capsule that has -- that is filled with test specimens. In this case, it's half-thickness compact tensile specimens, CHARPY-V and a myriad of small specimens; transmission electron microscopes, specimens of pure alloys of pure iron and carefully controlled alloys for irradiation damage work.

They are located at the pressure vessel surface at one-quarter thickness and the half thickness. They are lined in there in a bunch, and when this thing is irradiated they see the same neutron flux and spectrum as if that were pressure vessel walls at the quarter thickness. Of course, the advantage is that we can pull it out and test that material.

The experiment is also loaded with neutron flux monitors, so that we will know exactly what the neutron flux is at all of these locations. We will put in capsules at accelerated surveillance locations so we can pretend that we have a real power reactor surveillance irradiation here and make the comparison between the surveillance location and the pressure vessel wall.

This is the embrittlement experiment. There is one very similar to it, which is nothing but the PCA experiment, which is nothing but dosimetry. And here we have spectrometry ongoing, about five to six times more dosimetry. And this is where we are literally proving the calculational method versus the measurements.

MR. BENDER: The flux gradients that you are trying to model here, are they supposed to be representative of a number of kinds of reactor systems or just one specific one?

MR. SERPAN: We are trying to make it look like a generalized light water reactor, power reactor pressure vessel. And we are struggling with that, because if we really make it look like a power reactor, then we have to radiate the thing for ten years. We're doing a lot of scoping studies to determine

nte 19

how close we can bunch this thing up, literally, so that we can prove the flux but not destroy the spectrum aspects that you would get. And it is amazing how much variation that one has in there, and still have not -- don't significantly change the spectrum from a power reactor. So we are doing those studies in this PCA experiment now, and before the end of this month I will have to have a meeting with the licensing staff with the data that we have got and make a decision as to how we are going to go on this thing.

We are faced with going, irradiating for two years in order to get closer to our objective. Since we started this program --

MR. BENDER: Excuse me for interrupting. It is two years for what kind of reactor system? Is that for a PWR or a BWR? For a PWR or a BWR, it would be 20 times that two years; is that what you are saying?

MR. SERPAN: Yes, that's right.

MR. BENDER: It is really directed to PWR systems more than anything else?

e-6

MR. SERPAN: Yes, it is.

MR. SERPAN: The last topic has to do with embrittlement saturation. This is a topic that has come to the fore lately. Westinghouse came up with the evidence about a year ago that suggested that at a fairly low fluence, below 10^{19}, that embrittlement might very well saturate in power reactors. And you could go for very high fluence and not expect to see any more embrittlement.

EPRI was fortunate to get on the bandwagon on that one, and they managed to put together a very nice program of collecting about 10 surveillance capsules from the wide variety of power reactors, which the fluence from these was all down in the low range, where one would want to determine where one could see if the saturation effect were working.

They have started the program to measure the embrittlement from these 10 low-flux surveillance radiations and we have gotten into that, where we are going to be assist- EPRI in this in determining the flux and spectrum part.

EPRI is going to be concentrating mostly on the embrittlement, and we are going to provide as much assistance as we can to be sure that the dosimetry is as accurate as we can make it now. So those two tops lines then represent --

DR. SHEWMON: When EPRI has the stuff that has been in place for some time --

MR. SERPAN: Yes.

DR. SHEWMON: -- HEDL will put surveillance capsules back in?

MR. SERPAN: No, the capsules will be pulled as part of the program. EPRI is going to do the mechanical property testing, and they will have charge of the overall program that HEDL is going to participate with the dosimetry from the dose capsules to be sure we get the best possible dosimetry.

Then independent work -- NRL is going to begin a low-flux irradiation in a rest reactor with reference materials, so when we get the answer out, we have a far better idea of where the embrittlement is going because we will have a great deal of other irradiation data.

Most of the irradiation -- most of the steel in the surveillance capsules is from the reactors themselves, and you don't really have a good idea of what the trend is for that material. You can guess what it is, but NRL is going to be using reference materials where we have a great deal of information so that when we get a result, we will know whether it is saturated or whether it is --

DR. SHEWMON: "Reference" means it was studied before, or there are special alloys?

MR. SERPAN: It doesn't mean that it's anything particularly special. It means we have done a lot of work on it like the HSST-type UO_2. It has been irradiated all over the world, many many times, so that we have a good feel for how that responds to neutron irradiation. That is what we mean by a "reference material."

DR. SHEWMON: "Low-flux" means you take it out in 10 years or seven?

MR. SERPAN: They will take it to a low-flux, which is going to be probably at the high end of the low-flux, but we will see to it that it is within the regime that is considered to be low-flux.

KFA-Julich is also involved with the experimental irradiations in high- and low-flux reactor positions, working on the embrittlement saturation effect.

We have proposed now, and it will come up at the very end of this thing -- we are proposing to begin a really long-term reference steel irradiation in a power reactor surveillance position, literally something like 10 years, and to rebuild a surveillance capsule, but with reference material so that we will know -- we will be able to predict them better and put it in for 10 years.

We don't have the funding for it, but we think this is something that should be done.

DR. SHEWMON: If I look at the budget item here, you have the NRL going up, I guess, the next two years, somewhat faster than inflation in '81, and the HADL going up at somewhat the same rate, and the Oak Ridge program winding down.

Would you comment on what will be going on in each of those to reflect those trends?

jl 4

MR. SERPAN: The primary reason that Oak Ridge is going down so much is that they are running the test experiment, the irradiation that is the biggest thing that they are doing. So that irradiation is going to be conducted in '81 and just into '82, So once that is done, that will essentially take care of Oak Ridge, because then the testing of those specimens is going to be done at NRL. We have to put an increase in the money in NRL to pick up that testing.

HEDL has just --

DR. SHEWMON: You said it was being irradiated to 50. The increase in '81 is to help you get ready to do the testing in '82?

MR. SERPAN: I had originally thought -- as of last week, I honestly thought that we would irradiate for one year in fiscal '81 and the testing would start in '82 then -- to get started in '82. Now, we may even go longer. We have other things for NRL that we would like to have them do. It is not just the testing of this, of the irradiated dosimetry work.

MR. ETHERINGTON: The B&W capsule recently withdrawn from Three Mile Island showed a much higher fluence than calculated. B&W explains this away on core configuration.

Is NRC satisfied with this?

DR. SHEWMON: It was Fort Calhoun.

MR. ETHERINGTON: Excuse me.

546 217

MR. SERPAN: Yes, I saw that data, and I do not know the answer to that. I just don't.

DR. SHEWMON: One of the notes that I saw on that said that they would have -- Combustion, I think it was, was going to have a new calculation in July, which was the code that they use now, which they thought would do a much better job of that.

And when the Combustion individual gets here, I hope -- this is a memo from Quittschreiber, and Combustion stated their early codes did not have all of the features of their present codes.

When they perform the calculation, using their present code, PDM, and a bunch of numbers, SHADRACK, they expect the prediction will be much closer than calculated. They expect it to be completed in June. You have not followed this?

MR. SERPAN: I got the original input that it happened, but I haven't received anything else on it, no.

MR. ETHERINGTON: That doesn't give much consolation. It seems to indicate that the fluence are higher than have been calculated in general.

DR SHEWMON: This was two and a half to three times.

MR. SERPAN: I think we have probably seen it for the last 10 years; as long as I have been in this business, we have seen that the actual measurements that we get out seem to come higher than the calculations. I am sorry to see that, but I am not surprised by it. It has happened before.

What we hope -- and I really think will happen from this dosimetry program that we are running is that we can really significantly minimize those kinds of errors in the future, because we will have a good calculational benchmark against which all of the codes used by anybody -- and they can really check out their codes and see if they are accurate, because we really have the measurements in the places, in the kinds of environment that one is calculating.

I think we are going to make an improvement in the dosimetry with this program. In fact, I should say that there are enough studies and measurements that have been done in the PCA now that I think we are ready to make that kind of a step change.

What we have organized, or what we are organizing right now is a blind comparison of that PCA experiment. We have sent out a flyer to everybody in the world really who is interested in it. We will provide them with the input data. That can calculate that PCA and send in their answers.

Next February, I think, at NBS, we are convening a workshop where they are all going to come sit down, get the answers and find out how they did with it. By next February it is going to be there as to how they do it.

MR. ETHERINGTON: It looks as that we maybe should look more critically at the proposals to leave out thermal shields in reactors.

MR. SERPAN: We definitely should. I would not recommend that you leave out any thermal shields for awhile.

MR. ETHERINGTON: It is being proposed.

DR. SHEWMON: Can you comment on that? Is there likely to be someone here from DSS that can in the future?

VOICE: Yes, at 11:30.

DR. SHEWMON: The schedule calls for them to start talking at 11:30. I hope they make it.

DR. SHEWMON: Let's take a break and come back at 10:30. Two hours is enough. .

(Recess.)

(Slide.)

MR. SERPAN: The third area has to do with steam generator tube integrity and stress corrosion to develop an understanding of integrity and mechanisms of degradation of steam generators and steam generator tubing.

Furthermore, it is to develop an NPC capability to evaluate stress corrosion cracking in reactor materials. The objectives of the work that we have are to develop a prediction for the margin to failure under burst and collapse pressures of degraded steam generator tubes.

This work essentially has been done with machine flaws, and we are working on getting a rule through the

Licensing Staff right now; second, to develop a predictive capability for prediction of stress corrosion cracking of steam generator tubes. This is underway at Brookhaven, and is looking at a range of parameters so that you can try to predict, based on the environment within a steam generator, if you are going to have cracking. That work still has several years to go.

Third, to determine the degradation patterns and mechanisms in a retired steam generator. And I will talk at a little more length about that.

And finally, develop methods and criteria for evaluation of intergranular stress corrosiion cracking in BWR stainless steel piping and stress corrosion cracking in ferritic steel piping.

And as you requested, I will talk some more about that.

DR. SHEWMON: Is the main problem with the -- you talk only about stress corrosion cracking here. Is that the main concern or the mechanism for the fracture of piping in steam generators?

MR. SERPAN: No -- I see, you are talking about the second line here.

DR. SHEWMON: It shows up in the first objective, and it shows up in the second objective.

MR. SERPAN: A great deal of it, to the best of my j1 9

knowledge -- yes, a great deal of it is that cracks that come about, corrosion cracking. It is true there is wastage.

But as far as cracks are concerned, I'm not sure there is any other kind of crack but stress corrosion cracking.

DR. SHEWMON: Venting gives rise to stress corrosion cracking?

MR. SERPAN: Yes.

DR. SHEWMON: Are we talking about cracking in the plates, or --

MR. SERPAN: Primarily in the tubes, which is the upper band areas, and also around the bends.

DR. SHEWMON: I am glad we are talking about it only in the tube, because I guessed what --

MR. ETHERINGTON: A failure in the tube is due to the tube being pushed together as a result of the corrosion problems affecting the tube support plates. So ordinarily -- the normal stress -- you wouldn't expect these problems.

Are we addressing a problem that resulted from the general failure of the tube support plates that we would not expect in a resdesigned steam generator tube?

MR. SERPAN: I had my blinders on. I was talking about the first two programs, which we are just concentrating on the tubes themselves.

The latter program here, the third one, where we are

546 222

talking about retired steam generators, in those programs we will be looking at everything, the tubes and the support plates. We will be trying to find out what has happened to the support plates and why they have gotten that way and what the problem is and try to come with reasons as to how that can be prevented.

MR. ETHERINGTON: I undertand that, but I am getting back to my real question: Is there a problem of stress corrosion in the steam generator tubing? Has there been any that has not been caused by the tube sheet problem, the support plate problem?

DR. BERRY: The initial problems were with the tube sheet on top of the tube sheet.

MR. ETHERINGTON: On top of the tube sheet.

DR. BERRY: Particularly in the NBT, where you have a little bit of phosphate and some fresh water in the system. The calcium combines with the water, precipitates, and leaves free sodium behind and then causes caustic stress corrosion.

There have been some studies --

MR. ETHERINGTON: I guess that is stress corrosion anyhow. The troubles of the U-bends have been the more common. The mechanical, primarily in origin.

DR. BERRY: That starts on the primary side. What we're talking about is on the secondary side.

MR. ETHERINGTON: Right.

jl 11

DR. SHEWMON: It is still not clear to me that on the first two of those we are talking about a problem in future or even current steam generators.

MR. SERPAN: The first two programs are in direct response to requests we have had from the Licensing Staff. The first one --

DR. SHEWMON: May we see the letters? When were they dated?

MR. SERPAN: Several years ago.

The first one --

DR. SHEWMON: Once you have a letter, it is good for eternity?

MR. SERPAN: Well, it is good to solve that problem.

DR. SHEWMON: But the industry has already solved the problem if they have plugged those inner tubes and don't run fresh water through their secondary -- through the condensors any more.

MR. SERPAN: The first program was to get the data base in place for how -- for simply the integrity of tubes that had flaws in them. It doesn't matter how they got there. The Licensing Staff -- and actually it was the Licensing Board that went back to Pr Island, I believe. They were unsatisfied with the data base that the Staff had for predicting failure tubes.

DR. SHEWMON: They had been working on that one for j1 12

a couple of years.

MR. SERPAN: That first one -- yes, about two or three years, and the initial part of that work is done, as I said, with machine flaws. We want to validate that with real flaws.

DR. SHEWMON: No, we want to predict a capability --

MR. SERPAN: It is a small program. The second one is quite a small program at Brookhaven, that the Licensing Staff, again, asked us to do.

DR. SHEWMON: Could we see letters for that?

MR. SERPAN: Surely.

DR. SHEWMON: I am sorry that no one from Jim Knight's shop is here to talk about that, but I feel particularly --

VOICE: The user's request came out of DOR.

DR. SHEWMON: Is that where Noonan comes from?

MR. SERPAN: Wait -- I guess that was.

DR. SHEWMON: We should have has someone here to talk about how this interface goes.

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MR. BENDER: The first one is directed at the tube wastage problem.

MR. SERPAN: Cracks and wastage.

DR. SHEWMON: The vendors have pulled a few hundred, and the Board wanted a few thousand.

Corten made a comment that they hadn't learned any fracture mechanics the way they followed them. I am sorry he is not here to talk with you.

You have a copy of the letter.

MR. SERPER: There was a totally inadequate data base to be able to predict the failure of a steam generator tube, given a flaw in it. The Board simply was not happy with it, and said:

"Either find out what the integrity of the tubes is, or we will shut down the steam generator."

So we mounted this program to look at the range of flaw sizes and wastage, depths of wastage and extent of wastage, to determine how much pressure it could take as a function of the eddy current indication and that has been done.

In a nutshell, I guess what that does is very well validate the criteria that the Licensing Staff has been using, of the plugging between 40 and 60 percent when you have an indication -- eddy current indication between 40 and 60 percent you have to plug.

The data show, in general, that the flaws will not burst. The tube retains it integrity up to 60 percent of flaw depth -- indicated flaw depth. It is like about 4000 pounds -- 4- to 5000 pounds. It will withstand up to 60 percent degradation.

DR. ZUDANS: 60 percent of wall thickness.

MR. BENDER: For some reason or other, the statements you are making are too simplistic to satisfy my --

MR. SERPAN: I said "in general," but that is in general what we have come up with out of this test program.

MR. BENDER: That is what the Staff's regulatory basis is right now. It seems to me that it would have to be correlated with the kind of flaw and a few things like that.

MR. SERPAN: Yes, we have sharp cracks and we have wastage kinds of defects. And it is correlated with that, but they all tend to fall pretty much as I have said.

DR. SHEWMON: Is Mascar still in your shop? Where is he today.

MR. SERPAN: He's in the hospital. Somthing is wrong with his back, and they haven't figured out what it is. He is in terrible pain -- a slipped or ruptured disc. He is in the hospital; otherwise he would have been here. He has been out for almost a month, and I don't know when I am going to see him again.

DR. BERRY: Are you attempting to predict, based on composition of the primary coolant?

MR. SERPAN: That is one factor.

DR. BERRY: Based on highly sensitive --

MR. SERPAN: Trying to use a highly sensitive heat as an accelerated test and then use other normal heats, the kinds that we usually find, as controls on each other, but looking at water chemistry factors, pH, temperature, and also the material.

(Slide.)

I want to talk about the degraded steam generator program. We are at the point of trying to get the steam generator moved and quickly.

Where we are on that is that the feasibility study for acquiring, shipping, and housing this Surry 2 steam generator has been completed, and it is shown to be quite feasible to do this.

A conceptual design study for the facility is underway. We expect it to be complete by the end of this fiscal year.

Arrangements for the shipping are underway; and now, since this has taken so long, well, it looks like we will start the shipment in about November. We had tried to do it in about September, and construction of the facility should start in May of 1980. And we hope it will be completed in February of 1981.

It has been concluded that we can barge that steam generator from Newport News, through the Gulf, through the Panama Canal, and up to Richland. And the studies that have been conducted show that it probably makes most sense to put this facility at Richland, and PNL will be the contractor on it.

Once it gets there, the research program that we have planned, in that we have still got to get through the Licensing Staff and make sure they are happy with it, is in general as follows:

We want to start nondestructive examination research.

DR. SHEWMON: Let's stop a minute.

In getting it through the Licensing Staff, is that DOR?

MR. SERPAN: That is primarily DOR. They sent us their request in the first place.

DR. SHEWMON: Are either of you from DOR?

VOICE: DSS.

(Slide.)

MR. SERPAN: As soon as we get the steam generator too Hanford, we will begin nondestructive examination and steam generation tube characterization studies. We are going to get a baseline on the whole generator with current -- eddy current techniques, as well as advanced eddy current techniques.

That we can do while the steam generator is in storage and the overall research facility is being built. And we hope to start the research program in March of 1981. And the kinds of things that we have outlined to do are listed here: validation of improved nondestructive examination techniques and development of improved test methods -- this is primarily eddy current kinds of things for the tube inspection;

jl 17

development and validation of improved statistical models for in-service inspection sampling plans; development and validation of tube-plugging criteria; visual, chemical and metallurgical characterization of degradation and degradation products on the tubes, on the support plates, and inside the generator; determination of causative degradation parameters; improvement in mechanical thermohydraulic design and water chemistry; validation of the tube burst, collapse, and leak rate; predictive models for service-degraded tubes by pulling the tubes out and testing them; validation of the predictive models for stress corrosion cracking of steam generator tubes from the Brookhaven program; and validation of chemical cleaning, decontamination process use and procedures, confirmation of mechanical integrity following such treatments, and determination of long-term effects such as crevice corrosion and so forth that you might -- that might happen as a result of decontamination.

Obviously, it is a brief outline, but it is the kinds of things that we intend to work on.

MR. BENDER: With regard to the last item, is the frame of reference the work at Dresden?

MR. SERPAN: That is one of the things, yes.

MR. BENDER: What else might be available besides that?

MR. SERPAN: DOE has some programs in that. I guess

Dresden is part of it. I am not sure what other reactor they have going.

DR. SHEWMON: Dresden is their BWR; Indian Point 1 is their PWR.

MR. SERPAN: We would take advantage of that, whatever information comes from that.

MR. BENDER: In the light of Three Mile Island and the possibility of reactivating that plant at some time, how do you view the urgency of that last item?

MR. SERPAN: It could be a very, very significant facility in capability for learning how to contaminate something like Three Mile Island. I am afraid that this might come along after Three Mile Island were ready to go back up.

MR. BENDER: I don't know what we are doing, but this particular area has sort of been on the back burner for awhile. It has been going on; industry has been pursuing it some. I think the NRC has had a very passive position on it.

The cleaning and decontamination area, particularly as it effects the primary coolant system -- it looks to me like you ought to be thinking about the urgency of moving that program along in some way. And my intuitive judgment is that it is still on the back burner and not much is being done to accelerate it.

MR. SERPAN: I guess it would look that way, but we have been trying to get the steam generator moved from Surry to

Hanford this Spring as hard as we can; and it has just been a terrible job to get it, that's all.

DR. SHEWMON: But let's go back. Certainly with the reject steam generator bumped 3000 miles isn't the only way you can study cleaning of power plants.

MR. SERPAN: That's true.

MR. BENDER: I guess that is sort of what the point is. It looks to me like this is sort of the back doorway to get there. I wonder whether just putting that in in that place suggests that maybe there ought to be some broader effort to address the subject.

MR. SERPAN: It was put at the bottom of the list. It wasn't just an afterthought. We have a lot of other things we want to do with that steam generator before we can put on chemical cleaning or decontamination. We want to know where the crud is. We want to know what the crud is and how it was distributed.

We cannot go in there with chemical cleaning first thing,because of Three Mile Island, and expect to get any of the rest of it.

MR. BENDER: Is that the only steam generator that is available to you?

MR. SERPAN: No. There are six of them down there at Surry. We could have all six of them. I don't begin to have that kind of money in my budget.

MR. BENDER: I understand that you don't. We have to look at what things are important and what things are not important. And you judge some things important that may be relatively important, but not as important as some of the other things you could do if we think about what has come up in the last year.

MR. SERPAN: That's true.

DR. BERRY: The Three Mile Island is a different proposition of what you are dealing with at Surry. Surry -- you have wastage in the support plates. You shouldn't have that at Three Mile Island. It is relatively clean with respect to the corrosion product build-up.

MR. SERPAN: But it has sodium -- sodium hydroxide, and heaven knows what all else. It is a different kind of an animal.

DR. BERRY: The ramifications of the cleaning problem are quite different. You find out that you have no support plate left with Surry.

MR. SERPAN: There is another item that we have certainly thought about. There is the other item that when you do a treatment, what happens to it? Do you do more damage to the long-term integrity of that component by the chemical cleaning? If it is strong enough --

DR. SHEWMON: That has been a hobgoblin, whether it is a red herring or not. We seem to be able to do this for the

Navy in the United States and all of the reactors in Canada, but the NRC has great difficulty conceiving of it apparently for reactors on land in the United States.

MR. SERPAN: We haven't addressed it. That is all I can say.

MR. BENDER: My point is not so much challenge the desirability of doing things on a degraded steam generator. It is a good test specimen, and what you can get from it is useful; but there are not very many places where we can look at things like chemical cleaning and decontamination of critical components. Steam generator is one of the most important.

I think we ought to be thinking about whether -- because of what has come up in the last year, whether we ought to try to take advantage of that hardware to learn some more things.

DR. SHEWMON: What is BRG?

MR. SERPAN: Budget Review Group, the internal NRC review process on the budge.

DR. SHEWMON: This thing shows up on your budget under the PNL steam generator tube integrity test?

MR. SERPAN: Yes.

DR. SHEWMON: What would you guess '82 would be, relative to your '80 number?

MR. SERPAN: '82 is -- what do I have there? 1250.

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DR. SHEWMON: You don't have '82.

MR. SERPAN: For '81.

DR. SHEWMON: 1350?

MR. SERPAN: It is at least that, or 1500.

DR. SHEWMON: What sorts of things do you feel you couldn't do without this steam generator out of that list? All of those things are good things, and my reaction is that most all of them could be done in ways other than with that steam generator. But maybe that's too flip, so I want you to tell me what you think is most important with regard to using that particular test bed.

MR. SERPAN: I would have to mock up something to do the first couple of ones for improved NDE techniques; if I didn't have a steam generator, I would have to mock up one.

The reason for the third one, development of the tube-plugging criteria -- I could do that, but -- no, I can't.

DR. SHEWMON: That is what you have been working on for three years out there, isn't it?

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MR. SERPAN: I'm sorry. Yes, if you look at the integrity of the tubing from the standpoint of the integrity of the tubing. I was thinking from the standpoint of how many tubes are in there and what -- how many tubes are degraded and determining from the in-service inspection.

I'm sorry, I wasn't thinking right. That's right.

Tube plugging criteria I can probably get from elsewhere. I cannot get this one, because I have got to have real tubes from a real generator for that. So I have got to pull tubes out of some generator someplace and I need a lot of them.

DR. SHEWMON: You have been bursting tubes for years. Why can't you burst them, unless they have been in a steam generator?

MR. SERPAN: We have been bursting ones that have a machine flaw or machine wastage. That particular line talks about pulling our real tubes that have real dents, real cracks and real wastage, and validating what we have. We have always operated under the premise that we need to get as close as we can to the real thing to validate. That is why I have got to have the steam generator or a steam generator to get those tubes in order to do that job.

MR. BENDER: What kind of tubing is in those steam generators? Inconel? It is all inconel?

DR. SHEWMON: The vendors have been studying corrosion.

546 236

They have not corroded things big enough to do burst tests on, or what?

MR. SERPAN: Corrosion of the steam generator tubes?

DR. SHEWMON: Westinghouse, on their improved steam generator, has a special annealing treatment for their inconel that they have developed at considerable expense, to find out which ones are likely to give them the best life in probably the new Surry generators.

MR. SERPAN: One thing is corrosion rates, and then the other one is the integrity, given so much corrosion. And a lot of what we have been doing so far is to determine the actual integrity, given some kind of corrosion.

I am not familiar with what Westinghouse has done.

DR. SHEWMON: Who is? Is that Joe's shop, Joe Mascara, or who does follow it?

MR. SERPAN: We should -- if the information were available to us, we should follow it. We don't have it.

DR. SHEWMON: I got it at an international conference in Japan that Mascara attended, and they were talking about it in public there. So I doubt if it would be too hard to get it from Westinghouse.

MR. SERPAN: I wasn't familiar with it.

DR. BERRY: 700-degree Centigrade treatment, stress corrosion cracking. That is for stress corrosion cracking rather than overall wastage.

DR. SHEWMON: The concern here is some special kind of wastage that occurs in steam generators, in corrosion in steam generators, that can't be simulated in a laboratory.

MR. BENDER: There is a range of flaws of various types, and there is enough of them to give you statistical significance. That is what I interpret as being the intent of this program.

MR. SERPAN: That's right.

DR. SHEWMON: But it is a unique facility that has been kicked on the floor and bumped across the country and allowed to corrode in who knows what kind of humidity, for how many years, before you get at it. So the similarity between this and what is going to happen in 1983 in the steam generator in a real power plant, I guess I have difficulty with, is why --

MR. SERPAN: I don't think that is quite fair. It is not quite as bad as that. It is pretty carefully sealed up, and we are moving it by water because we don't want to bump it and we don't want to shake it up. We could have, conceivably, moved it overland, but that would shake things loose. So we are trying to be as careful with it as we can, so that when it gets to where it is going it is essentially in the same condition as when it came out.

These things were cut loose and plates were cut over them and they were closed up.

DR. SHEWMON: The other thing is, tnis has been abused worse than any other reactor in captivity, or steam generator. I hope people aren't abusing it that way now. But I can't really find anybody in the NRC who knows how they are controlling their chemistry, since you can't really learn. Since it is costing a hell of a lot of money to replace this thing, I can only assume that their self-interest is keeping the utilities from abusing them in this same way.

What you are going to get is the worst conceivable kind of -- or the worst available misabuse, and then go use it for decisions on different kinds of steam generators that have been treated in different ways and abused not near as much, and hope that it is relevant.

Maybe nobody can explain how it would be relevant. You have your opinion. We haven't got anybody else from NRC who can give an opinion on why they think it is going to be helpful, and thus my frustration.

Let me ask a different question. There was talk at one time of EPRI having an interest in joining you in this. Do they now?

MR. SERPAN: Yes. They have been expressing interest in it once we get it out. They have indicated that they would come in on the program at a fairly substantial rate.

DR. SHEWMON: And that individual, that is Martel's program?

MR. SERPAN: Yes.

MR. TUROVLIN: CE has done model boilers with tubes eight foot long.

DR. SHEWMON: To corrode them?

MR. TUROVLIN: To do their corrosion tests, controlling their water chemistry.

DR. SHEWMON: You wanted to make a comment on this area also? Why don't you come up and use the microphone? It would be easier for the reporter. Or use one there.

MR. TUROVLIN: I wanted to make a comment, and this is a personal comment --

DR. SHEWMON: Identify yourself.

MR. TUROVLIN: I want to make a comment personal, rather than for the branch. I have reviewed, sat in -- sat in on the review of the program for transporting the steam generator across country. I had reviewed the user's request, and my personal opinion is it is not worth the trouble.

When you move this steam generator across country on its side, you will so disturb the sludge deposit that any sampling you take afterwards will be highly suspect.

MR. ETHERINGTON: Won't most of the loose material have been removed in any case?

MR. TUROVLIN: I don't believe so. But if it has, of course, you change your experimental conditions. What you are trying to do, of course, is sample the sludge to see what the distribution is across the support plates.

MR. ETHERINGTON: And there is extensive decontamination just to reduce the personnel exposure, isn't there?

MR. SERPANS: Yes.

DR. BERRY: That is primary side.

DR. SHEWMON: Sludgel is secondary side and shouldn't be as radioactive.

MR. ETHERINGTON: You're only concerned with the plant side.

DR. SHEWMON: The radioactivity would be primarily on the primary side.

DR. BERRY: The sludge in the crevice areas is extremely hard and tenacious. You are bound to loosen up some of it, but by and large, that in the support plate crevice area is extremely difficult to reach. In fact, you have to chisel it, break it up.

MR. TUROVLIN: You are also moving the steam generator on its side, with the tubes unsupported along the side, and you do have support plates that are cracked around the periphery. Therefore, you really don't know at the end what the original condition was when the steam generator was in operation.

MR. BENDER: The fact it is not a perfect specimen doesn't necessarily invalidate the usefulness of it.

MR. TUROVLIN: My point is that it is far from perfect. But it is so imperfect that you can get most of this data by other means, without the radiation exposure.

MR. BENDER: What are the other means you are referring to?

MR. TUROVLIN: CE has done model boiler tests on eight-foot tubes where they have deposited sludge on their tubes and their support plates. You can get cracks that way and simulate your cracking.

MR. BENDER: If that were the only way in which the cracks were developed and you knew that was a good model, you certainly would probably prefer that. I think the question really is whether that is representative of all of the circumstances that might have to be evaluated.

DR. SHEWMON: Let me come back at this a different way. It seems to me I am at least getting confused on whether this is a research project to learn how to design better steam generators, which as I understand it is not the responsibility of the NRC, or whether we are here to develop criteria to help protect the public health and safety, which clearly is. And I guess in all of those things, they are interesting things we don't know, maybe.

But with regard to criteria for making sure that steam generators don't open up in a LOCA or something of that sort, I wonder whether it is worth the $4 or $5 million we are looking at over the next half-dozen years to go take it apart.

MR. SERPAN: The end result is to find out what has happened as a function of the operating conditions, so that one can tell whether it is going to open up.

DR. SHEWMON: You don't know the operating conditions, to my knowledge. I doubt if the utility knows what the operating conditions were, at least with regard to secondary water chemistry.

MR. SERPAN: We know in general the conditions in there. We do not know exactly the specific conditions, perhaps, minute by minute. But we certainly know the general conditions of what happened.

DR. SHEWMON: You do have -- I see the Surry people didn't seem to know how they had mistreated the first one, when we asked them about it, or how they were going to treat the second one better with regard to condenser leaks. Maybe the guy we talked to wasn't as communicative as who you can talk to.

DR. BERRY: It would seem to me it would be worth your while just to see that there is not a third or fourth mechanism that is going to sneak up on you in the future, that may be showing up in these steam generators. Every time something has happened, we change the water chemistry or the operating procedure or some other phenomena.

I think a post-test examination of this thing, hopefully, would reveal any of this type of thing that may be coming on that we are not aware of at this time. There may not be anything of that nature. But nonetheless, I would think that a detailed examination certainly is justified.

MR. BENDER: To support Dr. Berry's point, it seems to me the most useful thing in looking at this steam generator is to see flaws developing at every stage, perhaps to be able to see the whole spectrum of flaws that might exist in the steam generator.

Personally, I think it is a useful idea, even though it is costly to do it. I am not sure you have estimated the cost reasonably. It may be double what you are estimating, but we will see about that.

DR. SHEWMON: He very clearly hasn't presented any overall cost numbers, and that is probably why he is not doing that.

DR. ZUDANS: I wanted to agree with the comments of the previous two speakers and add one more thought, that while we don't precisely know what kind of an operating history this particular steam generator went through, one thing is clear: It was mistreated. So what you will find by dissecting it -- hopefully, you will find some new mechanisms, you will find some confirmation of mechanisms that you observed elsewnere.

And the only question that remains, how to treat it best so that you don't lose some information that is in the steam generator now. That is probably the question of how you ship it, how you handle it, whether you drop it once or twice or three times. That is important.

mte 10

MR. ETHERINGTON: The present chemistry is so totally different from the chemistry at which these same generators have been exposed, I am not sure that it is very meaningful.

DR. ZUDANS: Could we agree on one thing? Is the current chemistry less aggressive than the one that it has been exposed to?

MR. ETHERINGTON: AVT is supposed to be less aggressive.

DR. ZUDANS: In that case, you have a bounding case and you can assure yourself essentially that whatever happened to this one, it is really the extreme that can happen, or at least hopefully the extreme that can happen. So it is bounding.

DR. SHEWMON: It is not as simple as a one-dimensional stress-strain curve. There are many other ways to abuse something like this than the mechanical problems that a bounding case works on.

DR. ZUDANS: I have to agree with you if you use that kind of a comment. But I see the real piece of hardware, the steam generator. It has been in the plant. I think it is worth looking at.

MR. BENDER: If the chemistry control is as good as people say it is, the results may be irrelevant. But we have lots of plants around the country that we have already seen comparable environments, if not this specific environment.

MR. ETHERINGTON: The new treatment, the solids treatment, we have a lot of plants operating on this system now and they have operated with apparently no trouble. By the time we get the results from this test, we will have three or four more years of experience with many plants. I suspect we won't hit anything that will contribute useful information for the operation of those plants.

DR. SHEWMON: In that vein, the Japanese really don't have steam generator problems currently, although Mahami was a mess. And their best explanation is that they are exceedingly careful about leaks in their condensers. So that, indeed, they keep the impurity content in the secondary down to very low levels and it doesn't end up all being dumped.

MR. BENDER: I am not idealistic.

DR. SHEWMON: The question is whether what comes out of this in '84 is going to help.

MR. BENDER: Yes, that's true.

(Slide.)

MR. SERPAN: You asked for some discussion on pipe cracking. As we see it, some of the issues are that stainless steel bypass and core spray lines in BWRs crack and continue to crack. Design fabrication plus stress corrosion has resulted in a 370-degree crack in the Duane Arnold -- I guess you could call it a 360-degree crack, but I hope not.

Design sensitization and stress-assisted corrosion has resulted in the cracks in the KRB stainless steel stay pins, and stress-assisted corrosion cracks are now appearing in carbon steel steam generator feedwater lines and elbows in PWRs. That is kind of the things that we see as problems.

We don't pretend to begin to know all of the answers as to why pipes crack. But some of the reasons that we do know about are these. Some of the basic factors are the stresses, water chemistry and the material composition. Stresses come from cyclic thermal, residual. Water chemistry, of course, is important. pH, oxygen, is certainly very important for stress corrosion cracking. And we know of the material composition fabrication condition, like sensitization of stainless steel.

DR. SHEWMON: Do we know anything about oxygen effect in the PWRs or is that only for BWRs?

MR. SERPAN: Primarily for BWRs.

DR. SHEWMON: We are talking stainless steel?

MR. SERPAN: Primarily stainless steel, but it is occurring now, apparently, in ferritic. To the best of my knowledge, at least, I don't know that oxygen is a significant factor. It could be.

We know that water chemistry effects could be influenced by the temperature level, whether it is high or low. Different chemical species play different roles in initiation and propagation, especially with respect to the BWRs. Oxygen concentration can vary from equilibrium saturation limit to less than two-tenths of ppm, and the effects of this kind of a concentration range versus stresses in the operation and shut-downs I don't think are known.

DR. SHEWMON: Where has that work been done, the last point? Is that all EPRI? Is any of it work you have done?

MR. SERPAN: What I have laid out here is what we -- some of the ideas that we know about. A lot of the work is from GE and EPRI, what is known.

(Slide.)

We are trying to get work started in stress corrosion cracking in stainless steel and in ferritic steel. And based upon the pipe crack study group report, the kinds of things that we believe we should be involved in are listed up here. They start with studies of the reactor coolant makeup, which includes the major components and concentrations of the coolant, trace elements and concentrations of pH gases, concentration of them, changes brought about in the coolant by temperature, operations, transients, shutdowns.

Obviously, that is a large package, but those are the things we have to worry about. Given that we can come up with some of this information on the coolant itself, we believe, to find out what is going on in pipes that you have got to test them under controlled variation of the oxygen-water chemistry factors, stress and thermal cycles that simulate the startup, operation and shutdown conditions.

We would attempt to put into this program heat variability on sensitization and intergranular stress corrosion cracking, particularly for the stainless steel.

Alloy composition factors affecting stress corrosion cracking potential; this, of course, is for the stainless steels, but also for the ferritic steels, because you can adjust the alloy content to help improve your corrosion resistance.

We would like to determine the importance of reducing oxygen during startup or shutdown, or whether it needs to be done all the time. And we know that is important for BWRS, and it may be important in PWRs. We feel it is necessary to try to measure stress and strain in piping systems as a function of the operating conditions. We would like to conduct investigations of piping removed from service, so you can determine residual stresses in the presence of low-temperature sensitization.

We need to try to validate GE stress. And then one thing we would try to do would be to validate some of the techniques like the Japanese have come up with, like the induction heating stress improvement, or other sensitization mitigation techniques.

DR. SHEWMON: That covers the universe fairly well.

MR. SERPAN: True.

DR. SHEWMON: Other people are working on it. If you were going to put in a request for something next year, have you decided which of that it would be?

MR. SERPAN: Which we would work on?

DR. SHEWMON: And which would probably fit in most with both the regulatory needs and what others are doing?

MR. SERPAN: We would probably start at the top. We would try to get work started in these areas here as much as possible (Indicating), and within them, try to get testing started. And these are some of the variables that we would stick into that testing (Indicating).

This would be perhaps an analytical kind of thing to some extent. Removal of the materials from the systems, we would put as much emphasis on as we could, to try to get those things.

But it is kind of hard to just go out and say, I am going to start taking these pipes out. I think to some extent we could get work started in all of those areas.

MR. BENDER: Is there enough work being done outside so you don't feel motivated to do anything?

MR. SERPAN: That is one of the reasons why we haven't gotten into it up to this point. There is a great deal of work being done by GE and by EPRI in this area.

DR. SHEWMON: It is all done by the vendor, even EPRI's work, the last thing I heard.

MR. SERPAN: But we have got to the point where it is becoming apparent that we need to develop an independent capability to be able to assess what is being done, and we are getting increasing pressure to get this done, and we are trying to do it. We see the need to do it. We would like to do it. We think that there is a role for us in it. We are not trying to answer all of the questions, but we are trying to develop the focus of this, which would be to develop sufficient information that we would have -- the staff would have capability to act in a confirmatory sense.

We cannot begin to cover the whole field. I know it talks about it here, but we can't begin to cover every range of every parameter.

MR. BENDER: You suggested you might start on Item 1 initially. That is a fairly abstract approach, abstract in the sense that it doesn't start with any hard operating experience or experimental data. How would you start it with that point? How would you deal with it, with the data that is available?

MR. SERPAN: I guess I talked about that in the sense of what the experimental work would be, and I would guess that we would work on that. We would certainly review what the experience is, and we would talk to as many people in the field as possible. We would review what has been done and not duplicate, except as necessary. We would try to review and scope out what needed to be done before we got into the experimental work.

DR. ZUDANS: On this measurement of stress and strain of piping systems, how did you plan to do that? That appears

nte 17

to me to be an interesting item, if you could do it.

MR. SERPAN: It can be done. One can instrument piping systems. I think probably EPRI is doing that now.

DR. ZUDANS: Are any of the piping systems in any of the plants now under construction being instrumented, or do you -- you can instrument it after they are built?

MR. SERPAN: That can be done.

DR. ZUDANS: Can you comment on that, Joe, about what is going up in plants now, or whether you know of any?

MR. DANKO: There have been attempts to strain gauge some critical stainless steel lines in the recirculation system, in an attempt to get some information on the stresses and strains during operation. And there are plans to continue these experiments, and the problem we have is getting utilities to agree to attach these strain gauges.

There is a program in place now to do just that.

DR. ZUDANS: That is the only system that is being instrumented in a BWR?

MR. DANKO: In the BWR recirculation system.

DR. SHEWMON: Let's go on.

(Slide.)

MR. SERPAN: The last area that I want to touch on is nondestructive examination. Here we are attempting to establish improved methods and criteria for ultrasonic flaw detection and evaluation, and for continuous acoustic monitoring for flaw initiation and growth. The objectives in the kind of work we are working on is: first, to validate the improved SAFT-UT flaw characterization during in-service inspection. SAFT-UT is the system we have come up with at the University of Michigan. It is a synthetic aperture focusing technique. And the work has gone quite well in the laboratory, but we are now trying to get Southwest Research to adapt that for in-service inspection, and they have just run into some nasty technical problems on it.

We thought that we would have had it by now and we don't.

We feel there is a need to develop real improved, better quality real-time flaw detection techniques, and we are orienting our efforts next year and in the futu. to try to do that. What that really means is that the processing has to be done much faster, so that it is literally real time. We think this can be done and we intend to do it.

We have been focusing, emphasizing our work on characterization with UT, and now, although we are continuing the characterization, we are moving toward the detection.

DR. SHEWMON: What kind of user need letters do you have on this, and when were they dated?

MR. SERPAN: We don't have user needs. We have been working on this since we were with AEC. We don't have user need letters per se on this work.

We are working, then, to develop an improved interactive flaw display system, so that one can actually see what that flaw is, move it around and get to a much better idea of the size and shape of that flaw. It should be very useful for the people who are evaluating those flaws.

As I said before, we are attempting to establish the probability of flaw detection for specific size flaws. I mentioned this under the PNL program, and that work I talked about before in connection with the piping. We are trying to revise and update in-service inspection requirements for most critical flaw types and locations, and that also will come under that program at PNL.

Attempting to develop and validate improved eddy current in-service inspection techniques for steam generator tubes. This is a small work at Oak Ridge.

Finally, develop and validate acoustic emission and internal friction for continuous monitoring of reactor structural integrity. We are working to get the acoustic emission onto a reactor. We are trying to understand right now in the laboratory what the signals are, and we are making good progress on that.

We think next year we should be getting onto a reactor for the actual continuous monitoring. On the other hand --

DR. SHEWMON: Are you going to have cracking while you have it on the real reactor?

546 254

MR. SERPAN: We don't know. We don't know whether it will or not. But we have got to get on a real reactor system and prove that the system can operate in a real reactor system, with all of the noises going on.

DOE has a very large program right now where they are on a real system and they hear noises, they hear all kinds of things. They have no idea what they hear, they just hear it. What we have done is gone to the laboratory and tried to establish what a signal means when you hear it, so that you can pick a real cracking signal out of the noise. Now that we have that, we feel it is prudent to try to go into a reactor and listen, be able to be sure that we can hear it and pick the cracking out.

We will attempt to get in a situation like a bypass line, where there is going to be cracking.

DR. SHEWMON: You think you know what a crack sounds like in a quiet laboratory, a crack moving?

MR. SERPAN: That's correct.

DR. SHEWMON: It seems to me the chances of your picking this out of the -- all of the noise in a reactor -- you have enough trouble getting the operators to use something when they have got bolts and nuts and hulks of subassemblies rattling around in there.

MR. SERPAN: I don't think it's that bad. You could say the same thing for detection of cracks during welding, that with all of the racket of the electrical interference, with the welding, that you couldn't detect a crack formation. But that has been proven and that piece of work is done, and that worked like a charm. I really don't think that it is impossible to do that.

DR. ZUDANS: I think you are comparing the patterns. You are looking for changes and you analyze the difference between today and yesterday.

DR. SHEWMON: A crack, you have a distinct ping.

DR. ZUDANS: It will show up someplace in the history.

DR. SHEWMON: What you are looking for is anything... Crack growth in the primary pressure vessel is the rare occurrence. You are looking for incremental bits of it, and what you have is in the laboratory tests. It depends on the heat treatment, the composition, the micro-structure and the way you are straining the thing. And there is no theory for sorting these things out.

Some particular kind of a crack in some particular batch of steel may have it in a quiet laboratory on a good day.

MR. SERPAN: There is theory for sorting out cracks from random noises, and they have been --

DR. SHEWMON: The question is, what does it sound like on this steel versus this steel, with this heat treatment versus that heat treatment, and with this crack geometry versus that crack geometry.

DR. ZUDANS: That kind of resolution you will not have.

DR. SHEWMON: But that is what he has to find. He has to find the crack motion in that batch of steel, in that steam generator, with that heat treatment, out of all of the noise.

DR. ZUDANS: That would be too good to believe.

DR. SHEWMON: It may be, but that is what he is spending money on, and the budget is going up $100,000 every year.

DR. ZUDANS: I wanted to ask this question. I thought this was supposed to be a portable device for the field.

MR. SERPAN: That was for detection of sensitization in stainless steel. This is for acoustic emission detection, continuous acoustic emission detection of cracks.

DR. ZUDANS: I have a question connecting two items, one discussed earlier and one just now. We look at this measurement of stress in piping. Didn't we talk earlier in the conversation about setting up a computer program so that one would be able to call any piping system in the plant and determine the state of stress, and that state of stress would be programmed as a result of some analytical solutions.

If you think about this item of measurement and the other one of computer programming, wouldn't it be more appropriate to instrument critical locations and provide that information on a continuous basis, as another instrument reading, the state of stress with some enunciator if your stress exceeds certain points? Forget about analyzing; install instruments in the real -- gauges in the real system and use that information, use that source of information for keeping the operators informed as to what state systems are.

MR. SERPAN: You can't put enough strain gauges on a system, and they will not hold up. They will go to pot.

DR. ZUDANS: But the system does not --

MR. SERPAN: I think it is a good idea to get some information. We could certainly use it for validation.

DR. ZUDANS: On some important systems, systems you consider safety-related. There are not that many.

MR. BENDER: Let me just change the text slightly. Given that you are proceeding on this program, by the time that the expenditures you proposed are used up next year, where will we be?

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MR. SERPAN: Where will we be next year?

MR. BENDER: What will we know?

MR. SERPAN: Next year we will know if we can hear signals in a reactor and if we can differentiate knowing such signals from a crack signal. And given that, we will hope we will have an estimate, a first estimate, of what the severity of that crack is, because we intend to go that far, that given the fact that there is a crack signal there, we would like to have an estimate of what we think that crack is, what kind of a crack it is and the severity of it.

MR. BENDER: Why do you think you will know this?

MR. SERPAN: We expect to be on a system next year and starting to listen.

DR. SHEWMON: Whose reactor? Who is going to let you run cracks through their plant?

MR. SERPAN: We don't have it yet. That is part of this program for next year, to get a reactor under contract, if you will, and to get it implemented.

DR. SHEWMON: With known cracks running in it?

MR. SERPAN: We would certainly think that the bypass line, one that might be a suspicious bypass line would be a place to look.

DR. SHEWMON: You have got to have one running at 10:01, when the guy happens to have his instrument working.

MR. SERPAN: The idea of this is to have a continuous basis. The transducers will be placed on and they will be left, and they will sit there for a year or two. It is not turning them on one minute --

DR. SHEWMON: We are getting too much detail, but how you can pick out of the soup and know that you have picked out of the soup a crack when it is not clear what a crack sounds like in the particular alloy that you have in that reactor, I find very hard to follow.

MR. BENDER: You learn by doing.

DR. ZUDANS: I would like to return to the comment you made, Chuck, that the strain gauges wouldn't last, even if they are installed on systems. I would want to point out that it doesn't matter whether they last a year or a half year, because you collect the information you want to know better than any other analysis you can do.

MR. SERPAN: I agree with that, yes.

(Slide.)

I want to move -- that was the end of the technical program itself, the budget review. Do you want me to go through this in detail?

DR. SHEWMON: I have been watching it.

MR. SERPAN: That is what I suspected.

DR. SHEWMON: About six pages from the end is his budget stuff.

MR. SERPAN: I have shown on the bottom numbers in parentheses, and what they mean is, as we currently operate now, our budget review group has not approved those things we are sending on to the Commission and OMB.

DR. SHEWMON: Who is it?

MR. SERPAN: It is an internal setup in NRC.

DR. SHEWMON: Is it primarily RES?

MR. SERPAN: It is all RES. That is, before it gets to the Commissioners and before it gets to OMB and the President.

DR. SHEWMON: Do you ever go over the currency of user need letters? What is your interaction with DSS of their needs and DOR?

MR. SERPAN: With regard to the budget review group, they asked those kinds of questions -- why do you need this, why do you need that.

DR. SHEWMON: Is someone from DSS there who can explain why, or do you say, "We got a letter once"?

MR. SERPAN: Sometimes there is and sometimes there isn't someone there.

DR. SHEWMON: I guess next year -- I have made a note here to "let's get somebody from that shop and particularly go into what the user need and interaction is." Your situation seems to be much easier or looser in that regard than anybody else I have bumped into. Certainly, the fuels people don't have a grandfather clause permission on anything I have bumped into, like you seem to have on the NDT.

You say we did it before we got into that sort of thing so we keep on doing it. That seems to be the unique situation in my experience.

MR. BENDER: Let me ask one thing about these items that you have in the budget.

MR. SERPAN: Sure.

DR. BENDER: If I wanted to find out for all of these items where you expected to be next year, where would I look?

MR. SERPAN: Our zero-base budget application, I guess, for last year, for fiscal '80, and right now for fiscal '81, that has a summary of where we expect to be in these areas.

MR. BENDER: Thank you.

DR. SHEWMON: Do we have a copy of that?

MR. SERPAN: You should.

(Slide.)

There are a few other things, if you want to go through them. The trends, I don't think that is significant. You probably know where that is. I had addressed your ACRS recommendations in '78 as to where we sit on those.

DR. SHEWMON: Okay.

MR. SERPAN: To complete the HSST program, and we are doing that, we revised and redefined it, and we continue working on it.

We put a high priority on the piping reliability. I think what I have showed you today reflects the fact that we are doing that.

Coolant chemistry effects on crack growth, we are not doing that as much as you would like, but we are trying to. We are trying to get work started in it.

Saturation effects on radiation embrittlement, we are cooperating in a program with EPRI, and we are trying to get some money to do other experimental work.

DR. SHEWMON: that had to do with more analytical than experimental. There has been a lot of work on saturation effects. There was more in cladding and higher fluxes than here. And all of a sudden, a year ago, it was a great discovery. Yet, with the benefit of hindsight, one can see that if there is a temperature dependence, there probably is a rate effect.

I certainly wouldn't say that there is need for more experimental programs with regard to what one can learn from previous work in the field, or theoretical work about what you would expect for this sort of a thing.

I would think that there could very well be a useful program. That is a matter of finding the right people and getting their comments on it -- not sticking six more things in a reactor.

MR. SERPAN: I understand what you are saying. All right, fine.

The last one had to do with steam generator tube integrity. We are planning a program in cooperation with EPRI. And we are looking to get NRR endorsement of that program.

DR. SHEWMON: Who is NRR?

MR. SERPAN: Regulation that is primarily --

DR. SHEWMON: Who is it? Who is the individual?

MR. SERPAN: We are starting with Larry Shao.

DR. SHEWMON: Noonan's shop? Is there anybody here from DOR yet?

MR. GRIMES: I am not from Noonan's branch. I am Grimes, from the Division of Operating Reactors, but I am not from Noonan's branch or Shao's division.

DR. SHEWMON: Are you familiar with steam generators?

MR. GRIMES: I know what one is, but I am not a metallurgist.

DR. SHEWMON: Thank you.

MR. BENDER: I would like to quibble a little bit with Dr. Shewmon's comment about saturation questions. My guess is the data is not unambiguous. There is some evidence that the saturation effect exists, and I would think that you would need to determine whether there is an experiment needed to eliminate any ambiguity about the likelihood of saturation if, in fact, we think it really is a valid observation.

MR. SERPAN: We think we will find out a great deal from the program that EPRI has that we are contributing on the dosemetry side. We should find out a lot from that. That is the very first time that anyone really has ever seen that saturation at these kinds of temperatures in generally these kinds of fluences. It came as quite a surprise.

DR. ZUDANS: Westinghouse demonstrated this phenomena by themselves? Does that give you some clue as to how credible that situation is?

MR. SERPAN: No, because I think Westinghouse did an honest, good technical job on that.

DR. WECHSLER: You mentioned several times, I think, earlier, the radiation-sensitive B&W welds. Could you tell us briefly the state of understanding as to why the B&W welds are particularly radiation-sensitive?

MR. SERPAN: Because they have a great deal of copper in them, and they had an excess amount of phosphorous that came out of the weld wire and flux combination. Precisely how and why, I don't know. But from an empirical standpoint, it was because of those two things -- the weld wire and flux combination.

DR. ZUDANS: They used their own weld wire?

MR. SERPAN: They started a batch of the loop that they thought was homogeneous, had the right composition, and they discovered later that the end of the roll had the wrong composition. They aren't too sure where they used it.

(Slide.)

As for implications of TMI-2 to our branch, one of the things was the fact that Three Mile Island experienced pressurized thermal shock. We were certainly aware of pressurized thermal shocks in the past, and we were looking to cooperate with the Germans to get experimental data on pressurized thermal shock. That is not going to come along for several years now, out of the HDR program.

DR. SHEWMON: Where was TMI special with regard to pressurized thermal shock? We have had a program as part of the HSST program for thermal shock for years. What is special about Three Mile Island?

MR. SERPAN: Pressurized. We never intended to look at, from an experimental standpoint, at pressurized thermal shock. Most of it has been essentially at no pressure, which was also aimed at the very large break.

DR. SHEWMON: Calculating loss of pressure.

MR. SERPAN: Very rapid loss of pressure, and the problem with a pressurized thermal shock is that you might get that crack going and with the pressure there it could continue to drive it through the vessel wall.

MR. BENDER: I wanted to get in context which thermal shock you had in mind. Can you be explicit about what it is?

MR. SERPAN: Right at the very beginning the plant was hit with emergency core cooling water, but it was still at very high pressure. That is what we are talking about.

MR. BENDER: That's not new. That has happened before. Just in this particular case, it happened under some very undesirable circumstances. High-pressure injection systems have been turned on many times in reactor systems.

I don't want to get -- I don't want to make that issue, unless you really did see some very unusual -- it wasn't apparent to me that that happened.

MR. SERPAN: That is true. I wouldn't want to say that Three Mile was in great danger of rupture from thermal shock. It really wasn't. But it did point up the fact that these things can happen. All it has done, as far as I am concerned, is to say that we need to move up the priority on trying on pressurized thermal shock testing, because this, this kind of thing could happen with an old plant.

MR. BENDER: I am not crazy about them, about the observation at the moment. It seems to me that if TMI-2 is the basis, then I would like to know that TMI-2 has displayed some things concerned pressurized thermal shock that we wouldn't have expected to occur. At the moment, I don't know of any.

MR. SERPAN: It has not.

DR. ZUDANS: It has in one sense: It has seen higher temperature shocks, rather than lower temperature shocks which produce compression. So, you wouldn't have expected any problems of fracture. As far as cold water injection, by the time it reaches the locations, it is already mixed. And you are quite right: There is no difference between that and any other injection, that if the temperatures went high up for a short period. There you have the reverse situation from what you pv10

normally would expect.

MR. BENDER: The fuel went up. I don't know what happened to the pressure vessel. I think that is the question we are trying to address right now.

MR. SERPAN: Because of the hydrogen in there, we feel it would be useful to study hydrogen embrittlement under the conditions that Three Mile Island saw, and the possibility of looking at the integrity under hydrogen explosions.

But Mr. Etherington and I have had a discussion about that already this morning, and he is not convinced that there is any possibility of a hydrogen explosion. If that's the case --

DR. SHEWMON: You mean one within the pressure vessel? I would agree with him. I think the NRC just screwed up.

MR. BENDER: And why isn't hydrogen embrittlement a problem?

MR. SERPAN: Because of the high level -- the high amount of hydrogen that was generated in there, and it was at high temperatures also.

DR. SHEWMON: The hydrogen embrittlement is a low-temperature phenomena, not above 100 C.?

MR. ETHERINGTON: It is a low-temperature phenomena, but it arises from a solution with hydrogen of a high temperature. So, we have the high temperature at which the hydrogen could have dissolved at high pressure and then the cooling, you would get the crack.

DR. SHEWMON: Depends on how fast that came out.

MR. ETHERINGTON: Yes.

MR. SERPAN: This is a small effort, and we are looking at an analytical effort at this point, not experiments at all.

MR. ETHERINGTON: Analytic is all you are talking about?

MR. SERPAN: Yes. Analytical, not experiments.

Item 3 is inspection requalification after accidents.

DR. SHEWMON: When you do that, why don't you talk, or you might contact an oil company to do it, because the API has had programs for some years on exactly this.

MR. SERPAN: With regard to a requalification after accident, much of that work has been focused on other branches. We think there is some that we could do on acoustic emission, detection of cracks during hydro testing. That is all we have attempted to try to get.

Off-normal water chemistry, we believe there is work that needs to be done there, but that has been put in the Fuel Behavior Branch. That is not for us to work on. That is an internal decision, I guess.

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546 269

MR. SERPAN: In view of the time --

MR. BENDER: I would like to repeat the point that was phrased earlier regarding the decontamination and containment part of the system. That may not be in your branch, but it does seem to me that it ought to be.

MR. SERPAN: We thought so.

MR. BENDER: The question of materials integrity ought to show up as parts of these kinds of programs where the metallurgical capability is.

MR. SERPAN: We thought so, too.

MR. BENDER: I am surprised the NRC isn't doing it that way.

MR. SERPAN: In the initial shifting of the funds between branches up in research -- that kind of work has been put --

DR. SHEWMON: Would you like to get something in the letter to the Commission on fission clean-up. I would be pleased to inquire about how it is going to be done, and I would be pleased to second it.

MR. BENDER: I think we need to put something in the letter, and also I think we need to emphasize the need to use people that are competent in the field. Just as you made the point about the adequacy of the chemistry capability in the NRC, I am concerned about their putting the work in the wrong place. And I think we ought to say something about it.

MR. SERPAN: That's all.

DR. SHEWMON: Fine, thank you.

Would somebody scope me on what is going to happen next on the program -- who is here to talk about what?

MR. BOSNAK: There are three of us, and each one will get into the technical assistance contracts for their branch, however, in whatever detail you want to go into.

DR. SHEWMON: And the three branches are?

MR. BOSNAK: Mechanical engineering, materials engineering, and structural engineering.

DR. SHEWMON: That is the first item. What about the second item? Yes?

MR. LIAW: Division of operating reactors in the same area, materials, mechanical and structural engineering.

DR. SHEWMON: And the input is again the set of -- is this printout that we have in our folder, here. Is that what -- what is your pleasure on how you want to handle this.

Have you had a chance to go through them?

MR. BENDER: I got it last night. It was not readable, and I couldn't go through it.

DR. SHEWMON: I have questions on some of them. I would be interested in your comments. One of the things that came up today had to do with the interaction between you and the research program on user need letters or staying in touch with the results they are finding and how they get used in your program.

I guess one of the things that came up at the last meeting not long ago was how this gets fed into regulatory decisions and the degree to which NRR has defined what their needs are, and you interact with the program here to see how this need is fulfilled by the program.

Would you comment on how that works.

MR. BOSNAK: I speak more for our own programs. We have a user's request that went to Research several years ago in the area of design for the effects of pipe break. That has continued for several years. We don't feel we are in the position to use any of the results at this point for licensing needs.

One of the problems is that we don't have the personnel resources to follow through on some of these users' requests. We did have what I consider to be a good visit with one of our people and the personnel from the Research Branch doing the work which is Dr. Serpan's branch. We visited various architect engineers to study just what the practical problems were in the plants from the point of view of designing for the effects of pipe break, given that pipe breaks -- the emphasis has been on studies of crack initiation, crack growth, and, well, pipes break.

But we do have criteria that pipes must be designed for pipe break. Given those, how did you go about designing for them in a practical way?

So the programs have taken quite a while to develop. We hope that there will be the use that we can put them to in a practical sense. We have had another program that we have turned over to Research that we have had good results on, and that has been the verification of the benchmark programs for computer codes for, in this case, piping analysis.

Those are the only two examples that we have had. Again, perhaps it is a problem on both of our parts that we just don't get together often enough to discuss where the program is headed. I don't know if any of the other people in materials or structures want to add anything to that.

MR. CONRAD: I am the Section Leader of Metallurgy in the Materials Engineering Branch. I think, just to put some perspective on what we do with our technical assistance programs, we really have very limited resources to work with when it comes to technical assistance.

Our typical technical assistance program is about $50,000. For that amount of money, you could probably buy one or two experts for a year or part of a year at one of the national laboratories or other sources that we can draw upon. So it is a matter of making the best use of limited

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resources. And with these technical assistance contracts, I think what we try to do --

DR. SHEWMON: I am not talking about technical assistance. The question has to do with the guidance and interplay between Research and you people on Research's programs and how it will help regulatory decisions or impact regulations.

MR. CONRAD: What I have to say will lead to that.

DR. SHEWMON: Yes.

MR. CONRAD: What we get from the technical assistance programs is mainly someone who can review and evaluate what is being done -- what is proposed to be done in the respective fields and perhaps do some analytical work and bring us up to the point where we identify a need for some experimental work.

At that point where we identify a need for experimental work or testing, then we go to the research arm through the mechanism of the user's need, the request for research. I think one of the uses of our technical assistance programs is to get us in the position to intelligently generate a user's need request.

DR. SHEWMON: Let's say that you general a user's need letter in 1977. Is it updated every other year, or is that sort of a license forever?

MR. CONRAD: Just to use an example of what we have right now, we are just about to transmit a user's need request to Research in the area of hydrogen generation within containment from reactions between corrosive fluids such as the containment sprays and materials within the containment. As part of that request, we are asking that a Review Board be established which would contain members from our branch, DSSs branches who have interest in that, DOR and other interested NRR branches including research, that will essentially follow on with those programs.

And we hope this will probably be a mechanism to take care of this coordination problem that you are sensing here.

DR. SHEWMON: For that particular program?

MR. CONRAD: Right. And certainly any future programs we prepare will have that factored into it.

DR. SHEWMON: Anything under a grandfather clause is good forever.

MR. CONRAD: No. We talked to Chuck, and one of he purposes of our technical assistance contracts is to ave experts available to use who are evaluating what esearch has done in the field, including our own research nd advising us how we can factor that research into our icensing of new plants.

We are concerned in DSS in implementing the esults in the new plants. We are not concerned with

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backfitting or what we can do with current problems. We are trying to take a little longer range view.

MR. BENDER: Is there any visible evidence that the research organization has that you concur in their plan from year to year?

MR. CONRAD: Actual concurrence?

MR. BENDER: Yes.

MR. CONRAD: I think through these review groups. Some of the programs that we have do have review groups in existence. There is concurrence to the extent that the discussion on, say, the next year's plans are talked over in that review group. We do get the program plan from Research every year, and we provide comments to them.

MR. BENDER: I interpret that as being, if there is a review group, there is a review. And if there is not a review group, there is no review.

MR. CONRAD: As I said we do have limited resources.

DR. SHEWMON: In what areas are there review groups?

MR. CONRAD: In the fracture tougness, which I think Ron Gamble will address, if you want. We don't have a current user's need in the metallurgy area, so we — we do have a membership on the review group that covers the programs related to boiling water pipe cracking.

546 276

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DR. SHEWMON: Review groups are what? Are they an annual information reading?

MR. SERPAN: The review groups are groups that research funds to periodically listen to what is going on in the programs and advise Research as to whether the work being done is what we want to be done and what needs to be done. And we have review groups in every area of the program. We have them in corrosion steam generators, in non-destructive examination, in primary system integrity.

DR. SHEWMON: Can you provide us with a list of what review groups you have and who sits on them in the last year?

MR. SERPAN: Yes, I think that is probably available. We can do that. We have these meetings as often as we think are necessary, and usually it is a couple of times a year for all of these, and we review different parts of the program. We bring in specifically people from the licensing staff so they can tell us what they want.

DR. SHEWMON: The only people on the review group are DOR and DSS people?

MR. SERPAN: There are two categories of people on the review groups. One category are true members, and they are NRC employees. The other people are consultants, and we can have both kinds of meetings. They are both review groups. We can have meetings with outside consultants, which has been a much more general kind of meeting but it is still a review group where we criticize these program.s

We also have review groups where only NRC members are invited, and those meetings are generally when we are going to decide exactly hcw we plan to change a program, or if this is exactly what the staff needs.

DR. SHEWMON: Who chairs it, and who writes the report from the review group?

MR. SERPAN: The review group chairman, Joe Mascara, Pedro, or myself.

DR. SHEWMON: You people write up what other people think and review your program, because you look upon it not as a way to decide whether you should continue the program but how you should reorient it as it continues?

MR. SERPAN: Both things. If our review group tells us to describe a piece of work, I think we would have a pretty tough time keeping it going.

DR. SHEWMON: They don't meet by themselves. You always write the report.

MR. SERPAN: That's true. We call a meeting, but there is no reason that they can't get together by themselves and talk, and I know they do. They do talk about it, because it is obvious when they come into the meetings sometimes that they have been talking about it, and they know about it. But we are in contact with those people, and they are in contact with us, and we do review these programs, and the programs are changed.

I have to take issue with the grandfather issue that we have a letter and we just do this thing forever. They are, indeed, changed.

DR. SHEWMON: I'm sorry. I didn't say that they didn't change. But they do keep going. I asked you about a user need letter on ultrasonic inspections, and you said we have been doing that forever, so we don't have a letter. We did it in year one.

MR. SERPAN: That's right. When we started. That is correct.

DR. SHEWMON: That is what I call a grandfather clause.

MR. SERPAN: That's what we call it, too, and we have continued to do that. We have completely changed, then, what we are doing in that piece of work now, and we would like to think that it reflects what the licensing staff needs.

This is what we continue to get from them when we meet on it. That's all I can say.

MR. ALBRECHT: We have on the average about two meetings of the review groups, for example, the vessel integrity and the piping in the spring. We have a mid-year review group to which all of the licensing staff is invited.

546 279

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So right there there are three meetings -- three official meetings.

DR. SHEWMON: It is your meeting at which they are allowed to come in as visitors. What I am interested in is, if ever they go back and see if they want to recertify user need groups within an error, to what extent new problems get fed in, and whether they are always visitors or whether they end --

MR. ALBRECHT: They don't come in as visitors. They come in as active participants.

DR. SHEWMON: But it is your meeting, and you write the conclusions.

MR. ALBRECHT: Obviously, it is a technical meeting, and we will typically -- we will write agreements and commitments at these meetings. So it is not our conclusions, because they are not going to sign those things, those agreements and commitments, unless they agree with thim.

And we are held to them as much as they are.

MR. BENDER: I think the point that causes me some concern is the fact that the review group is made up of such a mixture. It is really not clear that the voice of the regulating arm of the Commission is adequately represented. I am not meaning to say that the review group isn't very competent. I am sure they always are. But it is hard to

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to discern whether the so-called users virtually are consciously expressing an opinion about the value of the program. I don't believe they necessarily ought to be overriding in their opinion, but it seems to me we ought to have something that is more concrete.

And from what I hear, you aren't getting anything except as it is provided by whatever voice that review group has.

MR. ALBRECHT: Let me give an example. Last week we had a meeting with the licensing staff, DOR, DSS. There were representatives on the testing of the second and third specimens of the second and third irradiation series at Oak Ridge -- what they told us that they needed by the end of the year -- and we have redirected the testing program to accomodate that.

There is a very close interaction between licensing and ourselves. We follow as much as we can their desires. We recognize we are here to serve --

MR. BENDER: They, being whom?

MR. ALBRECHT: Dick Johnson from DOR and Ron Gamble from DSS.

MR. BENDER: Then let me ask them. Do you feel that you are getting the kind of input to the programs that is needed? Do you wholly sanction what is being done?

MR. JOHNSON: You get a qualified yes. We have

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satisfaction. Obviously, it is a matter of degree as it is with all human endeavor.

MR. BENDER: Thank you.

MR. LIAW: In the area of the steam generator integrity program, in addition to the review group, where the licensing staff expresses our opinion on the progress of the work, the management of DOR, for example, also gives their input from our own staff and officially transmit a letter for comment on the program themselves. One example is the steam generator integrity program. We now feel that the test portion rate of the program was not going as well as what we had expected; the leakage rate test, it did not go as well as we hoped it would.

We did not hesitate to transmit an official comment, through our management, to RES management. And appropriate action, I trust, will be taken to correct the situation.

DR. SHEWMON: Have you also written a letter in that area explaining why you think it is worth the time and money to move the Surry generator across the country and work on it for several years out at PNL?

MR. LIAW: Are you changing the subject?

DR. SHEWMON: I am still on steam generators, and I am talking about the largest steam generator budget item for the next couple of years. I didn't mean to interrupt your train of thought. It has been primary in the discussion this morning.

MR. LIAW: Before I go into that, let me finish up what I had, when I was commenting. The review process is being carried in the general terms -- I want to emphasize that, in addition to the review group, we also transmit officially our comment to RES to rectify whatever shortcoming we see.

And your second question, on the Surry steam generator: Yes, their research need request is outstanding. My understanding was they are working on the detailed program as well as the moving the generator to PNL. That is the front-end work, and we trust that research people are capable of doing that. I don't see a need for us to interfere at this moment.

DR. SHEWMON: But if you start with that, it is a $5 million commitment. Have you looked at that? And I pick $5 million randomly, but the program is running on the order of a million a year.

MR. LIAW: $5 million, in the order of $5 million when research originally made the request.

DR. SHEWMON: It is your feeling -- and it is explained in the letter why you feel it is worth that kind of money to you?

MR. LIAW: Yes, sir.

DR. SHEWMON: And we can get a copy of that letter, I trust?

MR. LIAW: Yes, in the user request.

DR. SHEWMON: Isn't that what we are talking about?

MR. TUROVLIN: That is not in the review of the move.

DR. SHEWMON: I am not concerned about moving. But if you are going to move it all the way across the country, then you are providing job security for 50 people for X years out there. I would like to know what's the basis -- that we are thinking about it before we start it.

MR. LIAW: As I say, we have a request. What we'd like to do is outline the scope of work. And as far as the moving of the generator or a section --

DR. SHEWMON: If I said "moving, I'm sorry I set you off, because I only am concerned about the long-term commitment to work on that thing and whether you people have looked at it and feel that it is really -- you are going to get that kind of results out of it for that magnitude of money.

MR. LIAW: Yes, we did.

MR. SERPAN: We have a built in go; no-go on this thing. It is true that we are trying to commit the money to get it out to PNL. We are talking on the order of $1.5 million to get it out to PNL. We are not necessarily mortgaging ourselves for another $5 or $10 million by that action. We get it out there and once we get it out there we will have a final conceptual design and firm costs for the construction of the facility. We will also have a final review of the entire research program.

If either one of those things shows that we do not want to continue with this program, we can stop it, and we intend to stop it if necessary.

Now, having that generator out at PNL is still a good deal, because we can do a great deal of NDE work and characterize the entire steam generator tube layout. We can use it as an NDE device and run it for maybe a half year, and then we can get rid of it. We can bury it out there and not put another penny in it.

So we do have a method to -- we are not guaranteeing --

DR. SHEWMON: The reason we are particularly interested in the other people's comments is that if your review group is your contractors and yourself, who have a certain tendency to want to maintain budget, then the review may be somewhat less critical than if it is from somebody who at least has some sort of a tradeoff in mind.

MR. SERPAN: The review group, the consultants, as it were, are anybody we would like, and they come from the vendors, they come from national labs, they come from universities. They are people that we find across the country, regardless of their affiliation, that have a good technical background.

DR. SHEWMON: I am sure they are technically sound. It is just that you never put to them the decision: We have $1 million to spend this year. Do you think it would be best to spend it there or on a completely different project?

MR. SERPAN: The rules of the review group are, with the consultants around, they are not asked to decide whether that is the thing to do. On decisions on money, we only talk

nte 5

about technical matters with them. We talk about, where is the priority for money. That is an internal question and we talk about that with the NRC members, we do indeed. And we make decisions as to where the money goes in those meetings. And we get input from them, but we are not allowed to have external people who are not within the Commission make decisions on where the money goes.

Those are just some of the thoughts, some of the rules.

MR. ETHERINGTON: They wouldn't comment? They couldn't comment on whether it is worth doing?

MR. SERPAN: Yes, but we are not bound to take their word, and we do not seek that kind of an opinion from them. That is the way the review groups go.

DR. ZUDANS: Just a question, because it wasn't discussed when you made the presentation: Why couldn't you just do the job on the steam generators where they are now? You would have an extra 1.5 to do it.

MR. SERPAN: Surry won't have any part of it. They have a vault for the storage of the steam generators. They are putting them in the vault and they are closing it up. Anything that is done on the irradiation exposure goes on their license, and they cannot tolerate any more.

DR. ZUDANS: I think this is more like -- it is not a technical problem; it is a problem that is either public relations, legal or something.

DR. SHEWMON: Surry is not in the research business.

DR. ZUDANS: They don't have to do it. They just allow to provide the space for it.

MR. SERPAN: No. We have investigated that and it is not possible.

DR. ZUDANS: All right.

DR. SHEWMON: Okay. Let's go back to the technical assistance programs. I have got several that are dog-eared here and that's it. Do you want to bring up other questions on it or here -- go through a list or have a list read to you?

MR. BENDER: I would suggest that we go with comments.

DR. SHEWMON: Okay. One question I had here is, do you have any work on environmental effects on pipe cracking? And let's start with carbon steel. What are you doing in that area?

MR. CONRAD: With carbon steel environmental effects? At the bottom of our handout for materials engineering --

DR. SHEWMON: You have a handout?

MR. CONRAD: Yes.

The program is entitled --

DR. SHEWMON: Why don't you go on up to the podium.

(Pause.)

DR. SHEWMON: If you have a handout, tell us about it.

MR. CONRAD: I am with Materials Engineering.

(Slide.)

The Materials Engineering Program is proposing a new program to address corrosion of ferritic steels. This program is essentially to evaluate the mechanisms and the corrosion fatigue behavior of ferritic piping steels in environments of light water reactor-grade water and secondary water. The purpose of the program will be to evaluate the corrosion mechanisms and determine how to factor lessons learned into the licensing process.

We also would like to look into corrosion mechanisms in the reactor vessel steels in the presence of crevices, specifically cracks in the cladding on reactor vessels. This program is especially timely now because of the recent outbreak of cracking in feedwater lines in pressurized water reactors.

(Slide.)

DR. SHEWMON: And that is -- there is secondary and safety system corrosion that is at least not crack growth, general wastage or what?

MR. CONRAD: The secondary water chemistry. For our licensing of new plants, we hope to arrive at a point where we can identify rational requirements to be placed on the control of secondary water chemistry in reactors. We hope that we can arrive at something like a technical specification requirement.

Right now we are asking for certain licensing conditions with the emphasis on surveillance, namely, of instances of in-leakage in plants. But we hope to arrive at the point where we understand enough about the corrosion phenomena in secondary water steam generator tube and component interaction that we can arrive at a set of technical specifications that can be placed on plants similar to the primary coolant requirements that are in technical specifications. But a lot of work will, of course, have to be done before we arrive at that point.

DR. SHEWMON: You can talk with the Japanese, but also you will talk to what is being done in this country by some of the --

MR. CONRAD: Right. EPRI is working in that area, which we follow, in the secondary water corrosion chemistry, plus perhaps better methods of surveillance.

DR. SHEWMON: One of the -- it may have been Pilgrim, I don't know. But there was that utility system; I recall one of their corrosion people was here for a meeting a couple of months ago, and his comment was that they have brackish water as coolant on their -- in the Delaware Bay or wherever, and when they could detect an increase at the per billion level in sodium, in parts per billion, they went in to find out which part of the condenser it was in, which one of the six pans it collected in, and they would close that off and go find the leak.

Are -- is EPRI the one surveying what their current practice is?

MR. CONRAD: In DSS, we don't get into the operating procedures of operating plants. However, our feeling is that the key to helping with the steam generator corrosion problem is the quick action if there is an ingress into the system. I think Three Mile Island, one of its lessons learned is the utilities themselves would have to develop in-house expertise in these areas, and certainly take on a -- perhaps a heavier commitment upon themselves to follow all of these various areas where perhaps NRC has some criteria, but not detailed step by step criteria.

And I know that the plants that have had the less problems with the steam generator ingress or resulting corrosion are the ones who have always followed very conscientious programs, such as the one that you are speaking about.

DR. SHEWMON: I guess the reason I keep probing this, in view of that knowledge, what are you going to plan to do here? Are you going to study corrosion mechanisms in case you crud up your system, although we all agree that once you run seawater through it it does corrode faster?

MR. CONRAD: We hope to arrive at the point where we can understand enough about the corrosion mechanism so that the early warning aspects of when you are starting to get in trouble can be identified, so that we can place emphasis in our licensing requirement on those particular aspects. We can't -- as I said, our technical assistance programs really take a look at what is being done now and what is proposed to be done in the future, and then considering how we can best factor that into our licensing actions, make proposals to our research group for longer-range testing and so on, to answer the unanswered questions that we need to develop criteria.

MR. BENDER: Let me try to understand your program a little bit. Do you have something called corrosion and coolant chemistry that is identified as A3013, and the contractor is Brookhaven National Laboratory, and in FY '79 you had $80,000? You are going to phase that out next year and you aren't planning anything in '81?

At the same time, you are initiating in FY '80-81, something called secondary and safety system corrosion and something in FY '80 called primary system corrosion.

I am confused. Why are you stopping one and starting another, and where is the continuity?

MR. CONRAD: It is a problem of available resources. The current program -- two other programs are in effect a carry-on of the corrosion and coolant chemistry program which Brookhave is doing now. We have experienced not being able to get enough manpower at Brookhaven because of oth r commitments, such as DOR, which has priority. So what we hope to do is either get firm commitments for more manpower to be placed on our problems or go somewhere else. And to facilitate the use of our resources, we have broken it into two different categories, two different programs.

MR. BENDER: Basically the plan --

MR. CONRAD: The continuity is there.

MR. BENDER: -- to maintain some effort, and you may be shifting contractors?

MR. CONRAD: That's right. The continuity is there.

MR. BENDER: There is something down here called protective coatings that is going to start in FY '80. That is a new one on me. Where did that come from?

MR. CONRAD: Perhaps Ron Gamble could address that one. That is one of his programs.

DR. SHEWMON: You are both in DSS?

MR. CONRAD: I could say a few words about it.

DR. SHEWMON: Is DOR -- we get to them later? It seems to me the concern about secondary water, if indeed the NRC is willing to take that on as a matter of policy, it ought to have some interest there, too.

MR. GAMBLE: Protective coatings is a new program. This is very recent, probably in the last month or so. The idea of this program is to evaluate the protective coatings with respect to serviceability and response to chemical, thermal and other conditions that you might see in a reactor vessel or in a reactor in the normally postulated accident conditions.

Right now the NRC has no criteria or no review areas for protective coatings, and the idea of this program is to look at protective coatings, review protective coatings that are currently used, and develop any criteria that are necessary for acceptance of these various coatings in nuclear plants.

MR. BENDER: Primary piping, secondary piping, containment? What is it that you are investigating.

e-13

MR. GAMBLE: Wherever coatings are going to be used in nuclear plants.

MR. BENDER: Why '80 and not '79?

MR. GAMBLE: '79 is halfway finished.

DR. SHEWMON: We have been reviewing reactors for years. Why is it it is of concern and interest to you now?

MR. GAMBLE: The coatings are put on in many cases, for example, to help prevent corrosion. If coatings flake or spall or come off, you may have corrosion that you didn't anticipate because the coating was on there. Also, during some sort of accident conditions, such as Three Mile Island, you may have radiation effects or temperature effects that would degradate -- degrade the coatings and they wouldn't be able to perform their function.

As I understand, the coatings sometimes help in decontamination, and having the coatings spall or flake off would make it more difficult to decontaminate, if that were necessary some time in the future.

This is a new area. The NRC has not had any criteria in the past, and this is an area that we felt perhaps our current reviews are somewhat deficient.

DR. ZUDANS: There is an industry group working on criteria for coatings and NRC takes part in it.

MR. GAMBLE: Yes. As I understand it, the first meeting of an ASTM Committee has just met on the West Coast two or three weeks ago. And yes, there is someone who attended that meeting. But it is my understanding that that was the first meeting.

DR. ZUDANS: What about the other one, containment, coatings, paints and all of that? It goes under a different name, the group that exists for years.

MR. GAMBLE: I am not aware of that group, then.

MR. CONRAD: It has gone from American standard to ASTM standard. That is what happened; they reorganized.

MR. GAMBLE: I want to point out our particular effort in this program is not to go out and do a lot of research or anything like that. Our emphasis in this program is primarily to do a literature search and try to find out what the capabilities of the coatings that are currently used are. And when we define what they are, we may in fact either say what is good or not good enough, and write a standard review plan, or find out that there are deficiencies, in which case we would have to go to Research and ask them to do some follow-on work in this area.

The purpose of this program right now is to scope out --

MR. CONRAD: Why do you want to go to Research instead of writing a specification saying what criteria the paint should fulfill?

MR. GAMBLE: This is about a year in an 18-month program. We may find out, as a result of this program, that we can in fact do that at the end of this contract. On the other hand, we may find out that that -- we cannot do that, and we may have to ask for additional assistance.

MR. BENDER: I wanted to find out where this request for this came from. Is this a user request of somebody? In other words, it is not research?

MR. GAMBLE: A member of the staff felt this area was deficient.

DR. ZUDANS: They are the users, DSS.

MR. BENDER: I understand they are the users. I think my question really has to do with how this developed as a regulatory problem that required this kind of help. Why shouldn't it be at the research program instead of here, and --

MR. GAMBLE: As I say, what we are trying to do is understand something more about coatings than we do now, because we have never included coatings in our review area. In fact --

mte 15

and this program is relatively small -- when this program is completed, in fact, that is what may be necessary, is have research take over the program and complete whatever -- or determine whatever additional information is necessary.

DR. SHEWMON: It may be small, but you are asking for more money for it than for any other single project.

MR. GAMBLE: Yes. It may not take that money. The money there is somewhat indefinite.

What we are going to do is we are going to go out with a request for a proposal, and we are in the process now of writing work scope for that. The money was in there, quite frankly -- that is about the -- it was the most difficult amount for us to estimate for a technical assistance program, so we estimated high.

DR. SHEWMON: Let me come back to one other topic here.

DR. ZUDANS: I would ask one other question on this. The paint, for example, paint qualification specifications, the criteria as practiced now would be part of this scope. There are very specific rules now how to qualify paint, and quite complicated, quite demanding as well. I guess paints and coatings fall into the same group.

Is it that you are trying to understand better what the industry is doing, so that you can decide whether or not it is adequate, or is it that you are looking towards

546 297

developing the need for new criteria in this area?

MR. GAMBLE: I think what we are trying to do is understand whether the present coatings and paints used are adequate for normal operations and under postulated accident conditions. If the determination is -- if we can determine that, that they are, then I think --

DR. ZUDANS: How do you qualify suppression pool coatings today?

MR. GAMBLE: As far as I know, the NRC has no criteria. It does not review coatings in nuclear plants.

DR. ZUDANS: The industry has its own standards?

MR. GAMBLE: That's right. And to the best of my knowledge, we have not been active in that area.

DR. ZUDANS: Then I can understand the need for it, yes.

DR. SHEWMON: I would like to go back to another of the new projects. That has to do with something called environmental effect on fracture toughness, for example.

(Slide.)

MR. GAMBLE: This again is relatively new. This particular technical assistance request comes from work that has been done in Task Action Plan A-12, which it supports, and that Task Action Plan is managed by DOR, with some assistance from us.

When the scope of Task Action Plan A-12 was written, it did not include environmental effects. However, on working on that particular Task Action Plan, it was found that --

DR. SHEWMON: Which Task Action Plan? A-12? What is it?

MR. GAMBLE: Integrity of supports.

DR. SHEWMON: That is something that isn't on this list which was in previous years?

MR. GAMBLE: Task Action Plan A-12, with 19 others, is one of the unresolved safety issues that the NRC has. It is not part of any -- there are many technical assistance programs that go into -- that could go into one task action plan. It is a large overall program to resolve a safety issue.

As part of that program, when the original scope was written, it did not include anything on environmental effects. However, as people studied the program, they found out that in many support systems there are a lot of high strain bolting and other components using steels that are susceptible to environmental effects.

This particular program is meant to determine the fracture toughness -- not experimentally, now, but primarily I'm sure you can do a lot of this through literature search, because the aircraft industry has done a lot of this work in the past, to determine the environmental effects on high strain steels that are used in support systems, and then use that information to evaluate the integrity of these particular high strain components in environments that you find in nuclear plants.

DR. SHEWMON: I guess the other comment I have here by way of your prescience or whatever: Is anything being done to keep steam generators from getting that way, instead of how much to plug? And your response is yes, at least there is something up there on secondary system corrosion. This was apparently something the NRC couldn't see as being within their purview several years ago.

There is one down here, corrosion and coolant chemistry. The second item of scope is recommend licensing criteria that will result in improved oxygen control. Are you making any progress?

MR. CONRAD: You probably know John Weeks at Brookhaven. We have asked him to review everything that is available, contact the Japanese, and to make a recommendation to us on how we could implement this into the licensing of new plants. And he should come out with his recommendation in two months.

MR. BENDER: One of the things that troubles me about this has to do with the fact that the recommendations are fairly narrowly based in terms of expert opinion. I have a great deal of respect for Dr. Weeks. I think he has a lot of insight. But he is not the only person in the country. I have been a little troubled by the fact that when you are trying to deal with something that is as difficult and as controversial as this, your base of expertise is not broad.

MR. CONRAD: That's true. His input is only one input. We of course -- the responsible staff members are talking to industry members and other parts of NRC, DOR and Research, are looking into the same problems. However, as I said, our limited resources are applied to hire us one expert, and so we use the money the best we can, and this was one project that we sent to him to get his professional opinion on it.

MR. BENDER: You get a reactionary kind of response when you send something out for comments, as opposed to having people initiate something in the form of a proposal that represents a viewpoint that may be somewhat independently derived. I see a lack of that at the moment.

MR. CONRAD: I have talked to people at GE, and we do get other inputs. And as I said, John, his opinions are only one factor in our final decisions.

MR. BENDER: GE is so oriented to saving GE money that it has never objected.

MR. CONRAD: That may be true. But then we certainly can't ignore what their experts are saying. We certainly realize that GE has its own interest and that is certainly factored into our decision.

DR. SHEWMON: The research program doesn't have any corrosion program, and so they don't really provide any other --

MR. CONRAD: Not in this area, but some of the same people who are working in the corrosion area, we have access to them.

DR. SHEWMON: Name two.

MR. CONRAD: Mr. Danko was one of them when he was with GE.

MR. BENDER: If you are going to spend $5 million on something, would you rather spend $5 million on improving -- looking at a steam generator or spend $4 million in looking at a steam generator and $1 million in trying to improve your expertise in corrosion? Those are the kinds of questions we have to address.

I am surprised, though, that there is not that kind of consideration in NRC concerning where to spend useful research money.

MR. CONRAD: I make my proposal, which is essentially at the lowest level, and I fight for it up through management. And I fight for my programs as I evaluate them, certainly considering what I understand to be the overall priorities. I would expect each person who has responsibility in any one of these areas to identify what he thinks is important for NRC to get out of him, and to fight for his particular programs all the way up.

MR. BENDER: I am not trying to challenge your personal integrity. I know --

MR. CONRAD: That is how I think the system works.

MR. BENDER: But there is something wrong with the research program when it spends a lot of money on looking at detailed hardware and very little effort on fundamental understanding, just because it doesn't have enough money to hire a few experts. That's how I --

MR. CONRAD: I don't make that $5 million or $10 million decision, but I try to influence it the best I can.

DR. SHEWMON: I guess we have clubbed that one enough for now. If I go over here to another one, there is tearing stability in LWR piping. Who is working on it, if anybody? It is undesignated.

MR. GAMBLE: That must be fairly old, then.

DR. SHEWMON: May '79, the best we have available. I'm sorry if we are not talking to the right people or they didn't send us the right thing.

MR. GAMBLE: This is a contract that we had to go out for bid on, and we did in the contract -- it was just let around June 1st of this year. It is going to be done by Washington University, with Paul Paris as the principal investigator, I think.

And the objective of this program is to do tearing stability analyses for various flaw conditions, sizes, shapes, orientations, in light water reactor piping.

DR. SHEWMON: Where is that on this list you put up here?

MR. GAMBLE: The first one.

DR. SHEWMON: The first one. This is a brand-new program. The contract was just let. But you spent $35,000 --

MR. GAMBLE: That is not spent. That is allocated.

DR. SHEWMON: From last year's money.

MR. GAMBLE: No, this year. It was allocated in fiscal '79.

DR. SHEWMON: It was shifted so you have through September to spend it now.

MR. GAMBLE: Yes. The whole program is $75,000.

DR. ZUDANS: Is the work that Professor Paris is doing on this contract complementary to the work he is doing for RSR on the same subject?

MR. GAMBLE: I think it is more complementary to the work that DOR -- they are certainly complementary, because it is tearing stability analysis and the results that Research gets, as I understand it, is primarily to continue to verify the tearing stability contract. So certainly that information is going to be very important to us.

But our work and the work that DOR is doing on the reactor vessel -- we are doing piping, operating reactors, doing it on vessels; and this is to generate the analytical solution to predict unstable crack growth for various flaw conditions and load conditions.

DR. ZUDANS: This portion of work would be like application of his theory that he developed from the other program?

MR. GAMBLE: Yes.

DR. ZUDANS: This specifically to piping.

MR. GAMBLE: Yes, and Research is doing verification of the methodology and also experimental work to generate the material properties that are necessary to apply the analysis.

DR. SHEWMON: All right. Evaluation of buckling stress criteria for steel containment. Is there another handout for that?

(Pause.)

Irradiation embrittlement calculations at PNL. Is that yours or theirs?

e-14

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MR. JENG: I am a member of the Structural Engineering Branch in DSS. The program which was referred to is the buckling behavior of containments.

Some of you probably know, in our current SRP, there are no detailed specific acceptance criteria for considering the design of containment against buckling. We have been, in the past, using case-by-case review, with reference to some ASME Section 1 provisions, which may not particularly apply to the types of loadings we review. And in view of lack of information, which is pertinent to our type of loadings, we see the need to retain consultants to work on the program and to come up with recommendations for state-of-art-type practical design review and accident criterion.

And this, for one, is oriented to that goal.

DR. SHEWMON: You had another contract out last year with somebody in this area. Did it have the same goals or different goals, or what?

MR. JENG: Yes. The area of the contract which was completed last year was to scope what is available in the literature and what is the programs. If there is any solution at all, what are the approaches to proceed -- that was conducted and completed, and a report was issued.

And given that finding, we are proceeding to extend our effort to work on specific review criteria.

DR. SHEWMON: This will be done by setting up scale

jl 2

models or doing some experimental work?

Are you going to calculate some more, or what?

MR. JENG: This program does not involve the use of scale models because, number one, DSS, being in the licensing area, is not entitled to do large-scale research programs. We are only planning to implement pipe studies by various consultant -- expertise in the areas -- and come up with some combinations and give that study -- if it dictates the need for a scale model test, then we would consider it. And if so then determined, then we would refer to the RES people a user request for their taking over of the program and resolving the issue.

DR. SHEWMON: There is a particular number in that in front of financial. Does that mean the contract has been let?

MR. JENG: No. We issued a proposal. We are anticipating to receive a proposal from various experts in the next couple of weeks, and we have formed a panel to review those proposals.

DR. SHEWMON: What is a blank, or a letter or a number designation under FIN mean here?

MR. JENG: These are the program numbers for which funding has been allocated. Some of these programs are either completed or in progress. If you have a FIN number, you have the funding allocated by the offices.

jl 3

DR. SHEWMON: So you have funding, but you haven't got a fundee yet?

MR. JENG: Yes. With regard to buckling behavior contract, yes.

DR. SHEWMON: All right.

DR. ZUNANS: I have several questions.

First, I want to identify whether this program that you just talked about, with which I am well acquainted, has any similarity with the other program here that we have in Structural Engineering Research Branch, safety margins for containment and buckling of steel containments that apparently is managed by Larry Shao's group in RSR. Are these the same programs or not -- RSR project descriptions?

MR. JENG: I'm not familiar with what particular project you are referring to, handled by RSR, but I can explain to you what --

DR. ZUDANS: These are the two programs.

MR. JENG: Are you referring to the table?

(Pause.)

DR. ZUDANS: There are three programs in general that I find. This would be the third one.

DR. SHEWMON: Shao has a bunch of things in there he would like to see somebody fund someday. I am not sure that he has --

DR. ZUDANS: They are listed on these lists. I am

546 308

wondering whether that is the same thing.

DR. SHEWMON: I am not sure whether they are funded.

DR. ZUDANS: They are not the same?

MR. JENG: I don't think so. It seems that there is no funding.

DR. ZUDANS: They have the same money indicated as you.

MR. JENG: My answer is I am not aware of this one, and they should not be the same. We haven't had a chance to review these programs.

DR. ZUDANS: All right.

Very similar on the other one that David is not familiar with; but with this one here, I am very interested in the program of this nature, because during the period of other reviews, I hope to get the answer to the question of what are the bucking criteria, and we seem to always come back to the situation whereby we work on a case-by-case basis. There are no general criteria.

My concern with this program is not that it is not needed. My concern with this program is that it is not really completely thought out, what it will produce.

Let's look at the first question, the first items, design analysis of two typical steel containments, for firm data analysis with what tools?

I am looking at the second sheet. I am familiar with your RFP because my organization wanted to bid on the job. They decided to decline it, because we believe this research is not defined, that it will lead to any results of any use to you in your review work.

Weingarten and his team, in the previous research, found out nothing better than 1965 criteria, which they recommended to adopt on an interim basis at the ASME.

Now, if you throw that out and use just what they find as a tool to generate a bunch of calculations and to generate some charts, if you think you can do that, then you really go no place, because the big issue in this question is not the analysis how to do it, but what to use for the factor, -- for the unknown factor.

If you go with the linear analysis and use knockdown factor to transform the results into real structural results, then the only issue is what is the knockdown factor. The NASA report which Weingarten pointed out very effectively says that they seem to be different for types of stresses that you work with; for axial stresses is one, for shear stress is another. And they recommend a mixture to use it.

So anybody who bids on this job, other than Weingarten, would be forced to follow what is recommended in the NUREG that you issued as a result of Weingarten's work.

In my opinion, the net result in this research, very necessary, would be essentially zero. I think you really have

have to rethink this whole issue and define what you want to see as the ultimate set of criteria, what methods you want to use, and generate the data to supplement those methods.

If you want to analyze structures elastically, compute the bifurcation loads with real boundary conditions, with real loads, with nonsymmetrical prebuckling stages, then you have generate knockdown factors. That is the only issues.

So the program should be for generating knockdown factors, not to perform analysis of two typical containments -- what for? What are we going to learn from that?

That costs about $200,000.

MR. JENG: You are certainly one of the experts in this area. I agreed on almost everything you just commented -- but, however, this program, remember, is limited funding, and there is the need for information, for helping us make judgments. Because of that need, we have requested limited funding -- in our limited funding, and try to do the best off the resources that we get, and to propose objectives in the program.

Of course, anybody who participates in the bidding can, as part of its bidding or conditions of offering to serve, provide proposed changes like you are suggesting in the scope of work and the end product, and that would be reviewed by our review panelists. And hopefully it would be taken care of to suit more the needs -- your comments.

If you define your objective clearly, then we could end up doing nothing.

I would like to welcome you to give a proposal, in your view, what would be the best way to attain this goal which you and I agree --

DR. ZUDANS: I wrote two letters to Professor Shewmon, and one of the them explains what I consider to be an acceptable method. It really does not differ very much from what Weingarten did, except that I wouldn't end it that way.

I can write separately. I can discuss this with you, but I believe your objective is to get criteria that you can say, "Indeed, I can use these criteria. They are conservative."

The problem, as it exists now in the industry, is the fact that we don't have knockdown factors for any combined loadings except for bending. We don't have them. There are no tests. Everybody is very capable of testing pressure vessel for extended pressure or for axial compression or for bending. But when it comes to complicated loads like you see in MARK III containment, or in ice condenser containment, there are no tests. Nobody knows what the knockdown factors will be. That is what you miss.

You can analyze. You can model any containment on the finite elements if you are willing to spend money and compute theoretical stress for any complex conditions. You don't have that limitation now; you don't have developed computer codes. Once you compute them, what do you do with that number? You don't know by how much you have to compute the buckling load. You know that to say this is what the real structural is, and then you would apply a safety factor on that. So you research, in my opinion, in this context of developing criteria, would be to get knockdown factors.

The other program that I made reference to -- I showed to you -- is considering making a quarter-inch containment model -- quarter-scale containment model, which is very, very big, and testing that for buckling for complicated loads. That sounds like a good way to go except that it is a long-term program. You can't really produce much in a short time under those conditions. So I am concerned about this program.

I am also concerned about the fact that you really need it. You need it very badly.

DR. SHEWMON: Tell me a little bit about the need, if you would. What are the highest stress conditions, the type of vicissitude which is most likely to give buckling? Are we talking about seismic loads as being the extreme ones, or tornados, or the coming across Lake Michigan, or what?

MR. JENG: The most severe load combinations which could cause buckling in our view is the combination of the SSE, combined with the early stage of a LOCA, which would create pressurization within the containment, and combine to that effect -- you would see some compression forces, as compared to other portions, and this could cause combined maximum stresses to be critical.

DR. SHEWMON: The SSE by itself would not do it?

MR. JENG: Because of the shaking nature in one instant, it would cause compression on one side of the containment; and the next instant, it would be -- put inside stresses on the containment.

However, if they put compressive stresses on one side and consistent with the compression, the localized pressure, which of course is compression on the inside, then this may create a controlling situation. And that is the type thing that we have to consider.

DR. SHEWMON: But wind gusts do not do it?

MR. JENG: Generally speaking -- I said "generally" it should not control -- large SSE -- we are basing our design aginst, but all effects due to earthquake shaking would normally override those effects due to wind.

DR. ZUDANS: The big problem is not what combination will cause buckling. It is what you consider acceptable level of the combination of such loads.

DR. SHEWMON: Somehow I can't get too excited about the probability of simultaneous LOCA in a safe shutdown earthquake. If indeed we are safe against things aside from that, that puts one level of priority on it. If we thought that the loads which would test the analysis would come once a decade, that would put a different level of priority on it. And given that they don't know how to do it as well as they might, I would like -- the other thing that I want to get is some feeling as to how often do we think we are likely to be probing the limits?

If it is once very 10,000 years, why that's different from once a decade.

DR. ZUDANS: That is correct, that there are some approximate ways of saying what is conservative, not really knowing precisely the behavior, not precisely knowing the size of the knockdown factors.

However, I think it is a gap in technology really, more than anything else.

DR. SHEWMON: The gap in technology offends you a little bit more than it does me I guess. If it is a gap in the public health and safety shield --

DR. ZUDANS: You do not want the containment to collapse just when it is needed.

DR. SHEWMON: I grant that, but if it is not going to collapse until we have a simultaneous maximum LOCA and SEE, I may not live that long.

MR. JENG: I personally agree. Maybe that is no justification for combining two very unlikely events together, but from our licensing viewpoint, it means that the combination is one of the design requirements or design basis, and we have to assume this particular need has to be met properly.

DR. SHEWMON: If you do think it ought to be met properly, then why don't you organize a program to do it?

The main thrust of his point is you aren't organizing a program to do it properly. You are piddling along, which things -- that aren't going to get you anyplace, and Shao is trying to do it, too.

MR. JENG: We may be slow and maybe not as effective as we should be, but I think we are trying to do the first step to see what can be done without going to more of a testing -- large effort.

I believe some people feel there could be some way, without having to test, to find what the criteria should be for such an event. And we have to complete that first effort, that first phase; and given that completion, if it shows that the only way to achieve this goal is to go through testing that Dr. Zudans seems to implying --

DR. ZUDANS: Not necessarily.

end t15

DR. SHEWMON: Are there other comments?

MR. BENDER: I am unclear as to how this problem arose, and I am unclear as to how to resolve it.

MR. JENG: I didn't get that last comment.

MR. BENDER: How did it come about, and why is it so urgent to get it resolved by development of some kind of new analytical procedure?

MR. JENG: I tried my best to answer the question. My answer may not be inclusive.

The original SRP standards were issued saying: "operating a safety factor of 2." And by ASME, Section 1, it is simply based on the asymetric non-compression type of consideration. And we, at that time, we said, "Let's use the safety factor of 2 for the criteria."

And that was the criteria presented in the SRP. But as we learn more, and discuss with the experts more; and we have the review of the off-shore power plants, which is based on the containment; and then on top of that you have the add the deformation, due to the platform, which may cause some buckling situation -- maybe there is a need to study more. And this caused us to start a small project to retain ISE as a consultant.

In the mean time, in the industry there are working groups looking at this area. And they raised quite a few concerns about the adequacy of our criteria. We feel there is a concern, although we feel that the way that we have

ros 2

reviewed, that we should get a conservative result.

MR. BENDER: Is the problem mainly with the ice condenser containments today?

MR. JENG: Yes. It is one of the key concerns.

DR. ZUDANS: In the Mark III it wasn't so acute until we learned that there are asymetric loads in Mark III; and that was discovered because of the blow down, and then it became very critical. And the fact is, if you take the ASME code criteria, you cannot decide the containment under those loads. There is not enough --

In other words, industry is trying to do more precise analysis.

MR. ETHERINGTON: Tornado missiles, are they a particular problem in this connection?

MR. JENG: No.

MR. SHEWMON: Thank you.

Is this last hand-out yours? What is this that we have here? Al? Is there anything from DOR?

MR. LIAW: Yes, sir.

MR. SHEWMON: While that is going around, does the radiation embrittlement at Battelle -- that is one of yours. Could you comment on what that --

MR. JOHNSON: I will talk rather loudly, and I think I can cover anything that she might otherwise miss.

I am Richard Johnson, Engineering Branch Division

ros 3

of Operating Reactors.

And the question you asked, Professor Shewmon, I am afraid there is no one here who is intimately involved in it. It is not in our part of the DOR. However, I have been peripherally involved. It has to do with some calculations that were made by one of the Vepco contractors. It is a question of what is the neutron fluence at the neutron shield tank.

As I recall this, the licensee, one of the AE's, submitted something that said that there would be quite a bit larger neutron fluence than was expected, particularly by taking a count of those neutrons less than one mev out that far with all of the attenuation through all of the steel and the water in the neutron shield tank. There is quite a large flux of neutrons.

Of course, Serpan can probably handle this even better than me. At any rate, the long and the short of it is --

DR. SHEWMON: He can give some base numbers. He won't give me the calculation maybe, so go add.

(Laughter.)

MR. JOHNSON: The long and the short is that there are quite a number of damaging neutrons. The Nuclear Regulatory Commission questioned the calculation, went to the Brookhaven National Laboratory to have some confirmatory calculations made, and I believe, in summary, Brookhaven

ros 4

not only confirmed the calculations, but said that the licensee's contractor was a little on the conservative side. And I think we are, therefore, moving ahead in the direction of taking the next step -- questioning what would be the change of the ductile brittle transition in steel when one accounts for all of those neutrons.

Chuck, do you want to add anything?

MR. SERPAN: No. Brookhaven provides the spectrum type reactor physics calculations for DOR in a variety of projects, and what Dick said about that particular job, the Vepco job, was quite right. They did a nice job on it.

DR. SHEWMON: Can we have -- let's do this by questions, in view of the hour.

Do you have anything you would like to ask questions on on this, Harold? Or give us a chance to go through it?

MR. ETHERINGRON: I don't have any.

DR. SHEWMON: Then why don't we dispense with any formal question and answer on it.

I thank you for coming down. I guess we will adjourn for an hour, at which point we will hear from -- hand it out and let's look at it.

DR. WECHSLER: If I could ask a quick question about the last comment.

Roughly, what is the flux at the neutron shield tank? I am surprised to learn that it could be high enough

ros 5

to cause increases in the ductile brittle transition temperature.

MR. GAMBLE: I don't know the exact numbers, but the flux is just not one number. There is a spectral effect that they calculate, and they have calculated about eight different energy fluxes at eight different energy levels. The flux in those energy levels runs anywhere from 10^{18} through maybe 10^{19}, in that general vicinity. I can't tell you exactly what flux was.

DR. WECHSLER: Over what period of time?

MR. GAMBLE: I am talking about fluence at each of -- over the energy levels. The range would be -- over -- this is all end of life. And yes, it is surprising. We were surprised. We thought they had made a mistake, and that is why the confirmatory calculations were made.

MR. SERPAN: I thought it was low -- 10^{10}, the flux.

DR. SHEWMON: Who is defending this hand-out?

MR. BOSNAK: Mechanical Engineering Branch, DSS.

(Slide.)

DR. SHEWMON: Let me focus on the things you would like to do next year, I guess. Steam generator tubes. That is an advisory capability at Batelle, or Brookhaven?

MR. BOSNAK: That will continue at Brookhaven. This is the last year. FY-80 will complete the analytical development of a computer code.

ros 6

DR. SHEWMON: What is the in-service testing program?

MR. BOSNAK: It is purely a way for us to get additional assistance in the branch. It is to review about 10 to 10 to 15 plants that are already licensed, that are already operating. And they are operating on their technical specifications, but their in-service testing program for pumps and valves has never been reviewed.

And the -- what we are looking at is the things that the can't do with respect to meeting Section 11 requirements of the ASME code. So it is to buy additional manpower.

DR. SHEWMON: The last three are things you would like to have in next year, or a year from now?

MR. BOSNAK: We actually placed it in our FY80 budget, but because of resources and whatnot, they are now shown in the FY-81 budget. The criteria implementation review, code verification analysis, and pump and valve operability reliability; again, those programs are essentially to buy us help in doing our licensing reviews in those three areas.

The criteria implementation review would be to do more of the things that we did on the Diable Canyon, for instance. The kinds of things that the staff did on Diablo Canyon.

DR. SHEWMON: You wouldn't more reliable PORVs if you did it?

MR. BOSNAK: The PORV would be something tha ould

ros 7

be contained in the last items. The PORV, of course, on Three Mile Island was not -- it was not a code system. It didn't meet the reliability requirements of the code.

The pump and valve reliability and operability are things that we would like to look into further. I think you will also find them in the research program that Larry Shao has.

DR. SHEWMON: This would be only for code things that meet code?

MR. BOSNAK: Essentially, anything that is safety related is a code item.

DR. SHEWMON: What happened at Three Mile Island wasn't related to a safety related system when the PORV stuck open?

MR. BOSNAK: The PORV did not have to meet the ASME code. It is an extra valve put on there to take the service away from the spring safety valve.

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DR. SHEWMON: All right. That's all I have.

I think we are hungry. We will adjourn for an hour then.

(Luncheon recess at 1:21 p.m., to reconvene at 2:21 p.m.)

end #16

AFTERNOON SESSION

(2:25 p.m.)

DR. SHEWMON: This is a continuation of the morning session and all those good things I said about whatever, who was here, and freedom of information still applies.

This afternoon we will move on to the work done by other groups in the country in the general area of metallurgy and materials. The first half of the afternoon is devoted to EPRI's program, and the second half is to the vendors' programs.

The program says -- who is first from EPRI?

MR. DAU: I am Gary Dau.

DR. SHEWMON: Thank you.

(Slide.)

MR. DAU: Good afternoon. My name is Gary Dau. I am program manager for the nondestructive evaluation program at the Electric Power Research Institute. Today I would like to summarize our programmatic activities that are under way and then highlight a few specific examples of the research results that we are achieving.

The handout has been given out. And as backup material I have left copies of the blue-covered document which is our planning support document. Appendix A in this report gives summaries of each individual project that was under way up until about October 1978.

(Slide.)

546 324

The program philosophy has been broken down in this manner. We really are approaching three different levels of technology, if you will, or technical thrusts. There is improvement of code inspection techniques, those techniques that are being used in the field today. And our goal here is to optimize these techniques because we can provide some feedback for field use as quickly as possible in this area.

The second area that we concentrate on is new methods and device development. This is where we are looking to bring in innovative new concepts from other areas of technology as well as developing new approaches ourselves. In this case we realize it will take a bit longer to get this into field practice, but we are expecting much larger improvements overall in that area.

The third area we are concentrating on is the material property measurement, and this is trying to developing the technology so we can get into the position for preventative action. In other words, we can identify materials degrading before failure occurs so we can take corrective action before shutdown or catastrophic failure occurs.

(Slide.)

To give you some idea of how this affects the specific components in reactor system, we have either under way or completed fixed programs in the pressure vessel area: 12 oriented towards piping inspection, two on nozzle inspection, four on steam generator inspection. And this does not include those projects that are being addressed by the steam generator owners group, which project is being managed by EPRI staff. We have two projects under way which address turbines, specifically turbine bore inspection on the large 600 megawatt and larger turbines. And property measurement area, we have five projects under way. A total of 31 projects that have either been completed or are currently under way. And this is since our startup in about 1974, a total contract value of about $50 million.

(Slide.)

If you look at this in terms of function, it can be broken down in the following way: We have specific programs addressing improved hardware development for austenitic plant inspection, feedwater nozzle inspection, pressure vessel turbine rotor, and steam generator tube.

These will result in specific pieces of hardware that will go to the field starting late this year -- in fact, some of it is in the field right now -- and on through the next two to three years. In the more basic research area --

DR. SHEWMON: Let me stop on that for a moment, if you would.

MR. DAU: Sure.

DR. SHEWMON: Is that work done by people who would sell the equipment, or how do you get --

MR. DAU: Are you asking a question about technology transfer and how do we get our results into the field?

DR. SHEWMON: I guess I am, yes.

MR. DAU: I will address that later. We are setting up a special NDT center to help us in that area.

But as far as your specific question here, in these two, the people who are doing the signal processing work, the electronics development, have also made a commitment to go into production of the resulting hardware. In this area we haven't completed the research here, but we did involve a manufacturer of equipment as one of the subcontractors so that they would be in a position to manufacture tne hardware when our research effort was completed (indicating).

In this case we are still in the development stage, and we really haven't looked at who is going to be the purchaser of the equipment and the supplier of that service.

DR. SHEWMON: With your background, you don't have to be concerned about whether you are fair to all potential suppliers, as long as you have at least one potential supplier for the industry?

MR. DAU: That is close to correct. Often there is cost sharing put forth by some of the contractors that are really interested in moving into this.

On the other hand, though, part of the problem that we face is that the market for nondestructive testing equipment is so small compared to other instrumentation markets, it is very difficult to get people to go out on their own hook to develop new equipment. It is a problem we have recognized, and we try to factor that into the program so we may go a lot further in terms of building and qualifying hardware than other people might do, for that very reason. If the results are only in terms of a report on the bookshelf, they are not really satisfying our objective.

DR. SHEWMON: Thank you.

MR. DAU: In the research area we have some fairly basic work under way, a study on the physics of ultrasonic propagation, and ultrasonics really occupies a majority of our programmatic effort. We are also looking at eddy current flow flow patterns, with the idea if we better understand how eddy currents interact with materials, we can do a better job of designing equipment.

And then, acoustic emission. Our major effort here is a very fundamental effort at the National Bureau of Standards of really trying to understand the fundamentals of what happens in acoustic emission and establishing on an analytical basis what kind of signals we would expect for different type defect conditions.

In the material property measurement area, our major work right now is concentrating on the measurement of stress, specifically residual stress. And we have two efforts under way: one, looking at acoustics techniques with the hope that we will be able eventually to measure a stress profile through the wall, as opposed to a surface stress, and then a portable X-ray defractometer which is being configured so it could measure the stress on the ID surface of a four-inch diameter pipe. In this device we hope to be in a position to start some field measurements, field in this case being laboratory, welding development type laboratory measurements, later this fall. We have had some problems with X-ray tube supplier that is slowing us down. In this case we will have a device for limited evaluation ready in about three to four months.

DR. CORTEN: Why do you call it material properties when you are measuring a stress, your residual stress, which is really not a material property?

MR. DAU: It fit into some of our -- the way we broke some of them down.

MR. BENDER: Can we get back to the ultrasonic program for a minute. Is the thrust of that effort flaw discrimination or what?

MR. DAU: In here or here?

MR. BENDER: Where it says "Physics of ultrasonic propagation."

MR. DAU: Two things, improved detection of flaws: We had better know how the energy interacts with a flaw, and then we can design sensors and signal processing equipment to optimize on those conditions. The second part of the problem is once you detect a flaw, how do you size it and size it precisely? So, we are looking at those two aspects of it, of the problem.

And then, as far as the basic physics, when you get into dissimilar metal welds or coarse grain structure, your propagation parameters vary considerably, and it is no longer a linear material. So, we are trying to cope with those problems as well. I will have some specific results to show some of our improvements and results from that.

In the last category it is called "qualification and verification." That results from, once you develop some new equipment here, you have to pretty much verify that it really meets performance standards that you set in the first place. And second, you have to qualify it as a field-acceptable tool so the service companies and the utilities are willing to use it in the actual environment it has to be.

There are several parts of that: There are flaw characterization ability, how well or what can you detect flaws and size them, and defect detection probability we would like to get a hold of. Part of this effort also involves the generation of realistic flaws and I have indicated three types here. The IGSCC thermal fatigue cracks, like found in the boiling water feedwater nozzles and then fatigue cracks of other types.

All of these programs here, these and, to a lesser extent, this one (indicating), were working with actual flaw conditions. We started with machine notches, but we are growing our own cracks or using surface removal samples for stress corrosion cracks. And then we have recently cracked a mockup nozzle with thermal fatigue mechanisms, so that we are working with the actual flaw condition that we will have to see.

This is a very large effort in itself. I think, in the area of pipe flaws alone, we are probably spending over half a million dollars to provide samples this calendar year alone.

And the last item is pressure vessel shell course, which we have a full-size shell course. We have obtained, which is now being shipped to Westinghouse Tampa, we will weld some nozzles in with programmed flaws so we can test equipment out. It may also be useful for training operators.

(Slide.)

DR. SHEWMON: I think I know what a course of bricks is. Is a shell course related? A slice through?

MR. DAU: A complete ring. 110 ton. The shell course. The shipping costs alone are a major part of our program.

(Slide.)

This is really a list of things I would like to spend a little more time talking about. The dual element transducer for detection of intragranular stress corrosion cracks, eddy current signal analysis, ultrasonic signal analysis, and now we are talking about real-time analysis for automatic interpretation, portable X-ray source stress measurements that I indicated earlier, and then again this whole area of quantification and verification.

(Slide.)

The dual element transducer is a concept that has been around since 1969 in Europe, and about two years ago we started work on this as a possible near-term improvement for austenitic pipe inspection. It is a partially focused transducer arrangement, meaning there are two transducers: one acts as a transmitter, the other as a receiver that intersect at the zone of interest that you are trying to inspect. It is not a true focus, but it reduces the area that is being illuminated with sound so you have less scattering, and hence you should get an enhanced signal to noise.

From experimental work, we have established that 1.5 megahertz seems to be the optimum frequency. This was done both empirically, working with samples removed from BWR reactors and also some of our automatic signal processing work indicated the same region. We have had a fairly extensive evaluation of this transducer concept, and it shows that it is at least two to three times more sensitive to the IGSCC condition for detection than the conventional 2-1/4 megahertz transducer. These results have come from a series of tests by test laboratories, samples that have come from GE on field removal samples from various reactors. And we also have a direct comparison of this transducer against conventional technology on the Gundremingen samples in our project right now.

DR. CORTEN: What is more sensitive?

MR. DAU: The dual element one.

DR. CORTEN: How do you define it?

MR. DAU: We find cracks that in some cases have a greater amplitude than a conventional technique would, or, in some cases conventional techniques do not even detect them.

DR. CORTEN: It is twice to three times as good as, and I was wondering how you were specifying it.

MR. DAU: In terms of signal-to-noise ratio; in other words, a crack signal will stand out two to three times as high as the background noise level as you would find in a conventional transducer.

MR. BENDER: Let me try Prof. Corten's question another way. Is two to three times more sensitive a significant improvement?

MR. DAU: Yes.

MR. BENDER: Why?

MR. DAU: You have a tremendous amount of background noise from the grain scattering and from geometrical reflectors in the weld zone or the heat-affected zone that you are interested in inspecting. If you have an amplitude signal from a real flaw condition that is two or three times as high or much energy coming back from as conventional, you have got that much more signal to work with, and that much easier for the operator to make a decision.

MR. BENDER: Yes, I agree with the logic of it. But given a specific flaw size as detectable now, how much smaller, how much different, is the flaw you can detect with this device?

MR. DAU: In the case of the KRB samples, we are finding flaws -- well, we don't have destructive data yet. Next week or two weeks from now, we will have. We are guessing that in some cases the flaws may be in the order of, say, 50 mills on a 1.3-inch thickness, and we are seeing a signal amplitude of roughly twice the height as you would with the conventional technology. Or, in some cases we have found flaws or indications at this point that we believe are from cracks that we could not detect with conventional technology.

Until we get the destructive tests done, which we have planned, I can't answer any more specifically than that.

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546 334

(Slide.)

MR. DAU: The transducer concept is being used by most of the service companies performing the ISI on the BWR reactors in the U.S. right now. This is one area where the technology has moved into the field fairly rapidly.

DR. SHEWMON: Why is it used more in BWRs than PWRs?

MR. DAU: Looking harder, I guess, for intergranular stress corrosion cracking. It is optimized for that one condition.

DR. SHEWMON: Which is basically a tight crack?

MR. DAU: Tight crack in the heat-affected zone in austenitic welds.

(Slide.)

Moving on to the area of eddy current signal analysis, our major thrust here is to develop the capability to automatically process the signals that come in from conventional eddy current probes. What we want to do is detect the signals, classify them from a stress corrosion crack or from wastage, and then size whatever classification it is called.

This all looks very possible at the present time. It could be done in real time in the field. The hardware is not complete to do the signal processing. The processing routines, the programming of how you treat the data is about 80 percent developed. And, starting about September, we will move into an evaluation program of this; first with mark-ups,

ros 2

and then probably six months later, we will move the equiptment into an ISI group and have them do tests in piggyback fashion with conventional inspection.

We also have analytical work underway to support this. This is largely an empirical effort here, and these results are already giving us some guidance on what probe designs we should be looking at. And we are also applying the finite element analysis technique that is used in structures to map out the eddy current flow patterns.

The hope is that combining these two, eventually we will be able to analytically train these processing networks to new flaw conditions, and we can eliminate the need for expensive sample programs to develop the instrumentation.

(Slide.)

There is some radiography that is done in-plant today for confirmation of suspect regions detected by ultrasonic means. But it is hampered because of the lack of -- hampered by the lack of an adequate high-energy but portable, X-ray source. So we have started developing such a source using radar technology that has come out of the military area. And we have demonstrated the feasibility of this concept.

The design is completed. The hardware is about 90 percent complete at this time. We expect the prototype to start into a testing program in the Fall of 1979, and it should be available for field use sometime in 1980.

ros 3

The performance specifications are as follows: it will have between a 2 and a 4 in the energy beam. The dose rate of the beam will be 150 to 200 R. per minute per meter. And the weight is such that the head, the real business end of it, can be handled fairly easily by two people in containment; about 90 pounds is what we are shooting for now.

To give you some idea, the conventional head in the shops weighs from 2000 to 3000 pounds. It is definitely not usable for in-service inspection.

As I mentioned earlier, we are doing a lot of work on optimetic signal processing as a way of taking the operator dependence out of the inspection reliability problem.

(Slide.)

What we are doing in this case is applying many different technologies that are fairly well known in other areas to this particular problem. We are borrowing from radar pattern recognition techniques. Digital techniques have been here for a long time, but because of the micro-processor we have a convenient way of making it fieldable and portable.

The ultra-sonic physics have been known for quite a while. Automation, in this case, we are talking about in some cases a completely automated inspection. And then, data storage where we can store the complete wave form and position of that wave form, so you can go back and replay the complete inspection in your office or laboratory, if you would

ros 4

like.

Some of the benefits that come from this is that we can eliminate the amplitude dependence. This is a real problem in current techniques. The amplitude is not always linear with flaw size.

We can take out the transducer characteristics by a normalization process, and also eliminate a lot of the noise producing items like grains or transducer movement. And from this we can get a quantitative and automatic both ultra-sonic and eddy current detection and sizing capability.

The equiptment is portable, programable, with a different software routine it is digital, and it should be quite cost-effective because it is a generic instrument and you can modify the application by changing the software.

W< ll have the capability to record and store the data in an archival manner that is not really possible today.

I would like the 35 millimeter projector.

(Film.)

What I intend to do with the slides is to go through some specific results, and then show you the hardware that they were generated with.

(Slide.)

MR. DAU: I will try to go over this. As I mentioned earlier, there is really two parts to the inspection problem. One is the detection of the flaw condition that you are

ros 5

looking for. And once it is detected, the second part then becomes the sizing portion of it.

So, the primary one that we have to consider is the detection. And this is where the work that is underway comes in, in terms of the signal to noise enhancement. You want to be able to pick that signal out of a lot of conflicting or confusing information.

Basically, there are about five basic techniques to do this. We are working in four of them. One of them is to use what is termed a broad-band transducer. What that really means is that it is broad-band, it has a lot of frequency content, but it has a very short pulse in the time domain. The significance of that is a smaller volume of the material is being excited as the pulse moves through the material, and you have less scattering centers that are excited. This then becomes an important way of working with the automatic processing as well.

The focus probe -- there are two types of focuses. The true focus, which the French have worked on. We are doing the dual element, which is a partially focused, and I mentioned that earlier. It has a much greater utility than the true focus, because if you have a true focus you have a very limited volume that you can inspect, and it would require a whole host of transducers. You could go to higher frequency to get higher signal to noise ratio.

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That is not really an option in the austenitic materials, because of the high attenuation of the signal averaging where you can either time-average signals or do spacial averaging. And then there is the controlled signal approach that Karl Deutsch Company in Germany has developed. A system using very narrow frequency, and you select the frequency and the wave form.

It has some advantages. I think our assessment, after having a unit over here and working with it, it probably is a trade-off. The advantages probably match some of the disadvantages; the disadvantage being that you have to have a more knowledgable person operating it.

I think all of these are in the hand-outs.

(Slide.)

This is a raw signal coming in from a conventional UT device. It is a stress corrosion crack, 25 mils deep. That is about 7 percent of the wall in that sample. There is a ground loop from the electronics which gives this horrendous big signal. And this is what the inspector has to interpret in conventional technology by performing both time averaging and a match filter concept, which you design a filter to look for signals of a specific type representative of the flaw you are looking for.

You can clean it up to this point, and then by running it through the filtering concept the second time, you

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can come up with a very clean signal like this.

(Indicating.)

These results have been generated with our hardware, and we think they are very significant.

(Slide.)

That was 7 percent of the wall thickness. Here is one that is 4 percent, 15 mils deep in a 3/8-inch wall thickness.

There are weld reflections counter bore electronic spikes, and again the cracked signal here. Cleaning it out through the same process, we will get a much cleaner signal here. But by going through the final detector processing algorhythm, unambiguously identify that flaw.

MR. BENDER: What is this specimen you are examining?

MR. DAU: A piece of four-inch pipe, Schedule 80 -- a weld in it of an intergranular stress corrosion cracking induced in the heat-affected zone. Almost an exact duplicate of the conditions found in the field on the bypass lines.

MR. BENDER: The probe is along the external surface?

MR. DAU: Yes, the probe is moving on the external surface -- a 2-1/4 megahertz, share weight transducer at a 45 degree angle.

DR. SHEWMON: The difference between the middle and the last?

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MR. DAU: Two steps.

DR. SHEWMON: The second step seems to make so much more difference than the first step does.

MR. DAU: You will have to process the signal through this step in order to get it into the form where you can put your detector algorhythm, through that signals to identify the specific one you are looking for. It is an intermediate step. I'm getting to this.

In this case, we are averaging several different signals taken from the same point and then doing some filtering of that. In the last stage you are doing some low-pass and high-pass filtering, so you are cutting out the low-frequency noise. And you have the filter then that is looking for that specific condition.

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DR. ZUDANS: What are the indications between zero and ten?

MR. LIAW: Reverberations in the shoe or at the near surface. Because you know the location on the pipe, you don't worry about those. The deepest those could be, if they were real flaw conditions, would be ten to 20 mils each.

DR. ZUDANS: You said you would have to use specific software that contains the variation from this step to that step, and for each type of defect, you would have to have a different signal detector software. How general can you make that software?

MR. LIAW: The question on the generality of the software is not answered at the present time. We deliberatly kept the limits very narrow and are attacking one problem at a time. Now that the approach seems to be successful, we are developing programs to see how much work is needed to make a generic capability out of it.

At this point I think it is alot more general than we have allowed ourselves to believe so far. It is a good question. We really haven't addressed it in the depth it needs.

DR. ZUDANS: I assume to get a picture as clear as this, you have to define the precise geometry of the defect in your software.

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MR. LIAW: No. You have to define the reflection characteristics of an ultrasonic beam reflecting off of a stress corrosion crack. But stress corrosion cracks do not grow nice and neat. They have alot of geometry to them, if you will. So we are looking at the real condition, and we have the actual reflection characteristics built into the processing algorithm.

DR. ZUDANS: Okay.

MR. LIAW: That is why it takes so much effort in developing the samples, because we have to have real samples to work with.

DR. ZUDANS: You may have to scan your signal with many different packages of software for a whole range of different —

MR. LIAW: Yes. This program was put together to detect intergranular stress corrosion crackingin the heat affected zone of the stainless steel welds. That was the specific objection in that.

We are not looking for fatigue cracks, the ferritic materials, things like that. That is future work. We are trying to solve one problem at a time.

(Slide.)

And finally we have gone to the point where if you don't have a crack presently, you have alot of geometrical reflectors. You can sort those out.

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(Slide.)

Once you have detected a crack, you locate it. This is the automatic process data in the locations that the programs indicated. This is a replica of the inside surface of the plant where all of these flaws were present, and this is how they were called out by the processing.

(Slide.)

Now moving to the feedwater nozzle inspection area, this is a cross-section of the nozzle with stainless steel clad. Here a transducer works off of the blend radius to cover this area here. You move the transducer here and then it is also rotated at that nozzle when you look at it from this direction. This is a four millimeter deep notch that we were using at this time. It does not penetrate the stainless steel clad.

I have indicated six positions here that we have taken data. At position one, you'd have moved the transducer ahead a fraction of a degree, taken a second signal, third, fourth, on out to six. And there is about a 30 centimeters metal path here, and we are looking at something that does not penetrate that area.

(Slide.)

This is the typical raw data you would get, and this is the data be interpreted manually by the inspector in the field. There should be a flaw signal in each one of those. If you are lucky, you would guess this one, but it would be rather hard to pick those up.

(Slide.)

By doing what is termed "beam form", a modified version of the synthetic aperture focusing technique in the match filter, you can pull these signals out very clearly like this. And these signatures are also real in the remote conversion signals that occur when that primary beam bounces around inside that crack.

Since this time, we have produced thermal fatigue cracks in nozzles. We have gotten back and gotten data on those and are now processing that.

We think we are on to something very significant in the area of sizing the cracks, moving now from the detection to the sizing. If you transform this term amplitude signal into a frequency amplitude and then begin to look at different power ratios, the amount of power in this part of the frequency spectrum versus this, we are finding some monotonically increasing values that agree in slope at least with the increasing size of the cracks.

I think we shortly will have the capability to size this as well. It will be done by several different parameters. I have just indicated one here.

MR. BENDER: When you say sizing, the size parameters are length, depth, width. Are those the kinds of

546 346

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things you are talking about, or orientation, or some such thing?

MR. LIAW: In this case, we are talking about depth, and it could be the length but not the width of the crack.

MR. BENDER: How about orientation?

MR. LIAW: Well, the two examples we are looking at, we know pretty well what the orientation should be, so that isn't as big a factor as it might be in other cases. Most of the stress corrosion cracking cases are circumferential. We have been able to detect those that have been off-axis some, but we feel we can handle those conditions.

If you are talking about a crack that might be in the middle of a vessel wall, I am not really commenting on that.

MR. BENDER: This is really surface cracking, primarily, and in piping nozzles primarily.

MR. LIAW: Yes. Those two are the ones. If we can lick those two, then I think we have got the technology base to work on the others. This is the equipment that is being developed to do the automatic processing. It is less than 35 pounds in each box, so it is totally portable and easily transportable. The instructions are put in by a tape cassette here. You maintain a complete digital record of the wave form and position on this cassette. It is very similar to the cassettes being used in the back of the room.

This is the paper tape readout to help the operator give him a shorthand note of what is going on. And basically it is a portable computation center.

It also has provisions for a telephone mode connection so you can communicate to a master computer and put all of the batch duplicated data in a utility data bank, if you wanted to.

(Slide.)

This shows some of the equipment being set up an operating. You do all of the communications through this hand-held computer terminal. You talk with it in conversational English. It will prompt you and ask you questions -- if you want to scan, what area do you want to scan, what is the transducer number, who is the operator, what code name, what is the date -- and you can punch all of that information in.

(Slide.)

It also automatically controls the scanner, and this is the Southwest Research Institute pipe scanner being used to generate the data that I showed earlier on the four-inch pipe that came out of the General Electric pipe test laboratory.

DR. SHEWMON: That is an unprepared surface on

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the pipe. Right? It is not ground flat?

MR. LIAW: That is correct.

(Slide.)

Go ahead.

These are the actual welds, and it does not require anything special.

(Slide.)

This is the nozzle scanner at Southwest Research Institute. The transducer areas are setting in here.

(Indicating.)

The signal processing program was formulated around the idea that we had to use conventional pulser receiver technology, so we didn't require the industry to make a major new investment in detection capabilities instrumentation, and we also used available scanners so we wouldn't have to undergo that expense until we were sure the technology had worked.

(Slide.)

Some very recent results that we generated. Cast stainless is always a problem. In this case, we have part of, I think, a valve body. The objective here was to show that you could use ultrasonic as a sizing tool. This is about two and a half inches. There is a hole about one inch deep.

(Indicating.)

(Slide.)

Conventional technology sends out waves. If you send traces like that with a signal noise ratio of essentially zero, there is no way you can get a signal down to the back side of that part and back again and make a decision using some of the linear processing techniques.

We have got a signal to noise ratio of about four, but by going to some non-linear processing techniques where you weight the detection function differently, you can make this determination quite easily. And the results computed off of this trace agreed within two percent of what the physical measurement was.

I think there is some hope in the stainless inspection area.

(Slide.)

I have one final viewgraph. The question was asked earlier, how do you get your results into the field? That wasn't the exact quote of the question, but I think that was the thrust of it. That is something we have been very concerned about. So about one year ago, we started talking to our Industrial Advisory Committees and Board of Directors about ways that we could do something about this problem, so that our research results got into the field as quickly as possible.

The concept that was presented was to develop a

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dedicated utility industry center with nondestructive testing capability. The focus of this center is to provide technology transfer which can be a very specific definition or very nebulous.

In our case, what we really want is to be able to turn equipment over to this center, like the automatic processing equipment I just showed you slides of -- give it to these people who really don't have a bias and have them check it out in actual operations, make engineering modifications if necessary, and once they are satisfied with it, set up training courses for the utilities and service companies.

Also included in here would be things like development of a data base on defect detection probability, all of the information that is necessary to put together a code -- a good solid code.

Another function of this center would be training, and in this case we would be addressing those people who have a basic knowledge of nondestructive testing, but train them to the specific components or systems that they will have to inspect in nuclear power plants.

One of the things that goes along with this is full-size mock-ups, so that the people have a good understanding of what the physical restraints are of an inspection before they actually get into the radiation

546 351

environment and have to deal with it.

The third objective is the long term resource development, both in terms of people -- and specifically we are looking for academic involvement here to help get more people interested in the whole area of nondestructive testing -- both at the research level, the engineering level, and also at the technician level -- so there will be a fairly significant amount of resources put into working with academic institutions to try to get a long term solution to the manpower problem that we all face.

Also included will be some applied research. This whole center concept does not replace EPRI or R&D program which I have been reviewing, but it really supplements that and should make it a much more valuable program because we have a mechanism of getting the results evaluated and into the field when needed.

Specific benefits we have been able to identify so far is to speed the transfer of the R&D results into the field -- both in terms of qualified equipment and qualified procedures. We hope to avoid any commercial bias. We will have a mechanism by which we can qualify inspection people for the utilities and the service companies.

And we'll have some quick response capability to get on top of new generic problems, to define what the problem might be, and recommend research programs to solve

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them.

The status -- the Board of Directors of EPRI approved $60 million for a five year effort for this center on May 2. We have got the Request for Proposals issued, and the proposals are now in, and the proposals are under evaluation. Our goal is to have the proposals evaluated and contract negotiations completed for an October 1 start-up this year.

DR. SHEWMON: Would you pay for bricks and mortar? Would you go out to someplace like Southwest and put it on their place, or what are you talking about?

MR. LIAW: I' will be a contractgor-operated facility, operating under a contract with EPRI. We have specified in there that in the case of Southwest, they have to assure us that there will be no conflict of interest with their other activities -- in service inspection activities, so we have four proposals in place right now from four very diverse organizations.

We intend to rent the facility. We will buy some of the equipment that is needed to get it in operation. Some of the proposers have agreed -- have proposed cost-sharing with us.

DR. SHEWMON: Fine.

DR. ZUDANS: One little question. I am still very much interested in that crack program that you hav in there.

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Did that involve only the shape or also the size of the crack?

MR. LIAW: For the detection portion?

DR. ZUDANS: Yes.

MR. LIAW: We have worked with all different sizes of stress corrosion cracks, so we didn't want to develop our processing algorithms on a 20 mil deep crack and not have it apply to an 80 mil. So we tried to work up the whole spectrum.

DR. ZUDANS: It occurred to me that you could probably incorporate a variable within that program and scan different sizes of the same crack, the geometry, and determine the size.

MR. LIAW: Yes. It appears that is possible. However, the approach that we have taken is to do a quick survey and identify suspicious regions for cracks, go back and do a more detailed survey, and if you can angle the transducer ten degrees plus or minus, you get a tremendous amount more information. And your confidence of making a decision is greatly enhanced. So we are looking at it both ways.

Ideally, you would like to be able to do it on one pass because it is a much more economical inspection. But if you were doing it automatically anyway, and you don't have a man in the radiation zone, you can afford to go back

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and confirm with the transducer.

DR. SHEWMON: Thank you very much.

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(Pause.)

MR. DANKO: My name is Joe Danko. I am with the Electric Power Research Institute, the nuclear systems and materials department under Dr. Zabrowski. I am involved with materials development activities and materials projects in the nuclear systems and materials department.

I plan this afternoon to cover the materials development projects ongoing at EPRI.

Before I begin, I would like to make a comment. The reason that Gary Dau preceded my presentation is that what he presents is a natural flow into some of the information and projects that I will be covering.

I also want to comment that my presentation will be rather general, but give you an overall view of what the activities in the materials area is.

I have had an opportunity to quickly glance at Dr. Cowan's presentation which follows this afternoon. And much of the information that I have he will cover in greater detail.

(Slide.)

The presentation that I will cover will include the specific program areas of pipe chemistry and corrosion with specific attention on the BWR pipe cracking problem, briefly touching on the PWR steam generator projects, and discussing some of the basic thermodynamic work that is going on in the high temperature aqueous environments.

Also, then, moving into the plant materials and processes, looking at specifications and processing of materials, briefly touching on the steam turbine materials. This is a major effort in our organization. I don't plan to spend too much time other than to show that we do have some activities addressing the problems associated with steam turbines. Fabrication techniques in the field operations technology under the plant materials and processes will also be highlighted.

The area of the primary and secondary pressure boundary which covers materials properties characterization, materials response characterization, and finally, the engineering analysis of components and structures in the light water reactors.

The thrust of the program that we have is really one that addresses the reliability and availability of lightwater reactors.

And the emphasis of my presentation will be one some of the key highlights and the major program activities.

(Slide.)

This viewgraph presents a materials and corrosion program logic tree. And you will find as I move through the presentation we have each of the major programs presented in such a manner.

In the materials and corrosion program, the three specific areas we have are the plant chemistry and corrosion, the plant materials and processes, and the primary and secondary pressure boundary conditions in lightwater reactors.

The objectives covering the plant chemistry and corrosion, of course, is to develop a technology to avoid high impact problems caused by corrosion-related processes occurring in the PWRs and the BWR reactors.

The objectives of the plant materials and processes would include the assurance that the materials employed in the critical nuclear plant components structures have properties that are consistent with the design requirements that will meet the reliability and safety needs of the reactors.

And finally, in the area of primary and secondary boundary conditions, the objective here is to make sure that the methodologies are at hand and to develop these methodologies that are required to provide the analytical tools and the techniques and the statistical data to ensure that there is continued safe operation of the pressure boundary components and structures in the nuclear power plant.

Now Gary Dau has presented the work of the non-destructive examination. I would like to mention that that is very closely coordinated with the projects in the materials area.

(Slide.)

The plant chemistry and corrosion logic tree, Gary mentioned it covers the PWR steam generator area.

As you well know, there is a steam generator owner's group that is addressing the question of the steam generators in the PWRs. And the support that we have is primarily on a peripheral basis, providing support to that particular group. It is a separate organizational entity and they are covering things like tube denting, the mechanism of tube denting, looking at the corrosion and the corrosion of the secondary side and how the corrosion gets into the caustic stress corrosion cracking of the tubes and examining the secondary water chemistry conditions.

In the area of BWR piping, there is an extensive activity covering the stress corrosion cracking of the austenitic stainless steel piping as it relates to the circulation of the piping system covering the materials and alternate materials looking into the welding fabrication methods and what can be done there to improve the welding to reduce the effects of stress corrosion cracking.

And finally, addressing the various environmental factors associated with the BWRs.

The basic thermodynamics covers the fundamental studies, the high temperature, high purity water systems, and the effects of impurities in this system, and relating that back to the actual plant operations.

And there is an implementation phase where the feedback goes into the PWR steam generator problem area, as well as the BWR pipe cracking area.

There is an instrumentation activity. Specifically, we are trying to get a better understanding of crevice corrosion rates and crevice corrosion behavior as it relates to both BWR and PWR activities. And to actually get instrumentation involved in the steam generator and in the BWRs to get a measurement of the corrosive activity of the environments.

In the area of fundamental corrosion, we are looking at the causes of stress corrosion cracking. The tube denting, trying to establish the parametric effects, looking at basic crevice effects, trying to understand what specific conditions give rise to crevice so that this can feed back to the design engineers. Hopefully, he can design around crevice conditions, knowing what the specific dimensions are that lead to a crevice effect. And also, evaluating corrosion products.

The turbine cracking area I have already mentioned. We are working in this area primarily looking at the disk failures, corrosion fatigue of the disk materials and the contaminants in steam.

And again, there is a feedback there from the high temperature thermodynamics of the aqueous environments.

IMAGE EVALUATION TEST TARGET (MT-3)

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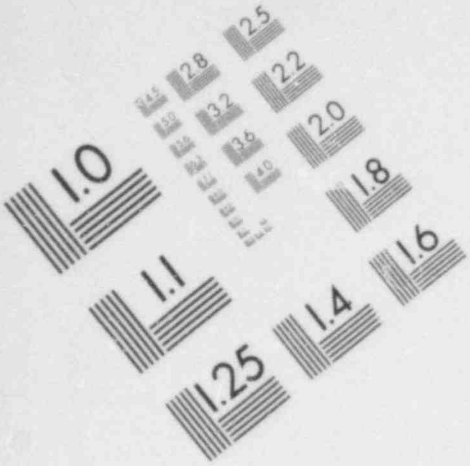
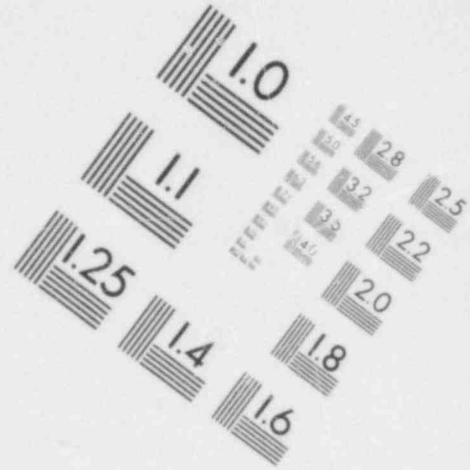
IMAGE EVALUATION TEST TARGET (MT-3)





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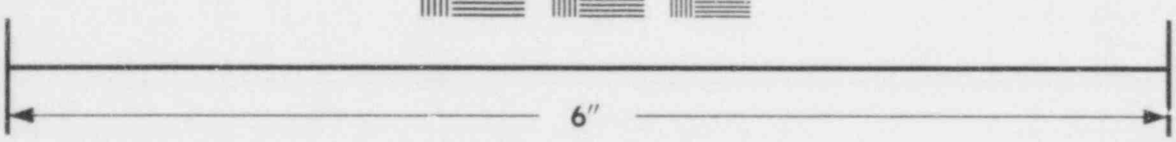

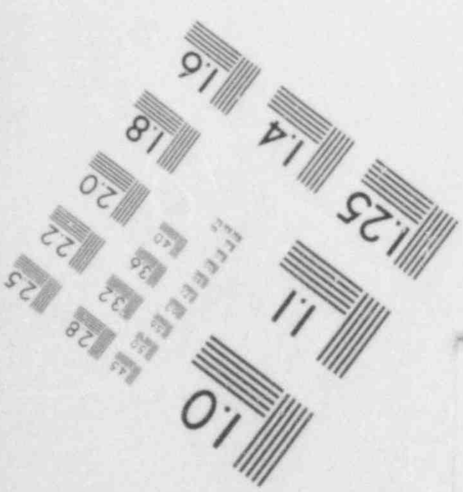

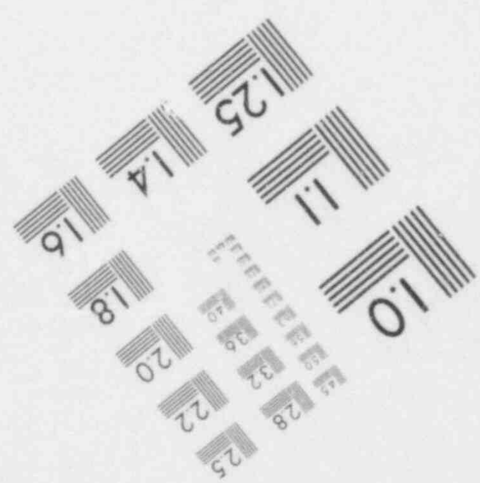

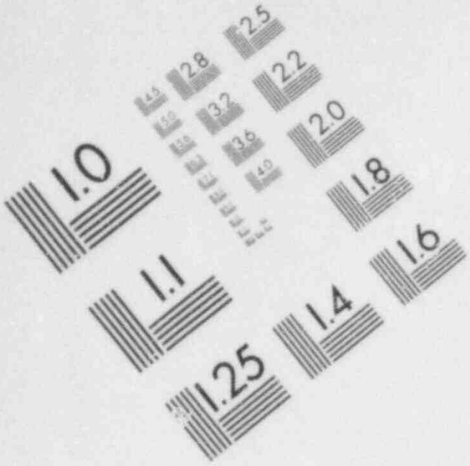

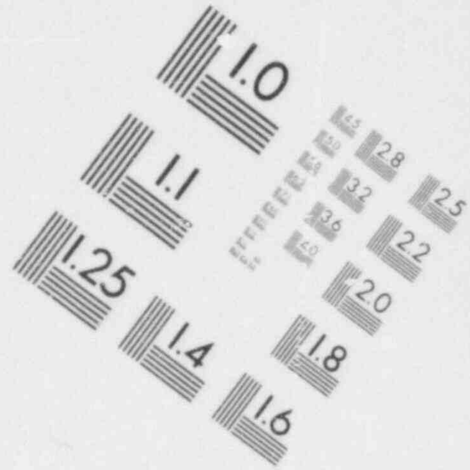

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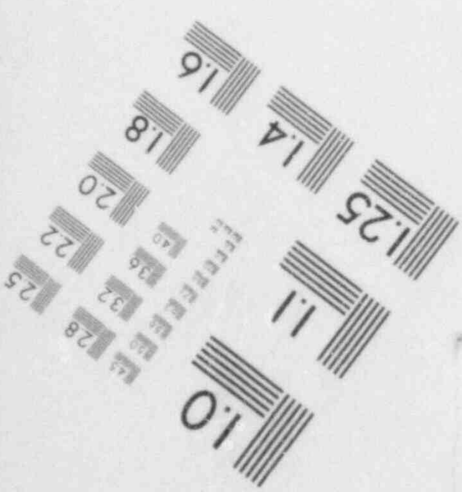

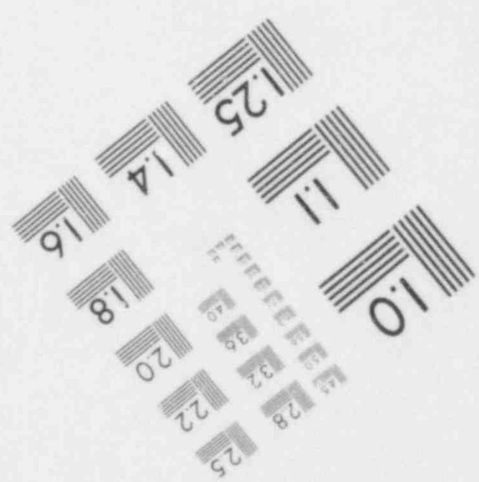

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As you can see, there are 22 projects underway in the plant chemistry and corrosion area. And the total value of these projects for this calendar year is approximately $18 million.

DR. SHEWMON: Before you leave that one, one of the questions that came up this morning had to do with the effect of plant chemistry on environmentally affected crack growth rates.

Some place in here, basic thermo-dynamics, the data base for plant operating temperatures. Are you talking about actually measuring at temperature things like oxygen content or pH? Or is that in lab systems that you hope will simulate?

MR. DANKO: The laboratory work, Paul, addresses getting some basic thermodynamic information on the environments. There are actual interactive measurements going on that I will comment as I move through my presentation.

We are covering both aspects of it.

DR. SHEWMON: Okay.

(Slide.)

MR. DANKO: On the plant materials and processes sub-program, we are covering specifications and processing of materials covering the variety of materials that are used in the construction of lightwater reactors. The steam turbine materials, again, looking at the reliability and the quality

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of the materials, the area of fabrication techniques, examining the specific area of welding, welding equipment, automatic welding equipment, hard facing materials primarily addressing the question of low cobalt wear-resistant materials to read us the cobalt build-up and transfer.

In the field operations technology, this is a fairly large activity here. Looking at actual components from the field and the removal of some of the components we are attempting to strain gauge to find out how much relaxation of residual stresses occurs. And performing an extensive post-test examination of these components.

There are 17 projects underway. The total value of these projects for the calendar year is approximately $9 million.

DR. CORTEN: Something like this where you are working on the utility to take something out of service, I presume, that they are testing something as well?

MR. DANKO: Generally speaking, the utilities are working, of course, with EPRI very closely. If there is a failure that occurs, we are informed. We make a request for that specific component or structure. They will ship it to us and we will pay for the expense of shipping and the post-test examination.

And what we request from them is background information with respect to the operational details and other

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factors related to the fabrication of the components.

(Slide.)

On the primary and secondary pressure boundary sub-program, one important aspect here is to recognize that the information generated by the non-destructive examination is a direct input into this particular sub-program. And it is extremely important.

It is from the analysis of the flaws that are present in the structures and the components that we are able to do a fracture mechanics analysis. In order to do this properly and successfully, we have materials property characterization.

Primarily, this area addresses the characteristics of the materials such as fracture toughness, and we measure the fracture arrest and crack arrest characteristics of the material.

There is extensive work going on in environmental fatigue of the materials. And looking at the radiation effects and the annealing effects of radiation damage. And finally, the material defect characterization.

This feeds into this material response characterization, which is really the fracture mechanics approach to determine the life of a component once there are defects picked up and the size of the defects have been determined.

I relies on things like continuing mechanics. the elastic plastic methodology, plastic methodology, and a complete analysis looking at it from a probabilistic fracture mechanics standpoint and a fatigue life analysis.

So this is a very important study, and as I mentioned relies very heavily on having good non-destructive examination techniques at hand.

Now the projects underway here, there are 23 currently ongoing with a total value of approximately $18 million for this calendar year.

(Slide.)

What I would like to do is to briefly describe some of the key projects and go over some of the highlights and accomplishments of these projects.

In the area of the BWR pipe cracking, we have had a major effort underway addressing the problem of BWR pipe cracking since 1975.

The concern here, of course, is the three or four stainless steel that is used in the recirculation piping system for the boiling water reactors. A major effort is to develop and qualify an alternate piping material that would be resistant to stress corrosion cracking for the plant lifetime.

And this material would also cover possible repair replacement of piping on existing plants.

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There is an area of what we call counter-measures for intergranular stress corrosion cracking. There are a number of plants that already had committed to the use of 304 stainless steel for impartial construction.

It was necessary to come up with counter-measures that would permit the use of that 304 stainless steel, and the counter-measures include a solution heat treatment of the shop welds of the 304 stainless steel piping.

This would eliminate the sensitization that has occurred in the weld heat affected zones, as well as eliminating the weld residual stresses. The application of a corrosion-resistant clad, the concept -- -- apply on the idea of a pipe a duplex material, one of ostenetic matrix with about 8 percent minimum delta ferrite.

This microstructure imparts a very high resistance stress corrosion cracking, protecting then the weld heat effected zone that is sensitized and also eliminating the effects --

DR. SHEWMON: We are somewhat tight on time and I think we have heard some of this. I wonder if you could --

MR. DANKO: I will cover those items that will not be addressed in Bob Cowan's presentation because there is a considerable overlap here.

DR. SHEWMON: Fine.

MR. DANKO: Environmental control was brought up this

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mor . I think there were some questions raised of Chuck here.

We do have programs in place to evaluate deaeration effects during start-up on the stress corrosion cracking of 304 stainless steel. Also, we are going to examine the effects of resin intrusion which causes changes in the water chemistry and how this might affect the stress corrosion cracking of 304.

We have a program where we are negotiating with the Swedes that uses a different deaeration technique to actually monitor the water chemistry during their start-ups, and also to evaluate the effect of their start-up conditions on stress corrosion cracking.

DR. SHEWMON: Deaeration — you mean --

MR. DANKO: They use a nitrogen blanketing technique. And they have had no failures in any of their 304 stainless steel lines to date.

But there are other complications. They do have a very tight spec on their 304 stainless steel. It is not clear whether it is the tight spec on 304 stainless steel or the deaeration.

We do want to address this and come up with a conclusion of whether it's beneficial.

DR. SHEWMON: The Japanese are deaerating?

MR. DANKO: Yes, on most of their plants now. And

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the one plant they have, which has been deaerated during the initial start-up, Shimoni (?) plant, as far as I know, they have had no stress corrosion cracking.

That has been operating about five years. We have mechanistic studies on sensitization and low temperature sensitization. And we are in the process of evaluating some of the KRB specimens to look at the low temperature sensitization.

We have also requested some specimens from the Gariglioni (?). That has about 15 years of operations and we can assess the effect of the low temperature sensitization. The PWR steam generator is under the owners group and the intent there is to assist them in solving the denting and stress corrosion cracking of alloy 600.

Most of these items, with the exception of the thermodynamics of high temperature water, will be made by Bob Cowan. So I will move on to the next sheet.

(Slide.)

One of the key items that has come out of the program on residual stress measurements is that the residual stresses associated with the 304 stainless steel weldments play a very important role in the stress corrosion cracking behavior.

I will present some curves on that shortly. We have a program to evaluate alloy 690 for BWR applications as a

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replacement for alloy 600. And there were some cracks and leaks in the Duane Arnold alloy 600.

We are pursuing the development of automatic remote welding equipment as it relates to pipe repair replacement. The intent is to reduce the exposure of personnel to the radiation environment and hopefully, come up with rugged equipment that can be done with a minimum of installation time and produce reliable weldments.

High isostatic processing in nuclear castings. Many of the castings I rejected because of internal defects. And this approach is to reduce the number of rejects using the isostatic process.

And it has proved successful.

Kinetic bonding of condensor tubes is a new program. Looking at a more economical way and one that produces a very reliable joint between the tube to tubesheet in the condensors.

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(Slide.)

This is a quick summary on the carbon steel. This will be covered by Dr. Cowan.

The isostatic processing does reduce the internal porosity and improves the quality of casting. The net result is properties closer to forging materials than casting materials. From the impurities standpoint, it has been found that small amounts of nitrogen, less than .1 percent, in 304 stainless steel, improves the resistance to sensitization.

MR. BENDER: I have a couple of questions.

First, when techniques like this are proposed by EPRI, is there some kind of understanding with NRC concerning the qualification requirements for these new techniques? How is that handled?

MR. DANKO: The transfer we have is to our utilities task force, where these programs are reviewed, presented. And that information is immediately transferred to them. We have a wide distribution report to architect-engineers, to vendors, to the NRC. And again, through these reports this information is translated to them.

We also have review meetings whereby key information is disseminated to the technical community to make them aware of these advances.

MR. BENDER: Let me be explicit. If you develop a new kinetic explosive bonding technique for tube to tubesheet attachments, or whatever it is you are talking about, how would that process be introduced into the reactor system technology? Through the codes or how?

MR. DANKO: There are several vehicles by which this can be accomplished. The particular program we have in place, we have a working group which includes the condenser manufacturers, utility members and EPRI people who are guiding the program.

Assuming that the technique is successful for the fabrication of full-sized condensers, the utilities can request, through the AE, that they want that particular condenser technology; or the AEs themselves, being aware of this, being party to this program, can recommend to the utilities to go with such a condenser. That would be a balance of plant activity. And particular vendors may not have the option of selecting that.

But through the AEs and through the utilities, that would present the best vehicle whereby that technology could be implemented into actual hardware.

MR. BENDER: But you wouldn't go through the regulatory approval process to see if any regulatory concerns about the use of that technique --

MR. DANKO: Where there would be a concern, we would do that. And I think in this case there would be no need for NRC approval of that particular technology. Correct me if I am wrong, Chuck.

MR. SERPAN: I don't know.

MR. DAU: On things that are direct regulatory nature between the utility and the NRC, our management has taken a fairly strong stand that that is really to be done between the utilities and NRC. We are not to get in between that. We provide the technology, we try to see that they are made aware of it to the best of our ability. If there is a licensing action required or a regulatory action, that has got to be done between the individual utility and the NRC.

MR. BENDER: Thank you.

(Slide.)

DR. ZUDANS: One little question. Is there any -- any of the existing steam generators or heat exchangers or condensers, actually built by using explosive bonding of tube to tubesheet?

MR. DANKO: Not that I know of.

MR. ETHERINGTON: Is that equivalent to an expanded tube?

MR. DANKO: Just use an explosive charge, and it is really an explosive bonding technique. And you place a small charge between the tube to tubesheet, and it expands the tube out to the tubesheet, effecting a metallurgical bond.

MR. ETHERINGTON: It is metallurgical?

MR. DANKO: Yes, it is metallurgical. The failure is occurring in the base pipe area, not in the joint.

DR. ZUDANS: It doesn't mean metallurgically; it is just expanded, that's all. I saw this used by Foster-Wheeler. They developed the technology. 24-inch tubesheet; how can you expand it? They put a charge the whole length. I thought there were heat exchangers like that.

MR. DANKO: There are none in operation that I know of.

MR. ETHERINGTON: I am not sure what you said. You say it is like an expanded joint?

DR. ZUDANS: It is the same thing. They put the charge stick in the tubesheet.

MR. ETHERINGTON: I thought you said it was metallurgical?

MR. DANKO: It is a metallurgical bond. We have examined it. You have a tremendous, you know, sonic wave there. It is a metallurgical bond.

And in fact, the other interesting aspect of this, you talk about the Rowe bonding technique it is work hardened. This is not. After this was done, they took the hardened traverses, and it is like annealed material.

DR. ZUDANS: It is a question to be used. Why isn't this used in industry? I thought Foster-Wheeler was making these tubesheets for other people.

MR. ETHERINGTON: There is a difference in the mechanism. You are really expanding the circumference, to lengthen the circumference, and here it is a radial movement.

DR. ZUDANS: Which lengthens the circumference as well, but also applies radial pressure.

MR. ETHERINGTON: It is a different pressure.

DR. SHEWMON: Could we go on?

MR. DANKO: In the area of fatigue crack growth of pressure vessels, work is under way to measure the crack growth pressure vessel materials in both BWR and PWR environments. There is a new program under way which is to develop a methodology for handling plastic fracture, and we need to understand the behavior or ductile materials as they move into the complete plastic regime and how they behave from a failure standpoint.

We have already touched this morning on Chuck's presentation on neutron embrittlement of reactor pressure vessel materials. We have a program which is coordinated with the NRC to examine the saturation effect as it relates to Regulatory Guide 1.99. There is a program under way to examine the annealing requirements of embrittled pressure vessel materials. If this is required, what is the procedures, what is the best technique, and what are the necessary time-temperature relations to remove some of the neutron damage from the pressure vessel material.

Repair welding of heavy section nozzle steels. This

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is a program which relates to how to repair a nozzle similar to the BWR feedwater nozzles that have thermal fatigue cracks, and it also relates, perhaps, to the feedwater nozzles on the steam generators that currently have been found in a number of PWRs.

And finally, there is the BWR pipe integrity studies. This is really to examine a large diameter pipe. Keep in mind that the KRB Unit A did have cracks and leaks on 24-inch diameter stainless steel piping; and can the concept of leak before break still be valid for the large diameter lines?

DR. ZUDANS: Were they in the straight ground or discontinuity on the big pipe?

MR. DANKO: They were on the nozzle side, which was sensitized, and on the pipe side they were circumferential. And in the pipe side, some of the cracks were extremely long, very large near the heat-affected zone.

(Slide.)

In terms of the BWR pipe integrity studies, an analytical study has been performed based on actual measurements of through-wall residual stresses, of a 26-inch diameter 304 stainless steel line. The analysis shows that the weld residual stresses play a very important role in the stress corrosion cracking susceptibility of the 304 stainless steel, and that, based on the results, it would suggest that the large lines may be less failure-prone than the small lines, because of the state of residual stresses through-wall that are quite different than for the small lines, the bypass and the core spray.

DR. CORTEN: Does that depend upon the number of the weldings?

MR. DANKO: It is the entire welding process technique. And the analytical studies that have been done show that the final pass really is a controlling one in terms of establishing the state of residual stresses in the weld heat-affected zone.

DR. CORTEN: Have we gone over those processes so we know what we have got?

MR. DANKO: That is falling out of the present project. It is a very important finding and it is one that you can control in the process of your weldings. Ed Ribicki at Battelle Columbus is doing that work.

DR. ZUDANS: That is analytical?

MR. DANKO: Yes. The through-wall stresses have been measured at Argonne.

DR. ZUDANS: The small pipes are more sensitive. Is there an explanation why small diameter pipes are affected more? Is it because the working stresses are in principle lower in smaller diameters than in larger diameters?

MR. DANKO: The analysis in NEDO-21,000, plus the analytical work in the measurements done under EPRI projects, again it falls out that the weld residual stresses are probably the dominating factor.

DR. ZUDANS: For all sizes?

MR. DANKO: All diameter sizes.

DR. SHEWMON: They also concluded that the residual stresses were larger in the small pipes? Was that the story at one time?

MR. DANKO: Yes, and that is still true.

DR. ZUDANS: That is the question: Is it because of the more three-dimensional nature than in the large-diameter pipes?

MR. DANKO: The nature of the weldment in the small diameter pipe leads to very high tensile residual stresses on the ID and very sharp residual stress gradients through the pipe, going from high tensile and finally hitting compressive on the OD; whereas for the large diameter pipes, based on the limited data we have, there is less tensile residual stresses on the ID, but immediately behind that you run into a compressive zone which appears to provide a crack arrest area.

And it is consistent with the findings of KRB that some of the cracks seemed to stop at about 4 to 5 millimeters deep, which is pretty close to what Argonne measured on a 26-inch diameter pipe. So we need more results, and it suggests that the weld residual stresses, that they are different from the big to the small pipe, suggests that the large lines may be less failure-prone. And statistically, that is what we found so far from the field operating histories.

DR. SHEWMON: On those next two items, I think we have gone over those this morning, probably.

MR. DANKO: I think we have. Let me see if there are any other key items here.

DR. SHEWMON: The last item there, I would like to get the Westinghouse people to talk a little about, assuming that we are talking about PWR feedwater nozzles.

MR. DANKO: That we can leave to Tom.

DR. SHEWMON: Why don't we take a short break here, as the schedule calls for, and then we will get back to the vendors.

(Recess.)

MR. MAGER: I am Manager of Metallurgical and MDE Analysis at the Westinghouse Nuclear Technology Division. Today I would like to present our research activity directed towards nuclear steam supply systems boundary integrity, primary boundary integrity. I will discuss our research activities, go through those, and then go into the feedwater line cracking as a separate item.

At Westinghouse, we are more or less dedicated to fracture mechanics, and our research efforts are directed that way, namely, we are interested in NDE, stress analysis, material properties. Of course, we have to factor in irradiation effects. And we put considerable emphasis on performing fracture mechanics analyses.

(Slide.)

Last year I presented a number of programs, and we will touch on those also. But listing our new activities for 1979-1980 that we are not pursuing in '78-79:

First, corrosion fatigue characterization of irradiated reactor pressure vessel steels. This is a program sponsored by EPRI. And I will go over each of these programs with the objectives and any accomplishments to date.

The second one is the development of a crack arrest toughness data bank for irradiated reactor vessel materials. Again, this is an EPRI-sponsored program.

The third one is steady-state irradiation embrittlement of reactor vessels. This is one where we hope to show the conservatism in Reg Guide 1.99. Again, this is an EPRI-sponsored program.

The next one is the inductive learning networks for ultrasonic testing. This is Nuclear Technology Division-sponsored program. Materials evaluation program, for replacement of high cobalt facing alloys. Again, this is a Nuclear Technology Division program.

Defect sizing by ultrasonic testing and comparison with radiographic testing. This is part of the Westinghouse-French cooperative program, Westinghouse, CDA and Framatome.

Developing controlled or program flaws within heavy section weldments. This is an EPRI-sponsored program, and what we are doing here is developing techniques to fatigue crack weldments, cutting out the fatigue crack, and inserting these weldments into test blocks and then "UTing" them.

Starting out with the EPRI-sponsored program, we will make up little blocks that I will discuss. We will also use these -- this technology or method to insert little blocks into much larger, say nozzle cutouts, where we are using both the UT and the RT, and eventually go to the reactor vessel shelf that Gary Dau discussed earlier.

DR. CORTEN: Will you discuss that later?

MR. MAGER. Yes, we will go through these.

A new program of Westinghouse-French cooperative is the residual element effects of toughness on ferritic steels. And as we go over the program, all we are going to do is go back over test reactors, look at residual elements, look at tensile properties and CHARPY-V properties, and see if we can get a correlation between toughness and residual elements in commercial steel.

And finally in the new programs, high-strength stainless steel with improved structural stability and fatigue properties.

DR. SHEWMON: For application where, or for use where?

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MR. MAGER: To replace in an internal, to replace our 174 material in the reactor, reactor vessel, various locations.

It also involves -- quickly touching on the programs from last year, continuing programs, vessel heat transfer after LOCA tests, improvement in linear elastic plastic mechanics analysis, elasto-plastic fracture methodology.

DR. SHEWMON: Why don't you let us run down through those.

MR. MAGER: Okay.

(Slide.)

I would like to present these programs first in terms of irradiation effects, and then move on to materials testing, NDE material testing, and finally the analytical effort.

(Slide.)

The first program is a continuing program of the feasibility and methodology for thermal annealing in the reactor vessel. It is an EPRI sponsored program.

The objective is to develop thermal annealing methodology for reactor vessels which maximizes fracture toughness recovery, minimizes free exposure sensitivity and minimizes down time.

(Slide.)

Now, we are right at the stage we are about to start testing materials. We have completed the first irradiation cycle at the University of Virginia.

At the end of July we will complete the second irraditional cycle. And we will start annealing. But following the first irradiation cycle, we are about to test the Charpy, the tensile, and the compact tension for J1-c measurement.

DR. SHEWMON: Is there any obvious division between this program and the work that Chuck is sponsoring at the NRL?

MR. MAGER: Well, we follow their work and they follow our work, and I believe we are coordinating it through EPRI, I would hope.

DR. SHEWMON: What are the main differences, or what is the complimentary?

MR. SERPAN: We are looking at some of the same materials, but EPRI and the Westinghouse program has considerably more materials from irradiations in it than we have.

We are attempting to determine upon the temperature variables ourselves with just a few materails, and thereby provide enough guidance to the licensing staff.

As a matter of interest, we had our program started several years before EPRI, and they concluded that they need more information, so they are getting a lot more annealing information.

MR. MAGER: We are also considering system parameters.

Last year I reported that WCAP was issued, discussing the capabilities of systems for annealing at 650, using pump heat. Right now we have just issued a topic report on the characterization, University of Virginia reaction, to radiation environment.

(Slide.)

This program will now take off. We have material in a post-irradiated condition.

(Slide.)

The second program, radiation effect, corrosion fatigue characterization of irradiated reactor pressure vessel steel.

Again, this is an ERPR sponsored program. What we want to do is develop and analyze erosion fatigue crack growth rate data for irradiated reactor vessel steel.

(Slide.)

As was discussed earlier by Mr. Danko, EPRI has a very large program with Babcock and Wilcox on unirradiated material. We are going to do the portion on irradiated material.

It is a rather small task. We are going to be looking at -- for one thing, reactor vessel material from surveillance capsules. Unfortunately, it is a very small specimen.

We are going to start out with specimens from the Zorita reactor.

We will also -- the irradiating, 1C, CT, specimens and use the same parameter that Babcock and Wilcox is looking at in the unirradiated condition.

We will also irradiated 2T, CTs, for future use if they decide they want to test them.

(Slide.)

The third program, development of a crack arrest data bank for irradiated reactor vessel material, again, an EPRI sponsored program.

What we want to do here is determine the pre and post-irradiated crack arrest concerns of Kla arrest and Kla minimum crack arrest for reactor material typical of current operating plants and also new plants that are using the current method of melting and welding practice. In other words, high upper shelf versus low upper shelf.

(Slide.)

And we also try to evaluate and improve procedures for predicting the irradiation crack arrest toughness. Again, this program just started in conjunction with BMI, and we are just at the stage where we are designing the capsule.

Again, they will be irradiating at the University of Virginia test reactor.

We will use the ASTM recommended specimen.

DR. SHEWMON: The aim here is to be able to go to fracture mechanics as opposed to Charpy testing?

MR. MAGER: Section 11 of the ASME code, Appendix A has section on crack arrest, for accident analysis.

All they do is take the Klr curve, or Kla curve, and shift it, based on trend curves.

Here we hope to demonstrate that the curves are conservative, or show that they are not conservative, that in the real world the crack arrest is lowered; one or the other. Hopefully it will demonstrate that the Section 11 Klr curve is conservative.

DR. CORTEN: Can you use Charpy data to get to this?

DR. SHEWMON: Had we before, but . we hadn't --

MR. MAGER: This would be less than they give in Section 11, Appendix A.

(Slide.)

I will touch on the Charpy specimen for crack arrest as part of another program.

The next program is steady state radiation embrittlement of reactor vessels. Again, this is an EPRI sponsored program.

As you may recall last year we presented information that showed that in a reactor pressure vessel as time goes on, you seem to reach a steady state condition with irradiation embrittlement.

And if you plot the Delta P versus the fluent, you will see a leveling off, and the trend curves in Reg Guide 1.99 are very conservative.

Now as part of this EPRI program, we hope to evaluate a minimum of 10 surveillance capsules. Right now it is up to 12 or 13, because we are including BWRs as well as PWRs, and also look at mechanisms for why this happened.

So the program is in two parts: One, test surveillance capsules, plot the data. The second part is take the Charpys and let the physical metallurgist start coming up with reasons why this is happening.

DR. SHEWMON: Steady state radiation embrittlement means once you are up on the shelf, apparently saturated?

MR. MAGER: No.

Okay; your Delta transition, 30 or 50 foot pounds, which ever it may be, or Delta RT, NDT versus fluents -- in the unirradiated condition -- and zero fluents -- we come up with fluent and level off.

And this is a 30 or a 50 foot pound where thix may be $2x10^{18}$, $1x10^{19}$.

But then if you look at the upper shelf, again, the upper shelf also does not drop. In fact, we believe the upper shelf levels off somewhere around $5x10^{18}$.

But if you look at the energy versus temperature, unirradiated, $2x10^{18}$, you get your shift, you get your drop, but then when you go to $1x10^{19}$, not only is this shift constant, but the shelf seemed to improve a little and go back up.

DR. SHEWMON: What does steady state mean?

MR. MAGER: That once you reach a certain fluent such $2x10^{19}$, you do not have any more irradiation embrittlement.

We are in the process of testing Point Beach 2. Since our last meeting we have evaluated San Onofre 1. This is approximately $5x10^{19}$, and it shows what we call saturation or steady state condition, that the material is not embrittling any more than it did five years ago.

MR. BENDER: How much data would you need before you could show statistically that you have got a case?

MR. MAGER: We believe we can show it now. We are in he process of going back; taking all of the data that has been generated and performing the statistical analysis.

We have never done this before, incidentally. We believe these 10 additional reactors will definitelly be sufficient.

DR. ZUDANS: What will this saturation take at say higher levels of irradiation that you might have during the reactor life. You talk about the irradiation levels as far as you have gone so far.

MR. MAGER: The Westinghouse surveillance capsules are not on the reactor vessel wall. So they leave the reactor vessel.

For example a four loop PWR, life fluents is approximately 1.5 to $2x10^{19}$.

DR. ZUDANS: So what you are saying; he reactor vessel will never reach those levels.

MR. MAGER: Right.

That is not to say that if you get out to 6, 7, $8x10^{19}$, this may take off again.

DR. ZUDANS: Is it in any way rate dependent.

DR. SHEWMON: It is all rate dependent. We didn't find it in test reactors at higher flux.

DR. ZUDANS: That ans that the reactor vessel wall will see a different rate.

DR. SHEWMON: If anything, it saturates sooner.

MR. MAGER: The reactor vessel will see a lower flux than the capsule. The test reactor sees a much higher flux than the capsule.

We believe it is related to the flux self annealing effect going on.

DR. SHEWMON: But since nobody has ever come up with a theoretical or an equation for this sort of thing, they can't predict anything. They must always keep taking data points?

DR. ZUDANS: We are out in a capsule like this the temperatures are higher, too, while you are irradiating.

DR. SHEWMON: I doubt it.

MR. MAGER: Not much, no.

DR. WECHSLER: Can you say a word or two more about the types of metallurgical tests that you will be performing on the broken Charpy bars?

MR. MAGER: We are going to be looking at OJ tests.

We are going to be doing micro-hardness, damping. We will examine the OJ specimens and we will examine the fracture surface for various element segregation.

Dr. Odette at the University of California has already come up with a model, with -- whether it will work or not is something else.

As part of this program, EPRI is sponsoring Dr. Odette as a consultant. We are going to take our data and work with him.

And you are going to look at some of this data at Iowa State.

DR. WECHSLER: Yes, we are.

MR. ETHERINGTON: I am a little bit confused. This is really a scientific development of a very simple minded concept that people have always had; temperature annealing will ultimately lead to equilibrium condition; am I right?

MR. MAGER: Yes, this is true.

People -- a number of people have been predicting this for years.

Now I guess we want to try to defend it.

MR. ETHERINGTON: That's what I thought.

MR. MAGER: If you go back to some of the earlier work that you did and talk about annealing activation energy, I think you would have predicted it.

DR. CORTEN: Is this a rate process?

MR. MAGER: A rate process, and if you go back to the early part of the trend curve, Delta RT, NDT, versus temperature -- copper, you can generally predict from the surveillance capsule what is going to happen, say, from the results of $2x10^{18}$, you can predict what is going to happen at -- in the reactor -- in your capsule later on, until you now you get out there and you see saturation.

MR. BENDER: This sort of contradicts what has been seen in the test reactors, I believe you said, and mainly because the test reactors irradiated the material out too fast.

MR. ETHERINGTON: The test reactors arecold.

MR. BENDER: I wondered if that was the case.

I think they have done tests at temperature and still got the effects.

MR. MAGER: In our test reactor we perform at operating temperature, 550. It is a matter that in the test reactor we attain $2x10^{19}$ in three months.

MR. BENDER: But implicit in it is that there is some annealing going on, and it is just that you don't get it in a short period of time.

Is there any attempt to try to measure that annealing effect independently of radiation? It must be there. Or doyou have to have some kind of radiation stress to work against the annealing phenomena.

MR. MAGER: I think that is an oversimplification to talk about annealing because there are many things going on there.

DR. SHEWMON: It may be an oversimplification, but if it is not, then you have to invent another word for the fact that it goes faster at higher temperatures than it does at lower temperatures.

MR. MAGER: This is why we are going the basic work in the program as well as testing the surveillance capsule.

DR. ZUDANS: Could you continue -- demonstrate the continued irradition in your test reactor until you reach a saturation level?

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MR. MAGER: This is why we are doing the basic work as well as testing the surveillance capsule.

DR. SHEWMON: It is temperature-dependent?

DR. ZUDANS: In any of your tests, could you also demonstrate, let's say, continued irradiation in your test reactor until you reach a saturation level in a test reactor? If the principle is working, it should work there.

MR. MAGER: We are planning to extend this program by taking surveillance capsule specimens out of surveillance capsules and putting them into the test reactor to see if it suddenly takes off again.

DR. ZUDANS: That would only prove the point that it continues the damage process.

MR. MAGER: If we look at specimens in the surveillance capsule, say, at two times 10-19, after two times, and then five times 10-19, and we have saturation, we take some samples at two times 10-19, put them in the test reactor, and go up to five times 10-19. And there is a difference. Then it would show.

DR. ZUDANS: Except that it wouldn't give you a handle on the rate effect. If you could continue in the test reactor beyond --

DR. SHEWMON: Next year they will come back and tell us more about it.

MR. MAGER: Needless to say, this is probably what we consider our most important program at the moment. If we go to the work on NDE, the first program, a continuing program, on reliability of UT of austenitic materials and welds, what we are doing is inducing fatigue cracks into weldments of centrifugally cast piping materials. We have three different operators looking at it and seeing if they can predict the size of the flaw. We are using control samples, no defects. And at the conclusion, the most important one is that the average crack depth before all three operators properly characterize the crack sample and a non-crack control sample of approximately 15 percent of the wall thickness. On a given day, two of them will identify a small crack; a third one will identify a crack in the control sample that is not a crack.

And if one of the three operators identify the flaw when they shouldn't, then the test is a failure, and we make the crack bigger and start over again, after 11 or 12 sets of samples. This is the conclusion.

We are also looking at European transducers. Some appear to be good; some appear to be not worth the time.

DR. CORTEN: The percentage of wall thickness, what wall thickness are you using?

MR. MAGER: About 2-1/2 inches primary coolant piping.

DR. CORTEN: This is a crack about two-tenths or three-tenths?

MR. MAGER: Yes.

I reversed these slightly.

(Slide.)

As I say, part of the EPRI program, we are developing controller program flaws in heavy section weldments. In talking about heavy sections, we are talking about anywhere from eight to 12 inches in thickness. We are talking about the reactor vessel belt line and nozzle shelf. And all we are doing in this program is developing the technique for coming up with fatigue flaws in weldments and being able to close them off so they will be embedded flaws, and we will insert these into nozzle cutouts and eventually into the reactor vessel shell course.

DR. CORTEN: When you say "insert," do you put them in there without that influencing --

MR. MAGER: This is the idea. First, we make up the weldment, and then we fatigue it, then we have a fatigue crack and we are going to close that off. We are going to cut it down small enough, have a hole somewhere, the nozzle cutout, and bury it. We would then go back and perform UT on it, and then we would also perform destructive analysis and see if we closed it up during welding, and then check it.

DR. CORTEN: You think the process of burying it will have a big effect on the whole thing?

MR. MAGER: We will find out. Eventually, the reactor vessel shell course that EPRI talked about this morning will be a very, very large calibration block.

(Slide.)

The next program is defect sizing by UT and compared with RT. This has two facets. The one facet is that we will be taking, if we are successful in developirg these flaws by fatigue, that we will insert those into the nozzle cutouts, and then we are going to use a piece of steel, something we can handle in the laboratory, and then see again if we are able to control putting them in this steel.

This will be the intermediate step before we go to the reactor vessel shell course.

We are also looking where we know we have UT indication or RT indication in a piece of steel to see if we can correlate the results so we can come up with a better or improved defect sizing technique.

(Slide.)

The next program we are starting, we are starting our adaptive learning networks for ultrasonic testing. Probably adaptive learning is a poor word, but we want to develop the in-house capability ourselves. We want to be able to develop a single processing method or single processing methods which are not dependent on time and amplitude information only.

Now, we are doing this with the austenitic or centrifugally cast stainless steel specimen. While this is a Westinghouse-sponsored program, we are going to cooperate with EPRI and let them use some of our specimen and see what they can pv5

come up with.

(Slide.)

The next program, we touched on this last year, and we a. . continuing. And that is the aging of cast stainless steel. The program objective is to evaluate the effective long-term thermal aging on the properties of cast stainless steel piping material. As you recall, last year the French claims that if you age austenitic or cast -- austenitic cast material, you get a degradement in the impact properties. So, we have been working with them on this, and it is true, with the ferrite content increased we see a degradation of charpy impact values, especially at room temperatures. As you go to operating temperature, 550 degrees, really the piping is probably on the order of 600 degrees F. You get a certain -- I wouldn't say a recovery -- your impact properties have not dropped as much. Your delta E, delta energy, at 600 is not as great as room temperature.

We are also performing fracture mechanics evaluation to demonstrate what effect this would have on the primary boundaries. Now, to date, we go down to the bottom here and look at where we stand today. The material has been aged at 800 degrees, and we get a reduction in energy from 160 foot-pounds to 30 foot-pounds at room temperature, and to 73 foot-pounds at 550 degrees F.

However, on occasion, we will be well above 73 foot-pounds, well on the order of 120-130 foot-pounds. We look at crack growth, the characteristi~s of aged and unaged material in air, and PWR environments, and we didn't see any difference. We looked at J-lc specimens; the slope of the J resistant curves at 600 was not affected by aging. The slope of the J resistance of aged material at room temperature was reduced. While it was reduced, it was still approximately equal to the slope of 600 degrees F.

The J-lc toughness of the aged stainless steel at room temperature at 600 degrees F was less than for the unaged.

DR. CORTEN: Significantly?

MR. MAGER: No. If you go and perform integrity analysis using the J-lc, plus if you use a limit load analysis, it will show that the aging does not create an integrity problem.

DR. ZUDANS: Is this aging a stress-free state?

MR. MAGER: Yes. That's true.

DR. ZUDANS: So is it directly applicable to what happens in a power plant where you have fully stressed pipes in the same conditions?

MR. MAGER: In all cases?

DR. ZUDANS: You could have closed the ends and capped them and put on the pressure.

MR. MAGER: That is something we have to consider, especially since we are considering doing a piping test on aged and unaged material to see if we can predict the behavior.

Again, aging a piece of pipe, we are aging it in the unstressed condition.

DR. ZUDANS: Yes.

DR. SHEWMON: Tom, since you said I was cutting off or we let you talk some but I cut you off on your most interesting or important topic earlier, could I move you on to your second most important topic, which is the comments you might have on the nozzle cracking, unless there is some particular program here -- there seem to be a fair number -- that you would like to single out, other than that one.

MR. MAGER: I believe there is nothing I would want. I guess I should say that the work on the analytical program is going well. We are looking at small specimen testing in crack arrests, and Herb is familiar with this. Joe Witt has been demonstrating by taking a small specimen; you can measure the crack arrest toughness by having to crack, unloading, and going back out.

We are also looking again on small specimen testing for J-lc as well. We are still convinced that the equivalent energy method will work. By taking a small specimen you can predict K-lc. But, again, remembering that you can only use the equivalent energy toughness failure in a linear elastic fracture mechanics analysis. If you use it on the upper shelf, you have to assume linear elastic behavior. And if you don't believe you have linear elastic structure behavior, then K-lc is not ap-- ·able on the upper shelf. I believe Herb is fairly fa..iar with this work.

That's the only important point.

DR. WECHSLER: If you don't mind, I would be very interested in hearing more about this residual element effect.

MR. MAGER: I believe that is a little misleading, but let's pull it out. There is another program I should mention, and then we will go to the residual thing.

(Slide.)

This is a program which was suggested by the French, and generally, when they suggest a program, they have something in mind. So, we are cooperating with them. The program is increasing the understanding the effects of residual elements on the toughness of pressure vessel material and increase the understanding of the effect of base metal segregation on the heat-affected zone properties of pressure vessel material.

I guess this is a little misleading when I say "pressure vessel material." What we have in mind is on the tube sheet, on the steam generator, when you put the cladding on, there have been cases where you have segregation, you have little micro cracks, and we want to look at this. And the program is designed to determine the residual element content in at least -- boundary materials, and develop the effect of the pipe and concentration of residual elements with the toughness of these theoretic materials. We are talking in terms of charpy impact energy.

We are going to be looking at 10, and the French will be looking at at least 10 heats of commercial material.

DR. SHEWMON: You mean substitutional elements, tin, copper? Is this traditional metallurgical?

MR. MAGER: Residual metallurgical.

DR. SHEWMON: So, it is not oxygen or nitrogen. Those aren't residuals?

MR. MAGER: No. Although we will be looking at them. The French are definitely looking.

DR. WECHSLER: Phosphorous, sulfur, arsenic?

MR. MAGER: Right. And anything else. When these show up in the analysis or it is in the chemical analysis. It comes with the heat. And the second is to develop by means of programmed chemical analysis and surface evaluation techniques an understanding of the effects alloy and non-metallic segregation on the heat-affected zone properties of pyritic primary pressure boundary materials.

Again, we are talking between the cladding and the base metal, as opposed to structural welds.

MR. BENDER: I thought you said it was just in the steam generator tube sheet. Are there other applications of it?

MR. MAGER: Of course, the reactor vessel, you have cladding.

MR. BENDER: I understand that.

MR. MAGER: It is really directed toward the tube sheet. Although we will be taking nozzle cutouts, for example. They are something we can examine very easily. We will be taking nozzle cutouts from reactor vessel, and whether we have segregation under the cladding there. Also, we do not expect to have a problem there.

MR. BENDER: What are the French worried about? That the cladding is separating?

MR. MAGER: They are worried about micro cracks in the tube sheets in the steam generator.

MR. BENDER: All right.

MR. MAGER: Not cracking in the cladding. In the tube sheet.

MR. BENDER: All right. I understand.

MR. MAGER: And finally, another program we are spending a lot of money on and placing emphasis on, the final one, is the material evaluation program for the replacement of high cobalt hard-facing alloys. We would like to minimize the amount of cobalt in the system, of course. And we are looking at ways to do this. If it comes down to replacement of the cobalt material in the hard-facing alloys, we may have to go this route. Again, this is a separate program Westinghouse sponsored, but the French also have a separate program. We are coordinating the two, although they are not the same program.

MR. BENDER: This is an attempt to eliminate the radiation-induced activity.

MR. MAGER: Yes.

DR. SHEWMON: Do you know whether Westinghouse in this country urges utilities to -- what is it? Hydrogen peroxide additions, just before they open things up or as they bring things down? I saw a report not long ago that Westinghouse recommends this to the Swedes as a way to loosen up crud that they can then filter out during the time they are down or before they are down.

MR. MAGER: I don't know.

DR. SHEWMON: I wanted to know whether anybody was interested in that aspect of water chemistry in the NRC, where would I go?

MR. SERPAN: I don't know.

DR. ZUDANS: The adaptive learning network, is it in any way similar to the one of EPRI's?

MR. MAGER: The adaptive learning, yes. It is very similar. We want to develop our own technique. We could go to EPRI and Adaptronics, and we would buy the system, but we believe it is advantageous to have our own.

DR. SHEWMON: Would this be something Westinghouse might market? You can plead the Fifth on that, if you want to.

MR. MAGER: Within the nuclear technology division, yes.

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(Slide.)

MR. MAGER: We were advised about a month ago, six weeks ago, that at D.C. Cook Unit 2 they discovered leakage in the feedwater line on loops 1 and 4.

You must remember, or you should remember the feedwater line going into he steam generator, once you refit feedwater line, that is the AE responsibility. That is not part of the nuclear steam supply system.

We are half an inch away, but it belongs to somebody else. However, e were asked to work with them and perform whatever evaluation was necessary.

It turns out that the steam generator feedwater nozzle in the majority of Westinghouse plants are A508, Class 24. They go into an A106 Grade B, elbow reducer or straight line of pipe, 16-inch diameter. They put a counter bore here and this counter bore, they have various radius from 15, 30, on up.

In some plants, they use a backing ring for welding purposes. Not all plants.

It just turns out that in the D.C. Cook Units 1 and 2, they used a backing ring. I will come back to this.

Since that time, the last six weeks, whatever it may be, the NRC came out with a bulletin requesting that CE and Westinghouse nuclear steam supply systems, the feedwater line, that it be evaluated and then mandated that they use

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RT to inspect the nozzle feedwater line junction.

A number of plants have been looked at. For example, Cook, as I stated, units 1 and 2. They "Rted" them and they found cracks.

Swedish State Power, they performed an RT and UT and they were clean. Northern State Power, Prarie Island, clean. Cracks in Surry Unit 1, Zion 1 clean, Turkey Point 4 clean, Farley clean, Robinson cracks, cracks in Kewaunee, cracks in San Onofree, and clean in Portland General Electric Trojan. Also Point Beach Unit 2 cracks.

DR. SHEWMON: Those are all Westinghouse plants?

MR. MAGER: Those are all Westinghouse plants. I believe the paper and the notice that came out in the paper on the NRC bulletin identified Westinghouse and two CE plants. Now the cracks, the main crack is always initiating from this counter bore. I should say on the piping side. It never initiates on the nozzle side.

In the case of Cook, Robinson, Beaver Valley, the crack always looked identical; namely, that you really had one major crack. Maybe some very small cracks. But in coming up the radius here, very clean. No pitting.

The Beaver Valley Unit 1, Cook Units 1 and 2, Robinson Unit 2, Kewaunee, they used an EB insert. They had multiple cracks, but again, they really had two major cracks. And it was not really like Cook or Robinson or Beaver Valley,

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but it was very similar.

However, if you look at San Onofre, they had very small cracks and they were everywhere. They were starting -- well, they started in the welds and came along here and you had pitting and cracking.

In the case of San Onofre, the defects were the order of 60, 70, 90 mils in depth. That was the deepest in San Onofre.

Beaver Valley, for example, was four-tenths of an inch deep, the main crack. Kewaunee had small cracks. Robinson was .75 inches in depth.

(Slide.)

What we have been doing at Westinghouse, the utilities, we have been requesting that they cut a sample down the center of the weldment so that they don't interfere with any cracks in the reducer or line.

They usually send us 4 to 6 inches. We run it in the laboratory. We perform RT on it, UT, and then we perform a metallurgical investigation, standard metalography, SEM, TEM, standard chemical analysis and also, we use EDEX and 4 DEMA to look at the oxide surface.

If you look at the -- this turns out to be Cook, but in the case of Cook, we took a close sample. That was the first one. But if you look at the UT, now we are looking for the steam generator into the feedwater line. So we are looking

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at where we cut through the weldment looking into the feedwater line.

And in this case, we had indications, probably from about 8:30 to 10:30, from 11:00 to 1:30, coming back down here from 2:00 to 4:00, from 5:30 to 7:00, 6:30.

So the cracks come all the way around.

DR. SHEWMON: Could we get on down? We are taking more of your time than we should.

MR. MAGER: The cracks, in some cases you see branching. In other cases, I am going to show you a picture of one now, this crack will go straight as an arrow through ferrite back and forth. It doesn't show any preference, very little branching. Maybe at the crack tip. Or if you run into an inclusion, it will branch off and then we will see it.

If you look at the surface, you will see marks on every one. Looking for striation spacing in the case of Cook, we were able to find them. They were well defined, although there were very few of them, very few areas with striation spacing.

This striation spacing was the order of 1, 2, 3 micro-inches. On San Onofre, we were able to find them again. They were pretty good. But the next one we looked at was Cook, and then we went to Kewaunee, and then Duquesne Light. And it seems like it would go on. It gets tougher to find striation spacing. We are removing the oxide. And when you

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remove the oxide, if, indeed, we are preserving striation spacing --

DR. SHEWMON: Were the walls the order of half an inch thick?

MR. MAGER: In the case of Schedule 80, we are talking about .85.

DR. SHEWMON: So if it is micro-inches, and half an inch, you have got thousands of cycles.

MR. MAGER: Our conclusion that we were serving high cycle corrosion fatigue, stress-assisted corrosion fatigue.

We are not saying that we believe it could well initiate it. The thermal transient leakage back through the thermal sleeve, or whatever the case may be once the crack is initiated -- also, it could take over and propagate by vibration, mechanical loading.

All these plants --

MR. BENDER: Just a moment. High cycle by definition now is what?

MR. MAGER: We call high cycle anything greater than 100,000, anything below the knee of the SN curve.

MR. BENDER: You are presuming that that is caused by what? Temperature cycling of the feedwater?

MR. MAGER: And/or vibration.

MR. BENDER: Or vibration.

MR. MAGER: We performed stress analysis. We go back

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and if you go through the operating history of the plants on the feedwater line, the heat up, cool down, whatever the case may be, nowhere can you account for this number of cycles.

The fix, before I show you the pictures, to go in and change this, take out this geometric discontinuity or round it off, that is one thing that you would want. And also try to put a little bit of control on the feedwater chemistry. Make sure that they keep the oxygen down.

To date, Cook, Kewaunee, San Onofre, Robinson, Beaver Valley will be permitted to go back up once they replace the reducer piping or elbow, whatever the case may be.

DR. SHEWMON: Why oxygen? Is oxygen a particularly bad actor for environment effects on carbon steel?

MR. MAGER: Based on EPRI/GE report -- and the number slips my mind at the moment -- they looked at A106 Grade B, and they also looked at 336, varied the oxygen content from .2 parts per million to 8 parts per million and they observed an increase with the increased oxygen content.

Now the feedwater line, we should be well below 2/10s of a part per million. However, when you look at some of these pictures, you can see the oxide. It is definitely there and you can see the pitting.

And while the environment may be not be the primary cause of the cracking, we believe it enhances the fatigue crack

547 047

growth and you cannot go to the Section 11 versus delta K curve and say this fits. It doesn't work out that way.

As I stated --

DR. SHEWMON: Why don't you show us your last pictures. I think we'd better go on. Show us your last pictures.

MR. MAGER: I want to show you -- I don't have a picture. I have a photo-microgram.

DR. SHEWMON: Okay.

MR. MAGER: A number of plants are instrumenting the lines. If you start with this one, you can see -- this happens to be Beaver Valley Unit 1 -- the same one on the edge

(Distributes documents.)

DR. BERRY: What temperature does this operate at?

MR. MAGER: About 440.

DR. BERRY: You don't need oxygen then. Just plain high temperature in the water will reduce the oxide.

MR. MAGER: Also -- that's true. On one or two plants you have a difference in the oxidation, the color, which suggests occurring at different temperatures.

DR. ZUDANS: You made a statement that you concluded this was high cycle stress corrosion fatigue. That was based on your SEM and TEM and all of the other examinations, right?

MR. MAGER: It was based on the fatigue striation, the high cycle.

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DR. ZUDANS: By examining the fracture, you concluded that, right? And then you went back and looked at the functional arrangements and you could not identify the source of such high cycle.

MR. MAGER: Right.

DR. CORTEN: This is not from operating conditions.

MR. MAGER: So we are in the process now of going back and trying to look at the operating history to see if they had any abnormal condition where they had vibration or look at the steam generator and look at the frequency to see if they are matching up with the feedwater line.

DR. ZUDANS: When you checked the numbers that were sitting on the elbow, I understand in the straining with the data being loose?

MR. MAGER: That is one of the requirements of the NRC, to go back and look and see if any hanger is loose.

DR. ZUDANS: Any markings --

DR. SHEWMON: The NRC people will come talk about this tomorrow. So that is one reason I am pushing.

DR. ZUDANS: Fine. Why don't we quit there? Tom, we will have you back again in the fall, I suspect.

MR. MAGER: You will have lots of pictures tomorrow night.

MR. MOORE: I am with the nuclear power generation group of Babcock & Wilcox. We are responsible for planning

547 049

and managing R&D and implementing and evaluating results.

I am going to give you an overview of our R&D program and get into some results of our reactor vessel owners group program.

So I will be splitting this into two groups of activities. The first, marked A, is the company-funded R&D projects, most of which I discussed last time. So I will hit on them kind of briefly and give you a brief rundown of where we stand.

The three sources of external funding we have for R&D is B&W owners group, which is an affiliation between B&W and utilities which have a common problem that they want to solve. And we are participating with them to try to solve this problem.

Of course, we have some programs that have already been mentioned sponsored by EPRI. And we are going to be participating in a small program with the Department of Energy which has to do with reactor vessel collection of data and analyzing certain cases.

(Slide.)

What we call our materials corrosion program is primarily aimed at Alloy 600 or steam generator tubing. This program has been going on for several years, and it is to look at the metallurgical effects of Alloy 600 in the PWR steam generator environment feedwater conditions and primary water.

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This program will be grinding down after this year. There will be some effort going on, but some of the recent results we have gotten were just recently completed. The effects of various levels of strain on Alloy 600, both millen yield plus strain in millen yield, plus stress relief or the condition that the material is in when it goes into the steam generator.

DR. SHEWMON: You people a year or two years ago were having some cracks with tubing in your steam generators. I assume this is connected with that, or have you shaken that one down or know what it is now?

MR. MOORE: This program has actually been going on for several years and it does interrelate. We are looking at primarily the normal conditions of primary water, secondary water chemistries. There is another effort which I admit to you that I didn't come prepared to discuss in detail, what we call the owners group program on Alloy 600.

But I will be talking about some of the fatigue tests we've done, company-funded fatigue tests. There is lots of planning going on with EPRI internal within B&W to decide what would be the best test to run to solve those problems we have been having.

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These items really go together. We are going to conduct corrosion tests in our model boilers to look at the effects of crud buildup in the system. What we are really trying to see is corrosion rates from the different materials in the system, to try to feed into analytical efforts, to try to look at the crud buildup.

This item is not currently funded, but I have it listed.

(Slide.)

Our effort here was to look at applicability of 400-series stainless steel in things like valves: Is it an acceptable material for valves or in applications where you might consider using 174 pH or 750, something like that. It may in fact be a better choice.

(Slide.)

I mentioned the fatigue test. Early on, we had some inclination that it might in fact be a fatigue mechanism. This related to the steam generator, so we started looking into what data is available.

For the time being, disregard this box right here. I will have an overlay that I will flip on here.

What these two bands represent are the upper and lower bounds of tests run at various conditions, both in water and air, with primarily an R ratio of minus one or no mean stress.

Now, our tests, as well as some of the data we collected from others, shows this trend here (Indicating). The B&W tests run in water and saturated steam, with an R ratio of zero or a mean stress of something like 30,000, we got these data here. And we feel that this, the fact that these lie below the line, is attributable to the mean stress that was imposed on these tests.

So for these particular conditions, we are not experiencing a problem.

There is an EPRI proposal out to look at various upset conditions, various environmental effects on the corrosion fatigue, possible fatigue corrosion aspects on Alloy 600. One of the vendors is going to be working on that.

DR. SHEWMON: Is that stuff awfully strong? You are running tests at 150,000 psi?

MR. MOORE: These tests were GE tests. I am not familiar with how they were conducted, but these tests, the stresses were like peak stress, peak alternating stresses of 55 to 60,000, with a mean stress of 30,000.

DR. SHEWMON: But you run your curve up to 500,000 psi.

DR. ZUDANS: Just cycling the strain. It is not the real stress.

DR. SHEWMON: Okay.

DR. ZUDANS: It is unfair to call it stress.

MR. BENDER: Those are tube tests to represent the steam generator tubes.

MR. MOORE: Right.

DR. ZUDANS: How far did you go in that curve? You show seven.

MR. MOORE: That is as far as we went.

DR. ZUDANS: It would be interesting to see if you have an endurance level.

MR. MOORE: Somebody in the EPRI program has the purpose of going out to 10^{11} or 10^{12}.

DR. ZUDANS: In the vibration environment, you might have cycles of that order of magnitude.

MR. BENDER: They have had a few tube failures.

MR. MOORE: Another major portion of our work, internally funded work, is fracture mechanics technology programs. We are spending a lot of effort and have been for some time now, looking at ways to perform fracture tests on surveillance specimens.

Now, I will be getting into the so-called reactor vessel owners group program that we have, and this is all intermeshed. We are providing this with company funding, but it really does fit together. And what we have developed now is a method of performing the unloading compliance method of conducting the single-specimen J test, for getting both J_{1c} and the R curve.

And all of the software has been developed at our Alliance Research Center and we are in the process now of transferring that to our hot cell, where we can test irradiated specimens.

All of our surveillance programs consist now of fracture specimens in addition to what is required by GNH 10 CFR 50, the CHARPY specimens. And we need this method in order to conserve the specimens and get the most out of our program.

As some of you probably know, there is a proposed method in ASTM for doing multiple specimen J tests. This would take quite a number of specimens, four, five, six specimens, to conduct that test. The capacity of the surveillance capsules would be like our one-inch thick specimens. We have like eight of those specimens in a capsule.

We also have a program under way right now to look at the effects of welding parameters, primarily flux on upper shelf toughness, both from the standpoint of CHARPY and actual fracture toughness, both current methods, past methods, primarily with -- we have some materials that have early vintage plants.

Most of the materials are low copper. We maintain a data bank of fracture toughness properties and continually upgrade data packages throughout the various divisions evaluating carbon steel properties, and we are active in monitoring industry-wide programs.

DR. ZUDANS: The data bank --last year you made a presentation -- how is it accessible? Is it public or proprietary or what?

MR. MOORE: We are anticipating an MPC effort to develop an industry-wide data bank. To answer your question directly, it is a company project, but we are participating -- and we will bring it up in this slide right here --

(Slide.)

We are very active in trying to set up a means of developing industry-wide data bank for fracture properties, for mechanical properties on materials.

The first item on the agenda is reactor vessel materials, develop a data bank that can be retrieved and analyzed in any form, say the CHARPY data to try to correlate fracture toughness, data like this. So we are very active in participating in this effort right here. And this particular project is what we call our joint industry program, where we spend company money to gain entrance into industry-wide programs. We have donated a considerable amount of material to these various programs, including NRC, EPRI and so on. If we have the material available, we would donate it. We have to make a weld and make it at cost.

In the last two or three years, we have donated a tremendous amount of material.

There is a new task within the HSST program in which they have asked for and we have supplied a low copper material or a material representative of our current vintage practice.

(Slide.)

This one here is an interesting program, because it relates to what Tom Mager was talking about on the equilibrium effect. Dr. Wechsler of Iowa State is going to be looking at materials we supplied to him which were taken, were irradiated both in a test reactor and a power reactor. And he is going to do a metallurgical examination of these materials to compare materials irradiated in two different sources, two like fluences.

And as I understand, he is going to be doing transition microscopy, OJ, the complete gamut of examinations. I think this is an important project to have the results from. I think it will blend very well with the effort going on to look at this equilibrium effect.

I would like also to mention that one of the guys in our group has been looking at this equilibrium effect and is in some disagreement with the idea that test reactor data doesn't show this saturation thing. I think we would like to say that all of the data needs to be looked at collectively. It would be an extremely favorable trend. We are not altogether convinced that it doesn't exist in, say, the HSST program and CHARPY data; and certainly is tied to some kind of rate phenomenon.

But some of the radiations, like at Oak Ridge, you are getting like 8 times 10^{19} in three months. Somebody correct me. I think that is correct. In some of the earlier radiations, we are getting like fluence in light a month to six weeks. So we have the opportunity to look at all of these data to try to determine if we do in fact have equilibrium effect.

We are just getting started in -- I understand this is under Chuck Serpan, this dosimetry program to evaluate dosimetry results obtained from various reactor vessel surveillance programs, and try to get a handle on it, on just what is an accurate picture of fluence measurements made from various sources.

(Slide.)

I will be getting into this program in a little bit, in a little bit more detail. It is our owners group program. These two have been mentioned previously (Indicating). We have ongoing efforts to look at reactor vessel surveillance capsules. We also are providing materials to the MPA. I am not sure -- it is a German -- Husmal. He is going to be looking at quite a number of materials for the effects of various welding parameters and possible heat-affected zone cracking.

MR. BENDER: Are you providing any ultra-pure material?

MR. MOORE: What he asked for -- Dr. Ayers of ARC -- there is a distinct difference of opinion, let's put it that way, in what they will find.

We were not worried about supplying these materials.

MR. BENDER: All right.

DR. SHEWMON: The difference of opinion is on what?

MR. MOORE: The tendency for German versus American materials to crack in the heat-affected zone.

DR. CORTEN: You think we will not see cracks in our material in the heat-affected zone?

MR. MOORE: If we see anything, it will be on the order of cohesions, heat cohesions, slight grain boundary separations, I think, as opposed to large cracks.

DR. CORTEN: I think they would all agree to that.

MR. MOORE: Yes.

As I mentioned a couple of times already, we have a program set up with our owners, utilities which have reactor vessels with high copper, relatively low toughness, weld metals. And I will be getting into some of the results here. I will flip through these.

The objective of this program is to fold -- really, what it boils down to is the first part and the near-term objective is looking at CHARPY properties and trying to take a detailed look at the current regulatory requirements in terms of the 50 foot-pound requirement at which you measure RT and DT.

The long-term objective is to collect real fracture data from irradiated materials, and with these data and all the analytical tools being developed within our own company and the large programs going on in the industry, we hope to demonstrate the materials, the reactor vessels, have adequate toughness for the full life.

DR. CORTEN: Even when their CHARPY energies are below or near the 50 foot-pound?

MR. MOORE: First of all, there are many things interacting. If we have an equilibrium effect, we may never have reached that point. I think the elastic plastic methods that we are spending so much money in the industry on, those methods are going to hold the key to analyzing and demonstrating adequate integrity of the vessels.

(Slide.)

On the near-term activity, we have completed a number of tasks, one of which is the -- an update on more refined neutron fluence calculations. We have a generic as well as a plant by plant fluence mapping of each weld, of each weld location.

Some of the plants contain both complete circumferential girth welds and longitudinal seams. Some only contain the circumferential welds. So we have a complete mapping of what the fluence is on each weld and its particular location.

I will have a slide on the characterization of chemistries. We have also completed a study on the drop of upper shelf as a function of several elements, as opposed to

Reg Guide 1.99, which is only copper. What we intend to do is send a report to our owners which combines the output from these three items for the purpose of showing what we predict from all of these data will be the time period a plant can operate before it would drop the 50 foot-pounds. We expect this to occur this year.

MR. BENDER: Would you clarify the point you made a moment ago about the drop in upper shelf as a function of several elements, as opposed to the Reg Guide; just to clarify that?

MR. MOORE: Sure.

(Slide.)

I would like to -- let me give you my shot on the weld chemistry. One of the tests we have just completed is a complete characterization of all of the available archive materials we had from reactor vessels. This includes dropouts from the nozzle belt area that contain welds, and also from our surveillance programs.

There are 27 different wire-flux combinations used in the operating reactor vessels that contain high copper low toughness or the low toughness problem. We have archive, large amount of archive materials from 14 of these wire-flux combinations. These have been analyzed 400 different times to look at through thickness variation. We have also done electron microprobe, looking for copper variations. And actually, this really has two purposes. One of them is that it is part of our predictive effort to try to make predictions on what a plant -- how much life a plant will have at 50 foot pounds.

The second thing is, it feeds into the long-range plan in that these are the materials from which compact fracture specimens were made and put in the surveillance programs, compact fracture specimens as well as material we supplied to test reactor programs. So we have a complete characterization of those materials that are going to be subjected to further radiation.

e-25

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(Slide.)

MR. MOORE: We have developed an empirical correlation based on a collection. This graph is confusing. I will get to it in a second. We called all available data from civilians programs, test reactor data, and developed an empirical model for drop in upper shelf as a function of chemistry.

We looked at carbon, phosphorous, nickel, molly, cooper, about eight elements. And what I have here -- it shows what the correlation is doing for us. We have the observed drop in upper shelf in percent versus what we predict from both the model, what we call the Model 1 here and a least squares fit through Reg Guide 1.99, which is based on copper.

Now our problem is we would like to show that we have an extended life, say if we could show that we don't drop 50 foot-pounds for fluents of, say, 5 times 10 to the 18th equivalent to significant life.

Reg Guide 1.99, at the time it was produced there wasn't enough low fluents data on which to get a good fuel for what the trend would be at low fluences.

Since that time, there has been quite a few other data points, particularly B&W programs, where we have looked at surveillance capsules that have anywhere from 8 times 10 to the 17th to low, 10 to the 18th fluence.

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Now this is what we get from our so-called Model 1. This takes into account all available data, everything that we could get our hands on -- GE, Westinghouse, CE. And ideally, it would be a 45 degree line. The Xs go with the so-called Model 1 empirical correlations based on the chemistry And the squares are the Reg Guide 1.99.

DR. CORTEN: The squares were used to get your model as well as the Xs?

MR. MOORE: Actually, it is the same data. But this is a least squares fit through what you would get if you were to use Reg Guide 1.99 based on copper alone.

DR. SHEWMON: The truth is along the horizontal axis, a vertical is always predicted.

So the points — the straight line, the solid line is the best plot through the Xs. And the dashed line is the best through what you get if you only take copper and the Reg Guide prediction.

MR. MOORE: Right.

DR. CORTEN: Thank you.

(Slide.)

MR. MOORE: We did the same thing excluding everything but those data generated from B&W manufactured weldments. And this would include Westinghouse as well. But we got a much better fit. But we don't have that many data points. We have an excellent correction. Again, observed versus

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predicted.

DR. SHEWMON: How much of that change is chemistry and how much is flux?

You said it was poor at the low fluence. Is the low fluence — it would be at the low end?

MR. MOORE: Right. I don't know how to answer that question.

DR. SHEWMON: The question was: Are you going to have to try to convince the regulatory people that they ought to take primarily efforts to convince them other than copper should be included? Or is the flux dependence the main thing that you would like to work on them on?

MR. MOORE: Taking into account the interacting chemical elements, we feel that looking at copper alone — plus the fact when they did Reg Guide 1.99, there wasn't a whole lot of data available at the low fluences.

But primarily, the answer is we want to use our so-called Model 1, which takes into account all data, and in taking into account the interacting effects of the various elements that we are using in the correlation.

DR. SHEWMON: Chuck, do you have any program that would provide data for something of this sort with the broader chemistry look on the effect on -- or do you get that out of surveillance capsules and help interpret it that way?

MR. SERPAN: We are trying to get more information out

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of the surveillance capsules. I think the whole program that we have got is going to help on this particular — on the dosimetry angle. So at least we will know that is correct.

DR. SHEWMON: Thank you.

MR. BENDER: The curve — the low curve is dominated at the low end. I suppose the controversial question is whether —

MR. MOORE: How far can we extend it?

MR. BENDER: Should you extend it from that?

MR. MOORE: Yes. We feel comfortable using Model 1 up to about 5 times 10 to the 18th. We don't feel that we can extend it beyond that.

Obviously, there is going to be a whole lot more data coming in in the next few years. This will be a continuing effort to upgrade this.

DR. WECHSLER: The points that are furthest to the left and down refer to about a 10 to the 18th. Let's say these four points that are so heavily weighted on the curve. What range of fluents would correspond?

MR. MOORE: I don't recall specifically.

DR. WECHSLER: It would be on the low fluent end.

MR. MOORE: Definitely.

DR. WECHSLER: And where the results might be least reliable.

MR. MOORE: You mean in terms of measuring an actual

693.26.5

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property change. Tha 's a good point.

DR. SHEWMON: Which leaves the end of life licensing questions.

DR. ZUDANS: And if you had saturation, wouldn't the point or the curves stop at some point there?

MR. MOORE: Yes.

DR. ZUDANS: My feeling is if you had to somehow quantify the rate effect, you could feed this material i to a test reactor and run it to saturation and go back and calculate the effect and see what it would be in the real reactor.

DR. SHEWMON: If you go to higher temperatures, you might.

MR. BENDER: We have been trying to do that for a long time.

DR. ZUDANS: The concept of saturation is not older than a year or so.

DR. SHEWMON: In this field.

DR. ZUDANS: I don't know.

DR. SHEWMON: I have the impression that the other people have talked about it like the cladding and that thing. But let's go on.

(Slide.)

MR. MOORE: The long-range plan, the long-range part of this program includes, like I said already, getting fracture properties on irradiated materials, which includes our power

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reactor surveillance program, which recently updated about two years ago. And all of the materials that we supplied of this vintage to the test reactor program -- we feel like we have a comprehensive program. We are going to be getting a lot of test data and we are going to be highly dependent on the results of industry-wide programs, particularly things like elastic plastic, as I already mentioned.

I feel like it is obviously apparent to everyone that there are many packets of work going on throughout the industry sponsored by government agencies, independent sources, and we need to do a good job of tieing all of these things together.

DR. SHEWMON: The HSST is one umbrella for that. Does this come under that?

MR. MOORE: It does.

DR. SHEWMON: Are you suggesting that there is need for another or what?

MR. MOORE: From the standpoint of getting irradiated material properties on our weldments, we feel like we have that pretty well covered. This is our so-called power reactor program.

I will overlay this briefly and then show it individually. It shows the redundancy in the power reactor and the test reactor program. We have quite a number of welds which are in our surveillance capsules. And as I mentioned,

693.26.7

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they have a whole series of different size compact fracture specimens all of the way up to an inch thick on the various sites.

I think it is only fair to mention that one of these sites was TMI 2. That situation is under evaluation. We are going to see the impact of that. But we have enough materials in different places that we can cover even that situation.

DR. CORTEN: What is the surveillance program that does collect all that together? HSST isn't doing it any more, are they?

MR. SERPAN: If you are talking about the surveillance information for B&W plants, no, that is not HSST functions.

DR. CORTEN: The irradiation studies program is not under HSST any more.

MR. SERPAN: Yes, there is a major irradiation effects program under HSST and we are doing irradiations of B&W weld metals.

MR. MOORE: It is shown on this slide right here in this schematic form. We have several welds in the HSST program. The testing is going on at the present time.

We have also donated materials to the NRC-NRL program. This thing about -- this question that Chuck was asked about, do they have programs in place to help us evaluate this thing, just recently it has been reported the NRL studies on about 9 B&W weldments, the work was done by

gsh

Russ Hawthorne. And I understand that there is going to be a detailed report written on the results of that work. I have seen kind of a rough outline of the results.

The results look quite favorable.

The one thing I haven't been abl to do, they are coded in a certain way that I can't go back and correlate what are codes. So there is going to be another report coming out. It will be a detailed report of the specimens that were tested in that program.

DR. SHEWMON: Fine.

DR. ZUDANS: All of these data end up eventually in your data bank as well?

MR. MOORE: They are going to be going into our program and will be part of — they will be included in reports and evaluations.

DR. ZUDANS: Is there any single unit some place in the country where the industry or government takes care of collecting all such data?

MR. MOORE: The MPC group that I mentioned has that goal. It is an ambitious project.

It seems to me that it would take them quite a long time.

DR. ZUDANS: That is a German group?

MR. MOORE: Materials property council. Their first goal, their first package of work they want to computerize is

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our reactor vessel materials.

DR. ZUDANS: Your data bank is simply a duplication of the same kind of group of industry?

MR. MOORE: We generate it for our specific needs. We have a way of collecting data, say, if we want fracture properties of 718, for example, or 106 piping, or somebody has a specific need in a fossil plant, boiler drum material, something like that.

We can call the information from which to analyze the fracture analysis.

DR. SHEWMON: Can you about tie things up?

MR. MOORE: Yes, I'm through.

DR. SHEWMON: One different question. It seems to me that last year we talked a little bit about efforts that you people were trying to make was that instantaneous double-ended pipe break was so uncommon that an SSE probably wouldn't set it off, or the probability of those two overlapping was pretty low.

MR. MOORE: It must have been a different forum.

DR. ZUDANS: I think that was CE.

DR. SHEWMON: CE brought it in and Westinghouse had a report on it, and I thought your users group — they must have gotten asked the same question, didn't they?

MR. MOORE: I am not familiar with that.

DR. SHEWMON: Well, we wait for our clean-up hitter,

693.26.10

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then. Mr. Cowan?

MR. COWAN: I arrived early this morning on the red eye from California so I don't know if I can remain coherent for another hour. I hope so.

DR. SHEWMON: I hope you don't for another hour.

(Laughter.)

MR. COWAN: I would like to fill you in on our development programs in the materials area related to the plan site of things as opposed to fuel.

(Slide.)

This is an overview chart of where our efforts lie. At the top of the list is stress corrosion cracking because that is the — in terms of availability, that is our main concern. And we have programs going trying to develop more fundamental understanding both in San Jose and our laboratories and exchanges with our licensees.

DR. SHEWMON: Given that this has been a major program with you and a continuing one, and that we were here last year, would you try to work on what we have -- what you think has changed or what has been added since last year?

MR. COWAN: Okay. As we go through, instead of outlining what the programs are, I have picked some of the key programs I think that have some results to show you.

DR. SHEWMON: Fine.

MR. COWAN: So I can stay awake. The parametric

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studies is a new program which I will get into short-term remedies. I will update you on the status. Ultimate materials has had impact on plants. I will go into that. Improvements applicable to operating plants covers a large program on improving residual stress at operating plants and would cover topics you mentioned earlier like deaeration or alternate water chemistry.

I haven't really addressed deaeration, and you asked about that earlier. GE has a recommendation out to utilities to deaerate.

DR. SHEWMON: We got it after last year.

MR. COWAN: What we are looking at now in the deaeration area is the best way to deaerate. Are there some risks involved in some of the methods?

Dr. Endig of our laboratories has found that you maybe can't simulate just in the laboratory with oxygen. You have to have a play-off of hydrogen peroxide plus oxygen to simulate the different deaeration modes. And we have a program with EPRI just beginning to look at that.

In this area, we have extensive initiation propagation studies with carbon, low allow, stainless, and inconel materials. We have a program with EPRI on wear resistant alloys. Welding techniques I won't talk about, but they are both for operating plants and for requisition plants where we have decided that we designed three or four years ago isn't the most prudent design. And from our laboratory results are changing things that are very difficult to change.

So we have to developed automated welding equipment that operates in restricted spaces.

DR. SHEWMON: The requisition plant?

MR. COWAN: On order, but not producing power. They are in that state for 8 years, 10 years sometimes.

DR. SHEWMON: Is that right?

MR. COWAN: Non-destructive test techniques. I think EPRI covered our programs, actually. I won't discuss those.

DR. CORTEN: What is that stuff at the bottom for?

(Slide.)

MR. COWAN: That is to show why we are pursuing these. It is mainly to increase plant availability. We feel that we have a comprehensive materials-related program within GE addressing BWR problems, and we get pretty good cooperating with the utilities, mainly through EPRI.

DR. ZUDANS: The driving point behind your program is increased availability.

MR. COWAN: Yes. The pipe cracking problem hurt our availability very severely for two years, the BWR availability

(Slide.)

In terms of where our funding on outside programs come from, we have one small program from the NRC office of research on a non-destructive method for measuring degree of

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sensitization in austenitic stainless steels.

We are using this in our factory in Wilmington to sort materials when they come in as a check to make sure it has had the 304 materials that has had the proper solution heat treatment. And we use it to inspect piping in our specs.

For the NRC, we are trying to develop a field method to measure degree of sensitization on pipe joints or pipes in operating plants to say whether these are high risk welds or low risk welds for stress corrosion cracking by comparing to the degree of sensitization.

e-26

We are not done with that program and we don't know how successful we will be and whether that weld fails or does not fail, if it has high enough stress.

DR. SHEWMON: You are not sure of the correlation or you can't get reliable results?

MR. COWAN: We get reliable results, but from our test laboratory results it looks like 304, if it is welded, if it is highly stressed, the chances are it has a high probability of failing. There is a very sharp cutoff between fail and no-fail.

What we hope to do is show that -- we also know that certain heats are highly susceptible. You might call them turkeys. You run an EPR in the base metal and you get a very high number. Right now we are correlating the base metal readings with the statistics from our pipe test lab, plus field failures.

We are hoping that is going to be a method to sort piping runs in the field.

I will go into the EPRI programs in more detail. The reason I am presenting the EPRI is that when we think we have a problem that needs to be worked on to help the utilities, we go to EPRI on a cost-sharing basis. Our main efforts, technical efforts, are joint programs with EPRI.

With DOE, we have an alternate water chemistry program that is now waiting signing for phase two. That is really not in the plant materials area, but we did the experiments originally to cull out what the specs would have to be for an alternate water chemistry to preclude stress corrosion cracking of 304. And now our new part of the program will be -- if you use that water chemistry, what does it do to other materials besides the austenitic stainless steel, such as the pressure vessel steel, high-strength bolt materials, that sort of thing.

(Slide.)

Most of the results I will be showing you were developed in our pipe test lab, which takes four-inch Schedule 80 pipes that have four to six-inch sections welded together. So one pipe specimen has 11 to 12 girth welds in the pipe. We pull on it axially to very high sustained loads on the order of maybe 136, 140 percent of the yield strength. And we have 72 such test stations.

They run in a refreshed manner with high-purity water, and there are several sub-loops to look at water chemistry effects, et cetera.

This facility was made at a cost of $4 million in 1977 dollars.

DR. CORTEN: You say 140 percent of yield, control load?

MR. COWAN: When it is load control. Some of the stations do have the facilities to do deflection control. Primarily the testing has been load control.

mte 3

DR. CORTEN: That must be approaching ultimate strenght.

MR. COWAN: No. Austenitic stainless steels, 136 percent is about 2 percent strain. Maybe 60 percent strain, right as it is bending over.

(Slide.)

This shows a typical load cycle used in the pipe test lab, zero to 136 percent yield in five minutes, a hold for 75 minutes, ramp-down in about one minute, hold for five minutes, and then back up.

The oxygen content of the water, it is air-saturated, so it is 6 ppm plus or minus 2, temperature around 540 to 550 degrees Fahrenheit. The pH is set by the carbon dioxide and San Jose smog at 5.5, and normally 136 percent of the load axial plus 4 ksi from the pressure stress.

We went up to 1200, I think, psi.

DR. ZUDANS: Is there any reason why you use stress control?

MR. COWAN: Yes. In our original studies in the late 60s and mid-60s, late 60s, sensitized stainless steel does not suffer stress corrosion cracking under a strain control. A bent beam sample of a severely sensitized sample, put in oxygenated water. Nothing happens.

You use that same material, the same -- and put it under axial sustained load, a primary load as opposed to a secondary load, and the material will crack if it is over yield. That is why we went to sustained loading, primary type loading in the pipe test lab.

(Slide.)

The first thing I would like to talk about is our qualification of alternate alloy, and that is, the objective is to find an alloy to replace 304 and to do it as quickly as possible and get it into requisition plants where the utilities are willing.

(Slide.)

Our approach -- this program started two years ago. This was to do screening tests to pick what looked like good candidates, and then do a qualification series in the pipe tests on a statistical number of heats of both 304, for reference data, and a stastistical number of heats for the alternate alloys; and then to implement it in the BWR services with the correct specs, working with the vendor and working with the utilities.

The candidate alloys that we chose for the screening stage of pipe tests, the statistical pipe testing, were 304 L and 304/nuclear grade--and I will explain what those are later -- just normal 316, 316 L and nuclear grade, and you can read the rest of them: CF-3, a cast alloy, XM-19, being Armco's trade name for -- it is a nitrogen manganese austenitic stainless steel which we have used successfully in our control rod drive applications. We qualified it for that use two years ago. It nitrites without sensitizing.

We have done our pipe screening studies, our pipe step testing, fatigue testing, that is, in the environment; low-cycle fatigue testing in the environment, static crack growth, cyclic crack growth, constant expansion rate.

I am going to show you the results of the first two, which are the hardest to do and the data that is the most applicable and interesting.

(Slide.)

This shows our reference-type 304. We have tested 19 heats, that is, 19 different heats of 304, Schedule 80, four-inch pipe, with 11 welds in each heat. And of the first 19, 14 of those failed by stress corrosion cracking, and the failures go pretty much by the carbon content. Down around .042 percent carbon, some heats fail, some don't. It is above .05 that they all fail in this very severe test.

We go to 316 L/nuclear grade. We tested 11. We have had no stress corrosion failures, although we have had -- because we are running out to very long times, we have had some fatigue failures. The low cycle, just fatigue.

And the same with 304 L/nuclear grade, 347. They all show, on a statistical basis, a factor of 20 better than 304, looking at these many heats. And that was the objective of the program, to show a factor of 20 on a statistical basis,

mte 6

which meant that the material would last the life of the plant without cracking. This is a first order statistic, based on a log normal distribution, which is kind of complicated. And I will just leave it at that unless you have some questions.

DR. SHEWMON: What is CF-3?

MR. COWAN: That is a cast version of 304 L.

DR. SHEWMON: All right.

(Slide.)

MR. COWAN: Next is fatigue initiation testing.

(Slide.)

We were using cantilever beam specimens, which we were cycling in this manner. This is the same kind fo specimen that was used in NRC-type rupture studies which we did in Dresden. This was the same kind of samples down in the lab in a sister autoclave, and you can look at the different alloys we locked at, the compositions, the number of heats. And we looked at smooth plus stuff that had been pickled, cold worked and welded. So we tried to look at surface conditions.

I will show you the results for 316 L. This is the air room temperature, air data curve, and this is the ASME design curve. What we did was, we did visual inspections at these points in time. So it wasn't failed here but it was failed here. It is just some uncertainty bend. It failed in there.

In any case, all of the data points are lieing along

nte 7

this strain line. These are pseudo-elastic stresses; that's why they look so high.

You will see the 316 L, no matter what condition, falls well above the design curve.

DR. CORTEN: What is your definition of failure?

MR. COWAN: Initiation of a crack that you can see visually with a 30X piece or broken in two. Sometimes it would be clean here and it would be in two pieces here. Some data points might be a crack you can see. We tried to be as conservative as we could.

DR. ZUDANS: These data points are actual fracture points?

MR. COWAN: Yes.

DR. ZUDANS: And the ASME design curve is a factor of two below the lower end of the curve of all --

MR. COWAN: No, a factor of two, and 20 on the mean.

DR. ZUDANS: On the mean, on the envelope, on the lower envelope.

MR. COWAN: The ASME cycles to failure curve, and this is the design curve, and that is how you get a factor of two and 20 on the design curve from that mean curve.

DR. ZUDANS: I thought there was an envelope. I guess this will have to be resolved later, right?

MR. COWAN: I guess this is the mean curve and this is the design curve. I think it is a factor -- so our data points are all above the design curve, and the design curve is to take in surface flaws and the environment and that sort of thing. I think the data is very conservative.

We developed this kind of data on the other alternate alloys as well.

(Slide.)

I said I would talk about nuclear grade. What we have done is, we would like -- what we want to qualify as an alloy or use as an alloy for piping is a -- out of these tests, is a low-carbon alloy, less than .02 percent carbon, and we want to have the strength of 304, 316. So we have written our specs and we call it 304 and put an upper limit of .02 on the carbon content.

So from a stress analysis point of view, it meets all of the requirements of 304, 316 mechanical properties. It is a tighter spec on carbon than 304 L or 316 L, but it has the mechanical properties of 304 and 316.

All of the heats we tested of the alternate alloys had the strength of the normal grade.

DR. SHEWMON: You get the additional strength by having the nitrogen be some higher, then?

MR. COWAN: In all our cases, we get the additional strength with the nitrogen being on the upper limit, like .06, .07, but within the .01 -- I'm sorry, the .1 range. There is a grade going through validating an ASTM to have an upper limit

nte 9

of -- have this kind of a range for nitrogen. I am not sure what it is going to be called, whether it would be LN, maybe LN grade. But we have been able to buy this material to our specification.

The bottom line of this program is the 12 requisition plants, 10 domestically, have ordered 316 nuclear grade to either -- they have either canceled their orders for 304 or are scrapping their existing 304 for the recirculation system, at considerable expense.

Our work on the alternate alloys continues, looking at the effects of, say, off-chemistry conditions. We are going to do some testing with very large, 16-inch diameter pipes. We have two stands to test large pipe. But we are confident enough on our data base to recommend this change to the utilities.

DR. SHEWMON: The nitrogen doesn't come out as a chrome nitrite, or if it does, it doesn't go to stress corrosion?

MR. COWAN: It doesn't come out as a chrome nitrite. The nitrogen solubility is higher than that of carbon. The XM-19 alloy I was talking to you about is .4 max nitrogen, and there is no nitrogen that precipitates nitrites

(Slide.)

I described our short-term remedies. For the last time, I will give you the status of where they are. The reference pipe 304, everything is gauged against this. This is

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nte 10

a different set of references than the alternate alloys, because they were started earlier.

And corrosion-resistant clad applied in the shop, the shop corrosion-resistant clad has a factor of improvement of 65, so we feel it is qualified for use. Corrosion-resistant clad done in the field -- the difference is, in the shop you provide the cladding, so the heat-affected zone from the first layer of duplex cladding is gone, so other heat-affected zones are in the solution heat-treated cladding, whereas in the shop -- or in the field application, you leave the heat-affected zone. It is not as good. We only get a factor of six for the shop application of corrosion-resistant clad.

For solution heat treatment of welds, as you would expect, it shows a factor of improvement of 65, which is as long as we have tested in heat sink welding, which is a technique of making the first two layers in a normal manner, and then either spraying or flowing water through the pipe while the filler passes are made, has shown a factor of improvement of 15.

So we are out to our requisition projects. Those that were committed are already welding in 304, you know, to use these fixes or these improvements of heat sink welding, corrosion-resistant cladding and solution heat treatment.

-27

Many requisition plants are getting most of their welds affected by one of these --

DR. SHEWMON: Solution heat treatment.

MR. COWAN: Is done in a shop. The welds are done in the shop, sent to a heat treater. The whole arrangement is jigged, put put in a big furnace and water-quenched.

DR. SHEWMON: The Japanese were talking about induction heating.

MR. COWAN: That's next.

(Slide.)

MR. BENDER: Can I back up for a minute? I would like to ask a question while it is still fresh. Your position on 316 material. First, you have had that option a number of times in the history of these plants up until now. Why was it that you have always wanted to go -- stay with 304?

MR. COWAN: That is a good question and I am not sure I know the answer.

316 is more expensive, but why not 304 L? Well, 304 L would require a new stress analysis on all of the piping systems, because it has different allowables. And nobody thought of the concept of trying to get low carbon with the -- maintaining the strength.

Plus I think we are a lot smarter now than we were five or six years ago. Plus I think designers are more apt to listen to materials people in the last several years than they were, for example, 10 or 12 years ago or 15 years ago, when most of the decisions for the plants that we're running now were made.

MR. BENDER: You are probably right. But it is a qualitative argument. I don't think money should have dominated the thing, because there is not that much difference.

MR. COWAN: I don't think money did dominate it.

DR. SHEWMON: How about mechanical engineers? Did they dominate?

MR. BENDER: They are kind of bullheaded sometimes.

MR. COWAN: Until '74 and '75, until we had that rash of pipe cracks, it was difficult, except for some lab data, to show why you should have a change.

MR. BENDER: I didn't want to divert you that much.

MR. COWAN: It has been the subject of some arguments.

(Slide.)

In your handout, it shows how these factors of improvement were calculated.

(Slide.)

Induction heating. The Japanese call this process induction heating stress improvement. In the United States, we are calling it residual stress improvement. It is an induction coil with flowing water. You turn the induction coil on, the inside remains at 100 degrees max, the outside goes to 500 C max. You plastically upset and when you cool down you wind up with compression on the inner surface.

DR. ZUDANS: If you don't crack it in the process, you develop fantastic tensile stresses on the outside.

MR. COWAN: Stainless steels are pretty tough.

The concept is, to answer your question, it is not a tremendous amount of plastic strains, because, again, it's a secondary type stress. So you can only put as much strain in as the delta T term. So I think we are talking even less than, say .3, .4 percent strain, which is nothing to stainless steel.

DR. ZUDANS: The inside surface gets beyond the U point.

MR. COWAN: But that does not crack stainless.

DR. ZUDANS: So you bring in the residual surface compression.

MR. COWAN: Right, and you end up down here at the end of the process with compressive residual stress (Indicating).

So our program is, knowing that and knowing that the Japanese have developed this technique, was to develop our own way of doing it. Not that it be different than the Japanese, but just to get people in the United States to learn how to do it and to learn ourselves how to do it, which we have pretty much done; and then to show to ourselves and then to the regulatory bodies that the darn thing works. And we want to show that by pipe testing.

And the third task is: It works, but how do you do it in a plant that is already operating in terms of radiation fields, containment, talking about big generators. So we have a task on how do you do it and then doing it, getting the capital equipment and maybe demonstrating it on one plant.

I might add that in Japan this has been done, even on the recirc system in an operating plant. So it is doable.

(Slide.)

Our schedule for these tasks, briefly put up here, is to have everything done by the middle of 1980, one year from now.

DR. ZUDANS: Would there still remain a question as to -- you demonstrate how you cure it. Wouldn't there be some process of relaxation and you may lose the effects at some point in life?

DR. SHEWMON: What you want to lose is the residual stresses that are in there.

DR. ZUDANS: It is the compression stresses you don't want to lose.

DR. SHEWMON: You don't lose residual tensile stresses. If we did, we would be very lucky.

MR. COWAN: There probably is some loss of residual stress initially, whether it is the tensile or compressive. And in our experimental matrix, we are treating these pipes at 500 degrees C. for 24 hours, which marks up -- should mark up the worst condition of in-service LTS plus in-service stress relaxation. So that is covered in the matrix.

DR. ZUDANS: You would go through a range of residual stresses, not just maximum amount every single time. In other words, there is a point where you do not get any more benefits.

MR. COWAN: That's correct.

(Slide.)

In this chart here, we have tried -- these are the conditions to optimize, where you get nice plastic upset, but it is not complete overkill. The reason I show this chart or brought this chart was to show you the kind of powers required for 26-inch pipe. It is almost 400 kilowatts, so it is a pretty big induction heating system to turn the inside surface of a pipe compressive.

For the 26-inch pipe, we are talking less than 200 seconds. For the four-inch pipe, we can do it in less than 13. But our licensees have shown that 200 seconds -- there is no chance of even sensitizing the outside. There is no chance to sensitize the inside, since it is always at 100 degrees C. maximum.

(Slide.)

Now, we have instrumented with strain gauges some pipes we have treated, and pulled them and gotten the stress-strain curves. I am showing one result to show how the apparent yield stress of the IHSI pipe is much higher than that of the reference pipe, and how it changes in going away from the center line of the weld, the residual stress effect as that falls off.

I have also shown that when you stress, when you test the stresses above yield in stainless is when you get the cracking. We haven't seen cracking in our laboratories at stresses below about 100 percent of the yield. So you have to be careful in testing the IHSI that you don't overstress it. That becomes important when I show you one of the results.

Our first test was to run, like we did the alternate alloys, where it doesn't really appear to matter what stress you test. You don't get intergranular cracking because it is not sensitized. Here we got sensitized material and if you overstress it you wipe out the compressive residual stress, and then it can fail.

And the disadvantage of going to lower stresses is the reference pipes take a longer time to fail. So it extends your program out, waiting for the reference pipes to fail and then waiting for your IHSI pipes to go some time beyond there, to say that it is at least 5 times or 20 times better than doing nothing.

(Slide.)

Our pipe testing in this area. We are simulating service exposure by the 500 degrees C. 24-hour treatment, and establishing points for first failure for treated and reference pipes, to establish the margin of improvement, using the formula that is in your handout. And we are making the pipe specimen's worst case conditions, with this low temperature sensitization treatment. We are grinding the IDs after welding, which improves cracking susceptibility. And of course --

DR. SHEWMON: Tell me what that last curve meant again? Tell me what low-temperature sensitization means?

MR. COWAN: That is some of the work that our corporate research labs have shown with time, at reactor temperatures of 300 C., that it may be possible that the sensitization in the heat-affected zone gets worse. This is a heat-activated process, and it may be in 20 years it is twice as bad as it was when it went in.

Knowing this, we used that in our tests. We give it a treatment of 500 degrees C. for 24 hours, supposedly the worst case of what it would be at the end of 40 years if this thing really happened. So it is kind of -- to test, to make the test more conservative.

(Slide.)

The progress is, we are just starting this program. It is our first reference pipe. The heat we bought to do the IHSI program failed. It went back on test again and it failed again.

You need a susceptible heat to show that the IHSI or the RSI technique is working.

(Slide.)

So in the treated specimen, five of the joints have done okay. We have had one intergranular failure after 463 cycles. It so happens this failure occurred in the weld prep. It had a fairly thin-walled area, so it was right on the edge of, evidently, the stress, that 136 percent of yield on a nominal basis. Locally, it was higher than that. It was over the edge of where the stress wiped out the improvement.

The other, thicker sections were right under the edge. We are looking at that carefully and how to do the rest of our program. We will probably drop down to 125 or 120 percent of yield, to show the effect.

I show this to say it does appear to work, but it is a testing problem to show -- in a reasonable time -- it may be a testing problem to show, in a reasonable time, how well it works.

DR. ZUDANS: In a thin-wall case, you may not have generated compressive stresses to the surface, because of heat transfer between the water and the metal.

MR. COWAN: It wasn't that much thinner.

DR. ZUDANS: I take back my comment.

(Slide.)

The weld prep was a little bit off-center, so there was a thinner region on one side. It was just up about 140, 140 percent, 141 percent of yield.

MR. BENDER: Have you looked at the Japanese data?

MR. COWAN: Yes.

MR. BENDER: How much better is it than yours, or how good is their data base?

MR. COWAN: Their data base is very good. They have done a lot of parametric studies on how to do the IHSI treatment. But they have done no pipe testing. They have relied on magnesium chloride testing to show, if you take a normal weld, put it in magnesium chloride for about eight hours, pull it out and PT it, there are cracks all over it from the residual stresses. If you do an IHSI-treated pipe, it is clean.

They say that's enough, it works. It makes the stresses compressive, so let's go.

MR. BENDER: That was helpful.

MR. COWAN: Another program is a parametric program to look at the effect of oxygen level stress cyclic frequency under pipe test laboratory conditions. And this is really to gain more insight into the field cracking that we have seen. Most of our testing has been on small samples, coupons without residual stress or without typical grinding of a weld. So this is to get data on prototypical or real field conditions.

I am going to skip the next slide, which just tells in more detail what that program is doing, and that program has just started.

(Slide.)

..other program that has just started is an

EPRI-sponsored program to look at large piping. Except for Grumingen, there were no leaks. We have seen no cracking in large diameter pipes. And in the 1975 period when we did our major work on the causes of cracking, the reason we hadn't seen cracking is because of the residual stress that was lower on larger pipes.

And then, looking at the Grumingen, it looks like there may be other factors that help as well. So this is an EPRI-sponsored program to see if we can show there really is a difference between the large diameter pipe and there really is more margin.

The kinds of things we are looking at on task two, which is the metallurgical stress corrosion part, we are looking at crack arrest in residual stress, crack arrest in weld metals. In Grumingen, they stopped where the Argonne results showed the residual stresses go compressive. But they also stopped when they hit the weld metal, which we know is very resistant to cracking, especially at ferrite levels above 3 or 4 percent. So we are not really sure why they stopped, whether it's residual stress or weld metal or a combination of both.

Then we will do some full-scale pipe tests with predefected samples to confirm what the fracture mechanic specimens will show. That program is just starting.

(Slide.)

And last, internally funded program on Alloy 600, in

mte 11

which we are looking at three heats of 600 and three heats each of 82 and 182, the filler metals. We are looking at a bunch of different heat treatments that are of industrial significance as-welded. And LTS, again, a treatment to simulate long-term service exposure.

We are looking at, under normal water conditions except high oxygen, hopefully to accelerate the test program using constant-load crevice to non-crevice samples, not pipes.

Constant extension rate testing. We have eight constant extension rate machines, which are essentially very slow tensile tests in our environment. And so far, most of these tests we have done have not -- we have not gotten cracking on inconel. It is a very difficult material to get data on. Our constant extension rate testing, which forces the sample to fail, then you look and see if it was intergranular or trans-granular -- it does look like we have hit upon the right extension rate to get intergranular cracking and susceptible heats.

I might say, the susceptible heats -- one of seven heats we have looked at has shown susceptibility.

e-28

This you used in your piping sometimes?

MR. COWAN: Never in piping. We used it in safe ends and some core internal application. This is a program that is ongoing, but the results are still kind of preliminary and scattered. We are still waiting for results.

DR. SHEWMON: Some of those meditative people at your research labs try to decide why the other six didn't?

MR. COWAN: Not yet. That was just the result of the last month as a matter of fact.

DR. ZUDANS: I have one question. Didn't you say that when you did the sample and put it in the large strain, it lost its (inaudible)?

MR. COWAN: That is correct.

DR. ZUDANS: If you look at this strain diagram, it shouldn't.

MR. COWAN: I think -- why shouldn't it?

DR. ZUDANS: Because you would return on an elastic curve in the tensile zone and move on in the plastic zone, and then on the return you would prestress it higher.

DR. SHEWMON: Go out in the hall, please.

DR. ZUDANS: I just want to make him think about it.

DR. SHEWMON: Good.

Please come over here. Tell us what Combustion Engineering is doing for the safety of nuclear reactors?

MR. AYRES: I am supervisor of special analysis, plant

plant engineering at Combustion Engineering Power Systems.

This afternoon I would like to talk only about two reserach programs at Combustion which are related to materials and mechanics of metal components.

First, I will talk about our program on irradiation effects on reactor vessel materials and then I would like to bring you up to date on my favorite topic, which is our work toward development of pipe break criteria.

As a supplier of nuclear steam supply system components, CE maintains a developmental effort in the area of irradiation effects in reactor vessel materials to provide maximum assurance of the integrity of the reactor pressure vessel. Specific efforts in this area include reactor surveillance program design, irradiation effects, prediction and analysis, fabrication methods and materials monitoring, and participation in the development of industry standards.

First, I would like to talk about our low copper program. The low copper program is a cooperative research effort by NRC, Combustion Nickel Research Laboratories to assess the effective copper content on irradiation sensitivity of commercially produced reactor vessel plates and weld region materials.

The results of the program were described in NRL Report 1977. The intent of my presentation to day is review the program results with respect to their impact on reactor vessel design for irradiation effects.

In general, it was found that restricting residual copper to 1/10th percent or less results in a significant reduction in radiation sensitivity.

(Slide.)

The data from the tests normalize the fluents of 3×10^{19} are shown in these two slides. The first one, copper and phosphorus are weighted, the same way they are in Reg Guide 1.99. For plates, further reduction in copper content, below 1.1 percent, does not result in additional reduction in DT shift. This would support present practice of using .1 percnet or .08 percent copper as a lower bound for shift productions.

For welds.however, the trend of reduced shift with copper content continues below .1 percent.

Figure 2 here is the same plot, with the phosphorus term omitted. The same trends are apparent, indicating that inclusion of the phosphorus term is not necessary.

These figures also indicate that welds tend to be more resistant to radiation than plates for a given fluence, end copper content.

(Slide.)

DR. SHEWMON: Before you read that, Mr. Moore didn't tell us his eight elements. Do you know what comes next, or will we get into that some on your next slide?

MR. AYRES: We will get into that after a couple of slides.

DR. SHEWMON: All right.

MR. AYRES: This slide shows a comparison of the data in the low copper program, predicted shift versus the actual. And this is relative to Reg Guide 1.99 predictions, showing clearly the predictions are very conservative.

This curve shows the data compared to the Combustion design curve, Combustion predictions versus actual. Again, except for the very high nickel weld material, we have a lot of conservatism in the Combustion design curve.

DR. SHEWMON: The keeps of that Reg Guide are likely to be the people in DOR.

MR. AYRES: Okay.

DR. SHEWMON: Who do you have to convince if you are going to get somebody to give up a conservatism?

MR. AYRES: It would be DOR. It would be an operating plant concern.

DR. WECHSLER: Where is that error pointing to with the high nickel welds? You don't mean the line, do you?

MR. AYRES: That means this point and this point here (indicating).

MR. ETHERINGTON: What is "high nickel"?

MR. AYRES: "High nickel" is, in this case, .78 percent. A definition of "high nickel" is .5 percent and above.

A definition of "low nickel" is .2 percent or less. And between that is anybody's guess.

Both methods, Reg Guide 1.99 and the CE design curve, you have more conservative predictions for the low nickel weld materials than for the plates, highlighting the need to separate weld from plate predictive techniques.

Results of an earlier CE study demonstrated that weld metal predictive techniques could be improved by factoring in the full chemistry of the weld. And here comes the additional terms.

(Slide.)

This figure is a modified representation of the original weld model of Combustion. The chemistry ratio, which is this term right here, is multiplied by copper content and plotted against normalized and ET shift.

Using 47 documented weld data points, a series of commuterizations were developed for an optimum relationship, and the final results show a more complicated relationship that looks like this.

(Slide.)

Again, this thing in the brackets is what we call the chemistry ratio.

(Slide.)

Using this chemistry ratio, using all of the elements in the prediction, we show here a comparison of the predicted versus actual shifts. 80 percent of the predictions fall within 50 degrees Fahrenheit of the actual results. Most of the points outside this band are for fluences, 3.5 X 10^{19} or more, or are for experimental weld compositions.

Reg Guide 1.99 predictions are compared to weld data in the next figure.

(Slide.)

Despite the fact that the guide utilizes upper bound curves, it is apparent that the degree of scatter is significantly high than in the previous slide.

DR. ZUDANS: What is the significance of these in the previous slide, predicting zero? Actual goes as high as 50 degrees.

MR. AYRES: In this slide?

DR. ZUDANS: Yes. On the zero line.

All of those triangles on the horizontal abscissa line.

MR. AYRES: The significance of this (indicating)?

DR. ZUDANS: Right.

MR. AYRES: Those are abviously very low fluence data.

DR. ZUDANS: That is what that is, low fluence data?

MR. AYRES: It has to be. Yes, because it is a very low actual --

DR. ZUDANS: It is not of any particular interest.

DR. SHEWMON: They aren't all low fluence. Most of them have the order of 3 X 10^{19}. They are triangles.

DR. ZUDANS: You go up to actual 50 degrees shift, and your prediction would be zero.

MR. AYRES: That's what that says.

DR. WECHSLER: But if you look at the previous figure, Figure 6, you can see that all the samples with less than 1/10th for this chemistry ratio would permit zero shift, and those points that you are asking about apparently are of that type.

DR. ZUDANS: Yes. So you couldn't really make a statement that .1 percent is clear sailing; right?

DR. WECHSLER: They shift up to 50 degrees.

DR. ZUDANS: That's right.

DR. PENSE: 50 degrees is a small shift.

DR. CORTEN: Your dash line is up to 50 percent, plus or minus 50 degrees?

MR. AYRES: That is 50 degrees on the next one.

DR. ZUDANS: You are saying there is no unthinkable situation where 50 degrees would be critical in design?

MR. AYRES: We are not saying that. What we are trying to do is find a correlation, and we are trying to improve upon the Reg Guide.

Now, what we have when we compare -- we talk about the Reg Guide curve here -- we get a lot more scatter.

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DR. ZUDANS: But you don't have the situation of prediction exceeding less than actual.

MR. AYRES: We still have a few points, but these are for real high fluences.

MR. BENDER: Why is it important to improve on the Reg Guide.

MR. AYRES: Why is it important?

MR. BENDER: Yeah.

MR. AYRES: Well, because if the Reg Guide is very conservative, we would want to take advantage of more realistic shifts.

MR. BENDER: But if you didn't, what penalties would be incurred?

There is an inference here that conservatism has always been thought to be good if you don't have to pay anything for it. And so I would like to have a little better definition of what we are losing by accepting the present Reg Guide conservatism. I am not saying we should accept them, but it seems to me we are either going to lose life in the vessel, which could be of concern to you, or it could be that there is some inflexibility in the operation incurred by the Reg Guide. But what is your perception of it?

MR. AYRES: I think it is matter of operation. It is flexibility of operation, startup and shutdown rates, procedures. You have -- either you have with Reg Guide curves or with very conservative shifts -- you create very small operating windows near end of life.

DR. SHEMON: You have to guarantee, as a vendor, that the vesse. vill meet some 40-year life?

The reason I phrase it that way is it seems to me the Westinghouse people were particularly happy with this saturation effect because, as I recall, they said they were having to buy vessels overseas to get the copper contents down to what they wanted for guaranteeing a 40-year life on it.

MR. AYRES: I would not want to comment on a guarantee, but we also buy vessel material overseas.

DR. SHEWMON: Because?

MR. AYRES: Because it has the controlled element chemistry that we feel is necessary for the best vessels we can make.

DR. SHEWMON: Do you go east or west to get it, out of curiosity?

MR. AYRES: We go east presently.

DR. SHEWMON: The Japanese make better steel than we do in some regards. I was just curious to know whether it was the Japanese or the Europeans.

MR. AYRES: It is the Europeans.

DR. ZUDANS: East is Europeans. You see, the largest departure in this correlation is about the same -- your correlation are the Reg Guide. In one case, you predict 100, actual 200.

DR. SHEWMON: Interestingly enough, the bad ones -- they do a better job of predicting.

Let's get on, please.

MR. AYRES: Okay. Fine.

(Slide.)

Let me go very quickly.

So far I've talked about radiation effects on impact properties, reactor vessel plates and welds. Much of current concern is with welds for which initial upper shelf energy is below current requirements.

We are in the process, as Mr. Moore also said, of looking at flux-type welds. I am going to skip through this, trying to assess, for the different flux types, the effect on upper shelf energy and what the causes of that effect might be.

As an example, there are two different fluxes, of different chemistry. There is a difference in Charpy, upper shelf energy.

(Slide.)

To summarize our radiation program, I would say that currently available predictive techniques provide conservative estimates for RT energy shift. The radiation behavior of both plates and welds is primarily dependent on residual copper content.

The major alloy elements modify the effect of copper on weld metal radiation response. Weld chemistry can be tailored to optimize both initial toughness and radiation resistance. Weld metal flux combinations were found to influence the initial upper shelf energy of the weld deposit by alterations in the chemistry of the material, particularly in oxygen content, and by the number of nonmetallic inclusions produced and retained in the deposit.

The weld flux combinations were also found to influence the irradiation response of the weld deposit by alterations in the chemistry of the material.

But for new plants, current specifications for high initial shelf energy and for low residual copper content should assure adequate resistance to neutron irradiation, making the effects of the flux type insignificant.

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I would like to move on to something that I know something about, and that is our work on what we call research for the rationalization of nuclear power plant pipe break criteria.

(Slide.)

Nuclear power plants are designed to withstand hypothetical loadings which are intended to conservatively envelope all possible accident conditions. Usually these loadings become associated with some initiating event which is judged to be more severe than any realistic event.

A hypothetical primary system pipe break is one of these initiating events which forms the design basis for many systems and components of a PWR. The present pipe break criteria are based on the most severe consequence of a hypothetical pipe break, but do not consider realistic mechanisms which might cause a possible loss of piping integrity.

For example, consider the double-ended or guillotine pipe break. This type of hypothetical break evolved from the design basis, because conservative loadings on the nuclear steam supply system result. The design of the pipe includes a demonstration that no loadings, including safe shutdown earthquake, can cause a loss of integrity of an intact system.

Perhaps, however, there is still concern that undetected and growing pipe break subject to severe loadings could lead to a pipe break. In previous presentations, we have discussed the results of analysis of cracks in pipes subject to pressure only. Those results have indicated that circumferential cracks must exist more than halfway around the pipe before they can lead to rupture of the pipe.

Similar analyses have now been performed for combined pressure and seismic loadings to determine the likelihood of a safe shutdown earthquake, causing pipe break. The analysis of cracks in pipes subject to pressure -- the pipes were considered to be free from constraint by other pipes or components, for conservative evaluation. That means we just looked at a piece of pipe free in space and cut a hypothetical crack in it, and watched it pop open.

In order to consider the response to the seismic loading, a fairly complete structural model must be used. This gives you a feeling for the kind of model we are talking about. These slides show the Combustion System 80 nuclear steam supply system arrangement, illustrating a region which is modeled for the analysis of a crack at the inlet nozzle to pipe weld.

The proper dynamic response of the pipe could only be obtained when the model extended from the bottom of the reactor vessel support columns to the end of the pump supports.

I have some more views of this, in talking about the model.

(Slide.)

Here is another view like that.

(Slide.)

And finally, in detail, we are talking about looking --

DR. SHEWMON: What do these laser beams represent?

MR. AYRES: These are the bloodlines of the System 80 reactor. This is a finite element model. This shows you from whence it comes. And this is the detailed model in the region where we are going to consider a crack.

We tried all kinds of ways to look at a small region of seismic loadings. There is no way we could make sense out of it until we got all the way out to where the seismic comes into the system.

DR. CORTEN: Each red line is an element?

MR. AYRES: Each red line is a series of elements. These are beam-type elements. They're traditionally used in a seismic analysis. And in this region we have shell elements (Indicating).

For this example, the crack was assumed to occur on the outside of the bend, which would allow greater opening area due to the motion of the pipe. And in this slide we show what we mean.

(Slide.)

We exaggerate the opening of the crack. But if we look down on the pipe -- and this is the nozzle right there (Indicating) -- that is the crack that we would see.

mte 4

DR. ZUDANS: In this model you go all the way around the circumference?

MR. AYRES: These are curved elements.

DR. ZUDANS: Curved elements, but all around the pipe.

MR. AYRES: They are all around the pipe. We are looking down here. If we looked into the end, we would see the whole ring.

DR. SHEWMON: It is a longitudinal crack.

MR. AYRES: This is a circumferential crack. This is the pipe elbow. The nozzle is here. And this is in the weld. It is a through-the-wall crack and it is halfway around, and it is on the outside, outside of the bend.

The seismic ground motion spectrum applied to the model is shown in the next figure here.

(Slide.)

The resultant loading is conservative compared to the most severe loading for any System 80 plant. The accelerations which are associated with this kind of a spectrum have velocities in inches per second, and we have ground motions, and that is in inches.

(Slide.)

That is the way they come out of the conservative loading condition.

DR. SHEWMON: Is the damping of the structural elements -- does that enter into this calculation? If they

mte 5

were bigger, would that make any real difference?

MR. AYRES: We have a very slight amount of damping in this model. It is a fraction of one percent.

DR. SHEWMON: You mean that is what you have put in?

MR. AYRES: We have put in.

DR. SHEWMON: If it were 10 percent, would it help you materially, instead of half a percent?

MR. AYRES: Yes.

DR. ZUDANS: Too short of a time for it.

MR. AYRES: More damping would retard the oscillation.

DR. ZUDANS: The time history doesn't extend to any significant length. You probably wouldn't see the difference.

MR. AYRES: Our objective -- actually, these accelerations in velocities and displacements are constructed from a program that was written by Kraftwerkunion in Germany. It is what we call an artificial earthquake, to compress the significant events to very short time, because we are going to do a time history analysis and we want to take small time steps, so we see short-term events. And we want to be able to afford to do it and do it within a reasonable amount of time.

DR. ZUDANS: But if you lower the frequencies of the system and take much longer periods than what you do in the histories, then you really don't see the worst points.

MR. AYRES: Well, yes. Our lowest frequencies we calculate are about 16 to 17 cycles per second, and we are taking the loading out here with doing time history beyond one second.

DR. ZUDANS: All right.

MR. AYRES: The initial condition for our event of consideration is the pipe sitting there statically, subject to operating pressure. The pipe was considered to be uncracked at the beginning of the vent, and a circumferential crack is prescribed, presumed to initiate at a critical point during the seismic event. We presume that the maximum strain during the seismic event would occur shortly after the acceleration peak.

On this basis, the large time step of a tenth of a second was chosen for the early portion of the dynamic analysis. Direct integration of the dynamic equation was performed according to Newmark data method and a small amount of damping was used.

From the time history plot of the acceleration, which got buried in here somewhere, it is apparent that a peak does exist near one second. If the frequency of interest is on the order of 16 to 17 cycles, as I mentioned before, smaller time sets must be used to sort out the events that are going on at this time. For this reason, a smaller time step was introduced as we approached nine-tenths of a second, while the pipe remained uncracked.

(Slide.)

This figure shows the response curve of velocity time history at the midpoint of the discharge leg, that is, halfway between the reactor vessel and the pump. We see here we have taken very large time steps to get us up to near where the peak is going to occur, and at this point we start using smaller time steps, and we are picking up the events in that basic frequency at the pipe.

The one-half circumference crack at the inlet nozzle weld was placed in the model at .99 seconds. The dynamic behavior of the pipe with the crack was stressed with small time steps, to determine the maximum pipe opening. Local plasticity effects were included.

The intensity values were calculated using displacement methods at each time step. The analysis was continued for a sufficient number of time steps to determine the total extent of crack opening and the maximum stress intensity at the crack tip due to combined pressure and seismic loadings.

For comparison of the seismic velocities, the plot of the velocity time history at the base of the reactor vessel support column is shown in this figure here.

(Slide.)

This is the velocity versus time again, at the reactor vessel supports. The analysis was carried out to a total time of about 1.2 seconds, well past the peak in the velocity curve. Similar velocity-time history at the midpoint

mte 8

of discharge leg is given in the next slide, and this is one for the crack.

(Slide.)

Here we see again the smooth -- taking large time steps to get up to the time of concern. We start with a small time step at this point, and here we initiate the crack. Now there are some very interesting observations here. I don't know if I can show them together. Let's try.

Can't do it.

(Pause.)

A noticeable difference in the velocity profile occurs at the point of the crack opening. The change is apparent both in magnitude and frequency. In comparison with the uncracked velocity-time history, it indicates that the peak velocity is reduced due to the incidence of the crack. This indicates the reduction in the kinetic energy of the pipe resulting from a change in stiffness. In effect, energy in the pipe is lost or released due to the crack opening and the response of the pipe with the crack is substantially different due to the change in the stiffness of the system.

The crack opening effects can be described in terms of stress intensity factor --

DR. ZUDANS: Why do you say substantially different?

MR. AYRES: I think it is a very different thing going on between these two things.

DR. ZUDANS: You are talking about a 10 percent change in velocity.

MR. AYRES: This is remote from the crack. This is bouncing around here, and this is really quite dulled, which shows there is a fairly significant change happened here, and it is a change that says the crack has made things go away.

DR. ZUDANS: I have a question. I think I had the same question last time, a year ago. I'm sorry.

When you release the crack, what did you do with the stresses that existed because the pipe was pressurized? Are those in any way considered as a step change at that point, applied through the walls in opposite directions to the previous state of stress? Or you simply separated the elements and still retained the surface pressures on the elements as they were before?

MR. AYRES: We separated the elements.

DR. ZUDANS: You do that?

MR. AYRES: We just separate the elements.

DR. ZUDANS: And you do not apply anything on the boundary?

MR. AYRES: We do not apply anything on the boundary.

DR. ZUDANS: And you retain the surfaces, the pressures as they were before?

MR. AYRES: The surface pressures are the same as they were before.

DR. ZUDANS: So you actually are not doing -- well, I have to phrase it carefully. You are not doing the real thing.

MR. AYRES: I think I'm doing the real thing, and I think this is where we ended up last year.

DR. ZUDANS: What about your pressure when you start to merge? You separate the large stresses along that axis that no longer existed.

MR. AYRES: If we looked at that, if we just had a bar and we separated that, that bar -- those two parts that were left would zip apart because of the stresses that were in them.

DR. ZUDANS: That is correct.

MR. AYRES: The same thing would happen here. The two surfaces are being pulled apart.

DR. ZUDANS: But your model doesn't show that.

MR. AYRES: Certainly.

DR. ZUDANS: And you i not answer my question.

MR. AYRES: Okay, try me again.

DR. ZUDANS: Initially, before you separate the crack element, you have internal pressure in the pipe.

MR. AYRES: Yes.

DR. ZUDANS: As it exists under normal operation.

MR. AYRES: Yes.

DR. ZUDANS: Which induced axial stresses,

nte 11

circumferential stresses. And now you perform the cut and you separated the stress. There is something on the surface there to remove, to be consistent with the previous model. It means that you had to apply residual stresses to cancel the pressure stresses that would be generated in the system. You have to have a stress surface, even if you left out --

MR. AYRES: I immediately have that stress-free surface developed in time, in my model.

DR. ZUDANS: You lose the instantaneous step load.

DR. SHEWMON: Answer if you have an answer. And after that I would like to make a comment.

Our primary purpose here is to try to see how the work you are doing interacts with the work that the regulatory people are doing or should be doing. This is interesting, but I am not sure it is germane to that. If you would bring it back or show me where it is --

e-30

547 113

MR. AYRES: I am almost done and I can do that.

DR. ZUDANS: The objective of this study, of this work, was to show it is not realistic to assume complete break.

DR. SHEWMON: I would agree with him but I am not sure that that is the primary purpose --

DR. ZUDANS: I could not say that I disagree with the ultimate objective.

DR. SHEWMON: Fine.

MR. AYRES: Okay. What we calculate also in our model is stress intensity factors as a function of time after the crack break.

And what we find here is that the stress intensity factor, or the likelihood of crack extension is less in this model with pressure and seismic than it is with the model isolated from the system with just pressure, because the system cannot respond. The crack cannot open.

We show also very small crack opening areas. The crack opening, the widest crack opening is on the order of 500ths of an inch due to the safe shutdown earthquake, plus the pressure --

MR. BENDER: You are saying that the crack is small enough so that there are no reaction loads from the fluid system due to leakage through the crack.

MR. AYRES: Well, reaction loads from the fluid

gsh

system I believe would tend to cause the crack.

MR. BENDER: Not if they are leaking out of them.

MR. AYRES: If there is a thrust force --

MR. BENDER: I don't understand what is happening.

DR. ZUDANS: It doesn't stay steady. It goes back and bounces back again.

MR. AYRES: It is a very small crack.

DR. SHEWMON: If it goes out to open up, then the reactive force is to push it back, which closes it up again.

MR. BENDER: It will help, but --

MR. AYRES: There is also --

MR. BENDER: I think if you look at the energy balance, you would have to conclude that it is not going to come all the way.

DR. CORTEN: What is the value of K when you have just internal pressure?

MR. AYRES: The static value comes out to be about 92. It is the seismic plus pressure outside the static value.

The value we would get in a dynamic opening of a crack of a small piece of pipe turns out to be about twice that because the pipe can really respond to such a very short time event, where this thing is connected to pumps and reactor vessels and long pipes. It just can't move out of the way.

MR. BENDER: How are you dealing with the energy absorption by the pipe just due to its fluctuation? Is that being treated as a damping effect because you're obviously, if it is doing what you are saying it is doing, it is way beyond its yield point in some places.

MR. AYRES: Oh, no. No, it's not. Only at the very tip of the crack. Only a very small region near the tip of the crack is beyond yield.

DR. CORTEN: We are having trouble with your model. You are raising a big question. Shouldn't we look at something more realistic than double-ended pipe break? I think that we would agree with you completely.

MR. AYRES: From this work, we believe that it can be concluded that circumferential cracks must be larger than halfway around the circumference before the effects of pressure and safe shutdown earthquake would cause rapid crack extension.

Pre-service and in-service inspections assure that large flaws do not exist in the primary piping weld regions. It is clear that a circumference flaw could not exist, and therefore, an SSE cannot cause a guillotine-type break at the nozzle to pipe weld.

Further work is continuing to demonstrate that seismic loading cannot cause a guillotine in the middle of the pipe. That is halfway between the pump and reactor vessel, where you don't have so much restraint from the components.

While the short-term results of this effort may be the elimination of the requirement to combine seismic and pipe rupture loads, our ultimate goal is to eliminate the need to consider the guillotine pipe break.

This can lead to improved piping system designs by eliminating or reducing the number of snubbers pipe restraints and improving access for in-service inspections.

We shall continue to work toward the goal of developing pipe break criteria as a result of safer and more reliable primary piping systems. This is the way we are going and this is what we think is our interaction with the Reg Guides already in process.

DR. SHEWMON: You have heard the story about the guy that bought the mule that had to be treated with tender loving care. You whispered in his ear. And finally, the neighbor came to show him how that really worked. He took a 2 by 4 and whacked him first and then he whispered in the mule's ear.

The main thing, I guess, with that abbreviated story is do you think you have a 2 by 4 that would help you get Noonan's attention, or the NRC to give up the conservatism, something which they do, are very loathe to do?

MR. AYRES: We think it is worth it to keep trying.

DR. ZUDANS: If I may comment briefly, let's not discuss the model any more because it is boring. But my comment is briefly, I think it would be easier to go in steps.

First of all, it wouldn't be too difficult to convince them because physical constraints -- presently in the system, there is no instantaneous opening. That is one thing. It would be more difficult to convince them to eliminate this kind of hypothetical accident because this is a lot larger in concept than just the capability to prove whether or not it may happen.

And your analysis, I would say there is no exception on my part for the model that you choose. The result is constraint for other components. But without thermal hydraulics' interaction with the structure, it cannot really prove the point.

MR. AYRES: I think that the amount of depressurization of cracks of this size is very insignificant. There is not a depressurization. We have assumed it keeps there at full pressure. This is a conservatism.

DR. ZUDANS: You would have a periodic load due to reduction in release of the flow through the crack as it opens and closes because of dynamic response, not static. It wouldn't take the hydraulic reaction and keep it there. It would come back.

MR. AYRES: The crack opening area that we calculate here is about two square inches.

DR. ZUDANS: Not much.

DR. CORTEN: What difference would this make, the differences in the design situation?

How significant would these differences be?

MR. AYRES: We have a man with the response.

MR. NATAN: It will just take me a couple of minutes. I just want to point out what it is that we do today and what are some of the things that we do — look like. Not because we want to. But this is the requirements, where they lead us.

First, the requirement to postulate pipe breaks, which has been relaxed significantly lately. It used to be breaks everywhere and now it is a limited number of breaks.

However, as part of the limited number of breaks, we have guillotines at at least several sections. Here at this nozzle, at the pump section nozzle, the steam generator nozzle, and the break in between, which causes — in order to minimize flow out of the break being a full guillotine, we have to stop the pipe somehow.

It used to be that we designed pipe whip restraints to prevent the broken pipe from damaging other pieces of equipment. Now we design pipe whip restraints to minimize flow area.

So that, number one, you don't build up excessive subcompartment pressures in the reactor cavity, the steam generator cavity. And number two, you don't build up excessive internal symmetric loads inside the reactor vessel.

The purpose of the pipe with restraint is to stop

547 124

the pipe and limit the flow area.

(Slide.)

One of the first things that we looked at is suppose we just put a flat plate on the end of the pipe and we put it very close to the pipe, like a half inch away. We said that will stop the pipe. And sure enough, if you consider only the stiffness of the pipe with restraint, which you can make as stiff as you want, you can do that very easily.

However, you are trying to grab the pipe at the bottom or on the side. And it has relatively little strength in that area. And if you include the flexibility of the pipe, you will find that, yes, you have stopped the end of the pipe. It isn't moving, but the center line is.

And that opens up the flow area on the other side of the pipe, which is what you are trying to stop.

Well, you would think that you have this kind of stiffness available. You really only have that kind of stiffness. And we did our analysis by applying the load to this k d of model, applying it to a region up at the top and finding out what happens.

(Slide.)

We considered both a saddle and a flat plate. This is the comparison. If you grab a pipe where it has some strength at the side, you get this kind of a load deflection

547 125

curve. If you put a flat plate under the pipe, you are just going to collapse the pipe. You are not going to stop it. So, okay --

(Slide.)

What kinds of things do we do, then? We put saddles on the pipes.

(Slide.)

We p t close fitting, closely machined saddles, very small gaps, perhaps a half inch, pre in-service inspect during system heat up and make sure that the gap is maintained between this saddle and that pipe.

This picture doesn't do it justice. We are talking about something that weighs a couple of tons.

Now field directions being what they are, some days somebody is going to put one too close and he's going to limit the thermal expansion. That worries me a lot more than having the guillotine break. I think limiting thermal expansion by not allowing this thing to move where it wants to move is far worse than, in the probability sense, if you are going to limit it, then the postulation of a pipe break.

DR. CORTEN: Far worse? In what sense?

MR. NATAN: If you are going to limit the expansion, you are going to cause a failure somewhere. Maybe a rupture to pressure bender. It may be a failure to a support. It may be something else. You are going to fail something. You are

gsh

not going to stop the system.

This is a system with 30 and 42 inch pipe, three and four inches thick, massive supports that are there for these breaks.

We are not going to stop the system. You are going to break something. You can cave in the pipe. You will do something.

DR. ZUDANS: That is for sure.

MR. NATAN: The other thing is — I don't want to talk about money, design effort, or anything else.

One of the problems with this kind of a system is in-service inspection. It is very easy in the steam generator compartment, very easy saying you pull up a crane, you pull one of these out, you inspect the weld and everything is okay.

In the reactor cavity, you are not going to send anybody in there to do that kind of inspection. The radiation levels are too high. So what do we do?

(Slide.)

We weld a lug to the pipe. Now this is a lot cleaner interface than having a saddle. It accomplishes the same thing as the saddle does. It puts the load into the pipe where the pipe is the strongest rather than here. It gives a nice clean interface, very well controlled.

But we have added a weld to the pressure boundary.

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That is what we lose.

We have added a significant amount of metal. We have increased the stress field around the pipe, done something which we would not normally do if somebody told you you would like to do this.

For operation, you would say that you are crazy, you don't want to do that. What is the purpose of this lug? What does it do?

I must say we don't use these for seismic restraints They are not used. The gaps are kept large enough, at least on paper, verify that during the seismic events, this piece doesn't touch that piece.

What is done in the field, what kind of reliability you can have in the field when these things are installed, that is another matter.

MR. BENDER: You are saying they are not used for seismic restraints. They are used primarily to restrain the pipe against the double ended break.

MR. NATAN: That is to restrain this pipe from breaking it, the nozzle, for the full double ended break.

I wouldn't need that piece if the break didn't run all the way through.

MR. BENDER: We understand your point well enough.

MR. NATAN: Thank you.

MR. BENDER: Thanks very much.

DR. ZUDANS: You have the concrete carrier serving the same purpose.

MR. NATAN: If you hit the pipe with a concrete gravity, you are going to collapse it. You will collapse the pipe.

MR. BENDER: The hour is getting late, and I think Dr. Shewmon mentioned once that there is a lot of room in the hall for discussions.

I would like to ask our consultants if they have any immediate things that they would like to bring up on this subject?

DR. BERRY: Nothing at this time.

DR. CORTEN: No. We are going to be here tomorrow?

MR. BENDER: Right.

DR. PENSE: Nothing here.

DR. MOTEFF: Nothing.

DR. ZUDANS: I have said too much already.

MR. PENSE: We are going to talk about this tomorrow.

MR. BENDER: Dr. Shewmon suggested if you could take the time to write down a few thoughts that could be discussed tomorrow or not as you see fit, it would be helpful. He plans to allow some time tomorrow to try to get reactions. And even to the extent of turning off questions from people.

I think he plans to have some kind of summation of the reactions to the program of NRC's research activities,

gsh

and hopefully, you will be able to contribute to it in any way that you think is constructive.

If there are no other points, this meeting is adjourned until the starting time tomorrow morning.

(Whereupon, at 7:08 p.m., the hearing adjourned, to reconvene at 8:30 a.m., Wednesday, July 11, 1979.)

T-29 through 31

COMBUSTION ENGINEERING INC.

RESEARCH PROGRAMS

IN

MECHANICS AND MATERIALS

Presented to

ACRS Metal Component Subcommittee

July 10, 1979

547 131

FIGURE 1

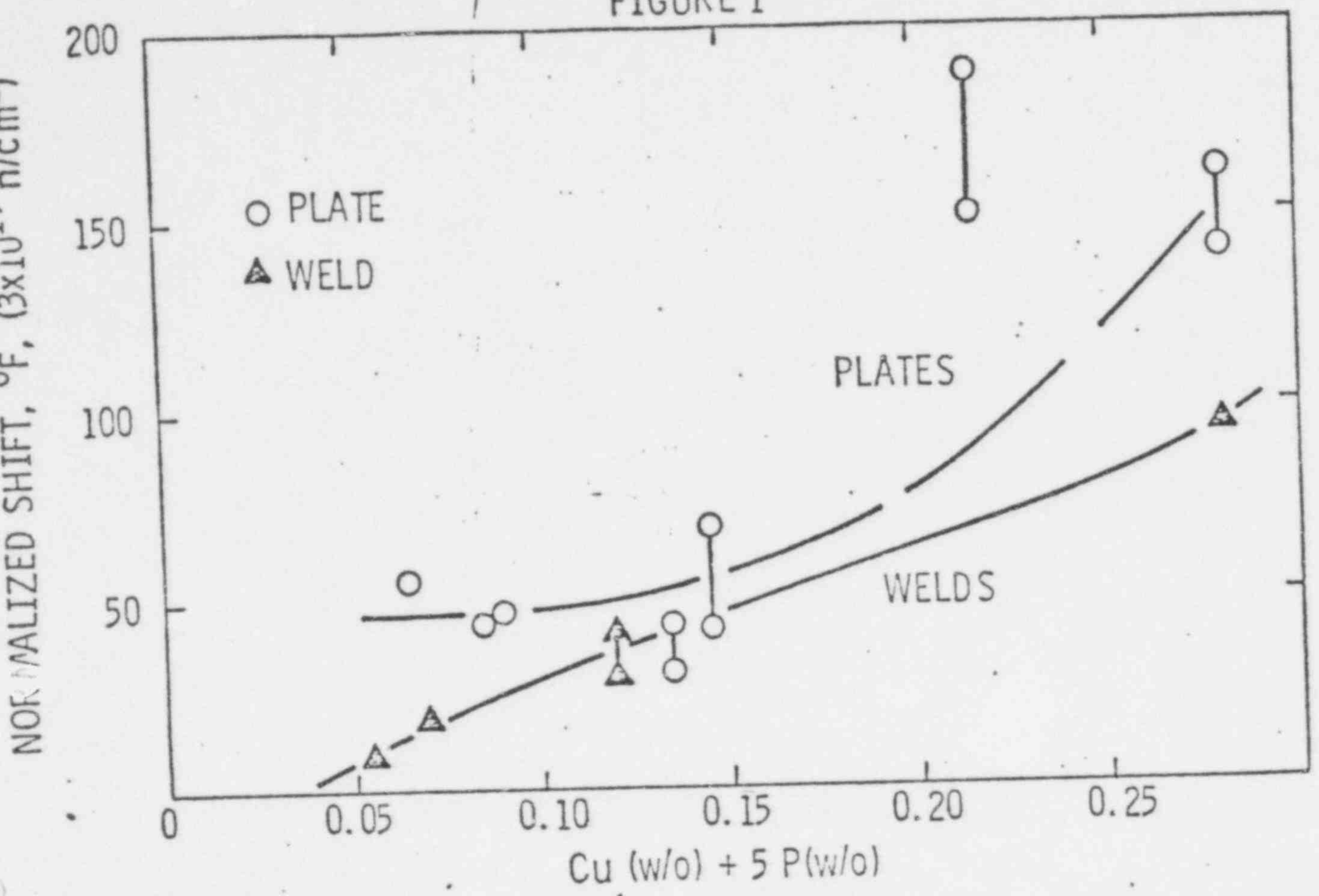
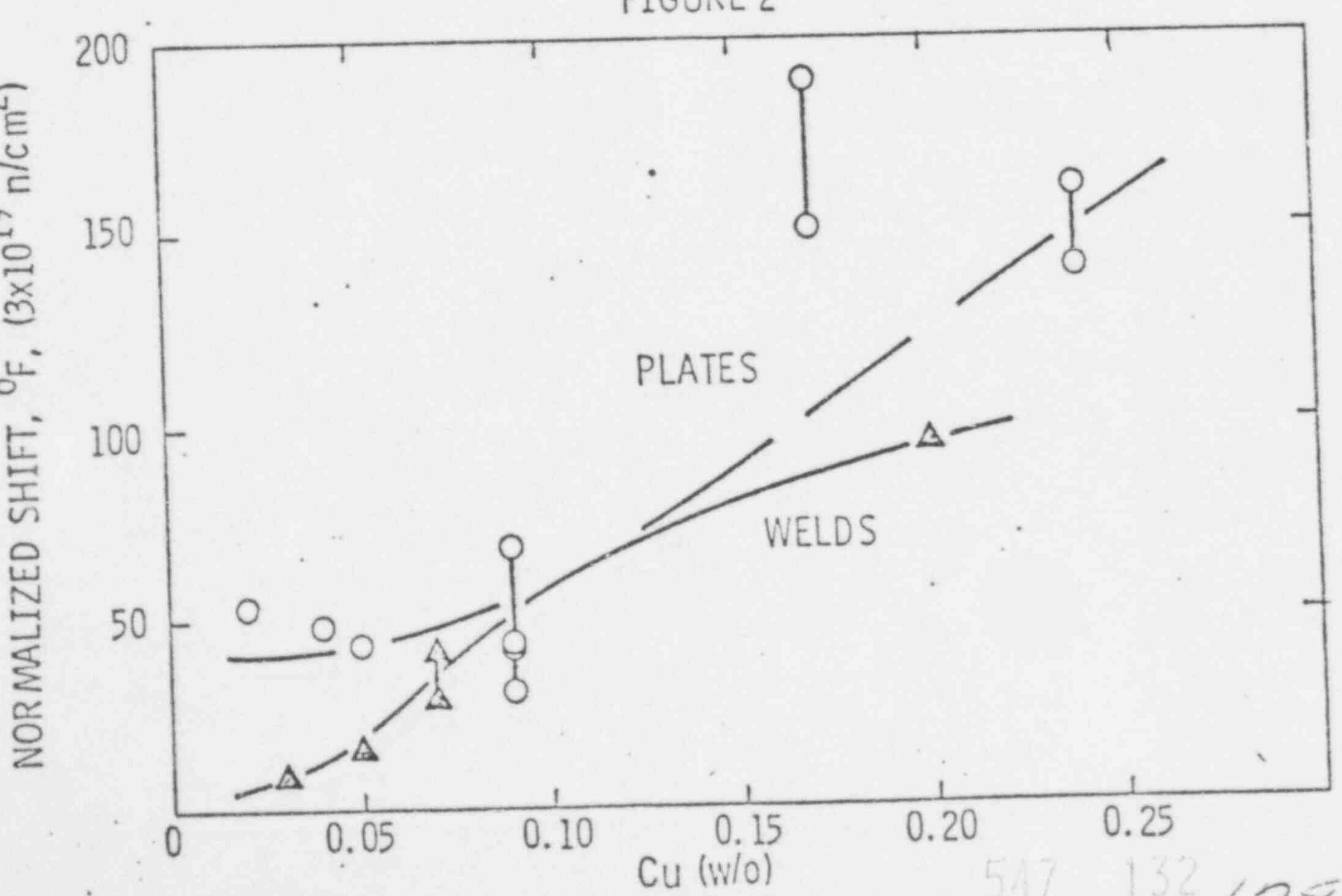


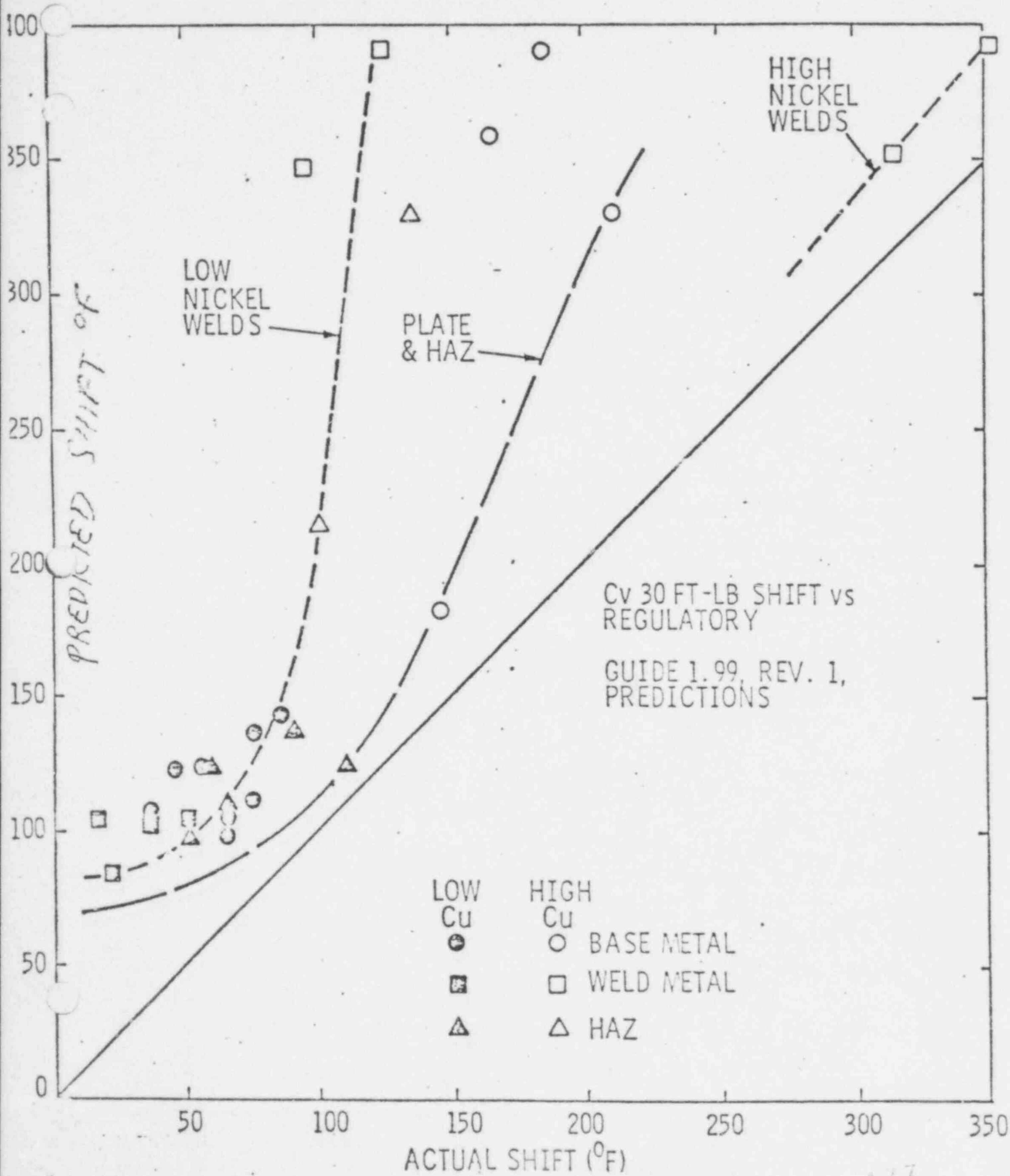
FIGURE 2



547 132

178

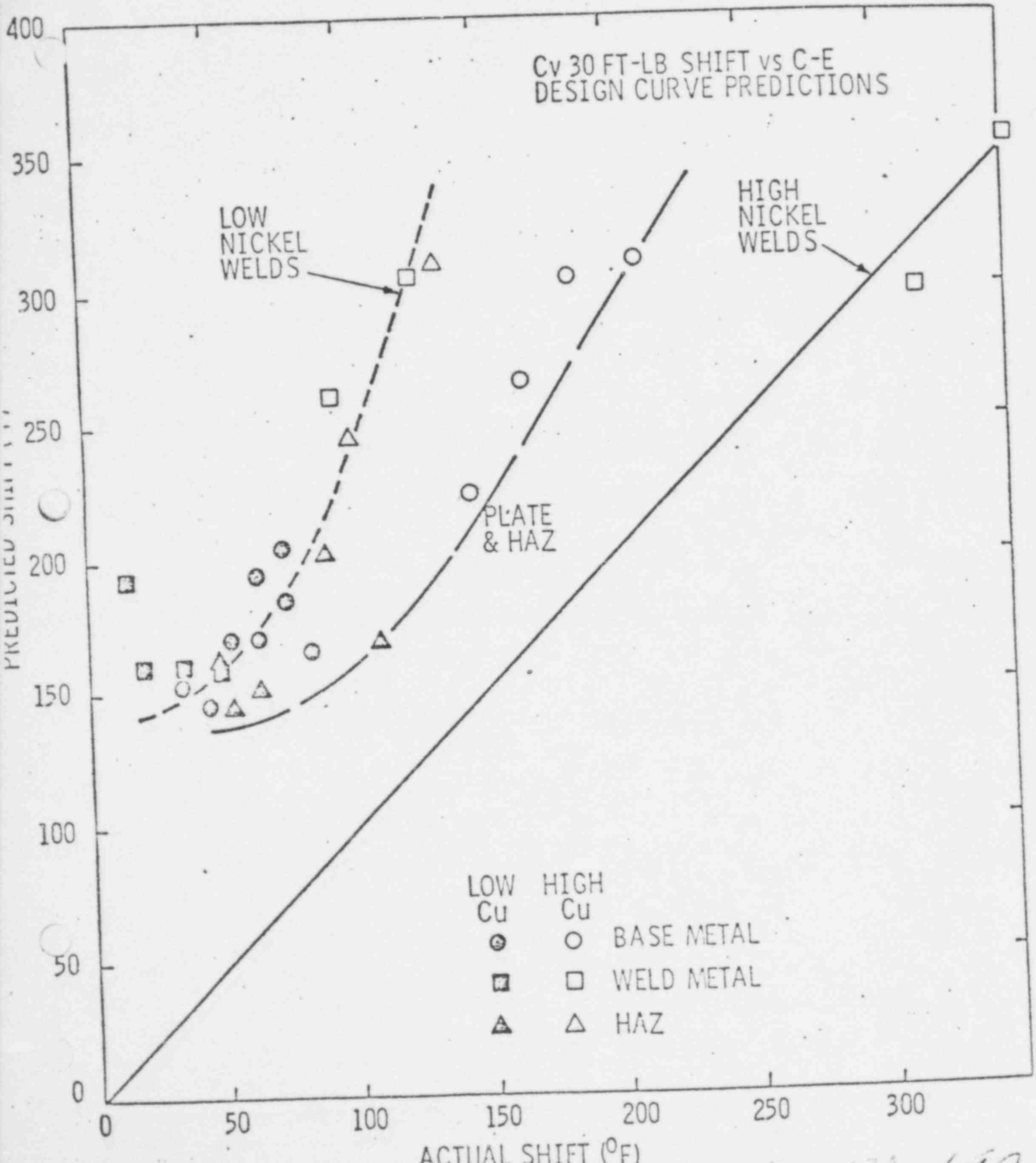
FIGURE 3



547 133

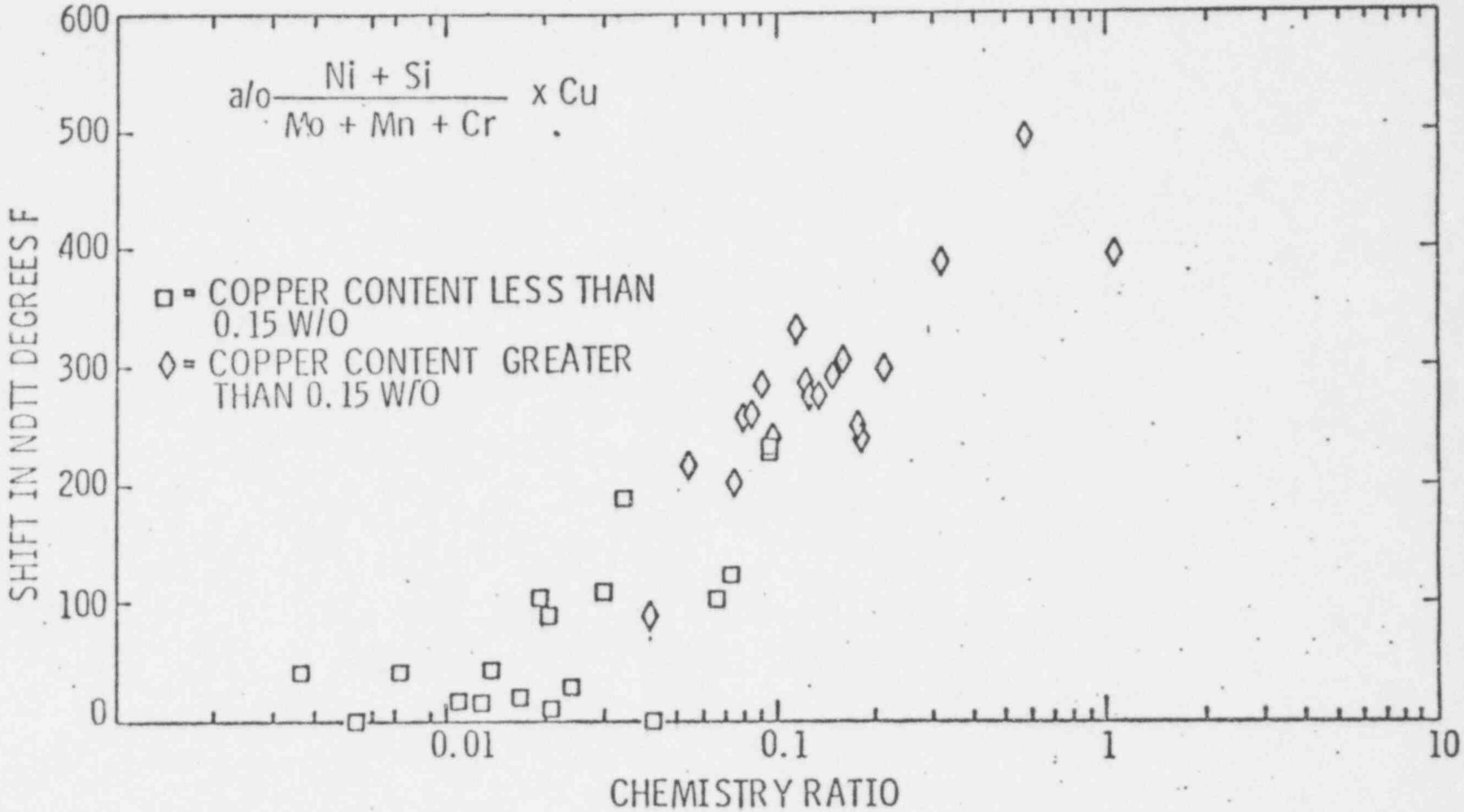
179

FIGURE 4



547 134 180

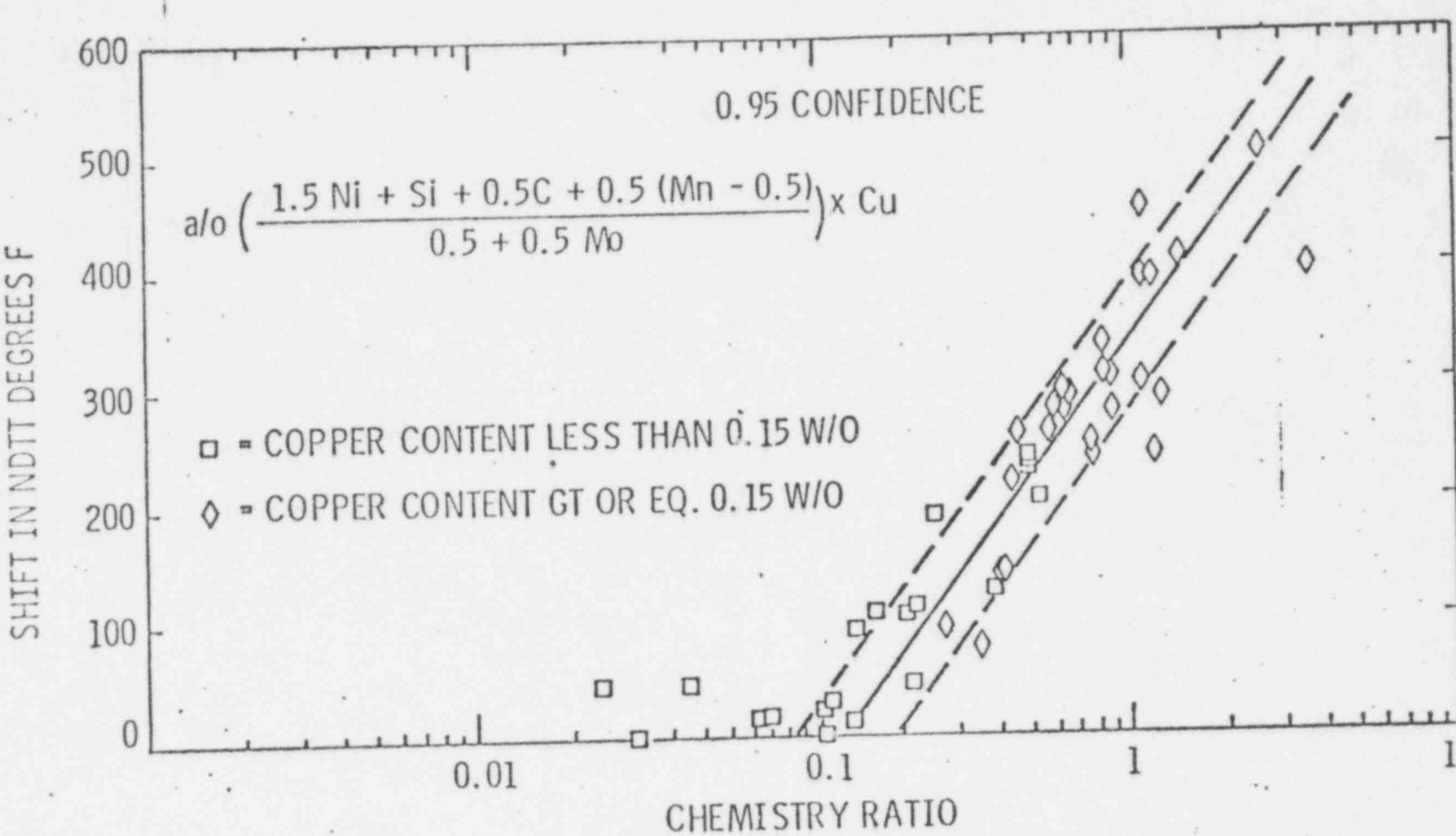
FIGURE 5
INCREASE IN NDTT AS A FUNCTION OF CHEMISTRY



547 135

FIGURE 6

INCREASE IN NDTT AS A FUNCTION OF CHEMISTRY



547 136

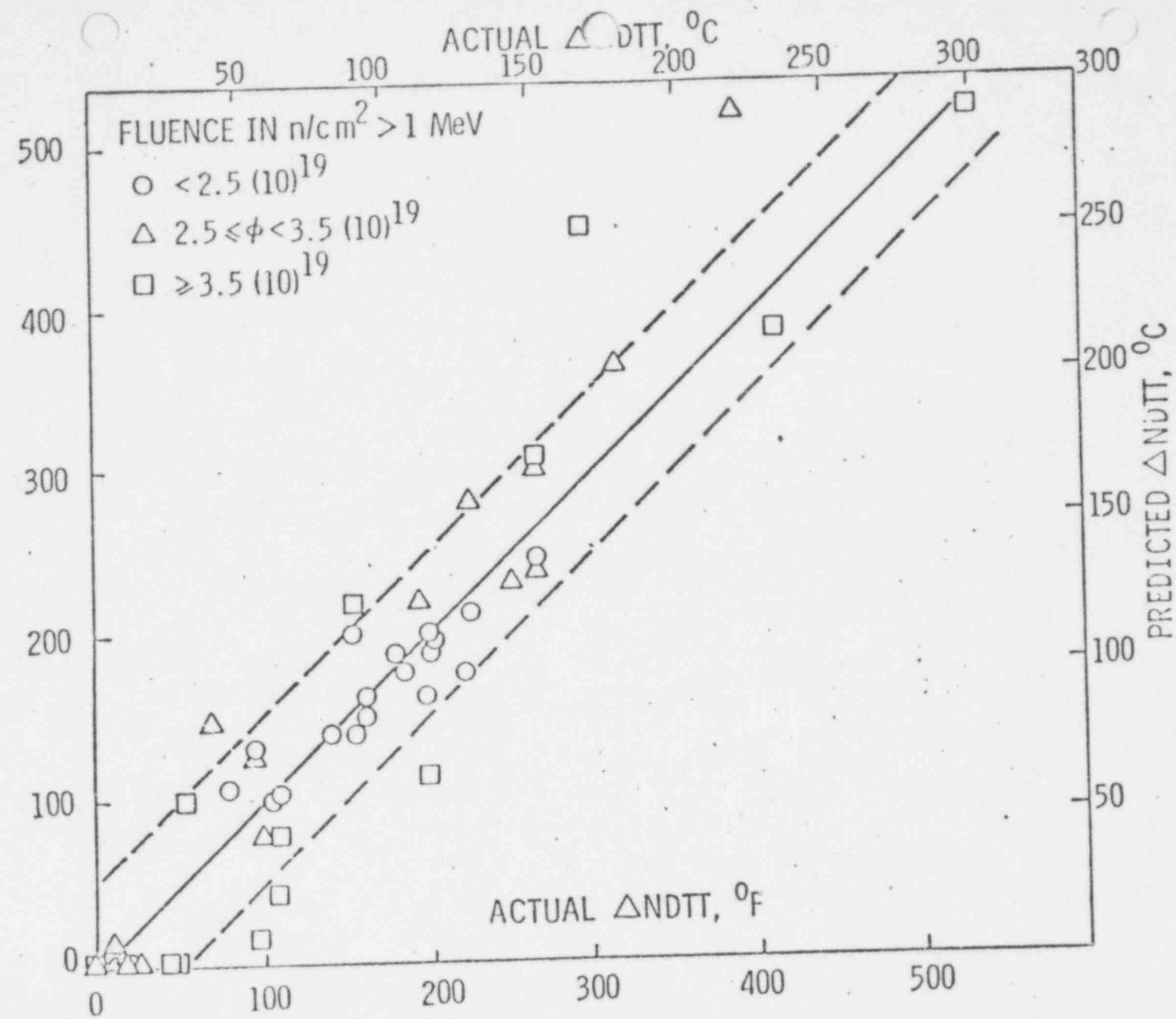


FIGURE 7

567 137

PREDICTED vs ACTUAL SHIFT IN NDTT - REGULATORY GUIDE 1.99

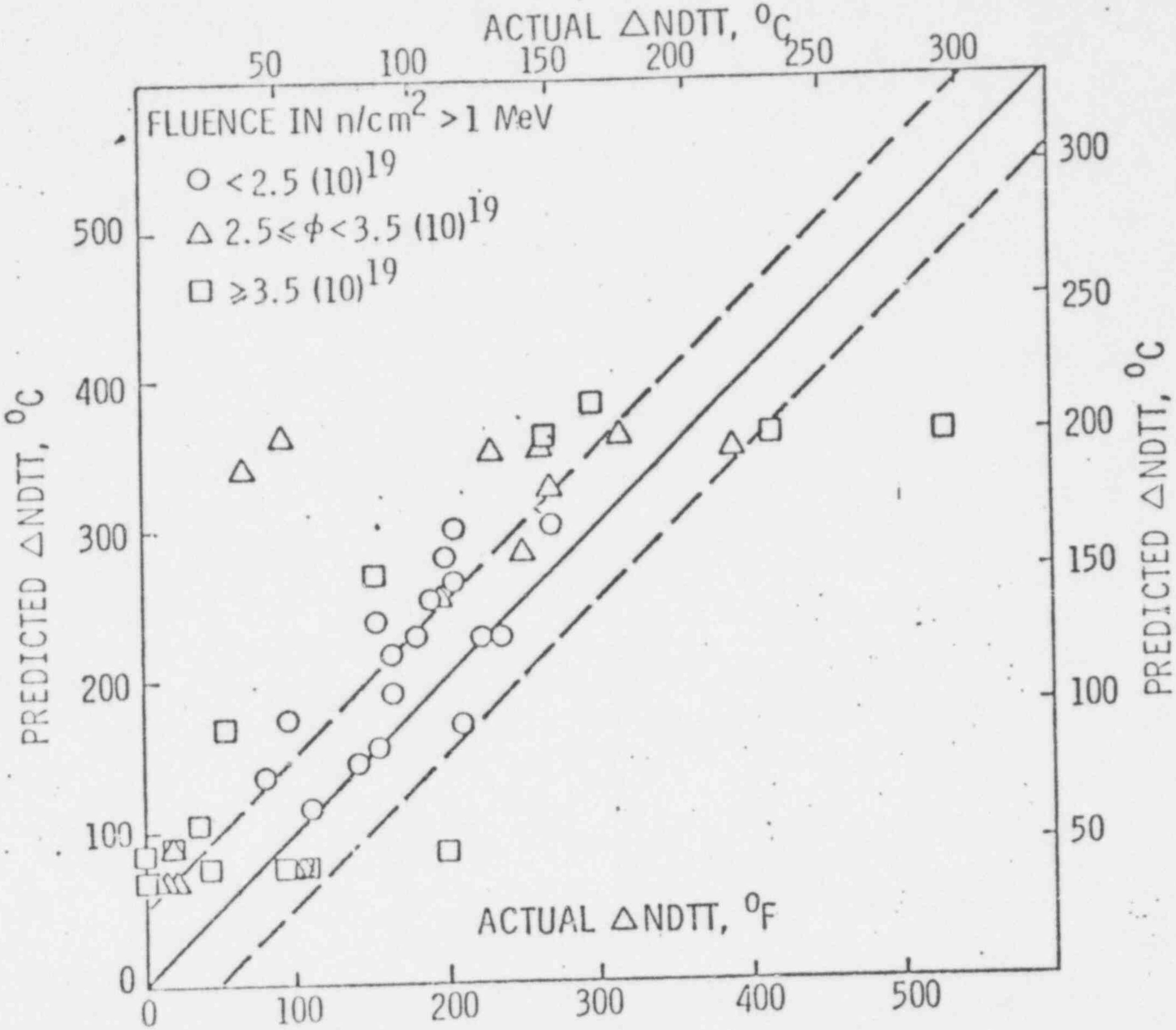
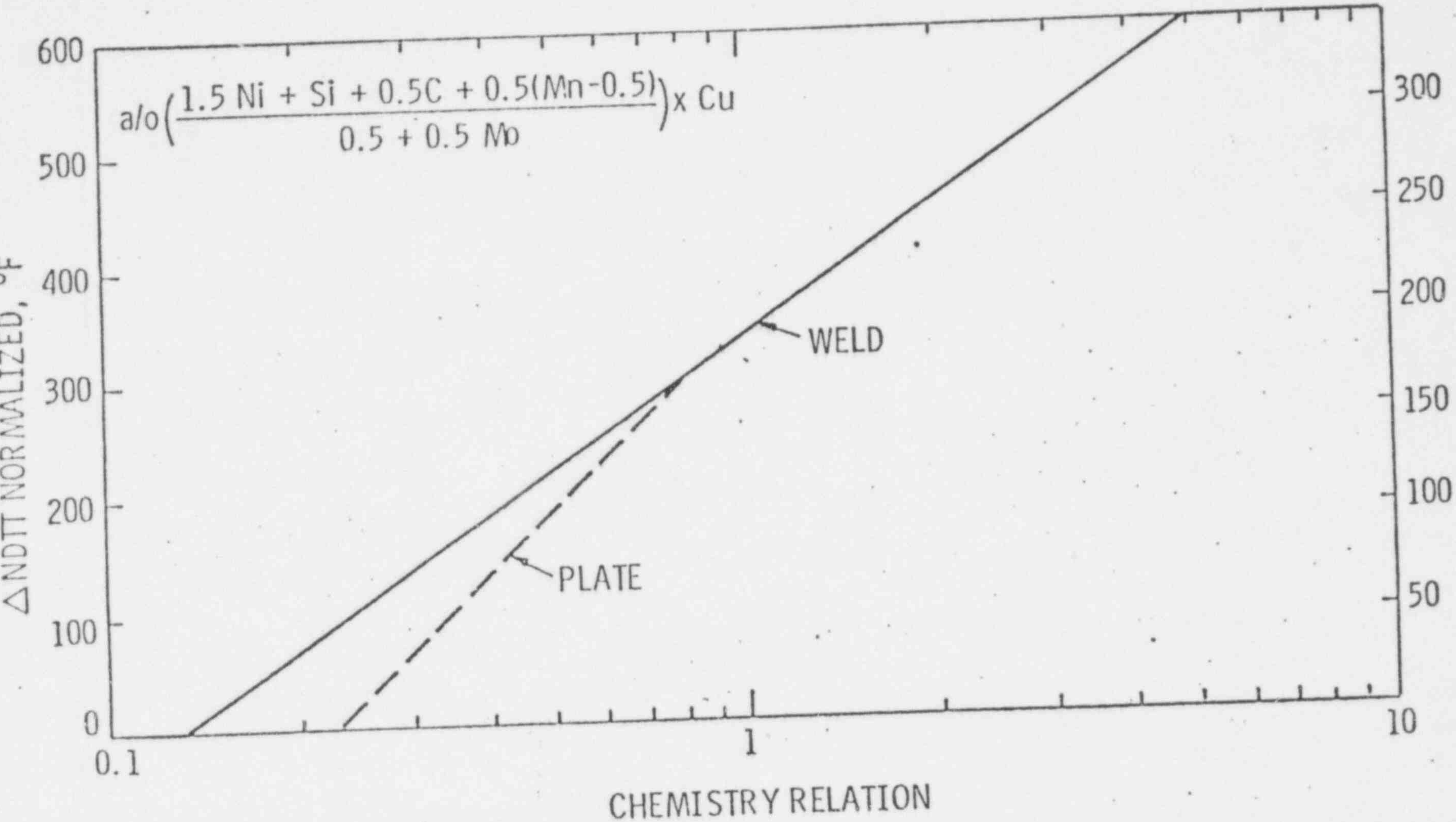


FIGURE 8

FIGURE 9

LEAST SQUARES FIT FOR WELD AND PLATE MATERIAL



547 139

TABLE 1

XPECTED TECT OF FLUX TYPE ON AS-DEPOSITED WE PROPERTIES USING THE SAME WELD WIRE*

Linde Flux Type	Flux Basicity Ratio (CaO/SiO_2)	Initial Charpy Upper Shelf Energy	Weld Metal Content: Oxygen	Non-Metallic Inclusions	Silicon	Managanese	Sulfur	Phosphorou
0091	High	High	Low	Low	Low	Low	Low	Low
1092**	↑	↑	↓	↓	↓	↓	↓	↓
124	↑	↑	↓	↓	↓	↓	↓	↓
80	Low	Low	High	High	High	High	High	High

*Arrows indicate increasing amounts

**Discontinued by Linde (replaced by 709-5 DC only)

547 140

TABLE 2

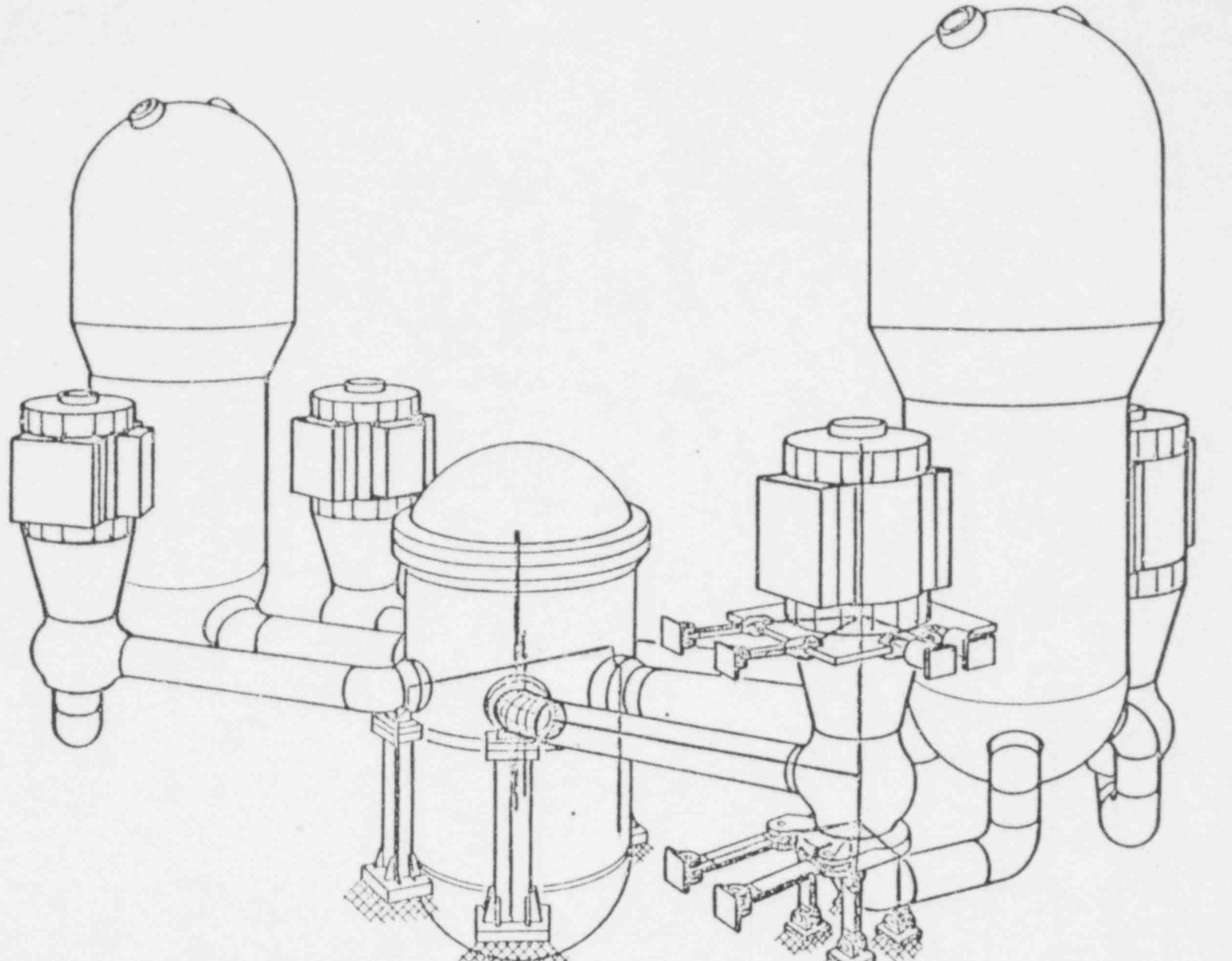
AS-DEPOSITED WELD CHEMISTRIES AS A FUNCTION OF FLUX TYPE

Chemical Elements	Weld Deposit Analysis (w/o) Linde 124	Weld Deposit Analysis (w/o) Linde 0091	Wire Analysis (w/o)
Si	0.42 ⟷	0.15	0.04
S	0.012	0.009	0.013
P	0.011	0.006	0.007
Mn	1.43	1.3[illegible]	1.98
C	0.094 ⟷	0.16	0.16
Cr	0.04	----	----
Ni	0.03	----	----
Mo	0.51	0.62	0.55
Cu	0.06	0.04	0.05
V	0.004	0.007	<.01
Cv USE (ft-lb):	116	125	

POOR ORIGINAL

547 141 /87

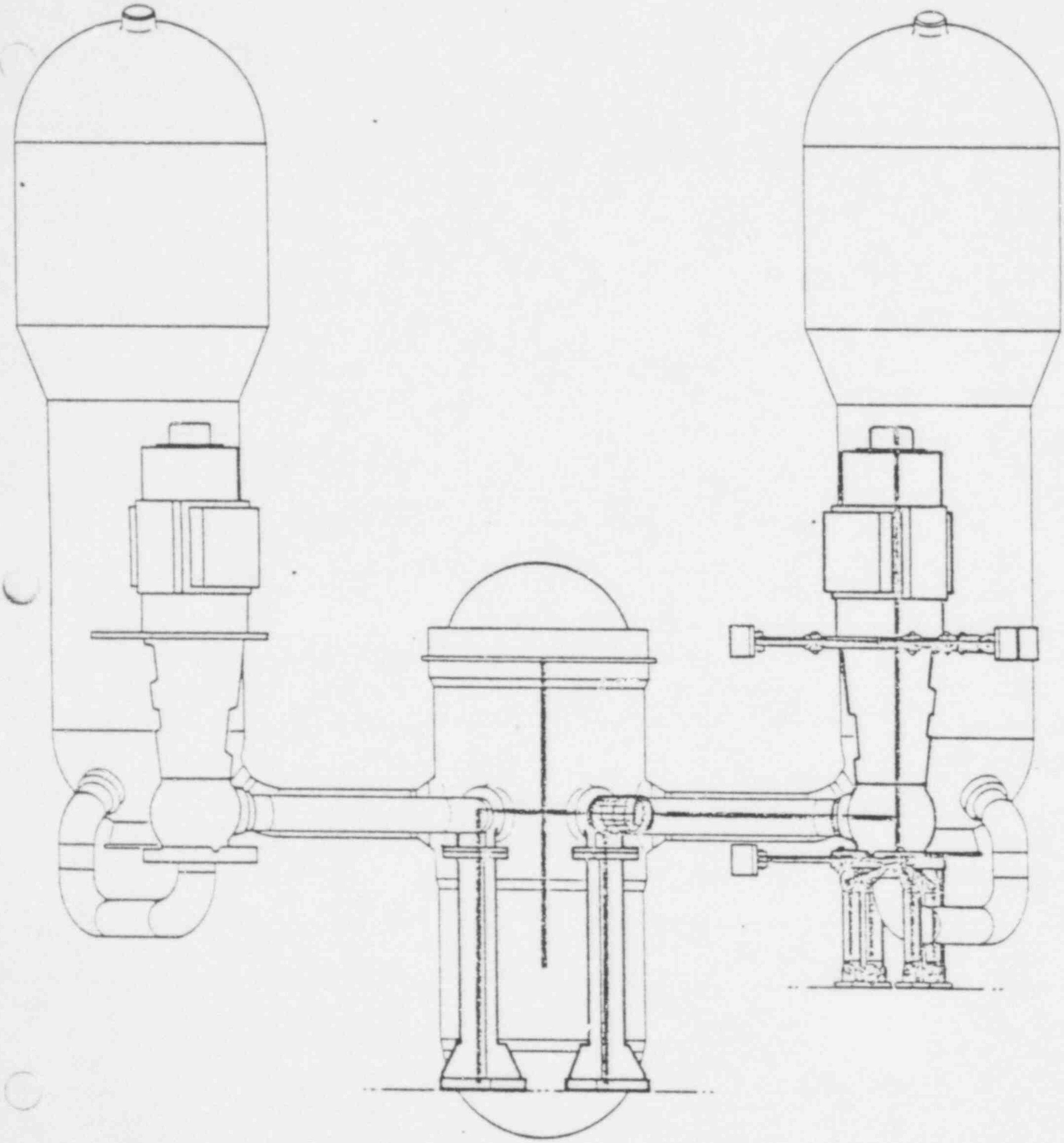
SYSTEM 80™ NUCLEAR STEAM SUPPLY SYSTEM



547 142

138

SYSTEM 80™
NUCLEAR STEAM SUPPLY SYSTEM



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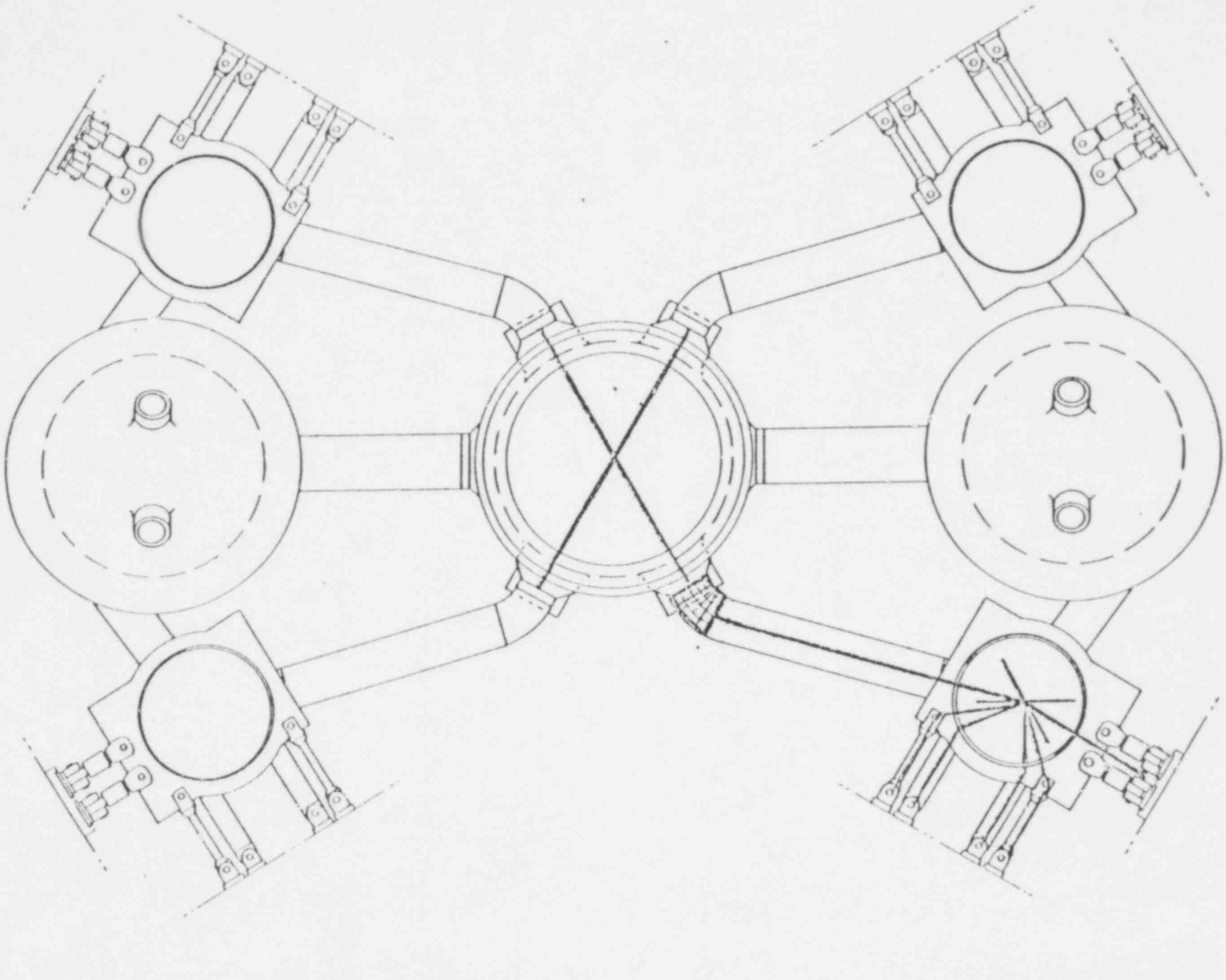
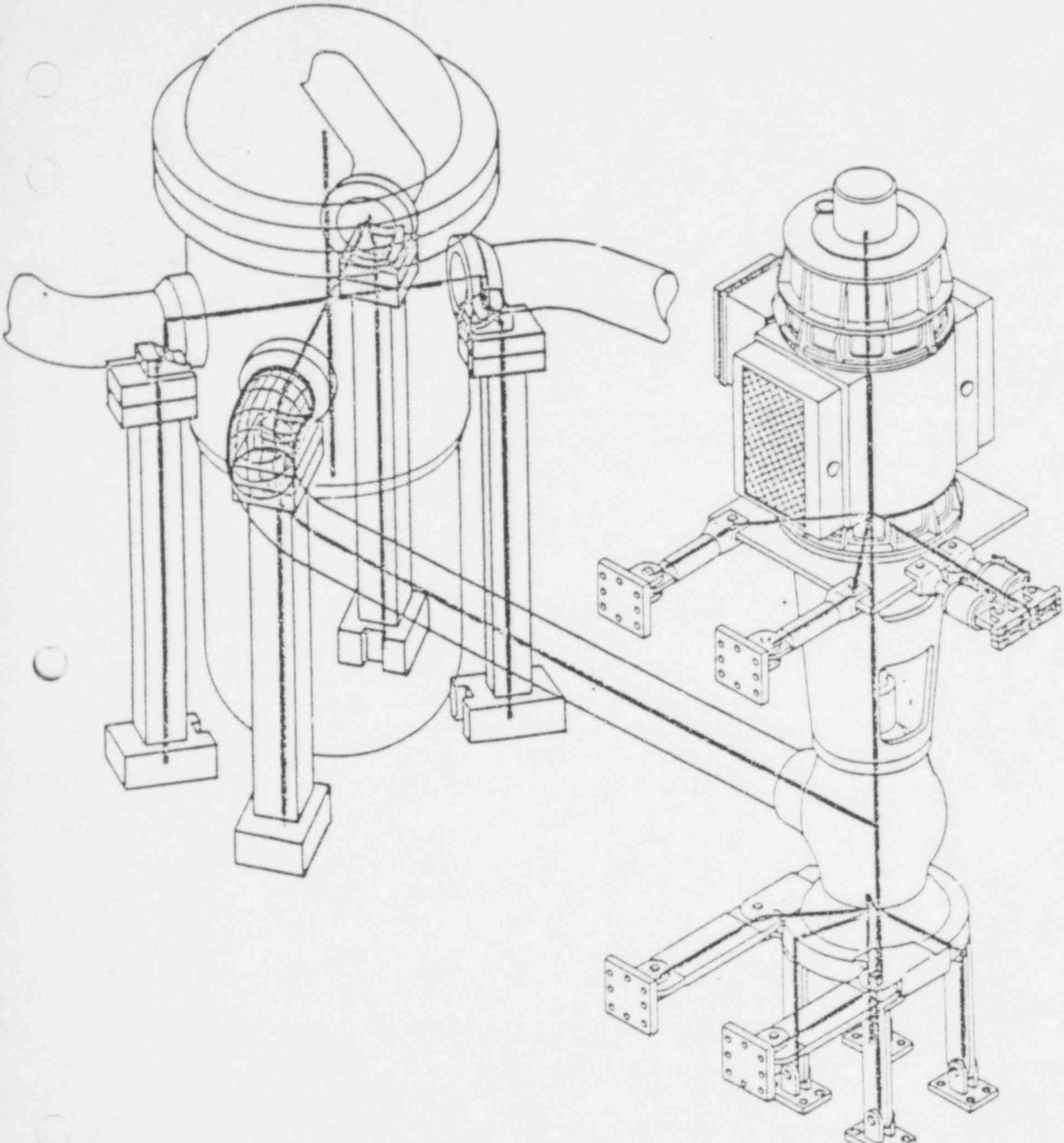
159

SYSTEM 80™ NUCLEAR STEAM SUPPLY SYSTEM



547 144

195



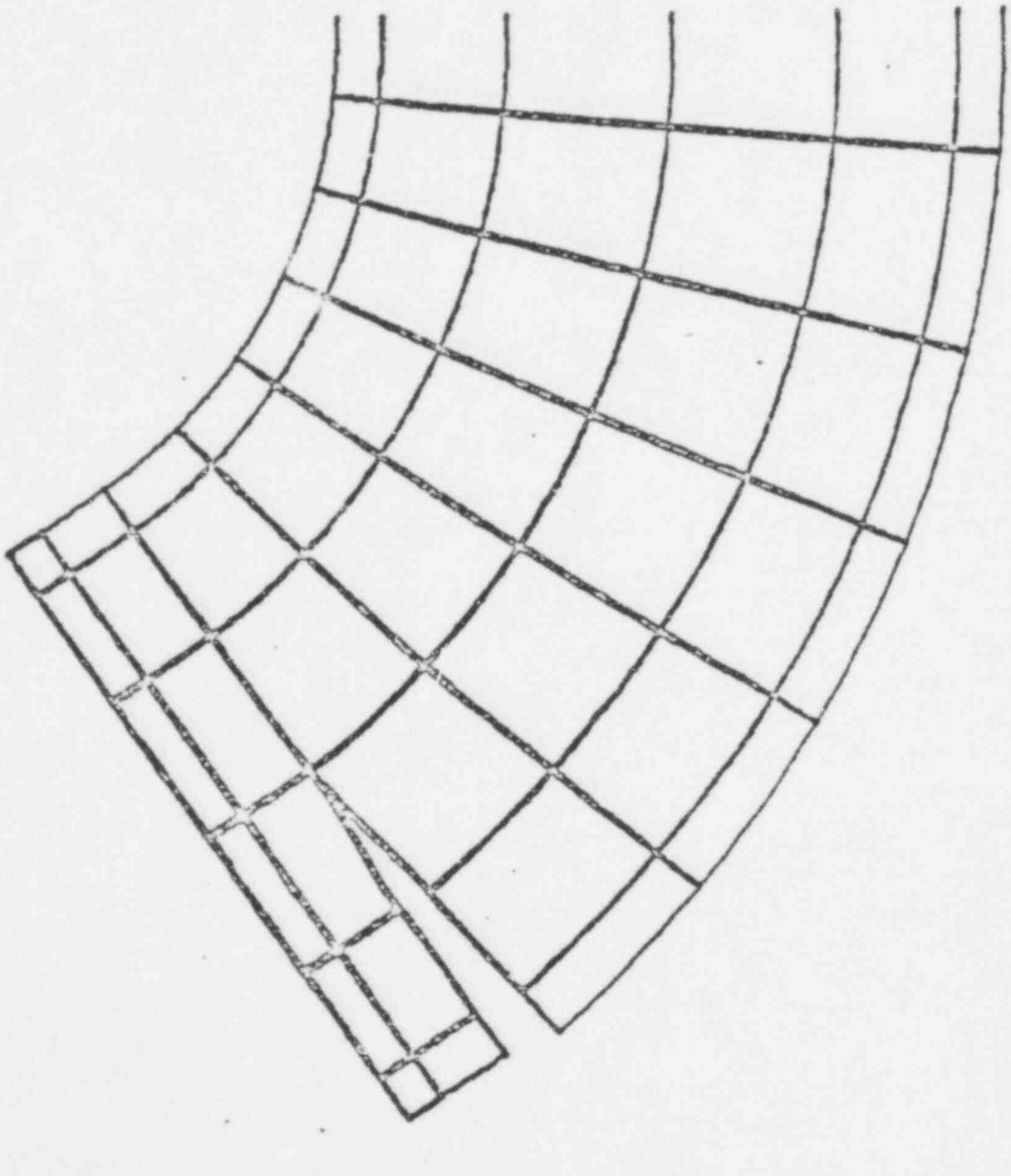


Figure 14

1% DAMPING
RV UPR COL SUPT.

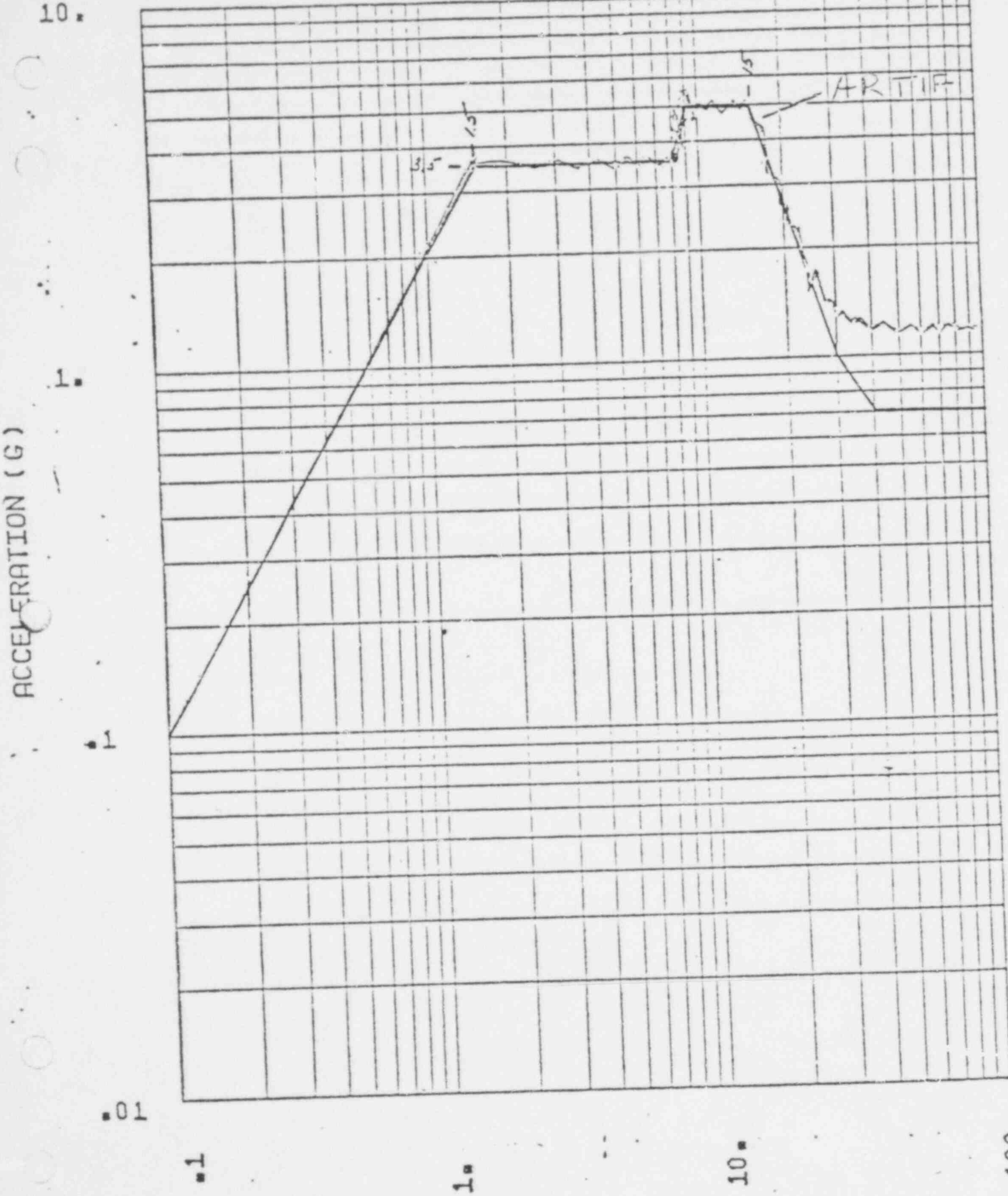


Figure 15

FRAME NUMBER 1

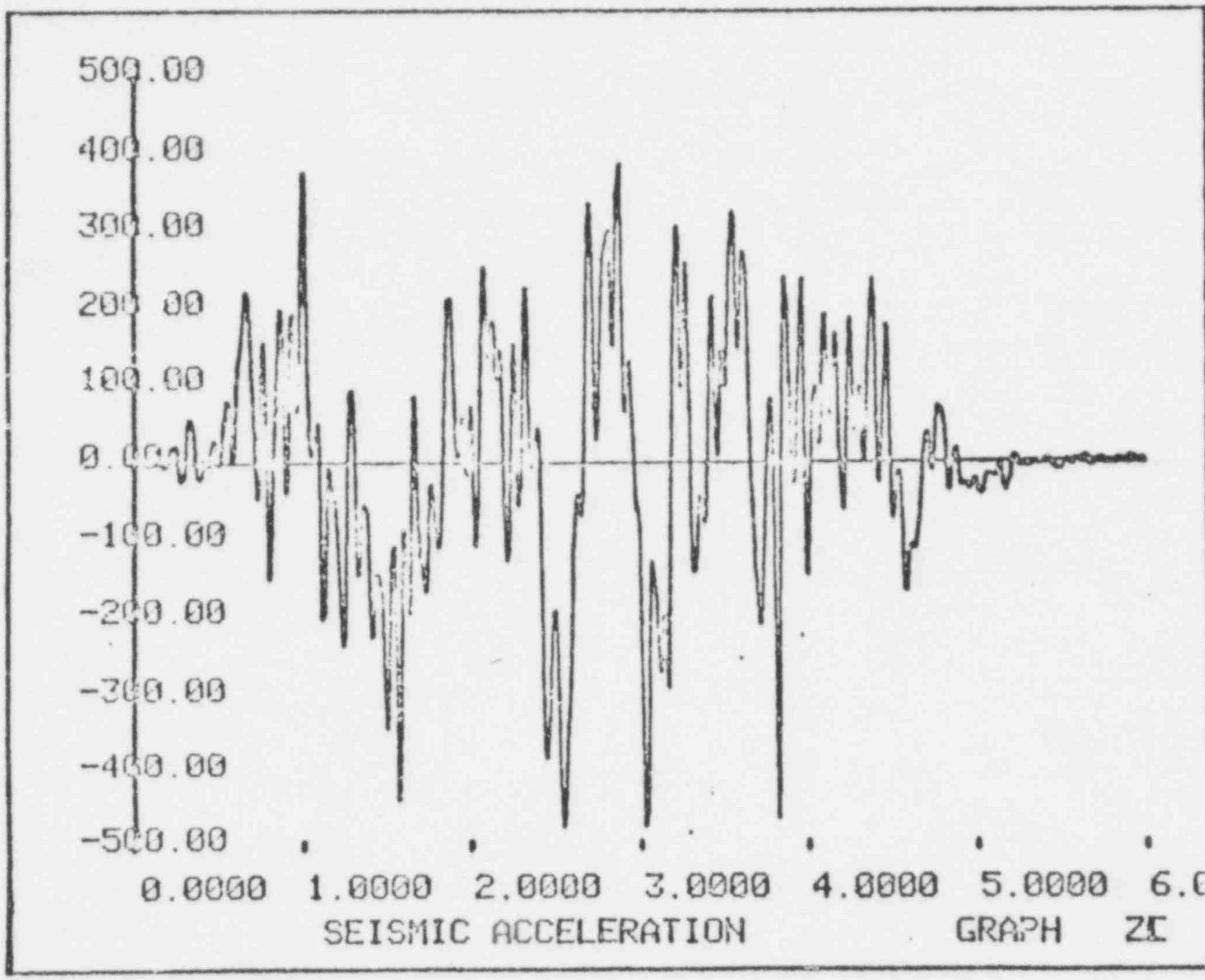


Figure 16(a)

547 148

194

FRAME NUMBER 1

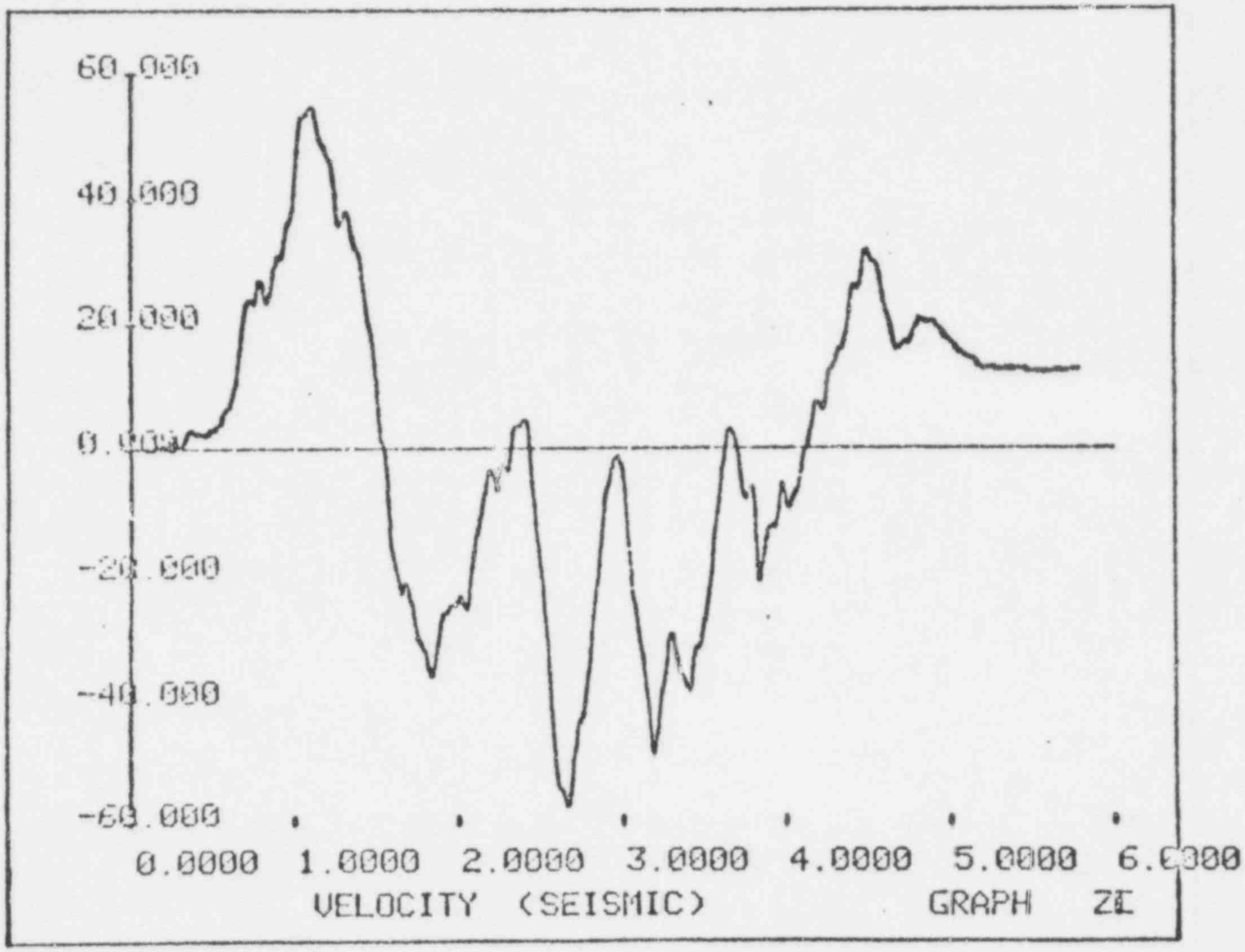


Figure 16 (h)

547 149

195

FRAME NUMBER 1

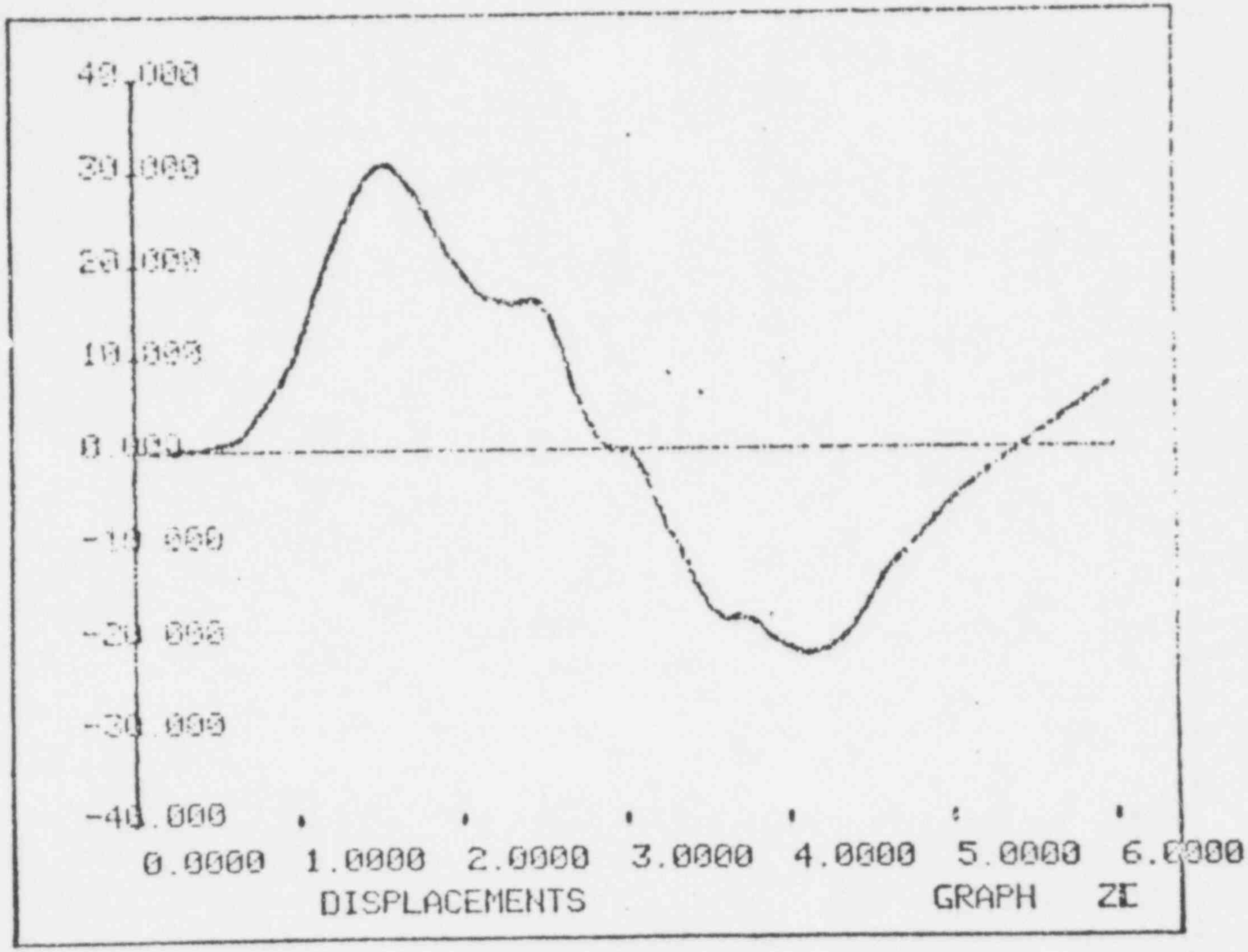
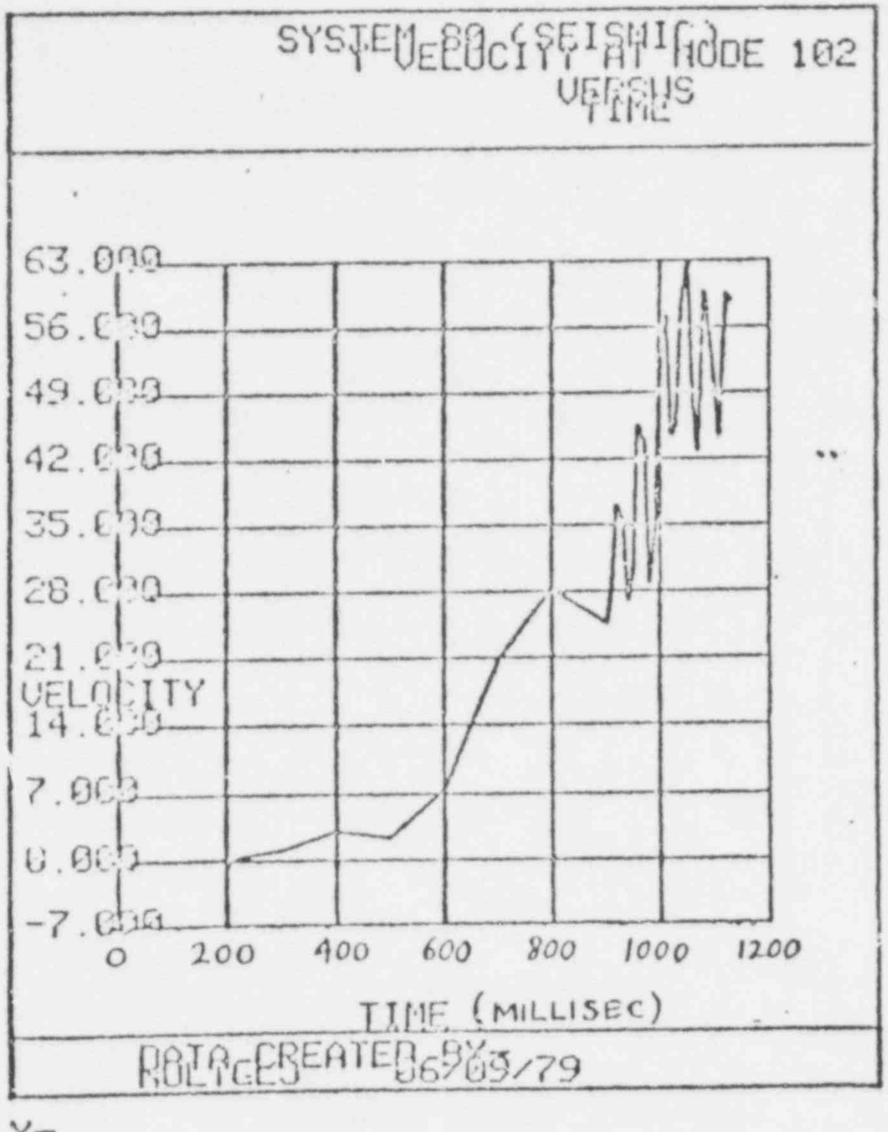


Figure 16

517 150

/96



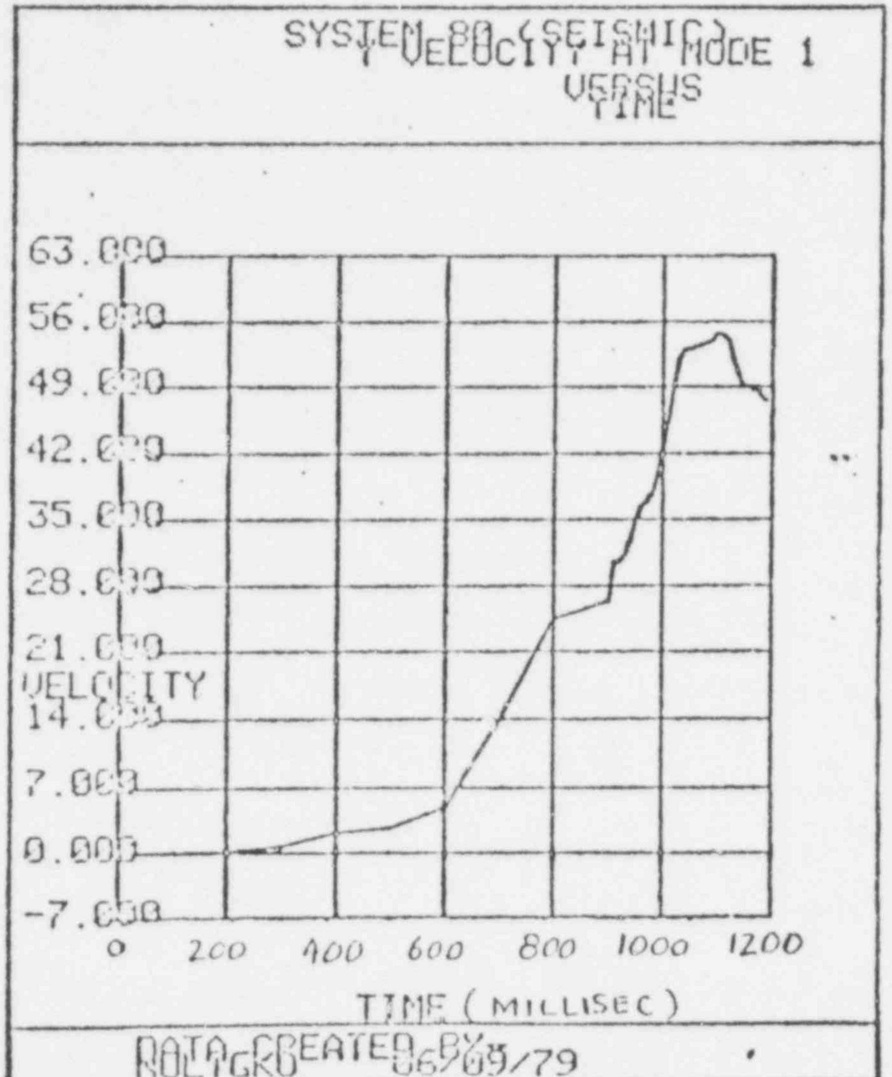
MID POINT OF DISCHARGE LEG
NO CRACK

DATA PLOTTED BY
NULTGRA

Figure 17

547 151

193



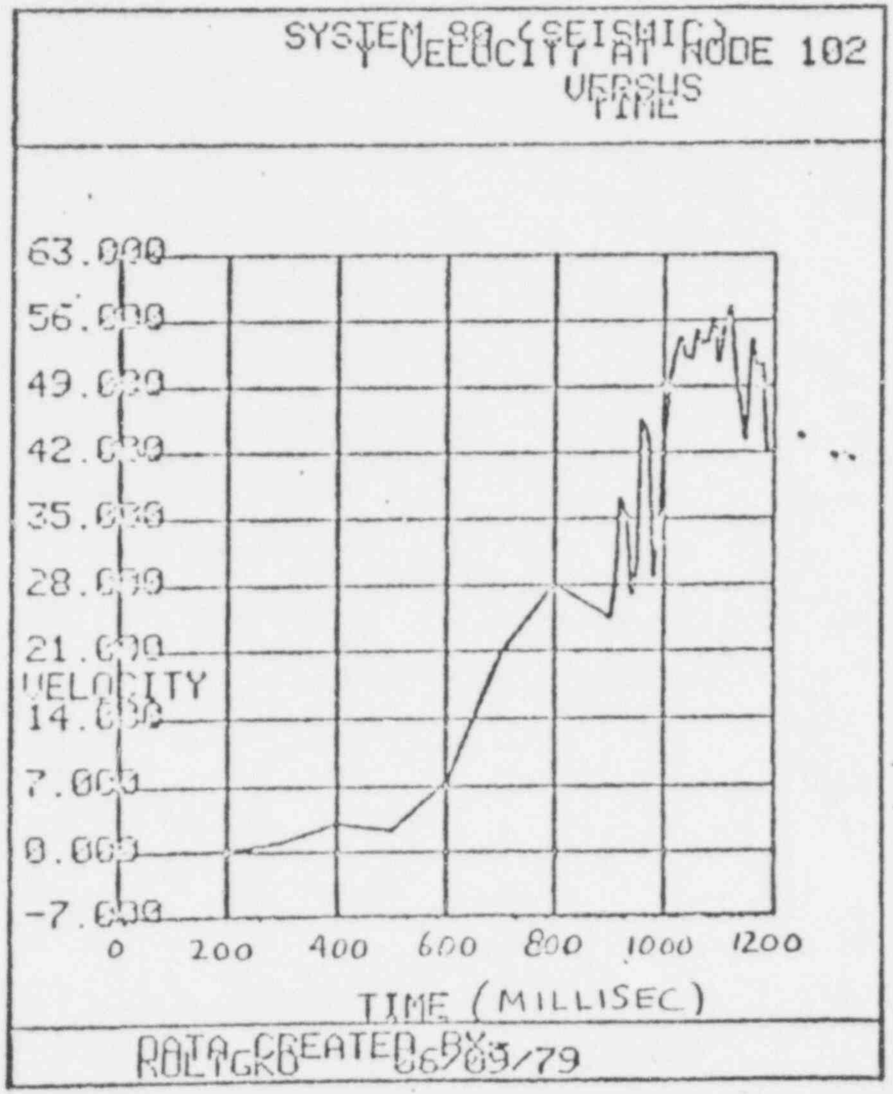
SUPPORT VELOCITY HISTORY

NULTE80 DATA PLOTTED B 03/12/7

Figure 18

547 152

192

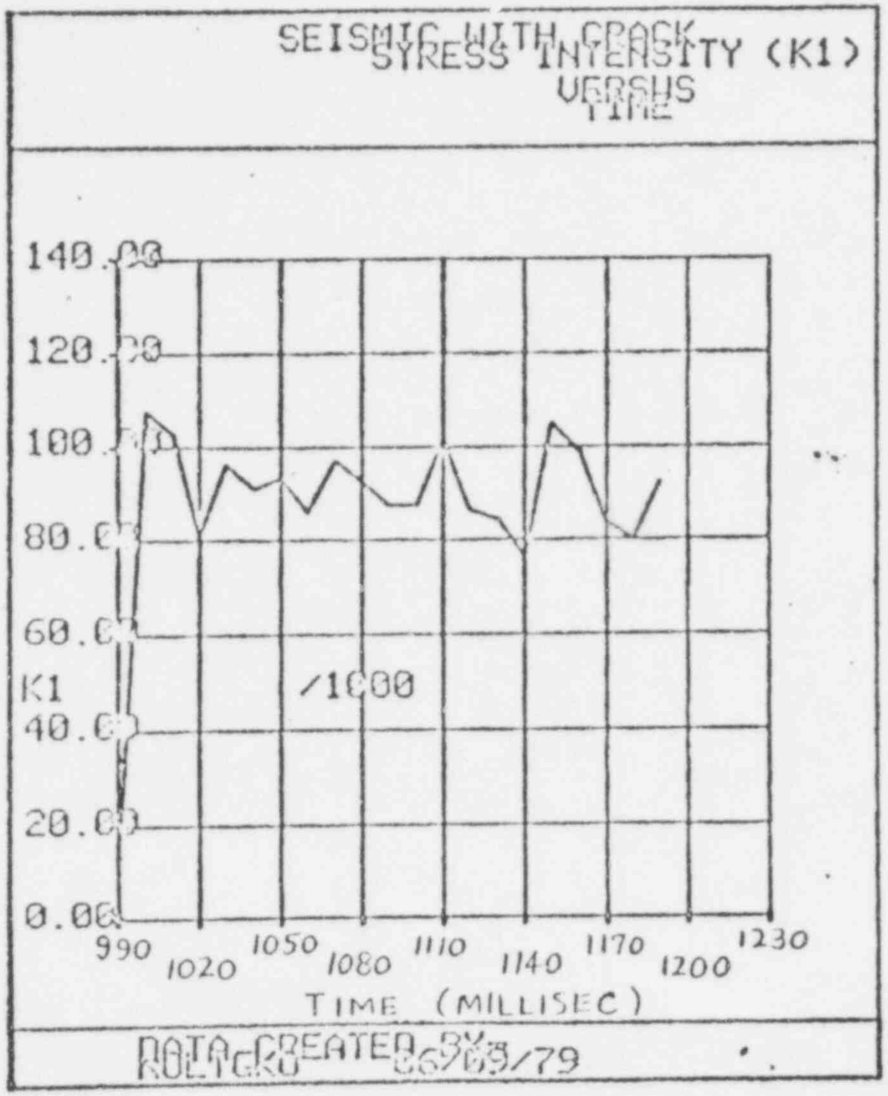


MID POINT OF DISCHARGE LEG WITH CRACK

DATA PLOTTED B
NULTGSO 05/12/7

Figure 19

STRESS INTENSITY VS TIME AFTER CRACK OPENS

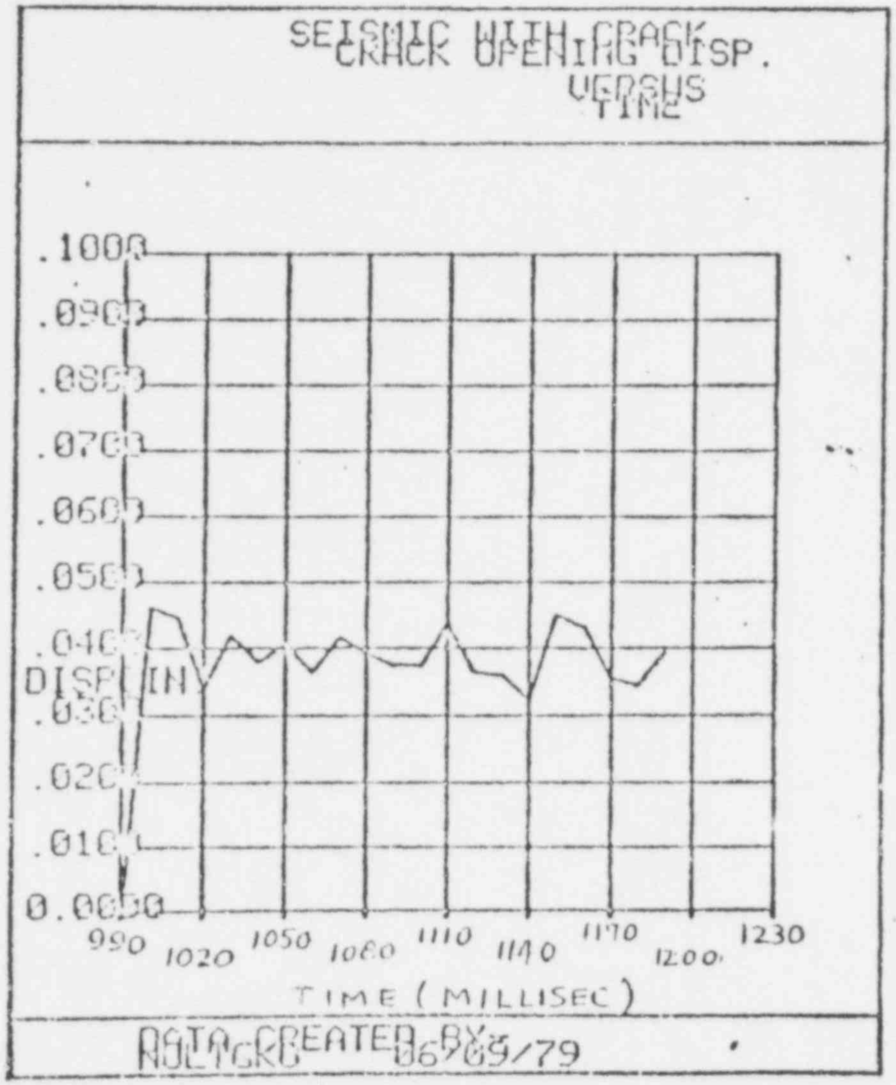


NULTG95 DATA PLOTTED B 03/12/7

Figure 20

547 154

205



MAXIMUM CRACK OPENING VS TIME

NULTGAP DATA PLOTTED B

Figure 21

5A7 155

201

F-26-28

GENERAL ELECTRIC COMPANY

NUCLEAR TECHNOLOGY DEPARTMENT

REVIEW OF PLANT MATERIALS RELATED DEVELOPMENT PROGRAMS

7/10/79

R.L.COWAN

547 156

PLANT MATERIALS DEVELOPMENT PROGRAMS

- EVALUATION OF STRESS CORROSION CRACKING OF BWR MATERIALS.
  - FUNDAMENTAL UNDERSTANDING
  - PARAMETRIC STUDIES
  - SHORT TERM REMEDIES
  - ALTERNATE MATERIALS
  - IMPROVEMENTS APPLICABLE TO OPERATING PLANTS
- EFFECT OF ENVIRONMENT ON FATIGUE PROPERTIES.
  - LOW AND HIGH CYCLE
  - INITIATION AND PROPAGATION
- WEAR RESISTANT ALLOYS WITH LOW COBALT.
- WELDING TECHNIQUES.
- NON DESTRUCTIVE TEST TECHNIQUES.

> - FOCUS ON INCREASED AVAILABILITY
> - COMPREHENSIVE
> - UTILITY COOPERATION EXCELLENT

547 157

7/10/79
R.L.COWAN

OUTSIDE FUNDED PROGRAMS IN

PLANT MATERIALS AREA

NRC
- ELECTROCHEMICAL METHOD FOR DETECTION OF DEGREE OF SENSITIZATION IN STAINLESS STEEL.

EPRI
- PARAMETRIC PIPING STUDIES OF STAINLESS
- QUALIFICATION OF NEAR TERM PIPING REMEDIES
- ALTERNATE PIPING MATERIAL QUALIFICATION PROGRAM
- CARBON STEEL FATIGUE
- LARGE DIAMETER PIPE SCC MARGIN
- PIPING RESIDUAL STRESS IMPROVEMENT

DOE (AS SUBCONTRACTOR)

- ALTERNATE BWR WATER CHEMISTRY

- HELPS FOCUS DEVELOPMENT WORK ON COMMON OBJECTIVES
- ACCELERATES APPLICATION

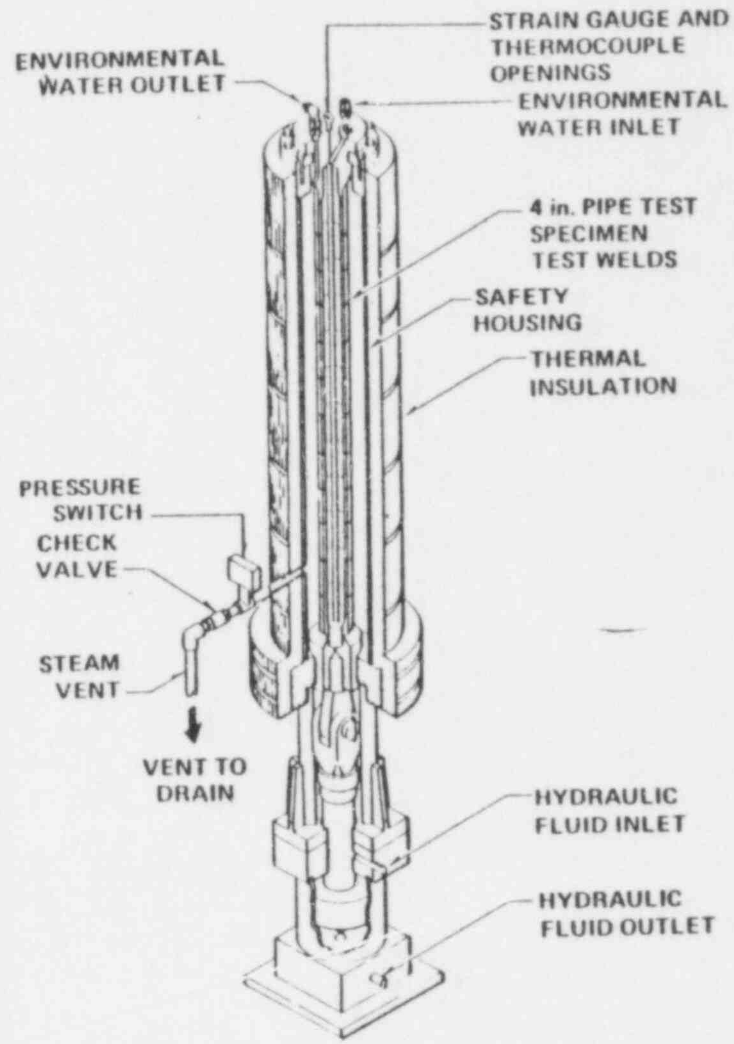
547 158

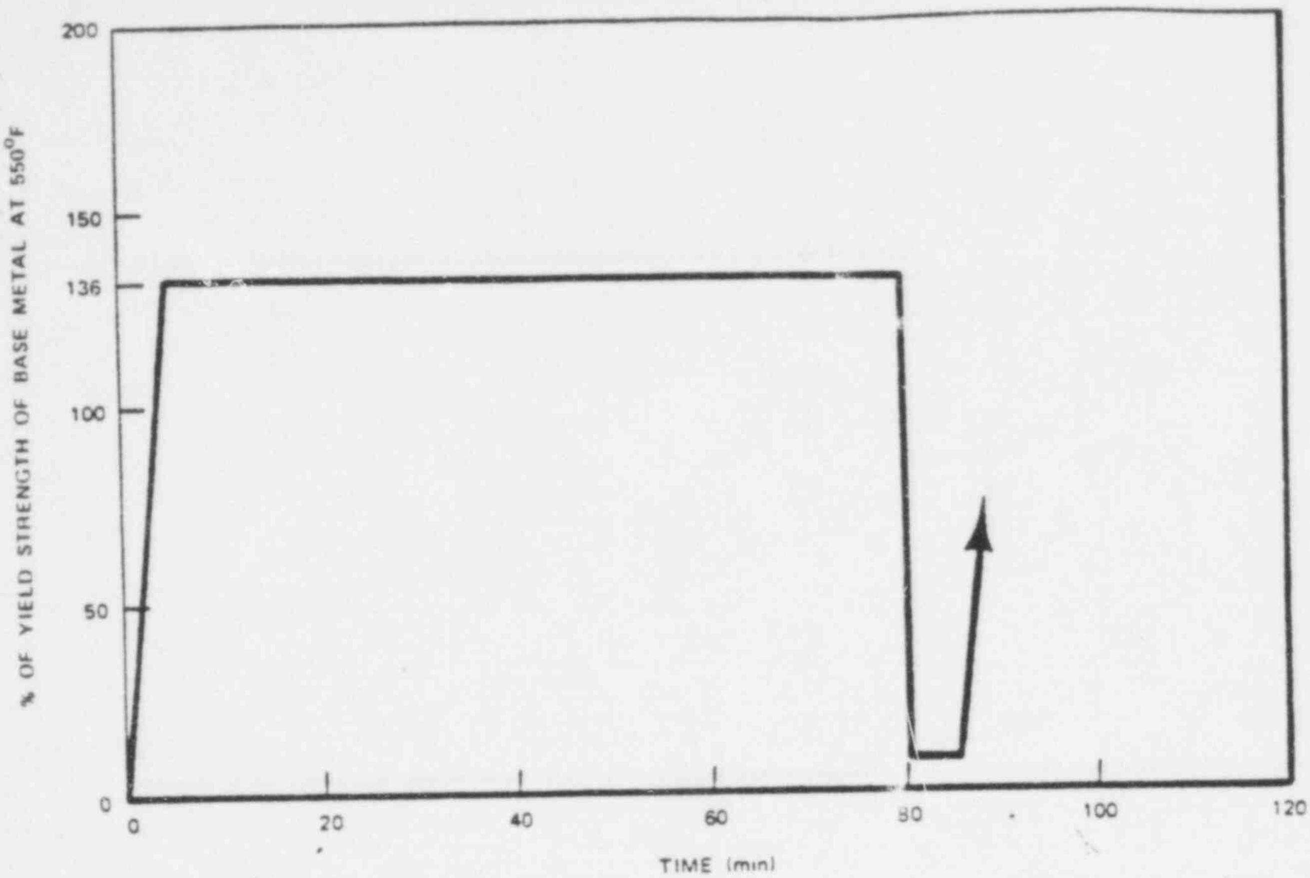
7/10/79

R.L.COWAN

146

4 in. VERTICAL PIPE TEST STAND





COOLANT DESCRIPTION:		
	OXYGEN	6 ± 2 ppm
	TEMPERATURE	540 ± 10°F (282°C ± 5°C)
	ph	5.5 ± .05
LOADING MODE:		
	AXIAL	136% OF σ_{ys} AT 550°F (288°C)
	PRESSURE	pr/2t ~ 4 ksi

QUALIFICATION OF ALTERNATE ALLOY FOR BWR WELDED PIPING

PROGRAM OBJECTIVE

- SELECT, QUALIFY, AND IMPLEMENT INTO BWR SERVICE ALTERNATE ALLOYS FOR TYPE-304 STAINLESS STEEL WHICH WILL NOT EXPERIENCE INTERGRANULAR STRESS CORROSION CRACKING WITHIN THE PLANT DESIGN LIFETIME.

547 161

129

METHOD OF ACCOMPLISHMENT:

1. SCREENING STUDIES AND SELECTION.

   - CHOOSE CANDIDATE ALTERNATE ALLOYS AND PERFORM SCREENING STUDIES.
   - SELECT ALTERNATE ALLOYS FOR QUALIFICATION USING DECISION MODEL.

2. QUALIFICATION.

   - PERFORM STRINGENT TESTS TO DEFINE IGSCC MARGIN OF SELECTED ALTERNATE ALLOYS.
   - PERFORM IN-DEPTH PHYSICAL AND METALLURGICAL CHARACTERIZATION OF ALTERNATE ALLOY PIPING OF VARIOUS SIZES AND MANUFACTURING METHODS.

3. IMPLEMENTATION INTO BWR SERVICE.

   - PROVIDE NUCLEAR GRADE MATERIAL SPECIFICATIONS.
   - QUALIFY MATERIAL SUPPLIERS.
   - ASSURE CODE AND REGULATORY ACCEPTANCE.

547 162

CANDIDATE ALTERNATE ALLOYS

- 304L/NUCLEAR GRADE
- 316
- 316L/NUCLEAR GRADE
- 347
- CF-3
- XM-19

547 163

/5'

SCREENING STUDIES

- PIPE TESTING
- FATIGUE INITIATION TESTING
- STATIC CRACK GROWTH
- CYCLIC CRACK GROWTH
- CONSTANT EXTENSION RATE

547 164

FINAL PIPE TEST RESULTS – SCREENING

ALLOY	PIPES TESTED	PIPES FAILED BY IGSCC	MAXIMUM HOURS ACCUMULATED	FACTOR OF IGSCC IMPROVEMENT
REFERENCE TYPE 304	19	14	7800*	1
REFERENCE TYPE 316L/ NUCLEAR GRADE	11	0**	8500	>20
REFERENCE TYPE 304L/ NUCLEAR GRADE	9	0	7800	>20
REFERENCE TYPE 347	8	0***	6900	>20
REFERENCE TYPE 316	3	0	7900	>20
REFERENCE TYPE CF-3	8	0	7400	>20

*MEAN TIME TO FAILURE FOR REFERENCE TYPE 304 WITH 0.05 TO 0.08% CARBON = 239 HOURS.

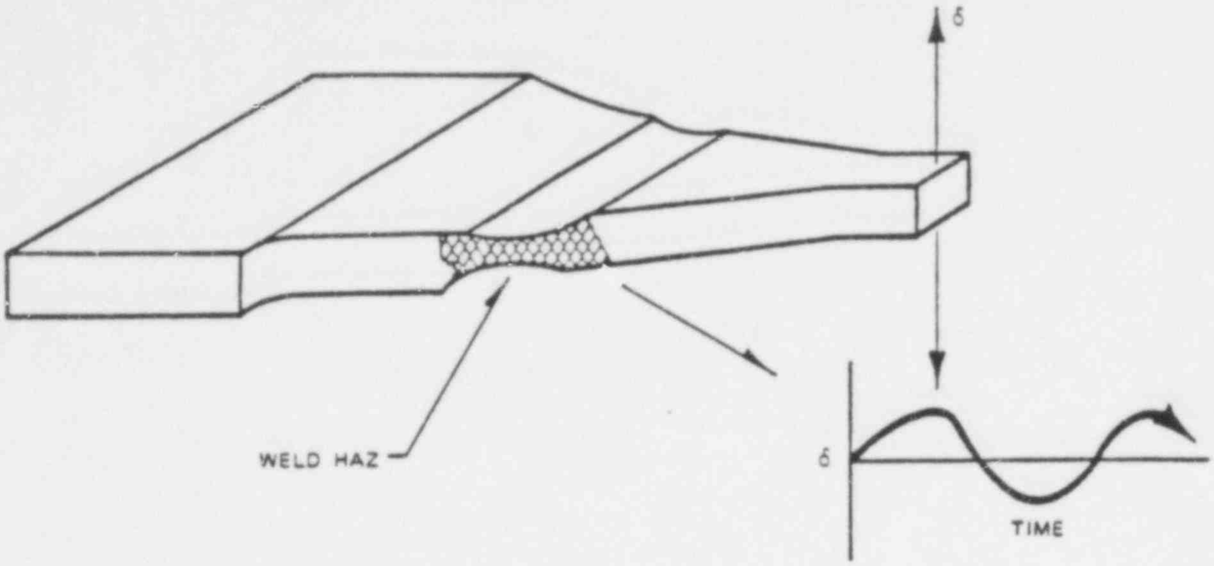
**TWO PIPES FAILED BY TRANSGRANULAR MODE WITH MINOR AMOUNT OF INTERGRANULAR FEATURES.

***ONE PIPE FAILED BY TRANSGRANULAR MODE WITH MINOR AMOUNT OF INTERGRANULAR FEATURES.

FATIGUE INITIATION TESTING

547 166

154

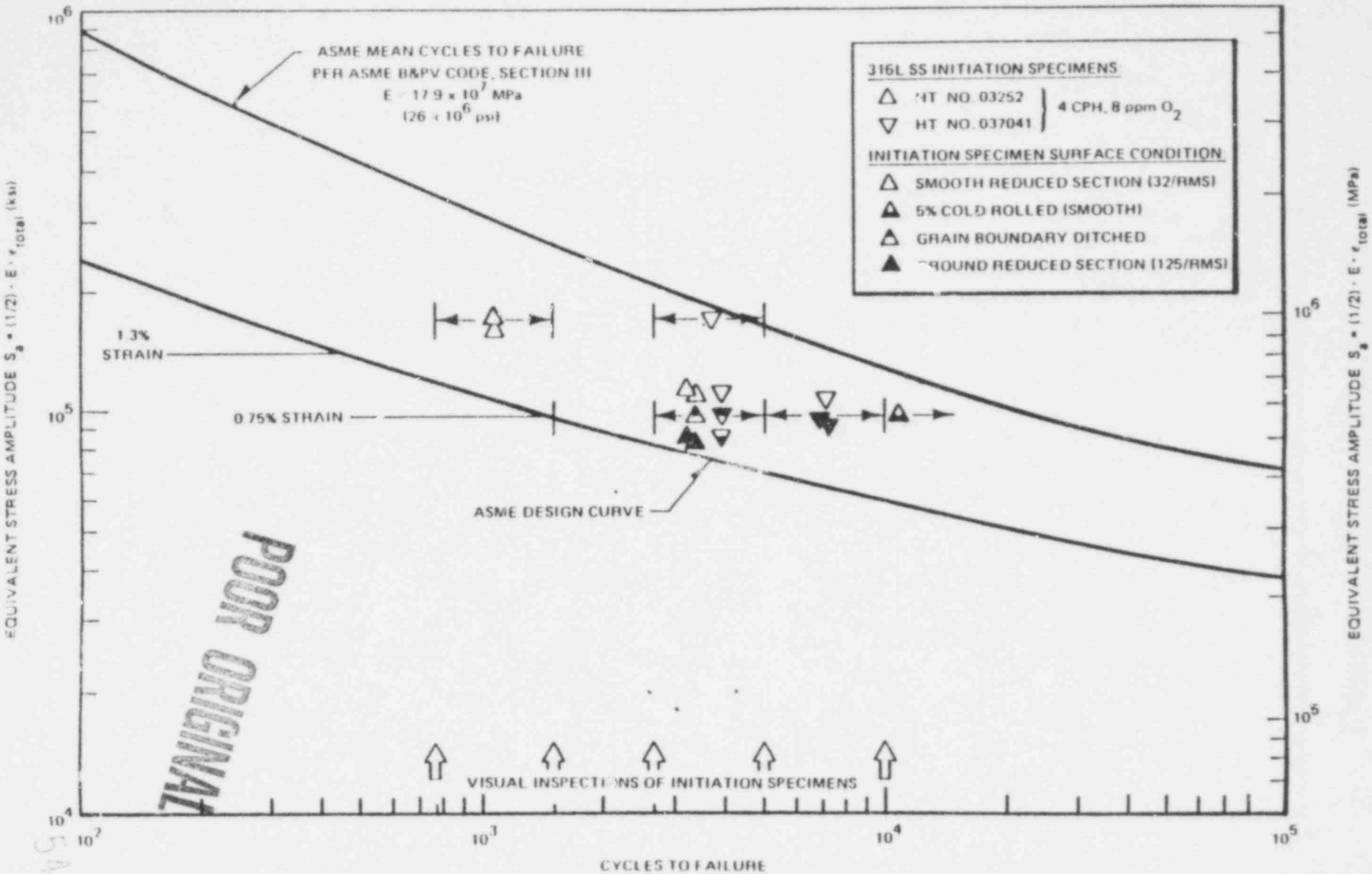


- SMOOTH (3/4%, 1-1/4% STRAIN)
- INTERGRANULAR ATTACK, COLD WORKED, AND WELDED
- ALL SAMPLES HAVE 932°F/24 hr LOW TEMPERATURE SENSITIZATION AFTER WELDING

ALLOY	COMPOSITION RANGE	NO. OF HEATS
316	0.06% C	1
316 (L	0.020 - 0.030% C	2
304 (L	0.018 - 0.027% C	2
347	0.023 - 0.038% C	2
XM-19	0.05% C	1
CF-3	10% α TO 25% α	2
REFERENCE 304	COMPLETE IN PREVIOUS PROGRAM	
SAMPLES ON TEST JUNE 1978		

POOR ORIGINAL

547 167



ASME MEAN CYCLES TO FAILURE
PER ASME B&PV CODE, SECTION III
E = 17.9 x 10^7 MPa
(26 x 10^6 psi)
316L SS INITIATION SPECIMENS:
HT NO. 03252
HT NO. 037041
4 CPH, 8 ppm O2
INITIATION SPECIMEN SURFACE CONDITION:
SMOOTH REDUCED SECTION (32/RMS)
5% COLD ROLLED (SMOOTH)
GRAIN BOUNDARY DITCHED
ROUND REDUCED SECTION (125/RMS)
1.3% STRAIN
0.75% STRAIN
ASME DESIGN CURVE
VISUAL INSPECTIONS OF INITIATION SPECIMENS
CYCLES TO FAILURE
EQUIVALENT STRESS AMPLITUDE Sa = (1/2) · E · ε total (ksi)
EQUIVALENT STRESS AMPLITUDE Sa = (1/2) · E · ε total (MPa)
POOR ORIGINAL

547 168

156

SELECTION OF ALTERNATE ALLOYS FOR QUALIFICATION

TYPE-316 NUCLEAR GRADE

TYPE-304 NUCLEAR GRADE

CARBON ⩽0.020%
NITROGEN* 0.06 – 0.16%

*NITROGEN CURRENTLY RESTRICTED TO ⩽0.10% BY ASME SA-240.

SUMMARY

- ALL CANDIDATE ALTERNATE ALLOYS EVALUATED (EXCEPT HIGH CARBON TYPE-316) WOULD BE MORE THAN ADEQUATE REPLACEMENTS FOR TYPE-304 STAINLESS STEEL, BASED SOLEY ON IGSCC RESISTANCE.
- CONSIDERING ADVANTAGES AND DISADVANTAGES OF EACH CANDIDATE ALLOY, AS DEFINED AND WEIGHTED BY THE DECISION ANALYSIS, TYPE-316 NUCLEAR GRADE WAS SELECTED AS THE BEST BALANCED CHOICE TO REPLACE TYPE-304 IN THE BWR.

COUNTERMEASURES FOR 304 SS
PROGRAM STATUS AS OF 6/79

MATERIALS CONDITION	NO. HEATS	WELDS FAILED/ WELDS TESTED	FACTOR OF IMPROVEMENT*
Reference Type 304 SS (All Heats)	3	23/53	1
Corrosion Resistant Clad Plus Solution Heat Treatment (Shop Remedy)	3	0/33	~65
Corrosion Resistant Clad As Deposited (Field Remedy)	2	0/22	~6
Reference Type 304 SS Sensitized Material	1	4/11	1
Corrosion Resistant Clad Deposited on Sensitized Material	1	4/13	~6

*To Date

547 171

159

COUNTERMEASURES FOR 304 SS
PROGRAM STATUS AS OF 6/79

MATERIALS CONDITION	NO. HEATS	WELDS FAILED/ WELDS TESTED	FACTOR OF IMPROVEMENT*
REFERENCE TYPE 304 SS (ALL HEATS)	3	23/53	1
SOLUTION HEAT TREATMENT	3	0/33	~ 65
HEAT SINK WELDING	1	2/24	~ 15

*TO DATE

- RECOMMENDED COUNTERMEASURES ARE EFFECTIVE
- GENERIC RECIRCULATION PIPING RECOMMENDATION MADE TO ALL BWR PROJECTS

547 172

150

EQUATION USED FOR FACTOR OF IMPROVEMENT CALCULATIONS

$$\text{LOG TEST TIME} = F + G + \sigma \left[-Q + U(1/n + r)^{1/2} \right]$$

WHERE:

F = MEAN LOG TIME TO FAILURE OF REFERENCE WELDS

G = LOG OF DESIRED IMPROVEMENT FACTOR

σ = STANDARD DEVIATION OF LOG TIMES TO FAILURE OF REFERENCE WELDS

Q = FACTOR ON σ FOR EXPECTED LOCATION OF FIRST ORDER STATISTIC ($Q = 1.5864$ FOR n OF 11)

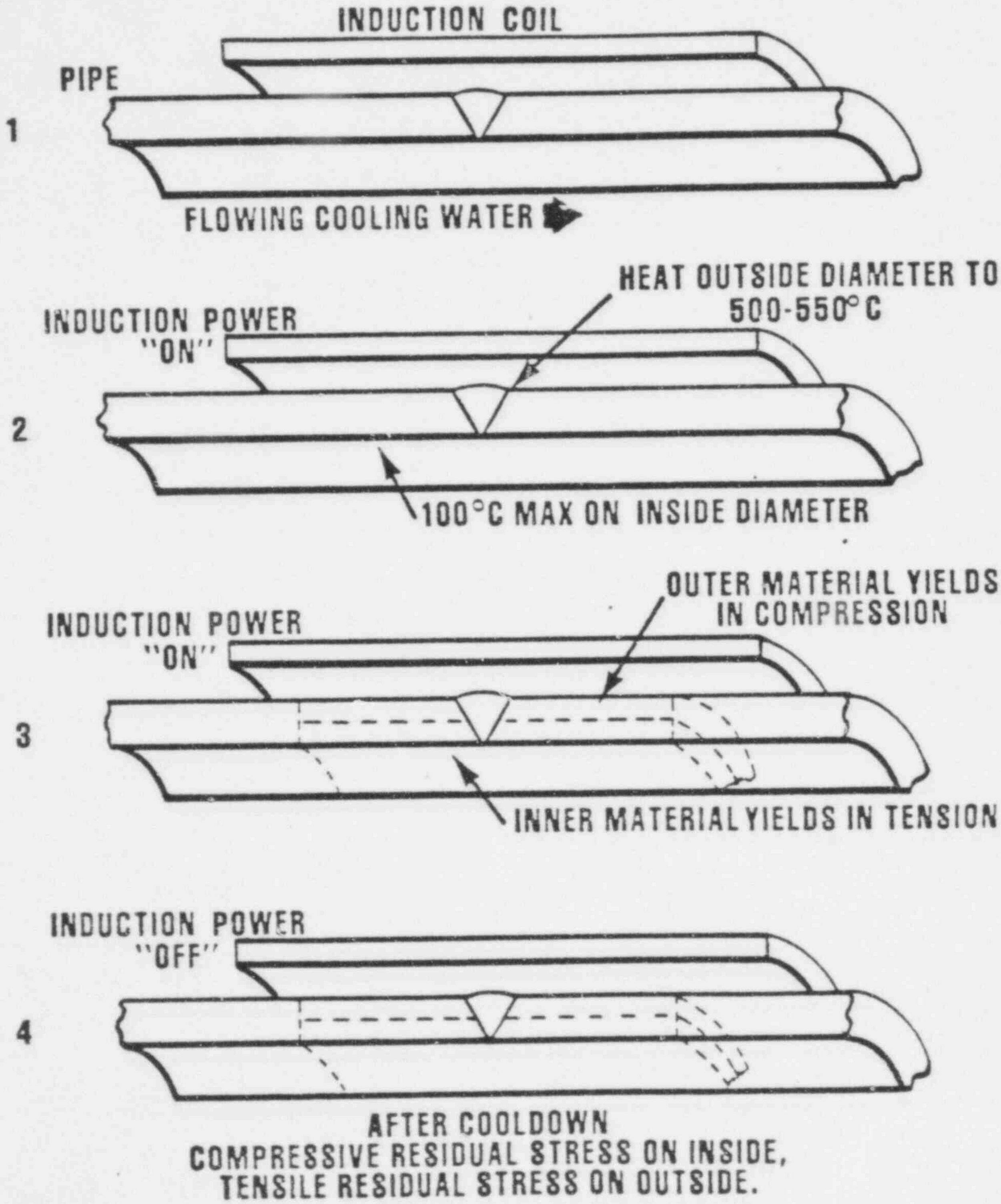
U = NORMAL DISTRIBUTION COEFFICIENT FOR 90% ONE-SIDED LIMIT ($U = 1.282$)

n = NUMBER OF TEST WELDS PER CONCEPT ($n = 11$)

r = FACTOR ON σ^2 FOR VARIANCE OF FIRST ORDER STATISTIC ($r = 0.3332$) FOR $n = 11$)

5A7 173 151

INDUCTION HEATING (RSI) PROCESS



Program Summary

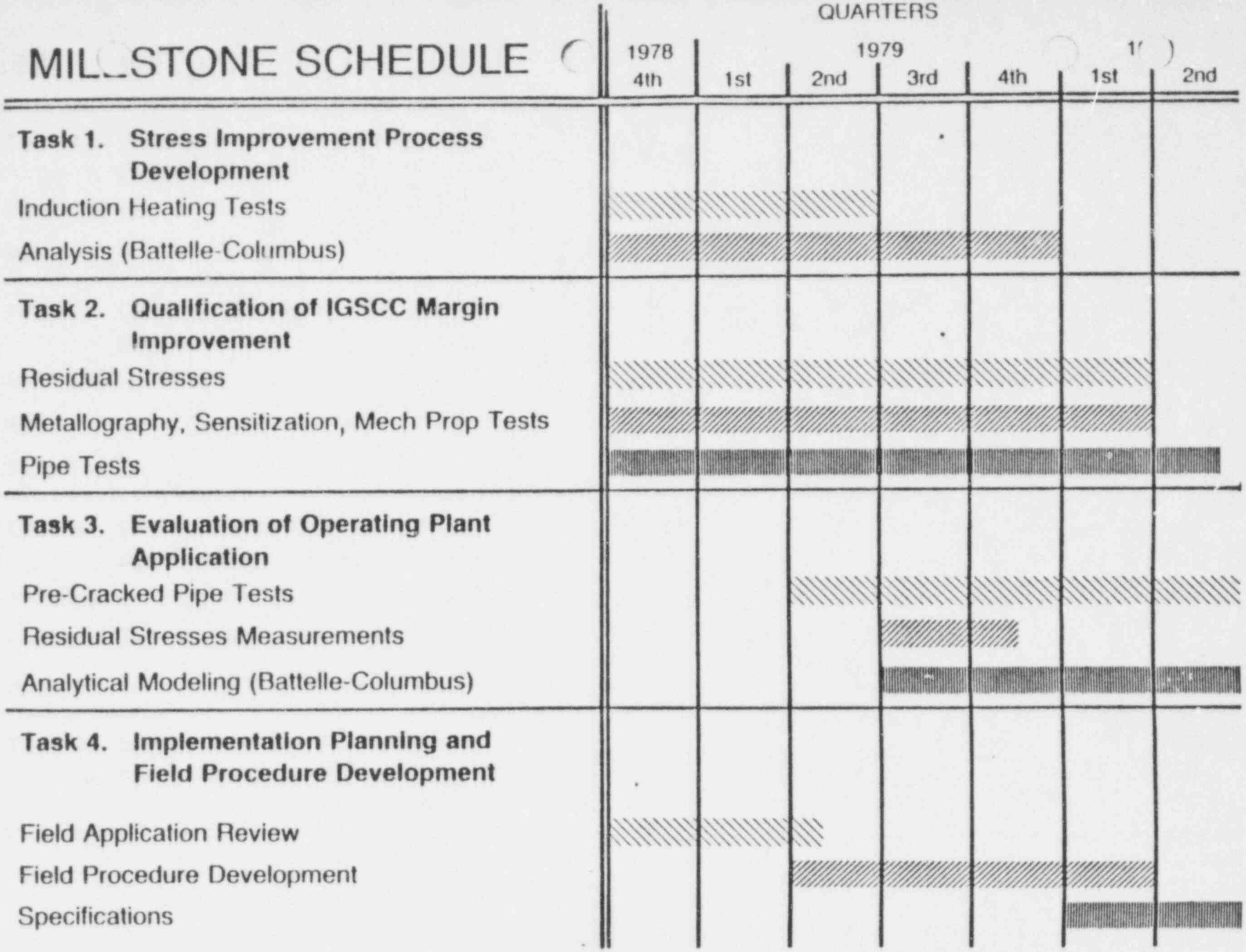
TASK 1 **Process Development and Optimization**

TASK 2 **Evaluation of IGSCC Margin Improvement**

TASK 3 **Evaluation of Operating Plant Application**

TASK 4 **Implementation Planning and Field Procedure Development**

MILESTONE SCHEDULE



507 176

164

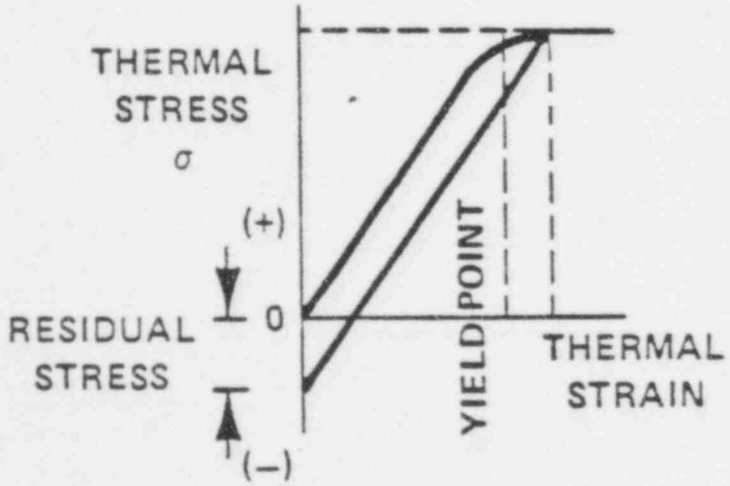
BASIS FOR SELECTION OF TEMPERATURE DIFFERENTIAL BETWEEN OUTER AND INNER PIPE SURFACES (ΔT)

PREMISE: THE THERMAL STRESS MUST EXCEED YIELD STRESS

THERMAL STRESS (σ) – LINEAR GRADIENT

$$\sigma = \frac{E\alpha \cdot \Delta T}{2(1-\nu)}$$

E – YOUNGS MODULUS
α – THERMAL EXPANSION COEFFICIENT
ν – POISSONS RATIO
ΔT – TEMPERATURE DIFFERENCE



547 177

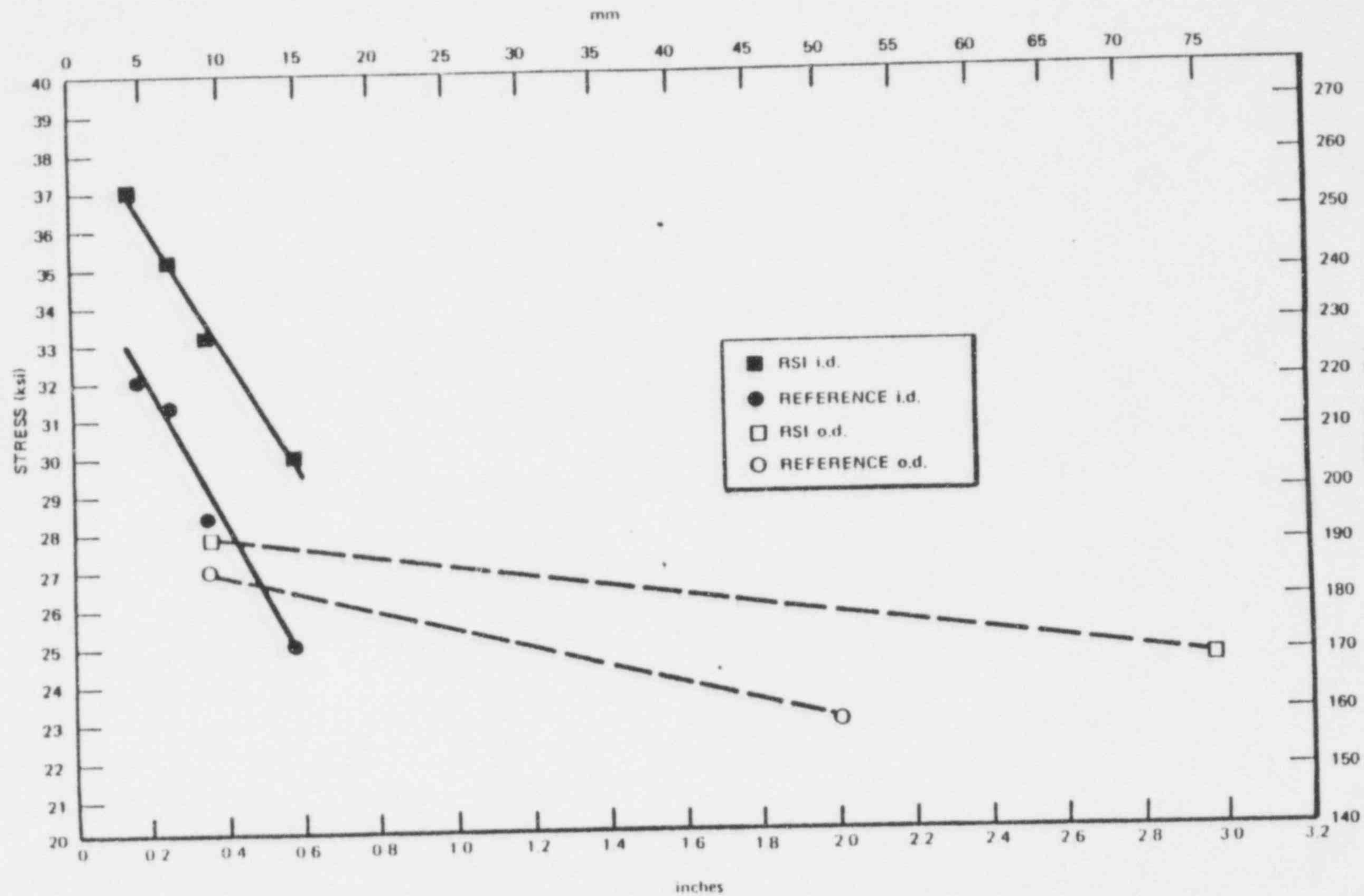
OPTIMIZATION TEST RESULTS

SELECTED RSI PARAMETERS

	PIPE SIZE AND SCHEDULE			
	4 in. PIPE	10 in. PIPE	16 in. PIPE	26 in. PIPE
ΔT	400°C ± 50°	400°C ± 50°	400°C ± 50°	400°C ± 50°
MAX o.d. TEMP	500°C $^{+50°}_{-0°}$	500°C	500°C	500°C
AXIAL TEMP LENGTH	3 in.	4 in.	6 in.	10 in.
TIME TO REACH TEMP	< 13 sec	< 40 sec	< 80 sec	< 200 sec
INDUCT FREQUENCY	3 kHz	3 kHz	3 kHz	3 kHz
COIL DESIGN*	SINGLE TURN	SINGLE TURN	SINGLE TURN	SINGLE TURN
i.d. WATER FLOW	1/2 m/s	1/2 m/s	1/2 m/s	1/2 m/s
COIL AXIAL LENGTH	4 in.	6 in.	10 in.	14 in.
HEATING POWER	120 kW	250 kW	370 kW	390 kW
PRE-HEAT MAX TEMP	< 200°C	< 200°C	< 200°C	< 200°C

* ALTHOUGH SINGLE TURN COILS ARE SPECIFIED FOR UNIFORMITY IN TEST SPECIMEN TREATMENT, THERE IS NO RESTRICTION IN THE USE OF MULTI-TURN COILS IN PRACTICE

YIELD STRESS vs DISTANCE FROM WELD CENTERLINE FOR THE REFERENCE AND RSI-TREATED SPECIMEN



547 179

153

PIPE TESTING

- SIMULATE SERVICE EXPOSURE
- ESTABLISH TIME TO FIRST FAILURE FOR TREATED AND REFERENCE PIPES
- ESTABLISH MARGIN OF IMPROVEMENT

547 180

FABRICATION VARIABLES

- LOW TEMPERATURE SENSITIZATION
- INSIDE DIAMETER GRINDING
- RESIDUAL STRESS IMPROVEMENT TREATMENT

PROGRESS

PIPE TESTING, REFERENCE SPECIMEN

- TEST CONDITIONS:

  STRESS, 136% OF 288°C Y.S.
  OXYGEN, 8 PPM.
  TEMPERATURE, 288°C.
  CYCLIC RATE, 0.67 CPH.

- FIRST REFERENCE FAILURE (THROUGHWALL CRACK) AFTER 456 CYCLES AT JOINT E.

- VISUAL AND U.T. EXAMINATION PERFORMED: ALL JOINTS EXCEPT HSW SHOWED SOME DEGREE OF CRACKING.

- SPECIMEN REPAIRED AND TESTING RESUMED. SECOND FAILURE (THROUGHWALL CRACK) 14 CYCLES AFTER TEST RESUMPTION (470 CYCLES TOTAL).

- TESTING OF REFERENCE DISCONTINUED AFTER SECOND FAILURE.

- FRACTURE MODE ON BOTH JOINTS, IGSCC.

PROGRESS

PIPE TESTING, INDUCTION-TREATED SPECIMEN

- FIVE OUT OF SIX JOINTS HAVE ACCUMULATED OVER 2800 CYCLES (>6X REFERENCE).
- ONE FAILURE (THROUGHWALL CRACKING) AFTER 463 CYCLES AT JOINT B.
- NDE EXAMINATION INDICATED NO CRACKING EXCEPT FOR JOINT B.
- FRACTURE MODE ON JOINT B, IGSCC.
- SPECIMEN REPAIRED AND RETURNED TO TEST. NO ADDITIONAL FAILURES TO DATE.

547 183

PARAMETRIC STUDIES ON IGSCC OF TYPE-304 STAINLESS STEEL PIPE WELDS

PURPOSE: TO DETERMINE THE EFFECT OF PIPE TEST PARAMETERS AND WELDING RESIDUAL STRESSES ON PIPE TEST RESULTS.

METHOD: PIPE TESTS WILL BE CONDUCTED WITH VARIATIONS OF TEST PARAMETERS AND RESIDUAL STRESSES. RESULTS WILL BE COMPARED TO REFERENCE SPECIMENS TESTED UNDER THE ACCELERATED CONDITIONS NORMALLY SPECIFIED FOR PIPE TESTING.

TASK ORGANIZATION

TASK 1 EFFECT OF APPLIED STRESS, OXYGEN CONCENTRATION, CYCLIC RATE AND TEMPERATURE ON PIPE TEST RESULTS.

TASK 2 EFFECT OF WELDING RESIDUAL STRESSES ON PIPE TEST RESULTS.

547 184

TEST SPECIMEN DESCRIPTION

TASK 1
- TEN PIPE SPECIMENS FOR TESTING IN A THREE-YEAR PERIOD.
- EACH STAINLESS STEEL PIPE WILL HAVE TEN WELD JOINTS.
- ALL JOINTS WILL BE GROUND.
- ALL PIPES FROM ONE SUSCEPTIBLE HEAT OF MATERIAL.

TASK 2
- ONE PIPE SPECIMEN WITH SIX WELDS FOR TESTING IN 1979.
- ONE WELDED SPECIMEN FOR RESIDUAL STRESS MEASUREMENTS.
- BOTH SPECIMEN FROM SAME HEAT OF MATERIAL AS TASK 1.
- NO GRINDING OR LTS WILL BE PERFORMED.
- TESTS ON ONE REFERENCE AND ONE INDUCTION-TREATED PIPE WERE INITIATED IN 1978.

PROGRAM:

THE GROWTH AND STABILITY OF STRESS CORROSION CRACKS IN LARGE-DIAMETER BWR PIPING - RP 1554-1

SPECIFIC OBJECTIVES:

1. DEVELOP A QUANTITATIVE UNDERSTANDING OF THE SAFETY MARGIN ASSOCIATED WITH PIPES CONTAINING CRACKS UNDER STATIC AND DYNAMIC LOADS.

2. DEVELOP A DETAILED QUANTITATIVE UNDERSTANDING OF FACTORS CONTROLLING THE RATE OF IGSCC IN LARGE-DIAMETER 304 STAINLESS STEEL PIPING.

3. DEVELOP AN OVERALL PREDICTIVE MODEL FOR THE GROWTH AND STABILITY OF CRACKS IN LARGE-DIAMETER BWR PIPING.

547 186

TASK 2: CRACK GROWTH/ARREST EVALUATION

SUBTASKS:

1. Fracture Mechanics Modeling
2. Evaluation of Crack Arrest due to Residual Stresses
3. Investigation of Crack Arrest in Weld Metal
4. Evaluation of Crack Growth Rates Expected for Service Conditions
5. Confirmatory Pipe Tests

547 187

ALLOY 600 STUDIES TEST PROGRAM

SPECIMEN METALLURGY

Alloy 600 Base (with Alloy 82-GTAW and Alloy 182-(SMAW) and Alloy 82 and 182 Weld Metal

- A W
- A W + P W V H T
- A W + P W V H T + L T S
- A W + L T S

Alloy 600 Base Metal

Heat treatment Before Welding

- P W V H T + W
- P W V H T + W + L T S

TEST CONDITIONS

GENERAL WATER CHEMISTRY:

288 C (550 F), 6 PPM O_2, 5.5 PH, 1 μMHO/CM COND., CL^- <.1 PPM

CONSTANT LOAD — (2) CREVICED; (2) NON-CREVICED

CONSTANT EXTENSION RATE

D O S* TEST ASTM G28-72 — (1) MODIFIED; (1) UNMODIFIED

MECHANICAL PROPERTIES IN 288 C (550 F) AIR — (2)

MECHANICAL PROPERTIES 288 C (550 F) ALSO OF AS RECEIVED AND OF HEAT TREATED BUT NON-WELDED ALLOY 600 BASE MATERIAL

*DEGREE OF SENSITIZATION

135

T25, 26

BABCOCK & WILCOX CO.

MATERIALS R&D

A. COMPANY FUNDED R&D PROJECTS

B. MATERIALS R&D FUNDED BY EXTERNAL ORGANIZATIONS

- B&W OWNERS' GROUP
- ELECTRIC POWER RESEARCH INSTITUTE
- DEPARTMENT OF ENERGY

POOR ORIGINAL

547 189

133

A. MATERIALS R&D PROJECTS

A-1 NSS MATERIALS CORROSION

- EVALUATE THE EFFECT OF CHEMISTRY ON SCC BEHAVIOR OF ALLOY 600
- EVALUATE THE EFFECT OF HEAT TREATMENT ON SCC BEHAVIOR OF ALLOY 600
- CONDUCT MODEL BOILER TESTS
- DETERMINE CORROSION RATES OF PRIMARY SYSTEM MATERIALS
- EVALUATE GENERAL AND LOCAL CORROSION CHARACTERISTICS OF 400 SERIES STAINLESS STEELS

547 190

A. MATERIALS R&D PROJECTS

A-2 FRACTURE MECHANICS TECHNOLOGY

A-2A REACTOR VESSEL MATERIALS

- DEVELOP SINGLE SPECIMEN J_{1C} TEST
- R.V.S.P. TEST CAPABILITY DEVELOPMENT
- ADVANCED R.V.S.P. FOR CURRENT AND FUTURE PLANTS
- STUDY UPPER SHELF TOUGHNESS OF R.V. MATERIALS
- EFFECT OF THERMAL AGING ON R.V. MATERIALS
- EVALUATE NDE RELIABILITY

A-2B FRACTURE TOUGHNESS

- MAINTAIN DATA BANK OF FRACTURE TOUGHNESS PROPERTIES
- EVALUATION OF CARBON STEEL PROPERTIES
- INDUSTRY WIDE R&D SURVEILLANCE
  - CRACK ARREST
  - ELASTIC/PLASTIC FRACTURE TECHNOLOGY

547 191

A. MATERIALS R&D PROJECTS

A-3. JOINT INDUSTRY PROGRAMS

- HSST - TASKS 2,3 & 4
- NRC/NRL - IRRADIATION PROGRAMS
- MPC MATERIALS PROPERTIES DATA BANK
- EPRI/AMES R.V. MATERIALS IRRADIATION DAMAGE STUDIES
- NRC-RSR; LIGHT WATER REACTOR PRESSURE VESSEL IRRADIATION SURVEILLANCE DOSIMETRY PROGRAM

547 192

B. MATERIALS R&D FUNDED BY EXTERNAL ORGANIZATIONS

- B&W/OWNERS' GROUP PROGRAM - REACTOR VESSEL MATERIAL PROPERTIES
- EPRI CORROSION FATIGUE PROGRAM
- EPRI WELD REPAIR PROGRAM
- RVSP CAPSULE EVALUATIONS
- GERMAN SAFETY PROGRAM

547 193

B&W OWNERS' GROUP PROGRAM

FOR

EVALUATION OF REACTOR VESSEL
MATERIAL PROPERTIES

- REACTOR VESSEL BELTLINE WELDS
  - LOW CHARPY-V UPPER SHELF
  - HIGH COPPER CONCENTRATION

547 194

BABCOCK & WILCOX OWNERS'

GROUP PROGRAM

- NEAR TERM OBJECTIVE

  INSURE THAT THE REQUIREMENTS OF APPENDIX G TO 10CFR50 ARE SATISFIED DURING THE FIRST 10 YEARS OF COMMERCIAL OPERATION

- LONG TERM OBJECTIVE

  DEMONSTRATE THAT BELTLINE REGION MATERIALS HAVE ADEQUATE TOUGHNESS FOR DESIGN SERVICE LIFE

Comprehensive Program — heavily reliant on Industry wide R&D

POOR ORIGINAL

547 195 /39

NEAR TERM ACTIVITY

1. REFINE NEUTRON FLUENCE CALCULATIONS - REDUCE CONSERVATISMS (COMPLETE)

2. CHARACTERIZATION OF REACTOR VESSEL WELDS
   - CHEMISTRY (COMPLETE)
   - IMPACT PROPERTIES

3. REFINE PREDICTIVE CURVES FOR IRRADIATION INDUCED PROPERTY CHANGES

4. USE OUTPUT FROM 1-3 TO DEMONSTRATE COMPLIANCE WITH "APPENDIX G" REQUIREMENTS

547 196

Weld metal chemistry

PURPOSE: ESTABLISH CHEMISTRY OF REACTOR VESSEL BELTLINE WELDS-EMPHASIS ON TRACE ELEMENT CONCENTRATION AND VARIABILITY.

WELD METALS INVOLVED

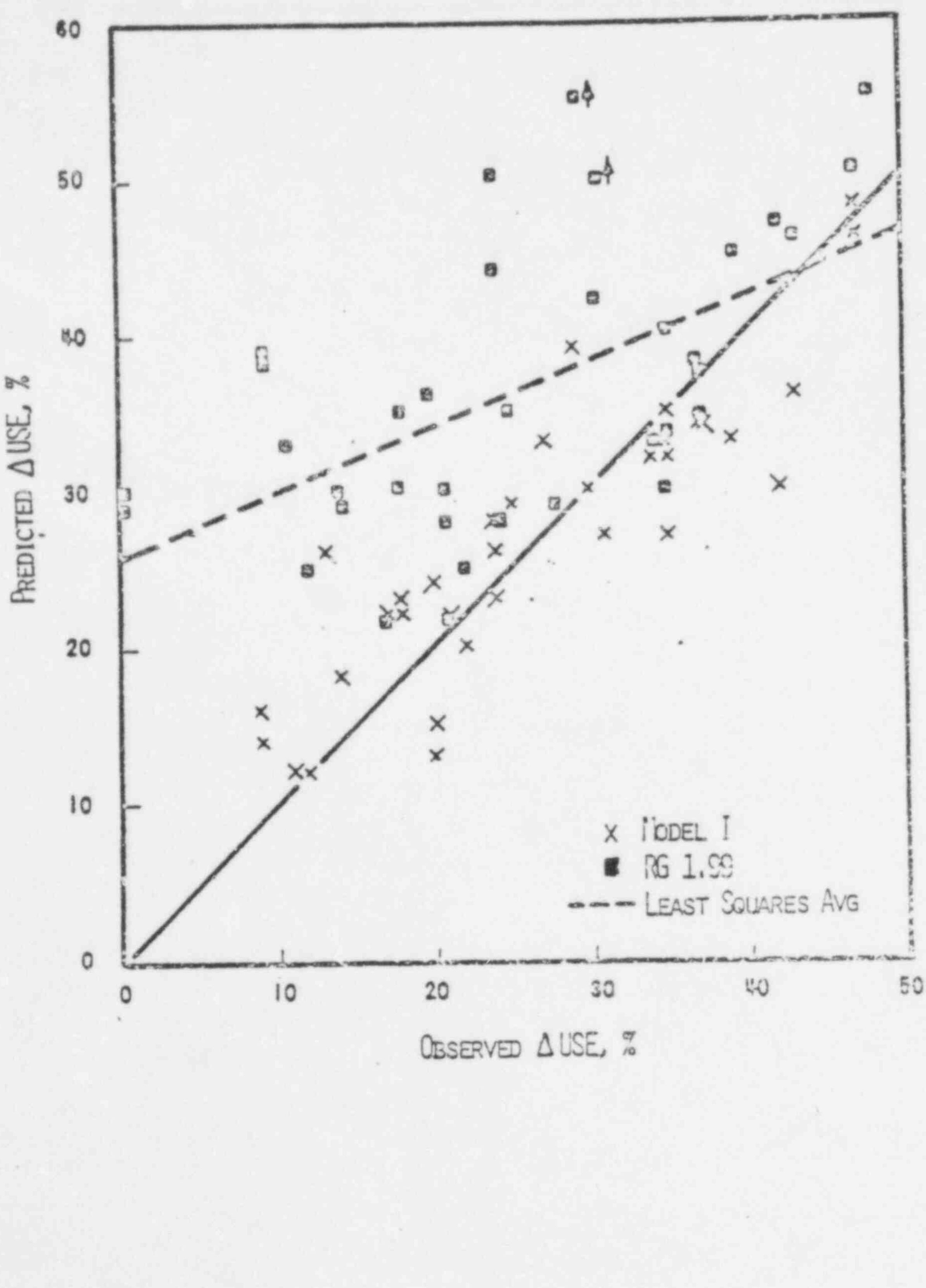
27 WELDS USED IN OWNER'S GROUP R.V.

- 13 HEATS OF Mn-Mo-Ni FILLER WIRE
- 20 LOTS OF LINDE 80 FLUX

14 RV WELDS AVAILABLE FOR WELD STUDY

- 8 HEATS OF Mn-Mo-Ni FILLER WIRE
- 12 LOTS OF LINDE 80 FLUX

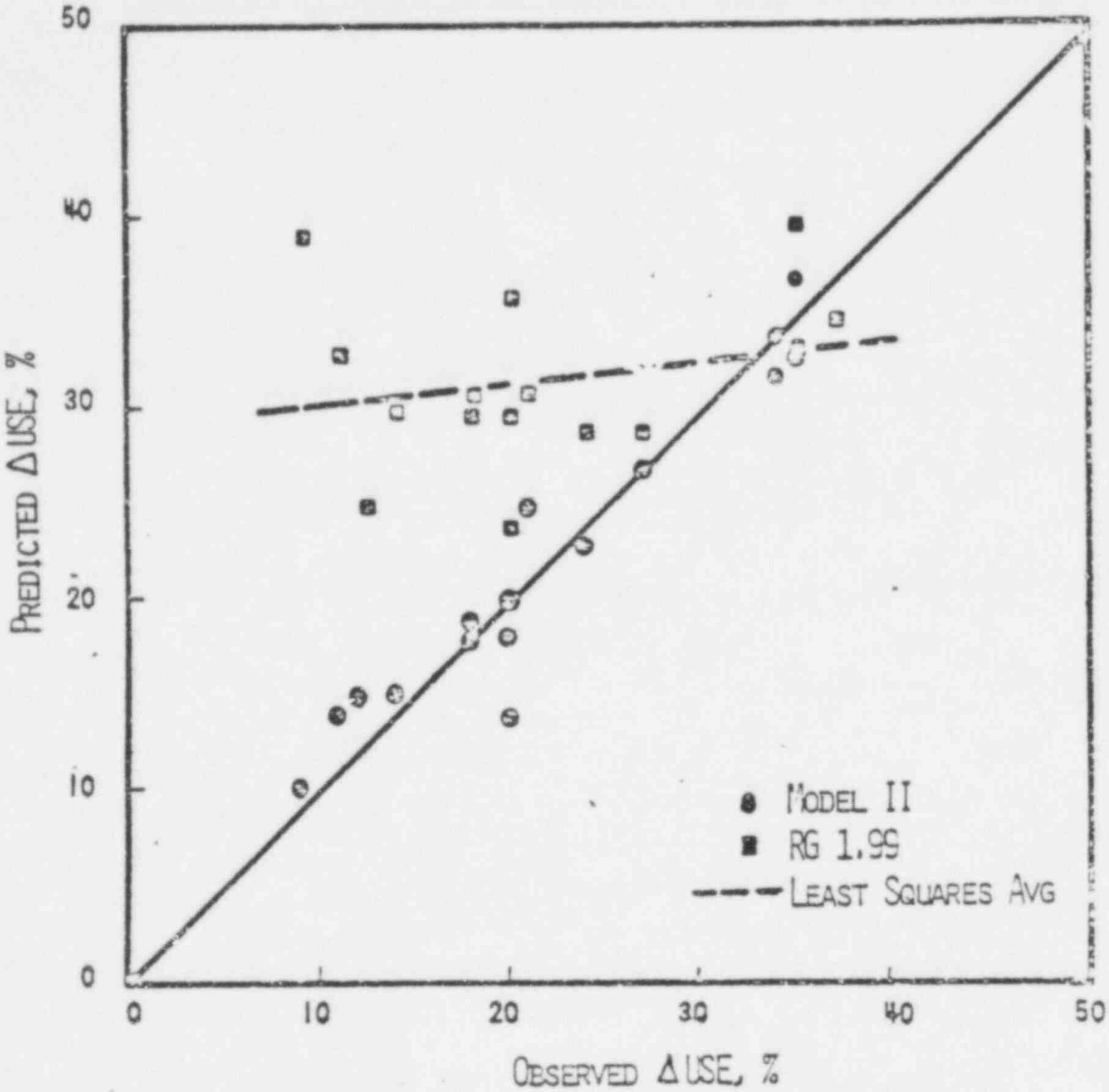
~400 ANALYSIS PERFORMED ON WELDS MADE WITH 24 WIRE/FLUX COMBINATIONS



60
50
40
30
20
10
0
Predicted Δ USE, %
0
10
20
30
40
50
Observed Δ USE, %
Model I
RG 1.99
Least Squares Avg

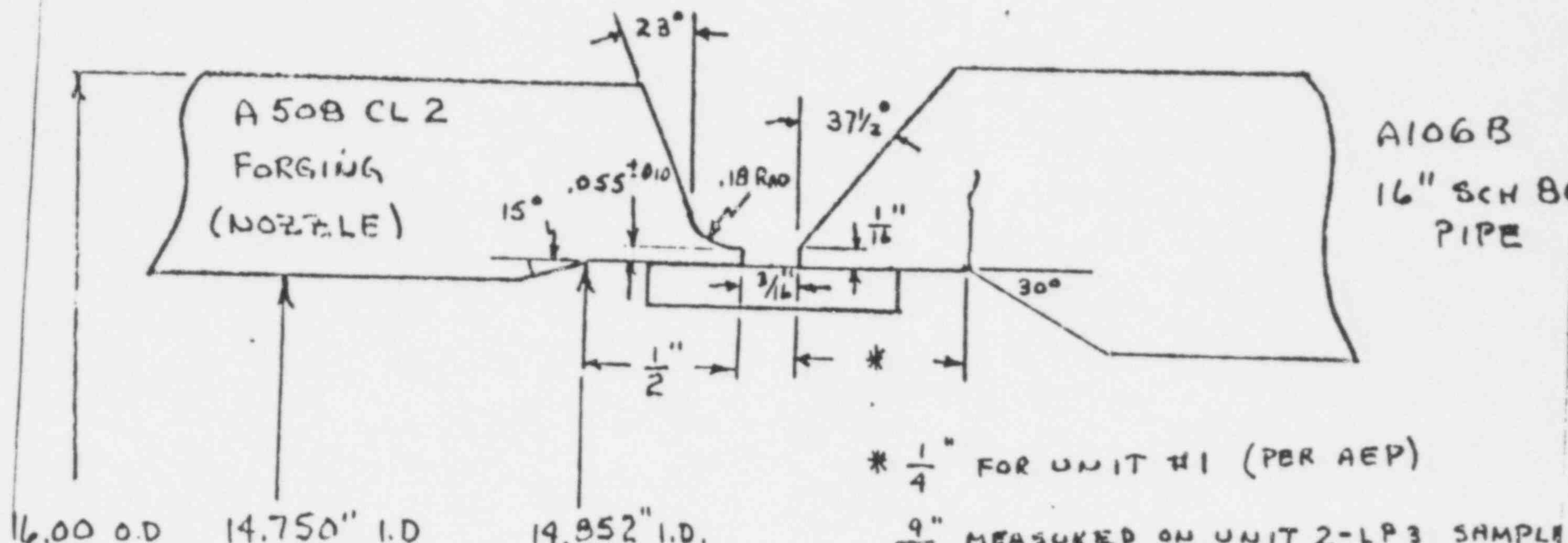
547 198

142


Predicted ΔUSE, %
Observed ΔUSE, %
0
10
20
30
40
50
Model II
RG 1.99
Least Squares Avg

547 199

143

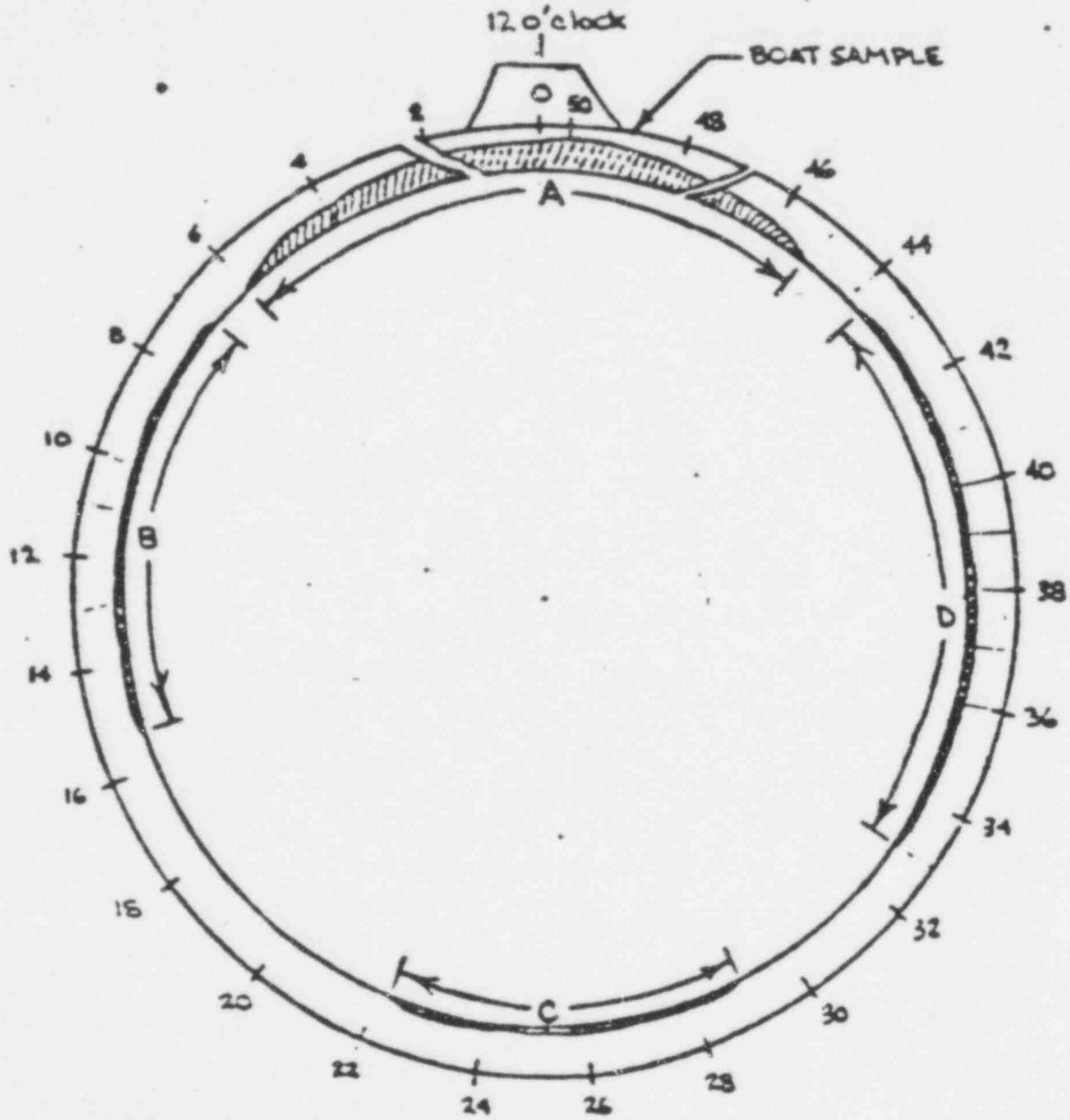


SUBJECT
NO.

130

TITLE DONALD C. COOK - LOOP 3, UNIT 2					PAGE
PROJECT	ENGR.	DATE	CHK.	DATE	CHK. DATE

DONALD C. COOK - LOOP 3, UNIT 2
ULTRASONIC TEST RESULTS
FEEDWATER ELBOW*



DEFECT DEPTHS VIA SECTIONING

AREA	DEPTH
A	0.5"
B	~0.03"
C	~0.02"
D	~0.02"

* VIEW IS FROM STEAM GENERATOR TOWARD ELBOW.

SUBJECT NO.

547 201

131

3M CATALOG NO. 3M CENTER, ST. MADE IN U.S.A.

STATUS OF FEEDWATER LINE CRACKING
(7/6/79)

AMERICAN ELECTRIC POWER	DONALD C. COOK	UNITS 1 & 2	RT	CRACKS
SWEDISH STATE POWER BOARD	RINGHALS	UNIT 2	RT/UT	CLEAN
NORTH STATES POWER	PRAIRIE ISLAND	UNIT 1	RT	CLEAN
VIRGINIA ELECTRIC & POWER COMPANY	SURRY	UNIT 1	RT	CRACKS
COMMONWEALTH EDISON	ZION	UNIT 1	RT	CLEAN
FLORIDA POWER & LIGHT COMPANY	TURKEY POINT	UNIT 4	RT	CLEAN
ALABAMA POWER COMPANY	JOSEPH M. FARLEY	UNIT 1	RT	CLEAN
CAROLINA POWER & LIGHT COMPANY	H. B. ROBINSON	UNIT 2	RT	CRACKS
WISCONSIN PUBLIC SERVICE	KEWAUNEE	UNIT 1	RT/UT	CRACKS
SOUTHERN CALIFORNIA EDISON	SAN ONOFRE	UNIT 1	RT	CRACKS
PORTLAND GENERAL ELECTRIC	TROJAN	UNIT 1	RT	CLEAN

5-21-24

W WRD

RESEARCH ACTIVITIES 1979/80 PROGRAMS

PRESENTATION BY T. R. MAGER, MANAGER

METALLURGICAL AND NDE ANALYSIS

W NTD

547 203

WESTINGHOUSE RESEARCH ACTIVITIES
NEW PROGRAMS 1979/1980

- CORROSION FATIGUE CHARACTERIZATION OF IRRADIATED REACTOR PRESSURE VESSEL STEELS
- DEVELOPMENT OF A CRACK ARREST TOUGHNESS DATA BANK FOR IRRADIATED RVP MATERIALS
- STEADY STATE RADIATION EMBRITTLEMENT OF REACTOR VESSELS
- ADAPTIVE LEARNING NETWORKS FOR ULTRASONIC TESTING
- MATERIALS EVALUATION PROGRAM FOR REPLACEMENT OF HIGH COBALT FACING ALLOYS
- DEFECT SIZING BY ULTRASONIC TESTING AND COMPARISON WITH RADIOGRAPHIC TESTING
- DEVELOPING CONTROLLED OR PROGRAMMED FLAWS IN HEAVY SECTION WELDMENTS
- RESIDUAL ELEMENTS EFFECTS ON TOUGHNESS OF FERRITIC STEELS
- HIGH STRENGTH STAINLESS STEELS WITH IMPROVED STRUCTURAL STABILITY AND FATIGUE PROPERTIES

547 204

WESTINGHOUSE WRD RESEARCH ACTIVITIES

1979/1980 PROGRAMS

- VESSEL HEAT TRANSFER AFTER LOCA TEST
- IMPROVEMENT IN LEFM ANALYSIS
- ELASTIC-PLASTIC FRACTURE METHODOLOGY
- FRACTURE PROBABILITY OF NSSS COMPONENTS
- CRACK ARREST METHODOLOGY
- FATIGUE STRENGTH LIMITS FOR AUSTENITIC STAINLESS STEEL
- AGING OF CAST STAINLESS STEELS
- EFFECT OF HIGH TEMPERATURE PRIMARY WATER ON THE STRESS CORROSION CRACKING OF REACTOR VESSEL STEELS
- EFFECTS OF HIGH TEMPERATURE PRIMARY REACTOR WATER ON FATIGUE CRACK GROWTH OF REACTOR VESSEL STEELS
- FATIGUE AND FRACTURE TOUGHNESS CHARACTERIZATION OF FERRITIC STEELS AND WELDMENTS
- RELIABILITY OF ULTRASONIC TESTS OF CENTRIFUGALLY CAST PIPE WELDMENTS
- FEASIBILITY AND METHODOLOGY FOR THERMAL ANNEALING AN EMBRITTLED REACTOR VESSEL

FEASIBILITY AND METHODOLOGY FOR THERMAL ANNEALING AN EMBRITTLED REACTOR VESSEL**

PROGRAM OBJECTIVE:

DEVELOPMENT OF AN OPTIMAL IN SITU, THERMAL ANNEALING METHODOLOGY FOR REACTOR VESSELS WHICH MAXIMIZES FRACTURE TOUGHNESS RECOVERY, MINIMIZES RE-EXPOSURE SENSITIVITY, AND MINIMIZES DOWNTIME.

DESCRIPTION OF PROGRAM:

COMPACT TENSION AND CHARPY V-NOTCH IMPACT ENERGY SPECIMENS FABRICATED FROM HIGH COPPER WELDMENTS WILL BE IRRADIATED IN THE UVAR. THE EFFECTS OF ANNEALING TIME, ANNEALING TEMPERATURE, AND FLUENCE ON THE DROP IN UPPER SHELF ENERGY AND THE INCREASE IN TRANSITION TEMPERATURE WILL BE STUDIED.

AN ASSESSMENT WILL BE MADE OF THE VARIOUS PROPOSED METHODS OF THERMAL ANNEALING AND THE SYSTEM'S CAPABILITY WITH THE PROPOSED METHODS.

STATUS:

* COMPLETED THE FIRST IRRADIATION CYCLE.
* STARTED THE SECOND IRRADIATION CYCLE.
* CHARACTERIZED THE PRE-IRRADIATION MICRO-STRUCTURE AND MECHANICAL PROPERTIES OF THE THREE AS-RECEIVED WELDMENTS.
* A TOPICAL REPORT, "CHARACTERIZATION OF THE UNIVERSITY OF VIRGINIA RESEARCH REACTOR RADIATION ENVIRONMENT," (WCAP 9429) WAS COMPLETED AND ISSUED.

** EPRI SPONSORED PROGRAM.

547 206

CORROSION FATIGUE CHARACTERIZATION OF IRRADIATED REACTOR PRESSURE VESSEL STEELS**

PROGRAM OBJECTIVES:

- DEVELOP AND ANALYZE CORROSION FATIGUE CRACK GROWTH RATE DATA FOR IRRADIATED RPV STEELS.
- BY COMPARING THE DATA OBTAINED WITH EXISTING INFORMATION ON THE BEHAVIOR OF IRRADIATED MATERIALS, ASSESS (1) WHETHER IRRADIATION HAS AN IMPORTANT EFFECT ON THE GROWTH RATE AND (2) WHETHER MATERIALS IRRADIATED IN POWER AND TEST REACTORS SHOW SIMILAR CORROSION FATIGUE BEHAVIOR.

A SECONDARY OBJECTIVE IS TO PROVIDE ASSISTANCE TO EPRI IN COORDINATING THE DEVELOPMENT OF MATHEMATICAL MODELS FOR CORROSION FATIGUE CRACK GROWTH IN RPV STEELS UNDER BOTH LABORATORY AND SERVICE CONDITIONS.

DESCRIPTION OF PROGRAM:

THE PROGRAM COMPLEMENTS THE EPRI-BABCOCK AND WILCOX (B&W) CORROSION FATIGUE CHARACTERIZATION OF REACTOR VESSEL STEELS PROGRAM THROUGH AN INVESTIGATION OF CORROSION FATIGUE CRACK GROWTH IN IRRADIATED MATERIAL. IN ADDITION TO SURVEILLANCE CAPSULE SPECIMENS TO BE PROVIDED BY WESTINGHOUSE, B&W IS TO SUPPLY SIX MATERIALS FROM WHICH SPECIMENS WILL BE MACHINED, IRRADIATED, AND TESTED.

THE PROGRAM ALSO INCLUDES DATA ANALYSIS OF THE RESULTS AND ASSISTANCE TO EPRI IN COORDINATING THE DEVELOPMENT OF MATHEMATICAL MODELS FOR CORROSION FATIGUE CRACK GROWTH IN REACTOR PRESSURE VESSEL STEELS.

STATUS:

- PROCUREMENT OF SURVEILLANCE CAPSULE SPECIMENS FROM UNION ELECTRICA ZORITA PLANT COMPLETED.
- MACHINING OF SPECIMENS FOR IRRADIATION IN UVAR UNDERWAY.

547 207 105

** EPRI SPONSORED PROGRAM

DEVELOPMENT OF A CRACK ARREST TOUGHNESS DATA BANK FOR IRRADIATED RPV MATERIALS**

PROGRAM OBJECTIVES:

° DETERMINE THE PRE- AND POST-IRRADIATION CRACK ARREST TOUGHNESS IN TERMS OF K_{Ia} AND K_{Im} FOR REACTOR VESSEL MATERIALS TYPICAL OF

-- CURRENT OPERATING PLANTS AND EARLY MELTING AND WELDING PRACTICES.

-- CURRENT MELTING AND WELDING PRACTICES.

° EVALUATE (AND IMPROVE) PROCEDURES FOR PREDICTING IRRADIATED CRACK ARREST TOUGHNESS.

DESCRIPTION OF PROGRAM:

CRACK ARREST SPECIMENS (PROPOSED ASTM) FABRICATED FROM HIGH COPPER - LOW UPPER SHELF IMPACT ENERGY AND LOW COPPER - HIGH UPPER SHELF IMPACT ENERGY MATERIALS WILL BE IRRADIATED IN THE UVAR. POST-IRRADIATION CRACK ARREST TOUGHNESS DATA WILL BE GENERATED. J_{Ic} AND CHARPY IMPACT SPECIMENS WILL ALSO BE EVALUATED FOR CORRELATION WITH THE CRACK ARREST TOUGHNESS DATA.

STATUS:

° PRELIMINARY SPECIMEN CAPSULE DESIGN COMPLETED.

** EPRI SPONSORED PROGRAM.

547 208

STEADY-STATE RADIATION EMBRITTLEMENT OF REACTOR VESSELS**

PROGRAM OBJECTIVES:

- VERIFY THE CONSISTENCY OF A "STEADY-STATE" IRRADIATION EMBRITTLEMENT WHICH HAS BEEN OBSERVED IN SURVEILLANCE CAPSULE TESTS.

- DETERMINE THE MECHANISMS INVOLVED IN RADIATION DAMAGE SATURATION IN PRESSURE VESSEL STEELS.

DESCRIPTION OF PROGRAM:

THE WORK INCLUDES TESTING SPECIMENS FROM TEN NUCLEAR REACTOR SURVEILLANCE CAPSULES, PERFORMING A STATISTICAL ANALYSIS OF TEST DATA, AND CONDUCTING METALLURGICAL TESTING TO DEVELOP AN UNDERSTANDING OF THE MECHANISM(S) INVOLVED SO AS TO PERMIT THE POSSIBLE DEVELOPMENT OF A PREDICTIVE MECHANISTIC MODEL.

STATUS:

- RECEIVED POINT BEACH NO. 2 CAPSULE R.

- STATISTICAL ANALYSIS OF EXISTING SURVEILLANCE CAPSULE DATA UNDERWAY.

** EPRI SPONSORED PROGRAM.

NOTE: "SATURATION" EFFECT OBSERVED IN SURVEILLANCE CAPSULE TEST RESULTS FROM LONG TERM CAPSULES FROM PT. BEACH #1, CONNECTICUT YANKEE, AND SAN ONOFRE #1.

RELIABILITY OF ULTRASONIC TESTING OF AUSTENITIC MATERIALS AND WELDS

PROGRAM OBJECTIVES:

A) DETERMINE THE MINIMUM THROUGH-WALL DIMENSIONS OF INSIDE DIAMETER AND OUTSIDE DIAMETER CRACKS THAT CAN BE RELIABLY DETECTED WHEN ULTRASONICALLY TESTING CENTRIFUGALLY CAST STAINLESS STEEL PRIMARY PIPING WELDS.

B) EVALUATE THE INFLUENCE OF OPERATOR PROFICIENCY, CRACK TYPE, WELD POSITION, AND METALLURGICAL STRUCTURE ON FLAW DETECTION.

DESCRIPTION OF PROGRAM:

A) PRODUCE 15 CENTRIFUGALLY CAST STAINLESS STEEL PRIMARY PIPING WELDMENTS.

B) FABRICATE TWO STRESS CORROSION CRACK SAMPLES, 90 FATIGUE CRACK SAMPLES, 45 CONTROL SAMPLES, AND ONE CALIBRATION SAMPLE.

C) PERFORM ULTRASONIC TESTS USING A 40° REFRACTED LONGITUDINAL WAVE TEST FIXTURE, SPECIAL DUAL AND FOCUSSED TRANSDUCERS, AND IMMERSION TESTS.

D) PERFORM DETAILED METALLOGRAPHIC ANALYSIS AT TEN SPECIFIC LOCATIONS IN VARIOUS SAMPLES.

E) PERFORM STATISTICAL TEST ANALYSIS BASED ON DATA FROM 40° REFRACTED LONGITUDINAL WAVE TEST DATA.

547 210

RELIABILITY OF ULTRASONIC TESTING OF AUSTENITIC MATERIALS AND WELDS (Continued . . .)

ACCOMPLISHMENTS:

* TWO STRESS CORROSION SAMPLES, 60 FATIGUE CRACK SAMPLES, AND 30 CONTROL SAMPLES HAVE BEEN EXAMINED BY THREE OPERATORS USING STANDARD TEST PROCEDURES AND THE 40° LONGITUDINAL WAVE FIXTURE. THE AVERAGE CRACK DEPTH NEEDED BEFORE ALL THREE OPERATORS PROPERLY CHARACTERIZE THE CRACK SAMPLE AND A NON-CRACKED CONTROL SAMPLE IS APPROXIMATELY 15% OF THE WALL THICKNESS.

* SEVERAL EUROPEAN DUAL AND FOCUSSED TRANSDUCERS HAVE BEEN EVALUATED. A 70° UNIT WAS VERY SUCCESSFUL IN LOCATING CRACKS EMANATING FROM THE SAME SURFACE AS THE SEARCH UNIT IS SITUATED. SOME OF THE 45° DUAL SEARCH UNITS APPEAR PROMISING AND WILL BE EVALUATED IN MORE DETAIL.

DEFECT SIZING BY ULTRASONIC TESTING AND COMPARISON WITH RADIOGRAPHIC TESTING

PROGRAM OBJECTIVES:

A) IMPROVE DEFECT CHARACTERIZATION IN RELATION TO FRACTURE MECHANICS CALCULATION REQUIREMENTS.

B) DETERMINE TEST PARAMETERS WHICH HAVE THE GREATEST EFFECT ON SIZING ACCURACY.

C) INVESTIGATE NEW TECHNIQUES WHICH MAY IMPROVE DEFECT SIZING ACCURACY.

D) COMPARE ULTRASONIC TESTING VS. RADIOGRAPHIC TESTING SIZING ACCURACY.

E) ESTABLISH NORMAL LIMITS OF CONVENTIONAL ULTRASONIC TESTING AND RADIOGRAPHIC TESTING.

DESCRIPTION OF PROGRAM:

A) INSERT 24 DEFECTS OF A KNOWN LENGTH, THROUGH-WALL THICKNESS, ORIENTATION, AND DEPTH FROM THE SURFACE IN THREE NOZZLE CUTOUTS.

B) ULTRASONICALLY EXAMINE THE THREE NOZZLE CUTOUTS USING A VARIETY OF TEST PROCEDURES, SIZING CRITERIAS, OPERATORS, TEST INSTRUMENTS, TEST FREQUENCIES AND SEARCH UNITS.

C) EVALUATE TEST RESULTS TO DETERMINE CORRELATION BETWEEN ULTRASONIC TEST PREDICTED SIZE AND ACTUAL SIZE AND DETERMINE PARAMETERS CAUSING THE MOST VARIATION.

D) MAKE RECOMMENDATIONS ON HOW TO IMPROVE ULTRASONIC TESTING SIZING ACCURACY.

E) CONDUCT ROUND-ROBIN STUDY WITH FRENCH PARTIES. 547 212

F) PERFORM CONVENTIONAL AND UNIQUE RADIOGRAPHIC TESTING OF THE THREE NOZZLES. PERFORM CORRELATION STUDY OF RADIOGRAPHIC TESTING VS. ULTRASONIC TESTING.

DEFECT SIZING BY ULTRASONIC TESTING AND COMPARISON WITH RADIOGRAPHIC TESTING (Continued . . .)

ACCOMPLISHMENTS:

* THREE NOZZLE CUTOUTS HAVE BEEN OBTAINED.

* MATERIAL FOR FATIGUE CRACK SPECIMENS HAS BEEN OBTAINED.

* DETAILED PROGRAM HAS BEEN DEVELOPED AT OFFSHORE POWER SYSTEMS SITE.

DEVELOPING CONTROLLED OR PROGRAMMED FLAWS IN HEAVY SECTION WELDMENTS**

PROGRAM OBJECTIVES:

A) DESIGN A FLAW INSERT GEOMETRY OR GEOMETRIES WHICH WILL PROVIDE THE NEEDED FLEXIBILITY TO VARY KEY FLAW SIZE, SHAPE, ORIENTATION, AND LOCATION PARAMETERS, MINIMIZE THE EFFECT OF WELDING ON PROPOSED FLAW SIZE, AND PERMIT EASY PLACEMENT OF THE INSERT INTO A FULL PENETRATION WELD.

B) DEVELOP AN INSERT CRACK-SEALING TECHNIQUE WHICH PROVIDES ASSURANCE THAT CRACK LENGTH AND THROUGH-WALL DIMENSIONS ARE NOT AFFECTED BY SUBSEQUENT WELDING OPERATIONS.

C) ESTABLISH THE OPTIMUM COMBINATION OF WELD PROCEDURES, WELD PREPARATION GEOMETRIES, AND OTHER PARAMETERS WHICH MINIMIZE SHRINKAGE STRESSES AND RESULTS IN MINIMUM FLAW DISTORTION.

D) ASSESS THE ABILITY OF THE WELDING TECHNIQUE TO PROVIDE REPEATABLE RESULTS.

E) DETERMINE THE DESIRED VERSUS ACTUAL FLAW SIZE TOLERANCE WHICH CAN BE ACHIEVED IN PRACTICE.

DESCRIPTION OF PROGRAM:

THIS PROGRAM WILL DEVELOP PROCEDURES FOR PRODUCING "REAL" DEFECTS OF A KNOWN SIZE, SHAPE, AND ORIENTATION AT SPECIFIC LOCATIONS IN HEAVY SECTION WELDMENTS. THE FLAW GENERATING TECHNIQUES AND WELDING PARAMETERS USED TO PRODUCE THE CONTROLLED DEFECTS WILL BE CRITICALLY ASSESSED TO DETERMINE WHICH PROCEDURE PRODUCES THE MOST REPEATABLE AND ACCURATE RESULTS AS DETERMINED BY NONDESTRUCTIVE TESTS AND METALLOGRAPHIC INVESTIGATION OF LABORATORY SPECIMENS. THE LENGTH, DEPTH, ORIENTATION, THROUGH-WALL THICKNESS, AND LOCATION OF THE FLAWS WILL BE VARIED TO SIMULATE THE NATURAL DEFECTS MOST LIKELY TO OCCUR IN VESSEL WELDS DURING MANUFACTURE AND SERVICE.

DEVELOPING CONTROLLED OR PROGRAMMED FLAWS IN HEAVY SECTION WELDMENTS
(continued . . .)

ACCOMPLISHMENTS:

* TWO TENTATIVE INSERT DESIGNS HAVE BEEN DEVELOPED FOR FATIGUE CRACK FLAW DEVELOPMENT.

* AN INSERT CRACK-SEALING TECHNIQUE FOR FATIGUE CRACK FLAWS AND OTHER FLAWS HAS BEEN DEVELOPED. THE TECHNIQUE, WHICH UTILIZES A MULTITUDE OF SMALL, LOW-HEAT INPUT, TIG WELD PASSES TO FORM A 1/4 INCH LAYER OF SOUND MATERIAL, NEEDS TO BE DUPLICATED ON AT LEAST ONE ADDITIONAL SAMPLE FOR VALIDATION.

** EPRI SPONSORED PROGRAM

ADAPTIVE LEARNING NETWORKS FOR ULTRASONIC TESTING

PROGRAM OBJECTIVES:

A) DEVELOP SIGNAL PROCESSING METHODS WHICH ARE NOT DEPENDENT ON TIME AND AMPLITUDE INFORMATION ONLY.

B) DEMONSTRATE THE CAPABILIT: OF THE SIGNAL PROCESSING SYSTEM BY DISCRIMINATING BETWEEN SIGNALS FROM FATIGUE CRACK AND IRRELEVANT STRUCTURE SIGNALS IN A SERIES OF CENTRIFUGALLY CAST STAINLESS STEEL WELDMENTS.

DESCRIPTION OF PROGRAM:

CONVENTIONAL ULTRASONIC TESTING SCREEN PRESENTATIONS DISPLAY ONLY TIME AND AMPLITUDE DATA FROM REFLECTORS. INFORMATION CONCERNING PARAMETERS SUCH AS FREQUENCY CONTENT AND PHASE RELATIONSHIPS ARE FILTERED BY THE TEST SYSTEMS ELECTRONIC CIRCUITRY. A PROMISING DATA EVALUATION TECHNIQUE WHICH DEVELOPS A LIST OF ALL SIGNIFICANT PARAMETERS AND PARAMETER RELATIONSHIP WILL BE STUDIED.

IN THIS PROGRAM, DATA WILL BE GATHERED ON CRACKED AND UNCRACKED CENTRIFUGALLY CAST STAINLESS STEEL PIPE SAMPLES, CANDIDATE RELATIONSHIPS WILL BE IDENTIFIED, AND MULTIPLE COMPUTERIZED ANALYSIS WILL BE PERFORMED TO DEVELOP A MATHEMATICAL MODEL CALLED AN ALGORITHM. THE ALGORITHM WILL HAVE THE CAPABILITY TO PERMIT DIFFERENTIATION OF SOME ASPECT OF AN ULTRASONIC REFLECTION. A SERIES OF ALGORITHMS, EACH WITH A SPECIFIC DISCRIMINATORY FUNCTION, WILL BE COMBINED TO SIGNIFICANTLY INCREASE THE RELIABILITY OF THE DEFECT EVALUATION PROCESS.

ADAPTIVE LEARNING NETWORKS FOR ULTRASONIC TESTING (Continued . . .)

ACCOMPLISHMENTS:

* THE TEST SYSTEM TO DIGITIZE R-F WAVEFORMS HAS BEEN SET UP.
* THE ULTRASONIC INSTRUMENTATION HAS BEEN INTERFACED WITH THE ECLIPSE COMPUTER VIA THE BIOMATION 8100 AND THE INTEL SDK 80. ALL INTERFACING SOFTWARE HAS BEEN DEVELOPED AND THE SYSTEM IS OPERATIONAL.
* WAVEFORM STORAGE FILES HAVE BEEN ESTABLISHED AND WAVEFORM DISPLAY SOFTWARE HAS BEEN DEVELOPED.
* PRELIMINARY DATA ANALYSIS CAPABILITIES NECESSARY TO OBTAIN THE ADAPTIVE LEARNING NETWORK VECTORS HAVE BEEN DEVELOPED.

AGING OF CAST STAINLESS STEEL

PROGRAM OBJECTIVES:

EVALUATE THE EFFECT OF LONG TERM THERMAL AGING ON THE PROPERTIES OF CAST STAINLESS STEEL PIPING.

DESCRIPTION OF PROGRAM:

FRACTURE TOUGHNESS CHARACTERISTICS INCLUDING J_{Ic}, CHARPY V-NOTCH, AND TENSILE PROPERTIES WILL BE DETERMINED ON CENTRIFUGALLY CAST STAINLESS STEEL PIPE MATERIALS THERMALLY AGED TO SIMULATE SERVICE. FATIGUE CRACK GROWTH RATE DA/DN VS. ΔK WILL ALSO BE DETERMINED IN AIR AND IN PWR WATER ENVIRONMENT. PIPING INTEGRITY WILL BE ASSESSED CONSIDERING THESE MATERIAL PROPERTY DATA. THE ASSESSMENT METHODOLOGY WILL BE CONFIRMED WITH A SERIES OF MODEL PIPE BURST TESTS USING AGED AND UNAGED CAST PIPING MATERIALS BOTH FLAWED AND UNFLAWED.

ACCOMPLISHMENTS:

° MATERIALS AGED AT 800°F (427°C) FOR 3000 HOURS SHOWED A REDUCTION IN CHARPY V-NOTCH IMPACT ENERGY--~ 160 FT-LBS TO ~ 30 FT-LBS AT ROOM TEMPERATURE AND TO ~ 73 FT-LBS AT 550°F.

* CRACK GROWTH CHARACTERISTICS OF AGED AND UNAGED MATERIAL IN AIR AND IN PWR WATER ENVIRONMENT WERE COMPARABLE.

* SLOPE OF J RESISTANCE CURVES AT 600°F WAS NOT AFFECTED BY AGING.

* SLOPE OF J RESISTANCE OF AGED MATERIAL AT ROOM TEMPERATURE WAS REDUCED AND WAS APPROXIMATELY EQUAL TO THE SLOPE AT 600°F.

* J_{Ic} TOUGHNESS OF AGED STAINLESS STEEL AT ROOM TEMPERATURE AND 600°F WAS LESS THAN FOR THE UNAGED CONDITION.

* PRELIMINARY ANALYSIS OF THE EFFECT OF AGING ON PIPING SHOWED NO EFFECT ON PIPING INTEGRITY - PRELIMINARY REPORT COMPLETED.

* AGING IS NOW BEING COMPLETED ON SAMPLE SECTIONS FOR THE MODEL PIPE BURST TESTS.

547 218

FATIGUE AND FRACTURE TOUGHNESS CHARACTERIZATION OF FERRITIC STEELS AND WELDMENTS

PROGRAM OBJECTIVES:

A) EVALUATION OF UNIRRADIATED AND IRRADIATED FATIGUE CRACK GROWTH BEHAVIOR OF REACTOR VESSEL MATERIAL IN A PWR ENVIRONMENT.

B) EVALUATION OF THE UNIRRADIATED AND IRRADIATED FRACTURE TOUGHNESS BEHAVIOR OF REACTOR VESSEL MATERIAL.

C) STUDY THE NEED AND FEASIBILITY OF IN-PILE FATIGUE CRACK GROWTH RATE MEASUREMENTS.

DESCRIPTION OF PROGRAM:

DATA ARE BEING GENERATED ON A533 GRADE B CLASS 1 STEEL PLATE AND A508 CL 3 FORGING MATERIALS TO PROVIDE A FRACTURE TOUGHNESS (STATIC, J_{Ic} AND DYNAMIC, K_{ID}) AND ENVIRONMENTAL FATIGUE CRACK GROWTH DATA BASE FOR DEFINING DESIGN INPUT FOR FRACTURE MECHANICS EVALUATION OF NSSS COMPONENTS. THE NEED AND FEASIBILITY OF IN-PILE FATIGUE CRACK GROWTH RATE MEASUREMENTS OF THE SAME MATERIAL IS ALSO BEING EVALUATED.

STATUS:

° UNIRRADIATED DYNAMIC FRACTURE TOUGHNESS TESTING COMPLETED - A533 GRADE B CLASS 1, A508 CLASS 2, AND A508 CLASS 3 TOUGHNESS ESSENTIALLY THE SAME.

* UNIRRADIATED STANDARD AND INSTRUMENTED PRECRACKED CHARPY TESTING COMPLETED.

° UNIRRADIATED ENVIRONMENTAL FATIGUE CRACK GROWTH TESTING IN PROGRESS.

* IRRADIATED DYNAMIC FRACTURE TOUGHNESS TESTING COMPLETED. SPECIMENS IRRADIATED AT 550°F TO A FLUENCE OF 3×10^{19} n/cm² (E > 1 MEV).

* IRRADIATED STANDARD AND INSTRUMENTED PRECRACKED CHARPY TESTING IN PROGRESS AND ABOUT 50% COMPLETE.

* ENVIRONMENTAL (PWR) FATIGUE CRACK GROWTH CHAMBER IS IN THE WESTINGHOUSE MHI AND HAS SUCCESSFULLY PERFORMED A DUMMY TEST.

FATIGUE STRENGTH LIMITS FOR AUSTENITIC STAINLESS STEEL

(20% COLD WORKED TYPE 316 AND ANNEALED TYPE 304)

PROGRAM OBJECTIVES:

A) DETERMINE THE EFFECT OF PRIOR PLASTIC STRAINING ON FATIGUE STRENGTH (TO FAILURE ON 3 X 10^5 CYCLES).

B) DETERMINE LOW CYCLE FATIGUE BEHAVIOR (TO FAILURE ON 3 X 10^5 CYCLES).

C) DETERMINE FATIGUE STRENGTH AT 10^6 AND 3.16 X 10^8 CYCLES.

D) DETERMINE DAMAGE FORMULATION FOR COMPLEX FATIGUE LOADINGS.

DESCRIPTION OF PROGRAM:

DATA ON LOW AND HIGH CYCLE FATIGUE RESISTANCE PROPERTIES OF AUSTENITIC STAINLESS STEEL WILL BE ESTABLISHED. THE RESULTANT DATA WILL BE USED AS AN ASSESSMENT OF FATIGUE DESIGN FACTORS.

ACCOMPLISHMENTS:

° FATIGUE STRENGTHS WERE OBTAINED ON 20% COLD WORKED TYPE 316 AND ANNEALED TYPE 304 UP TO 10^6 CYCLES UNDER TOTAL STRAIN CONTROL AND THE HIGH CYCLE FATIGUE FROM 10^6 TO 3.16 X 10^8 UNDER LOAD CONTROL.

° FATIGUE DATA ARE BEING ANALYZED FROM THIS PROGRAM AND FROM PUBLISHED DATA TO DETERMINE BOTH STRAIN CONTROLLED AND LOAD CONTROLLED DESIGN CURVES FOR UP TO A LARGE NUMBER OF CYCLES > 10^8.

EFFECT OF HIGH TEMPERATURE PRIMARY
WATER ON THE STRESS CORROSION CRACKING
OF REACTOR VESSEL STEELS**

PROGRAM OBJECTIVE:

TO DETERMINE THE VALUE OF K_{ISCC}, IF POSSIBLE, FOR PRESSURE VESSEL STEELS AND ASSOCIATED WELDS.

DESCRIPTION OF PROGRAM:

RESULTS OF STATIC LOAD STRESS CORROSION (K_{ISCC}) TESTS INDICATE THAT THESE MATERIALS DO NOT CRACK UNDER A CONSTANTLY APPLIED LOADING IN THE PWR ENVIRONMENT. A PRELIMINARY SERIES OF RISING LOAD TESTS CONDUCTED IN HYDROGEN SULFIDE GAS SHOWED THAT THE MATERIALS WERE NOT PRONE TO STRESS CORROSION CRACKING IN HYDROGEN ENVIRONMENTS. THESE WERE FOLLOWED BY LONG TIME TESTS OF BOLT-LOADED 1T-WOL SPECIMENS WHICH WERE SUBJECTED TO THE PWR ENVIRONMENT DURING THE CRACK GROWTH TESTS, SET IN THE BOTTOM OF TWO CHAMBERS. A SERIES OF THREE OF THESE SPECIMENS WERE REMOVED FROM TESTING AFTER NEARLY TWO YEARS, AND BOTH MACROSCOPIC AND MICROSCOPIC EXAMINATION SHOWED NO CRACKING.

STATUS:

° ANOTHER SERIES OF SPECIMENS CONTINUES IN TESTING AND HAS SHOWN NO CRACK EXTENSION AFTER OVER FOUR YEARS OF TESTING.

* DETAILS HAVE BEEN PUBLISHED IN HSST QUARTERLY PROGRESS REPORT - PERIOD MARCH-MAY 1979.

**W PWRSD - NRC/HSST PROGRAM

547 221

EFFECTS OF HIGH TEMPERATURE PRIMARY REACTOR WATER ON FATIGUE CRACK GROWTH OF REACTOR VESSEL STEELS**

PROGRAM OBJECTIVE:

CHARACTERIZE FATIGUE CRACK GROWTH RATE PROPERTIES OF FERRITIC VESSEL STEELS EXPOSED TO PRESSURIZED WATER REACTOR COOLANT ENVIRONMENT.

DESCRIPTION OF PROGRAM:

FOUR ENVIRONMENTAL CHAMBERS ARE IN USE AND THE FOLLOWING AREAS ARE BEING INVESTIGATED:

- CRACK GROWTH RATE AT HIGH ΔK
- CRACK GROWTH IN WELDMENTS
- STARTING CONDITION EFFECTS
- MECHANISMS OF CORROSION FATIGUE CRACK GROWTH

ALL OF THE FOUR CHAMBERS OPERATE AT 14 MPA AND 288°C. THREE OF THE CHAMBERS ARE FUNDED BY THE NRC/HSST PROGRAM AND THE OTHER WITH INTERNAL FUNDING.

STATUS:

° TEST UNDERWAY TO CONSIDER WHETHER THE TEST CONDITIONS ARE TRULY REPRESENTATIVE OF PWR REACTOR CONDITIONS, AND WHETHER STARTING CONDITIONS AFFECT THE RESULTS OF THE TESTS.

° HOLD TIME RESULTS IN LESS CRACK GROWTH THAN NO HOLD TIME.

* CRACK GROWTH IN HAZ IS EQUIVALENT TO THAT IN WELDS FOR THOSE TESTED THUS FAR.

** W PWRSD - NRC/HSST SPONSORED PROGRAM.

547 222

MATERIALS EVALUATION PROGRAM FOR REPLACEMENT OF HIGH COBALT HARD FACING ALLOYS

PROGRAM OBJECTIVES:

A) OBTAIN SCREENING TEST DATA TO SELECT CANDIDATE LOW COBALT MATERIALS WITH ACCEPTABLE WEAR AND CORROSION PROPERTIES.

B) PERFORM COMPONENT TESTS FOR VALVES, PUMPS, AND CONTROL ROD DRIVE MECHANISMS EITHER FULL SCALE OR SIMULATED.

C) REPLACE HIGH COBALT HARD FACES OR SOLID WEAR RESISTANT MATERIALS WITH LOW COBALT MATERIALS WHICH WILL RESULT IN REDUCING OUT-OF-CORE RADIATION DOSE BUILDUP.

DESCRIPTION OF PROGRAM:

THIS PROGRAM INVOLVES:

A) SCREENING OF AVAILABLE LOW COBALT MATERIAL BY METALLURGICAL EVALUATION OF HARDFACED DEPOSITS ON MATERIALS.

B) SCREENING OF MATERIALS FROM (A) AS WELL AS SOLID LOW COBALT MATERIALS BY WEAR AND CORROSION TESTS.

C) SELECTION OF OPTIMUM MATERIALS FROM (A) AND (B) FOR COMPONENT TESTS UNDER SIMULATED SERVICE CONDITIONS.

ACCOMPLISHMENTS:

* LOW COBALT MATERIALS HAVE BEEN SELECTED FOR METALLURGICAL AND WELD-ABILITY TESTS.

* TEST WEAR SPECIMENS HAVE BEEN PREPARED FROM ACCEPTABLE HARD FACED (WELDABILITY) TESTS.

* WEAR TEST EQUIPMENT HAS BEEN MODIFIED FOR LOW (~ 5000 PSI) AND HIGH (~15,000 PSI) LOAD TESTING.

RESIDUAL ELEMENTS EFFECTS ON TOUGHNESS OF FERRITIC STEELS

PROGRAM OBJECTIVES:

A) INCREASE THE UNDERSTANDING OF THE EFFECTS OF RESIDUAL ELEMENTS ON THE TOUGHNESS OF PRESSURE VESSEL MATERIALS.

B) INCREASE THE UNDERSTANDING OF THE EFFECTS OF BASE METAL SEGREGATIONS ON THE HEAT AFFECTED ZONE PROPERTIES OF PRESSURE VESSEL MATERIALS.

DESCRIPTION OF PROGRAM:

THIS PROGRAM IS DESIGNED TO:

A) DETERMINE THE RESIDUAL ELEMENT CONTENT IN AT LEAST TEN HEATS OF PRESSURE (PRIMARY) BOUNDARY MATERIALS AND DEVELOP THE EFFECTS OF THE TYPE AND CONCENTRATION OF RESIDUAL ELEMENT ON THE TOUGHNESS OF THESE FERRITIC MATERIALS.

B) DEVELOP, BY MEANS OF PROGRAMMED CHEMICAL ANALYSIS AND SURFACE EVALUATION TECHNIQUES, AN UNDERSTANDING OF THE EFFECTS OF ALLOY AND NONMETALLICS SEGREGATION ON THE HEAT AFFECTED ZONE PROPERTIES OF FERRITIC PRIMARY PRESSURE BOUNDARY MATERIALS.

ACCOMPLISHMENTS:

THIS IS A NEW PROGRAM AND IS JUST NOW BEING INITIATED.

547 224

HIGH STRENGTH STAINLESS STEELS WITH IMPROVED STRUCTURAL STABILITY AND FATIGUE PROPERTIES

PROGRAM OBJECTIVES:

A) OBTAIN AN ALTERNATE HIGH STRENGTH FERRITIC STEEL FOR PWR SERVICE.

B) ESTABLISH FRACTURE TOUGHNESS PROPERTIES, MECHANICAL PROPERTIES, AND CORROSION RESISTANCE DATA ON ALTERNATE HIGH STRENGTH FERRITIC STAINLESS STEEL.

DESCRIPTION OF PROGRAM:

AN ALTERNATE HIGH STRENGTH STAINLESS STEEL WILL BE CHARACTERIZED FOR MECHANICAL PROPERTIES, FRACTURE TOUGHNESS, AND CORROSION RESISTANCE. THE EFFECT OF AGING WILL BE EVALUATED.

ACCOMPLISHMENTS:

* DATA ON ALTERNATE CANDIDATE MATERIALS WERE REVIEWED.

* FERRITIC STAINLESS STEELS WITH DIFFERENT CHEMISTRIES ARE BEING OBTAINED.

IMPROVEMENT IN LEFM ANALYSIS

(3-D ANALYSIS)

PROGRAM OBJECTIVE:

IMPROVE THE PREDICTABILITY OF LEFM METHODS BY INCREASED CONTROL OF THE PRECISION OF THE CALCULATIONAL METHODS AND BETTER ASSESSMENT OF THE FRACTURE CRITERIA.

ACCURATELY PREDICT MARGIN OF SAFETY FOR HIGHLY STRESSED REGIONS OF REACTOR VESSELS UNDER THERMAL SHOCK CONDITIONS.

DESCRIPTION OF PROGRAM:

A "CRACK TIP" ELEMENT HAS BEEN DEVELOPED TO INSERT INTO FINITE ELEMENT MODELS. THIS ELEMENT HAS A SEMI-ELLIPTICAL CRACK MODELED IN IT. A COMPUTER PROGRAM HAS BEEN DEVELOPED TO DETERMINE THE K_I DISTRIBUTION AROUND THE CRACK BORDER BY USING THE PARK'S STIFFNESS DERIVATIVE METHOD. VARIOUS PLATES AND CYLINDERS CONTAINING SEMI-ELLIPTICAL SURFACE FLAWS HAVE BEEN SOLVED UNDER VARIOUS LOADING CONDITIONS WITH ACCURACY WITHIN 8%. OTHER GEOMETRIES WILL BE INVESTIGATED TO DEVELOP A TRULY THREE-DIMENSIONAL FRACTURE CRITERION.

THE EFFECT OF VESSEL CLADDING INTERACTION ON CRACK INITIATION OF FLAWS IN THE BELT-LINE IS BEING EVALUATED.

IMPROVEMENT IN LEFM ANALYSIS (Continued . . .)

STATUS:

° SOLUTIONS TO LONGITUDINAL SEMI-ELLIPTICAL FLAWS IN REACTOR VESSEL BELT-LINE HAVE BEEN OBTAINED.

° EFFORTS ARE UNDERWAY TO DEVELOP SOLUTIONS FOR CIRCUMFERENTIAL SEMI-ELLIPTICAL FLAWS.

° FINITE ELEMENTS METHODS NEEDED TO DEVELOP NOZZLE CORNER SIF HAVE BEEN DEVELOPED.

* BURIED FLAW ANALYSIS COMPLETED - REPORT IN PREPARATION.

* FRACTURE MECHANICS METHOD FOR TREATING NOZZLE CORNER FLAW BEING DEVELOPED - REPORT, EARLY 1980.

* K_I DISTRIBUTION WILL BE DETERMINED FOR BURIED FLAWS NEAR REACTOR VESSEL STRESS CONCENTRATIONS.

ELASTIC-PLASTIC FRACTURE METHODOLOGY

PROGRAM OBJECTIVES:

EVALUATE THE APPLICABILITY OF VARIOUS ELASTIC-PLASTIC FAILURE CRITERIA TO PRIMARY COOLANT PIPING AND NUCLEAR PRESSURE VESSELS SAFETY RELATED PROBLEMS AND EXTEND, AS NECESSARY, THE METHODS WITH HIGH POTENTIAL TO ASSURE THAT A DIRECT APPLICABILITY IS EVOLVED.

DESCRIPTION OF PROGRAM:

THE FOLLOWING ELASTIC-PLASTIC CRITERIA WILL BE EVALUATED AND EXTENDED AS NECESSARY:

A) J-INTEGRAL
B) COD
C) COA
D) PARIS' DUCTILE TEARING MODEL
E) TWO PARAMETER CRITERIA CONCEPT
F) GENERALIZED ENERGY RELEASE RATE
G) EQUIVALENT ENERGY/VOLUMETRIC ENERGY RATIO

STATUS:

° ELASTIC AND ELASTIC-PLASTIC FRACTURE TOUGHNESS PARAMETERS EVALUATED FOR SMALL SPECIMEN TESTS - REPORT IN PUBLICATION.

° GENERAL FRACTURE CRITERIA EVALUATED - REPORT PREPARED (PART I).

* FRACTURE TOUGHNESS OF LOW CHARPY SHELF ENERGY STEELS - REPORT BEING PREPARED.

547 228

CRACK ARREST METHODOLOGY

PROGRAM OBJECTIVE:

DETERMINE VIABLE DYNAMIC METHOD TO PREDICT CRACK ARREST IN NUCLEAR PRESSURE VESSELS AND APPLY THE METHODS TO PREDICT INTEGRITY OF VESSELS UNDER THERMAL SHOCK SITUATIONS.

DESCRIPTION OF PROGRAM:

CRACK ARREST TESTS ARE BEING PERFORMED TO MEASURE CRACK VELOCITY AND OTHER APPROXIMATE VARIABLES FOR REACTOR VESSEL MATERIALS. THE ULTIMATE GOAL OF THE TESTING PROGRAM IS TO DEVELOP CRACK ARREST TOUGHNESS VARIATION WITH TEMPERATURE ON IRRADIATED REACTOR VESSEL MATERIALS.

THE CRACK ARREST DEPTH OF LONGITUDINAL FLAWS UNDER PRESSURE/THERMAL SHOCK LOADING WILL BE DETERMINED. THE BASIC CAPABILITY TO DETERMINE STRESS INTENSITY FACTORS FOR DYNAMIC LOADING OF RAPIDLY PROPAGATING CRACKS WILL BE DEVELOPED.

STATUS:

° COMPUTER PROGRAM MODIFIED TO INCLUDE NEW DYNAMIC CRACK ARREST METHODOLOGY.

° APPLICATIONS METHODOLOGY IS CURRENTLY UNDER DEVELOPMENT.

* METHOD DEVELOPED FOR OBTAINING CRACK ARREST TOUGHNESS FROM SMALL SPECIMEN TESTING - REPORT UNDER PREPARATION.

547 229

FRACTURE PROBABILITY OF NSSS COMPONENTS

PROGRAM OBJECTIVE:

TO DEVELOP PROBABILISTIC AND STATISTICAL METHODOLOGY FOR THE ASSESSMENT OF STRUCTURAL INTEGRITY IN NSSS COMPONENTS.

DESCRIPTION OF PROGRAM:

PROBABILISTIC CONCEPTS ARE BEING UTILIZED FOR THE DEVELOPMENT AND APPLICATION OF A FRACTURE PROBABILITY MODEL. THE FRACTURE PROBABILITY MODEL INCORPORATES FRACTURE TOUGHNESS AND FATIGUE CRACK GROWTH PROPERTIES, FLAW EXISTENCE AND DETECTION PROBABILITIES AS WELL AS IRRADIATION EFFECTS.

STATUS:

° EVALUATION OF PROBABILITY OF FAILURE DURING HEATUP AND COOLDOWN - $<10^{-8}$.

° IDENTIFIED STATISTICAL METHODS FOR OBTAINING LOWER BOUNDS FOR FRACTURE TOUGHNESS CURVES.

* DEVELOPED METHODOLOGY FOR INFERRING INITIAL FLAW DISTRIBUTION BASED ON AVAILABLE INSPECTION DATE - REPORT PREPARED.

547 230

VESSEL HEAT TRANSFER AFTER LOCA TEST

PROGRAM OBJECTIVES:

A) IMPROVE VESSEL THERMAL ANALYSIS RESULTS (WITH RESULTING IMPROVEMENT IN FRACTURE MECHANICS ANALYSIS) BY DECREASING THE APPLICABLE HEAT TRANSFER COEFFICIENTS ON VESSEL SURFACE FOR THE LARGE LOSS OF COOLANT ACCIDENT.

B) DETERMINE APPROPRIATE HEAT TRANSFER REGIME (FREE, MIXED, OR FORCED).

C) DETERMINE APPROPRIATE HEAT TRANSFER COEFFICIENT CORRELATIONS TO BE USED IN EVALUATION OF REACTOR VESSEL INTEGRITY FOLLOWING THE LARGE LOCA.

DESCRIPTION OF PROGRAM:

* TEST FACILITY HAS BEEN DESIGNED AND BUILT TO TEST FOR FREE AND MIXED CONVECTION HEAT TRANSFER COEFFICIENTS ON THE REACTOR VESSEL INSIDE WALL SURFACE DURING A LARGE LOCA. THE TEST WILL COVER A RANGE OF FLOW TEMPERATURES AND FLOW RATES TYPICAL OF WESTINGHOUSE PWR PLANTS DURING THE LONG-TERM COOLING FOLLOWING THE LARGE LOCA. EQUIPMENT IS BEING CHECKED OUT. DATA COLLECTION TO START THIS FALL.

T-20,21

EPRI

ELECTRIC POWER RESEARCH INSTITUTE PROGRAMS ON MATERIALS AND CORROSION

J. C. DANKO

PRESENTATION TO
MATERIALS SUBCOMMITTEE
OF
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
JULY 10, 1979
WASHINGTON, D.C.

ELECTRIC POWER RESEARCH INSTITUTE

547 232

PRESENTATION TO MATERIALS SUBCOMMITTEE OF ACRS

AGENDA

- PLANT CHEMISTRY AND CORROSION
  - BWR PIPE CRACKING
  - PWR STEAM GENERATOR
  - BASIC THERMODYNAMICS
- PLANT MATERIALS AND PROCESSES
  - SPECIFICATIONS AND PROCESSING
  - STEAM TURBINE MATERIALS
  - FABRICATION TECHNIQUES
  - FIELD OPERATIONS TECHNOLOGY
- PRIMARY AND SECONDARY PRESSURE BOUNDARY
  - MATERIALS PROPERTIES CHARACTERIZATION
  - MATERIALS RESPONSE CHARACTERIZATION
  - ENGINEERING ANALYSES

SUBPROGRAM — APPROACH — TECHNOLOGY

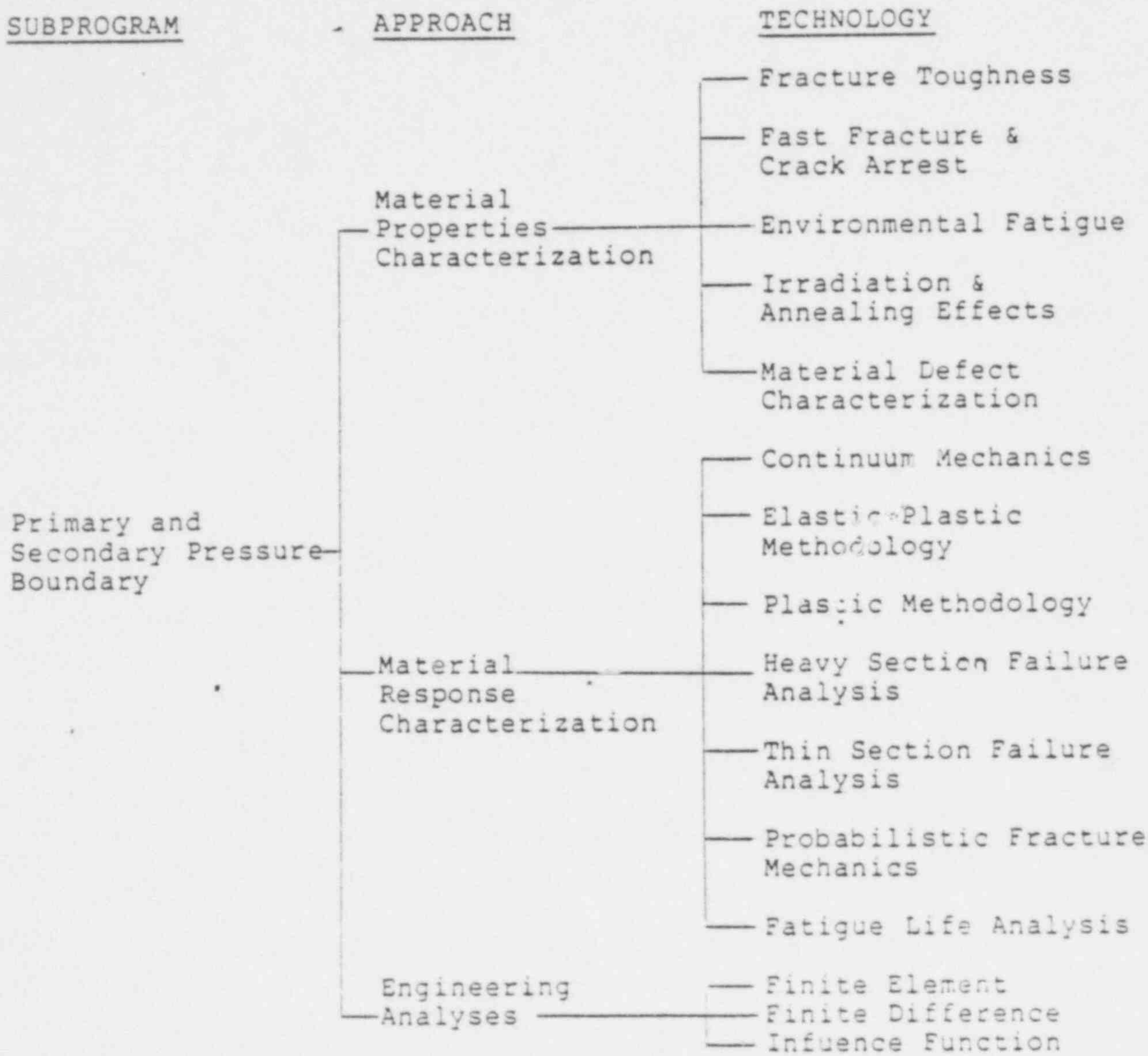
- Plant Chemistry and Corrosion
  - PWR Steam Generator
    - Tube denting
    - Corrosion
    - Secondary Water Chemistry
  - BWR Piping
    - Stress Corrosion Cracking
    - Materials
    - Welding
    - Environment
  - Basic Thermodynamics
    - Data Base for Plant Operating Temperatures
    - Implementation
  - Instrumentation
    - Crevice Corrosion Rate
    - Environment Corrosivity
  - Fundamental Corrosion
    - Causes
    - Parametric Studies
    - Crevice Effects
    - Corrosion Products
  - Turbine Cracking
    - Stress Corrosion of Disc Material
    - Corrosion Fatigue of Disk Materials
    - Contaminants in Steam

PROJECTS UNDERWAY - 22

TOTAL VALUE ~ 18M

PLANT CHEMISTRY AND CORROSION LOGIC TREE

547 234



PROJECTS UNDERWAY - 23

TOTAL VALUE ~ 18M

PRIMARY AND SECONDARY PRESSURE BOUNDARY LOGIC TREE

547 255

KEY PROJECTS AND HIGHLIGHTS (CONTINUED)

- THERMODYNAMICS OF HIGH TEMPERATURE WATER
  - CHEMICAL IMPURITIES
  - CREVICES

QUALIFICATION OF COUNTERMEASURES FOR BWR PIPE CRACKING

- MARGIN OF IMPROVEMENT BASED ON FULL SIZE PIPE TESTS

	FACTOR IMPROVEMENT
• SHOP CONCEPTS	
• SOLUTION HEAT TREATMENT	66
• CORROSION RESISTANT CLAD	66
• FIELD CONCEPTS	
• HEAT SINK WELDING	14.5
• CORROSION RESISTANT CLAD	7.0

QUALIFICATION OF ALTERNATE PIPING MATERIAL

SCREENING PIPE TESTS

MATERIAL	FACTOR OF IMPROVEMENT
316SS	>20
CF-3	>20

517 236

- NO SCC RELATED FAILURES OF CARBON STEEL IN BWR
  - SCC AND CORROSION FATIGUE FAILURES HAVE OCCURRED IN LABORATORY SIMULATED BWR ENVIRONMENT
  - KINETIC EXPLOSIVE BONDING OF TUBE TO TUBESHEET SUCCESSFULLY DEMONSTRATED
  - HOT ISOSTATIC PROCESSING REDUCES POROSITY AND IMPROVES QUALITY OF CASTINGS
  - SMALL AMOUNTS OF N IN 304 STAINLESS STEEL IMPROVES RESISTANCE TO SENSITIZATION

KEY PROJECTS AND HIGHLIGHTS (CONTINUED)

- BWR PIPE INTEGRITY STUDIES
  - WELD RESIDUAL STRESS DISTRIBUTION VERY IMPORTANT
    - LARGE LINE LESS FAILURE PRONE THAN SMALL LINE
  - HAZ OF 304 STAINLESS STEEL PIPE WELDS HAVE HIGHER YIELD STRESS THAN BASE MATERIAL
- CORROSION FATIGUE OF RPV STEELS
  - CURRENT DATA INDICATE ASME SECTION XI APPENDIX A REFERENCE CURVE FOR GROWTH OF FLAWS CYCLICALLY LOADED IN REACTOR COOLANT IS NOT ALWAYS CONSERVATIVE
  - DATA SCATTER IS CONSIDERABLE AND NUMBER OF TEST VARIABLES IS LARGE
- NEUTRON EMBRITTLEMENT OF RPV STEELS
  - U.S. NRC REGULATORY GUIDE 1.99 REV. 1 PROVIDE EXCESSIVELY CONSERVATIVE ESTIMATES OF EFFECT OF IRRADIATION ON TOUGHNESS

T-17

EPRI NONDESTRUCTIVE
EVALUATION PROGRAM

BY

GARY J. DAU
PROGRAM MANAGER

PRESENTED TO

MATERIALS SUBCOMMITTEE
OF
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

547 239

JULY 10, 1979

WASHINGTON, D. C.

GJD:RB
7/79

T-17 through 19

NDE Program

Approach	Goal
Improvement of code NDT techniques	Optimization: Systematic effort to upgrade conventional ISI technology. Expect smaller overall gains in exchange for providing quick help to field applications.
New inspection methods and device development	Innovation: Improvements brought about by introduction of new approaches, technology, etc.; expect large gains but may take longer to get into field application.
Materials property measurement	Preventive Action: Provide data for design/ fabrication feedback, can lead to on-line surveillance.
Failure analysis	Reliability: Accurately define the reliability of components by analyzing the frequency and severity of malfunctions that result in outages or that have potential safety significance.

Logic tree showing organization of EPRI NDE program.

POOR ORIGINAL

86

AREAS OF MAJOR PROGRAMATIC PROGRESS

- Dual Element UT Transducer
- Eddy Current Signal Analysis
- Ultrasonic Signal Analysis
  - IGSCC in Stainless Steel Pipe
  - Thermal Fatigue Cracks in Nozzles
  - Hardware
- Portable X-Ray Source
- Stress Measurement
  - X-Ray
  - Acoustic
- Verification/Quantification
  - Production of IGSCC Samples
  - Thermal Fatigue Cracks
  - Steam Generator Mock-ups
  - UT characterization

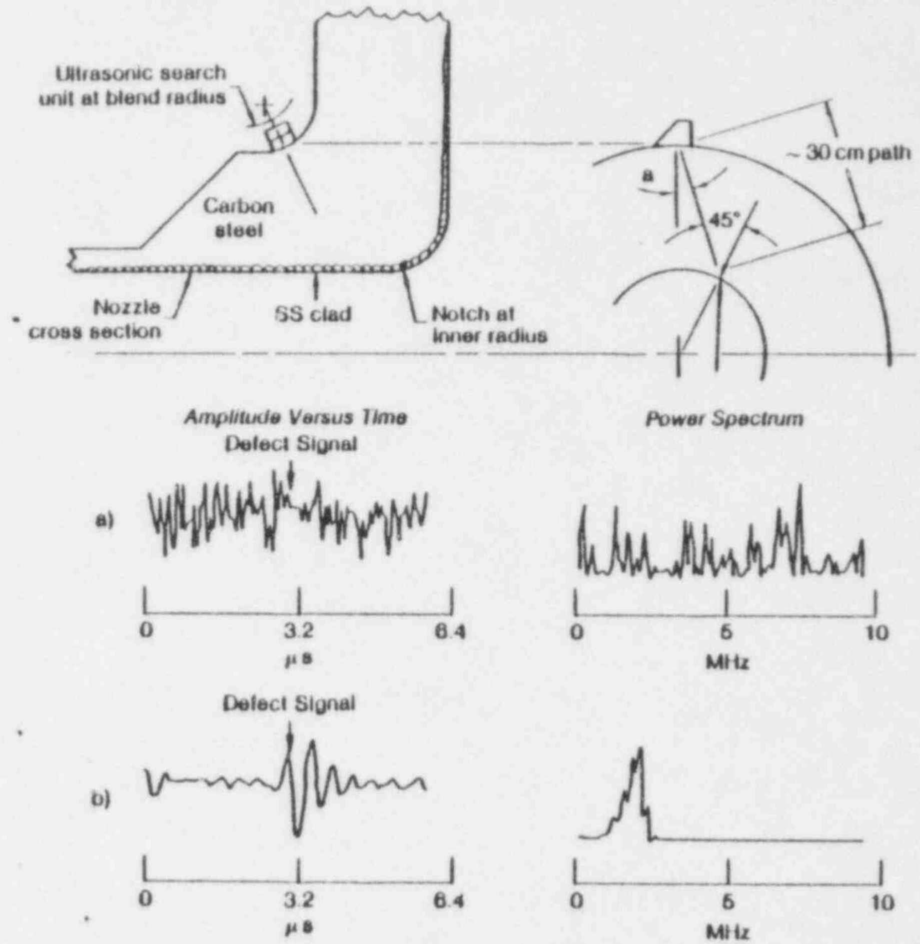
GJD:RB
7/79

DUAL ELEMENT TRANSDUCER FOR IGSCC

- Partially Focussed Pitch-Catch Mode
- Optimum Frequency Established at 1.5 MHZ
- 2-3 Times More Sensitive To IGSCC Than Conventional 2.25 MHZ Transducer
- Direct Comparison on IGSCC Samples from Gundremingen (KRB) Plant
- Widely Used in United States

SIGNIFICANCE OF AUTOMATIC SIGNAL PROCESSING WORK

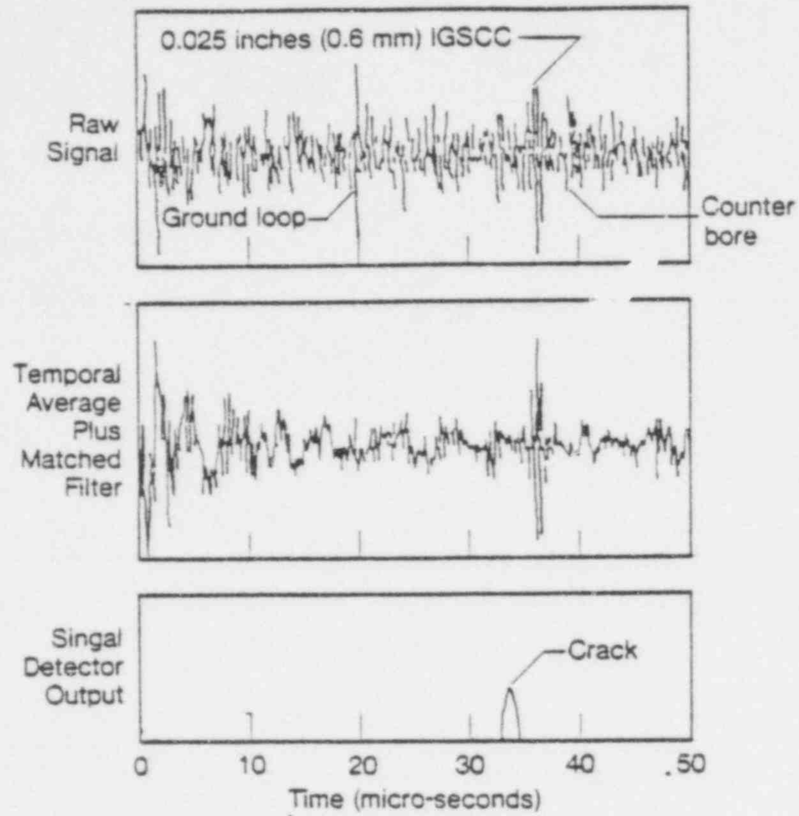
- APPLIES MANY KNOWN TECHNOLOGIES TO ULTRASONIC ISI IN SYSTEMATIC MANNER
  - Radar
  - Pattern Recognition
  - Digital Techniques
  - Microprocessor
  - UT Propagation Physics
  - Automation
  - Data Storage
- ELIMINATES AMPLITUDE DEPENDENCE
- INSENSITIVE TO TRANSDUCER DIFFERENCES AND OTHER NOISE-INDUCING ITEMS (GRAINS, WOBBLE, ETC.)
- QUANTITATIVE AND AUTOMATIC UT AND EC DETECTION AND SIZING CAPABILITY
- PORTABLE, DIGITAL, PROGRAMMABLE DATA ACQUISITION AND ANALYSIS SYSTEM
- COST EFFECTIVE INSTRUMENT -- SOFTWARE MODIFIABLE
- CAPABILITY TO RECORD AND STORE FIELD NDE DATA IN A STANDARD, ARCHIVAL FORMAT



(a) Typical ultrasonic waveform for reflection from a 4 mm deep and 50 mm long notch located in weld clad. (b) Same waveform after performing spatial and temporal averaging and filtering operations. A factor of 10 improvement in signal to noise was observed.

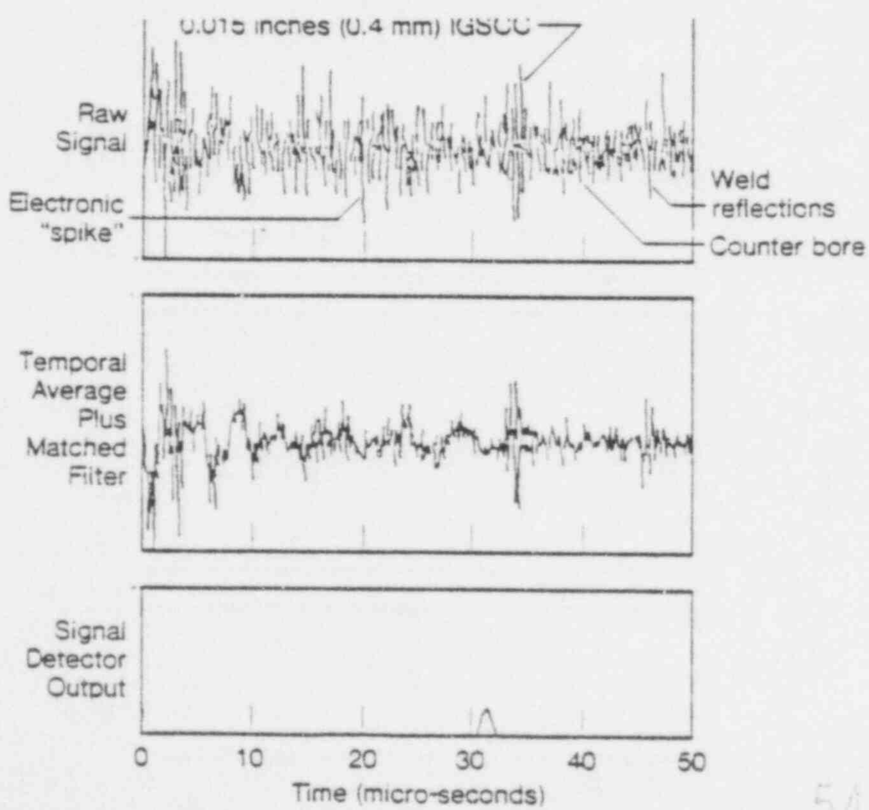
89

ENHANCED UT CRACK DETECTION



- 13 -

POOR ORIGINAL

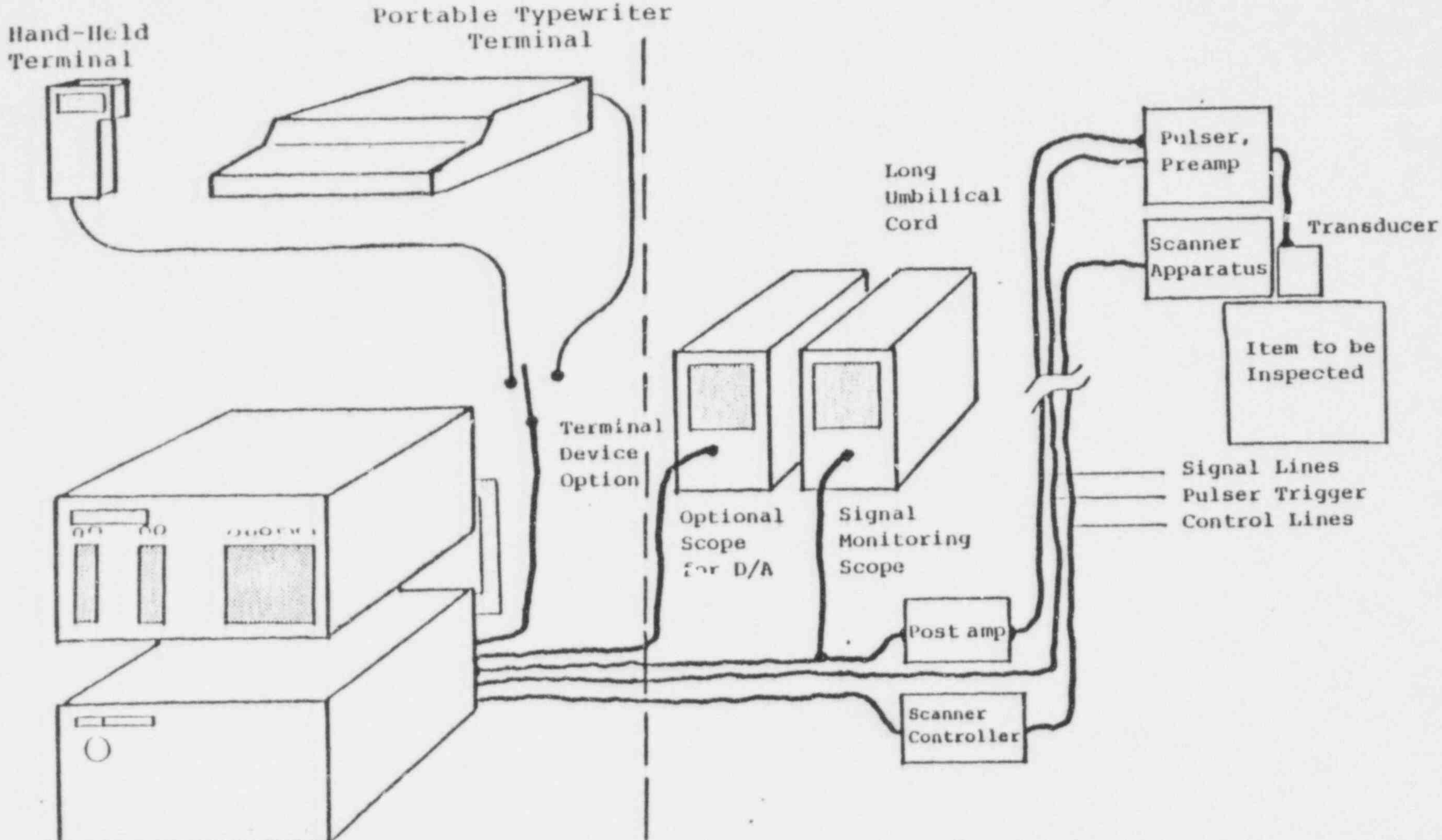


- 14 -

547 242

ALN 4000 SIGNAL INTERPRETATIVE SYSTEM

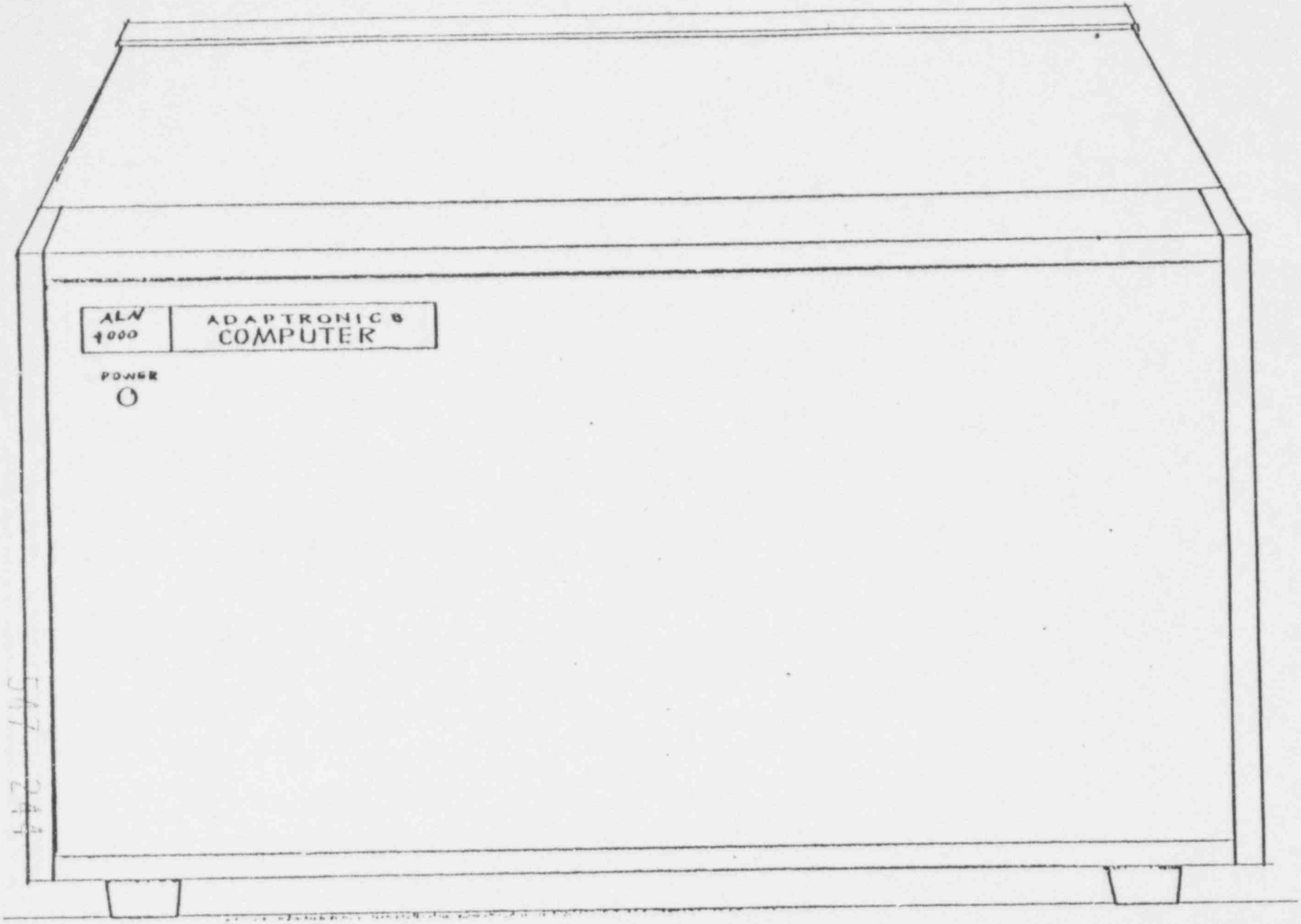
STANDARD NDE INSPECTION EQUIPMENT



- 17 -

SCHEMATIC OF ALN 4000 NDE SYSTEM INTERFACED TO
STANDARD NDE INSPECTION EQUIPMENT

90



FRONT PANEL LAYOUT OF COMPUTER UNIT OF ALN 4000
IN WHICH THE TWO Z80 MICRO PROCESSORS AND ALL MAJOR
LOGIC BOARDS ARE CONTAINED

EPRI NDE CENTER

OBJECTIVE:

- PROVIDE UTILITY INDUSTRY WITH DEDICATED NDE CAPABILITY

FOCUS:

- TECHNOLOGY TRANSFER
- TRAINING
- LONG TERM RESOURCE DEVELOPMENT
  - PEOPLE
  - APPLIED RESEARCH
- SUPPLEMENTS EPRI R&D EFFORT

BENEFITS:

- SPEED TRANSFER OF R&D RESULTS INTO FIELD QUALIFIED EQUIPMENT AND PROCEDURES
- NO COMMERCIAL BIAS
- MECHANISM TO QUALIFY INSPECTION PERSONNEL
- QUICK RESPONSE CAPABILITY

STATUS:

- BOARD OF DIRECTORS APPROVED $ 16M, 5 YEAR EFFORT 5/2/79
- REQUEST FOR PROPOSALS ISSUED
- PROPOSALS UNDER EVALUATION
- START UP TARGET, OCTOBER 1, 1979

GJD:RB

547 245

92

T-16

BASIC BUDGET - MECHANICAL ENGINEERING

TITLE	FIN	CONTR	FY 79	FY 80	FY 81
STEAM GENERATOR TUBES	A3110	BNL	50	70	-
BWR NOZZLE CRACKING	A3122	BNL	45	-	-
PRIMARY SYSTEM RESPONSE TO LOCA	A6152	INEL	80	70	-
CONTAINMENT PIPING PENETRATION	A2096	ANL	60	-	-
POSTULATED EVENT DEVICES	B1191	TELEDYNE	35	-	-
SNUBBER SENSITIVITY	B3076	ETEC	70	-	-
METHODS OF COMBINING DYN. RESPONSES	A3123	BNL	25	-	-
EVALUATION OF MARK II SRSS CRITERIA	A3311	BNL	55	-	-
INSERVICE TESTING PROGRAM	A6265	INEL	-	130	160
~~INSULATION DISPERSION (A-43)~~	-	~~UNDES.~~	-	~~150~~	~~100~~
GUARD PIPE DESIGN	-	UNDES.	_	50	_
LOAD COMBINATIONS, STRESS LIMITS	-	UNDES.	-	100	120
CRITERIA IMPLEMENTATION REVIEW	-	UNDES.	-	-	150
CODE VERIFICATION ANALYSIS	-	BNL	-	-	100
PUMP & VALVE OPERABILITY/RELIABILITY	-	UNDES.	-	-	150

547 246

71

(5) FY 79

TITLE: STEAM GENERATOR TUBE INTEGRITY

A3110-9

RAJAN START: 01/05/76 TERMINATES: 09/30/80

BNL OVERALL FUNDS: $170,000 FY 79 $50K FY 80 $70 K

OBJECTIVES:

. DEVELOP COMPUTER ASSISTED ELASTIC-PLASTIC FRACTURE MECHANICS TECHNIQUES TO CHARACTERIZE CRACK INITIATION AND GROWTH AS A FUNCTION OF LOADING IN STEAM GENERATOR TUBES.

ACCOMPLISHMENTS:

. DEVELOPMENT OF NFAP CODE BASED ON LARGE STRAIN THEORY

. DEVELOPMENT OF COMPUTATIONAL PROCEDURES FOR J AND COD RESISTANCE CURVES

. DETERMINATION OF J AND COD RESISTANCE CURVES FOR INCONEL 600

. WORK IN PROGRESS ON CRACK INITIATION AND GROWTH

PROBLEMS:

. J INTEGRAL AND OTHER DATA ON SERVICE EXPOSED INCONEL 600 IS UNAVAILABLE IN OPEN LITERATURE

LICENSING EFFORT BENEFITS:

. PROVIDES BASES TO JUSTIFY OR REJECT STEAM GENERATOR TUBE PLUGGING CRITERIA PROPOSED BY APPLICANTS

. INDEPENDENT VERIFICATION OF STRUCTURAL INTEGRITY OF DEFECTED TUBES UNDER POSTULATED ACCIDENT CONDITIONS

. INPUT TAP A-3, 4, 5

547 247

POOR ORIGINAL

TITLE: BWR FEEDWATER NOZZLE DESIGN

OBJECTIVE: TO PROVIDE MEB/DSS WITH THE TECHNICAL ASSISTANCE NECESSARY TO INDEPENDENTLY EVALUATE BWR NOZZLE/SPARGER DESIGN MODIFICATIONS PROPOSED BY G.E.

LICENSING EFFORT BENEFITS:

IF THE G.E. DESIGN IS ACCEPTED, IT WILL BE USED ON ALL NEW PLANTS.

① FY 79

1

TITLE: PRIMARY SYSTEM RESPONSE TO LOCA EXCITATION

A6152

R. MATTU START: 10/01/76 TERMINATES: 09/30/80

INEL OVERALL FUNDS: FY 76 - 35K, TRAS QTR. - 20K, FY 77 - 80K,

FY 78 - 100K, FY 79 - $80,000, FY 80 - $70,000

OBJECTIVES:

. INDEPENDENT REVIEW OF TYPICAL NSSS VENDORS BY CONTRACTOR

. DEVELOP ANALYTICAL MODEL FOR INDEPENDENT VERIFICATION OF RPV SUPPORT AND OTHER COMPONENT SUPPORTS DUE TO ASYMMETRIC LOCA LOADS

ACCOMPLISHMENTS:

. PROVIDES INPUT TO TAP A-2 FOR LICENSING PLANTS

. COMPLETED VERIFICATION OF:

NORTH ANNA (W-3 LOOP)

SAN ONOFRE 2 (C.E.)

ZIMMER (G.E. MK II)

. WORKING ON

ERIE (B&W)

COMMANCHE PEAK (W-4 LOOP)

PROBLEMS:

. ERIE & COMMANCHE PEAK DELAY DUE TO INEL INVOLVEMENT IN 5 PLANT SHUTDOWN

. ZIMMER REPORT DELAYED PENDING RECONCILATION OF RESULTS (GE & INEL)

LICENSING EFFORT BENEFITS:

. PROVIDED JUSTIFICATION FOR THE LICENSING OF ALL PLANTS SUBSEQUENT TO IDENTIFICATION OF ASYMMETRIC LOADING RESULTING FROM LOCA

POOR ORIGINAL

74

TITLE: PIPING CONTAINMENT PENETRATION DESIGN

OBJECTIVES:

- INDEPENDENT DESIGN REVIEW OF WELDED FLUED HEAD PROPOSAL FOR GE MARK-III PLANTS FOR PRESSURE, MECHANICAL AND THERMAL TRANSIENTS
- INDEPENDENT REVIEW OF INSERVICE NDE METHOD

LICENSING EFFORT BENEFITS:

- PROVIDES BASES TO JUSTIFY OR REJECT WELDED PENETRATION DESIGNS
- INDEPENDENT VERIFICATION OF GE TOPICAL FOR MARK III PLANTS

TITLE: PIPE WHIP RESTRAINTS "EFFECT OF POSTULATED EVENT DEVICES ON NORMAL OPERATION"

OBJECTIVE: TO PROVIDE THE STAFF WITH A METHOD OF ASSESSING THE EFFECT OF PIPE WHIP RESTRAINTS AND DYNAMIC MOTION SNUBBERS ON THE NORMAL OPERATION OF A PIPING SYSTEM, AND WITH A PROPOSAL FOR THEIR CONTINUED USE

LICENSING EFFORT BENEFITS:

. WILL ENABLE MEB TO EVALUATE COSTS/BENEFIT RATIO I.E., PED ADVERSE EFFECTS DURING NORMAL OPERATION VS. PROTECTION PROVIDED DURING POSTULATED EVENTS.

. WILL RESULT IN REVISIONS TO PROTECTION AGAINST POSTULATED EVENT CRITERIA WITH ASSOCIATED SRP REVISIONS.

. PED CRITERIA REVISIONS TO MINIMIZE PERSONNEL RADIATION EXPOSURE IN PERFORMING ISI.

TITLE: SNUBBER SENSITIVITY STUDY

OBJECTIVE: DEVELOP SIMPLIFIED RULES TO ASSURE DYNAMIC RESPONSE OF SNUBBER SUPPORTED SYSTEMS IS CONSERVATIVELY BOUNDED

LICENSING EFFORT BENEFITS:

- ORIGINALLY PART OF TAP A-13

- WILL STANDARDIZE TREATMENT OF SNUBBERS IN SYSTEM MODELS

- WILL IDENTIFY MARGINAL CONDITIONS IN EXISTING SNUBBER MODELS AND QUANTIFY EFFECT THAT SPECIFIC SNUBBER PARAMETERS PLAY

FY79

TITLE: COMBINATION OF DYNAMIC RESPONSES

A3123

HOU START: 10/01/78 TERMINATES: 09/30/79

BNL OVERALL FUNDS: 95K (FY 79 ONLY)

OBJECTIVES:

. DEVELOP REGULATORY POSITION ON RESPONSE COMBINATION METHODOLOGY

. DETERMINE ACCEPTABILITY & LIMITS ON SRSS

ACCOMPLISHMENTS:

. PARAMETERS GOVERNING CHARACTERISTICS OF RESPONSES IDENTIFIED

. TECHNIQUES USING MONTE-CARLO, NUMERICAL SOLUTIONS & CLOSED FORM SOLUTIONS DEVELOPED

. SENSITIVITY STUDIES COMPLETED

. WORKING ON

FINAL PHASE - RECOMMENDATIONS ON RESPONSE COMBINATION CRITERIA

PROBLEMS:

. DELAY & ADDITIONAL FUNDING CAUSED BY DIFFICULTY IN OBTAINING DIGITIZED [illegible]AL SIGNALS

. NOW, PROGRESS IS EXPECTED ON SCHEDULE

LICENSING EFFORT BENEFITS:

. WILL PROVIDE BASIS FOR DEVELOPING BRANCH TECHNICAL POSITIONS

. WILL PROVIDE GUIDANCE FOR APPLICANTS IN COMBINING DYNAMIC RESPONSES

. WILL EXPEDITE PLANT REVIEW, ESPECIALLY MARK-II PLANTS

TITLE: EVALUATION OF MARK II SRSS LOAD COMBINATION CRITERIA

OBJECTIVE: DETERMINE ACCEPTABILITY, ADEQUACY, AND LIMITS OF THE PROPOSED TWO KENNEDY/NEWMARK CRITERIA

LICENSING EFFORT BENEFITS: EXPEDITE MARK II PLANT REVIEW

11 FY80

TITLE: REVIEW OF PUMP AND VALVE INSERVICE TESTING PROGRAMS

JUSTIFICATION: NEW AND SIGNIFICANT DEMAND FOR DSS RESOURCES WHICH CANNOT BE MET AT CURRENT OR PROJECTED STAFFING LEVELS.

OBJECTIVE: OBTAIN EXPERT TECHNICAL SUPPORT TO ASSIST STAFF BY CONDUCTING DETAILED REVIEWS OF IST PROGRAMS AND PROVIDE DOCUMENTED BASIS FOR SER OR SER SUPPLEMENT.

ESTIMATED COST: FY 80: $130,000 FY 81: $160,000

DURATION: AUGUST 1, 1979 DURATION UNDETERMINED

SCOPE:

- VERIFY COMPONENTS LISTED IN IST PROGRAM AND P&ID ARE CORRECTLY IDENTIFIED.
- VERIFY THAT VALVES ARE CATEGORIZED ACCORDING TO ASME CODE VALVE CATEGORY DEFINITION.
- REVIEW BASIS FOR RELIEF REQUESTS TO ASSURE THAT REQUESTS ARE CLEARLY JUSTIFIED ON THE BASIS OF IMPRACTICALITY OR UNDUE HARDSHIP.
- DOCUMENT IST PROGRAM REVIEW PROCESS AND BASIS FOR SER OR SER SUPPLEMENT.

BUDGET DECISION CAT.: 4.a - CASEWORK, O.L.

POOR ORIGINAL

547 255

TITLE: DYNAMIC RESPONSE TO PIPE BREAK INSIDE THE GUARD PIPE

JUSTIFICATION:

- CURRENTLY, A QUANTITATIVE BASIS DOES NOT EXIST FOR JUDGING THE EFFECTIVENESS OF A GUARD PIPE TO PIPE WHIP & JET IMPINGEMENT. SRP REQUIRES ONLY DESIGN FOR PRESSURE & TEMPERATURE.
- APPLICANTS ARE POSTULATING DESIGN BASIS PIPE BREAKS TO AVOID INSERVICE INSPECTION OF THE PROCESS PIPE WELDS.

OBJECTIVES:

- PROVIDE DATA BASIS FOR DEVELOPING CRITERIA ON CONTAINMENT PENETRATION DESIGN
- DETERMINE THE NEED TO PERFORM A RISK ASSESSMENT ON THE USE OF GUARD PIPE IN FUTURE WORK

ESTIMATED COST: 50K (FY-80 ONLY)

DURATION: 10/01/79 TO 09/30/80

SCOPE:

- BASED ON PENETRATION DESIGNS IN PWR & BWR PLANTS, SELECT ONE GOVERNING CASE WITH SPECIFIED MAJOR DESIGN PARAMETERS.
- DEVELOP A FINITE-ELEMENT MODEL OF THE GUARD PIPE FOR THE GOVERNING CASE
- PERFORM A DYNAMIC ANALYSIS & CALCULATE STRESS DISTRIBUTION IN THE GUARD PIPE WHICH RESULTS FROM JET IMPINGEMENT & PIPE WHIP.

TITLE: DYNAMIC LOADS, DYNAMIC RESPONSE COMBINATIONS AND STRESS LIMITS

OBJECTIVE: FOR PWR'S & BWR'S DEVELOP:

- ACCEPTABLE LICENSING STANDARDS FOR DYNAMIC LOADING/RESPONSE COMBINATION REQUIREMENTS ON ALL SAFETY RELATED ASME III, DIV. 1 COMPONENTS

- A QUANTITATIVE METHODOLOGY WHICH CAN MEASURE THE SAFETY SIGNIFICANCE OF THE ABOVE REQUIREMENTS

WORK SCOPE:

- ESTABLISH ACCEPTABLE SYSTEM MODELS (W, C.E., B&W, & G.E.) WHICH CAN ILLUSTRATE QUANTITATIVELY THE CONTRIBUTION OF ANY ASME III COMPONENT STRUCTURAL FAILURES TO OVERALL RISK TO THE PUBLIC FROM A SPECIFIC COMMERCIAL NUCLEAR POWER PLANT. THE INFLUENCE OF ALL SUCH COMPONENTS WHICH MAY BE LOADED SIMULTANEOUSLY IS REQUIRED.

- SRSS STANDARDS: ASCERTAIN THE UNDERLYING REASONS FOR LARGE VARIATION OF SRSS NON EXCEEDANCE PROBABILITY VALUES.

- PIPING DESIGN OPTIMIZATION: PERFORM PRELIMINARY ANALYSIS OF A TYP. SIMPLE PIPING LOOP TO EVALUATE THE TRADE OFF BETWEEN STRUCTURAL RIGIDITY REQUIRED FOR EXTREME DYNAMIC LOADS AND FLEXIBILITY NEEDED FOR NORMAL THERMAL EXPANSION AS THEY AFFECT OVERALL COMPONENT RELIABILITY.

TITLE: CRITERIA IMPLEMENTATION REVIEW

OBJECTIVE: TO OBTAIN TECHNICAL SUPPORT TO ASSIST THE STAFF IN THE REVIEW AND EVALUATION OF (1) MECHANICAL SYSTEMS AND COMPONENTS AND THEIR SUPPORTS AND (2) THE QUALIFICATION OF ELECTRICAL EQUIPMENT AND THEIR SUPPORTS

WORK SCOPE: FOR EACH APPLICABLE PLANT:

1. REVIEW DESIGN PROCEDURES AND ANALYSIS RESULTS FOR DESIGNATED MECHANICAL SYSTEMS AND ASSESS THE SAFETY MARGIN OF THE DESIGN.

2. REVIEW QUALIFICATION PROCEDURES AND RESULTS FOR DESIGNATED MECHANICAL COMPONENTS AND ELECTRICAL EQUIPMENT SUBJECTED TO VIBRATORY LOADS FROM POSTULATED EVENTS.

3. REVIEW DESIGN ADEQUACY OF MECHANICAL SYSTEM AND COMPONENT SUPPORT ISSUES INCLUDING I&E BULLETIN 79-02, "PIPE SUPPORT BASE PLATE DESIGNS USING CONCRETE EXPANSION ANCHOR BOLTS"

4. AS A PART OF ABOVE REVIEWS, ASSIST STAFF IN MEETINGS WITH APPLICANTS, RECOMMEND SER INPUTS, PARTICIPATE WITH STAFF IN ACRS MEETINGS AND PUBLIC HEARINGS.

547 258

TITLE: CODE VERIFICATION IMPLEMENTATION AND CONFIRMATORY PIPING SYSTEM ANALYSIS

JUSTIFICATION: NEW AND SIGNIFICANT DEMAND FOR DSS RESOURCES WHICH CANNOT BE MET AT CURRENT OR PROJECTED STAFF LEVELS.

OBJECTIVE: OBTAIN EXPERT TECHNICAL SUPPORT TO ASSIST THE STAFF IN PERFORMING CONFIRMATORY STRUCTURAL ANALYSIS OF SAFETY CLASS PIPING SYSTEMS SUBJECTED TO STATIC AND DYNAMIC LOADING AND REVISING ITS STANDARD REVIEW PLANS TO PROVIDE FOR IMPLEMENTATION.

ESTIMATED COST: FY 80: $ 80,000
FY 81 $100,000

DURATION: STARTING OCTOBER 1, 1979, ~~DURATION UNDETERMINED~~

SCOPE:

- REVIEW BENCHMARK VERIFICATION OF APPLICANT'S AND LICENSEE'S PIPING COMPUTER PROGRAMS.
- SAR SUBMITTAL BY APPLICANTS AND LICENSEES OF SELECTED PIPING PROBLEMS AND STRESS REPORTS.
- CONSTRUCTION OF MODEL FOR COMPTUER ANALYSIS
- SOLUTION OF PROBLEM UNDER STATIC AND DYNAMIC LOADING
- REVIEW AND COMPARISON WITH APPLICANTS AND LICENSEE'S SOLUTIONS AND STRESS REPORT
- DOCUMENTATION IN SER.

547 259

POOR ORIGINAL

TITLE: VALVE/PUMP OPERABILITY/RELIABILITY WITH POSTULATED/NORMAL EVENTS (PHASE I)

JUSTIFICATION: CURRENT PROGRAM IMPLEMENTATION HAS NEVER BEEN SYSTEMATICALLY EVALUATED TO DETERMINE NEEDS AND CURRENT CAPABILITIES AND METHODS.

SCOPE:

(1) REVIEW PLANT OPERATING EVENTS
(2) DETERMINE OPERABILITY/RELIABILITY NEEDS
(3) SELECT REPRESENTATIVE VALVES AND PUMPS
(4) REVIEW DOCUMENTATION AND TESTS OF SELECTED ITEMS
(5) DETERMINE LEVEL OF OPERABILITY/RELIABILITY ASSURANCE AS DELIVERED
(6) PRESENT RECOMMENDATIONS FOR EQUATING (2) AND (5)

ESTIMATED COST & DURATION: FY 80 - 50K
FY 81 - 150K

BUDGET DECISION CAT.: 4.g CASEWORK, LIC. IMP.

NOTE: PHASE II OF THIS PROGRAM IS ANTICIPATED TO CONTINUE AT APPROXIMATELY 75-90K TO ASSIST STAFF IN IMPLEMENTING PROGRAM FOR AT LEAST FY 82 - FY 85.

POOR ORIGINAL

T-16

ENGINEERING BRANCH
DIVISION OF OPERATING REACTORS

TECHNICAL ASSISTANCE PROGRAM
FOR FISCAL YEAR 1979

CONTRACTOR	FY 1979 FUNDING
LLL	355K
EG&G	330K
BNL	175K
PNL	155K
SANDIA	105K
NRL	70K
WASH. UNIV.	44K
ORNL	30K
ANL	12K
TOTAL	$1,276,000

547 261

66

LLL TECHNICAL ASSISTANCE CONTRACTS

PROGRAM	TECHNICAL CONTACT	FY 1979 FUNDING
BUCKLING OF DYNAMICALLY LOADED COLUMNS	K. Herring	75K
VERIFICATION OF MARK I DYNAMIC MODELING	J. Fair	180K
SUPPORT FOR DOR SEISMIC REVIEWS	K. Herring	100K
		355K

547 262

67

EG&G TECHNICAL ASSISTANCE CONTRACTS

PROGRAM	TECHNICAL CONTACT	FY 1979 FUNDING
PWR CASE WORK FOR ASYM LOADS	S. Hosford	180K
RPV NOZZLE BREAK OPENING TIME	S. Hosford (LaGrange)	25K
COMBINING INELASTIC DYNAMIC RESPONSES	S. Hosford	30K
MECHANICAL RESPONSE OF OPERATING PWR PRIMARY SYSTEM	S. Hosford	20K
SEISMIC PIPING SYSTEMS REVIEW OF 5 SHUT-DOWN PLANTS	S. Hosford	75K
		330K

5A7 263

PNL TECHNICAL ASSISTANCE CONTRACTS

PROGRAM	TECHNICAL CONTACT	FY 1979 FUNDING
INSERVICE INSPECTION AND INSERVICE TESTING PROGRAMS	C. Y. CHENG	125K
PIPE CRACK STUDY GROUP CONSULTANT	W. HAZELTON	30K
		155K

547 264

69

SANDIA TECHNICAL ASSISTANCE CONTRACTS

PROGRAM	TECHNICAL CONTACT	FY 1979 FUNDING
STEAM GENERATOR STATISTICAL ANALYSIS	J. Strosnider	40K
NDE EVALUATION/SUPPORT	R. Johnson	65K
		105K

547 265

ENGINEERING BRANCH
DIVISION OF OPERATING REACTORS

TECHNICAL ASSISTANCE PROGRAM
FOR FISCAL YEAR 1979

T-14

CONTRACTOR	FY 1979 FUNDING
LLL	355K
EG&G	330K
BNL	175K
PNL	155K
SANDIA	105K
NRL	70K
WASH. UNIV.	44K
ORNL	30K
ANL	12K
TOTAL	$1,276,000

547 266

LLL TECHNICAL ASSISTANCE CONTRACTS

PROGRAM	TECHNICAL CONTACT	FY 1979 FUNDING
BUCKLING OF DYNAMICALLY LOADED COLUMNS	K. Herring	75K
VERIFICATION OF MARK I DYNAMIC MODELING	J. Fair	180K
SUPPORT FOR DOR SEISMIC REVIEWS	K. Herring	100K
		355K

EG&G TECHNICAL ASSISTANCE CONTRACTS

PROGRAM	TECHNICAL CONTACT	FY 1979 FUNDING
PWR CASE WORK FOR ASYM LOADS	S. Hosford	180K
RPV NOZZLE BREAK OPENING TIME	S. Hosford (LaGrange)	25K
COMBINING INELASTIC DYNAMIC RESPONSES	S. Hosford	30K
MECHANICAL RESPONSE OF OPERATING PWR PRIMARY SYSTEM	S. Hosford	20K
SEISMIC PIPING SYSTEMS REVIEW OF 5 SHUT-DOWN PLANTS	S. Hosford	75K
		330K

547 268

PNL TECHNICAL ASSISTANCE CONTRACTS

PROGRAM	TECHNICAL CONTACT	FY 1979 FUNDING
INSERVICE INSPECTION AND INSERVICE TESTING PROGRAMS	C. Y. CHENG	125K
PIPE CRACK STUDY GROUP CONSULTANT	W. HAZELTON	30K
		155K

547 269

SANDIA TECHNICAL ASSISTANCE CONTRACTS

PROGRAM	TECHNICAL CONTACT	FY 1979 FUNDING
STEAM GENERATOR STATISTICAL ANALYSIS	J, Strosnider	40K
NDE EVALUATION/SUPPORT	R, Johnson	65K
		105K

547 270

T-13

BASIC BUDGET - STRUCTURAL ENGINEERING

TITLE	FIN	CONTR	FY 79	FY 80	FY 81
DIABLO CANYON SEISMIC ANAL	B6533	NEWMARK	38	-	-
FAILLY SEISMIC ANAL	B6569	NEWMARK	12	-	-
SOIL STRUCTURE INTERACTION ANAL	B1153	D'APPOLONIA	33	-	-
FSI EFFECTS ON MARK II PLANTS	A3093	BNL	35	25	25
WPPSS-2 SPENT FUEL RACK	A6262	BNL	25	-	-
WATTS BAR BUCKLING STRESS CRITERIA	A6581	ISE	9	-	-
MIDLAND & SUMMER REVIEW	-	UNDES	-	55	45
BUCKLING BEHAV OF STEEL CONTAINMENTS	B6568	UNDES	-	125	90
LOAD COMB & SERVICE LIMITS FOR MK II DRYWELL	-	UNDES	-	65	-
LOAD COMBINATIONS & SERVICE LIMITS FOR PRESTRESSED CONCRETE CONTAINMENTS	-	UNDES	-	-	65
EFFECT OF VARIATION OF SOIL PROPERTIES ON STRUCTURES	-	UNDES	-	60	-
BENCHMARK PROBLEMS FOR COMPUTER CODE VERIFICATION	-	UNDES	-	-	70
STRUCTURAL MODELING OF CRACKED SECTIONS	-	UNDES	-	-	80
SENSITIVITY STUDY ON FREQUENCY DEPENDENT COMPLIANCE FUNC. APPROACH	-	UNDES	-	-	110
COMPUTER RESULTS AUDITING	-	UNDES	-		

POOR ORIGINAL

547 271

TITLE: DIABLO CANYON SEISMIC ANALYSIS

OBJECTIVE: THE OBJECTIVE OF THIS CONTRACT IS TO RETAIN THE EXPERT TECHNICAL ASSISTANCE TO AUGMENT THE STAFF CAPABILITIES IN THE SEISMIC/STRUCTURAL AREA FOR EVALUATION OF THE UNUSUAL PROBLEMS ASSOCIATED WITH THE DIABLO CANYON REVIEW.

WORK SCOPE: THE WORK REQUIREMENTS CONSIST OF:

(1) PERFORM A REVIEW AND EVALUATION OF THE APPLICANT'S ANALYSES FOR RESOLUTION OF THE OUTSTANDING ITEMS DESCRIBED IN DIABLO CANYON SER SUPPLEMENT NO. 7.

(2) PREPARE A FINAL REPORT CONTAINING CONCLUSIONS, INTERPRETATIONS AND ALTERNATIVES AND THE BASES THEREOF OF THE REVIEW OF THE ABOVE ANALYSES.

(3) PROVIDE WRITTEN TESTIMONY COVERING THE DIABLO CANYON OL REVIEW.

(4) SERVE AS AN EXPERT WITNESS FOR NRC AT THE DIABLO CANYON ASLB HEARINGS.

TITLE: BAILLY SEISMIC ANALYSIS

OBJECTIVE: PROVIDE EXPERT EVALUATION OF THE DESIGN OF THE PILE FOUNDATION TO WITHSTAND THE EFFECTS OF DYNAMIC LOADS AND TO SERVE AS AN EXPERT WITNESS

WORK SCOPE: REVIEW AND EVALUATE THE PILE FOUNDATION UNTIL ALL OUTSTANDING QUESTIONS ARE RESOLVED. THE CONTRACTOR WILL FURNISH A FINAL REPORT CONTAINING CONCLUSIONS, INTERPRETATIONS, ALTERNATIVES AND BASES OF THE REVIEW. THE CONTRACTOR WILL ATTEND VARIOUS MEETINGS (INCLUDING ACRS), PREPARE WRITTEN TESTIMONY AND SERVE AS AN EXPERT WITNESS AT PUBLIC HEARINGS.

TITLE: SOIL STRUCTURE INTERACTION ANALYSIS

OBJECTIVE: ASSESS THE ADEQUACY OF SOME ENGINEERING ASSUMPTIONS MADE IN THE DEFINITION OF SEISMIC INPUT AND METHODS USED FOR THE ANALYSIS OF SOIL STRUCTURE INTERACTION OF NUCLEAR POWER PLANTS AND DETERMINE THE RANGE OF APPLICABILITY OF THE ACCEPTANCE CRITERIA OF SRP 3.7.

WORK SCOPE: THE RESEARCH STUDIED THE FOLLOWING ITEMS:

(1) ASSUMPTIONS USED IN THE COMPUTER PROGRAMS SHAKE, LUSH AND FLUSH FOR SSI.

(2) INFLUENCE OF SUBSURFACE SOIL PROFILE ON SSI.

(3) APPLICABILITY OF R.G. 1.60 TO SITE CONDITIONS

(4) EFFECTS OF HORIZONTALLY PROPAGATING SHEAR WAVES ON SEISMIC INPUT AND STRUCTURAL RESPONSE

(5) EQUIVALENT LINEAR INTEGRATION PROCEDURES FOR STRAIN DEPENDENT SOIL PROPERTIES

(6) VALIDITY OF PLANE STRAIN ASSUMPTION IN SHAKE AND LUSH/FLUSH

(7) EMBEDMENT EFFECT

POOR ORIGINAL

547 274

TITLE: FSI EFFECTS ON MARK II PLANTS

OBJECTIVE: TO PROVIDE EXPERT TECHNICAL ASSISTANCE TO COMPLETE THE REVIEW OF THE MARK II PLANTS: ZIMMER, LASALLE, SHOREHAM

WORK SCOPE:

1. EVALUATE THE METHODOLOGY USED TO DEFINE THE BOUNDARY LOADS USED IN THE DESIGN AS A RESULT OF THE POOL SWELL PHENOMENA

2. EVALUATE THE METHODLOGY USED TO CALCULATE THE RESPONSE OF THE STRUCTURE AND THE STRESSES DUE TO THE DEFINED BOUNDARY LOADS. THIS ITEM WILL BE CARRIED OUT ON A GENERIC BASIS AS WELL AS ON PLANT SPECIFIC CASE.

POOR ORIGINAL

547 275

TITLE: WPPSS-2 SPENT FUEL RACK

OBJECTIVE: THE OBJECTIVE OF THIS CONTRACT IS TO PROVIDE THE STAFF WITH EXPERT TECHNICAL ASSISTANCE TO DETERMINE THE ADEQUACY OF THE SPENT FUEL CAN INTERACTION ANALYSIS SUBMITTED BY WASHINGTON PUBLIC POWER FOR THE WPPSS-2 PLANT

WORK SCOPE: BNL WILL REVIEW THE NUS CORPORATION TECHNICAL REPORT #2060, ENTITLED: "FUEL-CAN INTERACTION ANALYSIS." THE FOLLOWING ASPECTS OF THIS REPORT WILL BE EVALUATED:

1. THE VALIDITY OF THE ANALYTICAL APPROACH USED;

2. THE ACCEPTABILITY OF THE ASSUMPTIONS MADE;

3. THE COMPLETENESS OF THE REPORT TO JUSTIFY THE CONCLUSIONS CONTAINED THEREIN;

4. THE VALIDITY OF THE CONCLUSIONS REACHED.

547 276

TITLE: WATTS BAR BUCKLING STRESS CRITERIA

OBJECTIVE: TO PROVIDE EXPERT TECHNICAL ASSISTANCE TO COMPLETE THE OL REVIEW OF THE DESIGN OF THE STEEL CONTAINMENT VESSEL OF WATTS BAR NUCLEAR POWER PLANT.

WORK SCOPE:

1. EVALUATE THE METHODS AND ASSUMPTIONS USED BY THE APPLICANT.

2. EVALUATE THE ASSUMPTIONS AND METHODOLOGY WHICH ARE INCLUDED IN THE STRUCTURAL COMPUTER PROGRAMS USED BY THE APPLICANT.

3. PERFORM A SIMPLIFIED ANALYTICAL EVALUATION OF THE STEEL CONTAINMENT TO WITHSTAND THE DESIGN LOADING, TO DETERMINE WHETHER THE APPROACH USED BY THE APPLICANT IS CONSERVATIVE.

5A7 277

TITLE: MIDLAND AND SUMMER REVIEW

OBJECTIVE: TO PROVIDE THE STAFF WITH EXPERT EVALUATIONS OF SEISMIC DESIGN BASES AND ANALYSIS AND TO SERVE AS AN EXPERT WITNESS IN LICENSING HEARINGS PERTAINING TO SPECIFIC OL AND CP LICENSE APPLICATIONS. THE PROGRAM MUST BE FLEXIBLE ENOUGHT TO ENABLE THE STAFF TO OBTAIN EXPERT ASSISTANCE IN A TIMELY FASHION, AS THE NEED ARISES.

WORK SCOPE: THE SPECIFIC PLANTS TO BE REVIEWED AND THE DETAILS OF THE SEISMIC PROBLEMS TO BE INVESTIGATED WILL BE MIDLAND AND SUMMER. THE SCOPE WILL CONSIST OF:

(1) PERFORM REVIEW AND EVALUATION OF APPLICANT'S SEISMIC DESIGN BASES AND ANALYSES AS DESCRIBED IN THE FSAR, OR SUPPLEMENTARY REPORTS OF THE SPECIFIC PLANT.

(2) ATTEND VARIOUS MEETINGS (INCLUDING ACRS) IN WASHINGTON, D.C.

(3) PREPARE WRITTEN TESTIMONY AND SERVE AS AN EXPERT WITNESS FOR NRC IN LICENSING HEARINGS PERTAINING TO THE PLANT IN QUESTION.

POOR ORIGINAL

547 278

TITLE: BUCKLING BEHAVIOR OF STEEL CONTAINMENT SHELLS

OBJECTIVE: THE OBJECTIVE OF THIS PROGRAM IS TO DEVELOP AN UP-TO-DATE STAFF POSITION ON BUCKLING OF STEEL CONTAINMENT SHELLS FOR NRC REVIEW OF APPLICANT DESIGNS.

WORK SCOPE: THIS PROGRAM WILL CONSIST OF THE FOLLOWING ACTIVITIES:

(1) PERFORM DETAILED DESIGN ANALYSES OF TWO TYPICAL STEEL CONTAINMENTS.

(2) DEVELOP BENCHMARK PROBLEMS AND SOLUTIONS TO VERIFY COMPUTER PROGRAMS PRESENTLY USED IN BUCKLING ANALYSIS.

(3) ASSESS THE ASSUMPTIONS AND METHODOLOGY PRESENTLY USED IN CONTAINMENT BUCKLING ANALYSIS.

(4) CONDUCT PARAMETRIC STUDIES AND ESTABLISH GENERAL ACCEPTANCE CRITERIA FOR STATIC AND DYNAMIC STABILITY OF STEEL CONTAINMENTS.

T-13 through 14

BASIC BUDGET - MATERIALS ENGINEERING

TITLE	FIN	CONTR	FY 79	FY 80	FY 81
TEARING STABILITY - PIPING	B6571	WUTA	35	40	-
PIPING INELASTIC FRACTURE MECHANICS	B6587	NRL	43	38	-
FRACTURE TOUGHNESS CRITERIA (PUMP FLYWHEELS, TURBINES, SUPPORTS)	A6166	INEL	60	15	-
STATISTICAL ANALYSIS	B5885	SRL	25	35	40
WELDING EVALUATION	B0234	ORNL	45	35	-
INSERVICE INSPECTION	A6162	INEL	105	100	90
CORROSION & COOLANT CHEMISTRY	A3013	BNL	80	-	-
PRIMARY SYSTEM CORROSION	-	UNDES.	-	50	45
SECONDARY AND SAFETY SYS. CORROSION	-	UNDES.	-	-	60
FRACTURE TOUGHNESS - CONTAINMENT	-	UNDES.	-	60	-
PROTECTIVE COATINGS	-	UNDES.	-	70	130
ENVIRONMENTAL EFFECTS ON FRACTURE TOUGHNESS	-	UNDES.	-	-	100
MATERIALS SURVEILLANCE	-	UNDES.	-	-	50
FRACTURE TOUGHNESS CRITERIA 10 CFR 50 APP G	-	INEL	-	55	-
CORROSION - FERRITIC STEELS	-	UNDES.	-	35	40

547 280

POOR ORIGINAL

TITLE: INSERVICE INSPECTION (INEL)

FIN #: A6162

BENEFITS TO THE LICENSING EFFORT:

THIS CONTRACT WILL CONTRIBUTE TO LICENSING POSITIONS TO IMPLEMENT INSERVICE INSPECTION ASPECTS OF NUREG-313 ON BWR PIPE CRACKING AND NUREG-312 ON BWR FEEDWATER INLET NOZZLES. INEL WILL PROVIDE AN EVALUATION OF THE INSPECTABILITY OF LARGE PIPING SYSTEMS FOR THE JUSTIFICATION OF CERTAIN ISI RELIEF REQUESTS. CONSULTING SERVICES WILL BE PROVIDED TO SUPPORT LICENSING EFFORTS DURING THE SHOREHAM HEARING.

OBJECTIVES:

1. EVALUATE AUGMENTED ISI FOR MCGUIRE HIGH ENERGY PIPING TO IMPLEMENT SRP SECTIONS 3.6.1 AND 3.6.2.

2. EVALUATE UT TO DETECT IGSCC TO IMPLEMENT RECOMMENDATION OF NUREG-313 AND PIPE CRACK STUDY GROUP.

3. EVALUATE UT INSPECTABILITY OF PIPING SYSTEM 4: AND ABOVE TO ESTABLISH GUIDELINES FOR RELIEF REQUESTS TO IMPLEMENT 10 CFR PART 50, PARAGRAPH 50.55a(g).

4. CONSULTING SERVICES FOR SHOREHAM HEARING RELATED TO ISI.

LENGTH OF CONTRACT: ONE YEAR WITH EXPECTED FOLLOW-ON CONTRACTS.

FUNDING: FY 1979 IS 105K, EXPENDITURE THROUGH APRIL: 86K

ACCOMPLISHMENT TO DATE:

1. INEL WORK ON MCGUIRE ESSENTIALLY COMPLETE AND CONTRIBUTED TO THE RESOLUTION OF THE ISSUE OF HIGH ENERGY PIPE BREAKS.

2. REPORT PUBLISHED BY INEL IN FY 1978 WAS USED BY PIPE CRACK STUDY GROUP AND ASME SECTION XI WG ON NDE AS A POTENTIAL UT PROCEDURE FOR THE DETECTION OF IGSCC.

3. EVALUATION IN PROGRESS TO DETERMINE THE DEGREE OF INSPECTABILITY OF TYPICAL PIPING SYSTEM WELD DESIGNS AND TO DETERMINE THE EXPECTED RESULTS OF A SECTION XI EXAMINATION.

4. INEL IS CONTINUING THE REVIEW OF INTERVENOR CONTENTIONS RELATED TO ISI FOR THE SHOREHAM HEARING.

PROBLEMS AND DELAYS: NONE

OTHER KEY POINTS:

THE CONTRACTOR HAS A VERY KNOWLEDGEABLE EXPERIENCED AND RESPONSIVE STAFF WORKING TO SUPPORT OUR LICENSING TASKS. THE PROGRAM IS ON SCHEDULE AND WITHIN THE BUDGETED FUNDING.

TITLE: STATISTICAL ANALYSIS

FIN #: B5885

OBJECTIVES:

1. DETERMINE THE EFFECT ON TURBINE DISK INTEGRITY OF THE FOLLOWING FACTORS: FRACTURE TOUGHNESS, PRESERVICE TESTING AND INSPECTION, AND PERIODIC TESTING OF PROTECTIVE DEVICES.

2. REVISE PERTINENT DRAFT SECTIONS OF NUREG REPORT.

3. PROVIDE CONSULTING SERVICES TO MAKE ORAL PRESENTATIONS BEFORE VARIOUS GROUPS ON THE METHODS AND ANALYSES USED IN (1).

LENGTH OF CONTRACT: TWO YEARS (FY 79 AND 80).

FUNDING: THE AUTHORIZED FUNDING FOR FY 79 IS 43K, AND PROJECTED FUNDING FOR FY 80 IS 25K.

ACCOMPLISHMENTS TO DATE:

1. THE CONTRACTOR HAS ANALYZED SEVERAL POTENTIAL MODES OF TURBINE DISK FAILURE AND PERFORMED PRELIMINARY COMPUTER CALCULATIONS OF THE ANTICIPATED IMPROVEMENT FACTORS DUE TO HIGHER FRACTURE TOUGHNESS AND PRESERVICE TESTING OF TURBINE DISKS.

2. TASK 2 IS SCHEDULED FOR COMPLETION BY SEPTEMBER 30, 1979.

3. THE CONTRACTOR PROVIDED CONSULTING ASSISTANCE IN PREPARATION OF AN AFFIDAVIT FOR THE NORTH ANNA PUBLIC HEARING ON TURBINE MISSILES.

PROBLEMS AND DELAYS:

LOWER PRIORITY HAS BEEN ASSIGNED TO TAP A-37, "TURBINE MISSILES."

BENEFIT TO THE LICENSING EFFORT:

COMPLETION OF THIS TASK WILL ASSIST IN OUR LICENSING REVIEW IN THE FOLLOWING AREAS: (1) SRP 10.2.3, "TURBINE DISK INTEGRITY," AND (2) REVISION OF REGULATORY GUIDE 1.115, "PROTECTION AGAINST LOW-TRAJECTORY TURBINE MISSILES."

POOR ORIGINAL

547 282

TITLE: FRACTURE TOUGHNESS CRITERIA

CONTRACTOR: INEL

FIN #: A6166

BENEFITS TO THE LICENSING EFFORT:

ASSISTANCE IS PROVIDED TO ASSIST IN DEVELOPING LICENSING CRITERIA FOR PUMP FLYWHEEL INTEGRITY, PRIMARY COMPONENTS SUPPORTS TOUGHNESS REQUIREMENTS, AND TURBINE DISK INTEGRITY. THIS PROGRAM WILL AID IN REVISING MTEB REGULATORY GUIDES AND SRPs.

OBJECTIVES: THE OBJECTIVES OF THIS PROGRAM ARE FOUR FOLD:

1. REVIEW OF B & W TOPICAL PIPING REPORT ON BREAK OPENING AREA.

2. REVIEW OF PUMP FLYWHEEL REQUIREMENTS FOR R.G. 1.14 AND SRP 5.4.1.1.

3. ASSISTANCE IN PREPARATION OF STAFF POSITION ON PRIMARY COMPONENT SUPPORT MATERIALS, TAP A-12.

4. REVIEW OF TURBINE DISK INTEGRITY REQUIREMENTS, FOR SRP 10.2.3.

LENGTH OF CONTRACT: ONE YEAR

FUNDING: FY 1979 IS 60K, FY 1980 IS 15K.

ACCOMPLISHMENT TO DATE:

1. CONTRACTOR HAS COMPLETED THE REVIEW OF B & W 10127 AND ISSUED A REPORT, "AN ANALYSIS OF CRACK GROWTH POTENTIAL IN 42 INCH A 516 GRADE 70 PWR PIPING." AWAITING B & W RESPONSE TO RESOLVE ISSUE.

2. FINAL REVIEW OF A REPORT ON REVIEW OF NRC PUMP FLYWHEEL GUIDANCE REQUREMENTS IS CURRENTLY IN PROGRESS.

3. WORK IS IN PROGRESS ON SG AND PUMP SUPPORTS REVIEW REQUIREMENTS.

4. WORK IN PROGRESS ON REVIEW OF TURBINE DISK INTEGRITY REQUIREMENTS.

PROBLEMS AND DELAYS: NONE

KEY POINTS: CONTRACTOR IS COOPERATIVE AND RESPONSIVE TO OUR GUIDANCE AND REQUESTS. EXPENDITURES ARE WITHIN BUDGET.

POOR ORIGINAL

547 283

CONTRACT: PIPING INELASTIC FRACTURE MECHANICS ANALYSIS

CONTRACTOR: NAVAL RESEARCH LABORATORY

FIN #: B6587

LICENSING EFFORT:

WILL PROVIDE INPUT FOR COMPLETION OF TAP B-6; LOADS, LOAD COMBINATIONS AND STRESS LIMITS

OBJECTIVE: EVALUATE AVAILABLE ANALYSES AND EXPERIMENTS AND USE THESE TO DEFINE ACCEPTABLE METHODOLOGY FOR DETERMINING CRITICAL STRESS AND FLAW CONDITIONS FOR UNSTABLE FRACTURE IN LWR PIPING.

CONTRACT PERIOD: JANUARY 1, 1979 TO DECEMBER 31, 1980.

FUNDING LEVEL:

43K FY 79
38K FY 80

82K TOTAL

ACCOMPLISHMENTS TO DATE:

TASK 1 (LITERATURE SEARCH) TO BE COMPLETED MAY 3 , 1979.

DELAY: TASK 1 DELAYED ONE MONTH - NO ADDITIONAL DELAYS ANTIC PATED AT THIS TIME.

KEY POINTS: EXPENDITURES ARE WITHIN ESTIMATES. CONTRACTOR IS RESPONSIVE.

547 284

CONTRACT: TEARING STABILITY ANALYSES FOR LIGHT WATER REACTOR PIPING

CONTRACTOR: WASHINGTON UNIVERSITY

FIN #: B6571

LICENSING EFFORT:

WILL PROVIDE INPUT FOR COMPLETION OF TAP B-6; LOADS, LOAD COMBINATIONS AND STRESS LIMITS.

OBJECTIVES: PROVIDE ELASTIC PLASTIC TEARING STABILITY SOLUTIONS FOR VARIOUS STRESS AND FLAW CONDITIONS FOR LWR PIPING. THESE SOLUTIONS WILL BE USED TO PREDICT CRITICAL STRESS AND FLAW CONDITIONS FOR UNSTABLE FRACTURE IN LWR PIPING.

CONTRACT PERIOD: JUNE 1, 1979 TO DECEMBER 31, 1980.

FUNDING LEVEL:

35K FY 79
40K FY 80

75K TOTAL

ACCOMPLISHMENTS TO DATE: PROGRAM TO BEGIN JUNE 1, 1979.

DELAYS: PROGRAM INITIATION WAS DELAYED BECAUSE OF REQUIREMENT FOR RFP.

KEY POINTS: TEARING SOLUTIONS WILL BE USED WITH EXPERIMENTAL MATERIAL PROPERTY DATA FROM RES PROGRAM TO COMPLETE EVALUATION.

TITLE: FRACTURE TOUGHNESS OF CONTAINMENT PRESSURE BOUNDARY MATERIALS

OBJECTIVE: THE CHARACTERIZATION OF THE FRACTURE TOUGHNESS OF CONTAINMENT PRESSURE BOUNDARY MATERIALS AND THE DEVELOPMENT OF FRACTURE TOUGHNESS CRITERIA FOR USE IN THE NRC LICENSING PROCESS TO EVALUATE COMPLIANCE WITH GENERAL CRITERION 51.

WORK SCOPE: BASICALLY, PROJECT IMPLEMENTATION WILL CONSIST OF DATA SEARCH RELATED TO THE FRACTURE TOUGHNESS OF CONTAINMENT PRESSURE BOUNDARY MATERIALS. PERFORM CALCULATIONS AND PLACE IN PARAMETRIC FORM TO ALLOW EVALUATION OF CONTAINMENT MATERIAL RESISTANCE TO FLAW INDUCED FRACTURE.

TITLE: FRACTURE TOUGHNESS CRITERIA (10 CFR APP. G)

OBJECTIVE: THE OBJECTIVE OF THIS PROGRAM IS TO REVIEW AVAILABLE FRACTURE TOUGHNESS DATA FOR BOLTING, VESSEL, PUMP AND VALVE MATERIALS TO DEMONSTRATE COMPLIANCE WITH CURRENT CRITERIA FOR PLANTS CONSTRUCTED TO OLDER CODE EDITIONS.

WORK SCOPE: OBTAIN AVAILABLE FRACTURE TOUGHNESS DATA (C_V, NDT, K_{IC}) FOR MATERIALS USED FOR BOLTING, PUMP AND VALVE MATERIALS AND HIGH STRENGTH STEELS USED IN REACTOR COOLANT PRESSURE BOUNDARY.

PERFORM CALCULATIONS AND PUT IN PARAMETRIC FORM TO ALLOW ASSESSMENT OF COMPLIANCE WITH CURRENT LICENSING CRITERIA.

POOR ORIGINAL

547 287

TITLE: ENVIRONMENTAL EFFECTS ON FRACTURE TOUGHNESS OF HIGH STRENGTH MATERIALS

OBJECTIVE: THIS WORK WILL ASSESS THE EFFECT OF ENVIRONMENT ON THE FRACTURE RESISTANCE OF HIGH STRENGTH STEELS AND AID IN THE DEVELOPMENT OF SPECIFIC LICENSING REQUIREMENTS FOR HIGH STRENGTH MATERIALS USED IN PRIMARY COMPONENTS SUPPORTS. THIS WORK FOLLOWS ON PREVIOUS WORK ON COMPONENT SUPPORTS PERFORMED BY SANDIA (FOR DOR) AS PART OF TAP A-12, WHICH DID NOT INCLUDE ENVIRONMENTAL EFFECTS.

WORK SCOPE: THE CONTRACTOR WILL DETERMINE THRESHOLD K_{IAEC} FOR VARIOUS HIGH STRENGTH MATERIALS USED IN PRIMARY COMPONENTS SUPPORTS STRUCTURES SUCH AS BOLTING, PINS, CLEVIS, ETC. THESE DETERMINATIONS WOULD BE PERFORMED TO DETERMINE THE POTENTIAL FOR FLAW INDUCED FRACTURE USING CONDITIONS REPRESENTATIVE OF BOTH HIGH HUMIDITY AND ACCIDENT WATER.

TITLE: CONTROL OF PROTECTIVE COATING SYSTEMS FOR NUCLEAR POWER GENERATION PLANTS

OBJECTIVE: THE GENERIC CHARACTERIZATION OF PROTECTIVE COATING SYSTEMS APPLIED IN NUCLEAR POWER GENERATION PLANTS WITH RESPECT TO FORMULATION, APPLICATION, SERVICEABILITY AND RESPONSE TO CHEMICAL, THERMAL AND RADIOLOGICAL ENVIRONMENTAL CONDITIONS UNDER NORMAL AND POSTULATED ACCIDENT CONDITIONS.

WORK SCOPE: PROJECT SCOPE WILL INCLUDE A SURVEY OF COMMERCIALLY MARKETED NUCLEAR PROTECTIVE COATING SYSTEMS, EVALUATION OF QUALIFICATION CRITERIA APPLIED TO DATE AND DEVELOPMENT OF NEW QUALIFICATION CRITERIA MORE DEFINITIVELY RESPONSIVE TO THE NRC LICENSING PROCESS.

TITLE: MATERIALS SURVEILLANCE

OBJECTIVE: ACCESS DATA TO BE OBTAINED UNDER EPRI SPONSORSHIP BY WESTINGHOUSE TO DETERMINE THE EFFECT OF LONG TERM NEUTRON IRRADIATION ON THE FRACTURE TOUGHNESS PROPERTIES OF ACTUAL REACTOR VESSEL SURVEILLANCE TEST SPECIMENS.

WORK SCOPE: WESTINGHOUSE HAS REPORTED THAT THE TEST DATA ON ACTUAL SURVEILLANCE SPECIMENS INDICATE LESS SEVERE IRRADIATION DAMAGE THAN PREDICTED BY REGULATORY GUIDE 1.99, "EFFECT OF RESIDUAL ELEMENTS ON PREDICTED RADIATION DAMAGE TO REACTOR VESSEL MATERIALS." THE SCOPE OF THIS ACTIVITY IS TO REVIEW DATA TO BE GENERATED UNDER EPRI CONTRACT AND RESOLVE THE ISSUE.

TITLE: WELDING EVALUATION

FIN #: B0234

B & R #: 20-19-03-06-2

TECHNICAL MONITOR: G. B. GEORGIEV

OBJECTIVES: 1. TO PROVIDE A BASIS DOCUMENT TO SUPPORT NRC POSITION ON MEASURES TO REDUCE THE LIKELIHOOD OF LAMELLAR TEARING IN COMPONENT SUPPORTS.

2. TO REVIEW AND MAKE RECOMMENDATIONS AS TO NRC ENDORSEMENT OF ASME CODE CASES IN THE WELDING AND FABRICATION AREAS AS REQUESTED BY SD FOR INCORPORATION IN R.G. 1.85 AND 1.86.

LENGTH OF CONTRACT: THE SCHEDULED TERMINATION DATE IS MARCH 31, 1980.

FUNDING: THE AUTHORIZED FUNDING FOR FY 1979 IS 45K AND PROJECTED FUNDING FOR FY 1980 IS 34K.

ACCOMPLISHMENTS TO DATE:

1. REPORT ON STATE-OF-THE-ART WITH PRELIMINARY RECOMMENDATIONS HAS BEEN PRESENTED TO ASME CODE COMMITTEES. WORK IN PROGRESS ON FINAL REPORT AND RECOMMENDATIONS. PARTICIPATION BY ORNL IN CODE MEETINGS.

2. CODE CASE 1644 ON ACCEPTABLE MATERIALS FOR COMPONENT SUPPORTS HAS BEEN REVIEWED AND RECOMMENDATION ON DELETION OF UNACCEPTABLE MATERIALS IS BEING IMPLEMENTED BY NRC THROUGH CODE AND R.G. 1.85.

PROBLEMS AND DELAYS:

NO DELAYS OR PROBLEMS ARE EXPECTED OR HAVE BEEN ENCOUNTERED TO DATE.

BENEFITS TO THE LICENSING EFFORT:

IMPLEMENTATION OF NRC ACCEPTABLE MATERIALS AND PROCEDURES IN THE ASME CODE WILL PRECLUDE NEED FOR CASE-BY-CASE REVIEW OF COMPONENT SUPPORT MATERIALS. SRP CAN REFERENCE CODE WITHOUT NEED FOR APPENDIX TO LIST ACCEPTABLE MATERIALS AND PROCEDURES.

OTHER KEY POINTS: PROGRAM ON SCHEDULE AND WILL BE COMPLETED MARCH 31, 1980.

547 291

TITLE: CORROSION AND COOLANT CHEMISTRY

OBJECTIVES:

1. REVIEW PIPE CRACK STUDY GROUP REPORT AND PROVIDE RECOMMENDATIONS ON ITS USE IN LICENSING. PROVIDE EVALUATION OF DEAERATION TECHNIQUES AS RECOMMENDED BY PCSG. THIS TASK SHOULD BE FACTORED INTO A-42 WHEN ESTABLISHED.

2. PROVIDE CASE LICENSING WORKING CURVES FOR HYDROGEN GENERATION RATES IN CONTAINMENT. PROVIDE EVALUATION OF THREE SPECIFIC PLANTS USING THESE CURVES.

3. PROVIDE CONSULTING SERVICES TO MTEB. PROVIDE AN EVALUATION OF THE EFFECTS OF CORROSIVE ENVIRONMENT ON THE CRACK GROWTH IN TURBINE DISKS.

LENGTH OF CONTRACT: ONE YEAR BUT EXPECT FOLLOW ON CONTRACTS.

OVERALL FUNDING: FY 1979 IS 80K, FOR FY 1980 WILL BE 75K.

ACCOMPLISHMENTS:

1. PIPE CRACK STUDY REPORT ISSUED IN MARCH AND SENT TO CONTRACTOR. RECOMMENDATIONS ON LICENSING IMPLEMENTATION ARE IN PROGRESS AND EXPECTED TO BE COMPLETED BY MILESTONE DATE SEPTEMBER 1979.

2. WORK IS IN PROGRESS. PRELIMINARY WORKING CURVES DEVELOPED LAST YEAR ARE BEING USED BY CSB IN THEIR CASE REVIEWS. REFINED WORKING CURVES FOR HYDROGEN GENERATION SHOULD BE AVAILABLE JUNE 15, 1979. REVIEW OF THE THREE PLANTS SHOULD BE COMPLETED BY JULY 15, 1979.

3. CONTRACTOR PARTICIPATED IN BLACK FOX HEARINGS. WORK IN PROGRESS ON TURBINE DISK TASK, WILL BE COMPLETED BY JULY 1.

PROBLEMS AND DELAYS:

STUDY GROUP REPORT WAS NOT ISSUED UNTIL MARCH BUT CONTRACTOR WILL ACCELERATE WORK AND MEET AGREED MILESTONES.

BENEFIT TO THE LICENSING EFFORT:

HYDROGEN GENERATION RATE CURVES DEVELOPED BY BNL FORMED BASIS FOR CONTINUED LICENSING WHEN STAFF INFORMED BOARDS OF UNCERTAINTY IN EXISTING DATA. BNL PROVIDED SUPPORT AT BLACK FOX HEARING ON SHORT NOTICE.

KEY POINTS: CONTRACTOR IS VERY RESPONSIVE TO OUR CHANGING NEEDS, E.G., HYDROGEN GENERATION. BNL PROVIDES AUTHORITATIVE EXPERTISE WHEN NEEDED FOR HEARINGS AND STAFF DECISIONS.

547 292

TITLE: PRIMARY SYSTEM CORROSION

OBJECTIVE: THIS PROGRAM IS TO PROVIDE THE STAFF WITH CRITERIA FOR UPGRADING THE DETAILED CHEMISTRY CONTROL AND MATERIAL SELECTION TO REDUCE THE PROBABILITY OF CORROSION AND DEGRADATION OF NEW PLANTS AFTER THE START OF OPERATION.

WORK SCOPE:

1. REVIEW AND ASSESS THE PROPOSED PROGRAMS FOR MITIGATING STRESS CORROSION CRACKING SUBMITTED BY GE AND THREE SELECTED APPLICANTS. THIS YEAR'S PROGRAM WILL FOCUS ON THE STRESS RULE INDEX AND IHSI. SUBSEQUENT YEARS WILL FOCUS ON OTHER ASPECTS OF GE RECOMMENDATIONS.

2. EVALUATE THE EFFECTS OF CORROSION-FATIGUE ON FERRITIC MATERIALS IN LWR COMPONENTS. (SMALL OSCILLATING STRESS SUPERIMPOSED ON STEADY STATE STRESS).

3. PROVIDE EXPERT TESTIMONY AT HEARINGS.

POOR ORIGINAL

547 293 51

TITLE: SECONDARY & ESF CORROSION

OBJECTIVE: TO ANTICIPATE LONG RANGE DEGRADATION DUE TO CORROSION AND TO POSTULATE DEGRADATION MECHANISMS.

AFTER EVALUATION OF DEGRADATION MECHANISM TO RECOMMEND STAFF POSITIONS TO COMBAT THE DEGRADATION MECHANISMS.

WORK SCOPE:

1. EVALUATE THE TYPES OF PARAMETERS TO BE CONTROLLED IN PWR SECONDARY SYSTEMS. EVALUATE OPTIMUM POSITION FOR SENSORS. DETERMINE APPROPRIATE PROVISIONS TO BE PUT IN TECH SPECS.

2. REVIEW BASE DATA AND PROPOSE NEEDED EXPERIMENTAL PROGRAMS TO CONFIRM BTP ON CORROSIVE EFFECTS OF CONTAINMENT SPRAYS ON STAINLESS STEEL PIPES AND COMPONENTS.

3. PROVIDE EXPERT TESTIMONY AT HEARINGS.

TITLE: CORROSION OF FERRITIC STEELS

OBJECTIVE: TO EVALUATE THE CORROSION MECHANISMS AND THE CORROSION-FATIGUE BEHAVIOR OF FERRITIC PIPING STEELS IN AN ENVIRONMENT OF BWR AND PWR REACTOR GRADE WATER AND SECONDARY WATER. TO EVALUATE THE CORROSION MECHANISMS OF RV STEELS IN THE PRESENCE OF CREVICES, I.E., CRACKS IN RV CLADDING.

WORK SCOPE:

1. REVIEW AND ASSESS THE CORROSION AND CORROSION-FATIGUE MECHANISMS IN FERRITIC STEELS. THE PROGRAM IS TO FOCUS UPON THE PARTICULAR ALLOY BEING USED AND THEIR RESPONSE TO REACTOR WATER OF BWR'S AND PWR'S AND SECONDARY WATER OF PWR'S. THE PROGRAM SHOULD ALSO EVALUATE OFF-NORMAL CONDITIONS DUE TO INTRUSIONS OF VARIOUS APPROPRIATE ION SPECIES.

2. REVIEW AND EVALUATE THE CORROSION MECHANISMS IN THE FERRITIC STEELS IN THE PRESENCE OF CRACKS IN PROTECTIVE CLADDING, I.E., CREVICE CORROSION.

547 295

T-1, 8 through 12

547 296

SAFETY RESEARCH ACTIVITIES

IN

PRIMARY SYSTEM INTEGRITY

METALLURGY & MATERIALS RESEARCH BRANCH, RES

TO

ACRS, JULY 10, 1979

METALLURGY & MATERIALS RESEARCH BRANCH

PROGRAM AREAS

- o VESSEL AND PIPING FRACTURE MECHANICS
- o IRRADIATION EFFECTS AND DOSIMETRY
- o STEAM GENERATOR TUBE INTEGRITY AND STRESS CORROSION
- o NON-DESTRUCTIVE EXAMINATION

VESSEL AND PIPING FRACTURE MECHANICS

PURPOSE: ESTABLISH VALIDATED FUNDAMENTALS OF FRACTURE AND FRACTURE ANALYSIS FOR VESSELS AND PIPING TO ASSURE SAFE DESIGN AND OPERATION.

547 298

OBJECTIVES:

- o DEVELOP AND VALIDATE E/P AND TEARING INSTABILITY CRITERIA
- o VALIDATE THERMAL SHOCK AND STEAM LINE BREAK EVALUATION METHOD
- o ESTABLISH INTEGRITY OF VESSEL HAVING LOW SHELF MATERIAL
- o UPDATE ASME CODE CURVES FOR CRACK GROWTH RATE
- o ESTABLISH CRACK ARREST TOUGHNESS ANALYSIS
- o REEVALUATE COLD LEG BREAK CRITERIA
- o REEVALUATE CRITERIA FOR PIPE BREAKS AND PIPE WHIP
- o ESTABLISH PIPING ANALYSIS METHOD AND PROPOSE UPDATED LICENSING CRITERIA

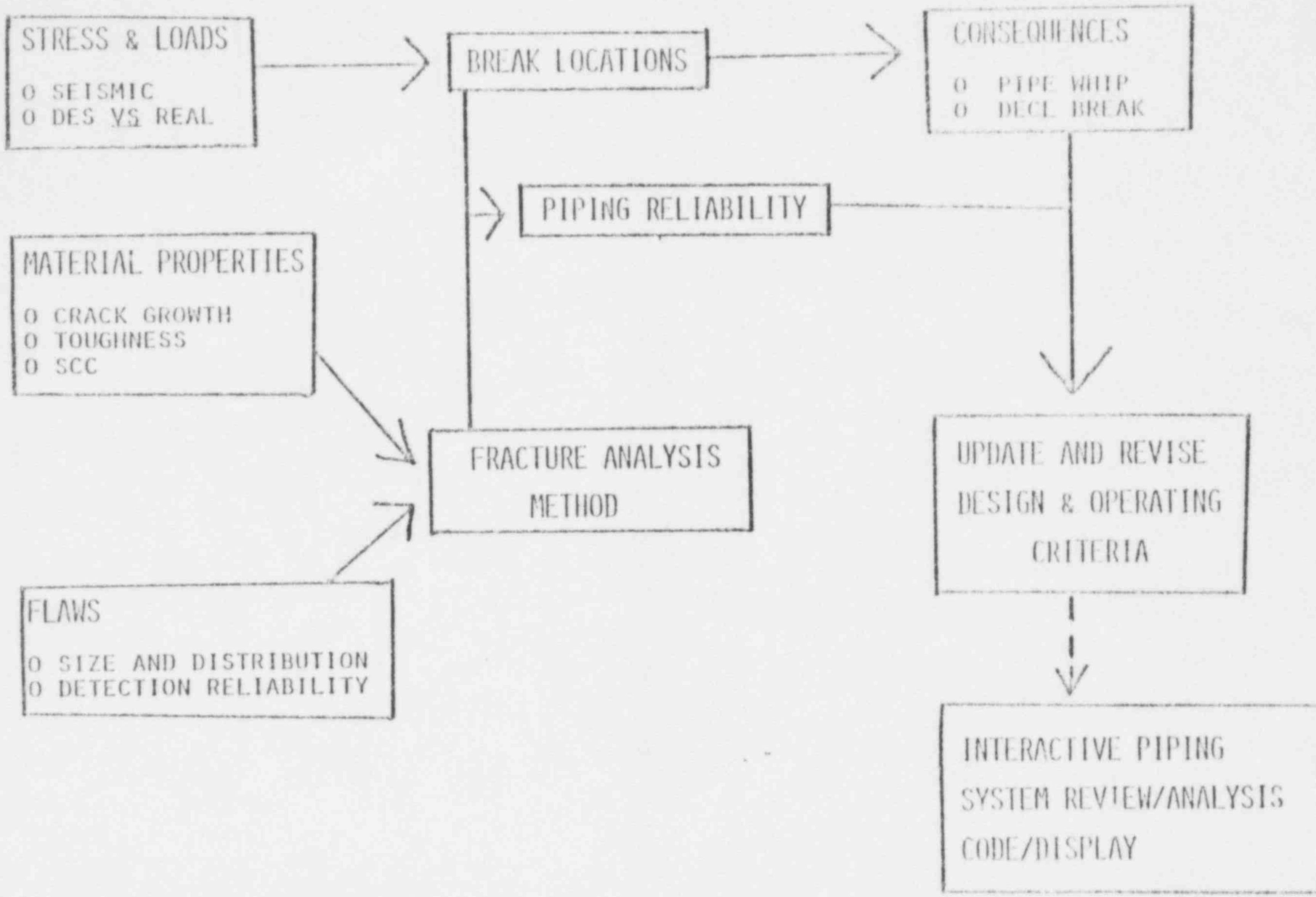
VESSEL AND PIPING FRACTURE MECHANICS

PURPOSE: ESTABLISH VALIDATED FUNDAMENTALS OF FRACTURE AND FRACTURE ANALYSIS FOR VESSELS AND PIPING TO ASSURE SAFE DESIGN AND OPERATION.

OBJECTIVES:

- o DEVELOP AND VALIDATE E/P AND TEARING INSTABILITY CRITERIA
- o VALIDATE THERMAL SHOCK AND STEAM LINE BREAK EVALUATION METHOD
- o ESTABLISH INTEGRITY OF VESSEL HAVING LOW SHELF MATERIAL
- o UPDATE ASME CODE CURVES FOR CRACK GROWTH RATE
- o ESTABLISH CRACK ARREST TOUGHNESS ANALYSIS
- o REEVALUATE COLD LEG BREAK CRITERIA
- o REEVALUATE CRITERIA FOR PIPE BREAKS AND PIPE WHIP
- o ESTABLISH PIPING ANALYSIS METHOD AND PROPOSE UPDATED LICENSING CRITERIA

RELIABILITY OF PIPING SYSTEMS



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POOR ORIGINAL

547 301

METALLURGY & MATERIALS RESEARCH BRANCH PROGRAMS ON PIPING

- o COLD LEG INTEGRITY EVALUATION (BCL)
- o REEVALUATION OF CRITERIA FOR PIPE BREAKS AND PIPE WHIP

    TWO-PHASE JET LOADS (SANDIA)

    DYNAMIC ANALYSIS OF PIPE WHIP (U. C. BERKELEY)

    RELIABILITY OF PIPING SYSTEMS (SAI)

- o SUPPORT PROGRAMS:

    MATERIAL PROPERTIES OF PIPING STEELS (NRL, NSRDC)

    NDE (PNL)

COLD LEG INTEGRITY EVALUATION

PURPOSE: DETERMINE IF THE SAFETY MARGIN AGAINST A LARGE BREAK IN A PWR COLD LEG -- DURING THE 40-YEAR PLANT LIFE -- IS LARGE ENOUGH TO MAKE THE POSTULATION OF A BREAK OVERLY CONSERVATIVE.

OBJECTIVES:

- o PLANT AND LOAD DESCRIPTION (ARKANSAS N-1, ST. LUCI-1, FARLEY-1)
- o STRESS ANALYSIS RESULTS OF PRIMARY PIPING SYSTEMS
- o FRACTURE MECHANICS MODEL FOR CRACK GROWTH
- o MATERIAL PROPERTIES (DA/DN, J-R CURVE)
- o DATA ON CRACK CHARACTERISTICS (SIZE, SHAPE, LOCATION, LARGEST MISSED FLAW)
- o ANALYSIS OF CYCLIC CRACK GROWTH AND FINAL INSTABILITY
- o EVALUATE NEED TO POSTULATE LARGE BREAK IN COLD LEG

5A7 302

547 303

TWO-PHASE JET LOADS

PURPOSE: TO ESTABLISH AN ACCURATE, SIMPLY APPLIED, PREDICTIVE METHODOLOGY FOR LOAD DETERMINATION OF JETS EMANATING FROM CRACKS OR BREAKS IN NUCLEAR PIPING SYSTEMS.

OBJECTIVES:

- o EVALUATE AVAILABLE TWO-PHASE FLOW ANALYSIS COMPUTER CODES (BEACON/MOD 2, TRAC, ETC.);
- o SELECT ONE(S) BEST SUITED FOR CHARACTERIZING TWO-PHASE SETS EMANATING FROM BREAKS OR CRACKS IN TYPICAL PWR PIPING SYSTEMS;
- o MODIFY IF NECESSARY;
- o COORDINATE WITH GERMANS ON THEIR ONGOING TWO-PHASE JET EXPERIMENTAL PROGRAM;
- o USE EXISTING EXPERIMENTAL DATA TO VALIDATE CODE;
- o DEVELOP SIMPLIFIED MATHEMATICAL MODELS TO BE USED IN THE LICENSING PROCESS FOR THE EVALUATION OF JET LOADS.

547 304

DYNAMIC ANALYSIS OF PIPE WHIP

PURPOSE: TO DEVELOP A SPECIAL PURPOSE COMPUTER PROGRAM FOR THE DYNAMIC RESPONSE ANALYSIS OF NUCLEAR PIPING SYSTEMS SUBJECTED TO JET LOADS AND TO IMPACT WITH ADJACENT STRUCTURES.

OBJECTIVES:

- o MODIFY EXISTING CODE (ANSR) TO ALLOW PIPE WHIP ANALYSIS CAPABLE OF DESCRIBING EFFECTS OF:
  - GAPS
  - GEOMETRICAL AND MATERIAL NONLINEARITIES
  - LARGE DISPLACEMENTS
  - ELASTIC PLASTIC RESPONSE OF RESTRAINTS
  - IMPACT WITH ADJACENT STRUCTURES; LOCAL DEFORMATION AND REBOUND.
- o IMPLEMENT CODE ON MINI-COMPUTER WITH INTERACTIVE INPUT AND OUTPUT.
- o COORDINATE WITH GERMAN PIPING EXPERIMENTAL PROGRAMS.
- o VALIDATE CODE USING EXISTING EXPERIMENTAL DATA.
- o DEVELOP MATHEMATICAL MODELS TO BE USED IN THE LICENSING PROCESS FOR THE EVALUATION OF PIPING SYSTEMS AND RESTRAINTS.

RELIABILITY OF PIPING SYSTEMS

PURPOSE: DETERMINE THE RELIABILITY OF TYPICAL PIPING SYSTEMS, BOTH INSIDE AND OUTSIDE THE CONTAINMENT, AND PROVIDE A SOUND TECHNICAL BASIS FOR DEFINING THE CRITERIA FOR POSTULATING BREAKS. FROM THIS WORK, REVISE REG. GUIDE 1.46, AS NECESSARY.

OBJECTIVES:
- o BEGIN WITH THE DETERMINISTIC FRACTURE MECHANICS MODEL OF CRACK GROWTH AND INSTABILITY;
- o ADD STOCHASTIC INPUTS FOR:
  - (A) INITIAL FLAW SIZE
  - (B) CRACK DETECTION PROBABILITY
  - (C) LOADING
  - (D) MATERIAL PROPERTIES;
- o COMPUTE THE PROBABILITY OF A PIPING SYSTEM FAILING BY:
  - (A) LEAK
  - (B) BREAK BEFORE A LEAK
  - (C) BREAK FOLLOWING A LEAK;
- o DETERMINE THE EFFECT OF ISI AND LEAK DETECTORS ON PIPE FAILURE PROBABILITIES.

547 305

MATERIAL PROPERTIES OF PIPING STEELS

PURPOSE: CHARACTERIZE THE CRACK GROWTH RATE AND FRACTURE BEHAVIOR OF THE FOLLOWING PIPING STEELS: A106, A516, TYPE 304 SS.

OBJECTIVE:

- o MEASURE CYCLIC CRACK GROWTH RATES IN PWR ENVIRONMENT (2, 100, PSI, 550°F, REACTOR GRADE WATER);
- o MEASURE J-R CURVES AT ROOM TEMPERATURE AND 350°F.

547 307

RELIABILITY OF ULTRASONIC INSPECTION

PURPOSE: DETERMINE THE RELIABILITY OF ULTRASONIC NDE APPLIED TO PRIMARY PIPING SYSTEMS AND ITS IMPACT ON FRACTURE MECHANICS ANALYSIS.

OBJECTIVES:

- o PREPARE PLATE AND PIPE SAMPLES -- CONTAINING SERVICE-INDUCED-TYPE FLAWS -- FABRICATED FROM A106, A516, TYPE 304 SS, AND SA 351 STEELS;
- o DETERMINE THE SIGNIFICANCE OF FLAW ROUGHNESS, ASPECT RATIO AND FLAW DEPTH ON DETECTION;
- o USING THE IMPORTANT VARIABLES FROM ABOVE, AND FLAW LOCATION, TIGHTNESS GEOMETRY AND ORIENTATION, AND INSPECTION TEAM AS VARIABLES, DETERMINE THE PROBABILITY OF DETECTING GIVEN FLAWS IN PIPING SYSTEMS.

IRRADIATION EFFECTS AND DOSIMETRY

547 308

PURPOSE: ESTABLISH VALID IRRADIATION EFFECTS TRENDS AND METHODS TO PREDICT FLUENCE AND EMBRITTLEMENT IN REACTORS.

OBJECTIVES:

- o ESTABLISH DUCTILE SHELF TOUGHNESS OF IRRADIATED WELD METALS
- o REEVALUATE 10CFR50 RULES ON CHARPY-V 50 FT-LB TOUGHNESS CRITERION
- o SUPPORT FRACTURE MECHANICS TECHNOLOGIES IN CRACK ARREST AND CRACK GROWTH RATE
- o ESTABLISH CRITERIA FOR CYCLIC IRRADIATION - ANNEALING OF PRESSURE VESSELS
- o VALIDATE PRESSURE VESSEL SURVEILLANCE - DOSIMETRY PROCEDURES
- o EVALUATE VALIDITY OF EMBRITTLEMENT SATURATION

POOR ORIGINAL

5A7 309

IRRADIATION EFFECTS AND DOSIMETRY (CONT.)

VALIDATE PRESSURE VESSEL SURVEILLANCE DOSIMETRY PROCEDURES

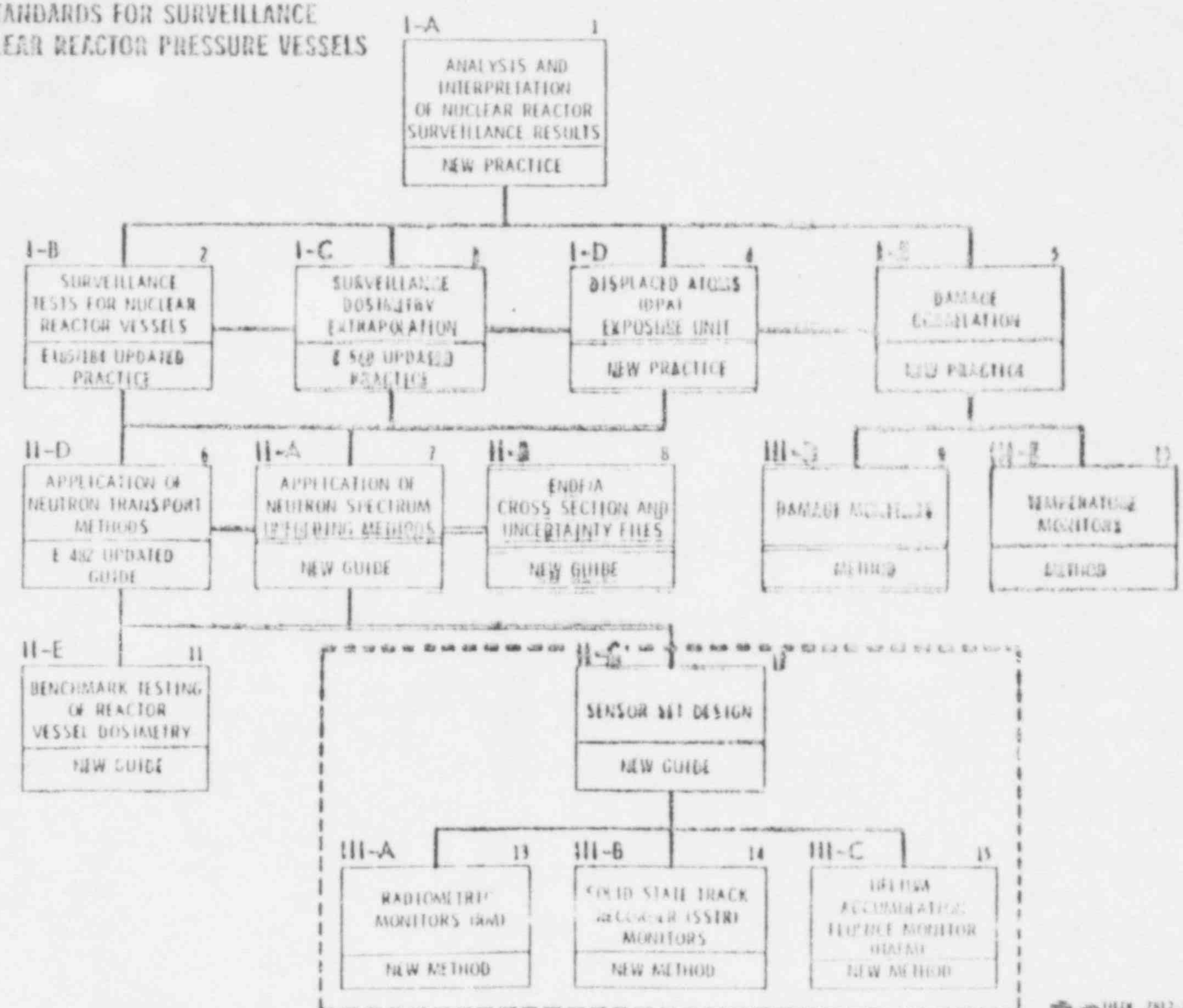
OBJECTIVE:

- ESTABLISH VALIDATED STANDARD PROCEDURES FOR MEASURING AND PREDICTING NEUTRON FLUENCE AND EMBRITTLEMENT IN POWER REACTOR PRESSURE VESSELS FROM SURVEILLANCE DATA.

APPROACH:

- VALIDATE TRANSPORT-THEORY CALCULATION METHODS;
- MAKE DOSIMETRY MEASUREMENTS BY DIRECT AND INDIRECT MEANS;
- ESTABLISH CALCULATION BENCHMARKS;
- OBTAIN IRRADIATION EFFECTS DATA ON STANDARD AND REFERENCE MATERIALS;
- OBTAIN CALCULATIONS, DOSIMETRY AND EMBRITTLEMENT MEASUREMENTS IN VALIDATION TEST;
- REEVALUATE REG. GUIDE 1.99 DATA BASE, AND EVALUATE POSSIBLE SATURATION EFFECT;
- WRITE STANDARD PROCEDURES FOR PREDICTIVE CALCULATIONS, MEASUREMENTS AND CORRELATIONS;
- REVISE STANDARDS AND PROCEDURES FOR REACTOR VESSEL SURVEILLANCE MONITORING.

ASTM STANDARDS FOR SURVEILLANCE
OF NUCLEAR REACTOR PRESSURE VESSELS



POOR ORIGINAL

LIST OF BENCHMARK AND REACTOR TEST REGION NEUTRON FIELDS OR LWR-PV DOSIMETRY VALIDATION AND CALIBRATION (12)

NEUTRON FIELD	TYPE OF DOSIMETRY	STATUS
BENCHMARKS FOR CALIBRATION		
^{252}Cf AND ^{235}U FISSION NEUTRON IRRADIATION FACILITIES AT NBS (STANDARD)	SENSOR CALIBRATIONS	PREPARATION OF FLUENCE COUNTING STANDARDS IN PROGRESS FOR PARTICIPATING LABORATORIES. ^{252}Cf IS ABSOLUTE FAST NEUTRON FLUENCE STANDARD
^{235}U FISSION FIELD AT CEN/SCK (STANDARD)	SENSOR CALIBRATIONS	FACILITY CHARACTERIZATION COMPLETE. APPLIED ROUTINELY INCLUDING TO HAFM, RM, ETC.
ISNF IRRADIATION FACILITIES AT NBS (STANDARD)	SENSOR CALIBRATIONS (PARTICULARLY DETECTORS WITH RESPONSE RANGE BELOW 0.5 MeV)	FISSION RATE RATIOS ESTABLISHED WITH FISSION CHAMBERS
CRMF IRRADIATION FACILITY AT EG&G (REFERENCE)	SENSOR CALIBRATIONS	AVAILABILITY BEING ESTABLISHED
BENCHMARKS FOR TRANSPORT CALCULATION VALIDATION		
IRON SHELLS FIELD AT CEN/SCK (REFERENCE)	ACTIVE AND PASSIVE RM, SSTR, NE	CEN/SCK SPECTROMETRY IN PROGRESS. NBS FISSION CHAMBER MEASUREMENTS COMPLETED. PLANNING STAGE FOR PASSIVE
PCA AT ORNL (REFERENCE)	ACTIVE AND PASSIVE RM, SSTR, NE	RADIOMETRIC, FISSION CHAMBER, TRACK RECORDER, MEASUREMENTS COMPLETE. NEUTRON AND γ SPECTROMETRY SCOPING FINISHED. ABSOLUTE SOURCE ESTABLISHED

HEDL 7902-039.13

POOR ORIGINAL

NEUTRON FIELD	TYPE OF DOSIMETRY	STATUS
TEST REGIONS FOR DOSIMETRY METHOD VALIDATION		
⊙ PSR-HSST DOSIMETRY-TEST (TEST REACTOR AT ORNL)	RADIATION MONITORS (RM)	IRRADIATION AND DOSIMETRY COUNTING COMPLETED, ANALYSIS STARTED
⊙ FRJ-1 AND FRJ-2 (TEST REACTOR AT KFA, GERMANY)	RM, HAFM, TM (MELT WIRES), DM (QUARTZ)	"TEST REGION" IRRADIATION IN METALLURGICAL RIGS IN PROGRESS. INTERLABORATORY DOSIMETRY
⊙ BUFFALO NRL-NRC (TEST REACTOR AT UNIVERSITY OF BUFFALO)	RADIOMETRIC MONITORS (RM)	PLANNING STAGE
⊙ UNIVERSITY OF VIRGINIA (TEST REACTOR)	RADIOMETRIC MONITORS (RM)	PLANNING STAGE
⊙ BR-3 (PWR POWER REACTOR AT CEN/SCK, MOL, BELGIUM)	RM, HAFM, DM (QUARTZ), TM (MELT WIRES)	DOSIMETRY AT SITE - READY FOR IN- AND EX-VESSEL "TEST REGION" IRRADIATIONS
⊙ ARKANSAS POWER AND LIGHT COMPANY PWR UNIT #1 (RUSSELVILLE, ARKANSAS)	RADIOMETRIC MONITORS (RM)	INITIAL EX-VESSEL "TEST REGION" IRRADIATION AND SENSOR COUNTING COMPLETED
⊙ GARIGLIANO REACTOR (BSR POWER AT ROME, ITALY)	RADIOMETRIC MONITORS (RM)	IN-VESSEL "TEST REGION" IRRADIATION IN PROGRESS
⊙ BROWN'S FERRY 3 (BSR)	RM, SSTR, IONIZATION CHAMBERS	IN- AND EX-VESSEL "TEST REGION" IRRADIATIONS IN PROGRESS
⊙ McGUIRE 1 (PWR)	RM, SSTR, PROTON RECOIL	EX-VESSEL "TEST REGION" IRRADIATIONS PLANNED AND SCHEDULED

RM: RADIOMETRIC MONITORS
SSTR: SOLID STATE TRACK RECORDERS
HAFM: HELIUM ACCUMULATION FLUENCE MONITORS

NE: NUCLEAR EMULSIONS
DM: DAMAGE MONITORS
TM: TEMPERATURE MONITORS

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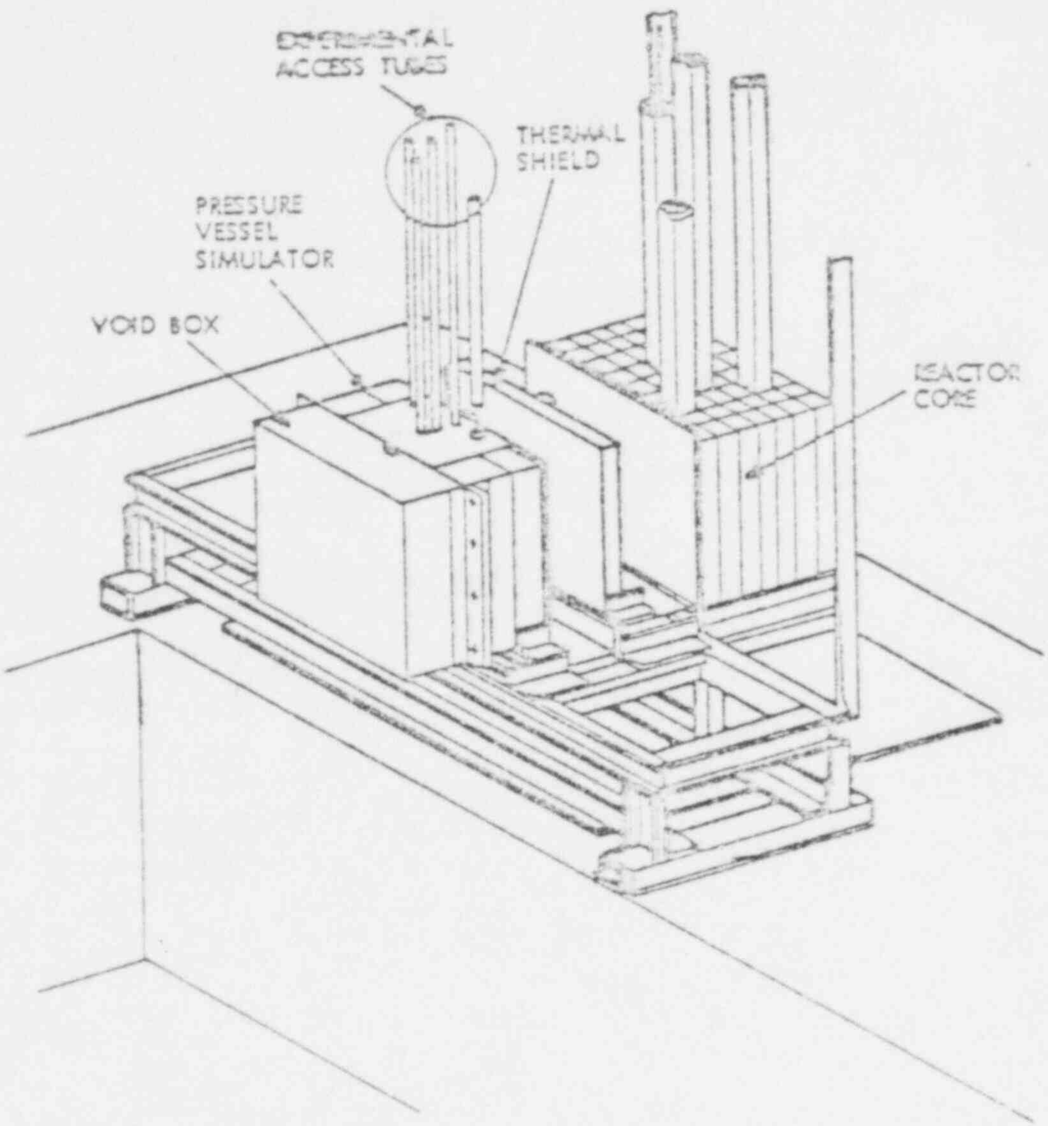
POOR ORIGINAL



HEDL 7804-025

FIGURE 12 Pressure Vessel Wall, Mock-up schematic of two equivalent facilities under construction at ORNL. The high-flux version at ORR (PSF) will include damage exposure of metallurgical test specimens; the low-flux version near a low-power critical assembly (PCA) will focus on active and passive dosimetry measurements.

POOR ORIGINAL

IRRADIATION EFFECTS AND DOSIMETRY (CONT.)

VALIDATE PRESSURE VESSEL SURVEILLANCE DOSIMETRY PROCEDURES

HEDL:
- o FLUX AND SPECTRUM CALCULATIONS OF SURVEILLANCE AND OTHER REACTOR LOCATIONS;
- o ASSEMBLY, IRRADIATION AND COUNTING OF NEUTRON FLUX MONITORS IRRADIATED IN MANY REACTORS;
- o FORMULATION OF MODELS FOR RADIATION DAMAGE AND DEVELOPMENT OF PREDICTIVE DAMAGE FUNCTIONS;
- o WRITING OF STANDARDS FOR MEASURING AND INTERPRETING NEUTRON FLUX/SPECTRUM AND EMBRITTLEMENT.

ORNL:
- o CONSTRUCTION AND OPERATION OF "BENCHMARK" FACILITIES FOR DIRECT SPECTROMETRY (PCA) AND FOR DOSIMETRY/EMBRITTLEMENT (PSF) IN SIMULATED VESSEL WALL ENVIRONMENT;
- o WRITING OF STANDARD METHOD FOR TRANSPORT-THEORY FLUX-SPECTRUM CALCULATIONS.

NBS:
- o STANDARDIZATION ACCURACY FOR ALL MEASUREMENT LABS IN PROGRAM;
- o ABSOLUTE FLUX MEASUREMENTS IN "BENCHMARK" TEST FACILITIES.

POOR ORIGINAL

547 314

IRRADIATION EFFECTS AND DOSIMETRY (CONT.)

EVALUATE VALIDITY OF EMBRITTLEMENT SATURATION

EPRI:	o	PROGRAM TO MEASURE EMBRITTLEMENT FROM 10 LOW-FLUX SURVEILLANCE IRRADIATIONS.
HEDL:	o	TO DETERMINE FLUX AND SPECTRUM FROM THE LOW-FLUX SURVEILLANCE CAPSULES.
NRL:	o	BEGIN LOW FLUX IRRADIATION IN TEST REACTOR WITH REFERENCE MATERIALS.
KFA-JULICH:	o	EXPERIMENTAL IRRADIATIONS IN HIGH AND LOW FLUX REACTOR POSITIONS.
PROPOSED:	o	BEGIN LONG-TERM REFERENCE STEEL IRRADIATION IN POWER REACTOR SURVEILLANCE POSITION.

STEAM GENERATOR TUBE INTEGRITY AND STRESS CORROSION

PURPOSE: DEVELOP UNDERSTANDING OF INTEGRITY AND MECHANISMS OF DEGRADATION OF STEAM GENERATORS AND TUBING; DEVELOP NRC CAPABILITY TO EVALUATE SCC IN REACTOR MATERIALS.

OBJECTIVES:

- o DEVELOP PREDICTION FOR MARGIN-TO-FAILURE UNDER BURST AND COLLAPSE PRESSURES OF DEGRADED STEAM GENERATOR (SG) TUBES.
- o DEVELOP PREDICTIVE CAPABILITY FOR STRESS CORROSION CRACKING (SCC) OF SG TUBING.
- o DETERMINE DEGRADATION PATTERNS AND MECHANISMS IN A RETIRED STEAM GENERATOR.
- o DEVELOP METHODS AND CRITERIA FOR EVALUATION OF INTERGRANULAR STRESS CORROSION CRACKING (IGSCC) IN BWR STAINLESS STEEL PIPING, AND SCC IN FERRITIC STEEL PIPING.

547 316

<u>STUDIES OF SERVICE DEGRADED STEAM GENERATOR</u>

ACQUISITION AND HOUSING

- FEASIBILITY STUDY FOR ACQUIRING, SHIPPING AND HOUSING SURRY 2 STEAM GENERATOR COMPLETE - SHOWN FEASIBLE.
- CONCEPTUAL DESIGN STUDY FOR FACILITY UNDERWAY - COMPLETE BY END OF FY 79.
- ARRANGEMENTS FOR SHIPPING UNDERWAY - SHIPMENT TO START IN NOVEMBER 1979.
- CONSTRUCTION OF FACILITY START MAY 1980, COMPLETE FEBRUARY 1981.

547 317

STUDIES OF SERVICE DEGRADED STEAM GENERATOR

RESEARCH STUDIES

- START NDE RESEARCH AND SG TUBE CHARACTERIZATION STUDIES IN SPRING 1980 WHILE SG IS IN TEMPORARY STORAGE.

- START RESEARCH PROGRAM - MARCH 1981:
  - VALIDATION OF IMPROVED NDE TECHNIQUES AND DEVELOPMENT OF IMPROVED TEST METHODS.
  - DEVELOPMENT AND VALIDATION OF IMPROVED STATISTICAL MODELS FOR ISI SAMPLING PLANS.
  - DEVELOPMENT/VALIDATION OF TUBE PLUGGING CRITERIA.
  - VISUAL, CHEMICAL AND METALLURGICAL CHARACTERIZATION OF DEGRADATION AND DEGRADATION PRODUCTS - DETERMINATION OF CAUSATIVE DEGRADATION PARAMETERS - IMPROVEMENT IN MECHANICAL/THERMOHYDRAULIC DESIGN AND WATER CHEMISTRY.
  - VALIDATION OF TUBE BURST, COLLAPSE AND LEAK RATE PREDICTIVE MODELS FOR SERVICE DEGRADED TUBES.
  - VALIDATION OF PREDICTIVE MODELS FOR SCC OF SG TUBES.
  - VALIDATION OF CHEMICAL CLEANING AND DECONTAMINATION PROCESSES/PROCEDURES, CONFIRMATION OF MECHANICAL INTEGRITY FOLLOWING SUCH TREATMENTS, AND DETERMINATION OF LONG TERM EFFECTS (CREVICE CORROSION, SCC, ETC.).

547 313

POOR ORIGINAL

ENVIRONMENTAL EFFECTS ON PIPE CRACKING

ISSUES

STAINLESS STEEL BYPASS AND CORE SPRAY LINES IN BWRS HAVE CRACKED AND CONTINUE TO CRACK.

DESIGN, FABRICATION PLUS STRESS ASSISTED CORROSION RESULTED IN 270° CRACKS IN DUANE ARNOLD INCONEL SAFE END.

DESIGN FURNACE SENSITIZATION PLUS STRESS ASSISTED CORROSION RESULTED IN CRACKS IN KRB STAINLESS STEEL SAFE ENDS.

STRESS ASSISTED CORROSION CRACKS ARE NOW APPEARING IN CARBON STEEL, SG FEEDWATER LINES AND ELBOWS OF PWRS.

ENVIRONMENTAL EFFECTS ON PIPE CRACKING

TECHNICAL FACTORS

- o BASIC FACTORS CAUSING SCC
  - ° STRESSES - CYCLIC, THERMAL, RESIDUAL
  - ° WATER CHEMISTRY - ESPECIALLY O_2
  - ° MATERIAL COMPOSITION AND FABRICATION CONDITION.
- o WATER CHEMISTRY EFFECTS INFLUENCED BY TEMPERATURE LEVEL.
- o CHEMICAL SPECIES PLAY DIFFERENT ROLES IN INITIATION AND PROPAGATION.
- o O_2 CONCENTRATION VARIES FROM EQUILIBRIUM SATURATION LIMIT TO LESS THAN 0.2 PPM. EFFECTS OF THIS CONCENTRATION RANGE VS STRESSES DURING OPERATION OR SHUTDOWN ARE NOT KNOWN.

547 320

ENVIRONMENTAL EFFECTS ON PIPE CRACKING

PROPOSED SCOPE OF WORK

STUDIES OF REACTOR COOLANT MAKE-UP INCLUDING:

1. MAJOR COMPONENTS AND CONCENTRATIONS
2. TRACE ELEMENTS AND CONCENTRATIONS
3. pH AND GASES
4. CHANGES BROUGHT BY TEMPERATURE, OPERATIONS, TRANSIENTS, ACCIDENTS, SHUTDOWNS.

SCC TESTING UNDER CONTROLLED VARIATION OF O_2, WATER CHEMISTRY, STRESS AND THERMAL CYCLES TO SIMULATE STARTUP, OPERATION, SHUTDOWN CONDITIONS.

HEAT TO HEAT VARIABILITY ON SENSITIZATION AND IGSCC.

ALLOY COMPOSITION FACTORS AFFECTING SCC POTENTIAL.

DETERMINE IMPORTANCE OF REDUCING O_2 LEVELS DURING STARTUP, SHUTDOWN OR ALL-THE-TIME.

MEASUREMENT OF STRESS/STRAIN IN PIPING SYSTEMS AS A FUNCTION OF OPERATING CONDITIONS.

INVESTIGATIONS OF PIPING REMOVED FROM SERVICE FOR RESIDUAL STRESSES AND PRESENCE OF LOW TEMPERATURE SENSITIZATION.

VALIDATION OF STRESS RULES.

VALIDATION OF IHSI, AND OTHER SENSITIZATION-MITIGATION TECHNIQUES.

NON-DESTRUCTIVE EVALUATION

PURPOSE: ESTABLISH IMPROVED METHODS AND CRITERIA FOR ULTRASONIC FLAW DETECTION AND EVALUATION, AND FOR CONTINUOUS ACOUSTIC MONITORING FOR FLAW INITIATION AND GROWTH.

OBJECTIVES:

- o VALIDATE IMPROVED SAFT-UT FLAW CHARACTERIZATION DURING ISI.
- o DEVELOP IMPROVED "REAL-TIME" FLAW DETECTION TECHNIQUES.
- o DEVELOP IMPROVED INTERACTIVE FLAW DISPLAY SYSTEM.
- o ESTABLISH PROBABILITY OF FLAW DETECTION FOR SPECIFIC SIZE FLAWS.
- o REVISE AND UPDATE ISI REQUIREMENTS FOR MOST CRITICAL FLAW TYPES AND LOCATIONS.
- o DEVELOP AND VALIDATE IMPROVED EDDY CURRENT ISI FOR SG TUBES.
- o DEVELOP AND VALIDATE ACOUSTIC EMISSION AND INTERNAL FRICTION FOR CONTINUOUS MONITORING OF REACTOR STRUCTURAL INTEGRITY.

DETAILED BUDGET - METALLURGY & MATERIALS RESEARCH BRANCH

(BASIC BUDGET - NO SUPPLEMENTS)

FIN #	CONTR.	TITLE	FY 79	FY 80	FY 81	FY 81
VESSEL AND PIPING FRACTURE MECHANICS						
B6290	NSRDC	J-R CURVE TESTING	122	100	SAME	100
A4046	BCL	CRACK ARREST	305	325	DOWN	100
B5609	BCL	COLD LEG BREAK	225	0	COMPL.	0
A0133	SAI	PIPING RELIABILITY	0	200	UP	200
----	UNDES.	DEGRADED PIPE STAB.	0	0	START	550
A0136	SANDIA	2-PHASE JET LOADS	(200) 0	330	SAME	330
A1216	U CAL.	PIPE WHIP	(150) 0	150	SAME	170
B0119	ORNL	HSST PROGRAM	2207	1890	SAME	1700
B0123	ORNL	DESIGN CRIT. PIPING	145	0	COMPL.	0
A9026	UMD	PHOTOELASTIC C/A	141	0	COMPL.	0
B6288	WASH. U.	TEARING INSTABILITY	108	175	UP	250
B0412	ORNL	RES. ENGR. IN FRG	70	80	SAME	80
----	UNDES.	HYDROGEN EXPLOSIONS	0	0	START	(200)*
----	UNDES.	HYDROGEN EMBRITTLEMENT	0	0	START	(200)*
----	UNDES.	INTERACTIVE PIPE CODE	0	0	START	(1500)*
----	ORNL	PRESSURIZED T/S	0	0	START	(1000)*
			3323	3250		3480 (6380)*

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547 323

DETAILED BUDGET - METALLURGY & MATERIALS RESEARCH BRANCH

(BASIC BUDGET - NO SUPPLEMENTS)

FIN #	CONTR.	TITLE	FY 79	FY 80	FY 81	FY 81
IRRADIATION EFFECTS AND DOSIMETRY						
B5528	NRL	IRRAD. EFFECT IN RPV	725	800	UP	950
B5988	HEDL	SURVEILLANCE DOSIMETRY	540	500	UP	625
B6224	NBS	DOSIMETRY DATA BASE	72	90	SAME	100
B0415	ORNL	PV SIMULATION EXP.	790	750	DOWN	250
			2127	2140		1925
STEAM GENERATOR AND STRESS CORROSION CRACKING						
B3012	GE	ST. ST. SUSCEPT. TEST	235	0	COMPL.	0
B2097	PNL	SG TUBE INTEGRITY	656	985	UP	1350
A3208	BNL	SG TUBE CORROSION	210	225	SAME	250
-----	UNDES.	SCC IN BWR PIPING	0	0	START	(1900)*
-----	UNDES.	CAST ST. ST. DEGRAD.	0	0	START	(200)*
-----	UNDES.	RESERVE	0	0	UP	200
			1101	1210		1800 (3900)*

*NOT APPROVED BY BRG (   )"

POOR ORIGINAL

-547 324

DETAILED BUDGET - METALLURGY & MATERIALS RESEARCH BRANCH

(BASIC BUDGET - NO SUPPLEMENTS)

EIN #	CONTR.	TITLE	FY 79	FY 80	FY 81	FY 81
NONDESTRUCTIVE EXAMINATION						
A4052	GARD	A/E WELD MONITOR	80	0	COMPL.	0
B2088	PNL	A/E VESSEL MONITOR	350	400	UP	500
B5605	SwRI	SAFT-UT FOR ISI	0	81	UP	200
A4047	U. MICH.	SAFT-UT DEVELOP.	237	200	UP	555
B0417	ORNL	EDDY CURRENT PROBES	93	114	UP	200
B6212	BAI	INTERNAL FRICTION (200)	0	200	SAME	250
B2289	PNL	INTEGRATE NDE & F.M.	274	645	SAME	600
B6327	UNDES.	IMPROVED DETECTION	0	0	START	200
-----	UNDES.	NEW TECHNIQUES	0	0	START	135
-----	UNDES.	----		360	DOWN	60
-----	UNDES.	REQUAL. AFTER ACCIDENT	0	0	START	(200)*
			1034	2000		2700 (2900)*
		TOTAL	7600	8600		9995 (15,105)*

NOT APPROVED BY BRG ( )

547 325

METALLURGY & MATERIALS RESEARCH BRANCH

RESEARCH TRENDS

PROGRAM DE-EMPHASIS

CRACK ARREST

FABRICATION NDE TESTS FOR WELD FLAWS AND SUSCEPTIBILITY TO IGSCC

PROGRAM EMPHASIS

STEAM GENERATOR TUBE INTEGRITY

RELIABILITY OF PIPING SYSTEMS

FLAW DETECTION AND RELIABILITY

IRRADIATED VESSEL PERFORMANCE

- LOW SHELF MATERIALS
- TEARING INSTABILITY ANALYSIS
- NEUTRON DOSIMETRY PREDICTION

547 326

ACRS 1978 RECOMMENDATIONS TO CONGRESS

METALLURGY & MATERIALS RESEARCH BRANCH

1. COMPLETE HSST PROGRAM
   - O PROGRAM CONTINUING AS REDEFINED BY RES AND NRR.
2. HIGH PRIORITY ON PIPING RELIABILITY
   - O PROGRAMS STARTED REFLECT A HIGH PRIORITY.
3. COOLANT CHEMISTRY EFFECTS ON CRACK GROWTH
   - O FUNDING DENIED IN FY 1980. DENIED BY BRG FOR FY 1981.
4. SATURATION EFFECTS OF RADIATION EMBRITTLEMENT
   - O COOPERATION UNDERWAY WITH EPRI; FUNDING NOT AVAILABLE FOR EXPERIMENTAL PROGRAM.
5. STEAM GENERATOR TUBE INTEGRITY
   - O PROGRAM BEING PLANNED IN COOPERATION WITH EPRI; EXPECT NRR ENDORSEMENT OF RESEARCH PROGRAM PLANNED.

IMPLICATIONS OF TMI-2 TO METALLURGY & MATERIALS RESEARCH BRANCH

1. PRESSURIZED THERMAL SHOCK
   - O MODEST FUNDING EXPECTED IN FY 80, 81 FOR PROOF TEST.
2. HYDROGEN EMBRITTLEMENT AND INTEGRITY UNDER HYDROGEN EXPLOSIONS
   - O MODEST FUNDING IN FY 80; NONE BY BRG IN FY 81.
3. INSPECTION REQUALIFICATION AFTER ACCIDENTS
   - O FOCUSSED IN OTHER BRANCHES; NOT APPROVED BY BRG FOR METALLURGY & MATERIALS RESEARCH BRANCH.
4. OFF-NORMAL WATER CHEMISTRY
   - O WORK FOCUSSED IN FUEL BEHAVIOR RESEARCH BRANCH.

547 328

FOREIGN RESEARCH ON PRIMARY SYSTEM INTEGRITY

VESSEL AND PIPING FRACTURE MECHANICS

FRG
- o MPA STUTTGART PROGRAM ON VESSEL INTEGRITY, THERMAL SHOCK, HAZ PROPERTIES, CRACK GROWTH.
- o HDR PROGRAM ON BLOWDOWN AND PIPING INTEGRITY, THERMAL SHOCK AND FULL SCALE INTEGRITY TESTS.
- o KWU PROGRAMS ON STEAM LINE BREAK, CRACK GROWTH, INTEGRITY ANALYSES.

JAPAN
- o JAERI TESTS OF PIPINC REACTION FORCES.

IRRADIATION EFFECTS AND DOSIMETRY

FRG
- o MPA STUTTGART IRRADIATION PROGRAM (4T).
- o KWU MATERIALS IRRADIATION.
- o KFA-JULICH SURVEILLANCE DOSIMETRY-IRRADIATIONS.

BELGIUM
- o CALCULATIONS AND DOSIMETRY FOR SURVEILLANCE.

UK
- o EMBRITTLEMENT FOR SURVEILLANCE DOSIMETRY.

ITALY
- o SURVEILLANCE DOSIMETRY IRRADIATION FACILITIES.

547 329

FOREIGN RESEARCH ON PRIMARY SYSTEM INTEGRITY

STEAM GENERATOR AND SCC

JAPAN o LARGE PROGRAMS BUT LITTLE INFORMATION AVAILABLE.

NONDESTRUCTIVE EXAMINATION

FRG o COOPERATION/EXCHANGE WITH IzfP SAARBRUCKEN.

o MPA STUTTGART VESSEL FOR NDE STUDY.

FRANCE o UT FLAW DETECTION AND EVALUATION.

JAPAN o LARGE EFFORT BUT LITTLE INFORMATION AVAILABLE.

CONCLUSION: FOREIGN RESEARCH BEING USED TO GOOD ADVANTAGE TO COMPLEMENT AND EXPAND UPON USA STUDIES. HOWEVER, FOREIGN RESEARCH, ESPECIALLY JAPAN, DIFFICULT TO FOLLOW BECAUSE OF SMALL FOREIGN TRAVEL BUDGET.

CONCLUSIONS AND RECOMMENDATIONS

- MANY YEARS OF CONVENTIONAL EXPERIENCE HAVE RESULTED IN FABRICATION AND OPERATION RULES THAT YIELD CONSERVATIVE SAFE OPERATION OF NUCLEAR PLANTS.
- UNIQUE NUCLEAR ENVIRONMENT CAUSES NEW PROBLEMS NOT PREVIOUSLY ENCOUNTERED AND DEALT WITH.
- MAJORITY OF UNRESOLVED SAFETY ISSUES AND TAP'S DEAL WITH OPERATING PROBLEMS IN THE PRIMARY SYSTEM.
- THE METALLURGY & MATERIALS RESEARCH BRANCH CONSISTENTLY OPERATES AT A SMALL BUDGET LEVEL DESPITE APPARENT NEED FOR RESULTS.

CONCLUSIONS AND RECOMMENDATIONS

METALLURGY & MATERIALS RESEARCH BRANCH RECOMMENDATIONS FOR FUNDING

- SCC IN STAINLESS AND CARBON STEEL.
- INTERACTIVE PIPING SYSTEM ANALYSIS/REVIEW CODE.
- DEGRADATION OF CAST STAINLESS STEEL.
- FLAW DETECTION AND NDE FOR REQUALIFICATION AFTER ACCIDENTS.
- DEGRADED STEAM GENERATOR RESEARCH.
- EXPERIMENTAL RADIATION EMBRITTLEMENT SATURATION STUDIES.
- ADDITIONAL FUNDS FOR FOREIGN TRAVEL.
- NRC REPRESENTATIVES IN FOREIGN COUNTRIES.

Planning Support Document for the EPRI Nondestructive Evaluation (NDE) Program

EPRI NP-900-SR
Special Report
December 1978

Keywords:
NDE
In-Service Inspection
Steam Generator
Nozzle
Piping
Pressure Vessel

Prepared by
Electric Power Research Institute
Palo Alto, California

547 333

Planning Support Document for the EPRI Nondestructive Evaluation (NDE) Program

NP-900-SR

Special Report December 1978

Prepared by

Gary J. Dau
Nuclear Power Division

With Contributions by
M. E. Stanhoff

POOR ORIGINAL

547 334

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3412 Hillview Avenue
Palo Alto, California 94304

547 355

[illegible]

[illegible]

POOR ORIGINAL

547 336

FOREWORD

Nondestructive evaluation (NDE) is one of the fastest-changing areas of technology and promises some of the largest near-term payoffs in plant safety and availability.

Large capitalized generating plants require a combination of many engineering and scientific disciplines for best performance. When operating plants are analyzed, it is increasingly noted that each unit has many unique elements in design, fabrication, and in operating history and environment. Attainment of high availability and reliability factors requires the effective use of current unit-specific information from in-service inspection and on-line instrumentation.

Some of the most impressive progress in this field is coming from minicomputer-assisted handling of the signals from various kinds of detectors. Acoustic, electric, magnetic, and radiation detectors can provide a wealth of data on the condition of key components in a power plant. The problem has been how to handle the enormous volume of information—how to discriminate the useful signals from the much larger amounts of noise. There is often the further need to prove the reliability of the detection and data-use system to the satisfaction of regulatory agencies.

[illegible]

- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

POOR ORIGINAL

547 337

ABSTRACT

This report describes the framework in which the EPRI Inspection Evaluation effort was established and is being implemented. Details on specific inspection problems are given along with the technical approach being followed to solve them. Planned future activities are also identified. A summary of each project underway or completed is given in an appendix.

547 338

CONTENTS

POOR ORIGINAL

547 339

POOR ORIGINAL

547 340

SUMMARY

This document was prepared to provide overall guidance for nondestructive evaluation (NDE) efforts to support commercial reactor operation.

The motivation for improved NDE technology comes from economical considerations, minimizing radiation exposure to inspection personnel, increasing efficiency and reliability of ISI, and credit in the licensing process. The NDE program falls within the responsibility of the Nuclear Division, reflecting the fact that nuclear plants are the only ones with a legal requirement for periodic inservice inspection. Thus, the initial program emphasis is on developing improved inspection technology for light water reactor systems with emphasis toward resolution of safety and inspection code performance issues. However, it is recognized that these efforts are generating a technology base that can be transferred to other areas that promise improvement in overall productivity.

Specific sections address the background, potential influence and potential solutions for inspections of steam generators, piping, nozzles, and pressure vessels. Another section addresses efforts underway to develop techniques to give early warning of material changes that could lead to decreased structural integrity. [illegible]

[illegible] completed [illegible] activities.

POOR ORIGINAL

547 341

Section 1

INTRODUCTION

Since 1974, a nondestructive evaluation (NDE) program has been actively pursued by EPRI to develop improved inspection technology for light water reactor (LWR) systems. The initial efforts developed and implemented projects that had high priority from a safety and inspection code performance viewpoint. Most of these projects are either underway or completed. As the program continues to evolve, it is expected that this technology base will be used to expand NDE techniques to other areas that promise improvement in overall productivity.

This document states the justification and provides overall guidance for NDE research and development efforts needed to support commercial reactor operation. In recognition of the fact that nondestructive evaluation technology is changing rapidly--due in a large part to EPRI-funded projects--it is planned to update this document periodically.

Section 2

INCENTIVES FOR NDE IMPROVEMENT

In 1971, the AEC[illegible] formally adopted the ASME Boiler and Pressure Vessel Code Section XI "Rules for Inservice Inspection of Nuclear Power Plant Components" (1) by incorporating Section XI into the AEC's "Codes and Standards for Nuclear Power Plants" (2) and indicated that Section XI fulfilled the requirements for periodic inspection stipulated in the AEC General Design Requirements (3) [illegible]. These requirements were then continued under the US Nuclear Regulatory Commission (NRC) when it was organized. As a result, compliance with the Section XI rules is a mandatory requirement for anyone seeking to license or build and operate a nuclear power station in the US. Thus, inspection is not an option for the utility owner. Rather, the motivation for continued development of improved inspection technology comes from sources such as economics, minimizing radiation exposure to inspection personnel, increasing efficiency and reliability of ISI, and licensing credit.

One of the more compelling forces to develop improved inservice inspection technology [illegible] as is illustrated by the following [illegible]. A recent [illegible] (4) listed many items that deserve attention in order to improve nuclear plant productivity. The recommendations on inspection included:

- [illegible]
- [illegible]
- [illegible]
- [illegible]

[illegible]

POOR ORIGINAL

547 343

Although inspection is only one of the many ways to improve plant availability [illegible] substantial [illegible] leverage. For example, the above report continues:

> ...assuming that [illegible] GW's of nuclear electric generating capacity will be in operation by [illegible], a one-percent improvement in capacity factor can be equated to a decrease in oil usage of [illegible] million barrels per year with the reduction of an industry financing need for approximately three [illegible] nuclear units at a cost approaching [illegible] billion ... and the [illegible] of approximately [illegible] million tons per year.

These figures illustrate that investment in [illegible] is [illegible] the most [illegible] available to the country [illegible] decade. Inservice ISI is an important part of the plant's [illegible] productivity.

The magnitude of the benefit from improved inspection (productivity and [illegible] through better equipment, higher efficiency, etc.) can be illustrated in still another way. Consider the modest goal that improvements in inspection and inspectability save one day's outage time for each nuclear plant per year. Assigning a value of $300,000 per day for replacement power costs for the [illegible] plants in operation today shows that achievement of that goal produces an annual savings of about [illegible] million.

Experience indicates that the longer a plant operates, the higher [illegible] will [illegible]. The [illegible]

> [illegible]

> [illegible]

POOR ORIGINAL

547 344

The dollar value of each man-rem accumulated is a significant factor in itself, but equally important is the availability of an adequate number of trained and qualified inspectors able to work in a radiation environment. It appears that the rate at which nuclear plants, with their attendant inspection needs, are becoming operational is increasing more rapidly than the manpower pool is growing. Some people feel that this increasing divergence is a problem today ([illegible]). Furthermore, the increasing concern over product liability and consumer activism is generating competition for those very people needed to perform ISI on nuclear systems ([illegible]). The net result is a strong incentive to keep radiation exposure accumulation as low as possible.

The present code provisions give considerable "licensing credit" to the belief that periodic ISI generates increased confidence in structural integrity. To quantify this, a figure of merit has been defined as the failure probability without inspection divided by the failure probability with inspection. [illegible] contains values of this figure of merit indicating that it theoretically increases from a value of [illegible] three years after startup to a value of [illegible] twenty years after startup under the optimum inspection program. Figure 2 illustrates this information and compares it with the alternate inspection schedule also described in Section XI of the ASME code. Obviously, these values and the attendant licensing credit are based on the expectation that a consistent, repeatable and efficient inspection program can be carried out.

Thus, there are obvious advantages to be gained from pursuing an aggressive program to improve in-service inspection technology for safety related reasons. [illegible]

[illegible]


Program A
Program B

Section 2

PROGRAM ORGANIZATION

In the Nuclear Division of EPRI the NDE activities fall within the Diagnostics and Evaluation Subprogram (No. 41-1). This is part of the Reliability, Availability and Operations program area (No. [illegible]), defined in the Nuclear Division portion of the EPRI Research and Development Program (5-year plan) [illegible].

For administrative purposes the subprogram is further broken down into the following categories: Materials Property Measurement, Significance of Flaws Detected, NDE Test Methods, Inspection Methods and Device Development, and Failure Analysis. This is shown schematically in the Program Tree presented in Figure 1 along with the technical thrust of each category. Although this is a convenient way to group specific technical efforts, the real goal is to solve specific problems. Figure 2 shows directly how and where projects are directed in order to resolve specific issues on various plant components.

Table 1 is included to identify effort present, in an abbreviated form, while Appendix A is included to provide more detail on each project's goals and accomplishments. For the benefit of the majority of readers who are more interested in [illegible] to specific issues, the [illegible] Fig. [illegible] [illegible]

POOR ORIGINAL

547 347

[illegible]

[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible] applications.	[illegible]
[illegible] DEVELOPMENT	EVALUATION: Improvements brought about by introduction of new [illegible] technology [illegible] take longer to get from field application.	[illegible]
FAILURE ANALYSIS	RELIABILITY: Accurately define the reliability of components by analyzing the frequency and severity of malfunctions that result in outages or that have potential safety significance.	[illegible]
[illegible]		

FUTURE

[illegible]	(a) Improve instrumentation [illegible]	
	(b) [illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	

[illegible]

POOR ORIGINAL

[illegible]

547 348

SUBPROGRAM	COMPONENT/ACTIVITY	TECHNICAL THRUST[1] (PROJECT NUMBERS)
NDE	— STEAM GENERATOR	403[2], 688 TPS 77-[illegible] [illegible] TPS 77-[illegible] [illegible] [illegible][4] 1088
	— PIPING	606, 610, 770, 800, 892, 1126, 1246 TPS 78-809
	— NOZZLE	892, 1126
	— PRESSURE VESSEL	248, 827, 605, 901, 916, 1246
DIAGNOSTICS AND EVALUATION	— PROPERTY MEASUREMENT	878, 604[3], 609, 702, 803
	— TURBINE	502[5]
	FUTURE	
	— PUMPS	
	— VALVES	
	— [illegible] CENTER	
	— INTERNALS	
	— [illegible] FUEL [illegible]	
	— [illegible]	
	— [illegible]	
	— [illegible]	
	— [illegible]	
	— [illegible]	
	— [illegible]	

(1) [illegible] Table 2.
(2) [illegible] Subprogram 403.
(3) [illegible] Subprogram 404.
(4) [illegible] Steam Generator Owners Group.
(5) [illegible] 430.

Figure [illegible]

POOR ORIGINAL

547 349

Table 2

Summary of NDE Projects

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Portable X-Ray Source	[illegible]	[illegible]
[illegible]	[illegible]	Battelle Columbus	[illegible]
[illegible]	Real-Time Flaw Imaging Studies	[illegible] Battelle Northwest	[illegible]
[illegible]	[illegible] Eddy Current	Battelle Northwest	[illegible]
[illegible]	Acoustic Emission and UT of Vessel Hydrotest	[illegible]	[illegible]
[illegible]	Turbine Bore Inspection	Battelle Columbus	
[illegible]	Digital Memory - [illegible] Monitor	Battelle Northwest	[illegible]
[illegible]	Defect Characterization by UT Holography	Babcock & Wilcox Co.	[illegible]
[illegible]	Real-Time Flaw Imaging Development	Battelle [illegible]	[illegible]
[illegible]	Assessment of [illegible] Applications	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

POOR ORIGINAL

547 350

Table 7 (Continued)

PROJECT NO.	TECHNICAL THRUST	CONTRACTOR	FUNDING
	MATERIALS PROPERTY MEASUREMENT		
[illegible]	[illegible] Pressure Vessel Materials	Acoustic Emission Technology Corp.	[illegible]
[illegible]	Ultrasonic [illegible] to Measure Stress	Battelle Northwest	[illegible]
[illegible]	NBS-EPRI AE Program	National Bureau of Standards	[illegible]
[illegible]	Acoustic Techniques for Stress Measurement	Stanford University	[illegible]
[illegible]	UT Surface Wave Stress Measurement	[illegible], Inc.	[illegible]
[illegible]	Portable X-Ray Diffractometer	Denver Research Institute	[illegible]
	FAILURE ANALYSIS		
[illegible]	[illegible]	Failure Analysis Associates	[illegible]
	TECHNICAL PLANNING STUDIES		
TPS 78-[illegible]	UT Round Robin	SwRI, Nuclear Services, [illegible], A.E. Peabody	[illegible]
TPS 77-[illegible]	Eddy Current Round Robin	[illegible]	[illegible]
TPS 77-[illegible]	Feasibility [illegible] Adaptive Learning [illegible] Eddy Current	[illegible]	[illegible]
	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

POOR ORIGINAL

547 351

Section -

STEAM GENERATOR

BACKGROUND

To date the industry has had a series of problems with steam generators including such things as contamination, vibration, fretting, water hammer, cracking, pitting, high-cycle fatigue and denting. Of these, the recent onset of denting has the most potential impact on the industry.

Denting is the term used to describe the results of a corrosion process and pitting on the secondary side of the steam generator. Corrosion products, principally non-protective magnetite, build up in the gap (crevice region) between the outer surface of the tube and the inner surface of the hole in the carbon steel support plate. With time, the thickness of this deposit grows and compresses or dents the tube in the tube support plate region. As the denting progresses, cracks appear in the tube and, eventually, penetrate the wall and cause leakage. When this occurs, the tube is removed from service by plugging. In severe cases cracks occur in the ligaments of the tube support plates. Figure 1 shows a typical U-tube steam generator configuration while Figure 2 illustrates the denting problem in more detail. The detailed causes of the problem are not fully understood, but it is believed that [illegible]

[illegible]

[illegible]

547 352

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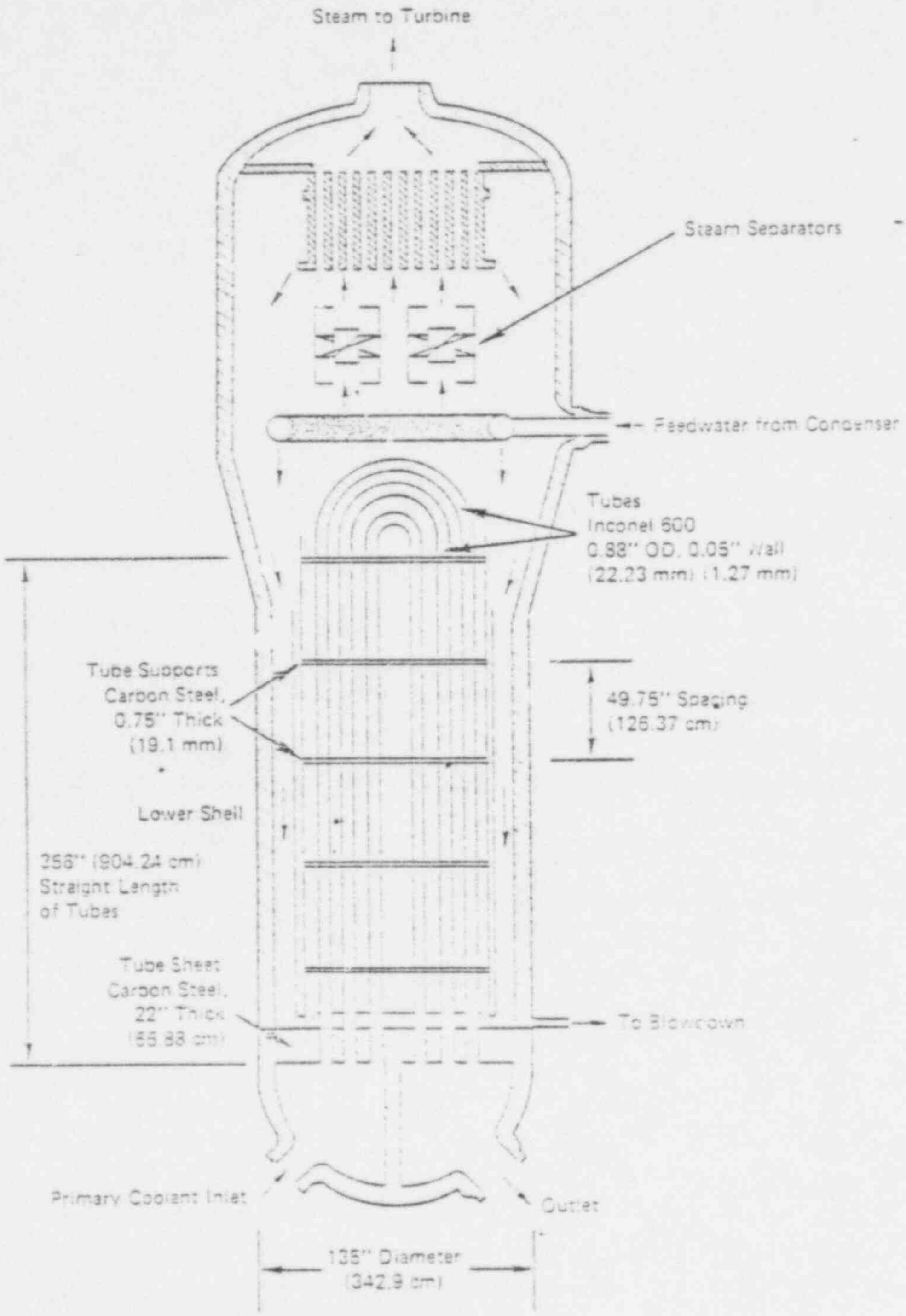

Figure 4. Typical Steam Generator Configuration.

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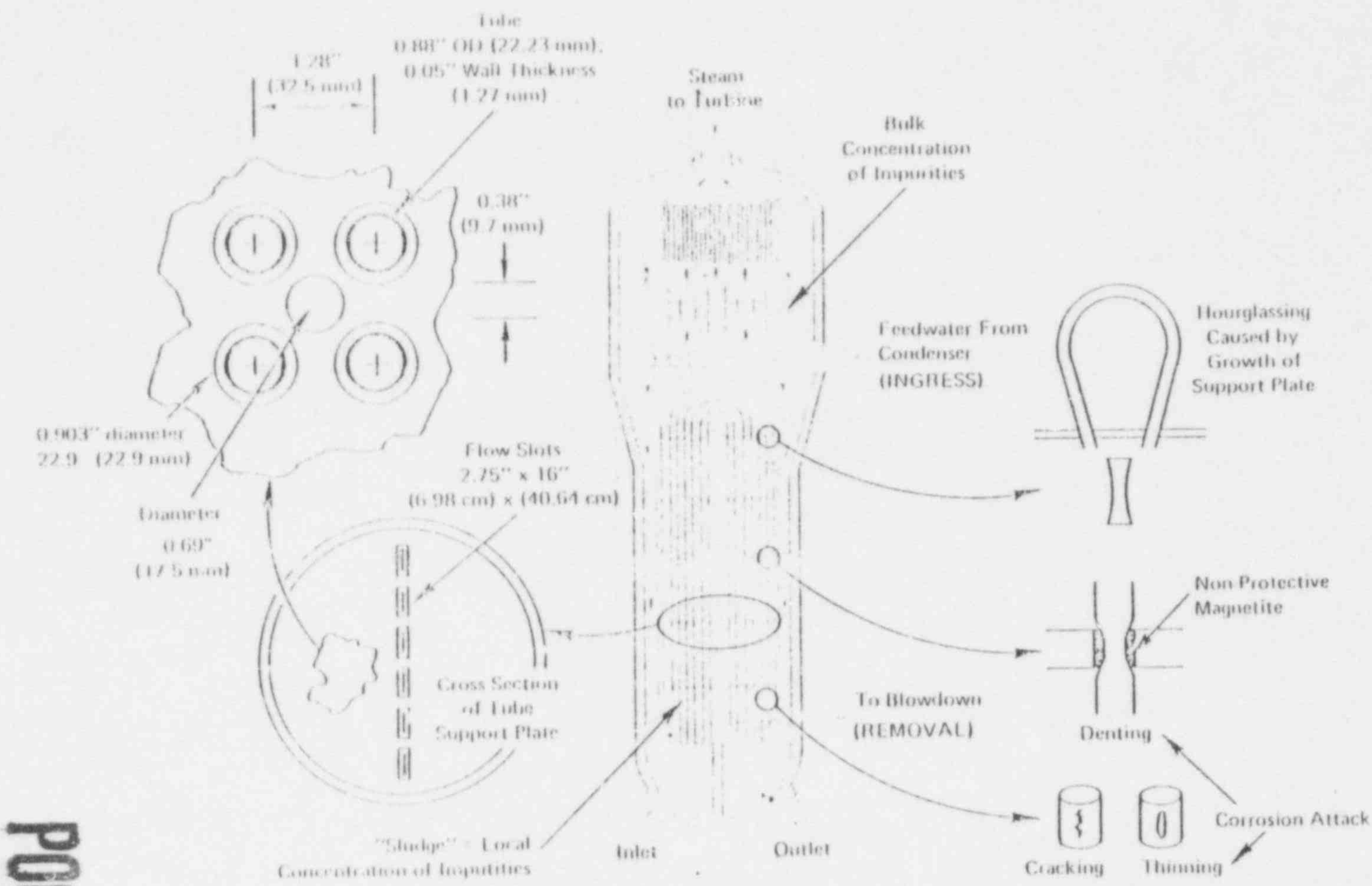

Figure 5. Details of Denting

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547 354

Because there are 46 utilities with 125 PWR units scheduled to be in operation by the end of 1986, the potential impact on the industry from the above sources can be enormous. Thus, there is considerable incentive to vigorously pursue solutions to this problem. The remainder of this section discusses the possible contributions of nondestructive evaluation techniques toward solving the problem.

From an inspection viewpoint, denting can be viewed in two separate but related ways. First, all plants must satisfy regulatory requirements to assure continued safe operation. This requires that tube integrity be verified by inservice inspection according to the requirements stipulated in the US Nuclear Regulatory Commission Guide 1.83 (10) and Section XI of the ASME Code. The second view is from a productivity standpoint. Measurements are needed to verify that the corrosion process is not underway in plants free from the denting problem. If the very early stages of corrosion are detected, chemical cleaning is possible to remove the corrosion products and thereby prevent denting. Both considerations, regulatory and productivity, must receive high priority from NDE development efforts. The specific interests that should be addressed to help assure continued plant availability are presented in Figure 6. The first two items, tube integrity and support integrity have a direct relation to safety and those are of concern to the plant owners and regulatory agencies. The remainder of the items impact plant productivity and are also of major interest to the plant operator.

TUBE INTEGRITY

Periodic inspection to assure integrity of steam generator tubes is required by the USNRC Regulatory Guide as stated above. The method specified is an eddy current test (ECT) usually at an examination frequency of 400 Khz. The basic principle behind this approach was first demonstrated in the field over 15 years ago. Since then engineering improvements have been made to provide better instrumentation, display, probe design, etc. However, data interpretation is slow and remains very dependent on the operator's skill and experience. The recent occurrence of denting and vibration-induced cracks indicates there are limitations in this approach for tube integrity verification. The limitations include lack of ability to discriminate flaw signals found in the tube near the region of tube support and tube sheet areas, influence of work hardening on the signal, need for increased precision for measuring tube thickness particularly in the range of 40% of wall thickness and below, need to increase speed of data interpretation, and removal of operator/inspector dependence.

547 355

COMPONENT	MEASUREMENT/ACTIVITY	SPECIFIC INTEREST	TECHNOLOGY	SPECIFIC ACTIVITY
Nondestructive Examination Techniques for Steam Generators	Determine Extent of Degradation/ Damage - Defect Characterization	Tube Integrity	Eddy Current (ECT) -	RP403; TPS 77-709; TPS 77-723; RP700
			Electromagnetic Acoustic (EMAT)	RP698; SGPO-S101
			Conventional Ultrasonics (UT)	
			Optical-Linear Diode Array (LDA)	SGPO-S103
			Miniature Television Camera (MTV)	
		Support Plate Integrity	ECT-Low Frequency	
			MTV	
			Fiber Optics (FO)	
			EMAT	
			X-Radiography	SGPO-S105
			Neutron Transmission (NRT)	
	Diagnose Precursors of Degradation/ Damage	Tube/Tube Support Crevice Blockage Detection	ECT	
			Magnetic Permeability	
			EMAT	
			Tube Vibrational Analysis	SGPO-S102
			Ultrasonics	SGPO-S107
		Sludge Depth Determination	ECT-Low Frequency	
			EMAT	
			XRT	
			NRT	
		Pre/Post Corrective Measure Evaluation	Cleaning	
			Other	
	Process/Evaluate Detector Output	Data Storage and Analysis	Digital	
			Analog	
			Nonlinear Analysis	TPS 77-723
			Long-Term Storage (Reduced Volume)	
			Automatic Data Interpretation	
		System Qualification/ Evaluation	Qualification Criteria	
			Standard Sample Generation	
			Qualification Test Rig	

Figure 6. Project Tree for Steam Generator ISI.

Earlier it was indicated that several different tube sizes were used in steam generators. As an aid to the further development of NDE equipment, the dimensions of those tubes now in service or planned for service are listed in Table 2.

Table 2

STEAM GENERATOR TUBE DIMENSIONS

Outer Diameter inches (cm)	by	Wall Thickness inches (cm)
0.875 (2.22)	x	0.050 (0.127)
0.750 (1.905)	x	0.050 (0.127)
0.750 (1.905)	x	0.043 (0.109)
0.625 (1.588)	x	0.034 (0.086)

Potential Solutions

Although Figure 6 lists four candidate approaches for improved tube ISI, practical constraints on the need for rapid routine inspection to screen tube conditions eliminates radiography. However, X-ray and neutron radiography may have potential for specific nonroutine measurements to confirm indications found during the normal inspection process.

Eddy current testing (ECT) is now used to satisfy code requirements and is familiar to most people concerned with ISI. These two factors, in addition to technical factors including ease and speed of use, lend strong support to the belief that an optimum system will include ECT. The limitations of current practice are inadequate ability to discriminate signal sources, low precision in sizing defects and high sensitivity to background conditions; e.g., tube supports. From the work now underway (described in the following section), it appears that an optimized ECT system will consist of a combination of shaped probes with multiple frequency excitation and more advanced signal processing, recording, and display.

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In principle, ultrasonic inspection techniques are possible candidates for steam generator ISI. However, the difficulty of keeping a fluid couplant between the transducer and the tube has dampened the enthusiasm for this approach. Recently, considerable progress has been made in developing transducers that can generate ultrasonic waves in metals by electromagnetic excitation. These electromagnetic-acoustic transducers (EMAT) have the significant advantage of not requiring a fluid couplant while sacrificing some signal generation efficiency when compared to conventional ultrasonic transducers. The potential exists for performing an ultrasonic inspection at speeds comparable to an ECT.

With the evolution of optical and semiconductor technology two optical inspection methods have considerable potential for tube inspection. Today, a commercial video system is available that can be used for inspection of the tube ID. In addition, the recent advent of light sensitive linear array diodes and fiber optic technology offers promise of another approach for optical inspection. This technology holds promise for a very rugged probe that can generate data in a format convenient for additional analysis by digital electronic techniques including microprocessors. The feasibility and usefulness of these approaches for field use deserve further evaluation and development of the optimum one pursued.

In summary, three complementary inspection approaches are candidates for an improved inspection system for tube integrity. Related ongoing work within EPRI is described in the next section while a "roadmap" showing the path to this system is discussed in the ROADMAP section. In addition, radiography may have utility under special circumstances.

EPRI Work Underway

Eddy Current. In recognition that there is a limit to the amount of information available from a single frequency approach, EPRI initiated a project (RP403) in January 1976 to investigate the potential of using multiple frequencies along with a multiparameter signal analysis. In the approach being followed for EPRI by Battelle-Northwest two (or more) frequencies are simultaneously used to inspect a tube region. For each frequency used 2 parameters of information are generated. By combining all parameters in a manner analogous to solving simultaneous equations, unwanted signals (such as those from probe wobble or the tube support plate) can be discriminated against. The hardware from this project was evaluated in a simulated field environment in mid-1977. The potential for improved detection ability was indicated. Modifications are now underway to further improve the system.

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547 358

In related efforts, two approaches are being followed to develop and investigate the use of "shaped" probes. The goal is to improve inspection ability by more precisely defining the eddy current field generated by the probe. One approach is being pursued by Failure Analysis Associates under RP700 while the second is being developed by Battelle Northwest as an extension to RP403. Both use ferrite materials to shape the eddy current field so it inspects a smaller volume than conventional probes, thereby generating greater sensitivity.

In a program completed in December 1977 (RP770), Adaptronics, Inc., with assistance from the Babcock and Wilcox Company demonstrated that a nonlinear signal processing concept called Adaptive Learning Network (ALN) can distinguish between different sources of ultrasonic reflections. In earlier related work under Air Force sponsorship, this team also showed that this approach can be used to enhance crack detection ability and provide a sizing capability for detecting fatigue cracks in aluminum. Based on these impressive results, a technical planning study (TPS 77-723) was started in June 1977 (and completed in November 1977) to investigate the use of ALN for eddy current signal analysis. The results show that using only 400 kHz data and the ALN processing it is possible to automatically and unambiguously discriminate between simulated pit and crack conditions. In addition, ability to size the simulated pits (±2.4%) and cracks (±3.6%) was demonstrated. A follow-on effort to develop and evaluate a prototype device is underway. The goal of the follow-on effort is the development and evaluation of hardware that will automatically identify flaw type and through-wall penetration in steam generator tubes. The analysis will be conducted in real time (RP1125 part 2).

Another technical planning study (TPS 77-709) was conducted to determine the capability of ECT. Using a round robin approach blind samples were inspected by several different groups; this effort established a baseline datum point for current field practice. In addition, selected advanced systems were also evaluated. This effort was completed in late 1977 and is reported in NP636 (3o).

Ultrasonics. In 1976, a project (RP696) was launched to evaluate the electromagnetic-acoustic concept for steam generator tube inspection. The laboratory proof-of-principle demonstration conducted by Rockwell Science Center has shown that it is feasible to use this approach. The results show the ability to detect cracks in normal and dented tube regions, inspect the U-bend regions, and make precise measurement of wall thickness. Based on these results, a follow-on effort to develop and field evaluate suitable hardware has been initiated (SGPO-S101).

547 359

SUPPORT PLATE INTEGRITY

There is evidence that the chemical attack that causes denting can also create conditions that lead to fracture of the tube support plate. Whether this condition occurs only after severe denting is not known now. However, there is concern that large-scale fracture of ligaments in the tube support plate could generate a condition where long expanses of tubes are unsupported. If one ruptured it might whip around like a loose fire hose and rupture other tubes and create a chain reaction.

As shown in Figure 6, six approaches have been identified as potential methods to measure support integrity. Of these low frequency ECT (2-10 kHz) is the most attractive. It is accomplished from the inside of the tube, is relatively fast and is a "known" technology which has been used to a limited extent in the field. Based on the results of the feasibility study reported earlier (TPS 77-723), it is expected that the use of Adaptive Learning Network signal analysis will considerably enhance the utility of this approach. An experimental effort to evaluate this potential is being formulated.

Ultrasonic techniques are another potential approach. It should be recognized that generating an UT wave inside a tube, transmitting it through a tube wall and a water gap into the support plate, interacting with a flaw and detecting the return echo presents a formidable challenge. Yet, the approach needs further evaluation.

Monitoring the neutron or X-ray transmission between between adjacent tubes is another approach to determine tube support integrity. The large number of tube-support plate intersections that must be inspected casts doubts on the practicality of either method for routine inspection of a large number of tube-tube support plate interactions. However, the combination of background work in X-ray tube inspection and the benefit of having an independent inspection method for confirmation of other results provided motivation to initiate a feasibility study on this approach (SGPO-S105).

Finally, it may be possible to optically inspect the ligaments with either a fiber optic probe or a miniature TV camera. However, this would require access to the secondary side of the unit, a procedure that is normally not done. Thus, practical considerations suggest that this not be considered as a high priority item.

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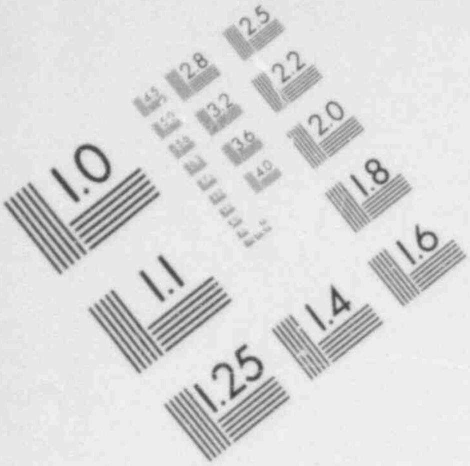


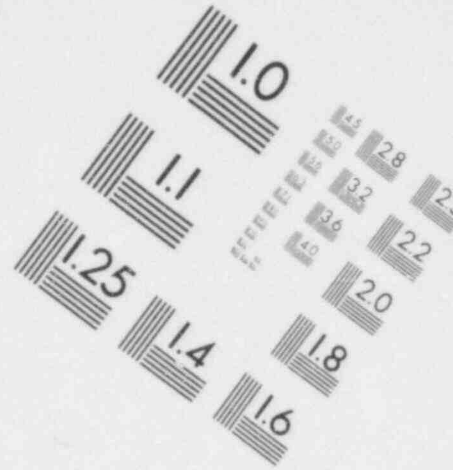
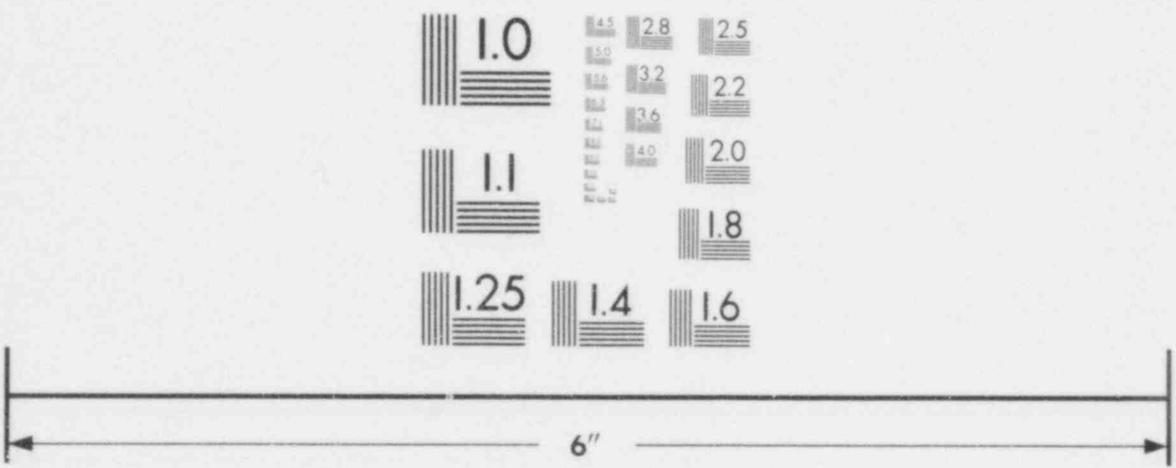
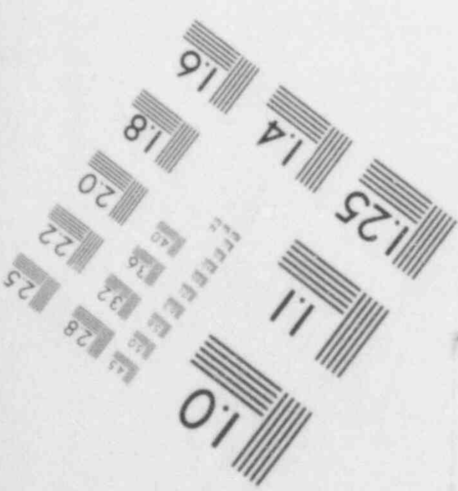
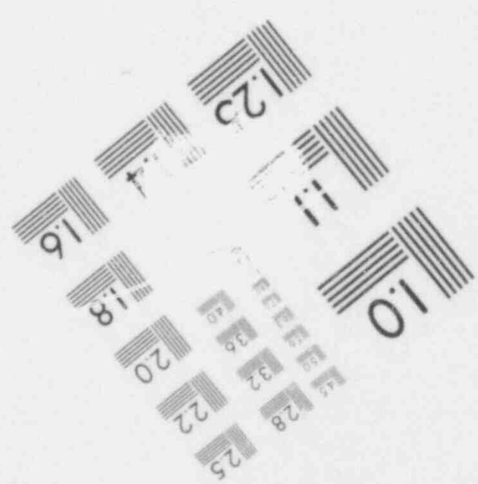
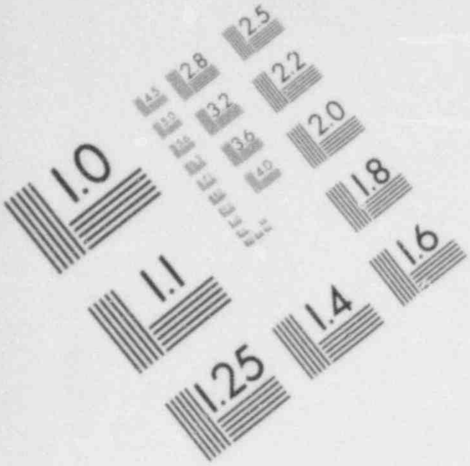


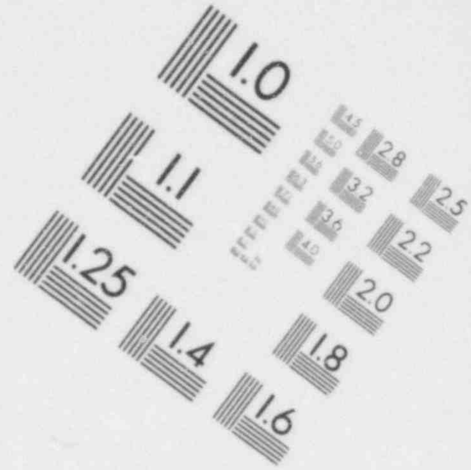
IMAGE EVALUATION TEST TARGET (MT-3)











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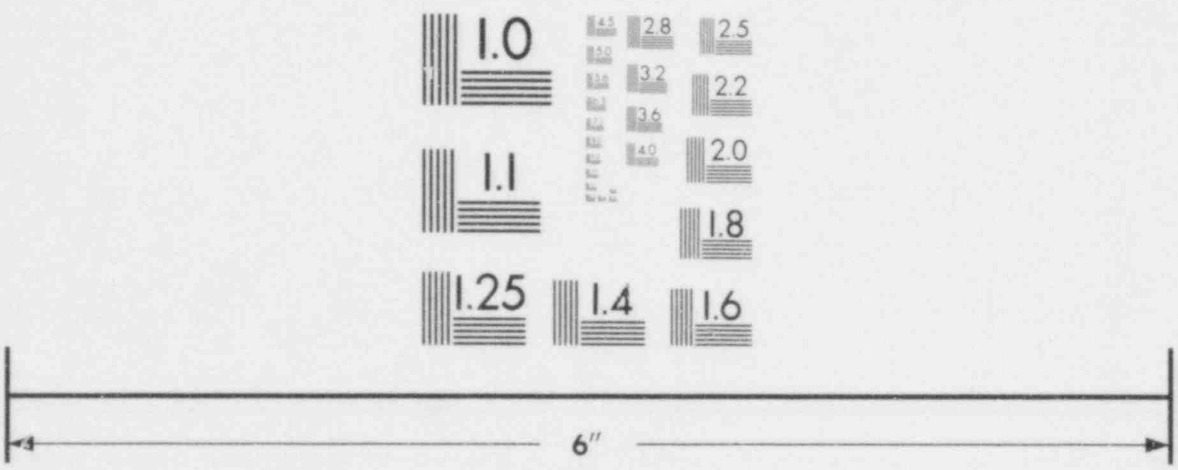

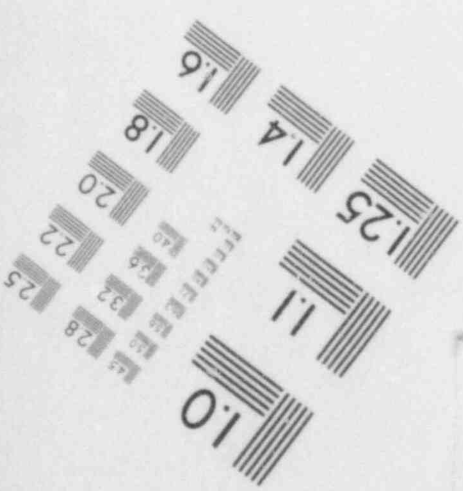

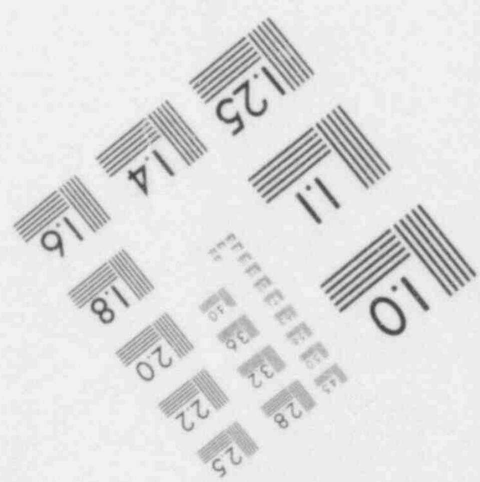

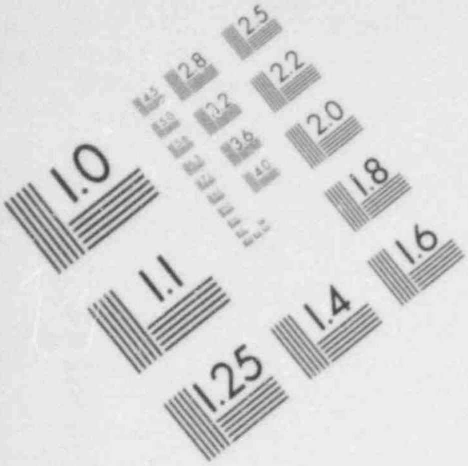

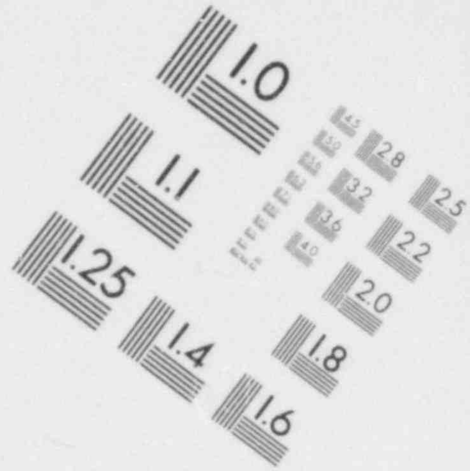

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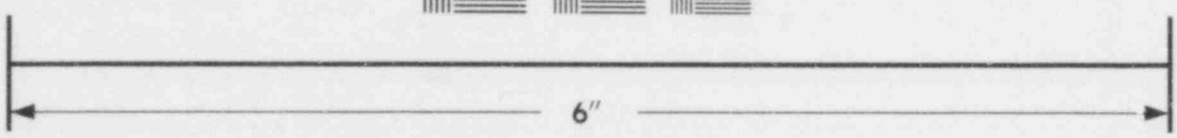
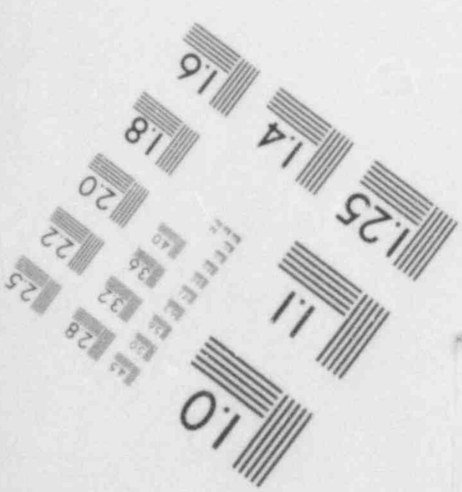
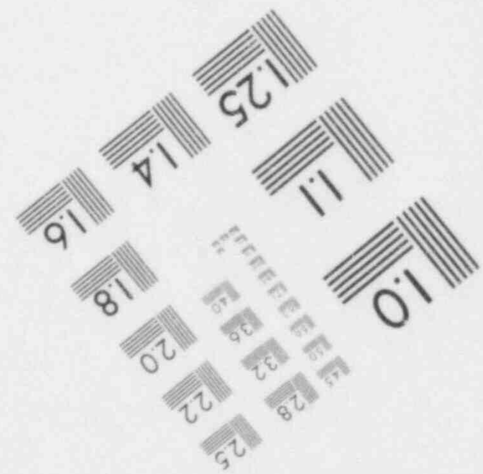
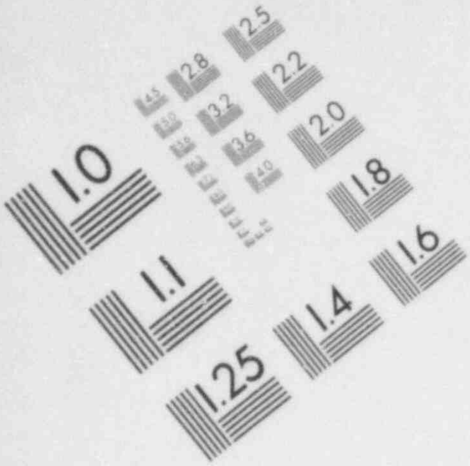








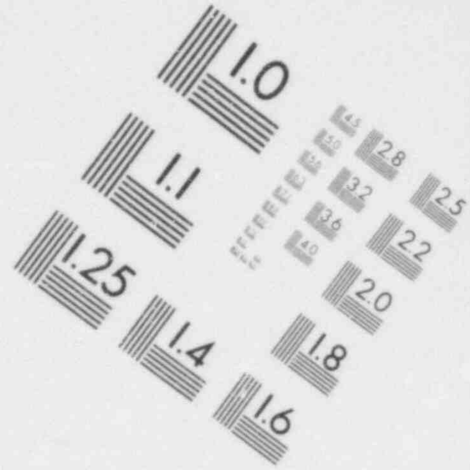
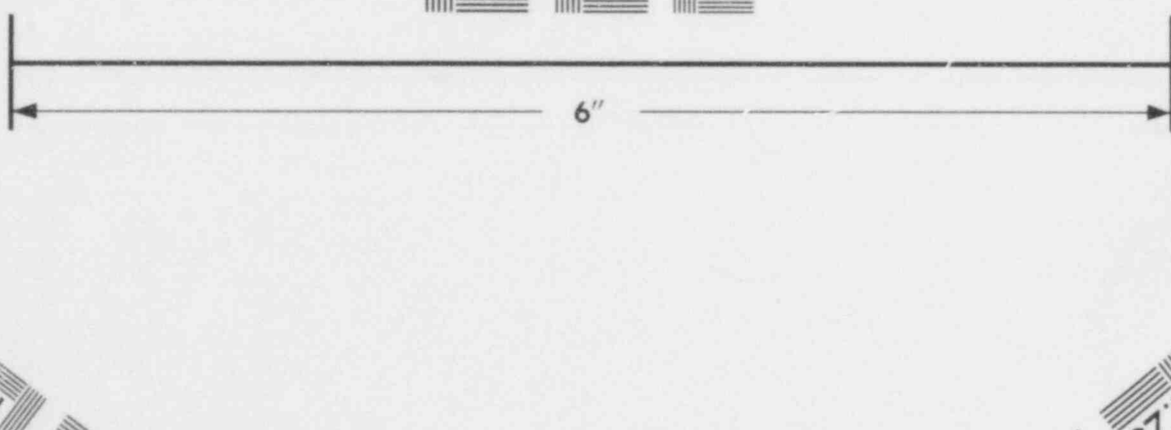
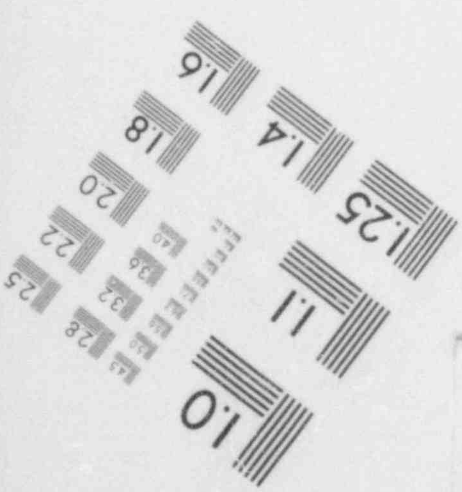
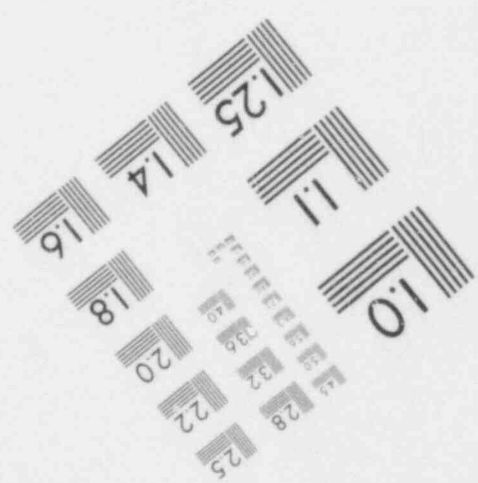


IMAGE EVALUATION TEST TARGET (MT-3)







At the beginning of the discussion it was mentioned that different support plate geometries exist. Figure 7 shows details on three different designs now in service.

TUBE/TUBE SUPPORT CREVICE BLOCKAGE

If means can be developed to measure the gap between the tube and tube support plate the onset of corrosion could be detected. As long as it is detected before flow blockage occurs chemical cleaning is possible thereby preventing denting from occurring. Thus, there is considerable incentive to develop this technique immediately in order to keep "clean" plants operating in good health.

Four approaches have some potential. The tube vibrational analysis technique consists of vibrating the tube at different frequencies while monitoring the acceleration of the tube in the tube support region. From the acceleration and frequency data it is possible to determine the crevice gap. Furthermore, by placing accelerometers at right angles, it is possible to determine clearance in both the x and y direction. Based on the fact that analytical results indicated feasibility, a project was conducted that experimentally confirmed feasibility (SGPO-S102). Low-frequency eddy current inspection (2-30 kHz) will also provide an indication of the mean tube support hole diameter. How well this measurement will establish that flow space exists in the crevice region is not known. In principle, ultrasonic techniques can also be used to measure the crevice gap. The magnitude of the challenge to generate an ultrasonic wave, detect the return echo with required precision, and inspect the many tube-tube support intersections is unknown but feasibility is being evaluated in a recently initiated project (SGPO-S107).

The fourth approach is based on the premise that the presence of magnetite will disturb the magnetic flux pattern from that expected from a clean crevice. Again, sensitivity and precision are unknown but the technique is believed to have potential and is being evaluated under SGPO-S125.

SLUDGE DEPTH

Measurement of the depth of sludge that accumulates at the bottom of a steam generator is a qualitative method of assessing the condition of the steam generator. This measurement was deemed very important when phosphate based water treatment was used. With the change to AVT, the importance of the measurement remains because sludge depth may influence denting in the tube sheet area.

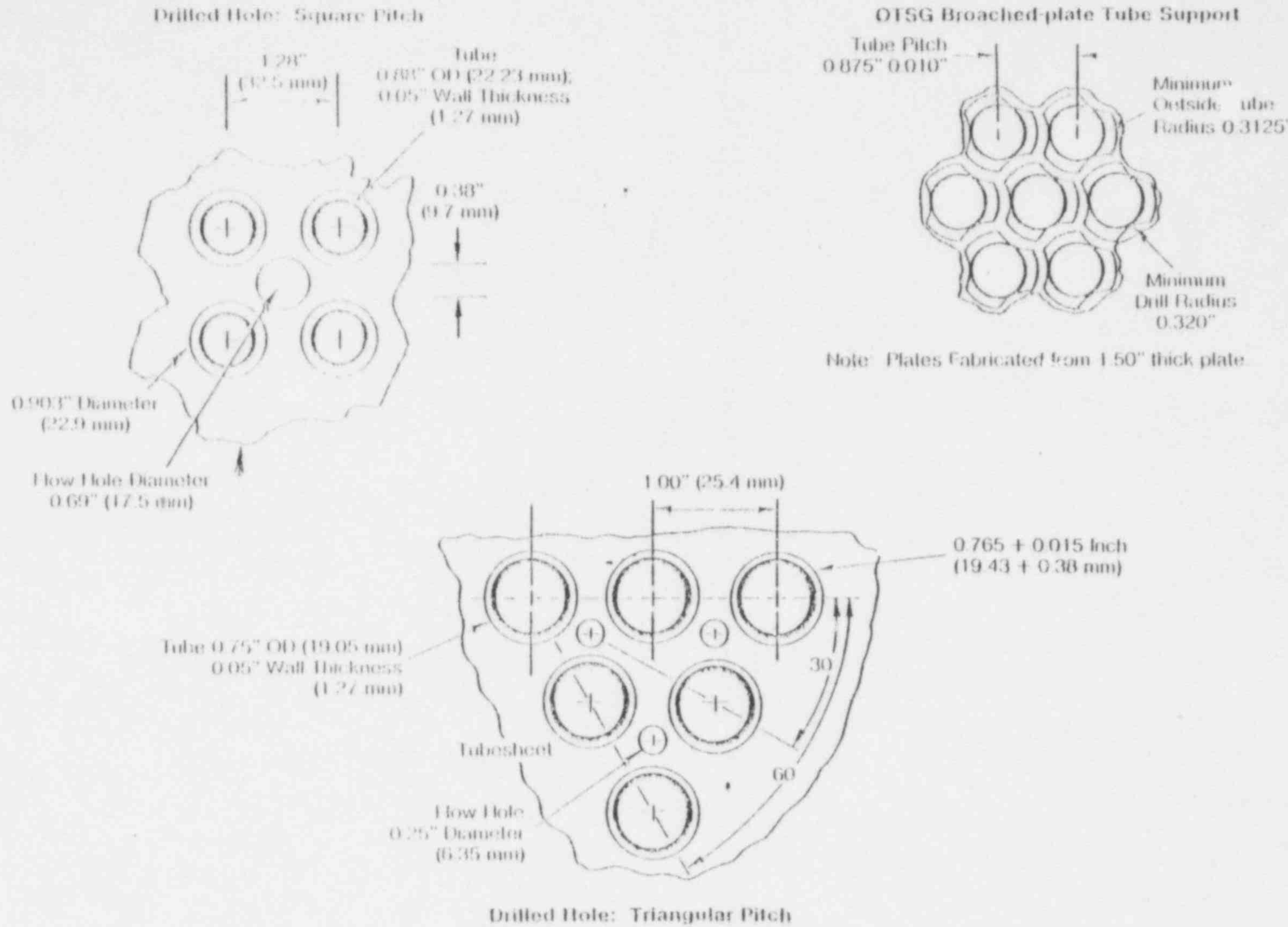


Figure 7 Details of support plate geometries now in service

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Three approaches are feasible. The first is use of low frequency ECT where the electromagnetic field interacts with the magnetite in the sludge producing a signal when sludge is present. In fact, this approach sees limited use in the field today. Its utility should be enhanced by application of signal processing methods.

Another approach is use of EMAT transducers to generate Lamb waves in the tube. The sludge along the tube wall will provide a damping that is easily detected while moving the transducer at speeds comparable with conventional ECT equipment.

Finally, monitoring the transmission intensity of a neutron or X-ray beam between tubes will also indicate sludge depth. Again, because of the added precautionary requirements needed for use of radioactive sources, its routine use is not practical. No specific projects have been initiated in this area to date because it is thought that spin-off results from other measurement activities will provide a solution to this problem.

PRE/POST CORRECTIVE MEASURE EVALUATION

Determining the effect of corrective measures, such as chemical cleaning, employed to mitigate denting and other types of damage is required to provide confirmation of steam generator integrity from a regulatory and a productivity standpoint. Work on this specific topic should include two separate efforts: (1) Development of advanced ISI techniques; and (2) Exploration of on-line monitoring. To satisfy item (1) techniques must be developed to assure that chemical cleaning has been accomplished as expected. The type of measurements needed to confirm this are ability to assure that crevice gap is within suitable tolerances, assure that all sludge has been removed and suitable tube and tube support plate integrity remain. Specific efforts mentioned in the earlier sections are expected to provide the required methods to meet this need. Prospective methods for on-line monitoring of steam generator conditions (e.g., tube and/or support plate integrity) before and after corrective measures are not clear but should be explored due to the great potential benefit available in limiting downtime for ISI.

DATA STORAGE AND ANALYSIS

The present ISI philosophy is to perform periodic inspections and compare the results with a base line case. This places heavy emphasis on obtaining and storing all ISI data in a format and mode that is as efficient to retrieve and use as possible. Today most of the ECT data is stored on magnetic tape which requires a sequential search to find specific information as well as considerable storage volume. However, much progress is being made in other fields for development and use of high-density, low-volume storage of data. These developments need review in order to incorporate the beneficial elements in ISI.

Considerable progress is also being made in many areas of nonlinear signal analysis. There is a high priority need to evaluate and incorporate some of these processes into ISI. Most of these approaches involve digital processing that can be implemented with microprocessor technology. Because these systems operate on a digital format consideration must be given to the optimum point for signal translation into this format.

SYSTEM QUALIFICATION/EVALUATION

The outcome of the concentrated R&D effort described above will produce an inspection system different than those now used. To ensure technology transfer in the shortest time possible, it is necessary to provide demonstrations, training and hands-on experience for the ultimate user. In addition, at some time in the future utilities may wish to develp criteria for certification of competency to assure that those who perform steam generator ISI are fully qualified. Several elements are necessary to accomplish each of these goals. The first is development of a common test bed that can be used to experimentally evaluate, sort, and select from the various technical approaches. The need for such a facility is amplified by the fact that adequate analytical tools are not available to compare one system with another. The initial design criteria were indicated by the recently completed EPRI ECT round robin (TPS 77-709) and focused more finely by a workshop held on November 16, 1977. The design of a fixed site steam generator mock-up and transportable modular mock-up is now underway (SGPO-S126 and RP1174). The completed products will provide a realistic simulation of known steam generator flaw conditions for the units now in service and those now under construction.

The mockups will serve three major functions. The first is to provide a facility where those developing new approaches can gain familiarity with conditions expected in the field both from an access viewpoint and instrument response. The second function is use as a common test bed to sort out the advantages and limitations of the various technical approaches. The third function is its use to establish overall system performance in a statistically significant manner. In the future a fourth use for inspection crew training is possible.

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RADIATION EXPOSURE CONTROL

A constant vigilance must be maintained to insure minimum man-rem exposure to ISI personnel. To maintain exposure as low as possible will require automation to the greatest extent possible. Some equipment is already available, but more effort may be needed to insure that automation is as complete and efficient as possible. However, under present guidelines, development of the mechanical fixturing is not considered as a part of this program. Rather, it is being left to the vendors and ISI service groups to develop this hardware.

PROJECT AREAS YET TO BE DEFINED

Additional categories of NDE activity have been identified for new project development. At this time the technical thrusts and alternatives have not been identified. The categories are external monitoring, new unit design and inspection of repairs. In the first case, a project must be defined that will explore the potential of using external sensors to extr ormation to assess the operating condition of the steam generator. For the second item, an effort must be defined and implemented to assure that all new steam generator designs take into account ISI requirements. The final item indicates the need to develop techniques to inspect areas that have been repaired. Examples are tube lugs and sleeved areas of the tubes.

ROADMAP TO OPTIMIZED ISI SYSTEM

Figure 6 illustrated the different parts of the needed steam generator ISI and candidate approaches. It is doubtful that all branches of the tree are equally feasible or practical for field inspection. Thus, the path being followed is to experimentally evaluate the different approaches starting with the technical feasibility. As the results from each step of an approach become available they will be reviewed and the less promising approaches dropped. Thus, in a step-wise fashion the tree shown in Fig. 6 will be pruned to include only those items that have potential for field use. The objective is not to eliminate all but one technique; rather, it is to develop several inspection "tools" that can provide independent confirmatory results in a rapid, unambiguous and reliable manner. Ultimately several inspection probes may be integrated into an inspection "train."

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OWNERS GROUP

In recognition of the fact that the denting phenomenon has many generic characteristics that could cause considerable expense to the industry, a Steam Generator Owners Group was formed by interested utilities. The thrust of this group is to provide funding in addition to the normal EPRI budget to solve these problems. The expectation is that a short-term accelerated effort can save the industry considerable future expense. The goal is a $40 million dollar effort spread over five years. The program definition and management is provided by EPRI staff functioning in a Steam Generator Project Office (SGPO). NDE is an important part of this effort. Thus, to insure that the total NDE effort is put into perspective, the technological need was concentrated on herein, without undue concern about defining the dividing line between administrative lines. However, it is recognized that the initial EPRI programs were started to insure that technology was available to satisfy regulatory concerns under normal conditions. The denting phenomenon has shown that this emphasis is too narrow.

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Section 5

PIPING

The majority of piping used in the pressure boundaries of BWRs and PWRs is seamless 304 stainless steel pipe. However, centrifugally cast stainless steel pipe is used in some systems. The intent of this section is to discuss the ISI requirements, limitations, and potential solutions for these materials.

Background

The requirements for inservice inspection of piping are covered by code procedures. The ASME Boiler and Pressure Vessel Code Section XI, Appendix III was recently developed to cover inspection of ferritic pipe. Basically, it calls for ultrasonic examination of the weld plus the lesser of 1/2 wall thickness or one inch on each side of the weld. Only a 45° shear wave is required. Other angles or techniques can be used in addition, if the operator desires. Appendix III procedures are mandatory for ferritic material, but are optional for austenitic materials. Although the desire was to make the procedures mandatory for austenitic materials, it did not seem feasible until reasonable approaches are available to deal with the conditions listed in Table 3.

Table 3

CONDITIONS ADVERSELY INFLUENCING INSERVICE INSPECTION OF AUSTENITIC PIPE

Environment

- Temperature 40-82°C (105-180°F)
- High humidity
- Possible high radiation zones
- Anticontamination clothing required

Design/Fabrication

- Spaces or access limitations
- Many geometrical reflectors found for each flaw (up to 1000 reported in one case)
- Rough weld crown
- Counterbore location unknown
- Counterbore chamfer angle too large
- Unknown weld root bead contour
- Variation in weld grain size

To verify the various influences on overall inspection performance, EPRI conducted a Round-Robin examination. Contracts were placed with five firms offering commercial ISI services to inspect (in the blind) pipe sections removed from BWR plants. The samples consisted of portions of 4- and 10-inch diameter pipe that included some service-induced stress corrosion cracks. Because the samples were still radioactive and required special handling, the inspection conditions closely reflected those found in the field. The results are reported in Refs. 11-13 and indicate areas where improvement in needed and possible. Other information useful to determine the status of pipe inspection is contained in Refs. 14-17. All of this information was used to develop and implement effective research and development efforts.

To date the majority of ISI development efforts has concentrated on techniques to assure structural integrity. However, it is recognized that often there are early but subtle indications that problems are developing. Thus, a growing thrust of this program is to develop nondestructive examination methods to give early warning of material degradation and confirmation measurement of material condition. The first thrust is development of better means of measuring residual stress. The intent is not implementation of routine stress measurements as a part of ISI, but rather developing a capability to support research projects in the materials and process areas and make field measurements when needed to resolve specific issues.

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Using the information discussed above, EPRI has launched a research effort to upgrade pipe inspection performance. The effort underway is summarized in the component technology tree shown in Figure 8 and discussed in greater detail below.

Potential Influence

Experience to data indicates that present practice does not produce results of sufficient accuracy and repeatability to permit reliable flaw identification and classification. This fact combined with the lack of procedure specification in the code for austenitic pipe inspection means that the potential exists for an extended outage for a plant while a defect severity judgment is made. Furthermore, if it is decided that the defect reflects a generic problem an entire series of plants of similar design may be mandated to undergo increased ISI.

To remove this potential economic impact while assuring safety, research efforts are needed to fill the gaps in ISI technology. Once technology is available, changes in the code are needed to reflect the improved technology.

Potential Solutions - ISI

A two-pronged approach to improve piping inspection is being taken. The first concentrates on optimization of the technology and practices concurrently used to meet code requirements. The intent here is to identify and confirm changes in the use of available technology or practice that will provide short-term help for field applications. The second thrust is to develop innovative approaches to provide significant improvements to the overall ISI practice. To do this requires development or application of new inspection concepts and influencing the design/fabrication community to take greater cognizance of ISI requirements. Specific details about these areas follow.

Based on the information gained from the Round-Robin program (TPS 77-706) and the austenitic pipe inspection workshop (Ref. 14), two major efforts are underway to optimize technologies now in use. The first is a large effort on ultrasonic optimization (RP892) that has the objective of improving conventional pulse echo inspection by optimization of the components that make up the inspection system. Thus, transducers, transmitter-receivers, display and data recording are receiving concentrated attention. As a part of this effort, an extensive effort is devoted to preparation of suitable specimens. Stress corrosion cracks will be produced in a series of heat-affected zone welds produced to code specifications. It is

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548 009

expected that the results will represent the optimum that can be achieved with conventional pulse-echo technology.

Although field use of radiography can often produce complementary information that is useful to ultrasonic data interpretation, it is used only sparingly. The main reason it is not used more often is lack of a portable radiation source of sufficient strength. To fill this need a contract (RP822) has been initiated to develop a high intensity X-ray source within the volume and weight constraints necessary to allow efficient field use. Initial results indicate that the project goal of developing an X-ray source of 200 rads/minute/meter and weighing less than 100 pounds is feasible using modern microwave technology. Twenty-three potential applications have also been identified.

Although significant improvement is expected from an optimization of conventional pulse-echo UT systems, use of the time-amplitude signal information alone presents some serious limitations. First, there is considerable change in attenuation between the base material, heat-affected zone (HAZ), and weldment in stainless steel. As a consequence any signal amplitude will be dependent on position. This factor coupled with the requirement to analyze any signal above a certain level means that considerable time d man-rem will be consumed evaluating reflectors with no safety significance.

To overcome the limitations of amplitude-only signal analysis, a project (RP770) was started to evaluate a nonlinear signal processing approach called Adaptive Learning Network (ALN). In this laboratory proof-of-princip evaluation the ALN demonstrated the ability to discriminate between different ultrasonic signals in stainless steel without primary dependence on signal amplitude. Initially, it was demonstrated that signals from fatigue cracks, side drilled holes, counterbore, weld bead and grain scattering could be unambiguously identified. Later it was shown that the same approach could again unambiguous y and automatically identify cracks found in stainless steel pipe welds while discriminating against geometrical reflectors. Based on this success and the fact that the ALN approach had demonstrated the ability to size flaws in earlier work (19, 20), a follow-on effort was initiated. The objective of this project (RP1125) is to design, fabricate and field evaluate a ruggedized ALN system for stainless steel crack detection and sizing. Successful completion of this effort will provide an automatic analysis technique and prototype equipment capable of both detection and sizing of SCC cracks in stainless steel; thereby, overcoming the amplitude dependence of conventional technology. Because this is primar[illegible]

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548 010

analysis approach that operates on the output from a conventional pulse-echo system, no major redesign of available commercial gear is required.

In a related effort, close communication is being maintained with the Hanford Engineering Development Laboratory effort. They have a major effort underway to develop a system for inspection of the FFTF piping. The thrust of this effort is to reduce amplitude dependence by incorporating cross-correlation analysis and power spectral density analysis in the frequency domain with time amplitude analysis (17).

In the last decade considerable progress has been made in medical diagnosis by the development and application of X-ray tomography. In an effort to evaluate the potential for reactor uses of the 3-dimensional image generation ability, a project was conducted utilizing a medical scanner (RP610). The results indicated that it is a potentially viable inspection approach and that a full-scale laboratory evaluation on actual pipe samples is called for. Such an effort is planned as soon as budget constraints permit.

As indicated earlier, the lack of a suitable source has restricted inservice radiography. Once one is available, it is believed that the imaging system represents the next area where improvement can be achieved. One approach to replacing film is the use of a real-time radiography imaging system. To evaluate the potential of this approach versus film, an evaluation effort has been launched (RP607-2). The results from this effort will be used to plan future research in this area.

Limited use of centrifugally cast stainless steel piping occurs in some reactor systems. Because of the long columnar grain structure, the material is difficult to inspect. In some recent work (21) the ultrasonic properties of this type material were studied and found to vary in a periodic manner as a function of the angle between the incident UT beam and the grain orientation. The attenuation was shown to change by a factor of 10 in 90°. Use of this information yielded an optimum weld design with regard to inspectability. Work similar to this is needed to establish a base line for ISI of cast SS pipe. Once this is done, the influence of the weld and the HAZ must be characterized. Work of this type is planned for the near future.

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Potential Solutions - Residual Stress Measurement

Efforts are underway to develop both ultrasonic and X-ray methods for residual stress measurement. In a preliminary project (RP702) use of ultrasonic surface waves were evaluated to measure residual stress in stainless steel. The results showed that the change in ultrasonic velocity per unit change in stress was too small to permit use of this approach. In another ultrasonic approach more success has been reported. Using tomographic reconstruction principles (RP504), it has been demonstrated that stress profiles can be produced. The great attraction of this approach is that it permits measurement of a stress profile throughout the thickness of a component. The ongoing work is now directed toward thick sections of carbon steel as found in pressure vessels. However, it may also be useful for piping, valve and pump bodies, so is mentioned here for completeness. As more is learned about internal stress profiles and their relationship with defects, this approach could also be a viable ISI tool with a prediction capability on material degradation rate.

The X-ray diffraction technique is the most widely known and accepted method for residual stress measurements. Even though it only measures surface stress, it would be used a great deal more if a convenient field instrument were available. Toward this end, EPRI has a contract underway to develop such a device. The concept being pursued combines the principles of classic X-ray diffraction with modern electro-optical detection devices to make a device capable of making residual stress measurements on the ID of a four-inch Schedule 80 stainless steel pipe. The recent laboratory proof-of-principle demonstration was successful on a ten-inch pipe sample. A follow-on effort has been initiated to use these results to develop a smaller version that will operate inside a four-inch pipe. The unit will be field evaluated by providing data to support laboratory investigation of stress corrosion cracking phenomena now underway under EPRI sponsorship. A summary of this work is contained in Ref. 22.

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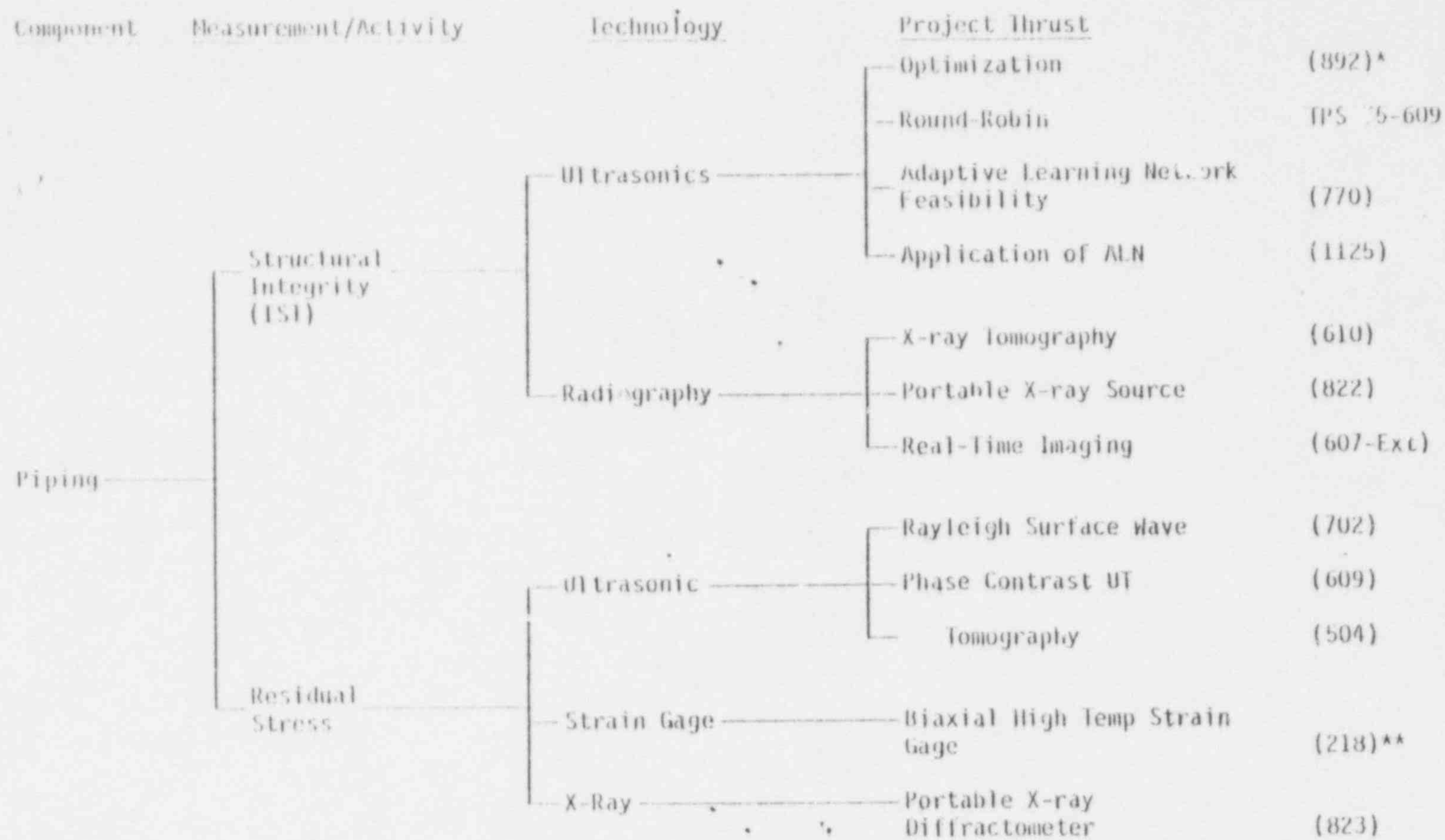

* Numbers in parentheses are EPRI project numbers. See Table 1 and Appendix A for more detail.

**For operating strain only.

Figure 8. Component Technology Tree for Piping

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Section 6

NOZZLE

The nozzle presents a formidable inspection challenge consisting of a surface curved in two planes terminated by a large manual weld on one end and a transition piece of dissimilar metal on the other. The geometrical complexities are complemented by stainless steel clad applied on the pressure side. Thus, a nozzle ISI must compensate for both geometrical changes and dissimilar metal interfaces. Figure 9 shows the cross section of a typical nozzle. Additional information is given in the sections that follow.

Background

Although the Section XI Code does not restrict inspection to ultrasonic methods, this approach has been the only one pursued for volumetric inspection. The primary reason is that it is the only method that has the ability (as defined by today's knowledge) to complete the large amount of volumetric inspection required in the nozzle and pressure vessel regions. However, as experience with the code has evolved, limitations on this technology have become obvious. A discussion of these limitations that apply to pressure vessel and nozzles follows.

<u>Design</u>. When a majority of the plants now in operation were in the design stage, ISI was not required. As one would expect, these designs made no deliberate effort to insure an inspectable product. Now the owners are faced with performing a creditable ISI without benefit from design assistance. As a consequence, completely adequate welds are present but often are difficult or impossible to inspect because of insufficient access clearance to operate an inspection probe, or surfaces left too rough to pass a probe over.

<u>Dissimilar Metal Bonds</u>. Reactor pressure vessel and nozzles are constructed from carbon steel alloys and then clad with stainless steel on the inside to take advantage of the latter's superior corrosion resistance properties. Similarly, the primary system piping is also stainless steel. The use of the dissimilar metals creates problems in ISI. In the case of the clad, it is usually left in the as-deposited condition and thus presents a rough surface of unknown contour on

548 014

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the surface and an ill-defined bond line. The former condition creates an additional "noise signal". The latter condition generates an unknown factor in signal amplitude because the attenuation of the two materials is markedly different. Both conditions generate an ambiguity in signal amplitude interpretation. Thus, as long as signal interpretation is based on time-amplitude information only (as is now done) an uncertainty is present.

A similar condition exists for inspection of the joints where the nozzle is connected to the primary pressure piping system. In this case, the influence of differing attenuation characteristic is predominate.

Geometry of Nozzles. The radius of curvature found in the nozzle geometry generates a problem in "knowing" what area is being inspected. The reason is that the curvature acts as a lens dispersing the beam as it travels through the large thickness of material (12-22 inches). This is a vexing problem because it is highly desirable to inspect some nozzles from the outside. Further complicating the geometrical problem is the fact that the beam also interacts with the clad surface on the ID adding additional ambiguities as discussed earlier.

Signal Acquisition and Interpretation. The prior discussion covered items that are part of the system to be inspected. In this part the focus will be on the system that performs the inspection. Because of the limited access and the need to keep radiation exposure to a minimum. the majority of the PV weld inspections are done with automated systems consisting of a track to guide a mechanical device along the welds. The inspection equipment is then mounted on this remotely controlled platform. The technology for mechanical inspection is undergoing significant improvements with efforts by the vendors and ISI service groups.

At the present time, no industrywide standard exists for the type of mechanical equipment employed. As a consequence, many one-of-a-kind systems exist. Thus, a question exists about the interchangeability of inspection systems. Another aspect of this problem is coupling the ultrasonic energy with the inspection probe. As the results are judged on the basis of an amplitude-only signal, an extremely stringent requirement exists to insure that the coupling is consistent throughout any given test and, furthermore, can be duplicated at a later date. The exact variation in coupling impedan[illegible] is not well-known but can be significant.

548 015

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Current practice does not include a performance standard for the design, fabrication, and use of the signal generation and receiving equipment. Generally, the gear used is a commercial product that has rather broad capabilities to appeal to a wide market. Thus, it does not represent an optimized design for this application, nor can it be assumed that equivalent equipment is used throughout the industry.

The ISI code specifies the use of fracture mechanics for determining the severity of any defect found during ISI. To properly take advantage of this powerful analysis method, information is needed to describe the size, orientation, location and depth of any defect. The people who developed the code recognized the limitations of ultrasonic technology to describe reflectors; hence, certain simplifying and conservative assumptions are made in the use of ISI data in a fracture mechanics analysis. With the many uncertainties outlined in the items discussed above, the ability to size is severely limited with time-amplitude-only information as is now done.

Qualified Manpower. Because of the above items it is obvious that the success enjoyed by ultrasonic inspection is due in a large measure to the skill exhibited by experienced inspectors. As the number of reactors in operation increases, additional inspectors are needed. The present trend shows that the demand for skilled operators is rapidly outstripping the supply; thus, a shortage of skilled operators is imminent. Two other driving forces on operators availability is man-rem exposure limitations and competition from other industries which are turning to increased NDE to combat product liability claims.

Potential Influence

The influence of the above factors can manifest themselves in many ways. Without regard to order of occurrence the effect is the same: increased operating costs due to excessive downtime for ISI and the potential for protracted plant shutdowns while the issue of a defect severity judgment is being resolved with regulatory agencies.

Potential Solutions

For those plants now in service or under construction, little can be done in the design/fabrication stage to increase inspectability. However, some improvement can be expected by making people responsible for design, etc., aware of inspection requirements. This is being done through professional meetings, papers, presentations, etc. Some appropriate papers are listed in Refs. 23, 24, and 25. However, any action taken at the design stage will not become evident in ISI practice for about a decade. Thus, the major short-term improvement must come through improved inspection methods.

The major short-term effort for improvement of nozzle inspection is the ultrasonic optimization project (RP892). The objective of this effort is to provide improvement via optimization of conventional technology. When completed, the results will be indicative of the maximum improvement possible with conventional ultrasonics. The development of a portable X-ray source (RP822) will also be beneficial in the short term.

For the mid-term there are several approaches that show considerable promise. The first is the use of holographic principles to quantify and characterize potential effects. At this time EPRI is sponsoring two programs in this area. The first (RP605) is oriented toward generating a comparison between ultrasonic holographic imaging, conventional ultrasonic inspection, and radiography. Whenever possible, confirmation of defect characteristics is being done by destructive analysis also. The objects being inspected include experimental pressure vessels, HSST vessels, specially constructed test plates and production vessels. Completion of this program will provide a significant data base on the merits of UT imaging for use by Code committees as well as provide guidance on future research and development efforts. When this project is completed (second half of 1978), the results will be published with a special effort given to informing the appropriate Code committees and regulatory bodies.

The second program (RP606) is oriented toward design of a dual function device. This device uses conventional UT approaches to perform a "search and locate" function. Once an anomaly is detected, the same gear is switched to an imaging mode to characterize the reflector. By use of this device, built around a linear array of ultrasonic transducers, it will be possible to perform a Code-acceptable UT examination at 5 times the speed of current technology. If a defect is found, simply changing a switch will permit the same equipment to form and display an image to characterize the defect. Laboratory evaluation of this device started in late 1977 and is continuing. Following successful laboratory demonstration on a large plate (one of the samples used in RP605), emphasis will be shifted to field demonstrations on pressure vessels. Following this accomplishment, effort will be devoted to adapting the hardware to inspect the nozzle regions.

The second approach that shows considerable promise uses Adaptive Learning Network (ALN) technology to process normal pulse echo signals as a function of transducer position. With this technique information is extracted from the frequency spectrum of the pulse in addition to the normal time-amplitude information. Data obtained on austenitic pipe samples (RP770) show that the approach is capable of identifying crack signals in the presence of a variety of geometrical reflectors found in stainless steel pipe welds on a real-time basis. Other data on aluminum samples obtained under an Air Force contract indicate the approach is also capable of sizing defects. Based on these successful proof-of-principle demonstrations, a follow-on program was initiated (RP1125). The objective of this effort is to design, fabricate and evaluate two prototype systems. The first system is oriented toward detecting and sizing cracks in stainless steel welds. The second system is being developed for the detection and sizing of cracks in the BWR feedwater nozzles.

It is important to point out that the ALN approach analyzes signals independent of the signal amplitude. Thus, it offers a new approach that eliminates many of the concerns about reproducibility of results.

Future consideration should include development of a standardized design for the mechanical equipment needed to inspect vessels and nozzles. Completion of this "EPRI Design" would then provide a reference design for use by all utilities in order to assure a variety of sources when contracting for ISI services. Another complementary effort is development of a standard format for the acquisition and storage of all ISI data. Such a format would insure that all data is obtained and stored in a compatible format for analysis capability that may be developed in the future. This will be discussed in more detail in Section 9.

Finally, consideration must be given to development of a test facility that would provide a standard, realistic simulation of components, such as PV welds and nozzles in a shell course, accessibility and environment expected during an actual reactor ISI. This facility would be used to evaluate new inspection hardware prior to actual field service. Also, it could be used to train ISI personnel in a realistic but nonradioactive environment. The training could serve as either a familiarization with actual field conditions or as a site to "qualify" inspectors prior to actual ISI experience.

Current budget projections will not permit initiating any action on the above projects prior to 1979.

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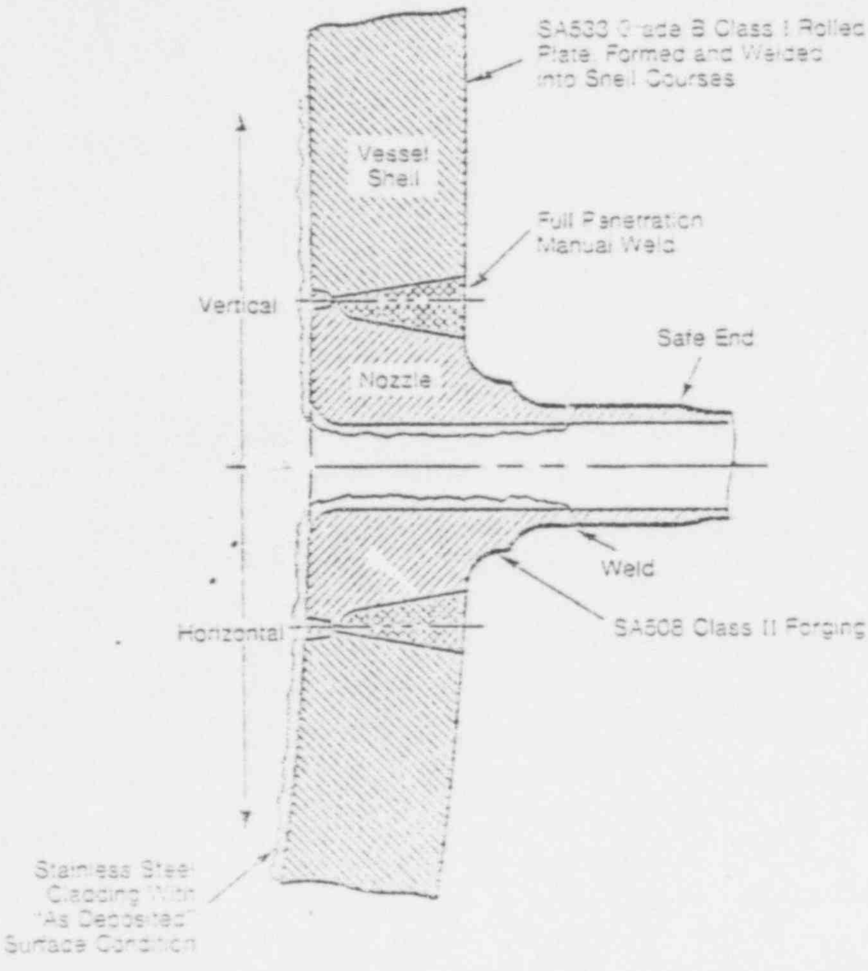

Figure 9. Cross section of a typical nozzle (BWR)

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Section 7

PRESSURE VESSEL

Background

The pressure vessel is a very large structure that provides the primary containment of the reactor. The size is a function of reactor type and thermal power output, and can reach 12-inch (30.5 cm) thickness, 20 feet (6 m) diameter and 60 feet (18.3 m) high. It is fabricated from a carbon steel alloy (A533) that has proven to be very dependable. To enhance corrosion resistance a stainless steel clad is welded on the inside diameter of the vessel. Generally, the clad is left in the as-deposited condition creating an undulating surface that must be penetrated by an ultrasonic beam if an ID inspection is conducted. When the inspection is conducted from the OD this dissimilar interface creates a reflector surface of changing properties on an otherwise "clean" material. Because of space restrictions and the need to minimize radiation exposure, a majority of the OD and ID vessel inspections are automated.

Additional background information and the potential influence on plant performance for the pressure vessel is essentially the same as that for the nozzles. To avoid duplication the reader is referred to Section 6 for additional detail.

Potential Solutions

The manufacture and acceptance of pressure vessels is governed by Section III "Nuclear Vessels" of the ASME Boiler and Pressure Vessel Code. To be acceptable under this code means that it must pass a radiographic inspection. Once it has passed the radiographic examination, the future pre-operation base line and periodic inspections required by ASME Section XI use ultrasonic techniques. Thus, a situation exists where fabrication quality is judged via one NDE technique and operational (performance) integrity is verified by a different NDE technique. The two techniques will show different sensitivities to the same defect because of the basic physical principles involved. Thus, one should not attempt to compare the approaches on a 1:1 basis. Rather, the increased confidence generated by use of complementary techniques should be stressed.

The significance of this discussion from a utility viewpoint is that if any fabrication artifact that can cause a significant ultrasonic signal exists when the vessel leaves the shop its significance (or lack of) must be well-understood. To help insure this condition, EPRI conducted a project to assess thick section radiography (RP607). The variety of variables that influence radiography were treated in a systematic manner in this work. The results are presented in a tabular format that indicates how system performance changes when parameters are changed from a reference system (26). In terms of future work, the project indicated that the image formation component of the system offers the greatest potential for improvement. A small project is now underway (RP607-2) to evaluate the potential of the real-time radiographic imaging approach.

In order to permit better utilization of fracture mechanics in defect severity analysis, greater ability to characterize flaws in terms of location, shape, size, type and orientation is needed. Acoustic imaging techniques offer considerable promise to supply the information. Thus, two projects to develop this technology are underway. The objective of the first project (RP605) is to establish the ability of acoustical holography to accurately characterize defects in thick section welds and plate. In order to relate these results to current practice the flaws will also be characterized by Section XI ultrasonic techniques commonly used in the US, the British approach to meeting this code, the advanced focussed probe approach developed by the French, radiography, and destructive examination. When the project is completed in 1978 the results will be published. In addition to providing guidance for future research and development, a special effort will be made to also convey the results and their significance to appropriate code and regulatory bodies.

The above project will establish the characterization ability of holography. To use this information in ISI, a second program (RP606) is underway to develop a suitable inspection device. This device uses conventional ultrasonic techniques to perform a "search and locate" function. If an anomaly is detected, the same gear is switched to an imaging mode to characterize the reflector. Laboratory testing of the device was initiated in late 1977. Continued successful development of this device built around a linear array of ultrasonic transducers will enable a code acceptable UT inspection to perform at 5 times the speed of today's technology. When ultrasonic anomalies are found the imaging mode will permit characterization of the reflector in less than one minute.

548 021

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A significant improvement in ISI ability is expected to materialize from the above projects in the next few years. At some future time it is conceivable that a further improvement can be developed by combining these results with the results expected from the use of Adaptive Learning Network concepts on nozzle and pipe inspection. For example, use of ALN on the pulse echo "search and locate" mode could provide an automatic decision function to switch to the imaging mode for characterization. This may be a very great benefit when a low signal-to-noise ratio is present; e.g., a small crack at the clad-base metal interface. A second potential application of ALN would be its use to automatically analyze the results obtained from the imaging mode.

Acoustic emission holds promise as a passive on-line surveillance tool for pressure boundary monitoring. To further this end, a program was conducted to evaluate the sensitivity and reliability of acoustic emission for detection and location of flaws in pressure vessels. A reactor pressure vessel was monitored during hydro-test. Later, an ultrasonic examination following Section XI procedures was made of target areas identified by AE. The correlation between the two methods was very good and in agreement with the same trend found in a recent critical assessment of A.E. (27). However, until some of the other issues identified in this review are resolved, only limited usage of AE as an on-line monitor is expected.

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548 022

Section 8

MATERIALS PROPERTY MEASUREMENT

The thrust of this section departs from previous examples by describing a measurement function rather than ISI of a specific component. Although many projects were initiated in the EPRI program to make a specific measurement on a specific component, it is believed that the concepts described in this section have rather general application. Hence, they are treated in a more generic sense.

Background

The major emphasis of nondestructive evaluation (NDE) has been to find defect regions after a component is fabricated and to ensure that new defect regions have not formed while in service. By analogy, it is working with the corpse instead of applying preventive measures. New developments in inspection concepts now make it possible to consider using NDE as a tool to determine material conditions that can lead to future defect generation. Examples would be verifying residual stress in welded joints of stainless steel or measuring the stress profile in thick section weld regions in order to generate actual data to compare design assumptions against. Recent experience with the BWR pipe cracking problem is one example of where actual field stresses exceeded those assumed in design. desgng. In this case, the ability to measure surface residual stress would have greatly aided a speedy identification of one component of the causitive mechanisms that generated the cracking. Another situation without definitive feedback is the stress profile in heavy section welds. Ability to measure this parameter would provide a powerful tool to confirm present practice and aid in the development of new welding procedures. Other examples are: measurement of surface residual stress, determination of the plastic zone contour surrounding a fatigue crack, direct measurement of stress intensity factor, measurement of fracture toughness, and development of an understanding of acoustic emission signals so structural integrity can be reliably predicted. In summary, successful development of techniques for materials properties measurement will permit verification of design assumptions thereby preventing "surprises" that occur when actual conditions do not duplicate design constraints. If a "surprise" should occur, measurement tools will also be available to quickly and precisely define the root cause.

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Potential Influence

One of the most difficult problems in structural analysis is the determination of actual residual stress in a structure. In the manufacture of large structures, such as pressure vessels, a number of very thick full penetration welds are required. The heat-affected zone surround the weld will contain residual stresses due to uneven cooling rates and weld metal solidification shrinkage. In practice, the largest of these stresses are relieved by heating the entire vessel to some appropriate temperature and then carefully controlling the cooling rate. However, because of geometric discontinuities, such as nozzles, and section thickness changes some residual stresses remain in the structure. There is, unfortunately, no satisfactory test for measuring these remaining residual stresses. If these regions of residual stress occur in critical areas, such as nozzle-to-vessel weld, and cracks subsequently develop, it is difficult to accurately assess the margin of safety remaining in the structure. In evaluation of the safety of a heavy steel structure, all stresses, including residuals, must be accounted for. Since actual values of residual stress are not known, conservative values are used in flaw evaluation calculation. This conservatism could lead to unnecessary outage for repair of structures which in fact are safe, were actual residual stresses known.

Development of materials property measurement capability wil[illegible]rmit comparing design assumptions with actual loading conditions. By closing this loop, increased confidence in present designs is possible while permitting development of new design and fabrication procedures that are more efficient and perhaps easier to fabricate.

Potential Solutions

Methods for measurement of materials property generally depend on the development of a new understanding of how mechanical and electromagnetic energy interacts with matter. In the last few years, several new technologies have been developed that aid in this quest. One of the more important is the rapid and recent advances in electronics. This, combined with advances in transducers, electro-optics, and new scanning approaches, indicates that the measurement goal will yield to a persistent and enlightened effort. The solutions now envisioned involve the use of tomography principles, ultrasonic attenuation, and miniaturized X-ray diffraction approaches.

A feasibility study was initiated (RP504) to determine the potential for mapping stress profiles in steel by use of ultrasonic tomography. In this approach, ultrasonic energy is transmitted through a sample in many different paths. The attenuation for each path is then used in a tomography reconstruction scheme to determine the attenuation profile. By use of an experimentally determined factor that relates ultrasonic attenuation to stress, the attenuation profile is converted to a stress profile (28). Based on the success of the initial effort the project was expanded to include the development of prototype equipment. Successful completion of this effort will enable the measurement of stress profile while having access to only one side of the material.

In a related program (RP609), phase contrast ultrasonic imaging concepts are being developed. The ultrasonic attenuation is being measured by noting the change in phase permitting measurement of smaller changes than possible with amplitude measurements. The results to date are very encouraging. Experimental results showing the stress pattern around a hole in a plate show good agreement for both positions and magnitude when compared with theoretical predications. There is reason to believe that this approach will lead to a direct method for measuring stress intensity.

Another program (RP823-1) is making a significant advance in use of X-ray diffraction technology for field measurement of residual stress. This advance results from combining the X-ray diffraction concept with recent advances in electro-optic techniques for X-ray detection and measurement. The resulting laboratory demonstration-of-principle equipment was small enough to fit inside a 10-inch diameter pipe. These results indicated that the standard, accepted X-ray stress measurement technique could be transformed from a laboratory tool requiring extensive sample preparation and time-consuming measurements to a convenient field measurement device. Thus, a follow-on effort was initiated to develop prototype equipment to make residual stress measurements inside four-inch diameter pipe. When completed the equipment will be evaluated by use in an EPRI project oriented to identifying pipe materials less susceptible to stress corrosion cracking.

A review of EPRI's residual stress efforts is given in Ref. 22.

Acoustic emission has great potential for detecting the onset of structural failure while under load and for monitoring the growth of known cracks. A project (RP[illegible]) is underway to help develop the technology so that this potential is realizable. The objective of this project is to develop and demonstrate the theo-

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retical bases, measurement techniques and calibration procedures required to evaluate the technical feasibility of using acoustic emission spectrum analysis for characterizing moving cracks and defects.

Future work will investigate ultrasonic propagation characteristics that result from the generation of different modes made possible by EMAT transducers developed in RP609. Perhaps additional data can be obtained by combining information from the horizontal and vertical shear wave propagation modes. Investigation of the use of Adaptive Learning Network for signal analysis will be considered.

POOR ORIGINAL

548 026

Section 9

STEAM TURBINES

Data gathered by EEI and analyses done at EPRI and elsewhere in recent years continue to show that the turbine system is one of the three leading causes of plant outages, both forced and scheduled. As means for streamlining nuclear plant refueling operations are developed and put into practice, turbine maintenance has begun to show up repeatedly on the critical path for the duration of scheduled outages. Finally, the occurrence of malfunction or extensive damage in turbines--even though relatively rare--can have a large adverse effect on the utilities or regions involved if one or two large baseload units, nuclear or fossil, represent a substantial fraction of the available generating capacity. For these reasons, EPRI initiated a number of projects aimed toward improved steam turbine operation.

A complete description of turbine-related projects is given in EPRI NP-886-SR (37). With liberal borrowing from this document, the turbine NDE-oriented efforts are discussed below.

The run-retire decision-making process for turbine rotor requires that the initial quality of the rotor forging, as well as service-induced damage, be quantitatively defined for evaluation according to the various possible fracture modes.

Nondestructive evaluation deals with the detection and characterization of macroscopic defects, such as segregation of nonmetallic inclusions and porosity, that constitute the origins of fracture, and of service-induced cracks. The most critical link between nondestructive evaluation and lifetime prediction is the determination of the size and spacing of defects and the extent of crack propagation from them. For example, since the maximum tensile stress developed in the rotor is tangential, the crack growth is primarily in a radial-axial plane; consequently, the dominant flaws will have their largest projected area in the (r, z) plane, and the most severe clusters will have their maximum area fraction on such a plane. In the case of clusters containing flaws which are not coplanar, it is necessary to account for out-of-plane linkup between flaws over some tangential distance.

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In making run-retire decisions, the utility operator does not have the advantage of the extensive correlations between the general quality of a forging and rotor reliability acquired by the manufacturers, nor is it practical to reproduce such a statistical data base. The utility operator accordingly requires a higher degree of certainty from the NDE procedure in the sizing and location of flaws and the ability to discriminate between flaws which have initiated cracks and those which have not. Normally, volumetric bore inspections of rotors are performed with ultrasonic techniques.

Golis and Brown (38) discuss many of the detailed performance characteristics of equipment being used in the field today for rotor inspection. Much of the information contained in the report came from operating inspection groups and other sources with special knowledge of rotor inspection. Consequently, these results determine the current state of rotor inspection methodology. As such, they are useful for making realistic assumptions for lifetime prediction models and identify areas where additional research is needed to improve steam-turbine bore NDE practices. In a follow-on effort an improved inspection system is being assembled for evaluation (RP502).

Inspection considerations and techniques similar to those used on rotors are also applied to the examination of discs. However, the techniques are not as advanced as for bore examination. Projects to upgrade this capability are now in the planning stage.

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Section 10

FUTURE ACTIVITIES

In this section, areas of future NDE activity are identified and, where possible, the appropriate technical thrust is identified. A majority of the items discussed do not have code requirements as a strong motivating force. Rather, it is believed that application of suitable NDE techniques can produce a significant benefit to operational performance or materially assist R&D efforts in other program areas.

Pumps and Valves

The Section XI Code specifies operational testing of pumps and valves on a periodic basis. Structural monitoring is also required but the specific procedures are not supplied. The pump and valve bodies are coarse grained cast stainless steel. From an ultrasonic viewpoint inspection is a challenge because of grain scattering and attenuation. Radiography is a possible alternative provided an adequate source is available. To a large extent, projects already identified or underway will develop suitable solutions to this ISI requirement. Specific examples are portable X-ray source (RP822); X-ray tomography, Ultrasonic Optimization (RP692); and Adaptive Learning Network for Ultrasonics (RP770 and NP1126).

While not oriented toward the ISI concern, Ref. 26 reviews the operational problems being experienced with valves.

Internals and Support Pads

The intent of the Section XI Code is to develop specifications for the ISI of core internal structures and component supports. Tasks groups are now in the process of defining the ISI procedures. It is expected that current projects will supply much of the basic technology needed to implement an ISI once the requirements are identified.

548 029

POOR ORIGINAL

Fuel Examination

EPRI has a comprehensive fuels research program underway (30). The objective of the program is to increase the performance and reliability of LWR fuels. As specifications changes or conditions are identified for inclusion in fuel manufacturing processes, it is appropriate to also develop and qualify NDE procedures to reflect the desired conditions. These methods could then be applied on the production line at the appropriate time. To insure that this occurs, close coordination between the NDE and fuels programs must be maintained.

In the case of pre-operational use of NDE on fuels, the available technology may be ahead of the fuels R&D. However, this is not true for postirradiation examination. In programs now underway, both eddy current and ultrasonic techniques have proven unreliable for identification of failed fuel rods either in the reactor storage base or in a hot cell (31). Work now underway for inservice inspection indicates that improvements are possible. Specific possibilities are the use of Adaptive Learning Network signal processing approach as demonstrated in ultrasonic signal discrimination (RP770) and eddy current signal analysis for steam generator tubes (TPS77-723). In addition, recent electro-optic developments indicate that a superior profilometry approach is feasible (32). Finally, the use of the EMAT transducers offer other advantages (RP698 and Ref. 33). Ref. 34 also summarizes NDE activities applied to postirradiation fuel inspection.

It is expected that a more active role in applying results from other EPRI projects to postirradiation fuel examination will commence during 1978.

Condensers

Condenser tube failures have had a major effect on plant availabilities (35). The failure modes that have been observed at different plants include: external stress corrosion cracking, steam side corrosion, tube inlet erosion, abrasive wear due to vibration and tubes being struck and damaged by foreign objects such as broken turbine blades, impingement baffles, and other loose parts. Although leak detection capability is quite good, the ability to identify the specific tubes needs improvement. Inspection methods used today include eddy current and ultrasonic techniques as well as other less popular approaches.

548 030

POOR ORIGINAL

There is considerable similarity between steam generator tube inspection and condenser tube inspection. Thus, it is expected that the techniques developed for improved steam generator ISI can be transferred to condenser tube ISI with only minor modifications. The changes would have to account for the different sizes and materials; this would be straightforward once the technique is developed and proven. Thus, no specific action is intended here until the steam generator effort is further along.

ISI Data Storage

Compliance with the ISI code means that a considerable amount of data is generated. Because of record keeping requirements and the fact that subsequent ISI's are referenced to a pre-operational base line inspection means that the records must be kept in a form that guarantees their integrity for long times. Furthermore, to be of maximum value, almost random access must be available. The lack of standardization to date has created a situation where data is stored in many different forms and formats. Although access to prior inspection data is possible, acquiring the information in a rapid and easy manner is the exception rather than the rule. As a first step to improvement, an effort is needed to identify all data generation and storage requirements for Section XI compliance. Once this is accomplished further effort is needed to identify an optimum data storage system that acknowledges the recent developments in digital electronics and storage devices. With an optimum storage system specified, then a format can be described for the output from each ISI device insuring standardization throughout the industry. The value of this accomplishment will increase considerably as the newer, more precise and reproducible ISI approaches are applied routinely.

Personnel Qualification and Training

It appears that the rate at which new plants, with their attendant inspection needs, are becoming operational is increasing more rapidly than the manpower pool is growing. The radiation exposure limits contribute to the problem also. Finally, the increasing concern over product liability and consumer activism is generating competition for those very people needed to perform ISI on nuclear systems. With these facts in mind, it seems that EPRI should take appropriate action to help stimulate the development of pe[illegible] knowledgeable in NDE. The need exists at several educational levels.

548 031

POOR ORIGINAL

First, additional qualified technicians are needed to perform the inspections. Second, additional qualified engineers are needed to supervise the inspection and interpret the results. Finally, more scientists/engineers are required to develop improved inspection concepts and develop additional information for the NDE technology bank. A greater involvement of the academic community is needed to help assure an adequate supply of manpower knowledgeable in NDE. The challenge is there, but ways must be found to motivate acceptance.

In a separate but related issue the industry needs to consider certification of inspectors to insure that only qualified people are permitted to perform inspections. What is suggested is a two-step process. The first step would certify a general level of competence in NDE and would be administered by an appropriate national organization. The second step would be a job or industry certification to insure that the inspector is knowledgeable about the code requirements, equipment, procedures, and the structure being inspected.

Test Facility

At some time during the development or evaluation of an ISI device it is desirable to encounter field conditions rather than laboratory samples. Because of operational restrictions it is very difficult to use an actual power plant. Thus, it is highly desirable to acquire a group of specimens to form a test facility. The types of specimens desired are: pressure vessel shell course with nozzle, stand-alone nozzle, pump and valve bodies, portion of a steam generator, and several examples of piping complete with welds. This facility could also be the final resting place for the samples fabricated for EPRI projects. Once the samples are acquired (many components that are now scrapped for minor flaws would be appropriate) actual maintenance of the facility should be minimal. But, its availability could provide significant benefits to many current and future projects. In 1978, an initial effort toward this goal is expected with the acquisition of a shell course and PWR nozzles. In addition, steam generator mock-ups are being assembled and samples of stainless steel pipe with stress corrosion cracks are being acquired, along with BWR nozzles. Thus, effort will be devoted to developing a means of maintaining all of these samples when current projects are completed.

POOR ORIGINAL

548 032

NDE Center

All of the EPRI NDE activities to date have been carried out under contracts with many organizations. From this experience it has become apparent that many areas necessary to implement a comprehensive and efficient NDE effort do not readily lend themselves to this mode of operation. Thus, consideration is being given to establishing a dedicated nondestructive evaluation (NDE) capability for the electric utility industry. This would be accomplished by establishing and operating an NDE Center that includes the following activities: evaluation of current inspection practice, technology transfer, development of improved ISI procedures, research and development, the fostering of greater academic involvement in NDE to help alleviate growing manpower shortages, and training and certification of ISI crews on full-scale component mock-ups prior to entering plant environment.

The center should be viewed as a supplemental effort rather than a replacement for the existing contract research effort. The supplementary nature is evident upon reflection because many of the activities identified are not now being pursued. The main reason is the difficulty in addressing the effort in a timely manner via contractual process.

A functional description of the center has been prepared and discussed with the industry advisory committees. They have strongly supported the concept and recommended that the Board of Directors take action to implement the concept.

Section 11

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POOR ORIGINAL

548 036

Appendix A

DESCRIPTION OF PROJECTS

Listed below in order of increasing project number are brief descriptions of all EPRI NDE projects completed or now underway. The information contained in each description includes objective, progress to date, contractor(s), contractor project manager, funding level, contract initiation and completion date, EPRI project manager, and available publications. The EPRI research projects are listed first (denoted by prefix RP-). Following this are descriptions of Technical Planning Studies (prefix TPS-). The third category lists the projects underway that are funded by the Steam Generator Owners Group (see Section 4 for details). The projects are denoted by the prefix SGPO-S___.

RP279 - ACOUSTIC EMISSION ANALYSIS OF PRESSURE VESSEL MATERIALS

The objective of this program was to obtain, record on magnetic tape, and analyze acoustic emission signatures for seventeen heat of steel to ascertain: (a) inception of crack growth, (b) temperature effects, (c) thickness effects. Each heat had twelve acoustic emission events monitored and analyzed: (a) tensile tests (6/heat), temperature range from 0° to 550°F, (b) one inch compact tension (5/heat), temperature range from -100°F top 150°F, (c) four inch compact (1/heat), temperature 60°F. The project has been completed. However, data acquisition problems rendered the data to be of doubtful value.

Prime Contractor: Acoustic Emission Technology Corporation (A. T. Green)
Duration: Completed
Total Project Cost: $29,000
EPRI Project Manager: Karl Stahlkopf

Reports: None

RP367 - REAL TIME FLAW IMAGING EVALUATION STUDIES

The objective of this project was to determine significant parameters that needed addressing and evaluation in the development of a real time flaw imaging system for pressure vessel inspection. The emphasis was on determining the ability of different ultrasonic imaging systems to detect size and classify defects in fixed

548 037

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ections of ... ur ... essel steel at near real time rates. Five separate studies were ... missione... and the results used to prepare a request for proposal for a rea... time flaw imaging device. The culmination of this effort is project RP... now ... way.

Prime Contractors: Holosonics, Inc.
Stanford Research Institute (SRI)
Southwest Research Institute
General Electric Research Laboratory
Battelle Pacific Northwest Laboratories

Duration: All projects completed

Total Project Cost: $50,000

EPRI Project Manager: Karl Stahlkopf

Reports: Summary Reports are available upon request.

RP403 - ADVANCED TWO FREQUENCY EDDY CURRENT SYSTEM FOR STEAM GENERATOR TUBING INSPECTION*

The basic concept used today for steam generator tubing inspection is the eddy current method introduced into the field about fifteen years ago. Since that time considerable engineering improvement has been made to the concept so today's systems are limited by the basic capability of the approach used.

Considerable laboratory work had been done in the past five years on a multiparameter, multifrequency concept that permits much greater signal discrimination. Under EPRI sponsorship, this concept is being refined and a breadboard unit constructed for field evaluation. The project results will allow complete evaluation of the two frequency eddy current system using multiparameter analysis to extract information on tube defects and thinning while discriminating against unwanted signals such as those from probe wobble and tube supports. The advanced two-frequency system is intended to reduce the reliance on operator interpretation of signal information and to improve characterization of material damage. Assuming success, this system will permit more rapid and more reliable steam generator tube inspection.

*Funded from Instrumentation and Control Subprogram 425.

POOR ORIGINAL

548 033

Prime Contractor: Battelle Pacific Northwest Laboratories (G. J. Posakony/T. J. Davis)
Duration: January 1975 through December 1979
Total Project Cost: $730,000
EPRI Project Manager: H. G. Shugars

Reports: Summary progress report available December 1977.

RP448 - ACOUSTIC EMISSION AND ULTRASONIC CORRELATION EXAMINATION OF LASALLE II PRESSURE VESSEL

The objective of this project is to evaluate the sensitivity and reliability of acoustic emission techniques for detection and location of flaws in nuclear reactor pressure vessels. Acoustic emission data obtained from a full-scale nuclear reactor pressure hydrotest will be correlated with ultrasonic inspection data. Acoustic Emission Technology Corporation will conduct the acoustic emission monitoring on LaSalle II primary pressure vessel during its hydrostatic pressure test at Chicago Bridge and Iron Nuclear Facility, Memphis, Tennessee. Based upon the acoustic emission data obtained, twenty-four of the most significant areas were identified and mapped for ultrasonic evaluation according to ASME BPVC Section XI requirements. The ultrasonic evaluation was conducted by a General Electric Co. inspection team. The results showed acoustic emission to be a potentially valuable inspection tool when used in conjunction with conventional ultrasonics for the initial shop inspection of a reactor pressure vessel.

Prime Contractor: Acoustic Emission Technology Corporation (A. T. Green)
Duration: March 1975 - September 1976 (Completed)
Total Project Cost: $60,180
EPRI Project Manager: Karl Stahlkopf

Reports

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Final report in draft form - available fall 1978.

POOR ORIGINAL

548 032

RP604 - EVALUATION OF ULTRASONIC TOMOGRAPHY FOR THE MAPPING OF STRESS FIELDS IN THICK METAL SECTIONS*

Tomography is a process whereby three-dimensional structure of an object is determined from two-dimensional projections of penetrating radiation. The most successful application of tomography to date has been in brain scanning for medical diagnostics. In principle, tomographic reconstruction is not limited by type of energy used.

The initial objective of this project was to evaluate the feasibility of mapping stress profile in thick metal sections by use of tomographic reconstruction of the velocity distribution of transmitted ultrasonic energy. Laboratory proof-of-principle demonstrations have confirmed the ability to measure residual stress by the approach. Based on these results, the effort has been expanded to development and evaluation of a prototype instrument.

Prime Contractor: Battelle Pacific Northwest Laboratories (B. P. Hildebrand)
Duration: July 1976 through December 1979
Total Project Cost: $466,000
EPRI Project Manager: Karl Stahlkopf

Reports

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POOR ORIGINAL

*Funded by Pressure Boundary Subprogram 408.

548 040

RP505 - DEVELOPMENT OF DIGITAL MEMORY ACOUSTIC EMISSION ZONE MONITOR/RECORD FOR BWR PIPE CRACKING

Under Federal Highway Administration sponsorship, a small battery-operated acoustic emission sensor and recording system was developed for monitoring highway structures. This system utilizes a semiconductor EPROM digital memory as a recording element that can record acoustic emission data as a function of time over an extended interval. After recording, the memory can be removed and quickly read out into hard data format. The objective of this project is to develop an inexpensive on-line monitor using this concept plus a coincident detection scheme that will allow recording of acoustic emission data from a preselected spatial zone on reactor piping. Successful completion of this project will result in a device that is capable of detecting the existence of acoustic emission that might be present during cracking in specific locations during normal plant operation. The development of the instrumentation is now complete along with laboratory evaluation of its performance. The next step is a field evaluation consisting of mounting the instrument package on stress corrosion cracking test sections and then subsequently on an existing power plant to observe performance over an extended time.

Prime Contractor: Battelle Pacific Northwest Laboratories (P. H. Hutton)
Duration: July 1976 through December 1978
Total Project Cost: $267,000
EPRI Project Manager: Karl Stahlkopf

Reports

K. E. Stahlkopf, P. H. Hutton and E. L. Zebroski, "Detection of Stress Corrosion in Stainless Steel Piping by Acoustic Emission," Proceedings, 3rd International Conference, Periodic Inspection of Pressurized Components, The Institution of Mechanical Engineers, London, England, September 20-22, 1976.

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RP606 - EVALUATION OF DEFECT CHARACTERIZATION BY ULTRASONIC HOLOGRAPHY

Development of ultrasonic holography lends considerable hope that an ultrasonic imaging device will be available for use during preservice and inservice inspection of the primary pressure boundary. The objective of this project is to determine the ability of ultrasonic holography to accurately characterize defects (e.g., size, shape, orientation, location, and type) in thick section welds. In order to relate these results to current practice the defects will also be characterized by ultrasonic techniques given in ASME Boiler and Pressure Vessel Code, Section XI, radiography, and destructive examination. The following types of defects will be inspected; production vessel welds, experimental vessel welds, specially prepared samples and an existing set of special test blocks. Ultrasonic inspection will be performed by at least four independent inspection teams. Two European teams, one from the United Kingdom AEA Risley, and the other from Saclay, France, will employ advanced NDE flaw characterization methods, and two ISI teams from the United States will perform ultrasonic examinations per the ASME Code, Section XI. The ISI per ASME Code has been completed by one United States agency. Acoustical holographic data has been obtained on two HSST thermal shock test vessels at Oak Ridge National Labs. This effort was coordinated through NRC, EPRI, and B&W. These nonproduction type vessels were evaluated to monitor crack growth. Holographic images have been obtained to size the "crack initiator" prior to thermal shock and after thermal shock to determine crack growth."

Prime Contractor: Babcock & Wilcox Lynchburg Research Laboratory (A. E. Holt)
Duration: February 1976 through December 1979

Total Project Cost:	EPRI	$395,000
	Babcock & Wilcox	$305,000
	Total Project Cost	$700,000

EPRI Project Manager: Gary J. Dau

Reports

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Amos Holt, "Acoustical Holographic Characterization of Defects in Pressure Vessel Materials," Proceedings, Third International Conference, Pressure Vessel Technology, Part I Analysis, Design and Inspection, Tokyo, Japan, April 19-22, 1977.

RP606 - REAL TIME FLAW IMAGING DEVICE DEVELOPMENT

The objective of this project is to design, fabricate, and field evaluate an ultrasonic imaging system for use in real time imaging of flaws encountered during the periodic ultrasonic inspection of a nuclear pressure vessel.

The concept being pursued uses a linear array of transducers that is electronically scanned in one direction while being mechanically scanned in the second direction. The system is able to operate in both the pulse-echo and holographic modes. It is designed to perform all pulse-echo inspections to ASME Section XI code requirements. When an ultrasonic reflector is detected by pulse-echo techniques, a holographic imaging mode for characterization of the ultrasonic reflector is used.

Prime Contractors Battelle Pacific Northwest Laboratory (G. J. Posakony)
Holosonics, Inc. (V. I. Neeley)

Duration: January 1976 to December 1978

Total Project Cost: $1,540,000

EPRI Project Manager: Karl Stahlkopf

Reports

G. J. Posakony, "Near Real Time Ultrasonic - Pulse Echo Holographic Imaging System," Proceedings, ARPA AFML Review of Progress in Quantitative NDE, Asilomar, CA, August 31-Sept. 3, 1976.

Larry Becker, et al., "Ultrasonic Imaging with a Linear Ultrasonic Array," 11th Symposium on NDE, ASNT and Southwest Research Institute, San Antonio, TX, April 20, 1977 (available from authors as BN-SA-727).

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B. P. Hildebrand, "HNDT Update," Materials Evaluation, Vol. 35, No. 2, p. 40, May 1977.

* Available from EPRI Project Manager.

POOR ORIGINAL

548 044

RP607-1 - ASSESSMENT OF THICK SECTION RADIOGRAPHY

The use of X-radiography is widespread in the nuclear industry as a nondestructive testing technique. It is used extensively in the quality control of materials and components during fabrication and also--to a lesser extent--during in-service inspection.

For the nuclear industry, the ASME Pressure Vessel Code requires that final acceptance of a component be based on meeting established standards of a radiographic examination. The high degree of component reliability required, combined with the thick sections (often over 12" or more of steel) encountered, strains the capabilities of the X-radiographic inspection technique.

The objective of this project was to assess thick section radiography methods analytically using an integrated model of the system, i.e., source, geometry and imaging system. The goal was achieved by modeling the system with detailed transport codes previously developed for shielding calculations. To check the validity of the calculations, results were compared with results from representative experimental data from the literature, from user organizations, and from bench mark experiments.

The basic results are: (1) the imaging system shows the most potential for optimization of present techniques, (2) further work with collimators shows little promise, (3) optimum energy range is 8-15 MeV, (4) backscatter may be significant in some applications, and (5) Xeroradiography does not appear to be promising for high energy radiography. Unresolved areas that warrant future efforts are identified.

Prime Contractor: Science Applications, Inc. (V. J. Orphan, D. E. Rundquist)
Duration: Completed.
Total Project Cost: $99,000
EPRI Project Manager: Sary J. Dau

Reports

D. E. Rundquist and V. J. Orphan, "Assessment of Thick Section Radiography," Presentation at LINAC USERs Meeting, sponsored by Varian Corp., Asheville, NC, May 6, 1976.

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D. E. Rundquist, et al., "Assessment of Thick Section Radiography," EPRI NP-461, Electric Power Research Institute, Palo Alto, CA, June 1977.

RP607-2 - EVALUATION OF REAL-TIME RADIOGRAPHY

The use of X-radiography for inservice inspection is hampered by the availability of an appropriate X-ray source and the inconvenience of using X-ray film. Project RP522 is developing a source suitable for field use while the conclusions from RP607 indicate that imaging represents a fruitful area for improved radiography.

The objective of this project is to evaluate an advanced real-time radiography imaging system. The steps to achieve this objective include (1) assembly of an appropriate system consisting of a source, an available real-time imaging system and positioning device for 4-inch dia. pipe, (2) form images of a 4" pipe sample containing stress corrosion cracks supplied by EPRI with both film and the real-time system, (3) evaluate the effectiveness of the system compared to conventional techniques, and (4) prepare a report documenting the results. The results will be used to guide the direction of future research.

Prime Contractor: Science Applications, Inc. (V. J. Orphan)
Duration: Completed July 1978.
Total Project Cost: $26,000
EPRI Project Manager: Gary J. Dau

Reports: Final Report in preparation.

RP608 - EPRI - NATIONAL BUREAU OF STANDARDS COOPERATIVE PROGRAM ON ACOUSTIC EMISSION

Acoustic emission has great potential for detecting the onset of structural failure while underload and for monitoring structures and the growth of known cracks. The realization of this potential is limited by the lack of knowledge of how to relate a recorded acoustic emission event to origination source and significance to structural integrity.

POOR ORIGINAL

548 045

The objective of this project is to develop and demonstrate the theoretical bases, measurement techniques and calibration procedures required to evaluate the technical feasibility of using acoustic emission spectrum analysis for characterizing moving cracks or defects.

The completion of this work will provide the electric power industry with an acoustic emission transducer calibration capability referred to national standards, an evaluated spectral analysis method for retrieving acoustic emission source signals and for distinguishing between defect motion and spurious signals, and demonstrations of the feasibility of the spectral method for predicting defect motion in controlled experiments. These results will provide the technical basis for the industry to incur (or not to incur) the cost of flaw and defect monitoring systems based on acoustic emission.

Prime Contractor: National Bureau of Standards (Don Eitzen)

Duration: Four years beginning October 1975

Total Project Cost:	EPRI	$756,000
	NBS	$283,400
	Total Project Cost	$1,040,000

EPRI Project Manager: Gary J. Dau

Reports

R. B. Clough, "Acoustic Emission Spectral Measurements of Defect Motion," Conference on NDE in the Nuclear Industry, Denver, CO, December 1-3, 1975.

J. A. Simmons, Presentation of EPRI-NBS Acoustic Emission Work at the ASTM E-7 NDT-AEWG Meeting, Ft. Lauderdale, FL, January 19-23, 1976.

E. Fuller, "Acoustic Emission from Indentation Cracks," Am. Cer. Soc., Cincinnati, OH, May 5, 1976.

R. Clough and J. Simmons, "Theoretical Basis of Acoustic Emission Spectra," 23rd Sagamore Army Materials Research Conference, Raquette Lake, NY, August 1976.

J. Simmons and R. Clough, "Theoretical Aspects of AE Spectral Measurements," 8th World Conf. on NDE, Cannes, France, September 1976.

POOR ORIGINAL

J. Simmons, Informal Presentation on EPRI/NBS Program on AE Transducer Calibration, European Working Group on AE, September 1976.

J. Simmons and R. Clough, "Theoretical Elements of AE Spectra," ARPA/AFML/Rockwell Review of Progress in Quantitative NDE, Pacific Grove, CA, September 1976.

R. Clough and J. Simmons, "Developments in Acoustic Emission," presented at the Univ. of Arizona, Tuczon, AZ, September 1976.

J. Simmons and R. Clough, "Theoretical Aspects of AE Spectral Analysis of Moving Defects," presented at Acoustic Emission Working Group Meeting, Williamsburg, VA, October 20, 1976.

F. Breckenridge, Informal Presentation of "Progress on the Development of AE Transducer Calibration Capability at NBS," to the ASTM-ASME Joint Task Group on AE Sensitivity Calibration, Williamsburg, VA, October 1976.

D. Eitzen, "Overview of Ultrasonics Program at NBS," Presented to Long Island Chapter, ASNT, Bethpage, NY, November 4, 1976.

N. Hsu, "Theory and Experiments on Acoustic Emission Signals," Invited talk presented at the Dept. of Theoretical and Applied Mechanics, Cornell Universty, Ithaca, NY April 27, 1977.

N. Hsu, "Acoustic Emission Signal Analysis - Theory and Experiment," ARPA/AFML Review of Progress in Quantitative NDE, Ithaca, NY, June 14-17, 1977.

G. Birnbaum, "New Ultrasonic NDE Standards and Calibrations at NBS, (Same Conference as listed above).

RP609 - ACOUSTIC TECHNIQUES FOR MEASURING STRESSED REGIONS IN MATERIALS

The objective of this program is to develop ultrasonic techniques for imaging stressed regions in materials. A specific aim will be the development of the ability to image the plastic zone around a fatigue crack. This project will build on the existing electronically focused and scanned ultrasonic imaging technology at Stanford University. Initially the images of interest will be produced by forming phase contrast images. Later nonlinear attenuation characteristics will also be investigated for meeting the program objective.

POOR ORIGINAL

548 048

Acoustic velocity variations due to stress in aluminum and steel samples have been measured, using both a standard fixed MTS testing machine and a special stressing jig which can be placed directly in the water tanks, used with electonically and mechanically scanned acoustic imaging devices. The stress field in the plastic zone around a fatigue crack has been measured. Good theoretical agreement between the measured stress field and the theoretically calculated stress fields around a hole in a stressed metal sample have been obtained. The above measurements were made in a computer controlled mechanical ultrasonic scanning system. An electronically scanned system has been used to obtain a direct image of a stressed region for the first time.

Most of the measurements have been obtained by determining the change in velocity of a longitudinal acoustic wave. Initial measurements have also begun with shear waves. For these measurements, a theoretical solution for the stress fields around a hole or a crack have been calculated. These solutions are being extended to the region of plastic strain by using a nonlinear numerical analysis.

Prime Contractor: Stanford Univerty (G. S. Kino and H. J. Shaw).
Duration: October 1975 through June 1981
Total Project Cost: . $1,002,000
EPRI Project Manager: Gary J. Dau

Reports

G. S. Kino, W. Leung, H. J. Shaw, D. Winslow and L. Zitelli, "Differential Phase Contract Imaging with Electronically Focused Acoustic System, Proceedings, Acoustical Holography Conference, August 1976. In Press.

J. Souquet and G. S. Kino, "Calibrated Phase Measurement Techniques for Measurement of Stressed Regions," Proceedings, Ultrasonic Symposium, Annapolis, MD, September 1976.

W. Leung, H. J. Shaw, G. S. Kino, D., Winslow and L. Zitelli, "Acoustic Phase Contrast Imaging with Electronic Scanning." Proceedings, Ultrasonic Symposium, Annapolis, MD, September 1976.

J. Souquet and G. S. Kino, "Acoustic Phasse Measurements of Stressed Regions," J.A.P. Letters, 47, pp. 5462-5463, 1976.

POOR ORIGINAL

548 049

D. M. Barnett, et al., "Measurement of Stress Profile by Phase Contrast Techniques," presented at ARPA/AFML Review of Progress in Quantitative NDE, Cornell University, Ithaca, NY, June 13-16, 1977.

RP610 - NONDESTRUCTIVE INSPECTION OF REACTOR COMPONENTS USING COMPUTER AIDED X-RAY TOMOGRAPHY

Tomography is the word used to describe a process whereby three-dimensional structure of an object is determined from two-dimensional projections of penetrating radiation. The most successful application of tomograpy to date has been in medical radiograpny. The objective of this project is to evaluate the feasibility of using X-ray tomography for inspection of reactor components such as piping welds, valve bodies, and other components. An existing medical X-ray tomographic scanner will be used to image purposely defected regions in materials in shapes similar to those of interest in the nuclear industry. Although the energy and intensity of the X-ray beam of the medical unit was very low useful experimental data were obtained. This, coupled with the results of analytical work, indicate that the next step should be an assembly of a laboratory system to evaluate the technique on actual pipe samples. Technical specifications of such a unit were prepared and reported.

Prime Contractor: Stanford Research Institute (D. G. Falconer).
Duration: Completed May 1976
Total Project Cost: $38,200
EPRI Project Manager: Gary J. Dau

Reports

David G. Falconer, "Component Inspection with Computerized Tomography," Proceedings, Instrument Society of America, San Diego, CA, May 1976.

D. G. Falconer and D. C. Gates, "Reactor Component Inspection with Computrized Tomography," EPRI NP-213, Electric Power Research Institute, Palo Alto, CA, July 1976.

RP698 - EVALUATION OF ELECTROMAGNETIC-ACOUSTIC CONCEPTS FOR INSPECTION OF STEAM GENERATOR TUBING

Inspection of steam generator tubes is required for all pressurized water reactors. The specific inservice inspection requirements are governed by Section XI "Rules for Inservice Inspection of Nuclear Power Plant Components" of the ASME Boiler and Pressure Vessel Code. At the present time, these requirements are met with an eddy current inspection method. However, in some circumstances it would be desirable to have a complementary inspection method.

Recent progress in the development of noncontacting ultrasonic transducer technology shows promise for use as an alternate tube inspection method. Thus, the primary objective of this project was to evaluate the feasibility of the noncontacting electromagnetic-acoustic concept for generating ultrasonic waves to inspect steam generator tubing. A secondary objective was the evaluation of the concept for inspecting carbon steel boiler tubes like those used in fossil-fueled power plants.

The results from this project indicate that it is feasible to efficiently excite ultrasonic waves in Inconel and ferritic tubes with noncontacting electromagnetic transducers, and that these signals can be used to sense a wide variety of defects. Included in the demonstration was the development of a new probe which excites torsional modes in the tube wall and the formulation of design models to describe its performance.

The test samples consisted of aluminum, steel and Inconel tubing. The probes were capable of inspecting an Inconel U-bend of 1-3/4 inch radius and could pass through and detect defects in a "dented" region. These results indicate that future work is warranted towards the design of a prototype ultrasonic inspection system. This system should then be tested in a mock-up and in an actual steam generator.

An unanticipated spin-off from this work was the development of a periodic magnet structure transducer that has some unique features. Specifically, this transducer can generate horizontally polarized shear waves whose angle can be electronically controlled. With conventional methods, this mode can only be excited by fastening the transducer to the component, thus precluding a scanning type motion. Because this wave will not mode-convert at a parallel interface, such as a counterbore, this approach needs further exploration for other inspection uses such as pipe inspection. In addition, it may prove useful for material property measurement research.

POOR ORIGINAL

548 051

Prime Contractor: Rockwell Science Center (R. B. Thompson)
Duration: Completed
Total Project Cost: $75,000
EPRI Project Manager: Gary J. Dau

Reports

C. M. Fortunko, C. F. Vasile and R. B. Thompson, "Ultrasonic Inspection Systems Using Electromagnetic Noncontact Transducers," 1977 ASNT Spring Conference, Phoenix, AZ, March 28-30, 1977.

C. F. Vasile, "Steam Generator Tube Inspection with EMAT's," ARPA/AFML Review of Progress in Quantitative NDE, Ithaca, NY, June 14-17, 1977.

C. F. Vasile and R. B. Thompson, "Evaluation of Electromagnetic-Acoustic Concepts of Inspection of Steam Generator Tubing," EPRI NP-519, Electric Power Research Institute, Palo Alto, CA, August 1977.

RP702 - DEVELOPMENT OF ULTRASONIC INSTRUMENT TO MEASURE RESIDUAL STRESS

Depending on design conditions, the presence of residual stress can be either helpful or harmful. As an example of the latter condition, it is believed that the presence of residual stress contributes to the initiation of stress corrosion cracking in BWR power plants and possibly to some PWR tube and pipe cracks. At present there is no convenient method of making residual stress measurements in the field.

The objective of this project was to evaluate the use of ultrasonic surface waves to measure stress in stainless steel components. Preliminary results indicated that the change in elastic constant that influence surface wave velocity as a function of stress in 304 stainless steel were too small to be of use. The project was then terminated.

Prime Contractor: Sonitron, Inc. (R. B. Benson)
Duration: Completed
Total Project Cost: $6,000
EPRI Project Manager: Karl Stahlkopf

Reports: None

POOR ORIGINAL

548 052

RP700-1 Failure Analysis and Failure Prevention in Electric Power Systems

The objective of this project is to more accurately define the reliability of key components and subsystems in order to reduce the frequency and/or severity of malfunctions that result in outages or have potential safety significance. This project continues and expands upon work begun under RP217-1. These aims are being achieved by:

Failure Diagnostics:

Task I: extracts the detailed information and understanding from performance and failure experience necessary to select appropriate short-term (engineering) and long-term (research) action to improve reliability;

Methodology Development:

Tasks II-VI: provide the new or improved analytical and experimental tools which enable marked cost savings or improve reliability; and

Specific Engineering Applications:

Tasks VII-XI: use improved methodologies to eliminate or reduce the impact of both immediate and potential generic problems.

Contractor: Failure Analysis Associates
Duration: April 1, 1974 - February 28, 1979
Project Cost: $2,092,894
EPRI Project Manager: Floyd Gelhaus
Principal Investigator: C. A. Rau

Publications: "The Application of the Boundary-Integral Equation Method to the Solution of Engineering Stress Analysis and Fracture Mechanics Problems," Research Project 217-1, May 1975.

"Inspection Uncertainty: The Key Element in Nondestructive Inspection," Research Project 217-1, Technical Report 1, May 1975.

"The Influence Function Method for Fracture Mechanics and Residual Fatigue Life Analysis of Cracked Components Under Complex Stress Fields," Research Project 217-1, Technical Report 2, July 1975.

POOR ORIGINAL

548 053

"Probabilistic Fracture Mechanics," Research Project 217-1, Technical Report 4, July 1975.

"Failure Analysis and Failure Prevention in Electric Power Systems: First Annual Progress Report," Research Project 217-1, Interim Report 1, August 1975.

"Cost-Risk Optimization of Nondestructive Inspection Level," Research Project 217-1, Technical Report 5, September 1975.

"An Engineering Fracture Mechanics Analysis of the Pilgrim I Nozzle-to-Pressure Vessel Weld Discontinuities," Research Project 217-1, Technical Report 6, October 1975.

"The Application of Elastic-Plastic Fracture Mechanics Parameters in Fracture Safe Design," Research Project 217-1, Technical Report 7, November 1975.

"A Study of Crack Growth Under Operational Conditions in Steam Turbine Steel: Phase I Report," EPRI NP-325, Technical Report 9, July 1976.

"Determination of Nondestructive Inspection Reliability Using Field or Production Data," EPRI NP-315, Technical Report 8, October 1976.

"Comparison of Finite Element and Influence Function Methods for Three-Dimensional Elastic Analysis of Boiling Water Reactor Feedwater Nozzle Cracks," EPRI NP-261, November 1976.

"Failure Analysis and Failure Prevention in Electric Power Systems," EPRI NP-280 (Research Project 217-1), Final Report, November 1976.

"Fracture of Zircaloy Cladding by Interactions with Uranium Dioxide Pellets in LWR Fuel Rods," EPRI NP-330, Technical Report 10, November 1976.

"Improved Evaluation of Nozzle Corner Cracking," EPRI NP-339, Final Report, March 1977.

"Fracture and Fatigue Properties of 1 Cr-Mo-V Bainitic Turbine Rotor Steels," EPRI NP-325, August 1977.

POOR ORIGINAL

548 054

"Estimation of the Defect Detection Probability for Ultrasonic Tests on Thick Section Steel Weldments," (in review), September 1977.

"Decision Methodology for Improved Power Plant Reliability," (in review), November 1977.

"Eddy Current System for Measuring Tube Profiles," Status Report, FAA-78-1-2, January 1978.

"Determination of Fit-up Stresses in the Recirculation Bypass Line in the Brunswick 1 Reactor," (in review), February 1978.

"BIGIF Fracture Mechanics Code for Structures," NP-838, July 1978.

"Retirement-for-Cause: A Workable Approach for Structural Life Extension and Response to In-Service Problems," NP-855, August 1978.

RP770 - DEVELOPMENT OF ADAPTIVE LEARNING NETWORK FOR PIPE INSPECTION

The ultrasonic inspection techniques used to inspect nuclear reactor piping to meet ASME code have severe limitations. Signal discrimination between different sources of acoustic energy reflection is based on signal amplitude only. During field assembly about 1000 geometrical reflectors are created for each defect that is ultimately found in service. Each reflector must be evaluated to insure it is not of safety significance. The results of an earlier Air Force contract showed that use of the nonlinear Adaptive Learning Network (ALN) enabled fatigue cracks ranging in size from 0.011" to 0.3" to be detected and sized. With conventional inspection techniques, only detection of flaws greater than 0.05" is possible and no reliable sizing capability exists. Other significant factors about this approach are that the ability to discriminate between signals is not primarily dependent on signal amplitude; it reduces inspection sensitivity to transducer anomalies and it is more tolerant of operator differences.

The objective of this project is to demonstrate that the ALN approach can discriminate flaw signals from geometrical reflectors in stainless steel pipe welds. Initial results show that this signal processing approach can discriminate between a fatigue crack, side-drilled hole, counterbore, weld bead and grain scattering in 304 stainless steel. The final results demonstrated that this approach can identify unambiguously crack signals in the presence of geometrical reflectors in stainless steel pipe welds. Follow-on work is underway in RP1126.

Prime Contractor: Adaptronics, Inc. (A. N. Mucciardi)
Subcontractor: Babcock & Wilcox - Lynchburg Research Center (W. E. Lawrie)
Duration: Completed
Total Project Cost: $250,000
EPRI Project Manager: Gary J. Dau

<u>Reports</u>

A. N. Mucciardi, "Discrimination Between Signal Sources in Austenitic Materials by the Adaptive Learning Network Approach," presented to EPRI Pressure Vessel Study Group, Palo Alto, CA, February 16-17, 1977.

A. N. Mucciardi, J. K. Chang and W. E. Lawrie, "Development of Adaptive Learning Networks for Pipe Inspection - Task 1: Defect Versus Geometrical Reflector Discrimination in 304 Stainless Steel," Adaptronics, Inc., Interim Report to EPRI under contract RP770, October 1976.

Ramesh Shankar, Murray H. Loew and Anthony N. Mucciardi, "Quantitative NDE Procedures for Measurement of Fatigue Cracks and Defects in Adhesive Bond Lines and Stainless Steel Weldments," 1977 ASNT Spring Conference, Phoenix, AZ, March 28-30, 1977.

R. Shankar, A. N. Mucciardi, W. E. Lawrie and R. N. Stein, "Development of Adaptive Learning Networks for Pipe Inspection," EPRI NP-688, Electric Power Research Institute, Palo Alto, CA, January 1978.

RP822 - DEVELOPMENT OF A PORTABLE RADIOGRAPHIC SYSTEM FOR IN-SERVICE AND REPAIR INSPECTION

Use of conventional ultrasonic inspection techniques has definite limitations when attempting to inspect certain components such as cast stainless steel pump and valve bodies and centrifugally cast stainless steel piping. Thus, it is highly desirable to have another inspection technique to provide additional information to resolve difficult judgments to insure meeting the intent of the ASME Section XI Code. Radiography is a prime candidate provided that an efficient portable X-ray source can be produced. The essential components to produce such a device seem to be available but have never been integrated into a system.

The objective of this project is the development and demonstration of a portable X-ray source. The specific steps to meet this goal include establishing feasibility, assess optimum application for inservice inspection, and adaptation of necessary component technology for fabrication of prototype system. After feasibility was shown a parallel real-time imaging task was added to the work scope.

Contractor: Southwest Research Institute (Sam Wenk)
Schonberg Radiation (Russ Schonberg)
Neal J. Norris
Philadelphia Electric Co. (R. Zong)
Duration: July 1976 through December 1979
Total Project Cost: $1,105,000
EPRI Project Manager: N. E. Lapides

Reports: None

POOR ORIGINAL

548 057

RP823 - DEVELOPMENT OF X-RAY DEVICE FOR STRESS MEASUREMENT

Depending on design conditions, the presence of residual stress can be either helpful or detrimental. An example of the latter condition is the residual stress that contributes to the initiation of stress corrosion cracking found in some BWR power plants. No convenient technique for measurement of residual stress is available. The available methods all have severe limitations that preclude their use to make the many measurements useful to characterize stress state during fabrication, assembly, and failure analysis.

Recent work under U.S. Army sponsorship has developed an X-ray stress measurement technique for aluminum that is both fast and portable. This significant achievement resulted from combining X-ray diffraction technology with recent advanced in electro-optic techniques for X-ray detection. The result can transform the standard, accepted X-ray stress measurement technique from a laboratory tool requiring extensive sample preparation and time-consuming measurements to a convenient field measurement.

The objective of this project is to develop, demonstrate, and evaluate a compact, rapid and portable X-ray stress measurement device for austenitic materials. The initial is a laboratory proof-of-principle demonstration of a device that will measure stress on the inside diameter of a 10-inch pipe has been successfully completed. A follow-on effort to develop a unit to operate inside 4-inch pipe is underway.

The approach is to build a stress measuring X-ray head of suitable size and shape to be manipulable inside of the pipe so as to measure hoop and longitudinal stresses. Available laboratory high voltage power supplies, computers and auxiliary equipment were used whenever possible to accomplish the proof-of-principle with minimum delay and cost. Now a complete transportable prototype is being developed. Included is the procurement of a specially designed X-ray tube necessary to make measurements inside a 4-inch pipe.

Prime Contractor: Denver Research Institute (Fred Vendetti and Clay Ruud)
Duration: July 1976 through December 1978
Total Project Cost: $407,000
EPRI Project Manager: Gary J. Dau

Reports: Phase I Interim Report in press.

POOR ORIGINAL

548 058

RP892 - ULTRASONIC OPTIMIZATION

The objective of this project is to provide significant near-term improvement for ISI of pressure retaining components. The approach being followed is to optimize the technology currently being used for nozzle, pipe, and bi- and tri-metallic joint inspection. Included are optimization of procedures, transducers, instruments, recording and data display. The total effort has been split into three interrelated projects. The first project will concentrate on developing the ultrasonic inspection system technology. This effort is the responsibility of Southwest Research Institute. General Electric Company is responsible for the second project. It concentrates on development of suitable test mock-ups to duplicate the natural flaws of concern in a BWR. The final project is charged with defining the present system performance, indicating the nature and level of improvements required and in independently evaluating and disseminating the technology developed in the first project. Battelle Columbus is conducting this effort. A separate but related effort is underway to establish the important parameters influencing bi- and tri-metallic weld inspection. This effort is being conducted by Nuclear Energy Services.

Prime Contractors: Southwest Research Institute (Amos Greer)
General Electric Company (Jack Clark)
Battelle Columbus (Matt Golis)
Nuclear Energy Services (Laird Johnson)

Duration: May 1977 to December 1980

Total Project Cost: $2,485,000

EPRI Project Manager: M. E. Lapides

Reports:

J. L. Rose and G. P. Singh, "Ultrasonic Pattern Recognition Study of IGSCC in SS Piping," EPRI NP-891, Electric Power Research Institute, Palo Alto, CA, September 1978.

E. R. Reinhart, "EPRI Program to Improve Nuclear Code Inspection Methods," Materials Evaluation, May 1978, Vo. 36, No. 6, pp. 36-42.

POOR ORIGINAL

548 059

RP1125 - APPLICATION OF NONLINEAR SIGNAL PROCESSING TO PIPE AND NOZZLE INSPECTION

The ultrasonic techniques used to inspect nuclear reactor piping to meet the ASME codes have severe limitations. Signal discrimination between different sources of acoustic energy reflection is based on signal amplitude only. During field assembly many geometrical conditions are created that reflect acoustic energy in a manner similar to flaws. These geometrical reflectors occur about 1000 times as often as flaws and frequently produce signals greater than real flaws. Each reflector must be evaluated for significance. Thus, considerable time is required to evaluate signals that have no safety significance. In addition, this "noise" level acts to decrease flaw detection ability both due to instrument characteristics and human factors.

Under sponsorship of EPRI (RP770), it has been shown in a laboratory proof-of-principle demonstration that ultrasonic signal sources can be distinguished by use of an Adaptive Learning Network concept. The results have demonstrated that the Adaptive Learning Network can distinguish between different sources of ultrasonic signals such as geometrical reflectors (counterbore), fatigue cracks, weld beads, side-drilled holes used in instrument calibration, as well cracks found in stainless steel pipe welds. The network can be implemented with modern semiconductor technology to provide real-time signal analysis capability using signals generated from conventional ultrasonic equipment.

Proceeding from the successful proof-of-principle results achieved to the design, fabrication and evaluation of a fieldable device for specific applications will greatly enhance current inspection technology. Implementation of this capability in ISI practice will enable the required inspections to be performed more efficiently, with much greater repeatability than is now possible, and with more definitive results, thus reducing or eliminating the potential of costly outage time spent in making defect severity judgments.

The objective of this project is to design, fabricate and field evaluate an Adaptive Learning Network signal processing system for use on austenitic pipe joints and nozzle inspections.

Based on the positive results of TPS 77-723, this contract has been expanded to include development and evaluation of ALN hardware for automatic interpretation of eddy current signals.

POOR ORIGINAL

548 060

Contractor: Adaptronics, Inc. (A. N. Mucciardi)

Subcontractors: The Babcock & Wilcox Co.
Southwest Research Institute

Duration: August 1977 through December 1979

Project Cost: $2,156,000

EPRI Project Manager: Gary J. Dau

Reports: None

TPS 75-609 - AUSTENITIC PIPE INSPECTION ROUND ROBIN

The replacement of cracked bypass and core spray lines in several BWRs in 1975 provided an unusual opportunity to evaluate ultrasonic inspection capability on samples with natural flaws. In addition, the flawed pipe sections are radioactive enough so that inspections must be carried out under field conditions with regard to radiation work procedure.

The objectives of this program were to evaluate current practice for inservice inspection of austenitic pipe welds, establish a baseline for determination of future research and provide information for establishing flaw detection capability. The objectives were met by having five ISI teams inspect "unknown" pipe samples under conditions specified by EPRI. The EPRI project manager analyzed and reported all data once it was collected.

Prime Contractors: Southwest Research Institute
General Electric Co.
Nuclear Services Corp.
Conam
Peabody Testing

Duration: Completed

Project Cost:	EPRI	$100,000
	GE	30,000
	Total	$130,000

EPRI Project Manager: Eugene Reinhart

Reports

E. R. Reinhart, "Study Evaluates Industry Inspection Practice," EPRI Journal, No. 6, April 1976.

POOR ORIGINAL
548 061

E. R. Reinhart, "Evaluating the Performance of In-Service Inspectors," EPRI Journal, No. 6, August 1977.

E. R. Reinhart, "A Study of In-Service Inspection Practice for BWR Piping Welds, "EPRI NP-436, Electric Power Research Institute Report, Palo Alto, CA, June 1977.

TPS 77-709 - EDDY CURRENT TESTING ROUND ROBIN

PWR operational availability has been affected by the recent discovery of deformation and cracking in steam generator tubing in several operating pressurized water reactors (PWRs). The more severe deformation is known as denting and occurs in the area of the tube support plates. The present code-sensitivity for detection of circumferential cracks, slow flaw growth, pitting corrosion, fatigue cracks and detection of any of these conditions in the region near a tube support plate. This study was initiated with two objectives. The first is to evaluate the capability and limitations of current practice for steam generator tube inspection. The second objective is evaluating the potential improvement and time to implementation of advanced approaches now under development. The approach used consisted of a six member team of experts that defined the test matrix, including samples, and witnessed the actual inspection. This group then reviewed the results of this test supplied by the inspection group. All findings will be documented into a report. The NDE system vendors or development groups selected for this evaluation are:

1. Zetec, Inc. - Conventional code accepted system with advanced probe designs.
2. Holosonics/Intercontrole - Multifrequency system used in Europe SG inspections.
3. Failure Analysis Associates - Specialized probe designs used with conventional and/or advanced systems.
4. Battelle-Northwest Laboratories - Multifrequency system developed under EPRI funding, RP403-1.

Contractors: Zetec
Failure Analysis Associates
Holosonics/Intercontrole

Duration: April 1977 through September 1977

Project Cost: $60,000

EPRI Project Manager: E. R. Reinhart

POOR ORIGINAL

Reports

S. D. Brown and E. R. Reinhart, "An Evaluation of Eddy Current Inspection Methods for PWR Steam Generator Tubing," EPRI NP-636, Electric Power Research Institute, Palo Alto, CA, Oc ber 1978.

RP1172 - EVALUATION, QUANTIFICATION, AND QUALIFICATION OF STEAM GENERATOR NDE TECHNOLOGY

The overall objectives of this project are (1) the development of methods and procedures to produce defects that realistically simulate operationally induced defects, (2) the development of an air-transportable module that contains a number of defective tubes chosen for their usefulness for technology assessment, and (3) the assessment of current system capability by the "round robin" technique when warranted.

In order to maintain maximum flexibility all efforts are closely correlated with the fixed site-mock-up discussed in SGPO-S126.

Where warranted, efforts will be exerted to acquire or reproduce eddy current signals useful for evaluation of defects.

Prime Contractor: Battelle Columbus (S. D. Brown)
Duration: May 1978 through June 1979
Total Project Costs: $200,000
EPRI Project Manager: Gary J. Dau

RP1245 - REACTOR PRESSURE VESSEL INSPECTION STANDARD DEVELOPMENT

The objective of this project is to prepare a PWR vessel shell course, twenty feet in diameter, eleven feet high, and twelve inches thick as a full-sized test bed for performance evaluation of inservice inspection tools. A full-sized test bed to develop flaw detection and sizing information will make it possible to quantify the relative performance of various inspection tools, and to optimize search and interpretation techniques. An accurate comparison of true field performance of inspection equipment and procedures will aid utilities in specifying instruments and procedures to be used in reactor inspection and provide objective assurance of performance levels for regulatory agencies. Such facilities will help develop improved devices and procedures which are optimized to full-scale reactor components rather than to idealized laboratory test blocks, which have an uncertain degree of correspondence to actual flaws.

Two PWR nozzles have been acquired, a shell course is being acquired, and a project (RP1245-2) is underway. The goal of the project is to develop a technology that will permit preprogrammed flaws to be welded into a full-size pressure vessel shell course. An example is to develop welding procedures that will permit insertion of a fatigue crack of a predetermined size and orientation into any area of interest.

Prime Contractor: Westinghouse (F. J. F. Enrietto)
Duration: September 1978 through November 1979
Total Project Cost: $160,000
EPRI Project Manager: Dr. Karl Stahlkopf

RP1395 - IN-SERVICE INSPECTION DATA ANALYSIS

EPRI projects RP770, RP1125, and TPS 77-723 demonstrated that considerably more quantitative information can be gained from ISI signal processing via an adaptive learning network (ALN) than is normally obtained from conventional approaches. As now understood, the implementation of the ALN concept requires the development of a specific processing network for each application. The objective of this program is the development of techniques to condition ultrasonic and eddy current signals so these signals can be handled in a generic signal processing module. Satisfactory achievement of this goal will enable the use of the hardware now under development for specific applications (RP1125) to be used for many other ISI uses.

Three projects are being implemented. The first will develop finite-element analysis techniques to predict the eddy current interaction with the inspected component and typical flaws (RP1395-2). The second effort is devoted to additional development of eddy current testing theory. The approach consists of evaluation of an integral equation of certain combinations of electromagnetic field quantities over a volume or surface determined by probe-flaw geometry. Experimental confirmation will be conducted (RP1395-3). The third effort consists of the use of random or pseudo-random signals and time integration to enhance signal-to-noise ratio and to develop specific algorithms to deal with austenitic grain noise (RP1395-4). Mr. Hugo L. Libby has been retained as a consultant to provide guidance on the eddy current work.

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548 064

Prime Contractors: Hugo L. Libby (RP1395-1)

Colorado State University - RP1395-2 (W. Lord)

Stanford University - RP1395-3 (B. Auld)

Purdue University - RP1395 (V. Newhouse)

Project Duration: 2 years beginning October 1978

Total Project Cost: $500,000

EPRI Project Manager: Gary J. Dau

TPS 77-723 - FEASIBILITY OF USING ADAPTIVE LEARNING NETWORK CONCEPT FOR EDDY CURRENT SIGNAL ANALYSIS

Present practice for interpreting signals received in an eddy current inspection of steam generator tubes is heavily dependent on the skill and experience of the inspector. As steadily increasing emphasis is being placed on determining steam generator tube integrity, it is mandatory that additional data be extracted from the signals, the data must be interpreted more rapidly and the analysis made less operator dependent. The results from another EPRI project (RP770) dealing with ultrasonic signal analysis indicated that Adaptive Learning Network (ALN) approach has potential to extract more information from a signal than is now possible at a greater speed and points toward complete automation of the signal analysis of eddy current data. The objective of this planning study is to determine the feasibility of applying the Adaptive Learning Network to eddy current signal analysis. The results show that with the use of ALN it is possible to unambiguously discriminate between simulated pit and crack signals both with and without the presence of support plates. Furthermore, the ability to size the spits to ± 2.4% and cracks to ± 3.6% with conventional 400 kHz data was demonstrated.

Contractors: Adaptronics, Inc. (A. N. Mucciardi)

Battelle Northwest (J. J. Posakony)

Duration: June 1 to October 1, 1977: Completed

Total Project Cost: $32,500

EPRI Project Manager: Gary J. Dau

Reports:

R. Shankar, et al., "Feasibility of Using Adaptive Learning Networks for Eddy Current Signal Analysis," EPRI NP-723, Electric Power Research Institute, Palo Alto, CA, March 1978.

548 065

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G. J. Dau, "Enhancement of Steam Generator Inspection Results," EPRI Journal, Vol. 3, No. 5, p.-42, June 1978.

SGPO-S101 - DEVELOPMENT AND EVALUATION OF A PROTOTYPE EMAT SYSTEM FOR STEAM GENERATOR INSPECTION

In project RP698, the feasibility of using the electro-magnetic-acoustic transducer (EMAT) to inspect steam generator tubes was demonstrated. The objective of this project is to design, fabricate, and evaluate a prototype system using the EMAT approach. The initial phase will end with an evaluation of the system on a steam generator mock-up system. A second phase is contemplated where the system may be upgraded (if needed), automatic signal analysis explored, and the system used on an actual steam generator.

Prime Contractor: Rockwell Science Center (R. B. Thompson)
Duration: May 1978 through April 1979
Total Project Cost: $229,000 (Phase 1 only)
EPRI Project Manager: John Mundis

Reports: None

SGPO-S102 - CREVICE GAP MEASUREMENT BY TUBE VIBRATIONAL ANALYSIS

Measurement of the crevice gap region between a steam generator tube and the support plate has been identified as a priority need for assessing the condition of a steam generator. The objective of this effort is to determine the feasibility of measuring this space by monitoring the displacement of the tube when stimulated into vibratory motion. This will be done initially in a laboratory environment where analytically-predicted vibration modes will be confirmed experimentally. The results of this effort will be used to guide future work. The work was successfully completed and a follow-on effort is being developed.

Prime Contractor: Applied Nucleonics Co. (Terry Scharton)
Duration: November 1977 to March 1978 - Completed
Total Project Cost: $40,000
EPRI Project Manager: John Mundis

Reports: Final report in preparation

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SGPO-S103 - SOLID STATE OPTICAL SCANNER

Visual inspection of the inside of a steam generator tube is a useful means of detecting and quantifying the extent of defects during inservice inspection. This method would also provide useful complementary results for other inspection methods such as eddy current testing. Two approaches are now available but each has limitations. The first is fiber optic borescope but is limited to the length of the tube that can be inspected. The second is use of a miniature TV camera (Vidicon). There is concern about the long-term reliability and resolution of the latter approach. A third possibility exists that has potential for a signif[illegible]t performance improvement. In this approach a probe contains a small light that illuminates the tube wall. By use of a conical mirror the reflect light is directed toward a lens where it is focused on a circular array of light sensitive diodes. As the probe is moved the diode arrays will form an image of the tube surface on a TV monitor.

The objective of this effort is to assemble a solid state optical scanner and experimentally evaluate its performance. The results will be compared with the video approach and priorities for future work established.

Prime Contractor: Science Applications, Inc. (V. J. Orphan)
Duration: November 1977 to May 1978 - Completed
Total Project Cost: $40,000
EPRI Project Manager: John Mundis

Reports: Final report in preparation

SGPO-S105 - RADIOGRAPHY FOR TUBE SUPPORT INTEGRITY

In prior work, hardware and procedures were developed for radiographic inspection of steam generator tubes. The objective of this project is to use this information to develop a radiographic approach for verifying tube support plate integrity. Once feasibility is demonstrated, effort will be devoted to increasing the inspection rate for field applications.

Prime Contractor: Combustion Engineering (R. Stone)
Duration: 18 months beginning March 1978
Total Project Cost: $181,000 (Significant cost sharing)
EPRI Project Manager: John Mundis

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Reports: None

SGPO-S107 - FEASIBILITY OF ULTRASONIC MEASUREMENT OF CREVICE GAP

The measurement of the crevice gap clearance is an important parameter needed to give early warning of the onset of the corrosion process that leads to denting. Ultrasonic thickness measurement concepts are a valid approach but their usefulness may be limited by slowness of movement. The objective of this effort is to confirm feasibility of this measurement approach and estimate the time needed per measurement. This information will then be used to determine what additional work is warranted.

Prime Contractor: Combustion Engineering (R. Stone)
Duration: 23 months beginning April 1978
Total Project Cost: $92,000
EPRI Project Manager: John Mundis

Reports: None

SGPO-S108 - MECHANICAL MEASUREMENT OF TUBE ID/REPLICATION OF DEFECTS IN SITU

The objective of this effort is to determine the ID contour of a dented tube region. Two approaches are considered. The first consists of using strain gages to monitor the deformation of a "feeler gage" in order to measure changes in diamter. The second method uses a replicating compound to form a solid contour of the area of concern. Feasibility of both techniques has been shown in laboratory settings. Additional effort is needed to develop the technique for remote application. Thus, the objective of this effort is to perform the development needed for field application. Once this is done each approach will be evaluated in simulated field conditions prior to field application.

Prime Contractor: Combustion Engineering (Windsor Locks)
Duration: 19 months beginning May 1978
Total Project Cost: $43,000
EPRI Project Manager: John Mundis

Reports: None

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SGPO-S125 - MAGNETIC FLUX LEAKAGE FOR MEASUREMENT OF CREVICE GAP CLEARANCE AND TUBE SUPPORT PLATE INSPECTION

Magnetic methods of nondestructive inspection have been used intensively in many industries. The underlying principle relies on the interaction of an applied magnetic field with material innohogeneities to produce a leakage field which can be detected by a test probe. The objective of this project is to determine the feasibility of magnetic methods for measuring and detecting changes in the crevice gap clearance region and detecting defects in the tube support plate.

Finite-element analysis techniques will be used to model the flux distribution to provide theoretical confirmation of experimental results and as an aid to probe design.

Prime Contractor: Colorado State University (Prof. W. Lord)
Duration: March 1978 through April 1979
Total Project Cost: $88,000
EPRI Project Manager: Gary W. De Young

Reports: None

SGPO-S126 - EVALUATION OF NONDESTRUCTIVE EXAMINATION METHODS USING A FIXED SITE STEAM GENERATOR MOCK-UP

The intent of this project is to construct and operate a steam generator mock-up to be used by EPRI to afford statistically conclusive evaluation of systems designed to inspect steam generators from inside the tubes. Secondary purposes of the mock-up will be to provide a platform for NDE training and interim evaluation of NDE systems.

A fixed site steam generator mock-up is being constructed based on current operational designs of the three PWR NSSS vendors. To the extent practicable, flexibility to allow inclusion of new designs into the mock-up will be provided. When completed the mock-up will be used for testing and evaluation of NDE systems and components. Evaluation procedures also being developed within this project.

Prime Contractor: Battelle Columbus (Stephen D. Brown)
Duration: April 1978 through June 1979
Total Project Cost: $246,000
EPRI Project Manager: Gary W. De Young

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Appendix B

SUMMARY OF MAJOR US NDE EFFORTS

INTRODUCTION

At the request of the Nuclear Systems and Materials Task Force NDE Subcommittee, a summary of the major US NDE activities was prepared. Considerable interest was shown when the material was presented on December 1, 1977; thus, it was included here for the benefit of the larger utility audience.

For the most part the data were accumulated by a series of phone calls and face-to-face discussions. The major emphasis was placed on government agencies that fund substantial amounts of work. The decision to include different programs was based on annual budget rather than significance. No effort was made to define the annual expenditure by private enterprise. The confidence in the budget figures is different for each agency and can be expected to change as budget changes occur.

ELECTRIC POWER RESEARCH INSTITUTE

EPRI is pursuing an aggressive three-pronged NDE effort. The three thrusts are: (1) optimization of code-approved techniques, (2) development of new innovative inspection methods, and (3) measurement of materials properties. A summary description of each project either underway or completed is contained as Appendix A in this report.

	1977	1978	1979
Budget (EPRI base) ($1,000)	2,600*	4,000*	4,500
Steam Generator Users Group	-0-	1,000	1,000
TOTAL	3,100	5,000	5,500

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*Excludes FAA's non-NDE effort.

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Table 8-1

MAJOR U.S. NDE FUNDING ($1,000)

ORGANIZATION	1976 (+T.Q)(2)	1977	1978	1979	COGNIZANT PERSON
EPRI(1)		2,800	4,000		Gary J. Dau
Department of Energy (ERDA)	3,600	3,200			Robert Reeber, (Geothermal) Ken Horton (Reactors), Don Erb Louis Ianniello (Research)
Department of Defense					
DARPA		1,000	1,400	2,100	Mike Buckley
Air Force		2,950	4,000	3,950	Don Forney
Army (estimate)		3,750	4,400		?
Navy (estimate)		1,900	2,300		?
Nuclear Regulatory Commission (NRC)		1,750	1,700		Joe Muscara, V. Goel
National Bureau of Standards (NBS)		700	1,000		Harry Berger
Aerospace IRAD (Best Guess)		1,000 to 2,000	2,000 to 4,000		
		$20,000	$25,000		

+Includes base program plus Steam Generator Project, excludes FAA's non-NDE efforts.

(2)T.Q. = Transition Quarter used when federal government changed fiscal years.

DEPARTMENT OF ENERGY (ERDA)

Essentially all NDE work supported by the Department of Energy is applications oriented with the principal thrust to solve specific NDE problems. Work underway is focussed on NDE of:

- Ceramics turbine materials
- Coal conversion equipment
- Austenitic pipe for FFTF/LFMBR (21%)
- Drill pipe for geothermal exploration
- Fatigue Monitoring
- Weapons Components (61% of total budget)

	FY 76+T.Q.	FY77	
Budget	3,600	4,200	($1,000)

DEPARTMENT OF DEFENSE

The Department of Defense (DOD) funds NDE work through many of its divisions and is the largest supporter of NDE R&D in the U.S. There is limited coordination of the overall effort making it difficult to obtain a precise overview of their activities. The estimates given below progress from highest level of confidence downward in terms of overall program definition and annual funding.

Advanced Research Projects Agency (DARPA)

DARPA is charged with initiating advanced research in a variety of areas including new materials and processes. Currently, a growing budget for NDE is included in this area. The major emphasis has been on ultrasonic inspection concepts with a goal to provide through research an improved basic technology that will enable ultrasonic inspections to be more quantitative, permit establishment of more precise flaw accept/reject criteria, and relate NDE measurements to fracture parameters of particular use to DOD organizations.

They depend on other DOD agencies to apply the results of their research. To help foster technology transfer, their projects are usually managed by one of the potential DOD users.

(Fiscal Year)	1977	1978	1979
Budget ($1,000)	1,000	1,400	2,100

U.S. Air Force

The Air Force NDE effort is more concisely defined than that of the other services. There are two major funding organizations; Air Force Materials Laboratory (AFML) located at Wright-Patterson Air Force Base and the Air Force Office of Scientific Research (AFOSR) located in Arlington, VA. In addition to funding outside R&D, AFML also serves as the focal point for Air Force NDE efforts. Both groups are closely integrated with the DARPA effort.

Air Force Materials Laboratory. The work funded by this organization covers basic research, exploratory development, and applications to manufacturing technology. The majority of the funding is in the latter category. The following technical efforts are underway:

- Ultrasonic transducer development
- Ultrasonic signal acquisition
- Ultrasonic signal processing
- Measurement of adhesive bond strength
- NDE of composite materials
- NDE of Ceramics
- Flaw characterization
- Turbine disk inspection
- NDE of fastened joints
- Field NDE reliability improvement
  - --ultrasonics
  - --liquid penetrants
  - --define sensitivity/capability
- Inspection of complex shapes

(Fiscal year)	1977	1978	1979
Budget ($1,000)	2,460	3,460	3,350

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548 073

Air Force Office of Scientific Research. The charter of this organization is to fund basic research for the Air Force. As a consequence, the NDE projects are oriented toward development of new concepts. The major emphasis is on signal acquisition including transducers.

(Fiscal year)	1977	1978	1979
Budget ($1,000)	500	550	600

U.S. Army

A comprehensive description of the total Army NDE effort does not exist today. However, a major task force is underway to develop such an overview. Results are expected in the Spring, 1978. From a variety of sources, it appears that a large fraction of their effort is directed toward application of NDE technology to manufacturing quality control of munitions.

(Fiscal year)	1977	1978
Budget estimate ($1,000)	3,750	4,400

U.S. Navy

Again, a comprehensive description of the total NAVY NDE effort does not seem to exist. From what information is available, it seems that significant effort is devoted to NDE of the nonnuclear portion of submarines and aircraft. The overriding goal seems to be increased availability of ships and planes.

(Fiscal year)	1977	1978
Budget estimate ($1,000)	1,900	2,300

U.S. NUCLEAR REGULATORY COMMISSION (NRC)

The majority of the NRC NDE effort is in the nature of confirmatory research funded by the Reactor Safety Research Division. Work underway covers:

- Ultrasonic characterization of flaws
- Acoustic emission structural monitoring
- Acoustic emission weld monitoring
- Incipient failure detection via internal damping

548 074

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In addition to the above, some effort is also supported by the Division of Engineering Standards. The major emphasis is oriented toward gaining information needed for inspection standards development.

(Fiscal year)	1977	1978
Budget ($1,000)	1,750	1,700

NATIONAL BUREAU OF STANDARDS (NBS)

In recognition of the growing importance of NDE, the National Bureau of Standards has a growing NDE effort. They are active in the areas of neutron radiography, ultrasonics, ultrasonic standards, and acoustic emission. There is some indication that they will also include eddy current and residual stress work in future years. NBS is also assuming a new role by performing contract research for others.

(Fiscal year)	1977	1978
Budget ($1,000)	1,750	1,700

AEROSPACE INTERNAL RESEARCH & DEVELOPMENT (IRAD)

This category is included to cover the amount of research accomplished by major DOD contractors funded as an allowable overhead cost. Today it is impossible to even try to estimate the range of technical activities while the budget estimate is only a best guess.

(Fiscal year)	1977	1978
Best Guess Budget ($1,000)	1,000 to 2,000	2,000 to 4,000

DEPARTMENT OF TRANSPORTATION

The Department of Transportation appears to have a growing NDE program. The major effort is in the Federal Highway Administration where a major goal is inspection of bridges. Work is also underway in the Federal Railway Administration and possibly other divisions. At this time no comprehensive description is available nor annual budget estimates.

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Finally, EPRI has developed and is maintaining a considerably number of contacts with foreign NDE programs. These discussions result from three factors. The first is the formal information exchange agreements that have been negotiated with many nations. The second is foreign representation on standing advisory groups such as the Pressure Vessel Study Group. The third factor is personal contacts established over a number of years by EPRI staff. The list of countries includes England, France, Germany, Italy, Japan, and The Netherlands. It is expected that in the future enough information will be available to prepare a similar summary for foreign efforts.

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