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ON AGING

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PUBLIC MEETING

Nuclear Regulatory Commission
One White Flint North
Rockville, Maryland

Monday, August 30, 1993

The Commission met in open session, pursuant to notice, at 2:00 p.m., Ivan Selin, Chairman, presiding.

COMMISSIONERS PRESENT:

IVAN SELIN, Chairman of the Commission
KENNETH C. ROGERS, Commissioner
FORREST J. REMICK, Commissioner
E. GAIL de PLANQUE, Commissioner

STAFF SEATED AT THE COMMISSION TABLE:

SAMUEL J. CHILK, Secretary

JOE SCINTO, Office of the General Counsel

JAMES SNIEZEK, Deputy ED for NRR, Regions & RES

ERIC BECKJORD, Director, Office of Research

THOMAS MURLEY, Director, NRR

WILLIAM RUSSELL

LAWRENCE SHAO, Director, Division of Engineering, RES

JOHN CRAIG, Deputy Director, Division of Engineering, RES

P-R-O-C-E-E-D-I-N-G-S

2:00 p.m.

CHAIRMAN SELIN: Good afternoon, ladies and gentlemen.

We're pleased to welcome members of the staff to brief the Commission on the NRC Research Program, at least that part of the program that deals with the aging of reactor components.

Aging is clearly a concern with currently operating plants and will be crucial to any assessment of the safety implications of license renewal. Today's briefing will cover pressure vessel and piping, vessel integrity, and the aging of reactor components.

The Commission was last briefed on the Aging Research Program this past month as a small part of the overview of the NRC research programs, but that was a more programmatic briefing and obviously intended to provide the Commission only a broad overview of the Aging Research Program. Today's briefing is a follow-up and will emphasize findings that have resulted from the research activities.

We're interested in hearing about results and insights from the Aging Research Program which are finding their way into the regulatory arena. I know

that the staff has made several recommendations regarding maintenance and testing practices. Some of them are published in a NUREG report. But the Commission is also interested in knowing if any of these recommendations are being turned into regulatory positions or requirements.

In my opinion, there are three major areas in which the aging project should be supportive of our regulatory programs: first, of course, ensuring the safety margins of currently operating nuclear plants are maintained; the second, providing a technical basis for renewal of nuclear plant operating licenses; and the third is the help in design of the advanced plants.

As you go through your briefing, the Commission would appreciate having these three areas addressed. You may also want to point out where results have been translated into useful and useable information for those who are operating today's nuclear plants.

We are particularly pleased to see that both RES and NRR are here, since this is clearly a topic that cuts across the responsibilities of both offices.

Commissioners, do you have anything else?

Mr. Sniezek?

MR. SNIEZEK: Good afternoon, Mr. Chairman and Commissioners.

In our briefing on the Aging Research Program today we will not only provide a very brief overview of that program in general, we will give a fairly in-depth description of the program associated with several key components and systems. During the discussion of these components and systems, we will identify the key issues which prompted the research, the results of the research to date, how the staff is utilizing the research results, future research planned in these areas, and the expected completion schedule. The fundamental staff approach for the other systems and components is similar.

With me at the table from my right are Larry Shao, John Craig, and Eric Beckjord from the Office of Research; and Bill Russell and Tom Murley from the Office of NRR.

With that, I would ask Eric Beckjord to commence the briefing.

DOCTOR BECKJORD: Mr. Chairman, Commissioners, in the presentation material that you have before you there is more than we can present to you by 3:30 when I understand you have another

scheduled meeting. Accordingly, we have selected reactor vessels, steel containments, reactor protection systems, service water systems, and probabilistic risk assessment insights on aging, which we can cover between now and 3:30. However, we're prepared to present the balance of the topics in the briefing package as time is available.

At the July 20th research overview, Commissioners asked a number of questions on aging phenomenon and research results. We have studied these questions and will answer them as we can by means of the aging research examples that we will present to you.

You were especially interested in the life cycle of aging and in the effectiveness of repair and rebuilding of components compared with replacement with new components. The data on rebuilt components is limited in a statistical sense. We have reviewed available data in the course of the research program and we have done extensive work in PRA to develop models of aging that can be applied to perturbation of customary PRAs in order to provide insights into the effect of aging on core damage frequency. We will address this topic in the presentation.

Aging Research is a program of long

standing and high priority in the Office of Research. Reactor pressure vessel research has been underway for about 30 years or a little more, reactor coolant piping research almost as long, and other critical and risk-significant components and systems work has been underway for about ten years under the Aging Research Program. In fiscal 1993, this year, the budget for reactor aging research is nearly $22 million or about 25 percent of the reactor research budget for the office.

So, with that, I'd like to ask John Craig to give you the detailed presentation.

MR. CRAIG: Good afternoon.

(Slide) Could we go to slide 3, please?

In the development of the Aging Research Program several objectives were key as the program was developed even a number of years ago before license renewal was a consideration. The program results are clearly directly applicable to current plant operation as well as license renewal with specific examples also for advanced plants and advanced plant designs. The objectives were to look at the service conditions at operating plants that would cause equipment to degrade, evaluate the causes and to determine whether -- to look at the current programs that were in place

and evaluate them to determine what additional actions may or may not have been necessary.

(Slide) Slide 4.

COMMISSIONER REMICK: John?

MR. CRAIG: Yes?

COMMISSIONER REMICK: To evaluate existing utility programs, some of these things that we talk about, certainly piping, erosion, corrosion, pump failures, things like that, are the type of problems that people run into not only in nuclear plants but in fossil fuel plants and so forth. So anyplace where you might know of where it's broader than nuclear industry where there are programs that we might have an opportunity to participate in or with those people or they have results that we could use, I would appreciate any insights there also, because many of these things are not unique nuclear power plant items.

MR. CRAIG: That's right.

One of the things I've learned since moving to the Office of Research a few months ago was the extent of industry involvement as part of peer review for the research results and involvement in national labs, and by doing that you've got people that were experts in piping or centrifugal pumps, et cetera, and that expertise indeed was not limited to

just the nuclear industry, so when you went to the national lab they weren't focused solely on the nuclear industry.

And another part of that is the interaction with EPRI. They've played a large role in peer review of the reports and clearly they look at a much broader spectrum than just the nuclear industry.

COMMISSIONER REMICK: And hopefully they're familiar with what other industries might have done and the results that might be available to us.

MR. CRAIG: And they sponsor a lot of research in those other industries also. Along those same lines, a number of the results have been and are being utilized in various codes and standards bodies, ASME code revisions, IEEE code revisions, and the results are reflected in a number of publications that have been made by EPRI.

(Slide) Slide 4.

An essential consideration as the program was developed is what equipment do we look at? What SSCs do we look at and why? The program reflects consideration of defense in depth and, based on that, the safety significance of the specific components was incorporated and/or addressed by the program. Those are supplemented by insights gained from risk

assessment, engineering judgement and operating experience as gained from operating nuclear power plants, and the engineering judgment of the staff as well as the engineering experience of the national labs, EPRI and industry in general.

(Slide) Slide 5.

This provides a list of examples of components and systems that we've examined and indeed when you look at these they reflect the risk-significance of the equipment. I'll note for this portion, which is commonly referred to as the Nuclear Plant Aging Research Program as opposed to the general aging research program in general, this is a subset. This work is scheduled to be completed in FY '95 and '96 and we looked at motor-operated valves, check valves and other components and some specific systems.

I'll talk about service water system, reactor protector system in a few minutes. The work on the service water system was done by Sandia and the work on the reactor protection system was done by INEL.

COMMISSIONER ROGERS: Is there any significance to the order here or is this just grouped by the systems?

MR. CRAIG: It's just random.

COMMISSIONER ROGERS: Okay.

MR. CRAIG: (Slide) Slide 6, please.

COMMISSIONER REMICK: I think that slide helps make my point. I think the only one of those that is unique to nuclear power plants is the reactor protection system and I would guess the chemical industry probably has something equivalent.

MR. CRAIG: Slide 6.

In addition to the systems and components that were listed on slide 5, in the general areas of materials engineering and civil structures, we're also including pressure vessels, generators and things as concrete and steel containments. In addition to those, there's some special considerations, there are special topics, including work with the -- looking at shippingport aging evaluations, some international activities and indeed under this looking at materials from the Trojan facility. I'll note that there's a meeting scheduled for September 1st to look at Trojan to discuss a number of potential research projects using such things as samples from the reactor vessel, reactor vessel supports, cable, steam generator tubes, et cetera.

COMMISSIONER REMICK: How about Yankee, Yankee-Rowe?

MR. CRAIG: We don't have any work currently planned using the Yankee facility. There were a number of discussions held with licensees some months ago and there was a number of potential proposals that were discussed. The licensee indicated if there was a generic benefit for any one of the proposals, they would support it. We had a meeting with DOE and EPRI and there was a general conclusion that none of the proposals had generic benefit and that effort has just sort of died.

DOCTOR SHAO: Trojan is a better plant. I think Yankee-Rowe has a lot of atypical components like vessels and generators.

MR. CRAIG: (Slide) Okay. Slide 7, please.

As Eric indicated, we're going to, in the interest of time, focus today on the pressure vessel containment, reactor protection system and service water system, followed by some risk insights and a summary of conclusions.

(Slide) Slide 8.

Reactor pressure vessel was in the area that's been ongoing for a number of years. The research is focused on four areas, embrittlement of the materials, fracture mechanics, the materials

properties and flaw distribution. The research in these areas has allowed us to address the PTS, pressure temperature limits and Charpy upper-shelf energy limits.

A large part of this program is actual testing materials, small samples and larger samples and the results of those programs then incorporated methodologies to address specific issues.

(Slide) Slide 9.

As an overview of the results in the reactor pressure vessel area, the early results showed that the calculations that were used were conservative. The current focus of our efforts is to look at the extent of the conservatisms in the margins and determine which ones, in fact, can be reduced. We've done that in a number of areas and those are actually being incorporated in a number of rules and reg guides that we'll get to in just a minute.

(Slide) Number 10, please.

Annealing is an area that's come under a great deal of discussion lately and we've had an ongoing program to look at annealing and to look at how much of the material properties can be restored by annealing. One of the things that is recently learned is the reembrittlement rate is not as severe as the

original trend was thought to be. So, the reembrittlement takes longer than was thought. So, there's some more potential benefits from annealing.

COMMISSIONER REMICK: What are the results here that indicate that, the origin of them? Are they from the -- from Russian experience or are samples here in the States?

MR. CRAIG: Largely working with the Russians, yes, sir.

DOCTOR SHAO: We test our own specimens too for material properties and for the whole area of annealing we get an experience from Russia.

MR. CRAIG: (Slide) And slide 11.

The way these results have been utilized are in a number of rules and regulatory guides. There's a draft annealing rule in the reg guide that's working its way through CRGR and ACRS right now to be issued for public comment. We expect that to be issued by the end of 1993. There's some generic letters that also have been issued concerning Charpy upper-shelf energy loss and I believe you're familiar with those.

(Slide) Okay. Slide 12.

Another recent utilization concerning neutron dosimetry is going to affect the area of

pressure temperature limits. We've had some significant advances in neutron dosimetry and in some revisions to cross sections that will allow a more precise and more accurate determination of the neutron fluence that a vessel wall will see. Part of those advances have been supported by developments in computers and ability to do fine mesh calculations. We presented a reg guide concerning that to ACRS and CRGR earlier this summer.

Okay. Slide 13.

COMMISSIONER REMICK: What is the general thrust of the proposed rule on annealing?

MR. CRAIG: The proposed rule will require utility to present its annealing program to NRR for review and approval before they do it. Following the anneal, they will have to certify that the anneal was conducted in accordance with the plan that was approved and further certify that the specific criteria, the temperature, the time, et cetera, were in fact maintained during the anneal.

COMMISSIONER REMICK: So, it's more a process type rule than a prescriptive how to do it?

MR. CRAIG: Yes, sir.

DOCTOR SHAO: You would cover not only the vessel, you would cover the adjoining piping, the

concrete to make sure they're not damaged during annealing.

COMMISSIONER REMICK: I see. Okay.

MR. CRAIG: (Slide) Slide 13, please.

We've completed a significant amount of research related to the reactor pressure vessel and a number of the results are reflected in revisions to the codes and to fracture mechanics and reflected now or will be reflected in operation of current plants. In addition to that, these results will be utilized in design for advanced plants. The large-scale validation experiments that were conducted were used to translate the small specimens to larger reactor vessels. The large-scale validation efforts were done at Oak Ridge and they're approximately 60 inches high, six inches thick and 39 inches in diameter.

(Slide) Slide 14.

As I indicated, the direction of future research will be to focus on test results and current analytical methods to reduce any unnecessary conservatism. We're going to look at the effects on a range of materials such as welds, plates and forgings. We're going to try and get some materials from a plant such as Trojan and do evaluations there. Additionally, we've done some work with the Japanese

power demonstration reactor and from materials removed from a German facility.

There are a number of international benchmarking experiments that are underway. One of those is the network for evaluating steel components and it's a cooperative effort with the British. This effort is scheduled to be completed in FY '98.

DOCTOR MURLEY: John, before we leave vessels, could I mention something for the Commission?

It gets back to the Yankee vessel. You recall at the time we were struggling with what to do and what decisions to make with the Yankee vessel, we didn't really know the weld material, we didn't know some of the plate material and particularly we didn't know the flaw density and flaw locations that might exist in welds. We've examined, as John said, with the industry what would be the value of going in and making such measurements and I think we've concluded that it is not prototypical of anything.

But there's another aspect to it that I guess I'll just leave with the Commission that I would find quite valuable and that is it would be a data point on how conservative or non-conservative our decision making was in the face of uncertainty. We have to struggle with these kinds of things, if not

everyday, frequently. This was an area where we struggled very hard and we made decisions and moved on ahead. So, in a Basion sense, I think this would give us one data point. I was not able to convince folks that it's worth a couple million dollars to do that. So, if we could somehow convince industry or whatever, it would be very nice for us to go back and know really what was the real embrittlement status of that vessel and how were flaws and how close were we when we were making decisions.

COMMISSIONER de PLANQUE: Is there any interest in pursuing that in the international community?

DOCTOR MURLEY: Not really and it's for the same reason, that they don't believe that it can apply to any other vessel.

COMMISSIONER de PLANQUE: Okay.

MR. RUSSELL: If I could, I'd like to just give one comment in another area to just illustrate how we are currently using some of these results. It's a very practical one. You have pressure temperature operating limits which are based upon the amount of embrittlement which has occurred and that generally establishes a floor for pressure and temperature for operation. But we also have low

temperature over pressure protection which has been put in place in the facilities. Typically it's done through establishment of relief valves and other administrative controls where the relief valves are set at a lower pressure such that during a transient or excursion you would protect the vessel when cold.

The work that's been done by Research in identifying and quantifying some of the margins that exist are giving us confidence that it's appropriate to proceed through a process to provide some relief on the establishment of the set points for the low temperature over pressure protection relief valves. Instead of using the previous factors of two, we're looking at using a factor of 1.8. We feel comfortable in doing that based upon the work that has been done and being able to quantify that and have a good feeling for what kinds of margins do exist. So, that's one practical example that we're seeing now. As vessels age, the gap that you are permitted to operate in between low temperature over pressure protection when starting up and your minimum temperature pressure curves is getting smaller and is creating operational restrictions. We expect to take that through with the code case and would do that hopefully shortly.

CHAIRMAN SELIN: I take it that these remarks indicate that this program is not just for aging unique to license renewal, but it's a broad aging program --

MR. RUSSELL: Yes, sir.

CHAIRMAN SELIN: -- much of which is relevant in the basic 40 year time period.

MR. RUSSELL: That's correct. This is for the 40 year operating life and you periodically review and establish new temperature pressure limits based upon radiation embrittlement to the vessel with time. You also look at the low temperature over pressure protection set points. Those set points can come down with time, just as the operating curves can go up with time due to radiation damage.

DOCTOR MURLEY: Just to complete the point, Mr. Chairman, it also is valuable for advanced plants. We've learned how to take this into account so that the designs of advanced plants should not have embrittlement as a basic problem and the risks should be very low.

COMMISSIONER REMICK: Before we leave pressure vessels -- Eric, did you want to make a comment?

DOCTOR BECKJORD: It seems to me that we

can do at least a part of what Tom is interested in with the Trojan vessel, even though the fluence is lower. But we can still compare the methods and get a good comparison with the difference between NRC and industrial methods.

CHAIRMAN SELIN: Would we feel better if there was a large margin or a small margin?

COMMISSIONER REMICK: If I recall, at Oak Ridge they're also doing some work to see if you could replace Charpy-type tests with other forms of tests and validating that. What's the status of that research?

MR. CRAIG: I'll have to ask Chuck Serpan to address that.

MR. SERPAN: Chuck Serpan from the Office of Research.

That work is underway. Mostly it's an irradiation effects study and the smaller specimens are being put into the irradiation capsules and they're being irradiated. As they come out, we're testing them. I don't have definitive results to give you now --

COMMISSIONER REMICK: I see.

MR. SERPAN: -- but it's ongoing and we're looking to get information on that same stuff from

people all around the world as well because there's plenty of others working on it too.

COMMISSIONER REMICK: Good. Thank you.

And is there anybody that we know is seriously considering the annealing possibility at the moment?

DOCTOR SHAO: Westinghouse is thinking of a demonstration --

COMMISSIONER REMICK: Excuse me. In the U.S.

DOCTOR SHAO: Westinghouse is thinking of a demonstration plan in the very near future.

COMMISSIONER REMICK: A demonstration what?

DOCTOR SHAO: Of annealing.

COMMISSIONER REMICK: I see. In an actual plant?

DOCTOR SHAO: In the next four years.

COMMISSIONER REMICK: I see. Okay.

MR. SNIEZEK: It would probably a shut down plant, wouldn't it?

MR. CRAIG: A plant hasn't been named.

COMMISSIONER REMICK: Yes, okay.

MR. CRAIG: We can't identify one.

(Slide) I'd like to go to slide 20,

please, and skip piping and go to steel containments.

The area of degradation in steel containments is one that's been around for the past few years in an isolated example or two, but it's also a current evolving issue as there's been identification of corrosion to an extent that was unanticipated or unplanned for and indeed in locations that people didn't -- the designers wouldn't have concluded there would have been corrosion in those locations.

Drainage from condensation and inadequate floor slopes has resulted in the puddling of water and some corrosion. In places like ice containments, poor drainage outside of containments has resulted in corrosion of Mark I containments.

This program is based basically in two parts. The first part is largely going to be done by Oak Ridge National Lab and that's data gathering to look at the current findings, the inspection techniques, et cetera, related to containment and to identify the extent of degradation. The second part is going to be done by Sandia and that's an evaluation of the extent of the degradation and to identify appropriate actions and indeed how to perform the analysis to determine what the extent of the reduction

and containment integrity is as a result of the degradation.

(Slide) Slide 21, please.

This is a new program that has begun late and recently, so we don't have any results yet. Again, the efforts centered on the material technology inspection techniques and evaluation of results.

COMMISSIONER REMICK: Some of the advanced plants have steel containment, right?

MR. CRAIG: Yes.

MR. RUSSELL: I might point out that this is one that we requested Research do as a result of problems that we observed at Oyster Creek and at Nine Mile Point, as well as problems we've seen. John mentioned the floor drainage problems within the ice condenser containments and the potential for corrosion products building up and maybe defeating the function of the containment by preventing the doors from opening to get the blow down through the ice baskets. These are the kinds of issues which have come up as operational experience for which we've requested specifically that they do research work and provide those results back.

MR. CRAIG: (Slide) Slide 22.

Under "Utilization" there's a proposed

rule that will adopt Subsections IWE and IWL. It's a revision of 50.55(a) and that will provide -- those subsections provide a clear process and valuation criteria inspection techniques for containments and those are going to be required of all plants. In addition, the future results will be used for further code revisions and we believe the results of this effort in addition to the ongoing revision to adopt IWE will result in future revisions to IWE as the results become available. The program is expected to be completed in FY '97.

CHAIRMAN SELIN: I'd like to ask you a question on a somewhat different topic. This does not imply I know what Subsection IWE is and I'm not going to ask you about that. What about some of the large structures where it's hard to get data, like the storage tanks or some of these pieces that we're not that concerned about in the first 40 years but they're sort of make or break items when it comes to plant life extension? This is something I asked about at the earlier briefing. Can one gather enough data to feel comfortable or uncomfortable about these large structures?

The other general area is cable. I'm not talking about cable that's exposed to heat or

radiation, just buried cable that would be very hard to replace if aging came up.

MR. CRAIG: I'll ask Doctor Murphy to address the large structures in general and what we're doing there. In the area of cables in general, as you know NRR has a task action plan that's related to environmental qualification of electrical equipment.

CHAIRMAN SELIN: But that's stuff that's under a lot of stress, either heat or flux. In addition to that, I'm just concerned about the miles of other cable you don't worry about.

MR. CRAIG: Yes, sir. What I was going to say is that we haven't at this point initiated a program to take a look at that cable and it reflects in part a lesser safety significance of that cable. So, they have not been included in the current programs.

MR. RUSSELL: Let me also add to your question regarding the structures as compared to other devices such as tanks. It is possible to perform in-service inspection on tanks. You have access to them. Some of the larger structures, there are areas where you do not have access, so it raises questions about your ability to inspect. For example, the Mark I containment where you have a sand liner with a short

distance to a concrete biological shield. It's not easy to inspect in those areas and so it raises questions about inspection techniques.

In this case, in particular some of the information on local corrosion problems where you may have pitting or a local wall thinning, we've basically found that the component could expand. It would then come in contact with the concrete structure behind and you would not be worried about a local effect becoming a gross failure of the containment.

We are looking at those. We're looking at them in particular because of the use of the steel shell containments for the AP-600 and for the CE 80+. We're looking at the mechanisms of embeddment of the steel containment into the concrete pedestal, how they would be able to inspect in those areas and what they're doing by way of design to minimize some of these problems that have occurred. It's that background that was the basis for our request to Research to look into some of those areas.

For other types of structures, like water intake structures, concrete facilities that may be degrading due to exposure to saltwater, environment conditions, we're also looking at those and have conducted a number of evaluations of current plants,

approximately six, and we're collecting those results and will be identifying additional requests to research in those areas.

So, we are looking at those areas and we're passing the information as we see need based upon operational experience and we are factoring it back into the design reviews for the advanced plants.

CHAIRMAN SELIN: I want to see what Doctor Murphy has to say and then I'll follow up on the question.

DOCTOR MURPHY: Excuse me. I think that Bill Russell has stolen most of my thunder at this stage. Indeed there is an ongoing program we anticipate completing next year in our concrete structures program and basically Bill said most of it at this stage. There are areas that we've looked at. There's some problem areas that we've made suggestions on how to look at them more carefully. But basically the concrete structures are in pretty good shape as long as they're carefully maintained. This seems to be a pretty good program in that area at this stage.

CHAIRMAN SELIN: I think you've answered this question, but I'm not sure, so let me put it a little differently. I'm not talking about the kinds of structures which we wouldn't normally worry about

in the first 40 years and to do an inspection and find a problem is fine, but you want to have an underlying aging model so you know whether it's an expected point or an unexpected point.

Are we gathering enough data through the steps that you were talking about, Mr. Russell, that are likely to give us an underlying model about how fast and in what way these large structures age, or is it just enough to say we're not yet worried because we haven't seen signs of --

MR. RUSSELL: Well, we have seen degradation and I would characterize that from the audits we did at existing facilities the degradation we observed was not sufficient to cause a concern about capability of the structure to perform its function. But if left unarrested or unremediated would raise a concern. Everything from leaking of containment and sleeves such that you may be getting grease in the concrete to degradation spalling of concrete due to freezing, exposure to water, salt environments, those kinds of things. But the types of degradation that we were seeing was relatively limited and did not raise questions about the structural capability, but would raise questions if it were not remediated.

So, the issue that we're focusing on is more what are the areas to inspect and to look at. That's why we requested that Research look at it in a longer term basis and that's where they're doing and provide us feedback.

DOCTOR MURPHY: And as he said, that's what we're trying to do. Particularly, I think, we're fairly well along with that program with the concrete. As far as the steel structures are concerned, our primary thrust at this stage is the gathering of data and the methods that are being used for inspection and repair and then to look at the analysis techniques that are available to tell us whether or not we have sufficient capacity in these degraded structures. Particularly I'm talking about the steel structures at the moment.

MR. RUSSELL: There is one other example that they've helped us on in the short-term and that's under conditions of extreme thermal loading we've looked at issues of buckling, particularly as it relates to the AP-600 and the CE 80+. More so for the AP-600 because of the shape of the containment, from the top of the containment, and there has been research work in that area that has helped us address those issues. We've recently gone forward with the

proposed resolution of those as a part of the advanced reactor -- excuse me, not advanced, the evolutionary and advanced light water reactor design reviews.

MR. CRAIG: (Slide) Slide 23, please.

We're going to shift gears a little bit and I'm going to describe the approach that was used to look at the systems and components that I mentioned earlier. It can be thought of in three phrases. The first phase is a post-mortem, to look at the failures that have been reported and various failure data, systems, LER data, NPRDS, et cetera, and to determine what the cause of those failures were and if it was age-related degradation to look at the degradation mechanism to identify the specific mechanisms and then look at the existing practices to determine whether or not they'd be adequate to identify and correct failures as a result of specific degradation mechanisms.

Phase II was a more indepth review and it included some specific testing for some components.

Phase III really overlaps phase I and II. That's the utilization of the information and dissemination of the information.

As I mentioned earlier, when the reports are prepared they're published for peer review and

that includes EPRI, the utilities that were involved in data gathering, vendors, et cetera. So, there was a large cross section of people that take a look at the reports and its findings. The utilization also has included revision to codes and standards, generic letters, bulletins, and is finding its way into rules and regulations to a little bit lesser extent and ultimately may be beneficial in license renewal, depending upon the final determination.

Indeed, it's in that context of specifically identifying the primary causes of failures for specific components that are active in systems and the actions to manage those that will be beneficial in the context of license renewal.

CHAIRMAN SELIN: If you'll remember, at the previous session I asked the question about looking at a system which was being refurbished and maintained as a system itself. In other words, what is the aging of the system given the refurbishment and the maintenance? What's the survival probability after the 11th overhaul compared to the survival probability of a new device, the same kind of thing that basically doctors are doing with people, bodies being reconstructed but never quite to scratch.

Are we doing some research in the aging of

refurbished systems? Some of these complex electrical and mechanical components fall in that category. That's what underlies this whole concept of effective systems for managing aging.

MR. CRAIG: I think the direct response is probably no in that we're not looking so much from an integrated systems perspective, we're looking more at the specific degradation mechanisms and its effect on a part of that system, a pipe, a valve, a pump, et cetera. But we do have, and I'll cover in a minute, some risk insights, I think, that considered failure data from systems as a whole. It gives us some insights into refurbishment versus replacement, in that context. But those insights are just that and they're initial. So, we haven't really taken a hard look from that perspective.

CHAIRMAN SELIN: Maybe I'll just plant a marker and wait until I hear what you have to say about what we're doing with these risk assessments, because even if it's a pipe or valve, what we're interested in is not just the aging but what happens to those risks after you refurbish them, how close to original do they get and for how long can you project the performance being okay.

MR. CRAIG: Right. Well, before I go to

the next slide, I want to one more time note that this work has been going on for a number of years and to a large extent to look in a rear view mirror. As the results of this work have been distributed and disseminated to the industry, what we've seen, particularly in the past few years, is there's an emphasis on looking at continued plant operation as their programs for life cycle management, et cetera, increased rigor in root cause determination and those kinds of things, that there are a number of programmatic improvements on a utility by utility basis and these results don't reflect those improvements. In a few years they will, hopefully by a lack of failures.

(Slide) So, with that, we'll go to slide 24.

Slide 24 -- bear with me.

CHAIRMAN SELIN: You're going to brief this?

MR. CRAIG: We're going to skip 24. I lost a paper clip.

(Slide) I'm going to go to slide 30.

CHAIRMAN SELIN: A very wise move. Twenty-four was to condition us for 30. If you just put this slide up without having shown us 24, you

know, we would have reacted much more negatively.

MR. CRAIG: Well, this is an, if you will, busy slide, but it makes a point. For any channel reactor protection system, this one happens to be typical for a reactor coolant pressure. There are a number of subcomponents or components within a system, transmitters, penetrations. The ISP is an abbreviation for instrument power supply. Buffers, test modules, bistables and relays. This is an example where we've concluded, I believe, that the current program that's in place and the implementation of the program is adequate to manage degradation of the components.

(Slide) Go to slide 31.

This is a pie chart which illustrates the causes of failures. Before I go into the causes of failures, I want to note that for this and the subsequent slides, when we looked at the data, a failure can be an undefined or a difficult to define condition. It could be a slow response time, it could be not meet a precise spec. It doesn't necessarily mean that a component or a system would be inoperable. It's a category that's entered in the various data collection systems and we just accepted whatever the plant personnel had indicated or classified as

failures.

When you look at the cause of failures in the reactor protection system, you see that there are three primary ones related to aging, environmental, drift and wear. You'll see a small cause of failure to this system as a result of aging.

(Slide) Slide 32, please.

This slide, I think, was interesting when I first saw it because it indicated that there's no individual subcomponent or part of the system that results in overall failures. Even though there's a big block called "others" at 35 percent, that's really to keep the slide clean. There are a lot of just small pie slivers that go in there.

(Slide) Slide 33.

What we found was that approximately 34 percent of the failures occurred on demand, and that's good news because a large number of those demands were tests. And so by frequent testing of the system, problems with instrument drift, things being out of calibration, et cetera, were identified and corrected.

We see that the overall failures related to aging account for a very small percentage of the failures. I'm not going to read and go through the aging mechanisms and their locations, but the results

did identify the specific mechanisms and subcomponents and how they'd be degraded.

(Slide) Thirty four, please.

Thirty four is the conclusion that I stated before. The current programs are adequate and they're adequately implemented. A lot of these components are frequently replaced as opposed to refurbished or repaired.

CHAIRMAN SELIN: I'd like to point out that the line of questioning I followed would affect systems in which components are replaced as well as just repaired, because the component may be replaced but the system is being refurbished.

MR. CRAIG: I understand.

CHAIRMAN SELIN: Okay.

MR. CRAIG: (Slide) Slide 35.

The results of this effort have been included in specific IEEE standards and a number of others and this is just one illustration, and I believe it's one of the strengths that the results of the program are being factored into various codes and standards bodies and used across the industry as a whole.

(Slide) Slide 36.

The research results of the research

program on the reactor protection system has been completed. The reports have been issued and they're available.

COMMISSIONER REMICK: With new digital I&C systems, will we have to start over again?

MR. CRAIG: Well, not entirely, I suppose.

We have some efforts looking at digital I&C systems and the stressors that would degrade those systems and those are ongoing. We're working very closely with NRR as part of their review and, indeed, the fact that operating plants are upgrading those systems today, but we do have an effort underway in that area.

MR. RUSSELL: In fact, if you think back to the earlier schematic that identifies the types of components, you've still got penetrations and other devices. Whether you would put A to D conversion inside containment and qualify it or you would bring the signals outside and then process it digitally, I think there would be a number of the components that would still be valid.

I would point out that, as a result of the conclusions and our concerns for what I will characterize as human error, we have made changes and basically have gone from a monthly testing to

quarterly testing in a number of cases to minimize the potential for human error during the interactions. That was a trade-off that was looked at.

COMMISSIONER REMICK: I was wondering if that will result in an increase or decrease in the failures on demand.

DOCTOR MURLEY: I think there will be new areas we don't even know yet. To give an example, when I was with the team in Germany, I guess it was a year ago, they mentioned that they're finding in some of their plants that because the voltages, the operating voltages in the systems throughout the plant are getting lower and lower, that there's the possibility for ground faults and stray voltages throwing entire systems off. In fact, they've seen it in some of their plants. I think we're going to have to look at something like that. We haven't really formulated a user request, but I'm quite sure that there will be something like that.

COMMISSIONER ROGERS: That's a consequence of introducing the digital solid state equipment?

DOCTOR MURLEY: Yes.

MR. RUSSELL: And then how well have you maintained grounds and what happens to grounds over time.

DOCTOR MURLEY: Right. It's a consequence of the lower voltages, yes.

MR. CRAIG: (Slide) Slide 37, please.

I'm going to shift to the service water system. This is a schematic, a simplified illustration of a service water system that is intended basically to show the severity, if you will, of the service conditions. The harshness of the water that's going to chemically attack the plates, valves, et cetera, is dependent upon the river or heat sink that comes in. Some of those are more pure, less corrosive than others.

This is a system that the current programs-- in part based on this research program, a generic letter was issued and what we found recently was a number of plants were continuing to have a lot of problems with their service water system. NRR has conducted a number of pilot inspections and they're going to continue to do inspections and I think inspect up to 50 or 60 percent of the plants in the country to look at service water systems and how they're being maintained.

COMMISSIONER ROGERS: Are any plants using closed service water systems?

MR. CRAIG: There are some that use

closed, yes, sir.

COMMISSIONER ROGERS: Is their experience different?

MR. CRAIG: Yes, sir, because the water chemistry is more controlled.

DOCTOR BECKJORD: It's better with the closed part of the system, but eventually they get back to the raw water.

MR. CRAIG: Right.

MR. RUSSELL: In fact, some of the closed systems introduce other problems. One example would be Southern California Edison's San Onofre where you have a single heat exchanger and then a closed system for circulating it around the site. If that heat exchanger is blocked due to seaweed or problems with your trash racks or kelp blowing at the wrong time of the year, then you have a high unavailability of that heat exchanger and a high unavailability of your heat sink, and so having fewer components that you then have to maintain can actually be a more serious condition.

We also saw that at Crystal River with the intermediate cooling system and the reliance on that and the interdependency, so there are trade-offs both ways as to whether you go open-cycle or closed-cycle,

but clearly you're able to maintain the closed-cycle better from a maintenance corrosion/erosion standpoint.

MR. CRAIG: (Slide) Slide 38, please.

The next slide shows, I believe, what we all would expect, that erosion/corrosion is a significant contributor to failures and problems within the system, followed closely by biofouling and debris and sediment.

(Slide) Slide 39.

Slides 39 through 41 identify or discuss the particular components within the system, pumps, valves, check valves, et cetera, and the causes or the degradation mechanisms that resulted in failure. As indicated by the pie chart, it's reflected here. Erosion/corrosion and biological fouling are prominent in causing failures for each one of the components in the system.

(Slide) Slide 42, please.

I indicated that the results of this program in part were used in the development of a generic letter. It was Generic Letter 89-13, and it provides a framework and insights to monitor aging in service water systems. It's performance-based and it discusses such things as monitoring heat transfer

across heat exchangers, inspections when you open a heat exchanger up to look for sediments, such things as clams, et cetera.

Another aspect of this program was the importance of having a rigorous root cause analysis as you looked at failures in the system. There are a number of examples where there were problems with MOVs that were attributed to the motor and indeed there was a problem of corrosion within the valve. What the experience has been as a result of the recent NRR inspections is by and large the root cause analysis for failures in this system and indeed the actions taken to manage biofouling, degradation, et cetera, are being upgraded at various levels at plants across the country.

(Slide) Slide 43.

The results of this effort are also being incorporated in the ASME operation and maintenance guidance documents.

COMMISSIONER ROGERS: When do you think those will be available?

MR. CRAIG: I'm not sure, Commissioner. The process, as you know, takes some time. The information is available already, but I'm not sure when they'll be updated or revised.

(Slide) Slide 44.

The research portion of research projects looking at service water is complete. The reports have been issued, as I indicated.

I should note here, as you think back to that earlier slide with the components and systems, that all of the research programs for those pieces of equipment are scheduled to be completed in '95 and '96.

(Slide) Slide 45 provides and overview of ongoing work, some phase I and some phase II, for connectors, terminal blocks, some safety relief valves and two other systems that are being looked at.

COMMISSIONER REMICK: What are we doing in the safety relief valve area? It seems like that's been an ongoing activity forever.

MR. CRAIG: I'll ask Mr. Vagins to address that.

MR. VAGINS: You're right. Safety valves have been going on forever for different reasons.

I remember one time we looked at Surrey. This was when I was in private industry. If the safety valves fired the way they were supposed to in sequence, one after the other, all five of them, they would have been ripped right off the containment wall.

So there've been problems. Basically the problems have been design problems, however there are aging problems and our program is just starting on safety valves because we think that many of the problems were handled because they were known design faults, so we're really just starting on safety relief valves.

COMMISSIONER REMICK: I see. This would be an area, I would think, once again that there would be a lot of industrial experience --

MR. VAGINS: Yes, sir.

COMMISSIONER REMICK: -- with safety valves. Are we attempting to get the benefit of previous work or ongoing work?

MR. VAGINS: Yes, sir.

DOCTOR SHAO: We are participating in all kind of codes, ASME codes, and getting a lot of experience from the industry. ASME codes normally include nuclear people, industry people too.

MR. VAGINS: For the record, my name is Milt Vagins and I'm with the Office of Research.

COMMISSIONER REMICK: Has industry in general had as much difficulty with relief valves as we have, and safety valves?

MR. VAGINS: In general, yes.

COMMISSIONER REMICK: They have?

MR. VAGINS: Basically, they look the same. I think they're the same valves.

COMMISSIONER REMICK: Okay.

MR. CRAIG: (Slide) Slide 51, please.

I indicated before that we have done some work which has given us some insights, from risk, from aging. And although we haven't tried to look specifically from a systems perspective at the overall risk or reliability of a system as particular subcomponents or parts of it are maintained, we have focused on plant specific data recognizing again that this is a premaintenance rule and preupgrades and recognizing that there are a large number of plant specific variables due to equipment, vendor support, training, and indeed the equipment itself. You can have two diesels in the same plant and from the same vendor and one works very well and the other one doesn't work as well.

We've observed some aging trends for some of the components. Largely motor-operated valves in an HPI system can contribute to risk, more I think than as a result of aging and we'll talk about that in just a little bit.

And we looked at two plants in particular

and went through the maintenance logs, one a BWR and one a PWR, and looked at the records and talked to plant personnel. One of the insights I think that came out of that was that the term "refurbishment" is not one that was used at those two facilities. They repair or they replace and so refurbishment would come under the guise, I think, of a repair to repair a valve disk or a seat and you continue to use it in an aged component, so the subcomponent might be new or repaired. The overall component continues to age.

COMMISSIONER ROGERS: Doesn't refurbishment sometimes really refer to a kind of complete clean-up of an older component, an older part of some sort, not only to repair whatever broke, but take it out, clean it up, inspect it, not only that part which failed but the whole thing so that what is put back is, well, it's a little bit closer to what it was when it was new than just the repair?

MR. CRAIG: Indeed, that's correct, but what we've seen is a number of -- it depends on the component and the subcomponent.

I think one of the examples probably that's clear is motor-operated valves where one portion is electrical, the other part's mechanical, and you may or may not when you take the valve apart

do anything with the motor operator, so it depends on the extent of the repair, if you will, how long it's been since a previous -- I'll use the term "overhaul" at the risk of getting in trouble, the previous overhaul and what was done. Some plants are much more rigorous about doing a refurbishment to look at the entire component while they have it torn apart than others are.

One of the things that I think we're seeing as plants focus on minimizing down time, only having outages be as long as they need to be, is indeed when something is torn apart they're looking at it to a greater extent today than they were five or ten years ago.

(Slide) Slide 52.

DOCTOR BECKJORD: We need some improvements in the definition of what constitutes rebuilding. I mean, refurbishment itself in the dictionary, if you read it there, means brightening something up and obviously it's important to go beyond that.

COMMISSIONER ROGERS: Right. Don't just improve the paint job.

MR. CRAIG: (Slide) Slide 52, please.

This is a curve that's referred to as a

"bath tub curve" and it shows an initial higher failure rate for new components or new subcomponents that's referred to typically as a "burn-in period." If there's something that's going to go wrong, it will go wrong with that new component as you install it, align it and test it. Then you get to the center flat portion and that's the portion of the equipment history that's considered in current PRAs. And then as the component ages, it becomes less reliable and you see an increased failure rate and that was the focus or is the focus on the aging work that we've done, to try and look at failure data and see how that could be incorporated or mated with current PRAs.

What we believe you can do from aging management is extend the flat portion of the curve. Certainly, if you can't keep it flat, you can control the rate of increase in failure for most of the components.

COMMISSIONER ROGERS: Are there some systems and components that simply don't follow this? I mean, it has a nice universal quality and you can argue as to why it ought to be that way, but I don't know. It would seem to me that it's conceivable that there is no flat portion for some systems, that they just age. When they start to age they start to --

after you get through the infant mortality period, that after that there's no flat portion, it just starts to climb and they age, and that the failure rate starts to go up, maybe not at a great rate, but it's not flat.

Are there some other studies that have identified systems or components that behave that way?

MR. CRAIG: I don't know the answer to your question, but the flat part of the curve is failure rate, not aging, so they will age and the degradation will increase, but it would result in failure, so the curve is --

COMMISSIONER ROGERS: Sort of associating those two together.

MR. CRAIG: Right.

COMMISSIONER ROGERS: You might be able to distinguish them a little.

MR. CRAIG: Yes, sir.

MR. VAGINS: John?

MR. CRAIG: Yes?

MR. VAGINS: I think I can answer that question very easily.

Again, Milt Vagins from Research.

Passive components, pressure vessels, piping, et cetera, exhibit exactly what you're talking

about, the slow steady aging growth, and sometimes it's going to break. There's generally no early breaks. If there are early breaks, they're because we did not understand the aging mechanism, such as the early days of the intergranular stress corrosion cracking.

What we're talking mostly here are components, active components which go along and function and then suddenly stop functioning.

COMMISSIONER ROGERS: I guess I'm thinking that maybe there's something that actually mixes both of those.

MR. VAGINS: In actuality, sir, everything ages and the aging is continuous.

COMMISSIONER ROGERS: Oh, yes, but the failure -- there isn't a flat failure --

MR. VAGINS: No.

COMMISSIONER ROGERS: -- as distinct from aging, but there isn't a flat failure. That's my question, not whether something ages or not, but whether there is a class of components where there isn't a flat failure rate, unless it's just a constant slope.

MR. CRAIG: (Slide) Slide 53, please.

This slide, we tried to give you some

insights into the different rates of failure, the relative rates of aging and thereby expected failures for active and passive components and we tried to separate it into a normal service environment and harsh. Harsh here I mean something like the service water condition that would be aggressive, not the definition of a harsh environment that's in 50.49, the condition you see as the result of a LOCA.

What we see is that the relative aging rates for all the components has a positive slope and for those that are in a severe environment that you could see the failure rate could double, say it's an active one in a harsh environment where the aging rate is 25 percent to 100 percent. The failure rate could double once every four years to as frequently as once every year. So, that's the thrust of this, to show that aging rate can play an important role in overall risk and degradation of a component, but it's highly dependent upon the specific environment that it's going to see.

COMMISSIONER ROGERS: Well, that's easy to appreciate, but I still don't quite understand what that table, those percentages really mean, particularly in view of our conversation just a couple of moments ago where Mr. Vagins drew a distinction

between failure rate and aging rate. This mixes active and passive components and talks only about aging rates. So, can you just enlighten me a little bit on that?

MR. CRAIG: Mr. Murphy will.

COMMISSIONER ROGERS: Okay. Good.

MR. MURPHY: Basically, once you get onto the not flat part of the curve, we have modeled it as a linear mechanism and these are the percent. It's a lambda zero plus alpha T and these are the alphas by which the failure rate increases.

Now, to get back to your earlier question, for some components like air-operated valves, there basically isn't a flat part of the curve. There's a simple mechanism and they start aging immediately and they would age at something like these failure rates. Now, the failure rates are generic. I wanted to emphasize that we have really a minimum of data on the actual change in the failure rates and it requires examining the maintenance logs of the various plants. One of the hardest things you have to do is separate out the effect of the maintenance from the aging mechanism itself. So, it's a difficult analysis.

COMMISSIONER REMICK: I'm having some trouble with that definition there or the terminology

"relative aging rate per year." Is it really a frequency of failures with age?

MR. MURPHY: They start off with a failure rate that's failures per year and now that failure rate increases in the case of, say, the normal components by approximately ten percent a year. So, if it was $1x10^{-4}$ in year one, it would be $1.1x10^{-4}$ in year two.

COMMISSIONER REMICK: But it is a failure rate.

MR. MURPHY: It is a failure rate that's changing with time.

COMMISSIONER REMICK: Yes. Okay. It's not a frequency either. Okay.

MR. CRAIG: (Slide) Slide 54, please.

We've already covered most of this slide and the point that I would make is that looking at the existing PRAs for the two plants that were done, reviewed, they identified relatively small components that contributed to the risk as a result of aging. Those were the two biggest. The biggest contributor that I recall is the motor-operated valves and the high pressure injection system.

The other thought here is that there's an increase in risk due to passive components that's sort

of hidden, I guess. In the early part of plant operation it would be secondary to failures of active components and as they age and degrade their contribution will increase over time.

CHAIRMAN SELIN: What type of components are you talking about?

MR. CRAIG: Passive components, like piping.

CHAIRMAN SELIN: Can I go back to the refurbishment question?

MR. CRAIG: Yes, sir.

CHAIRMAN SELIN: There are really three things. One is I'm aware of some of the work that's actually being sponsored by RES and although I don't know about it first-hand, I hear fairly good things about it. So, I get the feeling you're being a little shy about putting some of this up. Is it because it's early or you just don't want to be embarrassed or it's not as good as I thought it was or what?

DOCTOR BECKJORD: Go ahead and address that, Joe.

MR. MURPHY: Basically what we've done and we're sponsoring this work that Bill Vesley did for us, we did sensitivity studies on aging rates and it showed, not surprisingly, that if the aging rate was

high, the risk importance of aging could be significant.

In addition to that, we took data for a specific plant and ran that through the -- changed the PRA accordingly as a function of time and looked to see what effect that would have. Now, in our sensitivity studies basically we assume that when we repaired or refurbished there were two possible answers. One is that at the end of the work the product was as good as new, which would be the same as replacement. The second assumption was that it was good as old. In other words, you took out the failed piece part and you repaired it and replaced it or replaced it with another aged piece part of the same age, so that the component really didn't see the effect of the failure. It was still an aged component.

Now, the truth is neither one of those is probably a true assumption, but they do ground the problem. Intuitively, one would think that the more complex the component the more likely it would be that the repair would be closer to as good as old rather than as good as new because of the various kinds of failure rates that -- you have various mechanisms which could fail the component and you were only

repairing one of those.

In any event, we've done the bounding analysis and then we went back and we took one specific plant and we ran the data through it for that plant to see what the effect would be. The effect was that over a period of -- let me check the numbers to make sure. Over a period of ten years it was a factor of three increase in core damage frequency that would be predicted and over a factor of 20 years it was an increase of about seven, a factor of seven. What's important about this is not so much the individual numbers, but the fact that the individual components that contributed to this was relatively small. So, you could then focus your maintenance program to make sure you were picking up the kind of failures that were identified in the program. Presumably if they're maintenance-preventable failures, they'd be picked up in the maintenance rule.

CHAIRMAN SELIN: That gets me to my second question which is, is NRR comfortable from maybe a more theoretical basis that we know what to expect if we're going to put reliance into the extended lifetime on not so much a priori probabilities of failure, but being able to pick up failures to know whether they're just specific systems that need to be repaired or

whether they're signs of aging with overall refurbished systems. The theoretical backgrounds were --

MR. RUSSELL: Let me address it and give you a practical basis for what Joe has just discussed. That is in the past the approach to surveillance testing and regulatory requirement was essentially conduct the test and if it failed the test take a restoration action to get it back to the point where it would pass the test and you could declare it in service. We kept track of component failures very poorly. In fact, it was a replacement for the component in most cases. We did not focus on the impact of the piece part failure other than the fact that it had a surveillance, you had a time frame that you had to repair or you had to take a shutdown if you couldn't repair within that time frame. That's the condition that exists somewhat today.

Under the new maintenance rule we have tried to focus on train availability and reliability, for whatever caused it to fail to perform its function or for whatever time it was unavailable due to maintenance activities. This is a relatively new concept for the industry, what caused the failure, find the root cause of that failure and address it

specifically and it's having the effect that John mentioned. That is when you have something out of service, look at it more broadly than just the narrow component that has failed.

So, as you start keeping track of performance at a train level, you may see that one train is behaving poorly relative to the other and that would cause you to do more of an evaluation as to why that is happening and may, in fact, cause you to conduct a complete overhaul to improve its performance. So that the incentives that exist with the establishment of goals and trending and performing root cause analysis and having records for the more safety significant components and trains within the context of the maintenance rule, I think, will give us a slightly different picture than what we've had in the past. We're no longer testing to get it to pass and not keeping track of how many times it's failed in the past or how many times you've tested it. As long as the last test was successful, you can operate until the next required test. So, it's a rather different regulatory context that we're moving to and I think that it will result with time in improvement and you will identify trains or systems which are not performing well and then be able to take corrective

action for those and address them.

CHAIRMAN SELIN: Which gets me to my third question. Sometimes like diesels, you're not really so worried about whether a particular component or a particular system has failed but you have very high reliability, but also very high reliability demanded. What you're trying to find out is if the population is aging as opposed to a particular piece. In other words, if reliability is going from 99 to 95 or 96 percent, where one test doesn't tell you very much about one component, but the universe tells you a lot about the universe.

Is there research to be done? Is there just a question of building componentorial models to say as we get into the extended period and as we're using the monitoring of failures of a whole universe, are we set to say we're starting to be concerned about some set of components, even though we're talking about small numbers of failures?

MR. RUSSELL: Clearly as it relates to a plant-specific basis, the requirements that are embodied within the maintenance rule would gather that information on a plant-specific basis. I believe that we have a paper and we're going to be discussing with you how industry experience is collected broadly, both

from an availability, reliability standpoint as it relates to trains and systems. So, I believe that's a topic for a separate discussion. That is a question right now where the staff has some concerns and we are interacting with industry to try and address those concerns.

CHAIRMAN SELIN: Thank you.

MR. CRAIG: (Slide) Slides 55 and 56 provide the overall summary of findings from the Aging Research Program. There's several aspects of it that I think are particularly significant. One is that the results are applicable to operating plants and are being utilized by the industry already. As I indicated, we've seen that not just from our publications but from the utilization of our results in other publications and we've seen that also as a result of plant inspections. We've made significant progress in the area of the reactor pressure vessel over the years and indeed we're developing a rule to address annealing for reactor pressure vessels as well as relatively new programs to look at containments.

So, as you look at aging, you identify issues that relate to current plants, older plants and future plants and we're trying to address those and incorporate the results in all those three activities.

We've found some hard spots where current programs don't address degradation at check valves because some check valves aren't taken apart and you can't determine from current testing methods whether the check valve is going to open fully on demand or seat fully on demand.

(Slide) Finally, there are two additional issues that are listed on slide 56 that you're familiar with, EQ and fatigue. I'm not going to discuss those, but they're also issues that are related to aging.

(Slide) Slide 57, please.

The other aspect of the utilization of the Aging Research Program results are incorporated, I guess, or addressed as part of the report preparation and indeed in some aspects even as we go to the plants and look at the equipment failure data and discuss with plant personnel what we're looking at, what we're interested in and getting feedback and insights from them and working with the various owners groups and conducting workshops and going to meetings and preparing papers that are published in journals.

(Slide) Slide 58.

An overall wrap-up. The primary system pressure boundary we expect to complete in 1998. As

I indicated, the major electrical mechanical components, I think I said '94 and '95, '96 and '97. The aging of concrete structures sooner than that and, as I indicated, steel containments in '97.

If there are no further questions --

COMMISSIONER REMICK: What do you mean by closure in a case like the primary system pressure boundary?

MR. CRAIG: We believe that the issues that -- the questions that we're addressing on the research program right now will have completed those efforts in the reports prepared.

COMMISSIONER REMICK: There could be other issues that come up in the meantime?

DOCTOR SHAO: Half of that will be maintenance level.

COMMISSIONER REMICK: So, we presumably would maintain the expertise and so forth?

MR. CRAIG: Right. Yes, sir.

MR. RUSSELL: We continue to have problems almost on an annual basis. So, the ones they know about today they expect to complete and address by that time frame, but as time marches on we'll probably add more issues to the request.

CHAIRMAN SELIN: We've talked a little bit

today about the risk analysis where we're talking about refurbishment, but that doesn't appear on this chart. Do we have a more -- or is it implicit in something else?

MR. CRAIG: I think as Joe Murphy indicated, it's an ongoing effort that we're going to continue. We've developed some initial insights and that work was being done under the Division of Engineering. The PRA expertise is another division and so we're working closely with that division to determine what the next step is. Included in that are people and the expertise within NRR.

CHAIRMAN SELIN: I would suggest that probably the probabilistic background is more important than the engineering background in that type of analysis.

Commissioner Rogers?

COMMISSIONER ROGERS: You didn't have a chance to say much about -- or anything much, I guess, about cables. I wonder if you could just take a couple of minutes to say something about what exists today with respect to reliable techniques for monitoring the degradation of signal and power cables in plants? There's a wide variety of different types in use, many of them not very accessible for visual

inspections. What work is ongoing? Do you feel that there are adequate techniques available, NDI techniques to detect degradation of signal and power cables?

MR. CRAIG: Well, NRR has developed a task action plan specifically for EQ and that will address a number of the questions that you raise.

The power cables are of a little bit less concern, because they're not as sensitive to grounds. Major shorts, of course, are a problem, but degradation that you would expect as a result of normal service conditions pose more of a problem to the lower voltage, lower current cables.

There are today no reliable techniques to correlate degradation of cable insulation and its properties with age. There are a number of specific tests that have been discussed and pursued, some by the Germans, Japanese, and others, and part of the EQ task action plan is to specifically look at these techniques, see what was learned and determine what research we should do to pursue the one or two or three tests that are most promising, but right now there just aren't any techniques that are reliable.

There are some electrical signal signature test processes that provide information, but, given

the large number of different cables and types and configurations, it poses some significant technical challenges to come up with one or two tests that you can use for the various cables.

MR. RUSSELL: We have also requested that Research look into the elasticity of the insulator and see if there could be some correlation developed which would allow you to take a sample and maybe test elasticity and then correlate elasticity to age and/or insulating properties and capability to perform. So those are the types of things we've requested and we've grouped them into instrumentation, such as nuclear instrumentation cable coax where you've got to have a very high signal to ground ratio to control and low power cables and then high power cables. We've developed this as a result of our findings on failures that were done for NRR as a part of our technical assistance activities, looking at specific cables and how they performed if they had been slightly damaged, which came out of the issues from the Tennessee Valley Authority at Watts Bar.

MR. CRAIG: Two additional points on cables. One, as I mentioned, we're going to have a number of people at Trojan this week and one of the specific proposals we're going to discuss is getting

cable samples from the Trojan facility and indeed doing some in-place in-situ monitoring and then try and correlate those and get some new cables, if we can find some of the same type, to correlate the aged specimens that are in Trojan with the new. So, we're going to do that.

The other aspect, as I mentioned, the NRR task action plan on EQ, we're working closely with them to develop the potential research efforts to be pursued related to cables and environmental qualification and that will be discussed with the Commission at a later date.

COMMISSIONER ROGERS: What about some of the --

DOCTOR BECKJORD: Late this fall, probably. It would be ready late this fall.

COMMISSIONER ROGERS: -- defense nuclear plants that are being shut down. Are there any attempts to try to get cables from those that might provide some additional information?

MR. CRAIG: Not that I'm aware of. It's certainly something that we could pursue and I don't know if it was one of the things that was laid out in the task action plan.

Bill, do you know?

I just don't recall.

MR. RUSSELL: I'm not able to answer that.

COMMISSIONER ROGERS: Might be worth looking into. There might be some sources there --

MR. CRAIG: We will.

COMMISSIONER ROGERS: -- with some useful information.

COMMISSIONER REMICK: Just a couple questions mostly of what we didn't talk about, but the first one is related to the pressure vessel. I remember being impressed with the low contamination level of some of the former Soviet Union reactors and one of the explanations given was the fact that they did not use stainless steel liners.

Have we looked or has EPRI looked at the pros and cons of liners other than stainless steel from the standpoint of keeping contaminants low?

MR. CRAIG: Not to my knowledge. I'll ask Chuck Serpan if he knows.

Bill, do you know?

MR. RUSSELL: No, I don't.

MR. CRAIG: I don't know.

MR. SERPAN: Chuck Serpan, again, from the Research Staff.

We put that question to the industry and

they're aware of it, but they just haven't looked into it. I think the designs for future plants, in any event, are pretty well set.

COMMISSIONER REMICK: Yes.

MR. SERPAN: And as a result of that, why, they felt they probably weren't going to be able to take advantage of what the Russians have come up with.

COMMISSIONER REMICK: I see. Thanks, Chuck.

What has been the success of the replacements in BWRs of primary systems from the intergranular stress corrosion cracking? Have the new steels worked out quite well?

DOCTOR SHAO: It has been very successful, yes, both replacement and also weld overlay. Both have been very successful.

COMMISSIONER REMICK: Good. So we have, what, maybe a decade of experience for those replacements now or close to it?

DOCTOR SHAO: Right.

COMMISSIONER REMICK: Good.

And then one on page 27. You need not refer to it, but the statement is made, "Turbine driven pumps have much lower reliability than motor driven pumps." I couldn't resist mentioning this

because it reminds me of the discussion that has cropped up from time to time with ACRS on the question of does one have diversity for diversity's sake or does one have diversity for reliability's sake.

I must admit here is an area that to me always steam driven pumps and electrical pumps made sense to me from a diversity standpoint because you have a completely different energy supply for driving the system, but it is a case apparently where that diversity leads to lower reliability. I just couldn't help but make that point because from time to time we get into that discussion of should you have diversity just because you should have diversity or what is important. You do it from a reliability standpoint.

Is there any way of improving reliability of those steam-driven auxiliary feedwater pumps? Is it a question of maintenance? Is it a question of design?

MR. CRAIG: I think the single largest contributor to unreliability is the governor controls of the turbine. The turbine is pretty reliable if the governor is good. We're making improvements. The industry is making improvements in that area, so I think the reliability of the governor systems for turbines is improving and that's another area that

affects not just the nuclear industry but that these governors are used for turbines elsewhere also.

COMMISSIONER REMICK: Yes. I guess we need better mechanical engineers, from what it sounds like here. All of our problems, steam generators, all these things, need better mechanical engineers.

Thank you very much. I found the presentation very good, very helpful. I look forward that maybe with some future ones you might even have some visuals so we can see things like some of your actual testing that's underway, show us some of the things that are being done. It was a good presentation.

CHAIRMAN SELIN: Commissioner de Planque?

COMMISSIONER de PLANQUE: I have one very general question and I'm really only looking for a ball park answer. You mentioned in the beginning that we're spending about $22 million on the whole aging program and Commissioner Remick pointed out that aging of these types of components is of interest to a lot more industries than just the nuclear power plant industry. Do you have any feel for what fraction of the total research being done on aging of these types of components is coming from NRC?

MR. CRAIG: I don't have a good feel for

it. Somebody else might. I can say that in the area of materials, as a result of the international efforts, that we're reaping significant information for a lot less than it would cost us if we had to do it by ourselves, so I can address that.

I think as far as the other components and systems, the bulk of that effort is NRC effort as opposed to foreign effort.

DOCTOR BECKJORD: EPRI has a large program on motor-operated valves. I've heard a number --

DOCTOR SHAO: 18 million.

COMMISSIONER REMICK: How much?

DOCTOR SHAO: 18 million.

COMMISSIONER de PLANQUE: Just on the valves?

DOCTOR SHAO: On MOVs, yes.

MR. RUSSELL: That's really driven by Generic Letter 89-10. That was not driven by --

COMMISSIONER de PLANQUE: No cost responsibility here. Okay. Thank you.

That's all.

CHAIRMAN SELIN: This was an excellent presentation, Mr. Craig, and others. The last one opened a lot of questions which I didn't really existed. This has started to answer more than a few

of them and I think we'll be very interested in where we go and the results. I would hope that a comparable effort on the PRA side of things continues in parallel with the more straight engineering materials and components piece. Not that that's the ultimate question, but how these components add up to an overall risk assessment clearly is a critical question.

You know, Ricky Pierce makes 97 percent of his foul shots. If he misses three in a row is it because he's getting old or is it because he missed three in a row? That's the kind of thing that we have to worry about with diesels and some of these related items.

Thank you very much.

MR. CRAIG: Thank you.

(Whereupon, at 3:34 p.m., the above-entitled matter was concluded.)

CERTIFICATE OF TRANSCRIBER

This is to certify that the attached events of a meeting of the United States Nuclear Regulatory Commission entitled:

TITLE OF MEETING: BRIEFING ON NRC RESEARCH PROGRAM ON AGING

PLACE OF MEETING: ROCKVILLE, MARYLAND

DATE OF MEETING: AUGUST 30, 1993

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

Carol Lynch

Reporter's name: Peter Lynch

THE AGING RESEARCH PROGRAM

BRIEFING TO THE COMMISSION

August 30, 1993

Office of Nuclear Regulatory Research

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THE AGING RESEARCH PROGRAM
PRESENTATION OUTLINE

- Development of Aging Research Program
  - Program Objectives
  - Process for Identification of SSCs
- Research Topics
- Discussion of Specific Topics
  - Issues
  - Results
  - Utilization
- Insights From Aging Risk Analysis
- Overall Summary
- Closure

THE AGING RESEARCH PROGRAM
DEVELOPMENT OF AGING RESEARCH PROGRAM

PROGRAM OBJECTIVES

- To Identify, Characterize, and Assess Aging and Degradation Effects Which Could Impair Plant Safety.
- To Evaluate Inspection, Surveillance, and Monitoring Methods.
- To Evaluate Existing Utility Programs.

THE AGING RESEARCH PROGRAM
DEVELOPMENT OF AGING RESEARCH PROGRAM

PROCESS FOR IDENTIFICATION OF SSCs

- **Defense-In-Depth Framework**
    - **Integrity of Reactor Coolant Pressure Boundary**
    - **Capability to Shutdown and Core Cooling**
    - **Ability to Remove Decay Heat**
- **Insights Gained From Probabilistic Risk Assessment (PRA)**
- **Operating Experience**
- **Engineering Judgement**

THE AGING RESEARCH PROGRAM
RESEARCH TOPICS

Electrical & Mechanical Components & Systems

30 Components

Examples:

- Motor Operated Valves
- Check Valves
- Aux. Feedwater Pumps
- Batteries
- Chargers/Inverters
- Transformers
- Diesel Generators
- Circuit Breakers/Relays
- Heat Exchangers
- Cables

20 Systems

Examples:

- Auxiliary Feedwater System
- Service Water Systems
- Reactor Protection System

THE AGING RESEARCH PROGRAM
RESEARCH TOPICS (CONTINUED)

Materials

Reactor Pressure Vessels

Steam Generators

Piping

RPV Internals

Special Topics

Risk Significance of Aging

Component Prioritization

- For Study
- For Inspection

RecordKeeping Needs

Non-Destructive Exam

Fire Susceptibility

JCCCNRS W.G.s 3 & 12

Shippingport Aging Evaluation

Civil Structures

Concrete Structures

Steel Containments

THE AGING RESEARCH PROGRAM
TOPICS TO BE DISCUSSED

- Reactor Pressure Vessel
- Reactor Coolant System Piping
- Steel Containment
- Electrical & Mechanical Components & Systems
    - Auxiliary Feedwater System
    - Reactor Protection system
    - Service Water System
    - Cables

THE AGING RESEARCH PROGRAM
REACTOR PRESSURE VESSEL

ISSUES

- Embrittlement and Integrity of Reactor Vessel
    - Pressurized Thermal Shock
    - Pressure Temperature Limits
    - Charpy Upper Shelf Energy (the 50 Ft-Lb Limit)

THE AGING RESEARCH PROGRAM
REACTOR PRESSURE VESSEL

RESULTS

- Fracture Mechanics Methods Developed and Validated
  - Linear Elastic Fracture Mechanics In ASME Code Validated by Intermediate Vessel Tests at ORNL
  - Pressurized Thermal Shock Analysis Methods Validated by Vessel Tests at ORNL
  - Elastic Plastic Fracture Mechanics Used for Low Upper Shelf Toughness Adequacy Evaluation

- Embrittlement Trends Result From Neutron Fluence and Chemical Composition of Steel and Welds
  - Copper, Nickel, Neutron Fluence, and Operating Temperature Primary Factors Affecting Embrittlement

THE AGING RESEARCH PROGRAM
REACTOR PRESSURE VESSEL

RESULTS (Continued)

- **Annealing Research Results**
  - **Can Restore Most of Original Fracture Toughness**
  - **NRC and Industry Research Shows Recovery of Initial Properties for 850°F Anneal Temperatures**
  - **Interaction With Russians Confirms Recovery Observations**
  - **Reembrittlement Rate Not Accelerated -- Original Trend is Conservative Estimate**
  - **NRC/Industry Team Visited Novovoronzeh-3 to Witness Annealing of VVER-440**

THE AGING RESEARCH PROGRAM
REACTOR PRESSURE VESSEL

UTILIZATION

- **Provided Technical Basis for PTS Rule and Regulatory Guide (10 CFR 50.61 and R.G. 1.154)**

- **Developed R.G. 1.99 -- Embrittlement Estimation Methods -- Used in P-T Limits and RT_{PTS}**

- **Developed and Provided Basis for 10 CFR 50, App. G -- Fracture Toughness Requirements**

- **Developed Draft Guide on "Evaluation of Reactor Pressure Vessels With Charpy Upper-Shelf energy Less Than 50 Ft-Lb"**

- **Developed Draft Guide on "Calculational and Dosimetry Methods For Determining Pressure Vessel Neutron Fluence."**

THE AGING RESEARCH PROGRAM
REACTOR PRESSURE VESSEL

UTILIZATION (Continued)

- Technical Basis for ASME App. G
  - P-T Limit Evaluation Methods
- Analysis Methods Used in Plant-Specific Evaluations
- Technical Basis for Proposed Rule and Regulatory Guide on Thermal Annealing
- Potential Mitigation Methods
  - Flux Reduction
  - Annealing - Rule and Regulatory Guide in Concurrence to Issue for Comment

THE AGING RESEARCH PROGRAM
REACTOR PRESSURE VESSEL

STATUS

- **Completed**
  - ▸ **Research To Develop Basic Pressure Vessel Safety Criteria And Analysis Methods -- Normal Operation Criteria And Accident Conditions**
  - ▸ **Research to Develop Material Property Data And Irradiation Effects Data**
  - ▸ **Large-Scale Validation Experiments**

THE AGING RESEARCH PROGRAM
REACTOR PRESSURE VESSEL

STATUS (CONTINUED)

- Future Research
  - Revise Analysis Methods to Reduce Unnecessary Conservatism
  - Expand Irradiation Effects Studies to Address Broader Range of Materials and Conditions
  - Validate Irradiation Analysis Methods Through Examination of Materials Removed From Service
  - Validate Analysis Methods Through Analytical Research and Participation in International Benchmark Experiments
  - Annealing (Emphasis on Engineering Issues)
- Schedule to Complete in FY 1998

THE AGING RESEARCH PROGRAM
REACTOR COOLANT SYSTEM PIPING

ISSUES

- Pipe Cracking and Degradation
  - Erosion/Corrosion
  - Fatigue
  - Intergranular Stress Corrosion Cracking (IGSCC)
- Non-Destructive Examination (NDE)

THE AGING RESEARCH PROGRAM
REACTOR COOLANT SYSTEM PIPING

RESULTS

- Developed Technical Basis for Evaluating Degraded Piping

- Defined the Effects of LWR Environments on Cracking and Fatigue

- Developed Technical Basis for Leak-Before-Break

- Evaluated Existing and New NDE Methods.

- Evaluated the Parameters Used in EPRI's Computer Code on Erosion-Corrosion

THE AGING RESEARCH PROGRAM
REACTOR COOLANT SYSTEM PIPING

UTILIZATION

- **Technical Basis for Accepting Leak-Before-Break in GDC-4**
  - Design Certification
  - Current Plants
- **Experimental Basis for ASME Section XI Procedures on Flaw Evaluation for Piping**
- **Evaluated Industry Proposals for "Fixes" to IGSCC**
  - Water Chemistry
  - Weld Overlay
  - Induction Heating
  - Replacement Material

THE AGING RESEARCH PROGRAM
REACTOR COOLANT SYSTEM PIPING

UTILIZATION (Continued)

- Provided Experimental Data and Developed Model to Predict Toughness Loss In Cast Stainless Steels
  - Degradation Not as Severe as Once Believed
- Provided Interim Curves for Assessing Effects of LWR Coolant on Fatigue Life of Components
- Validated Inspection Procedures And Operator Training For Inspecting Pipes Containing IGSCC

THE AGING RESEARCH PROGRAM
REACTOR COOLANT SYSTEM PIPING

STATUS

- **Completed**
  - IGSCC Testing on 304 SS in BWR Environment
  - Fracture Tests on Large Cracks in Straight Pipe And Welds Under Quasi-Static Loads
- **Future Research**
  - Environmental Effects on Fatigue Life
  - Fracture Tests Under Seismic/Dynamic Loads
  - Proposed New Industry Position Concerning First-of-a-Kind Engineering -- Major Change in ASME Design Code Proposed
- **Schedule To Complete In FY 1997**

THE AGING RESEARCH PROGRAM
STEEL CONTAINMENTS

ISSUES

- Appearance of Unanticipated Corrosion in Steel Containments
  - Ice Condenser Containments (4)
  - Mark I Containments (9)
- Inspection Requirements and Effectiveness of Inspection Techniques
- Effects of Local Corrosion on Margin to Failure

THE AGING RESEARCH PROGRAM
STEEL CONTAINMENTS

RESULTS

- No Results to Date, Effort Just Begun
- Effort is Centered on:
  - Materials Technology and Inspection Techniques
  - Projections of Performance Over Time
  - Predictability of Localized Failure Modes

THE AGING RESEARCH PROGRAM
STEEL CONTAINMENTS

UTILIZATION

- Future Results Are Intended to be Used Both in ASME Code Revision And in NRC Staff Positions

- Improvements in Inspection Requirements And Acceptance Criteria For ASME Section XI, Subsection IWE

- Basis For NRC Staff Position on Acceptability of Localized Degradation

STATUS

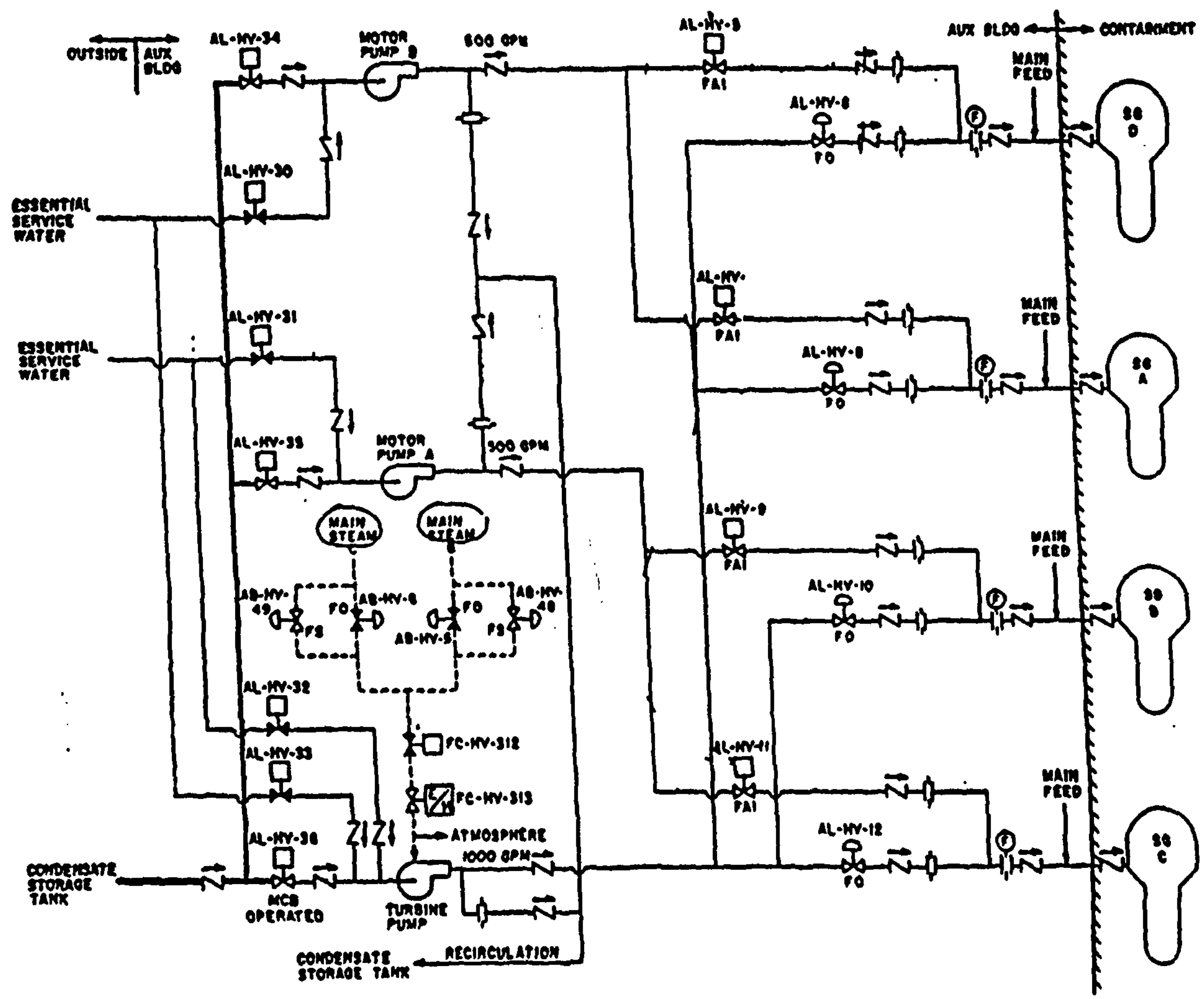
Program Will be Complete in FY 1997

THE AGING RESEARCH PROGRAM
ELECTRICAL & MECHANICAL COMPONENTS

APPROACH

- Phase I:
  - Review Operating Experience (Post Mortem)
  - Evaluate Existing Activities
- Phase II For Selected Systems & Components:
  - Evaluate Effectiveness of Monitoring Methods to Detect Aging Degradation
  - Perform Selected Confirmatory Testing, If Warranted
- Phase III
  - Utilization

THE AGING RESEARCH PROGRAM
AUXILIARY FEEDWATER SYSTEMS (AFWS)

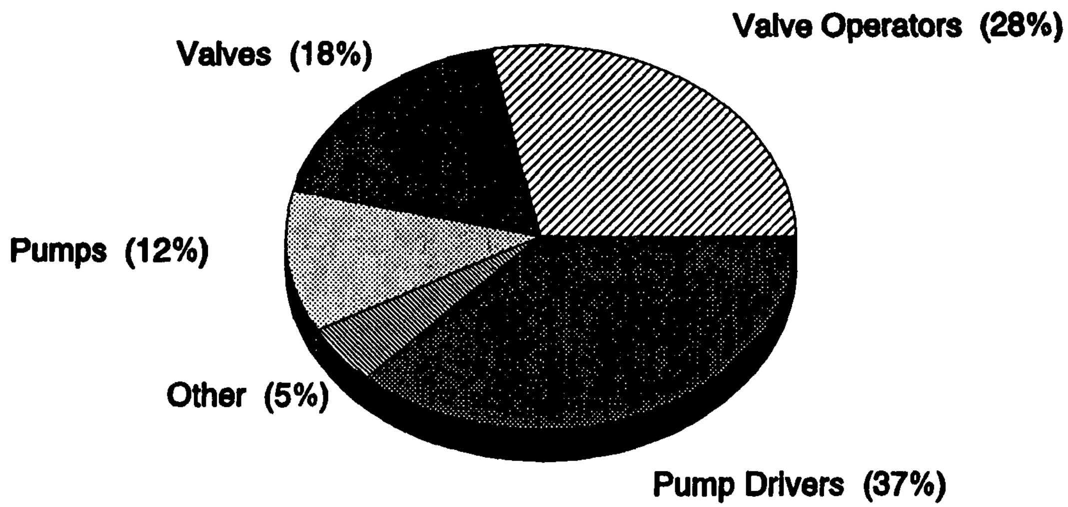


THE AGING RESEARCH PROGRAM
AUXILIARY FEEDWATER SYSTEMS (AFWS)

RESEARCH RESULTS:

RELATIVE SOURCE OF FAILURE

Total Failure Count = 1,767 through 1987



THE AGING RESEARCH PROGRAM
AUXILIARY FEEDWATER SYSTEMS (AFWS)

RESEARCH RESULTS (Continued):

- Aging Mechanisms and Their Locations In The AFW Pumps Include:
  - Bearing Wear, Corrosion
  - Shaft Seal Deterioration
  - Wear Between the Rotating and Stationary Parts
  - Impeller Wear
  - Thrust Balancer Wear, Galling and Seizing
  - Shaft Breakage
- 20% (354) of Failures Were Experienced on Demand
- Cavitation During Low Flow Operation Contributes to Diffuser Vane Damage.
- Low Flow Hydraulic Instability Results in Premature Pump Degradation, Bearing, Seal and Thrust Balance Device Wear

THE AGING RESEARCH PROGRAM
AUXILIARY FEEDWATER SYSTEMS (AFWS)

<u>CONCLUSIONS:</u>

- **Current Testing Programs Do Not Detect Some of The Potentially Significant AFW Pump Degradation Prior to Failure**
- **Turbine Driven Pumps Have Much Lower Reliability Than Motor driven Pumps**
- **The Refurbishment of Piece Parts May Not Be Effective to Mitigate All Significant Aging Mechanisms Within a Component**

THE AGING RESEARCH PROGRAM
AUXILIARY FEEDWATER SYSTEMS (AFWS)

UTILIZATION:

- **ASME Updating the Operations & Maintenance (O&M) Standard 6 "Requirements for Performance Testing of Pumps in Light Water Cooled Nuclear Power Plants."**
- **Results of Research Being Used by the Industry in the Development of Their Life Cycle Management Programs**
- **Supported NRR in the Implementation of Bulletin 88-04, "Potential Safety-Related Pump Loss"**

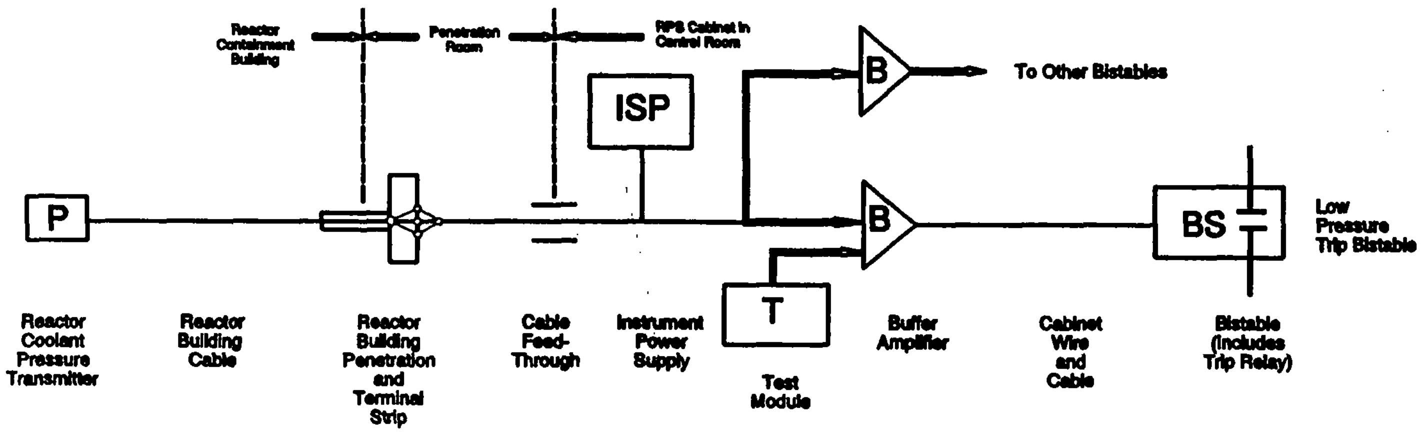
THE AGING RESEARCH PROGRAM
AUXILIARY FEEDWATER SYSTEMS (AFWS)

STATUS

- **Research is Complete**
- **Dissemination and Utilization of Research Results Will Continue**

THE AGING RESEARCH PROGRAM
REACTOR PROTECTION SYSTEM (RPS)

RPS REACTOR COOLANT PRESSURE CHANNEL

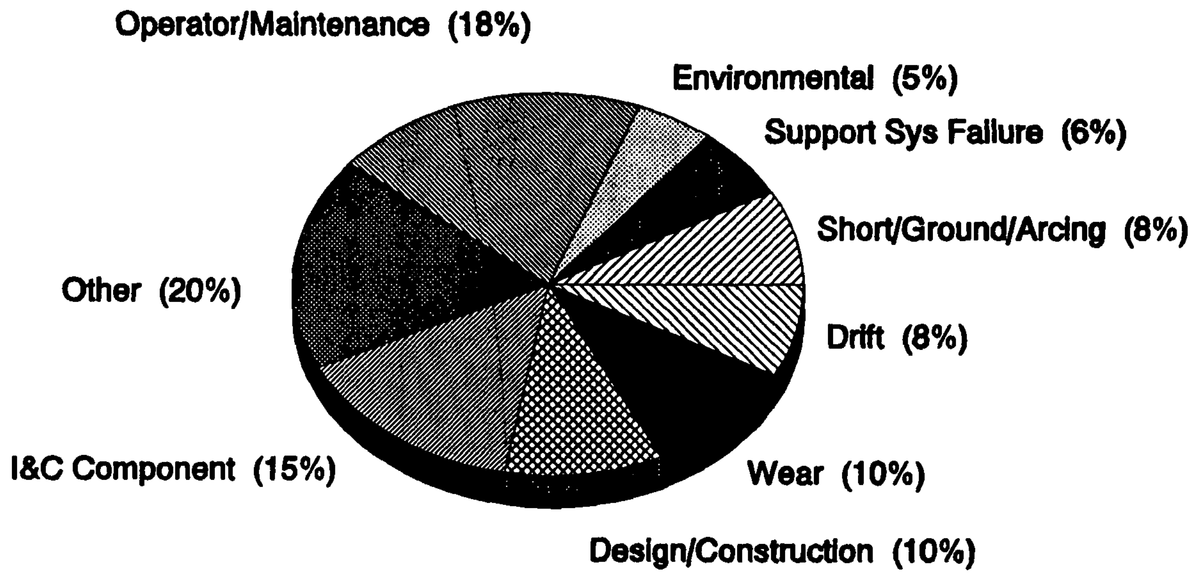


THE AGING RESEARCH PROGRAM
REACTOR PROTECTION SYSTEM (RPS)

RESEARCH RESULTS:

Causes of Failure

(Total Number of Failures = 3,533, NPRDS to 1988)

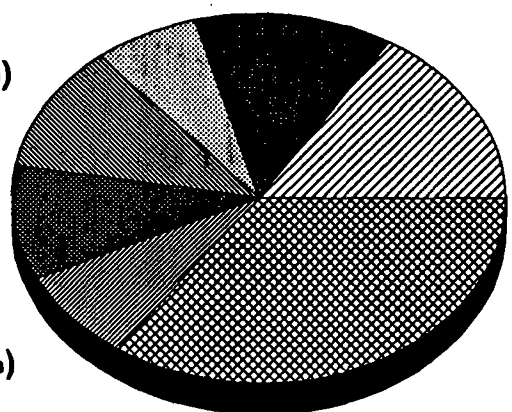


THE AGING RESEARCH PROGRAM
REACTOR PROTECTION SYSTEM (RPS)

RESEARCH RESULTS (CONTINUED):

SUBCOMPONENT FAILURE SUMMARY

FAILURE COUNTS = 1060 ALL PWRS



THE AGING RESEARCH PROGRAM
REACTOR PROTECTION SYSTEM (RPS)

RESEARCH RESULTS (Continued):

- **Approximately 34% of the Failures Occurred Upon Demand**
- **Of the Aging Related Failures Found Approximately 0.2% (6) Resulted in Overall Protection Functional Failure**
- **Aging Mechanisms and Their Locations Are:**
  - **Mechanical Wear of Relay Contacts**
  - **Sensor Drift**
  - **Short Circuits/Grounding/Arcing Due to Degradation of Insulation**
  - **Normal Wear of Moving Parts/Light Bulb Wear out**
  - **Corrosion of Contacts and Sensors**

THE AGING RESEARCH PROGRAM
REACTOR PROTECTION SYSTEM (RPS)

CONCLUSION:

- Current Programs are Adequate to Manage Age Related Degradation of Components in RPS -- Components Are Frequently Tested And Replaced.

THE AGING RESEARCH PROGRAM
REACTOR PROTECTION SYSTEM (RPS)

UTILIZATION:

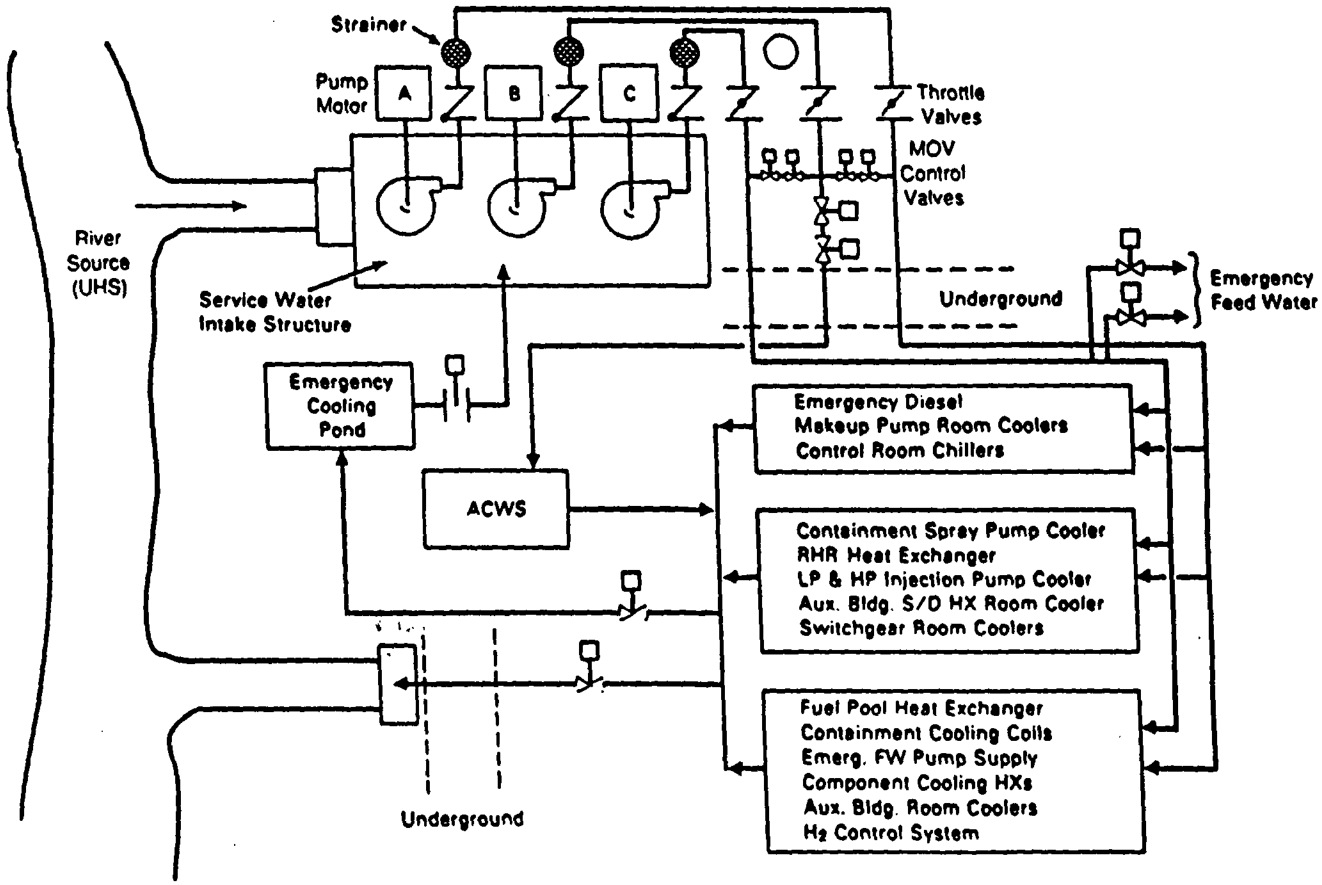
- **Results of The Study Were Incorporated in IEEE Std 1205-1993, "Guide For Assessing, Monitoring, and Mitigating Aging Effects on Class 1E Equipment Used in Nuclear Power Generating Stations"**

THE AGING RESEARCH PROGRAM
REACTOR PROTECTION SYSTEM (RPS)

STATUS:

- **Research is Complete**
- **Dissemination and Utilization of Research Results Will Continue**

THE AGING RESEARCH PROGRAM
SERVICE WATER SYSTEMS (SWSs)



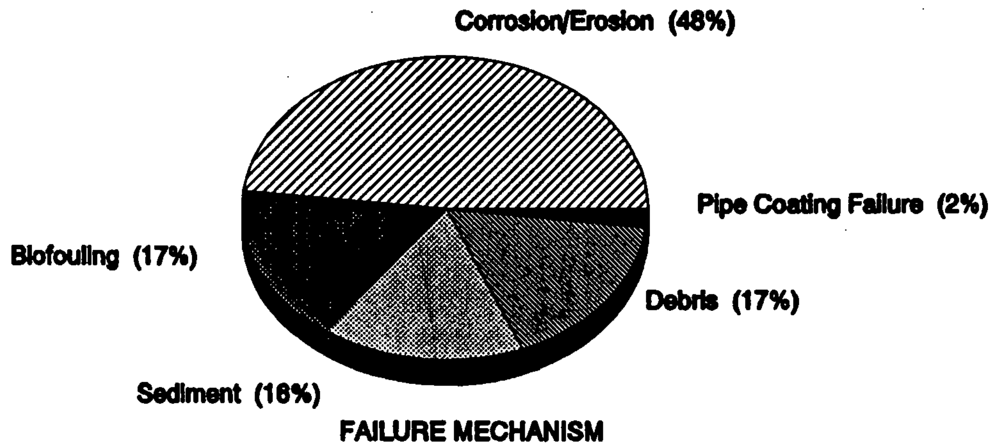
Open Service Water System - Once-Through-System

THE AGING RESEARCH PROGRAM
SERVICE WATER SYSTEMS (SWSs)

RESEARCH RESULTS:

BASED ON LER DATA FROM TO 1980 TO 1987

Total Failure Counts = 980



THE AGING RESEARCH PROGRAM
SERVICE WATER SYSTEMS (SWSs)

RESEARCH RESULTS (Continued):

- **Significant Aging Mechanisms and Their Locations Include:**

  - **Pumps**

    - **Impellers are Subject to Wear, Cavitation, Inorganic Attack (Chemical) and Erosion**
    - **Casings are Subject to Erosion, Cavitation, and Inorganic Attack**
    - **Bearings are Subject to Vibration, Corrosion, Wear, and Lubrication Degradation**
    - **Packing and Seals are Subject to Corrosion, Erosion, and Wear**

THE AGING RESEARCH PROGRAM
SERVICE WATER SYSTEMS (SWSs)

RESEARCH RESULTS (Continued):

- **Valves**
  - Bodies are Subject to Corrosion, Erosion, Microbiologically-Induced Corrosion (MIC), and Pitting
  - Seats are Subject to Corrosion, Erosion, and Deposition
  - Discs/Gates are Subject to Corrosion, Fatigue, and Biological Attack
  - Stuffing Boxes are Subject to Corrosion and Wear

- **Heat Exchangers**
  - Tubes are Subject to Corrosion, Biofouling, MIC, Erosion, and Inorganic Attack
  - Tubesheets are Subject to Corrosion, Biofouling, MIC, Debris Accumulation, and Inorganic Attack
  - Waterboxes are Subject to Corrosion, Biofouling, Organic Attack and Inorganic Attack

THE AGING RESEARCH PROGRAM
SERVICE WATER SYSTEMS (SWSs)

RESEARCH RESULTS (Continued):

- Piping
  - Walls are Subject to Corrosion, Coating Loss, Biofouling, Deposition, Sedimentation, Inorganic Attack, Pitting, and MIC
  - Flanges and Gaskets are Subject to Corrosion, Erosion, and Pitting
- Intake Structure
  - Intake Structures are Subject to Biofouling, Corrosion, Debris Blocking, and Sedimentation

THE AGING RESEARCH PROGRAM
SERVICE WATER SYSTEMS (SWSs)

CONCLUSIONS:

- GL 89-13 Provides An Effective Framework to Monitor Aging in SWSs
- Aging Degradation of Components of Service Water Systems is the Major Cause of System Failure. (Approximately 60% of All Failures)
- Importance of Root Cause Analysis Evaluation to Address Overall Aging Issues of the SWS Demonstrated
- Recent Experience Demonstrates Continuing Problems

THE AGING RESEARCH PROGRAM
SERVICE WATER SYSTEMS (SWSs)

UTILIZATION:

- Used In the Development of Generic Letter 89-13, "Service Water System Problems Affecting Safety-Related Equipment."

- Results Being Incorporated in ASME O&M Guidance Documents

THE AGING RESEARCH PROGRAM
SERVICE WATER SYSTEMS (SWSs)

STATUS:

- **Research is Complete**
- **Dissemination and Utilization of Research Results Will Continue**

THE AGING RESEARCH PROGRAM
WORK TO COMPLETE

- Electrical & Mechanical Components
  - Remaining Phase I And Some Phase II Aging Assessments, For Example:
    - Connectors, Terminal Blocks, and Safety Relief Valves
    - Reactor Core Isolation System, and Chemical & Volume Control System

THE AGING RESEARCH PROGRAM
CABLES

ISSUES

- **How to Assure That The Safety Related Cables Will Perform Their Required Function Under Harsh Environment at The End of Their Qualified Life?**
  - **A Proven Non-Destructive, In Situ Degradation Monitoring Technique For Cables Does Not Exist**
  - **Determination of Residual Life is Difficult Due to Localized Hot Spots and Anomalies**

THE AGING RESEARCH PROGRAM
CABLES

RESULTS

- The LER Database Contains 72 Reports of Cable Failures Attributable to Aging, Mechanical Damage, and Misapplication
- Sandia LOCA Test Results of Pre-Aged Cables Show Some Failures at 20 Years, at 40 Years, and at 60 Years of Accelerated Aging
- Some Okonite Cable Failures Occurred During NRR Sponsored Testing

THE AGING RESEARCH PROGRAM
CABLES

CONCLUSIONS

- Failures of Some Qualified Cables Raises Concerns Relative to Artificial Pre-Aging and Adequacy of Current Environmental Qualification Methods

- Additional Research is Needed to Develop Technical Bases and Criteria for Assessing Cable Degradation

THE AGING RESEARCH PROGRAM
CABLES

STATUS

- In Response to Specific User (NRR) Need RES is Developing A Research Program To:
  - Assess Validity of Current Qualification Methods
  - Evaluate The Use of Accelerated Pre-Aging in Qualification
  - Test a Representative Sample of Cables
  - Evaluate Methods For In Situ Testing And Condition Monitoring of Cables

THE AGING RESEARCH PROGRAM
CABLES

STATUS (CONTINUED)

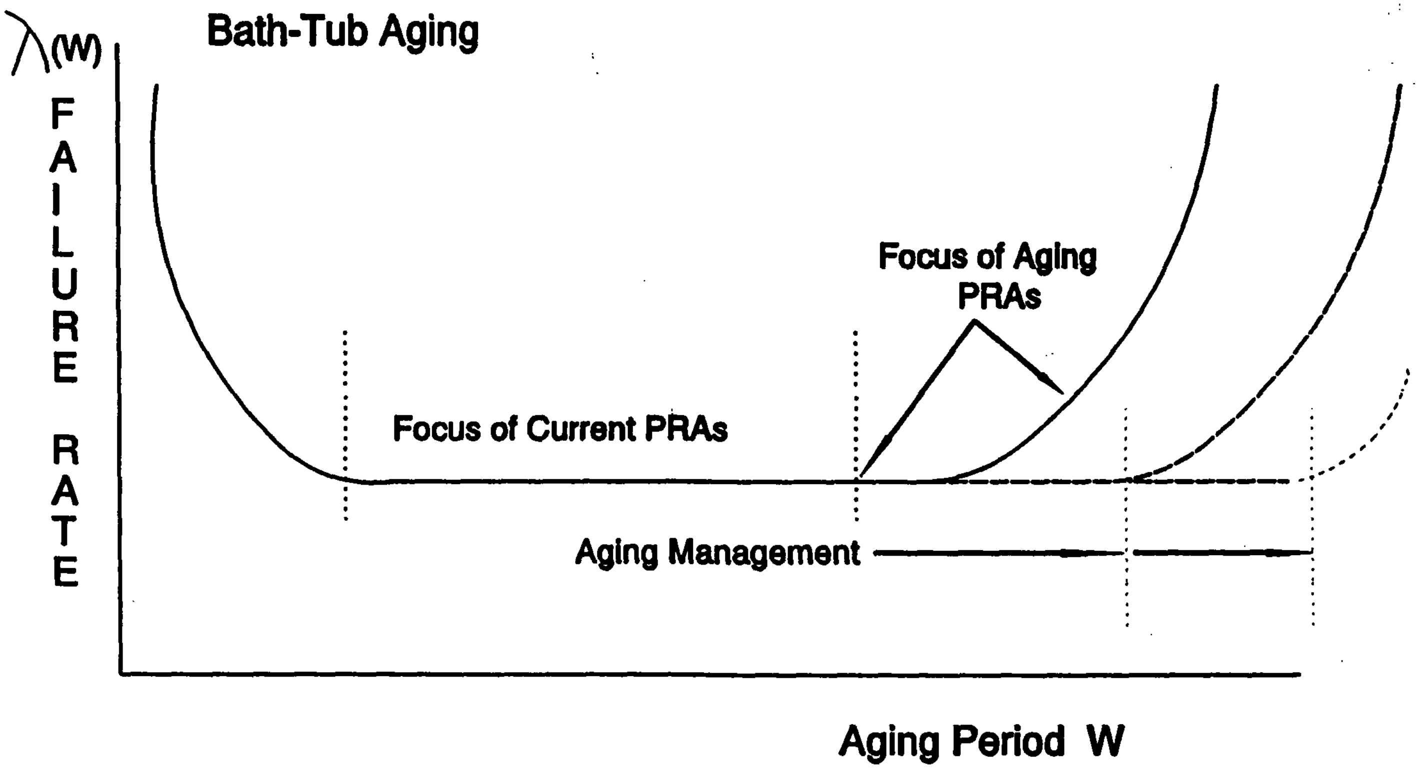
- **Early Research Activities Will Include**
  - **Experts Meeting(s)**
  - **Review And Analysis of Existing Data/Information**
  - **Review of Foreign Experience**
  - **Review And Analysis of Applicable Codes and Standards**
  - **Acquire Naturally Aged Samples of Cables (Trojan, ...)**
  - **Develop a Cable Testing Program**

THE AGING RESEARCH PROGRAM
INSIGHTS FROM AGING RISK ANALYSIS

- Plant Specific Data
- Plant Specific Variables
  - Programs vs Implementations
- Significant Aging Trends are Observed in Some Components
- Aging Degradation Could Lead to Common Mode Failure - Failure of Redundant Components - Not Considered in Present PRAs
- For The Two Plants Considered, Most Failed Components Were Repaired Rather Than Replaced

THE AGING RESEARCH PROGRAM
INSIGHTS FROM AGING RISK ANALYSIS

THE BATHTUB CURVE OF FAILURE RATE VERSUS AGE



THE AGING RESEARCH PROGRAM
INSIGHTS FROM AGING RISK ANALYSIS

SUMMARY OF RELATIVE AGING RATES:

COMPONENT	ENVIRONMENT	RELATIVE AGING RATE (PER YEAR)
ACTIVE	NORMAL	5% - 20%
ACTIVE	HARSH	25% - 100%
PASSIVE	NORMAL	3% - 10%
PASSIVE	HARSH	15% - 25%

THE AGING RESEARCH PROGRAM
INSIGHTS FROM AGING RISK ANALYSIS

- Relatively Few Aging Components are Generally Risk Significant

- However, These Relatively Few Components Can Cause Large Risk Increases if Not Carefully Maintained

- Aging active Components Can Cause as Large Risk Increases as Aging Passive Components

- Refurbishment vs Replacement:

    - The Plants Studied Generally Used Repair (Refurbishment) Rather Than Replacement; eg. Using Old Parts - New Components Limited.

THE AGING RESEARCH PROGRAM
OVERALL SUMMARY

- Structures, Systems, and Components Are Subject To Aging Degradation Such as, Corrosion, Erosion/Corrosion, Fatigue, Embrittlement, Wear, Creep/Shrinkage, Chemical/Biological Attack.
- Environments Are Extremely Important to Aging Degradation
- Embrittlement Trends vs Fluence, Material Composition
- Effectiveness of Annealing
- Aging Mechanisms And Their Locations in Components/Systems Evaluated
- The Most Important Passive Components For Aging Are The Reactor Vessels, Steam Generator, and Cables, And One Aspect of Piping (Erosion/Corrosion).

THE AGING RESEARCH PROGRAM
OVERALL SUMMARY (CONTINUED)

- Relatively Few Aging Active Components Are Generally Risk Significant. However, These Relatively Few Components Can Cause Large Increases in Risk if Not Carefully Maintained.

- The Two Plants Studied in Detail For Risk Analysis Generally Use Repair (Refurbishment) Rather Than Replacement. Failure Rates For Repaired Components Are Higher than For Replaced Components.

- For Many Components, Current Programs Are Adequate But For Some of Them There is Need For Improvement in Implementation. (e.g. Erosion/Corrosion, Service Water System)

- For Some Components, Current Programs do Not Detect Potentially Significant Degradation Prior to Failure

- Equipment Qualification And Fatigue Are Two Major Issues To Be Addressed.

THE AGING RESEARCH PROGRAM
OVERALL SUMMARY (CONTINUED)

- NRR/RES Activities to Utilize Research Results
- Information Supplied to The Industry And The Public
  - Professional Societies (IEEE, ASME, ANS)
  - Water Reactor Safety Information Meetings
  - Workshops and Seminars
  - Peer Reviewed Journals
- Coordination With The International Community

THE AGING RESEARCH PROGRAM
CLOSURE

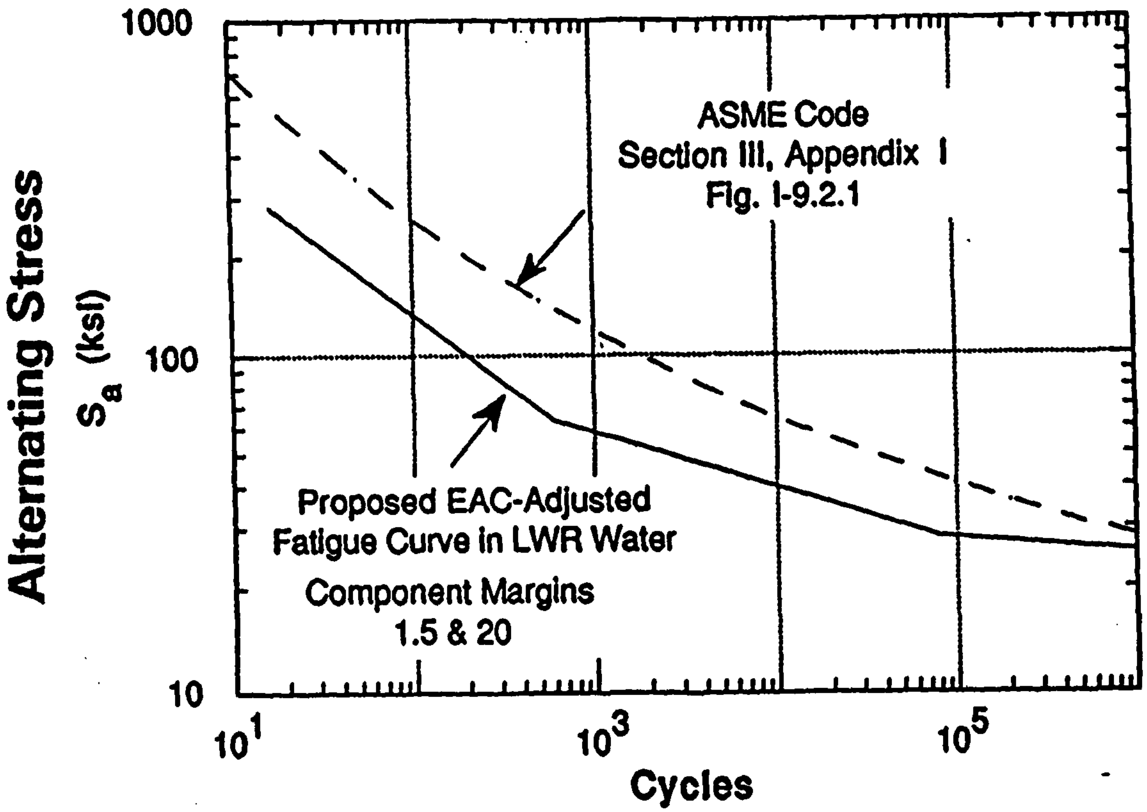
• Primary System Pressure Boundary	1998
• Major Electrical & Mechanical Components	1996/1997
• Aging of Concrete Structures	1994
• Aging of Steel Containments	1996/1997

THE AGING RESEARCH PROGRAM

ADDITIONAL INFORMATION

- Revised Fatigue Curve(s)
- Concrete Structures
- Batteries
- Digital I&C

THE AGING RESEARCH PROGRAM
ADDITIONAL INFORMATION



Proposed EAC-adjusted design curves for austenitic stainless steels in water at temperatures between 200 and 320°C

THE AGING RESEARCH PROGRAM
CONCRETE STRUCTURES

ISSUES

- Structural Capacity (Margin) at The End of Design Life
- Effectiveness of Current Inspection & Repair/Preventive Maintenance Programs
- Assess Capacity of Aged/Degraded Structures

THE AGING RESEARCH PROGRAM
CONCRETE STRUCTURES

RESULTS

- **Developed a Concrete Materials Aging Database and Produced a Report, With Examples, on How to Apply the Database (ORNL/NRC/LTR-92-8)**
- **Developed a Means of Evaluating the Safety Significance of Structural Degradation Mechanisms (ORNL/NRC-LTR-90-17)**
- **Developed a Methodology for Reliability-Based Structural Condition Assessments (NUREG/CR-6052)**
- **Program is Being Completed in FY 1994**

THE AGING RESEARCH PROGRAM
CONCRETE STRUCTURES

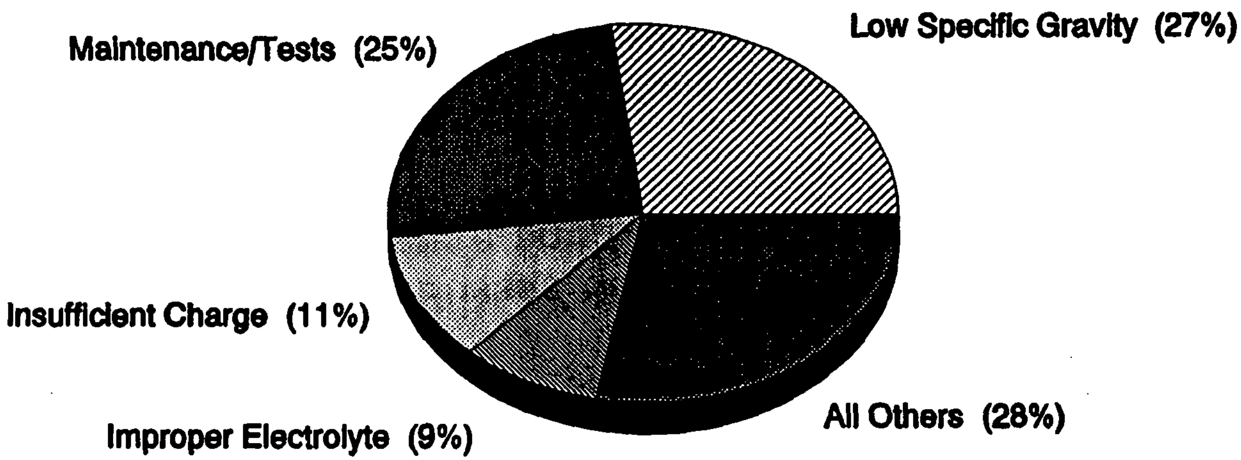
UTILIZATION

- ISI & Assessment Data to Evaluate Current & Future Conditions for Use by NRR
- Techniques to Predict Rate Effects of Aging Mechanisms, and Procedures to Mitigate These Effects
- Guidelines for NRR Structural Reviewers to Evaluate Repair, Replacement, & Retrofitting of Degraded Structures
- Method to Quantify Current and Future Conditions of Structures

THE AGING RESEARCH PROGRAM
BATTERIES

RESEARCH RESULTS:

BATTERY FAILURE EVENTS IN LERs



THE AGING RESEARCH PROGRAM
BATTERIES

RESEARCH RESULTS (Continued):

- Thermally Induced Oxidation of Grids and Top Conductors.
- Oxidation of Top Conductors (Leads) Causes Them to Become Brittle and Susceptible to Breaking
- Plates and Internal Busses Become Brittle When Subjected to Excessive Temperature and Overcharging or When Contaminants are Introduced
- Low Specific Gravity, Insufficient Charge, and Corrosion Contribute to Degraded Battery Conditions
- Batteries Are Now Being Replaced Every 6 - 11 Years

THE AGING RESEARCH PROGRAM
BATTERIES

CONCLUSIONS:

- **Batteries Maintained and Operated in Accordance With IEEE Std 450 and Regulatory Guide 1.129, and Technical Specifications Surveillance Requirements, Provide Reliable Service Life**

THE AGING RESEARCH PROGRAM
BATTERIES

UTILIZATION:

- Research Results Were Utilized
    - In Developing IEEE Good Maintenance Practices
    - In Updating IEEE Std 450
    - In Updating Reg. Guide 1.129
    - In Standard Review Plans for License Renewal Chapter on DC Power Systems

STATUS

- Research Is Complete
- Dissemination And Utilization of Research Results Will Continue

DIGITAL I&C HARDWARE QUALIFICATION RESEARCH

ISSUES

- Technical
  - No Nuclear Plant Experience Base
  - Obsolescence - Present Technical Infrastructure (Analog Parts and Expertise) is Disappearing
  - New Materials and Packaging
  - Different Response Mechanisms to Environmental Stressors (Including EMI)
  - Increasing Functionality and Level of Integration
  - Real-Time Highway Communication: Multiplexed, Distributed Architectures
  - Electromagnetic Compatibility

DIGITAL I&C HARDWARE QUALIFICATION RESEARCH

ISSUES (CONTINUED)

- Regulatory
    - ▸ Develop a Methodology and Technical Bases For The Qualification of Digital I&C Hardware to be Used in New And Replacement Systems
    - ▸ Document a Standardized Approach For Regulatory Use And For Licensing Requirements to Facilitate Consistent Qualification of I&C Equipment Used in New or Replacement Systems
    - ▸ Develop Acceptance Criteria And Regulatory Guidance For EMI/RFI And Qualification of Digital I&C

DIGITAL I&C HARDWARE QUALIFICATION RESEARCH

RESULTS

- Developed a Methodology For Identifying Functional And Environmental Issues
- Developed Environmental Stressor Template For Westinghouse AP-600, GE ABWR/SBWR, And ABB/CE System 80 +
- Issued For Internal Review, Draft NUREG/CR-5904, "Environmental Qualification And Functional Issues For Protection Systems in Advanced reactors."
- Developed Technical Bases For Regulatory Guidance on Susceptibility of Digital Systems to EMI And RFI (Draft NUREG/CR-5941)
- Developed Draft Regulatory Guide DG-1029, "Guidelines For Electromagnetic and Radio-Frequency Interference in Digital I&C Systems For Nuclear Power Plants."

DIGITAL I&C HARDWARE QUALIFICATION RESEARCH

UTILIZATION

- Developed Draft Regulatory Guide DG-1029 and Draft NUREG/CR-5904 And Draft NUREG/CR-5941 As Previously Stated

STATUS

- This Relatively New Research Program Will continue Through FY 1996 to Accomplish The Following:
  - Develop Regulatory Guidance and Acceptance Criteria For EMI/RFI in Digital Systems
  - Develop Regulatory Guide(s) for Qualification of I&C Equipment
  - Experimental Verification
    - EMI/RFI Testing
    - Selected Smoke, Humidity and Temperature Testing