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(202) 234-4433

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PUBLIC MEETING

Nuclear Regulatory Commission
One White Flint North
Rockville, Maryland

Tuesday, July 20, 1993

The Commission met in open session, pursuant to notice, at 1:30 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

DONALD HASSELL, Office of the General Counsel

JAMES TAYLOR, Executive Director for Operations

ERIC BECKJORD, Director, Office of Research

CLEMENS J. HELTEMES, JR., Deputy Director, Research

THEMIS SPEIS, Deputy Director for Research

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

1:30 p.m.

CHAIRMAN SELIN: Good afternoon, ladies and gentlemen.

We're pleased to welcome the staff to brief us on the NRC research program. The goal of the program is to provide the independent expertise and technical information needed to support our regulatory activities and to develop the regulations and guidelines necessary to implement Commission policy.

Commissioner Remick and I went down to OMB about a year and a half ago to try to find all the other places in the federal government where nuclear safety research was being carried out and, folks, you are it, so we're depending entirely on you for our independent basis.

Today's briefing will provide an overview of the research program. There are a large number of topics in the handouts, reactor licensing support, reactor regulation support, nuclear material, low-level waste safety, and high-level waste disposal safety assessment. We have two hours, so what we're going to do is we will just take this a topic at a time.

Now there's a risk, of course, that the

overview of the research program might be lost in this, but, since we have such an interest in each of the areas, I think this will probably be the most efficient way and we will cut off at 3:30 and if we haven't gone through the material then we'll reschedule a second piece at which point, Mr. Taylor and Mr. Beckjord, we'll expect you to summarize the program and the priorities, but we'll follow this bottoms-up approach if that's acceptable.

We were briefed earlier this month by the Nuclear Safety Research Review Committee on many of the activities that will be covered today. We would be interested in any new perspectives or updates that the staff may wish to make regarding the briefing that we received earlier this month regarding what you have to talk about today and other related topics, but we'd encourage the staff to emphasize findings that resulted from the research activity as well as closure plans on major issues.

Of course, the viewgraphs are available at the entrance to the room.

Commissioners?

Mr. Taylor?

MR. TAYLOR: Good afternoon.

With me today are Eric Beckjord, Themis

Speis, and Jack Heltemes.

I should note that the Commission has been briefed on parts of the research program, but it's been at least several years since we've given a complete overview.

I'll start off by noting that there certainly have been changes in the conditions and emphasis of the program in recent years. There have been budget pressures which have increased. We have focused the research effort on the regulatory needs of user offices. Completion is now in sight for extensive research in severe accidents and nuclear power plant aging, including aging during extended operation under license renewal.

There is new emphasis in research on passive and advanced light water reactors. There's increased emphasis on international safety research cooperation, cooperation with Eastern Europe, the successor states of the former Soviet Union.

Other safety research programs in support of reactor licensing and regulation in connection with nuclear materials and waste continue with occasional adjustments to address emerging issues.

The presentation this afternoon will cover an overview of the major research programs

constituting the overall program. We'll identify the issues addressed, note important results and outline the plans for completion.

Doctor Beckjord will continue.

DOCTOR BECKJORD: Thank you, Mr. Taylor.

Mr. Chairman, Commissioners, I'm pleased to be here to present this overview to you. It's been several years, as Mr. Taylor said, since we've done this although we have presented parts of the program in the intervening time.

(Slide) Could I have the first slide, please?

This is the outline of the presentation and it is in fact the budget as well. It's the current budget structure and so it shows functions that we're carrying out. It's not an organizational slide.

I am going to focus on the research program and attempt to get through as much of it as time will permit between now and 3:00. I do have some general observations at the end on the program and on administrative actions that are underway.

(Slide) If I could have the second slide, please, this is the budget in dollars in the left-hand column by these same categories and the FTE allowance

for fiscal year 1993 is shown in the columns on the right. There are three columns there: the part of personnel, the part of the FTE budget which is devoted to research on the left of the three; regulation development in the middle column; and the sum of the two in the right-hand column.

COMMISSIONER REMICK: Eric, on that slide on regulatory development on nuclear materials and low-level waste, I was surprised to see the number of people in regulatory development in those two areas. What are the type of things -- and I see that's for fiscal year '93 -- what are the type of things that they are doing?

DOCTOR BECKJORD: Well, first of all, since you've called our attention to that, there is a correction which I should make in the distribution on low-level waste. The total of 25 is really 9 on research and 16 on regulation development, so there's a difference of two each way there.

I think the left-hand column is indicative of the research, which I will be covering, and the middle column is the people who are working on the nuclear material support, which is medical applications, things of that nature, as well as decommissioning. And, by the way, low-level waste is

low-level waste and decommissioning. The budget says "low-level waste," but when you read on further it says "low-level waste and decommissioning" and that's what's indicated here. So, we have a substantial good effort in decommissioning which is taking place under the low-level waste --

COMMISSIONER REMICK: Could you give me some examples of that because I just didn't have a feeling for the type of activities in those two areas that we would be doing in the regulatory --

DOCTOR BECKJORD: Well, that's covered in the -- I was going to cover that later --

COMMISSIONER REMICK: Okay. Later on. Okay.

DOCTOR BECKJORD: -- when we get to it.

COMMISSIONER REMICK: Okay. I was trying to contrast the research activity and the regulatory development.

DOCTOR BECKJORD: Well, the presentation today, the focus is on the research part and not on the regulatory development. So, I don't have a slide which covers the regulation development. But we can comment on that.

MR. TAYLOR: I think, Jack, you can probably comment on that when we get to it.

Do you mind waiting?

COMMISSIONER REMICK: Whatever. Whatever.

DOCTOR BECKJORD: As a matter of interest, the FTE allowance for the end of this fiscal year is 240. The actual number of people on board is 244. So, we are approaching that level. The numbers look good, but there are imbalances in skills that are required and it's going to take some time, as I think we've -- as you've been made aware before, to recover that balance.

(Slide) Okay. If I could go on to the third slide.

The first topic is the support of standard reactor designs. The issue can be summarized as follows. Operating plants depend on emergency power in the event of such things as station blackout to operate emergency safety systems. The aim of the passive plant design is to remove this dependence to the greatest extent possible and to create designs, nuclear plant designs that after an accident would require only minimal human operator actions to maintain a safe and stable condition, at least for a period of time, several days. This would allow adequate time for planning and preparing whatever additional response might be needed.

The question is whether the passive plant dependencies on such passive components as check valves and on the low head of gravity pumping systems, which are very simple in principle, but whether that dependence is going to be reliable. One thing that we know is that designs which are simple in concept tend to become more complex in the course of actual design development. So, it is that question of pursuing the detailed designs against the question of reliability that we're looking at.

(Slide) If I could have the next slide, please.

First, this relates to the design basis thermal hydraulics for the AP600. A careful study was done by our thermal hydraulics people beginning some time ago actually, beginning perhaps four years ago, on the thermal hydraulic performance of the AP600. At that time it was for the purpose of -- it had several purposes. One was a scaling review and that turned out to be important because we had to make a choice of what size test facility we would go for. The ROSA-V test facility, which will carry out the AP600 test, is at a volume scale of 1 to 30, which is quite a good scale size.

The work was also done for the purpose of

selecting the critical test to be done and to prioritize these tests and for the AP600 we believe that the most important tests are the small break loss of coolant accident, the steam generator tube rupture, the main steam line break, the pressure balance line break. That's the connecting line between the core makeup tank and the pressurizer, and the reactor vessel injection line break and finally a failure of the ADS, an inadvertent opening of the automatic depressurization system valve.

So, the results of this early analysis came up with this list of tests and it has been very helpful in the plan and designing of the test facility at ROSA.

COMMISSIONER de PLANQUE: Eric, is that all on schedule?

DOCTOR BECKJORD: Yes.

COMMISSIONER de PLANQUE: Okay.

DOCTOR BECKJORD: The facility will be turned over for check out in December of this year and if there are no problems that will take about a month and it should start the testing cycle in January.

CHAIRMAN SELIN: Are there any other clever questions we should ask? Is the test design on schedule? Is the analysis on schedule? You know, is

the whole program doing okay?

DOCTOR BECKJORD: The analysis on AP600 is well on schedule. The next slide I'm going to come to I can't make that claim, but it's going very well. In fact, the list -- the test list has grown somewhat from what you heard a year ago when we were proposing it. So, I think that program is proceeding very well.

CHAIRMAN SELIN: Okay. Well, if you have a good one, you ought to polish it up and --

DOCTOR BECKJORD: Parade up.

COMMISSIONER REMICK: Eric, it's my understanding that the Japanese ran some experiments before they modified ROSA-V mocking up the AP600, mocking up core makeup tanks and so forth. Do we have access to that data and have we done any validating of our codes based on that information?

DOCTOR BECKJORD: No, we haven't done any code validation. I think we're aware of the test. Yes, we do have the data.

COMMISSIONER REMICK: We have the data? On that slide you also indicate that you're still considering a use of the Oregon State University reactor. Why has not a decision been made on that? What's the hold-up on deciding whether to do it or not?

DOCTOR BECKJORD: Well, the facility is still in construction and it's a Westinghouse facility and they have their own test series. The testing that we would do on it would be when they are finished. So, when the time comes for that, I think that we will -- that's the time that we would open discussions.

COMMISSIONER REMICK: It's an Oregon State facility, isn't it? I mean Westinghouse is paying for the use of it.

DOCTOR BECKJORD: Westinghouse built it at Oregon State University. It's a contract there.

COMMISSIONER REMICK: I thought it already -- no, you're right, it was recently constructed.

DOCTOR BECKJORD: I think this fall it will be completed and go into test. There are some things that we're thinking about. What would be done there is the test of the long-term cooling systems, the in-reactor water storage tank and how that provides water over a long period of time.

I think that there's a good possibility that we would want to proceed and my understanding is that it's available for -- it would be available for doing testing on a contract.

(Slide) If I could have number 5, please, Bob.

This slide shows the status of the design basis accident work in thermal hydraulics on the General Electric SBWR and the AECL CANDU-3. The first point is that the SBWR is a smaller departure from design practice compared to the latest BWR designs in comparison with the Westinghouse AP600, which is more of a departure from their standard design concepts. So, the program for doing tests and for validating codes on the SWBR is in concept and I think it will be in fact a simpler program to carry out.

What's underway now is a review of the design and calculations. We're about perhaps nine months behind the schedule that we had on the AP600. In other words, the status of calculations for the SBWR is perhaps about nine months behind the AP600 work. We have been observing and will observe future tests that GE is doing on its own, both in Switzerland and in Japan. We are about to award a contract to a university for the test facility itself. I can't yet disclose this in public because the negotiations are not complete. But our intent is to construct the test loop, carry out the test program and improve whatever models in the codes need to be improved for the purpose of then turning around and analyzing the full scale SBWR.

As I say, that program is -- I want to emphasize the program hasn't slipped, it's always been behind the AP600 test program. But the facility is -- once the work on the facility gets underway, I think it will be completed in good time and tests will start on schedule when -- about a year.

The final point there on CANDU, the Atomic Energy of Canada eliminated CANDU-3. The note here relates to the request of the AECL for certification of the CANDU-3 design as opposed to the preliminary design review of the concept which AECL originally requested. The research that we're looking at addresses the matter of the positive moderator coefficient considering anticipated trip without scram and also severe accidents for this reactor. The principal difference is the horizontal core and the use of the heavy water moderator. So, that will make some difference to severe accident sequences. The program which we are going to outline and present to you late this fall will account for those things.

CHAIRMAN SELIN: How much of your plan is postulated on any particular AECL plan as opposed to some other plan? In other words, if you knew that they were going to stay in this precertification indefinitely, would you do one thing, if you expected

an application for certification would you do something different?

DOCTOR BECKJORD: Well, I think there's a difference of magnitude in the two, yes. I think that in the preapplication you could probably do a lot of analysis. It seems to me that when you're talking certification the question of testing comes up.

CHAIRMAN SELIN: What is the assumption in your plan?

DOCTOR BECKJORD: Well, we're developing that plan now. I think today I would say that very likely that would call for some kinds of experiments for certification.

MR. TAYLOR: This is going to take a Commission decision on what we do here. If we do analysis it's one thing. If we begin to look at in-depth research, then the issue becomes, I think, the line that the Commission has drawn for the research that we're conducting on AP600 and SBWR. This is research not required for certification. It's confirmatory research. Then the question for CANDU will be is this research necessary for a certification process? We're not ready to answer that question yet, but that's an important question that will have to be considered if they decide they are going to come in

for certification. So, keep that in --

COMMISSIONER ROGERS: Well, do you have to wait for them to firm up that or document that decision? My understanding is they said they're coming in for certification, but to what extent they back that up with paper, I don't know. But do you have to have that in hand to be able to decide what research would have to be done if, in fact, they do come in for certification?

MR. TAYLOR: I think we can lay out basic plans.

Do you all agree?

DOCTOR BECKJORD: Yes.

MR. TAYLOR: Before they make that decision. That's what we'd come to tell you.

DOCTOR BECKJORD: It's based on the assumption that they will come in with their request for certification.

MR. TAYLOR: We will outline the type of program that would be necessary --

COMMISSIONER ROGERS: Can you put a cost on that?

DOCTOR BECKJORD: I'd rather not at this point. I mean it just would come off the top of the head.

MR. TAYLOR: We're not prepared --

COMMISSIONER ROGERS: No, I mean not right here today, but I'm just saying that is it possible to --

DOCTOR BECKJORD: Well, I think when we come in with a plan we'll have a pretty good idea.

MR. TAYLOR: We'll have an estimate.

DOCTOR SPEIS: May I say something? One of the things that we will ask them to do is for them to do certain experiments or certain tests basically. So, we're not talking about what we will do ourselves, but what we think they should do to support the certification.

COMMISSIONER ROGERS: Well, that's a separate question from what we're talking about today. Today we're talking about what we're doing or what we might do.

DOCTOR BECKJORD: No.

COMMISSIONER ROGERS: No?

DOCTOR BECKJORD: What I was addressing was the question of what are the kinds of results that might be needed in connection with the certification, regardless of who does it.

MR. TAYLOR: Of who does it.

COMMISSIONER ROGERS: Oh, I see.

DOCTOR BECKJORD: Either us or in Canada.

COMMISSIONER ROGERS: Oh, I see. All right. Well --

MR. TAYLOR: I think there are two pieces to it.

COMMISSIONER ROGERS: To whatever extent you can sort those out would be very helpful if you do come to some conclusion that we should do something versus they must do something. That would be helpful to know.

MR. TAYLOR: We will make that distinction.

COMMISSIONER REMICK: And I'd just like to add to that. On the part that if you determine there are things that we should do for confirmatory reasons, I trust you'll identify what should be done, not necessarily what we can do within our anticipated resources. In other words --

MR. TAYLOR: Yes.

COMMISSIONER REMICK: At least should we identify what should be done from a confirmatory standpoint and regardless of whether the resources are there or not, we should at least know rather than somebody coming and saying, "This is what we'll do for confirmatory, but we didn't know that perhaps we

should have done more." I hope you'll include that.

DOCTOR BECKJORD: Well, our first step will be to prepare a plan for what we think should be done and then the next step would be to look at it and see what we think ought to be done in one place as opposed to another.

MR. TAYLOR: We'll keep you informed.

COMMISSIONER REMICK: Yes.

DOCTOR BECKJORD: (Slide) If I go to slide 6, please.

The next topic is reactor aging and license renewal and the issue here expresses the question of -- it's the following question. Considering aging degradation, what are the losses of function of key components or systems that could occur? What's the loss of redundancy and redundant systems or the loss of diversity? What is the loss of defense in depth that could accrue from aging? And finally, are there common mode failures in emergency safety systems which are not normally operating which could make a system totally unavailable as a result of aging? I think that's the basic issue.

The second point is that there's a lot of experience with plants. We know that the total reactor years are more than 1500, but it's important

to look at the distribution. Zero to 10 years there's a great deal of experience. Ten to 20 years there's considerable experience. Twenty to 30 years there's some. Thirty to 40 there's a little and 40 to 60 there's no experience. What we can say is that the frequent and the moderately frequent transients which have already occurred will reoccur during a license renewal period, the 40 to 60 year of operation. I think we can also assume that the less frequent transients and the sequences that have not occurred may occur during the 40 to 60 year period.

So, it's in that kind of -- that's the framework for looking at aging research.

COMMISSIONER ROGERS: Well, that's talking about the challenges though, in a sense, isn't it?

DOCTOR BECKJORD: Yes.

COMMISSIONER ROGERS: Yes. But that doesn't by itself address the question of the aging phenomena that might be giving rise to degradation of any piece of equipment such that it can't meet that challenge.

DOCTOR BECKJORD: No. That's the background.

COMMISSIONER ROGERS: Yes. Well, to what extent are you taking that kind of a point of view,

that to look where there might be vulnerabilities that have not turned up so far. You've already pointed out that 40 to 60 years there's no data at all in any kinds of equipment as a result of aging phenomenon. Rather than going back and looking to see, well, what's failed in the past.

DOCTOR BECKJORD: Well, I think there are two questions and this was done in the days when the program was planned, which was about ten years ago. It's been done at recurring intervals since then, what have we learned, what's the new data, what can you conclude now, are there any changes. As I understand it, the people who worked in planning this program, some of whom are here in the back row, and others of whom are in the agency, but they did take a systematic look at aging mechanisms and asked the question where can these kinds of failures occur. In the course of planning it, then they also started looking at the data on component and system failures.

So, I think the two questions reinforce each other. It's a kind of a dialectic process. You look at the one and then you look at the data.

COMMISSIONER ROGERS: Well, it's sort of one starting from a general approach and another one from a specific approach, bottom up versus top down in

that sense and to see where they meet and where, for instance, there might be some suggested places that one might look even though they have not turned up yet for possible aging failures.

DOCTOR BECKJORD: Well, I think that the phenomena of aging from a practical point of view are identified. It's a question of the rate of aging, which there is still going to be uncertainty until we get some more reactor years. It also may be that the combinations in different systems will give different rates. That is to say fretting and corrosion is a good example of that. If you add vibration to something, the fretting can make the corrosion go very much faster. So, I think there's still new information coming in on rates, but I think the basic mechanisms are pretty well identified.

COMMISSIONER ROGERS: Yes, but it's -- you have to know something about history of individual components.

DOCTOR BECKJORD: Yes. Well, I think that there's been an effort to bring that into the program and develop component histories and evaluate performance history.

CHAIRMAN SELIN: I'd like to ask you three questions and they're very big questions, so you have

to think about these a little bit. Number one, what have you found? Where do we see the most significant aging question? What about cables? What about some of these large structural elements that are -- where it's hard to get a lot of history? What do you do for relatively low probability, but high impact questions, which you might not find just looking at experience? Particularly what about embrittlement, what about ways to deal with embrittlement? So, that's question one.

Question two, is the program going to automatically cover aging questions that are relevant to the first 40 years? If we wanted to provide a lot of support to the current inspection program, would we have to do other things?

Number three, should we be doing research on mixed components, refurbished components, et cetera? As I understand the theory, it sort of says you take some cable and you look at them for 20, 40, 60 years. Well, what about components that are undergoing regular preventive maintenance? These individual pieces we don't really care about. What we care about is the super system. You know, how does the system react if -- how does a pump react if, in fact, you're changing each of the cells within the pump? These are organisms, not tissues that we're

talking about. I'm not just interested in the tissue level research, but the organism level. Are we doing anything to answer these questions because the touchiest question in licensee renewal are the characteristics of systems that have been maintained regularly along the way. Do they overall age or if you keep refurbishing them are you sort of resetting them to zero? Then, when you finish those, I've got some easier questions for you.

DOCTOR BECKJORD: Well, I think with respect to your third question about refurbishment and effective maintenance, I think a big part of the answer is the following. In connection with the program, a lot of work has been done on the diagnosis, monitoring and inspection of components.

CHAIRMAN SELIN: That's good.

DOCTOR BECKJORD: In particular developing the analogue to a cardiogram by means of vibration monitoring, by means of looking at motor currents because motor currents tell you a lot about what's happening in a system.

CHAIRMAN SELIN: Okay. But --

DOCTOR BECKJORD: So the refurbished components subject to the same methods of test and inspection, you'll be enabled to follow the history.

CHAIRMAN SELIN: But let's take the cardiogram. A physician, cardiologist, has some idea about how hearts age even though tissues get replaced. The EKG gives them some feeling that he's going to know how a specific heart compares to the universe, but he can also give you or she can also give you information about how the whole thing ages. Do we have some sense of that? Are we assuming that refurbishment can keep components -- well, a simple definition. Is the probability of failure increased with age as it's being refurbished or is the probability of failure -- you know, the mean time between failure is constant as the object is refurbished. Do we have any research that would address that for different components?

DOCTOR BECKJORD: Well, I can't myself give you an answer to that except to say that I think if you take the motor current example you find out whether the -- in the case of a motor driving a valve, you find out when the valve is actually closing and whether there's some kind of interference. When gears are degraded, that interferes with the performance of the valve and that kind of thing shows up very clearly in the --

CHAIRMAN SELIN: That's half the problem.

I mean we need to have confidence that if something goes wrong we'll be able to detect this in time and then action can be taken, which could be closing down the plant or replacing the whole object. But what about the other half, just the overall characteristics because there's an implicit assumption that preventive maintenance will keep -- will basically keep the composite organism from aging. That's basically a lot of what's in the rule and we don't have a basis for it.

DOCTOR BECKJORD: As I understand your question. I think the answer is that we have not researched a life cycle of a motor and valve system. We have looked at it as a system, but we have not taken up the question of refurbishment.

Am I correct on that?

DOCTOR SHAO: We haven't looked that much in detail. Let me give you an example. If we looked at a service water system, the service water system consists of pumps, valves, interior structures, heat exchangers and piping. So, we look at piping, what's called degradation and valve fouling and so on. We look at the heat exchangers, we look at the pumps, we look at the valves, we look at it also intake structures. And also, in some cases we look at a

refurbishment. How often do they replace certain parts, certain seals, certain bolts and so on and we have give a general recommendation. We looking pretty details from whatever we know for that component.

CHAIRMAN SELIN: But what I'm asking is related, of course, but it's a little bit different. I'd like to know if there's a set of components that are hard to keep in mint condition through refurbishment. It's not does refurbishment work or not. That's much too broad a question. But is there a set, are there motor-operated valves? Are there bends in pipes? Are there bearings? Are there certain devices within the reactor itself where you can do all the preventive maintenance in the world, but you're going to slow down aging, but these are the ones we should worry about particularly in license renewal.

DOCTOR SHAO: Okay. Let's say we look at MOV. We look at different degradations. MOV can be erosion, corrosion part of it, can be cracking or can be vibration. For every component we look at different so-called degradation mechanism and we try to address each of them.

CHAIRMAN SELIN: But now take the next question. When we look at an MOV through its life

cycle where people are doing repairs, they're doing refurbishment, is this -- as maintained, not just looking at the original MOV, as maintained.

DOCTOR SHAO: We do look at the maintenance program too. We look at the surveillance program, maintenance program. Also their inspection program.

CHAIRMAN SELIN: Is a ten year old properly maintained motor-operated valve as good as new?

DOCTOR BECKJORD: I think of it this way. If you take the analogy of keeping a car maintained and repaired, you know that there's a certain time for the brake pads. They will run maybe 8,000 miles or something like 8 or 10,000 miles for in town traffic. If you find that you're having to replace brake pads more often than that, there may be something more fundamental wrong with the mechanism and then you go look for it. I think that will be the same --

CHAIRMAN SELIN: Let me try this once more and then I'll drop it. I'm not interested in the brake pads. I'm interested in knowing whether the stopping system of the car is one that will eventually be something that will mean it's just too expensive -- even if you do everything right, it's just too

expensive to maintain the car. I know you can keep overhauling an engine. Very few cars last as long as their engines can last. I'd like to know if we have a research program that's trying to identify major subsystems within the reactor plants that say, even with proper refurbishment, each time you fix it you take another eighth of an inch off the metal or you're taking another three months off the life and eventually these -- even with proper refurbishment.

We have one view in the industry that says a refurbished component is as good as a new component. That's the implication of saying these are components that are not subject to age-related degradation unique to license renewal. There's another view that says if you don't switch out the whole component, you've got to do an extensive amount of analysis. It seems to me that someplace in our research program we should be trying to identify -- I'm sure for some components the first view is true and for some components the second view is true, but we really should be -- I don't want to be prescriptive in the hearing, but it just seems to me that we ought to be worrying about mechanisms, organisms as properly refurbished rather than just the original components.

DOCTOR BECKJORD: We'll take a look at

that. I don't -- as I said, I don't think that we have done that in a systematic way in this aging research program.

CHAIRMAN SELIN: Commissioner de Planque?

COMMISSIONER de PLANQUE: Really after the analogy is biological versus chronological age of the system.

DOCTOR BECKJORD: Yes. Yes. And we have not looked at it in that fashion.

MR. TAYLOR: I think we may have enough information to pull that together though.

DOCTOR BECKJORD: The main point I'm making is we're considering very important rules now which have a couple of assumptions as to the underlying physics and technology. Commissions make guesses, but those will have to be verified over time, depending on how we come out on these guesses.

MR. TAYLOR: Let us come back to you.

CHAIRMAN SELIN: Yes, but partially informed decisions --

DOCTOR BECKJORD: (Slide) Let's go on to slide 7.

I've summarized a lot of information here --

CHAIRMAN SELIN: You know you didn't

answer my other two questions.

DOCTOR BECKJORD: Well, it seemed to me the first question comes up on the reactor pressure vessel.

CHAIRMAN SELIN: Right. Okay.

DOCTOR BECKJORD: On reactor pressure vessels we have looked and are in the process now of settling an important question relating to the material toughness, the low upper shelf which is indicated by Charpy test specimens. The material toughness decreases under irradiation. As you know, embrittlement occurs and it moves the nil ductility temperature to the right. Something like that also happens on this material toughness. The upper shelf of the Charpy test, that is the toughness at high temperature, is reduced by irradiation and that becomes an important question because of crack arrest, in the event of crack growth during vessel use. It applies today to about 17 PWR reactor vessels and it applies to three or more boiling water reactor vessels.

As you know, the screening test for irradiated vessels is 50 foot pounds for the Charpy test. We know that material can be acceptable at less than the screening value, in fact as low as 40 or even

lower than 40 foot pounds. A lot of work has gone in in the last few years to developing a technique, measurements and an analysis of elastic plastic crack arrest and that is described in a reg guide which is 1.023, which is being completed now and it will come out this fall. That information has been incorporated in ASME code cases and that will define the tests and the analysis that should be done on materials that do not pass the 50 foot pound screening test. As I say, that will be out late this year and that's a very important piece of work.

A second area is pressurized thermal shock for the reactor pressure vessels. We are updating Appendix G, which is fracture toughness requirements, and also Appendix H of Part 50, which is surveillance methods that apply. That will also be done this year.

There's a third effort which has been underway which came out of the work on the Yankee-Rowe pressure vessel. There were differences between the fracture mechanics analysis that was done by people in the industry and by people in NRC and we have a working group with Electric Power Research Institute to resolve the difference in those fracture mechanics methods. That's coming along well. That actually will take another year or more to complete.

COMMISSIONER ROGERS: Does that deal at all with this question that was brought up when we were looking at the Yankee-Rowe pressure vessel of the effect of grain size? I remember that was an issue that came up.

DOCTOR BECKJORD: That was another issue.

COMMISSIONER ROGERS: It seemed to me it was never really quite put to bed, although most of the EPRI experts seemed to agree that that was not much of a mitigating factor, but nevertheless it was there and there were some people who felt that it was important and I don't think we ever really settled that issue. Did we?

MR. MAYFIELD: Mike Mayfield.

Yankee's test data, what of it was completed, indicated that the large grain size was not an issue and in fact the limited test data that they finally developed showed it went quite the other way. The larger grain size gave them a moderately higher level of embrittlement. It was probably more scattered than real, but went exactly the opposite direction.

COMMISSIONER ROGERS: From the claim?

MR. MAYFIELD: From the claim, yes, sir.

DOCTOR BECKJORD: Mr. Chairman, I've

misplaced your second question.

CHAIRMAN SELIN: The first question was sort of what have we found as the vulnerable systems to aging.

The second is, if we were relatively more interested in aging in plants during their first 40 years, would we be doing anything different or in addition to what we're already doing or would we cover that --

DOCTOR BECKJORD: No, that's covered in the current aging program. The phenomenon of aging apply within the first 40 years and they apply to the 40 to 60 year period and we haven't found any aging which occurs only in the 40 to 60 year period which does not appear, any aging phenomenon which does not appear during the operating life.

CHAIRMAN SELIN: There haven't been such fast aging things that they've led to conclusions that maintenance programs have to change or just different actions from those that are taken now?

DOCTOR BECKJORD: No. I think the maintenance actions which are indicated could occur in the 40 year operating period. Many of them have. So it's the -- well, your first question, certainly reactor pressure vessels, piping and steam generators

that I'm going to come to, a great deal of work has been done on piping and on the effects of seismic loading.

There've been some significant accomplishments. One of them recently completed is work on thermal aging of the cast austenitic stainless steel piping which is in many of the pressurized water reactors and the results of that are favorable, that some of the earlier concerns do not appear as important as they were. We have done extensive testing of the growth of cracks, long cracks in piping, especially under seismic loading. You may have seen some pictures of that. We are working now on testing short cracks in piping to determine what we can about their loadings and what effect that has on rate of crack growth. That work is still continuing.

In connection with the piping, we've done a lot of research and development of the ultrasonic testing methods, the aperture focusing that has much improved the information that you can get from those tests, and the technology transfer of that technique is underway now to industry.

With regard to steam generators, in this past year we have done a lot of work, as you know, on the Trojan shutdown that occurred last fall to develop

a method of leak rate evaluation as to what the leak rate might be under unfavorable assumptions. The limiting case turned out to be, as it was suspected, either a break of a main steam line or what has a higher frequency of occurrence, a safety valve opening when pressure goes up but then when pressure comes down after it's been relieved the safety valve sticks open and then the possibility during this transient that because the primary system pressure on the inside of the tubes stays about what it has been and the secondary pressure eventually after a long time would fall and then you would have a higher than normal pressure differential across the tubes.

The question is, given that higher differential pressure, what are the chances that cracks in the tubing will develop large leaks or in fact that you could have a tube rupture. We did a lot of work in that analysis and came to a conclusion on it which I think you've all seen, and we went on and have worked with NRR since that time in developing a draft document for the criteria for the interim plugging criteria for steam generators. That is now out for public comment and it will be revised after comment has been reviewed on it.

We also organized a meeting for the

Nuclear Safety Research Review Committee in April on the inspection methods, the testing methods for steam generator tube cracks and specifically what is the probability of crack detection that you can expect now. That was reviewed in some detail and it's been documented and I think you may have seen it. We've just received the Committee's views on that subject. So I think the steam generator issue is going to be getting some more attention and I think we've not come to the end of that.

I heard last week that NRR has received some very interesting information from the French in a very systematic set of measurements and evaluations that they've made on their steam generators which I'm sure we'll apply in considerable part to ours.

CHAIRMAN SELIN: Before we get off that, I have a substantive question. On the reactor pressure vessel, are we looking at ways to rectify some of this aging? Do we have an annealing program going?

DOCTOR BECKJORD: Yes. The information on annealing will be coming out late this year, both the rule and the reg guides, probably by December of 1993, which define the means of recovering early or perhaps even original properties of the pressure vessels.

CHAIRMAN SELIN: Do we have a solid research program to back that up?

DOCTOR BECKJORD: Yes. That's been underway for a long time.

CHAIRMAN SELIN: We also have foreign data, Russian data and other data?

DOCTOR BECKJORD: We have the Russian data.

CHAIRMAN SELIN: Are you comfortable that we've got a good basis for this?

DOCTOR BECKJORD: Yes.

CHAIRMAN SELIN: And then the procedural one is, on something like steam generators, is it possible to describe how much of the impetus comes from the research staff and how much comes from NRR? Can you talk a little bit about the interaction between your customers, in this case it's mostly NRR, and the researchers themselves? I understand we have a very large effort on steam generators now or coming. Where does that come from?

DOCTOR BECKJORD: Well, it comes from the interaction between Research and NRR. That's been going on for a long time, because steam generator diseases as I think of them have been going on in the commercial industry for a long time. They may have

been going on longer than that in naval reactors, but at least since 1968. That's when I was first exposed to this. There has been a whole raft of steam generator diseases and each one tends to be unique.

The outer diameter stress corrosion cracking is a somewhat new -- well, it's a phenomenon which was first observed, I think, in the mid-1980s and it has a different characteristic from the other designs. It's related, apparently, to material properties and chemistry, and it has been somewhat slower to develop so there has been less information on it.

But now between what we've learned in the last couple of years, and I think the French data has added a lot of knowledge on that, the interaction between the two offices has been very good. Because, NRR has to deal with the problems day to day and that's where the information comes from on tube ruptures, which we've had a number of them, and we also get the results of the current inspections on steam generator tubes.

And Research has worked since at least and maybe before 1985. I'm not really aware of that, but the work on the first Surry steam generator that was removed and taken to the state of Washington and

examined very carefully and that provides a lot of the basis of the information that was used for making the leak rate evaluation. And in connection with that Surry program, a lot of laboratory work was done on electro-machining of cracks in tubes and then doing bursting tests and leak rate tests and that kind of thing and so this interaction has been going on in some detail for at least eight years and I think it's been very productive. I mean, it gets the empirical data in and it gets the empirical and laboratory data together.

The Electric Power Research Institute now has a considerable activity in this area concentrating on inspection results and leak rates.

COMMISSIONER REMICK: Eric, to what extent is it possible and to what extent has it been done by industry, presumably, to model the steam generator in detail from a standpoint of thermal hydraulics, stresses, chemical reactions? Has there been any attempt to do that and is it possible to really look at it other than as a black box or a point value and so forth in thermal hydraulics? Has there been much of really trying to understand the --

DOCTOR BECKJORD: I don't know the details of that myself. I have understood from conversations

with people in industry that they have looked at these questions in some detail and that they develop new designs, the designs for the advanced concepts, taking into account experience and providing features which will improve the lifetime performance of steam generators. But I can't tell you in detail about that. Maybe some of our people here have --

COMMISSIONER REMICK: It would be interesting to know because my impression is based on experience changes are made, but I don't know how much actual science based on complete analysis is done from an understanding of the thermal hydraulics and the stresses and so forth. I realize it would be a complex problem but no more complex that we currently tackle in many areas these days.

DOCTOR BECKJORD: Well, I don't think the manufacturers have been anxious to disclose much of their knowledge for competitive reasons there.

MR. SERPAN: Chuck Serpan from the Research staff. The vendors and EPRI have done some model boiler studies in the past in order to understand the relationship between the chemical species and the corrosion. So, EPRI in particular has gotten that information into their steam generator guidelines. So, that's primary where that stuff is

coming from. So, they have done that kind of work.

COMMISSIONER REMICK: Thank you, Chuck.

DOCTOR BECKJORD: I was going to move on to the electrical and mechanical area and try and -- since there's a lot of information there. In fact, I'm giving a presentation on this to the reactor safety course at MIT and that list is going to take about an hour. So, I didn't plan to cover that in detail here, just except to say that the development of that program resulted, as I said before, that is in the electrical and mechanical area as in the rest of the aging program, it developed from a systematic review of components and systems for their susceptibility in each case, case by case to the known aging mechanisms. Then going to examine the failure data for components and knowing what kind of failure occurred, to factor that in. Then to determine the specific aging mechanisms that apply to each of these components individually and to find the locations of where that aging degradation occurred. Then to prioritize how to do testing and inspection to uncover problems as they exist and to develop, as I said earlier, means of getting signatures, getting indications while equipment is in operation of impending troubles, and then developing how a

maintenance program as to how you would maintain these specific components. And all of that material is reported in the transactions of the workshop that we had a year ago this spring and it was up to date as of that time on each one of these systems.

Then finally estimation of residual life. We've done that in some cases and that work is continuing in others.

I thought I'd move on to the structural area, structural elements.

CHAIRMAN SELIN: Are there any show stoppers in the electrical and mechanical?

DOCTOR BECKJORD: Well, I think the cables are certainly difficult because of the problems of replacing cables. We have some new information on failures from testing that NRR has done, has completed, and we are working with NRR to do some more testing. That program is evolving. It's in development right now and we will be getting that underway hopefully.

CHAIRMAN SELIN: Is there some non-destructive in-situ way to test the cables without having to dig them up or do you have to just look at a universe of cables and say, this is a problem, this isn't?

DOCTOR BECKJORD: Well, as I understand it, the problem with cables, there's a lot of experience on cable life in conventional plants out beyond 40 years. The problem with the nuclear plants is not just that kind of aging, it's that kind of aging plus a readiness to accommodate an accident and the conditions that might occur.

CHAIRMAN SELIN: I'm sorry. Let me be a little more precise. Are you concerned about how the cables that are irradiated handle the radiation or are you concerned how normal cables which have always been observed under sort of room temperature, how they would react to the high pressures and temperatures and fluids that would go in case of an accident?

DOCTOR BECKJORD: Both. It's both. The major effect of radiation on cables is on the insulation, and heat is actually a bigger effect. High temperatures degrade the insulation, make it elongate and embrittle and then if there's mechanical work on it, the insulation breaks down and then you can have a short.

CHAIRMAN SELIN: This is stuff for which we don't normally have a refurbishment or a replacement program, do we?

DOCTOR BECKJORD: That's correct. That's

correct.

CHAIRMAN SELIN: So we're talking about a pure aging question at this point?

DOCTOR BECKJORD: Yes.

CHAIRMAN SELIN: And you may get the feeling I'm interested in the substance of what you're doing and not just the process, you know, what are the answers, where do we -- that's too strong, but where are we going on these questions, when will we have -- are we likely to get answers that are useful in actually evaluating existing plants and future ones? Is this all tied up in the equipment qualification program or do we have a specialize point --

DOCTOR BECKJORD: Yes, that's right. We can comment. I'll ask --

DOCTOR SPEIS: We are in the process, Mr. Chairman, of doing a comprehensive testing program. There are a number of questions involved. You just don't take a cable and test it.

CHAIRMAN SELIN: Sure.

DOCTOR SPEIS: One of the questions that also is on the table is how do you age, what are the appropriate ways or what are the theoretical aspects of it and the experimental aspects of it. Another question is the synergism between radiation and the

thermal aspect. You know, if after normally operating for 20 years and all of a sudden you have a thermal load, how do you simulate that, plus the radiation effects?

We're not the only ones that are facing those problems. The French and others are facing problems like that. So, we're looking the whole arena right now, what they're doing in France and what we might do in the United States. So, in the next -- I think you got a Commission paper from NRR saying that the program is under development. So, we're working with them to structure such a program. One of the things that we have to do is prioritize what are the most important questions to address first cables and so on.

CHAIRMAN SELIN: It seems to me there are two different issues. One is what are the properties of the universe of cables that get the kind of stress in a broad sense, not physical sense, that you get in a power plant, et cetera? Then the second is like your motor current thing, what are the diagnostics that will tell you where a particular cable is likely to be an outlier compared to the universe? In other words, not just the cable's age, but how do we know if some of our cables are aging worse than others? Or if

you can't, do you have some remedial process that just assumes you can't test it? In other words, is there an actual test that goes with the cables for aging to find out how a particular cable, a particular set of cables are doing, and you just have to go on universal statistics?

DOCTOR BECKJORD: Well, I think one of the good tests is in -- it's a destructive test because you look at the elongation of the insulation and the elongation tends to be a very good indication of the problems. As to other methods, in-situ, do we know anything about that?

MR. VAGINS: Milt Vagins, Office of Research.

We have spent considerable effort trying to determine an effect of in-situ tests to determine the status of the insulation on the cables, the function of aging. As of this date we have found no really in-situ effect. However, there are some which tend to give us some data. For instance, EPRI has developed an indenter, which depends upon the flexibility of the cable, correlation of the physical bending of the cable insulation to its insulation properties with age.

Was that the question that was asked?

CHAIRMAN SELIN: Yes, sir. Thank you very much, Mr. Vagins.

COMMISSIONER REMICK: Has industry or have we given any thought, since there are a couple plants now like Trojan and San Onofre, of possibly taking some plants that have had 20 years of getting some point tests?

DOCTOR BECKJORD: Yes.

DOCTOR SPEIS: We are working with them and that's one of the considerations in developing a test program basically, to use cables from such places a Trojan.

DOCTOR BECKJORD: Yes. Trojan has offered the availability of equipment there for that kind of testing.

Well, I thought we'd move on to the structural elements. There are about 20 plants that have had various problems with corrosion of the containment, corrosion of liners, tendon corrosion, rebar corrosion and the research on that has looked at what the developed or probabilistic method for estimating the residual structural margin in containments after a given amount of destruction of strength members by corrosion.

Also, we've developed guidelines for

decisions on cathodic protection systems which can moderate the effects of corrosion, and on in-service inspection programs, what should be inspected and how do you go about it, how do you tabulate the results, that type thing. And we are closely following these problem areas in structures which I've outlined.

(Slide) Okay, the next, number eight, Bob, shows the closure plans on current research in aging for the primary system pressure boundary, electrical and mechanical components, and so forth. And I think at that time we will have, with the exception of this cable program which has just come up which may turn out to have a separate completion date from those indicated here -- this indicates the time when we expect the current research work on these items to taper off to a maintenance level.

And I know you're interested in the question of what does maintaining a capability mean, and I thought I'd mention that, and that would apply in each one of these areas and I think it's the following things.

First of all, a clear mission and application for the work that we're talking about. And in the case of aging, it will be both aging in operating plants but as time goes by, you'd expect it

to relate more and more to license renewal questions. So, first is a clear mission and application.

Second is a group of dedicated and motivated experts and enough of them so they can interact with each other, a critical mass so to speak.

A third thing that we need is good aging failure data specific to components and to phenomenon.

I think a fourth thing, I would like to see industry programs such as those that EPRI has undertaken in a number of areas; motor operated valves and steam generators to mention two.

And finally, sustained funding. You need funding to keep that activity on. But our aging program in total is very large now and as we scale back, I think it should not be difficult to maintain stable funding for ongoing work. And there may well be new information and new problems, the kind that you raised earlier, that may require more work which hasn't been accounted for here. But I think those are the elements that are needed for maintaining an activity after a very large amount of research such as these programs has been completed.

COMMISSIONER ROGERS: Well, how you going to use that? I mean, all right, these are the elements, now what are we going to do with that? I

mean, can that be --

DOCTOR BECKJORD: Well, as these programs taper off, I think it's appropriate this year and next to make a detailed plan as to what we would carry out in each area. I mean, there's a lot of effort going on now, and there's still a lot of work to be done and it's a good time to plan those activities now.

CHAIRMAN SELIN: Mr. Taylor, I think that this a conjecture which we'll think about before we do an SRM, but I think it might be useful to ask some of these same questions to NRR, because they're the customers in the sense of saying given this sort of general discussion, what are you depending on that we don't know, where are the technological as opposed to operational weaknesses, what are the questions. I'm sitting here and I can see a billion dollar research budget without stretching. I mean, obviously, we can't do all of those things, on the other hand we can't just plunge ahead with some of these programs without answers to the questions that Mr. Beckjord has identified. And for some of the big ticket items on the major programs, the corrosion, the pressure vessel, the aging, some of the equipment qualifications, you know at some point we need to get a feeling for are the resources right, are the

questions/answers in a timely basis, should we slow on some aspects of our policy setting or feel more comfortable and what has to be squeezed to get some of these programs supported.

I wasn't kidding when I said originally, as far as the government goes, you are the safety research organization. We have nobody else to depend on. And even if you get good research from EPRI or from the industry groups, at least it has to be confirmed and in many cases it will probably have to be reproduced. It's an enormous responsibility on you and on us for you. And we need to close the gap -- not the gap, but the cycle between what NRR is counting on and what you think is feasible to produce. You can't produce results just on demand. I mean, they have to come out of the research program.

COMMISSIONER REMICK: Eric, it's my impression that the NRC has put a considerable amount of resources in aging research. Are there any other countries putting a large amount in and do we have ready access to that information of what is being done?

DOCTOR BECKJORD: Well, it's true, we've put a lot of effort into it because we didn't used to call the reactor vessel work aging, but it really is.

And including that, the work goes back to the early 1960s, and I haven't totaled up the amount of money that's been involved, but it would be very considerable.

We have cooperative efforts with most of the large nuclear -- the countries that have nuclear programs. And I think there's good exchange of information now. And I think that while there have been several occasions when people would tend to bargain for information, and I know that in a recent case there was an effort made overseas to sell information which they had available to them; not to us but to utilities in the United States. But I think this recent example of the information which Bill Russell brought back from France that's a very good indication of cooperation, because I don't think there's anything that they held back on it. And it's very interesting. It's a very interesting package on steam generator tube performance.

So, I think that people are recognizing that it's to a mutual advantage to exchange information.

COMMISSIONER REMICK: If we summed up all the rest of the world activity, would it equal, do you think, what we've done?

DOCTOR BECKJORD: No.

COMMISSIONER REMICK: I wouldn't think so either.

DOCTOR BECKJORD: No. I think there's a lot of talk about the United States losing its place in various areas of research, but I really don't see that happening myself. I think certainly it's leading in the aging. I don't think there's any question about that.

COMMISSIONER REMICK: And I know we make our information available to everybody.

DOCTOR BECKJORD: Yes. Yes.

COMMISSIONER REMICK: But you feel we are now getting in return information from those who are doing work?

DOCTOR BECKJORD: Yes.

COMMISSIONER REMICK: Good. Good.

DOCTOR BECKJORD: (Slide) Okay. If I could go on to nine, please, Bob.

The next area is plant performance. And I think this, by the way, is an example of a maintenance level effort thinking of it as the follow on to an extensive effort which went into thermal hydraulic code development. And it's used now for the analysis of operating margins, of operating events and

transients. Example would be the BWR instability in natural circulation when their recirculation pumps are off.

We used it in connection with the Trojan steam generator tube break analysis early this year to look at the details of the main steamline break and to determine what the pressure across the tubes would be. And that's an example, of which there are many others.

There are two other examples here that are shown which are not for design basis, but for actual beyond design basis accidents; and that is the natural circulation of hot gases during severe accidents and in a severe accident the primarily system in a BWR would be relieved through the pressurizer and as the accident proceeded the gases would become hotter and hotter and would heat up the piping and the pressurizer or surge line is the one which would be most affected because it's a small line. And eventually that would lose strength and break and cause the system to depressurize, and that's a better result than having a reactor pressure vessel fail. But it's the ability to do that evaluation was dependent on these thermal hydraulic plant codes, so they've been very important.

A second example of that is the last one

on the matter of the lead screws for the TMI control rod drives. During the removal of materials from that vessel some years ago, they discovered from the metallurgical specimens that were taken that the lead screws were not hot, as just about everything else in the vessel was. And so our people have undertaken an analysis of that and the explanation is, it's been verified, that it's natural circulation within the guide tubes that kept the lead screw temperatures down.

So, those codes are very powerful.

COMMISSIONER REMICK: Eric?

DOCTOR BECKJORD: Yes.

COMMISSIONER REMICK: In the area of maintaining computer codes, do we have within our own organization people capable of running all of the codes that we wish to maintain? To what extent are we reliant on contractors?

DOCTOR BECKJORD: We've completed one step in the RELAP code and we are undertaking to train our people in the use of all of the codes, both the TRAC-PWR and the TRAC-BWR and SCDAP-RELAP. We'll be able to use those within house.

And, in fact, they have been used within house, some of them, for several years with these

special parallel processing computing machines that we've had for about three or four years.

COMMISSIONER REMICK: Yes. Yes. Do we still have in-house capability in the reactor physics code area? It's another area like criticality engineering and aging.

DOCTOR BECKJORD: We have some. We have one person who is an expert in that area who has been working, among other things, on the CANDU-3 transient analysis. So we have limited capability there.

CHAIRMAN SELIN: Is that person getting near aging -- or near retirement?

DOCTOR BECKJORD: No, no, no. He's not high on the aging curve.

COMMISSIONER REMICK: Do we look at our expertise that way, though, from the standpoint of existing expertise we have which we might eventually lose through retirement and --

DOCTOR BECKJORD: Oh, we're very mindful of that now because of what I mentioned earlier. We have an imbalance. We've got a lot of skills, but most of them tend to reside at the high end of the age curve, and so they're the people who are retiring. So we have to replace those.

COMMISSIONER ROGERS: Well, are you doing

anything, though, not only about replacing the people but trying to somehow or other collect their knowledge in the form of expert systems and things of this sort? This is an ongoing activity in many, many places and every place I go today I hear more and more about it. And I see the problems that we have here all the time of -- we've just heard that we are the agency that is the safety research, nuclear safety research agency in the country, perhaps the world in some ways, and yet we know that a lot of that expertise is going to retire from the agency in the foreseeable future.

It seems to me that we ought to be making every effort that's reasonable and affordable to somehow or other to develop a way of codifying that information and being able to pass it on, not just hire another new Ph.D. to fill an office when the office vacates but somehow or other have a way of actually transferring something of the expertise of the individuals, which is not always simply written down in papers and things of this sort. A great deal of it is experience that, perhaps, gets transferred, you know, through conversations and things of that sort and perhaps could be captured in an expert system.

DOCTOR BECKJORD: Well, it's a good idea.

We haven't undertaken anything like that.

COMMISSIONER ROGERS: Well, it seems to me it's worth really giving some hard thought to.

DOCTOR BECKJORD: We'll do that.

(Slide) The next slide, number ten, is on the plans. I mentioned the four codes there that we are working with. And also I want to mention the international cooperative program on the use of these codes that we have with a number of the nuclear countries around the world who are using our codes.

And that CAMP program is a big benefit to us. It provides a dialogue with the users of those codes. We get feedback on their code assessments. We get detailed knowledge of the plant transients that took place that they then proceed to calculate. So it's very helpful.

CHAIRMAN SELIN: Are the entrance fees affordable by the folks who sort of have marginally small programs? A couple of times people have said, "Yes, we'd really love to do this," but they can't seem to ante up what don't seem to me to be very large amounts of money, or is that a significant problem?

DOCTOR BECKJORD: Well, Mr. Chairman, there's been a lot of negotiation with several countries on that point, but I can't think of a case

where they didn't come into it. And I don't think the fees are exorbitant.

CHAIRMAN SELIN: We don't have a CAMP scholarship program or anything?

DOCTOR BECKJORD: Well, I will say, without naming names, that the fees have been negotiable.

CHAIRMAN SELIN: Okay.

DOCTOR BECKJORD: And the final point here is we intend to maintain certain test facilities. The PWR loop at the University of Maryland, when the SBWR loop, when that contract is settled, the contract is for 3 years construction and operation but I think it's certainly in our interest to extend that beyond. So I think that will be an ongoing program.

CHAIRMAN SELIN: What's the program? What are the initials?

DOCTOR BECKJORD: SBWR, that's the GE --

CHAIRMAN SELIN: At the University of Maryland?

DOCTOR BECKJORD: No. That one is being negotiated now, but I can't say where because they're not completed with the negotiations. But they will be very soon at Division of Procurement.

CHAIRMAN SELIN: Okay.

MR. TAYLOR: We're going to advise the Commission as soon as that's releasable.

COMMISSIONER ROGERS: Just this last bullet, maintain test facilities at universities, we're all concerned in some way about the future of university reactors. I don't know about all of us, but I think most of the Commissioners are.

CHAIRMAN SELIN: All of us. All of us.

COMMISSIONER ROGERS: I've been quite concerned about this. And I wonder if you could say anything about just how important university reactors are, and have been, and might be in the future for our needs? Some of these may be unanticipated needs at the moment.

DOCTOR BECKJORD: Well, the university reactors are very important. There are a couple that we have done work on over the years. For example, the reactor pressure vessel specimens, the specimens that were used for annealing, that work was done at university test reactors. And I think it's certainly in our interest to see that those continue.

At the same time, I'm thinking of one problem that I have right now of a potential rather large bill from one of the university reactors for a cleanup job. And we're going to have to enter a

negotiation with them on how to handle it. This is a matter that refers to work that was done quite a long time ago, but it's possible that it will be an expensive financial proposition.

But I favor the maintenance of test reactors available for testing. Very important.

Apart from that, apart from the test reactors, as I understood there was a question about more general than that, but maybe you were thinking only of test reactors.

COMMISSIONER ROGERS: No, I'm thinking about all of the non-power reactors.

DOCTOR BECKJORD: All of? Right. But not research at universities that is not related to a test reactor?

COMMISSIONER ROGERS: No, I'm just talking about the reactors.

DOCTOR BECKJORD: Oh, okay.

We do not spend a great deal of our money at university test reactor work. We pay for the irradiations that we carry out, but that's not the large part of our program.

COMMISSIONER ROGERS: But if they weren't there, what would you do?

DOCTOR BECKJORD: If they weren't there at

all, we would look to the laboratories, Oak Ridge, for example or overseas. We've done some work in Canada at White Shell. We could do it there, we could do it in Europe, possibly in Japan.

COMMISSIONER REMICK: I think there are only a couple of DOE reactors operating anymore.

DOCTOR BECKJORD: That's right.

COMMISSIONER de PLANQUE: True.

DOCTOR BECKJORD: There's discussion about a new reactor at Oak Ridge.

COMMISSIONER ROGERS: So in effect we'd have to go to some place that is willing to support their reactors, even though we might not be willing to do it in this country?

DOCTOR BECKJORD: I think that's correct.

COMMISSIONER ROGERS: Yes. I think we ought to keep that in mind.

COMMISSIONER REMICK: There is a related question that, too, without the research reactors I think the number of nuclear engineering programs would die in the country and access to that talent for your other research activities when they're not irradiation services but other talent and so forth, whatever area, would also go away.

DOCTOR BECKJORD: Well, that's a fact. I

mean, the nuclear engineering departments are restructuring themselves around the country to survive.

Okay. Shall we move on then? We've got some time left.

CHAIRMAN SELIN: You're doing just fine.

DOCTOR BECKJORD: Well, the next four slides have to do with human factors -- let's see, my count is four -- and I just wanted to mention what they are because they together make up the human factors program. And the four slides deal with the following topics.

(Slide) The first one is personnel performance, and that's looking at the causes of human error.

(Slide) The second one coming up is the human-system interface, and today that's primarily the application of digital instrumentation and control systems.

(Slide) The third one is organizational factors relating to the effects of a nuclear power plant's organization and management and its policies therein, the effect that that has on the performance of the operating crews.

(Slide) And the fourth one has to do with

human reliability and how that can be used to perturb a probabilistic risk assessment to see what effect human error might have on a plant PRA.

CHAIRMAN SELIN: Do we have a program, maybe it's in the fourth one, that is just a black box, it's not really trying to model how human behavior varies with different inputs, but just, you know, what's a reasonable error probability to use for people in certain kinds of situations, an empirical program or anything like that?

DOCTOR BECKJORD: Well, that really came up in the first box. There's been a lot of work done there which we have used from other places, Department of Defense, but we've also done work ourselves in that area, which I was going to refer in that slide.

CHAIRMAN SELIN: Do we put these into PRAs? I mean, are they subsumed in error calculations and risk calculations within the PRAs or do we assume people don't make blunders? I mean, how do we use these data?

DOCTOR BECKJORD: Well, there's a lot of interest on the part of NRR, and has been for some time, in that approach to see if you can say, "Well, for this kind of error if the performers at this plant are prone to errors of a given kind, it's going to

multiply the core damage frequencies by five or by ten or by something like that."

I don't think we're there in a quantitative way that you can say well for this level of performance at a plant, this is what the impact is going to be on the PRA. I think you can put a range on it and certainly that approach is used in evaluations made here at the Agency when individual plant performance is discussed.

CHAIRMAN SELIN: Well, the way you put the issue would suggest that one has an expected value for performance and now we're trying to look and see how that would be affected by variations in working conditions or inputs. But, in fact, do we have that much? I mean, say if operators had to react to certain kinds of signals 1,000 times, that they would get it right 997 times?

DOCTOR BECKJORD: Well, the detail work on this was done not for the kinds of plant operations that we do. There's good data for some kinds of manufacturing operations.

We have some data, and our people could comment on it if you'd like to.

CHAIRMAN SELIN: At some point, yes, I would. I mean, it's obvious that human errors are a

big part of everything and it's obvious that they're very, very hard to model and understand. But what's not obvious is what -- at least to me because I haven't looked at it -- is what we know today. You know, what's our base and from where are we starting.

DOCTOR BECKJORD: Let's see, why don't I go to the first of the slides, which is 10, and then 11?

(Slide) The issue stated here is the effects on performance of staffing, that is the numbers of people and their qualification that are assigned to a shift. That's the first subject.

The second one is the working hours.

The third one is the environmental conditions that the human performers work under. And by environmental conditions we're talking about temperature, humidity, noise in the working environment, vibration if they're out in the plant somewhere, and light, whether it's dark or light.

On staffing, the studies that we're doing for now for operating plants, the minimum staffing levels that are required for dealing with normal operation plus plant transients, that work is complete now. But we've got a new question from NRR stemming from some work done in AEOD. And they have found some

cases where they believe that the minimum levels that are being used for staffing are not adequate for all plant transients. So NRR is asking us to look into that, and we're going to, and it will probably take about a year or so to reach a conclusion on that.

Now, we are also undertaking to work on the last item on that chart there, effects of advanced designs on staffing levels. And really the question is the other way around, how do the staffing levels that are proposed for these designs affect the safety and performance there? And this has largely to do with the new control systems, new control rooms and control system designs that will be incorporated. There are some differences and I think the industry feels that they should be able to decrease staffing levels to operate as well as they do now with the existing systems which were not designed in a systematic way.

The question is whether and our study is addressed to the question of whether the proposed staffing levels will be adequate for dealing with plant transients. That is getting underway now. We haven't really done more than start on that.

CHAIRMAN SELIN: What's the standard? I mean, do we have some measure of the performance of a

currently acceptable staffing level in some kind of canonical current plant? I mean, do we have numbers for that or do we just say whatever it is? Are there reasons to believe better instruments can reduce this percent?

DOCTOR BECKJORD: It varies. It tends to be somewhat plant specific. I think I'd like to ask Frank Coffman to tell you some more about that.

The question has to do with the norm for staffing levels.

MR. COFFMAN: Frank Coffman.

The norm for staffing levels for current plants, or the minimum, is stated in 10 CFR 50.54(m). For advanced reactors I know of no standards.

CHAIRMAN SELIN: Well, let's take the current standard. Do we have some measure of performance of, you know, a nominally well-trained crew in a BWR-6 of standard size or is it more of a relative thing that says we can't put a number, but we can see that the better data processing would allow the staff to be reduced 20 percent and still carry out the same performance?

I mean, I'm aware of a lot of analytical work where nobody can say what the status quo ante is, but you can't evaluate variations from that base. And

in other cases you would just try to measure how often would that crew be handle a particular set of stimuli? I mean, would they blunder one out of a 1,000, one out of 2,000? I mean, what is the state of the art? I have no preconceived views of what we ought to know, but I'd like to know what we do know now.

MR. COFFMAN: Well, the concerns on staffing for its adequacy have been generated -- the empirical evidence that we have comes from two sources, two research, but we in research don't have an independent source at this point, to my knowledge. But AEOD has been investigating events where the adequacy of staffing has been raised. And then there is evidence that comes from the requalification examinations that take place where, in fact, some of the scenarios require supplemental staff to complete the scenarios.

CHAIRMAN SELIN: That's a kind of deterministic test, isn't it?

MR. COFFMAN: Yes.

CHAIRMAN SELIN: You just need five pairs of eyes to carry out that and there are only four pairs in the room as opposed to you have enough of a crew. I mean, my question is a little different. I mean, in a place where in the deterministic sense

you're okay, you have enough people to do the work, do we have an estimate for how often the crew will just screw up, will not get it right and that's just one of the factors we have to use in PRAs or is that really a much tougher question to answer than my question makes it seem?

MR. COFFMAN: Yes. I didn't realize you were focused on crew performance. But there was an effort that is -- I should say there is an effort we're trying to wrap up on looking at measures for the effectiveness of crew performance and how they interact. To my prediction of where we're going to come out on that, is it will not establish any standards.

CHAIRMAN SELIN: I mean, my question doesn't talk to a model. In other words, I'm not asking can we predict how changes in crew performance or in stimuli will effect -- I mean, I'm sorry, in crew composition or stimuli will effect. I mean, just do we have an estimate of how a standard well-trained crew in a fairly standard reactor under a standard set of circumstances will perform or is that hard, or is it just sort of irrelevant? You know, what I call a black box estimate without being able to model it and predict it, just say empirically we've observed that

crews get their tests right 99.9 percent of the time.

DOCTOR BECKJORD: I think that there is an answer to that because the requalification exams divide the population in two; there are those who pass and there are those who don't pass. And this is based, in part, on it's partly written and partly simulated.

CHAIRMAN SELIN: Sure. But my question is a random one. I mean, let's say everybody passed the exam. I mean, presumably the exam gets rid of the guys who are defective. Now take the universe that's not defective. I mean, even a properly operated diesel won't start occasionally, and we have good figures on that. How about a properly trained crew? How often will they -- I mean, is that an irrelevant question or is a hard question or is it just one that's hard --

MR. COFFMAN: It is a hard question because of the number of parameters that are involved in performance of crews. Training would be one of them, but it's very tough to run an experiment where you hold everything else constant and vary the training with the crew. So it tends to be empirical evidence that comes from the integration of many factors and become tough to sort out.

We have an effort underway to try and look at the requal examination data that the Agency collects, sort out what might be extracted from that data for the purpose of estimating error rates. And that would be an empirical base, but it's a difficult question because of the number of parameters.

CHAIRMAN SELIN: Fine. Thank you.

MR. TAYLOR: Mr. Chairman, I believe, and Themis, you'll have to fill in, though, in the various PRAs there are error rate values used in the sequences, right?

CHAIRMAN SELIN: For human performance?

MR. TAYLOR: Yes.

DOCTOR SPEIS: Oh, yes. This information has been collected basically from other industries. There is, in fact, a classic example in studies done by David Swain, but that information is kind of approximate number of errors.

Let me give you an example. Some of the older plants, the way they coded for, when you had a LOCA the water would go directly into the vessel, but then of course it will empty because you had a LOCA. So after the RWS tank emptied, then somebody had to manually turn the pumps to get the water from the sumps back into the reactor, so that was a manual

operation. So Mr. Swain used the information and extrapolations from other sources and he came up with an error rate, when would somebody make an error improperly, initiate this system.

But these are the type of things. You have to focus on a specific operation. One of the key things that France had was training and training involves procedures, so all these things have to be integrated before some reasonable value can be assigned in these type of operations.

So PRAs address specific operations. There are many other things that are very subjective and PRAs basically do not address most of those.

COMMISSIONER REMICK: On the matter of the current staffing standards in 50.54(m), isn't it fair to say that that was a deterministic matter based on the fact that the TMI accident it was determined there weren't sufficient staff there to handle the accident, so this was decided that this seemed like an improvement over what was in existence before that time, and the only different it doesn't distinguish between BWRs or PWRs, it distinguishes between single units and multiple units and whether those multiple units have a common control room or a signal control room? It was a judgment call --

MR. TAYLOR: Yes, it was.

COMMISSIONER REMICK: -- that was made after TMI.

MR. TAYLOR: Yes. NRR's nodding at me, too.

COMMISSIONER REMICK: Eric, I was surprised to see that you still had the question of hours in there. Certainly that question goes back eight or ten years. I thought it was put to rest. There were hours on the number of hours that people can work consecutively. There was a question of whether 12 hours versus eight hour shifts, but I thought all that was put to rest some years ago. I was surprised to see it. Am I wrong?

DOCTOR BECKJORD: Well, there's been some ongoing work, and that is coming to a conclusion now.

COMMISSIONER REMICK: I see.

DOCTOR BECKJORD: And the quick finding is that in looking at eight versus 12 hour shifts, the response of the average response on 12 hour shifts is slower, but it is at least as accurate. So it may be somewhat better, which is kind of interesting, than the eight hour shift.

The other finding is that the fatigue is cumulative and when people have been working extended

hours for a long time, they have to have recovery.

COMMISSIONER REMICK: But aren't those all old findings? I think Frank wants to add something.

MR. COFFMAN: No, I was just prepared to answer, but yes they are old. It's old research that is being wrapped up. I wouldn't call it old research, but it's at the stage in this research that we're wrapping it up.

COMMISSIONER REMICK: I see. Okay.

MR. COFFMAN: And sometimes the conclusions of the research get out and get implemented before the formal wrap-up of the research.

COMMISSIONER REMICK: I see. Okay.

DOCTOR BECKJORD: The next point, the environmental conditions, there's a handbook which is coming out this fall, November, on the findings on temperature, humidity, noise, vibration and so forth. And it defines the levels or the thresholds beyond which you can degraded performance, and we will turn that over NRR this fall.

(Slide) And I think we've covered number 11 and move over onto 12. As I said, this relates to the new digital instrumentation and control systems that are on the horizon for advance reactors, but in fact they are coming into use now in replacements for

things like feedwater control systems.

And the benefits, there are important benefits for these systems, whether they are replacements in operating reactors or for new ones. They can reduce the safety system challenges, and that's a direct input on core damage. Secondly, the digital systems and software can integrate the data for higher levels of information that's referred to in the trade parlance by chunking of data. And an example would be in a pressurized water reactor an operator has to watch the temperature and the pressure. And they can combine those variables of temperature and pressure to give a variable in which they will show that the combination is in an acceptable range, which is okay, or if it moves to an unacceptable range, it's not okay. If it moved, for example, toward saturated conditions in a PWR system, that would be not okay.

And the third is that these systems can advise operators on all parameters and advise actions which should be carried out, and can track the success of the operator in carrying out those actions and prioritize these things, say which should be done first.

Our work at Halden is related largely to

this. And at Halden the people on the Halden project are very important leaders in this area.

There are, of course, concerns that relate also to these new systems. How to accept the computer products in the software; what are the criteria that they should satisfy? That's one.

A second one is the problem of the unintended function; how do you test the system to assure that there is nothing written into it which could cause a problem? There are important examples of that, which I think everyone's aware of. The AT&T telephone crash which depended on a software error and the refueling machine in Canada, which caused an accident by shifting when it should not have. And that was a software program error.

And the question here is how to find the errors and also how to assure that the system specifications are correct and that the software will meet those system specifications.

So those are the concerns.

There is a workshop in September 13 and 14 sponsored by NRC. The National Institute of Standards and Technology is helping us with getting ready for that. We have speakers coming, experts from around the U.S. and overseas. And one of the important

themes in that workshop is going to be the draft standard review plan which NRR has written. And that's going to be presented to the people who are giving papers there and it will be up for discussion. And, as I say, it's one of the main themes of the workshop to do a review of that draft standard review plan.

So, I think this will be a very important meeting. Commissioner Rogers is going to kick it off. So, I think that covers this area.

CHAIRMAN SELIN: We've got eight minutes, so I'll try to ask a short question because I predict a long answer.

When you go into an existing control room, which when I did two years ago I was just shocked at how complicated they were and how poor the human factors, et cetera, is there anybody in the industry who believes that they can do an analysis of the reduction in risk by replacing one of these control rooms with a more logical control room? Because any time you ask the shift supervisor, he will tell you, "Oh, it looks pretty bad to an outsider, but once people are trained on it they can run these centers as well as a well designed center."

Has there been any work on -- I don't mean

present versus future control rooms, but sort of standardized simplifications of existing control rooms and some quantification of the improvements, either reduction in training time. I'm not saying things to the point where you could get by with three people where you otherwise need four because there are so many meters, but with a given staff, what improvements could --

DOCTOR BECKJORD: To my knowledge, what's being done in existing plants is replacing particular systems, not the whole works. Now, if there is somebody who knows of a place which is going forward in that, speak up.

CHAIRMAN SELIN: Well, I'm sure you can redesign the control room sensibly if you look at them and say, this is clearly better than that. But has anybody gone a step further and tried to do an evaluation of what's the payoff? Do you get shorter training time or higher recertification rates or better performance in a crisis or anything like that?

DOCTOR BECKJORD: Well, I know something about one example, which is replacement of feedwater control systems, which tend to be troublesome at low power when a system is just going into operation, either after coming out of a -- coming from a reactor

start-up or possibly even a short time for a shutdown. And feedwater control systems have been troublesome for years and years and years and the digital systems provide -- well, to give you an example, the intuitive thing to do when the water level falls is you say, "Well, what I should do is open the feedwater valve and let more feedwater in," right, and that will raise the level. Well, that's wrong. That's not the right answer. You put cold water in with feedwater, which is what you're doing, and that suppresses boiling. Boiling is what takes a lot of volume in a steam generator and so it avoids collapse and the water level falls even further.

Well, digital control systems address that problem and arrive at a control strategy which maintain the right amount of fluid in the steam generator or the reactor, as the case may be. So, that's a big improvement because you get a lot of trips from the conventional systems. I don't know if we --

DOCTOR SPEIS: Well, Frank is going to say something. But Mr. Chairman, after TMI the question the way you posed it, it was a hot item for many years and many studies were done about synergism between the operators in the control room and what's the optimum

configuration and so on and so forth. A number of things were done, but because of backfit considerations and the expense, you couldn't just throw everything away and start over again. Maybe Frank can tell us some of the things that were done to improve --

CHAIRMAN SELIN: I'm not interested in the redesign of the control room. I'm asking if anybody has done some evaluation of how operators in better control -- you know, quantify how much better they are or are not than acceptable, but more complicated control rooms.

DOCTOR BECKJORD: You can quantify for an individual system because in the case of the feedwater controller, the new controllers will eliminate the feedwater trips.

MR. COFFMAN: As I understand the question, it's what's the total effect on the operator or crew performance given the new control rooms. Well, to my knowledge there's nobody who has a complete picture on this and we are chipping away at it on several fronts, one of which is to try to first look at what the impact on error rates has been in those plants that have, in fact, implemented pieces of it. So, we're kind of creeping up on it. And the

other aspect --

CHAIRMAN SELIN: We are doing that?

MR. COFFMAN: Yes, sir. The other aspect that we're doing, and this is through the Halden Project, is that the Halden Project evaluates given computer operator support systems, these different aids, computer-based aids that they put in. They evaluate those individually, but they have an effort underway to look at an integrated control room and the integration of these different causes and what effect that has on overall performance, not only performance in reacting to specific systems, but to the total plant state. It's a difficult question because you have to be able to get some measure of what the operator's awareness of the total situation is. So, there is that effort that is underway. Both those efforts are underway, but to my knowledge no one knows at this point what the net effect is.

CHAIRMAN SELIN: Forrest, you had a question?

COMMISSIONER REMICK: How did you notice?

I couldn't resist a facetious remark because I was going to say DOE must have done this work because of some of the proposals they've made for staffing of the MHTGR and PRISM plants where they're

talking about one operator for three units and so forth. They must have done this type of -- that's a facetious comment you don't have to respond to.

DOCTOR BECKJORD: Commissioner, I think the designers made the proposal. I don't think it was ever systematically reviewed.

COMMISSIONER REMICK: I'm thinking back to some days when DOE people did push it, before ACRS, as well as designers.

DOCTOR BECKJORD: Well, Mr. Taylor, we're a little over a third of the way through and --

CHAIRMAN SELIN: Why don't you go through the other human reliability charts. That would be a natural stopping place and then we'll call a pause at that point.

DOCTOR BECKJORD: You've got a few minutes?

CHAIRMAN SELIN: Yes.

MR. TAYLOR: Go ahead.

DOCTOR BECKJORD: (Slide) Okay. The next one is 13, human reliability and organizational factors.

The points to make on this chart are the following. First of all, we have done research on organization and management. We've spent a

considerable sum of money on it in the last five years. The result of it was that three techniques were tried of sending people to a plant and doing observation. These were teams of skilled observers in the human performance area. At the same time, individual interviews were done of the operators at the plant and then also surveys were taken. These were prepared surveys which everyone was asked to fill out and the results of these three investigations were correlated and what we found out was that they track each other pretty well. Now, the information is not the same in each case, but what it said -- the conclusion is that you can learn things from interviews and from surveys which will track with observation.

Now, the most important of these is the observational technique. That's a very expensive thing because the teams are expensive, and they have to be at the plant for some long period of time, maybe a couple of months. It uses both the time of the team and of the people who are at the plant. So, it's very resource intensive.

Further, we tried to translate these results into a perturbation of a PRA and that work was not completed and it was not very successful. This

was reviewed broadly by senior management at NRC last fall. There were a couple of meetings on that and the decision at that time taken was to close out the work and to report on it and to not continue it. Some of it was applied and it's been reported in documents which have been made available to NRC inspectors for their use on this technique of observation.

Now, that's the second point, that the management reviewed it with that conclusion.

The third is that we still have some work going on at the University of California at Los Angeles by George Apostolakis, whom you know. What he has been doing is a work process analysis of the jobs, the various jobs needed to run a plant, and then to classify what the attributes are of job performance and then to do a performance evaluation. And also to attempt to relate what the effect of company organization and management policies are on operator performance. Then when he accomplishes this, the idea is that he can then give a quantitative perturbation of what the effect of organization is on the plant PRA through the individual performance multiplier.

We're reviewing that now to determine whether and how to continue to work. I believe we're giving a recommendation to Mr. Taylor in October on

that point. So, the work is -- we haven't reached a conclusion on whether to carry on with it or not.

So that's where we stand -- but we will do so in October. That's where we stand on the organization and factors. There are some other aspects of this which I think you're aware of which, if you are, I won't repeat. But following a meeting with the Commission in January of a year ago we undertook to convince industry to pick up in this area, in the organizational area. I think we've described this to you. It came down to INPO because INPO is the group that is responsible for it. Several of us went to INPO. I went with the idea that I could convince them to pick up work in this area and that was not successful.

What we found was that they had developed their own technique for doing corporate management evaluation and they were conscious and had -- they were well aware of what we were doing and they had applied that and some other kinds of things that they'd learned from the management, the Booz-Allen Organizations, I guess, and perhaps McKinsey. I was very impressed with what they did and felt that there wasn't really a great deal they could pick up by carrying the work on. So, that was not a successful

effort.

There is an ongoing work at MIT in a program that Professor Hansen started several years ago which is a broad program in reactor safety, but they are working in this organizational area. In fact, I recently received a report of the work that they've done in the past year on that.

(Slide) The next one is the next and last, 14, on human reliability analysis and its effect again on PRA. The first point that's mentioned here is the effect of cognitive error or a failure in awareness on the part of operators as to what is going on that would be important for them to know about. The evaluations in this area, as I understand it, are now based on expert opinion and the project that is underway in research under Frank Coffman is to generate a database from reactor simulator reruns of actual events and these are being done in the course of reactor requalification. The purpose is to determine from those simulator runs which situations are demanding of the operators and then to attempt to infer from that information what the cognitive error rate might be. That's the first project.

The second one is this one that refers to methods for risk impacts of technical specifications.

What this is about is evaluating the effect of taking equipment out of service for repair or for maintenance while a plant is operating and relating the lack of the unavailability of that equipment to the PRA.

The group that's working on this, Carl Johnson is working on it and some others, are writing a handbook for NRR. That will be completed in April of 1994 and it's being written for the specific use of the Technical Specification Group in NRR. It's attempting to develop a systematic way for the reviewers to review requests for exemptions from the tech specs on these matters of removing equipment. That will deal with such things as the allowed outage time and surveillance intervals and that kind of thing and that's going well.

COMMISSIONER ROGERS: Why is this a human reliability topic? Maybe I'm missing something. Is it when you substitute a human for a system which is out that then the comparative reliability of those situations? Is that what --

DOCTOR BECKJORD: Well, I guess it's the -- my understanding, Commissioner Rogers, it's related to the PRA application and it's -- the purpose of it is to be able to make a judgment as to whether a specific request for exemption is going to unduly

change the risk at the plant where it's requested.

COMMISSIONER ROGERS: Yes, but --

DOCTOR BECKJORD: Why is it human --

COMMISSIONER ROGERS: Yes, why is that a human reliability issue?

DOCTOR BECKJORD: Well, that's a good question. I guess it's more PRA than it is human reliability.

COMMISSIONER ROGERS: I mean I could see if you were substituting a human for a system --

DOCTOR BECKJORD: This is one of these organizational --

COMMISSIONER ROGERS: -- you know, that's out of service, then you might want to understand, well, is the risk equivalent or different?

DOCTOR BECKJORD: I guess the only answer --

COMMISSIONER ROGERS: But just taking it out of service and changing the PRA, I don't see it as a human reliability issue.

MR. COFFMAN: Excuse me. I don't think there's a rational answer because it was inherited.

COMMISSIONER ROGERS: I see, it's an organizational question.

MR. COFFMAN: Yes, sir.

DOCTOR BECKJORD: That's what I was going to say.

MR. COFFMAN: The branch was formed in '87 and it was called the Human Factors and Reliability Branch.

COMMISSIONER ROGERS: I see, that's where it wound up. Okay.

DOCTOR BECKJORD: The people who were doing it happened to be in that branch.

COMMISSIONER REMICK: Along this line, Eric, a couple months ago I heard a paper that was quite thought provoking. I'm not sure I believe it, but it was a paper presented that indicated that when you took one diesel generator out of service, the core damage frequency was actually less with one diesel generator available than two. The reason being that when you take the one out of service you pay a lot more attention to the support systems and so forth. As a result, reliability of that diesel goes up and the overall risk goes down. It was, as I say, kind of thought provoking.

DOCTOR BECKJORD: I'd certainly agree with that, if you take the right one out of service.

COMMISSIONER REMICK: And maybe we could take both of them out --

COMMISSIONER ROGERS: That's an interesting path to go down, isn't it?

CHAIRMAN SELIN: We won't have the wrap-up on the overall research point, but if the Commissioners care to make any other comments on the human reliability stuff, we'll do that and then we'll just pick up at the next --

COMMISSIONER ROGERS: Well, just one point and that is that maybe I'm out of date, but I know a few years ago in talking to the B&W people, it was my understanding that the B&W owners group had decided that eventually they as a group would change out their whole control room, the core of it. Not just piece by piece, to some kind of a digital system. I'm not sure whether it was a combination digital and analogue or what, but at any rate a totally new system. It was my understanding that they had a date by which they were going to start to put this into effect and so on and so forth. I don't remember what that date was, but I haven't heard anymore about it and the other day when I asked the Research Committee about replacement of the total control room, they seemed to indicate that they weren't aware of anybody thinking of anything like that. So, I don't know whether B&W owners group has changed their position or if they haven't changed

their position how aware we are of their thoughts.

MR. TAYLOR: Let's try to find that out. Frank Miraglia is signaling from the sidelines.

MR. MIRAGLIA: Frank Miraglia from NRR. I believe what you're referring to, Commissioner Rogers, is as part of the B&W reassessment that was done several years ago was going to be a reexamination of an integrated control system and that is being done by B&W and that would result in different kinds of control systems, but it was not going to result in a whole different new control room. It was the system by which they would control the reactors, integrate the feedwater control with the other non-safety related systems. So, it was that aspect, I think, that --

COMMISSIONER ROGERS: But that would result in a different look at the --

MR. MIRAGLIA: In certain parts of the control room, yes.

COMMISSIONER ROGERS: Yes.

MR. MIRAGLIA: And also different kinds of digital and control systems within a plant --

COMMISSIONER ROGERS: Right.

MR. MIRAGLIA: -- but not a whole new integrated design of a control room. So maybe that's

--

COMMISSIONER ROGERS: Well, all right. Maybe I read a little bit more into --

MR. MIRAGLIA: I'm just inferring based upon what you said in the time frame, which is --

COMMISSIONER ROGERS: Yes, but maybe there would be some implications there where there's some human factors implications of that changeover that perhaps we ought to take a look at.

CHAIRMAN SELIN: Do you have anything, Forrest?

COMMISSIONER REMICK: I don't have a comment on what we heard, but looking ahead to the fact that we will continue, I agree, Mr. Chairman, it's helpful to know not only the topics that we have done or are doing, but some of the interesting results and those interesting results sometimes can be that we haven't found anything that's helpful to us. Also in two cases it was helpful to me to know that Professor Apostolakis and Professor Hansen were doing it where appropriate. It would be helpful if you indicated this was being at Oak Ridge or this was being done at Idaho just to give us a feeling, as you think that's appropriate, so we get some feeling of who is doing the work.

The other thing is in all of the research that you were doing, you must have some interesting visuals, whether they're videos. I remember seeing some of the dramatic ones and blowing up containment out at Sandia. The EDO recently mentioned the work being done in Russia on the melting of corium that's spreading. I don't know if there are videos of that, but you might think about either in the next presentation or perhaps at some other time if you have something interesting for us to see, a visual, to give us a little better feeling for the type of research, I personally would find that quite interesting.

DOCTOR SPEIS: We have all kinds of them.

CHAIRMAN SELIN: Well, we don't want all kinds of videos. We want certain kinds of videos.

MR. TAYLOR: He didn't mean that literally.

COMMISSIONER REMICK: That helps us, rather than dealing in the abstract, of some of the results and who is doing it.

MR. TAYLOR: Maybe we can get something for the next portion of the presentation.

CHAIRMAN SELIN: MTV is the most popular network in the world, for good reason.

Commissioner de Planque?

COMMISSIONER de PLANQUE: I didn't pursue this area earlier because I assumed you probably didn't have a lot of information right on hand, but I am interested in the impact of our fee system on the university reactors and how dependent the research program is on the existence of those reactors, both for the reactor research and possible materials research. Maybe you could give us a better handle on that when we do our continuation session.

MR. TAYLOR: We'll give you a list of all the places.

COMMISSIONER de PLANQUE: Okay.

CHAIRMAN SELIN: I don't mean to be unkind, but this presentation was a little bit like what you would do for your budget examiner. Here are the programs and here are the kind of activities. I think the Commission would be interested in having a more substantive and less -- I mean if we had to choose to have it more substantive, even if less programmatic as we continue.

We'll try to schedule this in the not too distant future. This is really the core of the future of the Agency and the support for an awful lot of the things that we do. In addition to our responsibilities for overseeing the research program,

we need to understand, at least I need to understand, and my colleagues are more aware than I am of the research program, the basis on which some of the regulatory decisions are made. So, it's both the substance of what comes out and also how we're investing our taxpayer and ratepayer money in carrying it out.

It was an illuminating discussion. Thank you very much and we'll pick this up in the not too distant future.

(Whereupon, at 3:45 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 OVERVIEW OF NRC RESEARCH PROGRAM

PLACE OF MEETING: ROCKVILLE, MARYLAND

DATE OF MEETING: JULY 20, 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

OVERVIEW OF NRC RESEARCH PROGRAM

ERIC S. BECKJORD, DIRECTOR
OFFICE OF NUCLEAR REGULATORY RESEARCH

COMMISSION BRIEFING

JULY 20, 1993

OUTLINE

INTRODUCTION

REACTOR LICENSING SUPPORT
- ADVANCED REACTORS
- REACTOR AGING

REACTOR REGULATION SUPPORT
- PLANT PERFORMANCE
- HUMAN RELIABILITY
- REACTOR ACCIDENT ANALYSIS
- REGULATORY IMPROVEMENTS (SEISMIC)

NUCLEAR MATERIAL AND LOW-LEVEL WASTE SAFETY

ASSESSING SAFETY OF HIGH-LEVEL WASTE DISPOSAL

CONCLUDING REMARKS

NUCLEAR REGULATORY RESEARCH BUDGET - FY 93

	M$	FTE		
		Res/Reg	Dev/	Total
REACTOR LICENSING SUPPORT	46	67	1	68
Standard Reactor Designs				
Reactor Aging & Licensing Renewal				
REACTOR REGULATION SUPPORT	42	80	34	114
Plant Performance				
Human Reliability				
Reactor Accident Analysis				
Safety Issue Resolution & Reg. Improvements				
NUCLEAR MATERIALS	3	8	18	26
LOW-LEVEL WASTE	6	11	14	25
HIGH-LEVEL WASTE	6	6	1	7
TOTAL	103	172	68	240

STANDARD REACTOR DESIGNS: AP600 AND SBWR DBA THERMAL-HYDRAULICS

ISSUES

- Reliability of passive systems
- Acceptability of new technology & features
- Computer codes for NRR

DBA THERMAL-HYDRAULICS -- AP600

RESULTS -- AP600

Preliminary analysis of thermal-hydraulic characteristics in accidents, including containment feedback.

PLANS -- AP600

- Complete ROSA-V modifications and run confirmatory test program in FY94 and FY95.
- Improve code modeling and assess accuracy.
- Consider possible use of Oregon State University facility for low-pressure testing.

DBA THERMAL-HYDRAULICS - SBWR & CANDU-3

RESULTS -- SBWR

Data from the GE gravity-driven cooling system integral system test (GIST) facility were reviewed and inadequacies for code assessment were identified to NRR.

PLANS -- SBWR

Construct test loop; carry out test program. Improve code modeling and assess accuracy.

PLANS -- CANDU-3

Prepare research program for Commission consideration.

REACTOR AGING & LICENSE RENEWAL

ISSUE

- WILL AGING OF SAFETY-RELATED EQUIPMENT AND STRUCTURES RESULT IN COMMON-MODE FAILURE? REDUCE DEFENSE IN DEPTH? RENDER EQUIPMENT NEEDED FOR ACCIDENT MITIGATION INOPERABLE?

- HOW TO ASSURE RELIABILITY AND READINESS OF SAFETY-RELATED SYSTEMS AND COMPONENTS
  - DURING INITIAL 40-YEAR LICENSE
  - DURING EXTENDED PERIOD UNDER LICENSE RENEWAL

REACTOR AGING & LICENSE RENEWAL

RESULTS

- PRIMARY SYSTEM INTEGRITY
  - REACTOR PRESSURE VESSEL
  - PIPING
  - STEAM GENERATORS

- ELECTRICAL AND MECHANICAL COMPONENTS
  - PUMPS, VALVES
  - BREAKERS, RELAYS
  - DIESELS
  - CABLES
  - REACTOR PROTECTION SYSTEMS
  - SERVICE WATER SYSTEMS

- STRUCTURAL ELEMENTS
  - CONCRETE DURABILITY, CORROSION OF REINFORCEMENT
  - STEEL CONTAINMENTS

REACTOR AGING & LICENSE RENEWAL

CLOSURE PLANS

• PRIMARY SYSTEM PRESSURE BOUNDARY	1998
• MAJOR ELECTRICAL AND MECHANICAL COMPONENTS	1996/1997
• AGING OF CONCRETE STRUCTURES	1994
• AGING OF STEEL CONTAINMENTS	1996/1997

PLANT PERFORMANCE

ISSUE

Maintain assessed computer codes for staff analysis of events and regulatory issues in operating reactors.

RESULTS

- Analyses for steam generator tube plugging criteria.

- Natural circulation of hot gases during severe accidents: transport of heat to the hot-leg and pressurizer surge line.

- The unexpectedly low temperatures in the TMI-2 lead screws explained.

PLANT PERFORMANCE

PLANS

- Maintain codes (RELAP, TRAC-PWR, TRAC-BWR, and RAMONA) for use by staff and contractors.
- Complete user training for NRC staff in FY94.
- Continue international program (CAMP).
- Maintain test facilities at universities to provide needed data.

HUMAN RELIABILITY
PERSONNEL PERFORMANCE

ISSUE

Effects on performance of staffing, hours, environmental conditions, and advanced designs

RESULTS

Method to investigate causes of human errors

PLANS

Effects of advanced designs on staffing levels

HUMAN RELIABILITY
HUMAN-SYSTEM INTERFACE

ISSUE

Technical basis for acceptance of advanced instrumentation and controls

RESULTS

- Verification and validation guidelines for expert systems
- Reviewed existing standards on high-integrity software

PLANS

- Guidelines for acceptance of advanced control rooms
- Evaluate alternative facilities for conducting research

HUMAN RELIABILITY
ORGANIZATIONAL FACTORS

ISSUE

Effects of nuclear power plant organization on safety

RESULTS

Initial approach used plant data to estimate effects

PLANS

- Current-year projects are being wrapped up
- Senior Management review of interest in additional effort.

HUMAN RELIABILITY
HRA/PRA APPLICATIONS

ISSUE

- Effects of cognitive errors in PRAs
- Methods for risk impacts of Tech Specs

RESULTS

- NUCLARR
- Methods to evaluate allowed outage times, configuration control, and surveillance test intervals
- Methods already being used to review Tech Specs

PLANS

Regulatory guide on reliability methods for Tech Specs

SEVERE ACCIDENT RESEARCH PROGRAM

GENERAL ISSUE

- Is early containment failure a likely consequence of severe accidents? (E.g., direct containment heating, hydrogen combustions)
- Closure of severe accident issues on existing plants.
- Support licensing and rulemaking on future LWRs.

GENERAL APPROACH

- Small-scale experiments about phenomena of severe accidents.
- Conduct scaling analysis when appropriate.
- Develop/assess analytical models (codes).
- Use probabilistic framework to couple the different stages of an accident.

SEVERE ACCIDENT RESEARCH PROGRAM
IN-VESSEL CORE MELT PROGRESSION

ISSUE

What are the characteristics of the melt released from the core and the vessel? Threshold for ceramic pool meltthrough? Melt drain or core blockage in BWR?

RESULTS

- Blocked cores give large ceramic melt release like TMI-2. Low metal content in blocked core ceramic melts
- Ceramic and metallic melt behavior

PLANS

- Post-irradiation examination, analysis of results, and DEBRIS modeling (complete December 1993).
- Analytical modeling of melt pool thermohydraulics (complete March 1994).
- Review group to consider need for further research (late 1993).

SEVERE ACCIDENT RESEARCH PROGRAM
DIRECT CONTAINMENT HEATING

ISSUE

Is early containment failure a likely consequence of high pressure melt ejection (DCH)?

RESULTS

- Containment compartmentalization was a dominant mitigator of debris/gas heat transfer.
- Autoignition of hydrogen on DCH time scale is not likely.
- SNL and ANL database is prototypic.
- Simplified models (CLCH, TCE) provide a reasonable conservative estimate of DCH loads for the Zion and Surry plants.

PLANS

Complete the last integral effects and separate effects tests. Assess DCH loads for selected plants and accident sequences. (Late 1993). Peer review.

SEVERE ACCIDENT RESEARCH
DEBRIS COOLABILITY

ISSUE

Whether core debris can be cooled ex-vessel to avoid debris/structure interactions and substantial generation of noncondensible gases.

RESULTS

Results inconclusive: no firm demonstration of debris coolability.

PLANS

Currently assessing usefulness of additional testing versus accepting current uncertainty.

SEVERE ACCIDENT RESEARCH PROGRAM
SEVERE ACCIDENT CODES

ISSUE

Development of codes to calculate severe accident consequences for all nuclear plants licensed or proposed to be licensed by the NRC.

PLANS

- As models are developed and validated, assessments are made on:
  -Inherent limitations of codes and experiments
  -Need for further accuracy
  -Ability to obtain further accuracy
  -Peer review results

- Overall plan is to bring codes to a degree of validation where further major experiments are not justified (FY 1996)

- Efforts will continue at lower level to ensure capability to understand and analyze severe accidents is maintained.

TMI-2 VESSEL INVESTIGATION PROJECT (VIP)

ISSUE

Challenge of severe accident conditions to reactor vessel integrity at TMI-2

RESULTS

- Benchmark to validate computer codes that model in-vessel severe accident phenomena
- Improved understanding of TMI-2 accident to determine impact on potential vessel failure
- Insights for possible accident management strategies

PLAN

Project nearly completed - final report September 1993

LOW POWER AND SHUTDOWN PRAs

ISSUE

Implications of shutdown events (e.g., Vogtle) for plant safety.

RESULTS

- PWR mid-loop PRA shows that time-weighted CDF is comparable to full power CDF
  - Actual CDFs during periods of mid-loop operations are substantially higher.
- Early results for BWR at cold shutdown appear similar.

PLANS

PWR PRA scheduled for end of FY93. BWR cold shutdown PRA is scheduled for completion by mid CY94. Analysis of other operational modes is to be determined.

EARTH SCIENCES, PLANT RESPONSE TO SEISMIC EVENTS

ISSUE

CHARACTERIZE SEISMIC HAZARD CHALLENGE TO NUCLEAR POWER PLANTS TO STRENGTHEN THE TECHNICAL BASIS FOR SAFE SITING, DESIGN, AND OPERATION.

RESULTS

- METHODS FOR SEISMIC PRA, SEISMIC MARGINS, IPEEE
- PIPING: REVISED DAMPING VALUES REDUCED NUMBER OF SUPPORTS/SNUBBERS, PROVIDED SAFER PIPING SYSTEMS
- PROPOSED REVISION OF SEISMIC SITING CRITERIA (10 CFR PART 100, APP. A)

PLAN

RESOLVE DIFFERENCES BETWEEN SEISMIC HAZARD METHODS

NUCLEAR MATERIAL SAFETY

- Radiation protection of workers and members of the public

    - Improved health effects data and models
    - Hot particle characterization and clarification of threshold for ulceration
    - Dose calculation methodology for embryo/fetus
    - International cooperative efforts with former Soviet Union to obtain health effects data from Chernobyl and other facilities

- Residual radioactivity

    - For decommissioning
    - Monitoring for release of facilities & equipment
    - Recycle/reuse dose pathways

MATERIALS LICENSEE PERSONNEL PERFORMANCE

ISSUE

Sources of human errors in performing remote afterloading brachytherapy (RAB) and teletherapy

RESULTS

Function and task analyses for RAB and teletherapy at representative sample sites provided to NMSS

PLANS

- Evaluate manual brachytherapy
- Prioritize significance and evaluate alternatives

DECOMMISSIONING

- Parametric assessments of costs associated with decommissioning including sensitivity to levels of residual contamination and LLW disposal costs

- Characterization of hazards presented by reactor facilities following permanent shutdown and preparations for decommissioning

LOW-LEVEL RADIOACTIVE WASTE RESEARCH

ISSUE **(NMSS, AGREEMENT STATES)**

Improve technical basis to evaluate LLW disposal safety

RESULTS

Models developed & tested for source term, engineered barriers, radionuclide transport

PLANS

- Use iterative performance assessment (PA) to focus program on addressing uncertainties with greatest impact. Develop improved models; tests to support.
- Larger-scale field confirmation of site characterization and PA strategy
- Complete improved models; field scale data to test them FY98.

HIGH-LEVEL WASTE RESEARCH

ISSUES

Provide technical basis for

- Safety review of DOE site characterization

- Assessing natural features of site, performance of engineered barriers, performance for times of 300 to 10,000 years.

RESULTS

- Methods and techniques for site characterization (unsaturated, fractured rock)
- Measurement and modeling of sorption properties of zeolites
- Began studies of volcanism and tectonics
- Seismic & thermal stability of tunnels
- Performance assessment methodology - develop/improve

HIGH-LEVEL WASTE RESEARCH

PLANS

- Support review of DOE Exploratory Studies Facility and surface testing programs

- Complete Engineered Systems and Geochemical Programs FY95; Containment and Geology '96; Hydrology and PA '97.

INTERNATIONAL ACTIVITIES

- Cooperative activities with most of world's nuclear power users
  - 54 agreements in effect, incl. 14 signed or extended FY 93
- Russia, Ukraine:
  - Research Working Groups of Joint Coord. Committee for Civilian Nuclear Reactor Safety
  - Expanding NRC activities to provide safety analysis code capability for Russian-design reactors
  - Participating in evaluation of RASPLAV test program (core melt/PV interactions)
- Japan: ROSA V AP600 integral testing

RESEARCH MANAGEMENT

- **CRITERIA FOR INITIATION, CONDUCT, AND CONCLUSION OF RESEARCH PROJECTS**

  - Part of Research Philosophy in Five-Year Plan
  - Criteria aid decision making; do not replace knowledgeable, informed, competent, involved management

- **STRENGTHENED ATTENTION TO NEXUS OF RESEARCH TO REGULATORY ISSUES IT SUPPORTS**

- **CLOSURE OF MAJOR PROGRAMS WHEN COMPLETED**

  - Maintenance-level efforts to enable NRC to respond rapidly when need arises

- **NSRRC, ACRS REVIEWS**

- **INTERNATIONAL SAFETY RESEARCH COOPERATION**

ADMINISTRATIVE ACTIONS

- DOE voucher approvals
- Upgraded computer capability
- Closeout of completed DOE projects
- DOE property inventory disposition
- Project file management
- Project management training
- Plans for improved efficiency/effectiveness

REACTOR SAFETY RESEARCH IN TRANSITION

- Research management
- Completion in sight
  - Aging
  - Severe accidents
- Continuation
  - Licensing support, regulatory standards
  - Seismic hazards
  - Controls, operations, human factors
- New Emphasis
  - Passive advanced reactors
  - Cooperation with Eastern Europe and CIS